EAI/Springer Innovations in Communication and Computing

Teresa Guarda
Sajid Anwar
Marcelo Leon
Filipe Jorge Mota Pinto *Editors*

# Information and Knowledge in Internet of Things

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Filipe Jorge Mota Pinto
Editors

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EAI
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*Editors*
Teresa Guarda
Systems and Telecommunication
Santa Elena Provincial State University
Santa Elena, Ecuador

Sajid Anwar
Khyber Pakhtunkhwa
Centre for Excellence in IT,
Institute of Management Sciences
Peshawar, Pakistan

Marcelo Leon
Universidad Tecnológica
Empresarial de Guayaquil
Guayaquil, Ecuador

Filipe Jorge Mota Pinto
Instituto Politécnico de Leiria
Bidoeira de Cima, Portugal

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# Preface

Internet of Things (IoT) is currently one of the most challenging areas of the Internet, enabling communication and ubiquitous computing between global citizens, networked machines, and physical objects, providing a promising vision of the future integrating the real world of knowledge agents and things with the virtual world of information. IoT is seen as a network of trillions of agents and machines that communicate with each other, being a profound technological revolution, which is the current reality and the future of computing and communications, supported by a dynamical technological evolution in many fields, from wireless sensors and wireless sensor networks to nanotechnology. Due to its broad impact in many fields, it has rapidly gained global attention from academia, governments, industry, and the citizenry. This change in the network of agency profoundly modifies the landscape of human activity, particularly as regards to knowledge acquisition and production, offering new possibilities but also challenges that need to be explored and assessed.

This book contains a selection of chapters accepted for publication in the book *Information and Knowledge in Internet of Things*, belonging to EAI/Springer Innovations in Communication and Computing series.

The program committee was composed of a multidisciplinary group of more than 90 experts from 30 countries, with the responsibility for evaluating, in a "double-blind review" process, the chapters received for each of the main themes proposed for the book: Decision Support Systems in IoT; IoT Knowledge Management; IoT Sensing Technology and Applications; Security and Privacy; and Smart Environments.

We received 55 contributions from 14 countries around the world. The acceptance rate was 38%.

The accepted chapters are published by EAI/Springer Innovations in Communication and Computing series, and will be submitted for indexing in Scopus, Ei Compendex, and zbMATH.

We acknowledge all of those who contributed to this book: authors, program committee, and editors. We deeply appreciate their involvement and support that were crucial for the success of this book *Information and Knowledge in Internet of Things*.

Santa Elena, Ecuador — Teresa Guarda
Peshawar, Pakistan — Sajid Anwar
Guayaquil, Ecuador — Marcelo Leon
Bidoeira de Cima, Portugal — Filipe Jorge Mota Pinto

March 2021

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# Part I
# IoT Knowledge Management

# Chapter 1
# Data Science and Advanced Analytics in Commercial Pharmaceutical Functions: Opportunities, Applications, and Challenges

**Antonio Pesqueira**

## 1.1 Introduction and Conceptualization

In recent years, we have been witnessing an exponential growth of technological advances and new processes based on data science (DS) and advanced analytics (AA), attracting significant attention from pharmaceutical executives and industry decision-makers due to the immense opportunities to provide real-time insights, solutions to complex problems, and competitive information inputs for decision processes.

With this widespread use of DS and AA in the pharmaceutical industry and across different global regions, there is a significant need for new research and following all the new developments and implementations from the last 20 years. With the sheer dimensions and value of data generated within the pharmaceutical industry, more than even several organizations are being pushed to discover new methods and processes to proceed with data and systems integration for competitive advantage gain and to be able to make more effective use of data in business-driven decision processes and connected with activities, resulting in better business models and an increase in competitive advantage [1].

The pharmaceutical industry registers a significant influence from regulators, HCPs, and patients, which has led to the emergence of the importance of strategic functions like DS and AA in better understanding scientific exchange insights from medical interactions and information support from commercial activities. With these new developments in the current times, DS and AA have assumed a central role in several different pharma operations and the responsibility to create effective insights

A. Pesqueira (✉)
Universidade Europeia, Lisbon, Portugal
e-mail: antonio.pesqueira@live.com

 
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and outcomes to critical business questions that can prevent deadly pitfalls and challenges.

Data in any kind of shape is considered an extremely asset for pharmaceutical organizations, and DS allows pharma organizations to identify meaningful insights and business value outcomes, using a considerable set of methods and techniques in AA contexts.

We continue to witness a growing investment in new processes and technology connected with both terms but more space for processes structure and better insights architecture. Without exception, we also see a growing need from pharma organizations to manage different challenges from different spectrums of the business strategy [2].

Moreover, the current digital transformation processes are stimulating the growth of digital data, encompassing different aspects like the capacity to aggregate large quantities of data to be managed and stored on distributed computation or integrated software platforms.

In a pre-COVID-19 timeline, we were already assisting with an escalating pressure on pharma revenue streams, R&D pipelines, and organizational business units to be more agile in the processes and methods that are generating new capabilities in new decisions and market positioning [3].

Hence, as we will better understand in this research study, DS and AA can be the correct answer to some of these challenges with efficient utilization of resources and efficient data storage [4].

Pharmaceutical organizations are facing currently many strategic and operational challenges, and this article is positioned to explore DS and AA potential in the support of decision-making processes and commercial strategies definitions. This research study also aims to develop a systematic approach to DS and AA through the following research question: *Which advanced analytics and data science opportunities, challenges, and use cases are being most relevant and decisive to pharmaceutical commercialization processes and capabilities?*

In that manner, the selected RQ aims to identify advanced analytics and data science projects that most influence commercialization processes and capabilities within the pharmaceutical industry. The defined RQ first aims to understand how pharmaceutical organizations' ability to effectively adopt and implement novel DS and AA technologies with the right value to the commercialization processes. Hence, this research study aims to achieve the understanding and provide answers to these research objectives, through a relevant literature review and a focus group with a group of decision-makers and relevant professionals from the selected industry.

To analyze the problem under study, the chapter is structured as follows: after the introduction of the problem, a section with the research approach and methodology, then the results of the systematic literature review, followed by the findings and contributions from the second methodology selected, and finally the conclusions [5].

## 1.2 Preliminary Literature Review

### *1.2.1 Data Science in a Commercial Pharmaceutical Context*

For pharmaceuticals companies, a strategic and modern decision-making process needs to be able to map out and identify industry trends, areas of improvement, and business opportunities and to anticipate future trends and behaviors of healthcare professions (HCPs) and decision-makers, key opinion leaders (KOLs), and other stakeholders to better create a competitive positioning on the market [6].

In this context, some variables need to be considered by organizations to define a data science (DS) strategy, like data volume and value, computing, and human capacity in obtaining valuable information from large and heterogeneous data sources (e.g., patients, hospitals, physicians, suppliers, and others) data mining capacity to apply multimodal learning methodologies and to produce promptly insights from combined information sources in supporting decision-making processes [7].

Furthermore, the use of external data such as patient lifestyle information or biomarkers for research and development and also for marketing is a vital process to gain knowledge from that information and define the strategies and the new trends on research and development of new products [8].

Without surprise, we also see a growing need from the industry to better being prepared for new market demands, challenges, and needs from different spectrums of stakeholders that might involve payers, governmental institutions, regulators, clinical and nonclinical decision-makers, key opinion leaders, patient groups or associations, and other relevant healthcare organizations [9].

From a more technical spectrum, data quality is a significant issue as the decisions are taken based on data that is sensitive, and there are high responsibilities and expectations regarding data accuracy and the quality of analytics tools [10].

The increasing data captured through public data sources and internal data sourcing projects needs analysis about also data ownership and as a key needed a trigger to raise awareness around data protection and privacy laws and legislation to protect patients and companies [11].

Currently and according to the literature, privacy and security are key primary concerns for any pharmaceutical company and mainly due to the sensitivity and confidentiality of all the involved pharma data such as medical data is highly sensitive information; besides, there are strong regulations at national and global levels.

The privacy challenges currently that pharma faces for the practical implementation of a data science strategy also require specific considerations and deep discussions with several different internal departments like legal, privacy, compliance, and medical affairs [12].

The evolution and dynamics of commercial data needs that most of the time create the necessary space for DS projecting result in complex questions that now require different types of data sources and analytics to perform even the basic tasks and responsibilities in the sales and marketing context.

With pharma, all data resources can be sometimes a very complex topic, where we can find different perspectives on the use of electronic medical records (EMRs), electronic health records (EHRs) biosimilars, registries, medical claims, and patient- or physician-level data almost daily.

Currently, DS is already allowing pharma companies to bring new developments in core commercial excellence processes, like segmentation and targeting, reporting and analytics, and patient flows and journey tracking. From a five-year perspective, the sophisticated, informed, and knowledgeable sales and marketing processes with full data privacy and compliance alignment will be a strong reality, where mobile apps, analytical systems, and web services along with digital offering will allow confident solutions to sales and marketing functions (e.g., commercial operations, marketing intelligence) that simply need another type of data consumption services, mixing more information into the data visualization models [13].

According to the literature review, we were also able to better understand some of the DS use cases and business applications. Let's have a review of those examples and business cases of DS in sales and marketing:

- Data science for disease trends analysis and HCP's behaviors/needs/preferences patterns understanding
- Market/sales data analysis and sales forecasting and competitive intelligence-associated data
- Monitor biosimilar markets due to biologic patent expirations
- DS to monitor the influence and relevance of new KOLs and decision-makers and other influencers, using public data sources like medical publications, clinical trials, and decision groups platforms
- New clinical and medical influencers and scientific classification and profiling models that can better anticipate the likelihood of relevant industry experts in accepting an advisory board or congress invitation
- Automation trial design having iterations with KOLs to help define a trial population to ensure meaningful endpoints and reimbursement
- Intelligent systems that use machine learning and AI to integrate HCP portals, marketing automation tools, and incorporating new technologies like chatbots into customer relationship management (CRM) systems to support internal medical education and plan scientific exchange follow-ups effectively
- Using remote Webinars and virtual events throughout the products lifecycle to interact virtually with regulators, key stakeholders, and opinion leaders
- Text interpretation and analysis using natural language processing techniques

Actionable and meaningful data can be used for a variety of purposes in trying to identify the highest groups of opportunities, customer clusters, sales forecasting options, or patients' journeys.

As DS advance within pharma, there will be many opportunities to develop cost-effective and better-targeted systems and solutions for sales and marketing functions, such as competitive intelligence, commercial excellence, or event market access, for the effective and timely manner detection of new market insights and opportunities and monitoring of new major trends in HCPs', regulators', payers' and others' preferences, needs, and procedure changes. These solutions will also allow companies and sales and marketing service providers to put the right competencies and processes in place and allow the pharma industry to rapidly get more omnichannel-oriented.

### *1.2.2 Advanced Analytics in a Commercial Pharmaceutical Context*

The world keeps changing drastically due to new technology implementation, as well as due to uncertainty coming from a new pandemic crisis. The pharmaceutical industry is also going through some serious changes, and new AA methodologies and technologies are being called into action more than ever.

Many pharmaceutical leaders are using advanced analytics (AA) to cope with new challenges and better produce results in complex and changing environments. AA has all the power to improve decision-making processes and knowledge generation within different departments and functions, but commercial pharma functions are playing a decisive role in bringing new applications of AA into the industry [14].

Based on the current literature, most of the common AA definitions have been assuming a broad perspective where, from this article's understanding, AA is described from a myriad of five specific areas and the combination of all different areas that can help us to better understand what is AA like descriptive, predictive, prescriptive, detective and cognitive analytics.

AA for pharma commercial activities and processes is evolving in many companies with significant growth in terms of business applications and use cases. The actions for this recent evolution require organizational leadership commitment and work process adaptation from the leadership teams and business unit procedures. Similarly, from headquarters to local in-field operations, AA has a decisive role in terms of anticipation of challenges, risks, and misplaced decisions [15].

Also, we continue to witness a disconnection between commercial (business) and IT departments before the integration of the AA supporting data in all possible commercial needs [16]. The recent technical and scientific advancements in AA lead to exponentially growing sets of data and more processes for data controlling and quality [17].

These modern technologies impacting all pharmaceutical marketing departments (e.g., Veeva Digital CRM, context analysis, and advanced KOL identification, insight capture, recognition of natural language, and predictive analytics) also make the lives of marketers simpler and more convenient. But these new technologies and technology advancements without proper performance and team dynamics, the methodology might simply don't work as we need. AA makes the data assessment process faster, transparent, and accurate as from a data visualization perspective, all flaws are extremely visible. It can require multiple cross-validation, and data quality controlling mechanisms via the definition of an effective and modern data governance model as well as strengths put a concrete goal in front of a working team as well as give comments and recommendations that will help any data governance plan to improve their performance in the future and better design any data management activity and as a key support to any AA program [18].

Within the pharmaceutical context, AA is also being used to analyze patients' preferences and healthcare professional's involvement in publications or research activities and decide on what direction to take in with new product indications, pricing strategies, or sales operating models. Also, AA makes it possible to better predict market share growth, penetration rates, evolution index, new business capture, and many other sales parameters. But we can also apply AA to medical, market access, and marketing.

In some of the pharma companies currently already using AA, most of the use cases are around the view of sales figures (e.g., target achievement analysis, sales unit prices vs target, sales by net sales, gross sales, discounts, and rebates) and answers to understand how the business is performing and what steps might need to be taken to improve.

Most of the complexity in the pharma industry lies in most of the cases on the different product lifecycles, regulatory landscape, governmental pressure, and/or competitors' advantage gain.

A fully automated AA platform can identify patterns or changes in a key opinion leader's prescribing habits and competitors' move and quickly adapt the multichannel planning or engagement strategy based on the collected insights.

When we look at commercial AA examples, some of the most generic use cases are:

- From patient data for disease understanding, diagnosis improvement, new treatments, and patient safety improvement
- Sales and financial investment scorecards that include market shares, performance index, cost of goods, penetration and variation indexes, etc.
- Personal and electronic medical records and electronic health records for patient journeys discovery
- Augmented field force teams with active digital compliance and regulatory alignment
- Remote patient monitoring in health risks prediction and use of ML/AI to provide optimal medical support

### *1.2.3 The Value of Data in Pharmaceuticals*

Some pharma companies are adopting new commercial and marketing exploration strategies, such as focus group with HCPs, where the company can simply observe and discuss new relevant topics with HCPs to understand the pain points of specific customer groups and generate new ideas for innovative methods that the company can support in the future [18].

Clearly, in several cases, a multichannel program is the first step in the commercial transformation of a pharma company. However, one of the biggest problems with these new adoption programs and implementations is the designed strategy of a multichannel program or the capacity to have an integrated connected data governance model, which for almost all the cases are conducted as a one-off and single tactical perspective. Until today, just a very few pharma companies are being able to overcome the silo-based approach to all the new commercial and marketing channels and under the same targeted HCPs or KOLs, by having a connected data governance model to understand all the surrounding environment and what is the role of the KOLs in that space.

So, this new approach should be defined by the following key success factors to triumph:

- *Segmentation strategy*: Better integration of segmentation with marketing brand planning with guidance on using the sources of business and channel mix defined in the brand plan to inform the segmentation strategy, allowing the channel allocation to be driven by brand lifecycle, strategy, channel responsiveness, and cost-to-serve.
- *Profiling*: Additional profiling criteria to guide channel allocation like channel responsiveness and cost-to-serve criteria, having total guidance on using other channels selectively to support customer profiling. Here, the current multichannel CRMs (e.g., Veeva.com or Salesforce.com) offer quite a lot of options to effectively manage different channels within the same system (e.g., approved emails, remote detailing, eDetailing, engagement meetings webinars, and events capture).
- *Segments and channel mix*: Segment design according to physician preference, behaviors, prescription potential, and coverage rules flexed by brand lifecycle stage and strategy, with extended "know-how" sections on the analyses required to support frequency decision and guidance on using cost-to-serve to define segments, channel mix, and frequencies.
- *Channel deployment*: Guidance on aligning available and required capacity across multiple channels with options to use other channels in resolving short-term capacity misalignment between and within territories.
- *Interaction/contact planning*: Contact plans by channel to be created for all channels, creating an integrated cross-channel customer contact plan to avoid overcalling and drive better customer contacts and also without forgetting any data privacy (e.g., GDPR) limitations or compliance restrictions.
- *Execution and monitoring*: Measure execution of call plans by channel with new KPIs, big data, and competitive intelligence framework models, to obtain single-channel execution KPIs to multichannel execution KPIs. Here, the main goal should be data connection (where all relations are connected and all data is part of the same existing ecosystem).

Advances in high-advanced, next-generation technologies have a strong meaning that pharmaceutical sales and marketing (part of commercial), for example, now require the management of vast quantities of data, which aren't dispersed, fragmented in different inaccessible places of the business. The necessary data when is increasingly diverse and comes from several different sources, increasing the capacity demand for any organization to manage more complex business requirements and problems that will require a more connected data ecosystem.

For example, when we need to understand the affiliations and relationships of a medical publication author, it's enough to know the author wrote the publication on a specific date and location or to support our decision-making process we need to understand "who" the author is connected, co-authors, related tweets to that specific publication, and many other dimensions, relations, etc. [14].

More will still need to happen to bring more connectivity in pharma data, where dissimilar data sets are continuing to grow to generate and collect data from several sources, including R&D, clinical, translational, genomic, and health records, where more than ever pharma companies must effectively manage, integrate, and analyze this data to enable more informed decision-making [1].

## 1.3 Methodologies

Through this section, an overview of the selected methodologies and investigation strategy will be presented and further detailed. This research investigates how DS and AA can be the correct answer to some of the current commercial challenges in pharma with efficient utilization of resources, efficient data storage, and more capacity in decision-making to exploit new methods and procedures.

In a summary, this study consists of a hybrid approach for a deep theoretical and practical understanding of a systematic quantitative literature review of academic articles indexed on the PubMed, Elsevier, iMedPub, Sage Journals, and Google Scholar databases and a focus group with 25 pharmaceutical professionals ranging from analysts to executive directors.

As pharmaceutical organizations are facing currently many strategic and operational challenges, this article is positioned to explore DS and AA potential in the support of decision-making processes and commercial strategies definitions. This research study also aims to develop a systematic approach to advanced analytics and data science through the following research question (*RQ*): *Which advanced analytics and data science opportunities, challenges, and use cases are being most relevant and decisive to pharmaceutical commercialization processes and capabilities?*

In that manner, the selected RQ aims to identify AA and DS projects that most influence commercialization processes and capabilities within the pharmaceutical industry. The defined RQ first aims to understand how pharmaceutical organizations effectively adopt and implement novel DS and AA technologies with the right value to the commercialization processes.

To analyze the problem under study, the chapter is structured as follows: after the introduction of the problem, a section with the research approach and methodology, then the results of the systematic literature review and focus group, followed by the findings and contributions from both methodologies, and finally the conclusions.

This paper is also aimed to support a better understanding of a secondary research objective that are presented below:

- *RQ2*: Which DS and AA techniques and models can influence commercial pharma projects?

The secondary research question investigates how organizations are using DS and AA techniques and models and their influence on commercial pharma projects. All research objectives are intended, first, to improve the understanding of how pharmaceutical organizations' commercial departments and functions are adapting internal processes and applying DS and AA.

### *1.3.1 Systematic Literature Review*

As already presented in the previous section, this research aims to identify possible missing connections between the research of DS processes, technology, and procedures with AA giving a practical and theoretical context.

With a clear intention to increase the knowledge and understand the quantity, quality, and deep of research of all published literature on the selected topic, a systematic bibliometric literature analysis review using a well-known software tool for constructing and visualizing bibliometric networks, VOSviewer, was performed.

The aim of using the software VOSviewer in this study was to identify all relevant publications, articles, and mentions with applicable examples and explanations of the use of DS and AA and develop recommendations for a better understanding of both constructs.

As we will be able to understand from Fig. 1.1, it was drawn from the selected initial methodology (systematic literature review) examples of DS and AA where in total 492 items were assessed and evaluated.

Important factors during all data and information collected will be not only the added value of all conclusions and data points but also the quality of the collected evidences and observations, which we can better understand from the described process below in Fig. 1.1.

The approach taken of the systematic literature review evolved from the initial conception into the execution phase, and the major steps like the definition of the search terms were always designed not only to be deriving from the research questions keywords but also to allow in the future the conclusions drawn to support a better understanding of all the involved search terms.

Complementary to the previous rationale, a preliminary literature analysis to ensure quality and relevance checks were performed, as well as to also be able to validate and solidify the design of the search terms in strong combination and

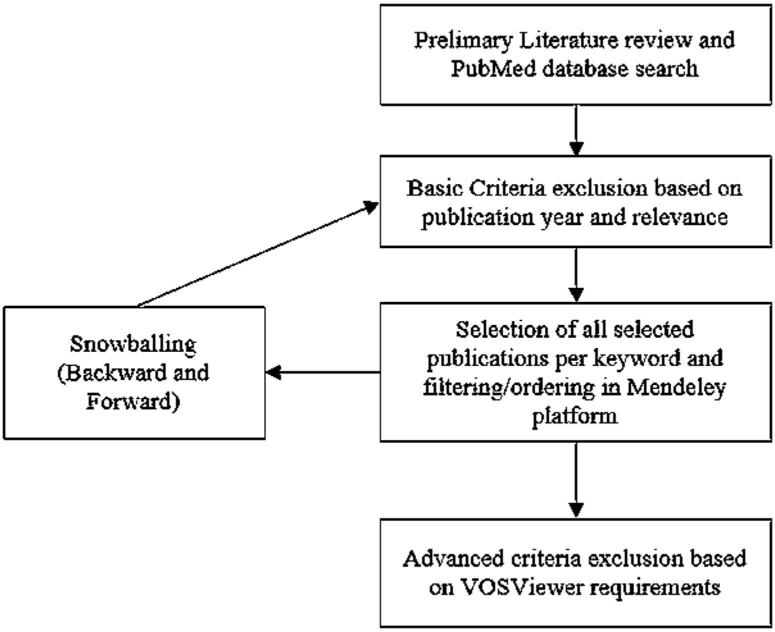


**Fig. 1.1** Overview of the applied systematic literature review

junction with the next predefined step: qualification and exclusion according to the defined criteria parameters.

One of the challenges faced during the process was the probability to ignore or skip relevant research papers or previous publications in which a combined search strategy with the literature review was selected that was performed as a preliminary step and to avoid any missing relevant information from the selected data sources: PubMed, Elsevier, iMedPub, Sage Journals, and Google Scholar database search.

During this, a systematic literature review was extremely important to discover and collect evidences to the presented research questions that fitted the prespecified eligibility criteria and to answer with clear evidences and facts the research questions.

The systematic literature review mainly aims to minimize any kind of bias by using explicit, systematic methods that are documented in advance with a predefined protocol. To that, the snowballing technique was fundamental in terms of identifying a concrete set of papers identified throughout the databases that were selected and including as a key driver the necessary criteria factors to any relevant factors the predefined selection removed and ensuring that inclusion of evaluation factors relevant to the selected and identified research studies were considered like the year, title and content.

The initial selection of the number of publications had a total of 838 articles to which the necessary validations and qualification mechanism to continue with a solid validation that data science and advanced analytics were indeed key terms and observation points during the entire process were defined. During the selection of all publications per keyword and ordering using the Mendeley platform, additional advanced criteria parameters were applied to exclude nonrelevant publications and to comply with the VOSviewer requirements for a successful data visualization [17].

The applied keywords were (a) pharmaceutical advanced analytics, (b) pharmaceutical data science, (c) decision process problems, (d) decision making, (e) advanced analytics in commercial, (f) pharmaceuticals biotechnology analytics, and (g) pharmaceuticals biotechnology data science.

During the entire process, the targeted literature scope was defined to include all relevant publications in the life sciences (pharmaceuticals and biotechnology) with application in medical, clinical, or biology-related activities or processes.

In terms of the selected exclusion criteria, the defined terms were (a) exclusion of published in non-peer-reviewed publication channels such as books, theses or dissertations, tutorials, and keynotes; (b) not available in English; (c) a duplicate; or (d) published before 2000.

To make a better sense of the selected targeting population of all publications, we also produced advanced analysis in terms of selection criteria and as follows: all selected papers were classified as (a) relevant, (b) irrelevant, (c) or uncertain, wherein the available information on the title and abstract is inconclusive. Only the papers evaluated as relevant were selected for inclusion in this research. These advanced criteria were connected with the data extraction, in which the full text of the papers was thoroughly read. In the data extraction processing, a spreadsheet editor to record relevant information and to map each article's metadata was used.

In the following figure (see Fig. 1.2), the initial publications selected were 2247. After all the above-described processes, all refinement and exclusion criteria factors where the result was 32 papers were applied. The figure below allows us also to understand the number of involved articles excluded from the final selection of articles.

#### 1.3.1.1 Search and Selection

Related to the selection criteria previously explained in both figures (Figs. 1.1 and 1.2), a mix of data analysis was then applied: (1) co-authorship analysis and (2) co-occurrence.

The co-authorship analysis presents the relation levels of all connected authors and co-authors from the publication scope and where the ordering and leveling are defined according to VOSviewer algorithms based on the number of involved documents and relationships networks.

The co-authorship observations and analysis followed a standard counting method from VOSviewer and applied the logic of a minimum number of documents of an author to one, whereof from the total of 2551, 630 authors met the selection criteria and threshold. For each of the 630 authors from the 492 publications, the

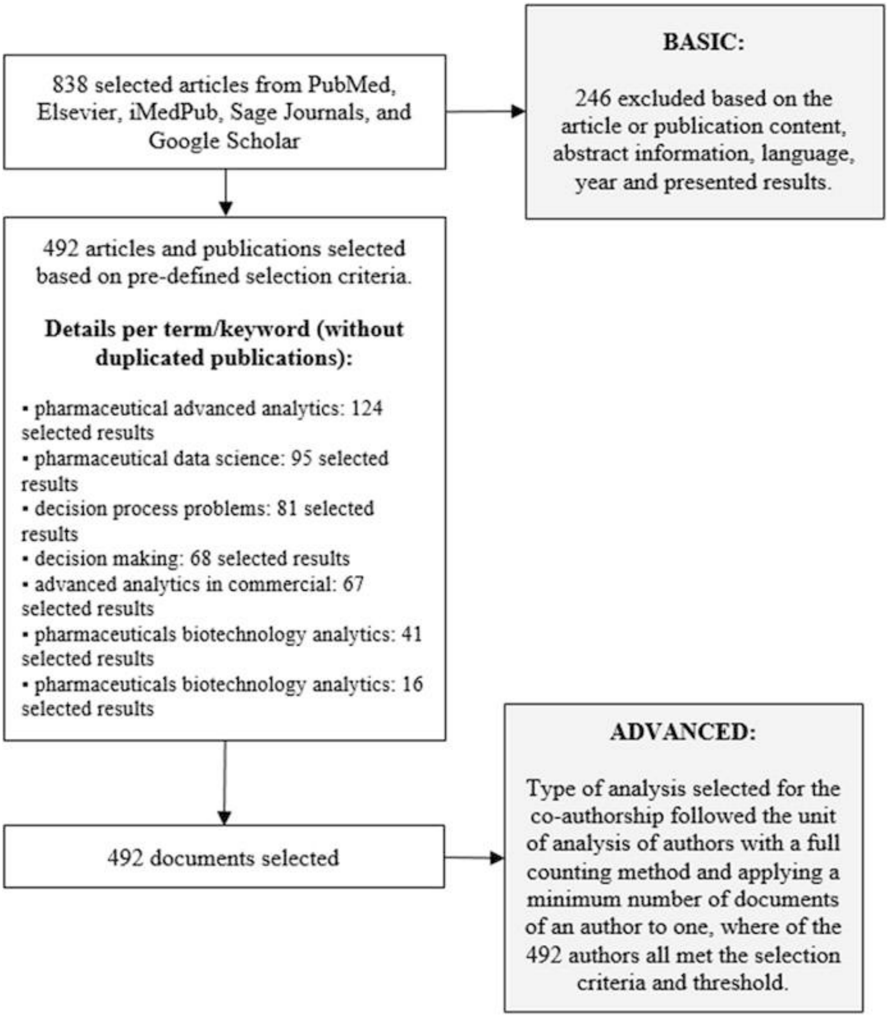


**Fig. 1.2** Overview of the database search and selection criteria

total strength of the co-authorship links with other authors was also calculated with the data analysis focusing on the total link of strength from those relationships.

For the co-occurrence analysis, the authors' and co-authors' relationships are not the key differentiating factor, but the keywords from the selected publications where the data analysis has the main determination of the number of documents and all related search terms and keywords in which they occur together.

During the data analysis, the following parameters were also taken into consideration: (1) minimum occurrence of a keyword from the total of incidence, (2) total of the strength of the co-occurrence (3) weight of occurrences, (4) analysis and

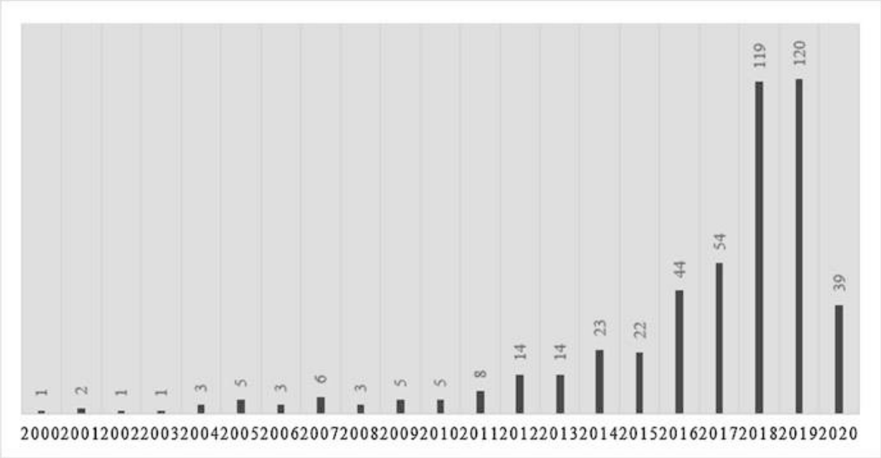


**Fig. 1.3** Distribution per year

validation of all selected cluster of analyzed items from VOSviewer algorithm, (5) usage of default values in association normalization for data layout visualization, and (6) merging of small clusters.

The search terms and selection criteria as explained in the previous section are described as following: "big data," "data in pharma," "big data in pharma," "medical big data," "clinical trials big data," "genetic data," "patients data management," "big data in R&D," "big data in sales," "big data in marketing," "big data in regulatory affairs," "professionals skills," or "skills data management."

#### 1.3.1.2 Results

The results from the systematic review process had as the main basis the bibliometric indicators from the 492 selected articles and, as explained in the previous point, whereof the statistical analysis allowed us to better understand the results with concrete data and measurable indicators from the scientific network of all co-authorship analysis and co-occurrence analysis.

In the following figure, we can visualize the distribution of all 492 items since 2000 and until today. About 24% of the total number of the studied items were from 2019, showing a clear reflection of the importance of the research questions to the entire community and research world (see Fig. 1.3). We also can conclude that since 2015, there is a growing trend in the number of publications related to the selected keywords and with exponential growth since 2017.

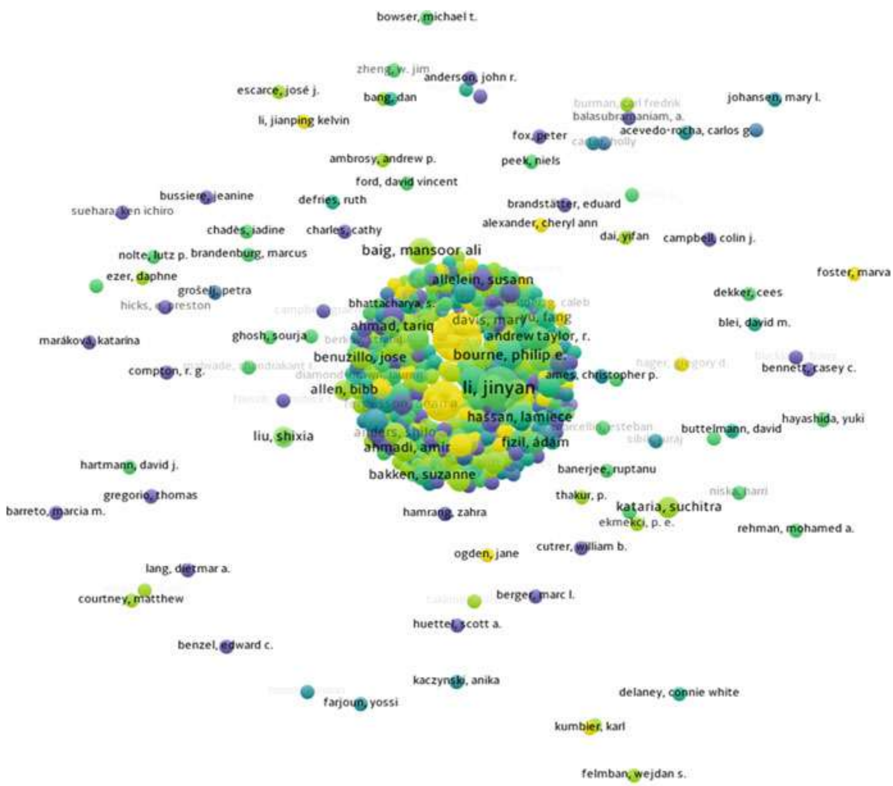


**Fig. 1.4** A high-level overview of all co-authorship relationships network from the verified 2551 authors

#### 1.3.1.3 Co-Authorship and Co-Occurrence Data Analysis

From the 492 selected publications, the total number of authors was 2551, in which some of those authors in the selected networks were not linked between them and were the largest set of connected authors consisted of 250 authors that showed connections between all and part of the same cluster.

Therefore, in total, we had 432 clusters where the most represented cluster had as mentioned before 250 authors, as we can see in Fig. 1.4. For each of the authors from the 492 publications, the total strength of the co-authorship links with other authors was also calculated, and the authors with the greatest total link of strength were selected in several different analyses (see Fig. 1.5).

The co-occurrence analysis, as explained in the previous sections, have, as the main source of data analysis, the key terms and words present in the selected publications, wherefrom a total of 1396 keywords, only 57 of the keywords were part of the largest set of the connected items and met the desired threshold. The analysis made expressed a clear correlation between key term areas like machine

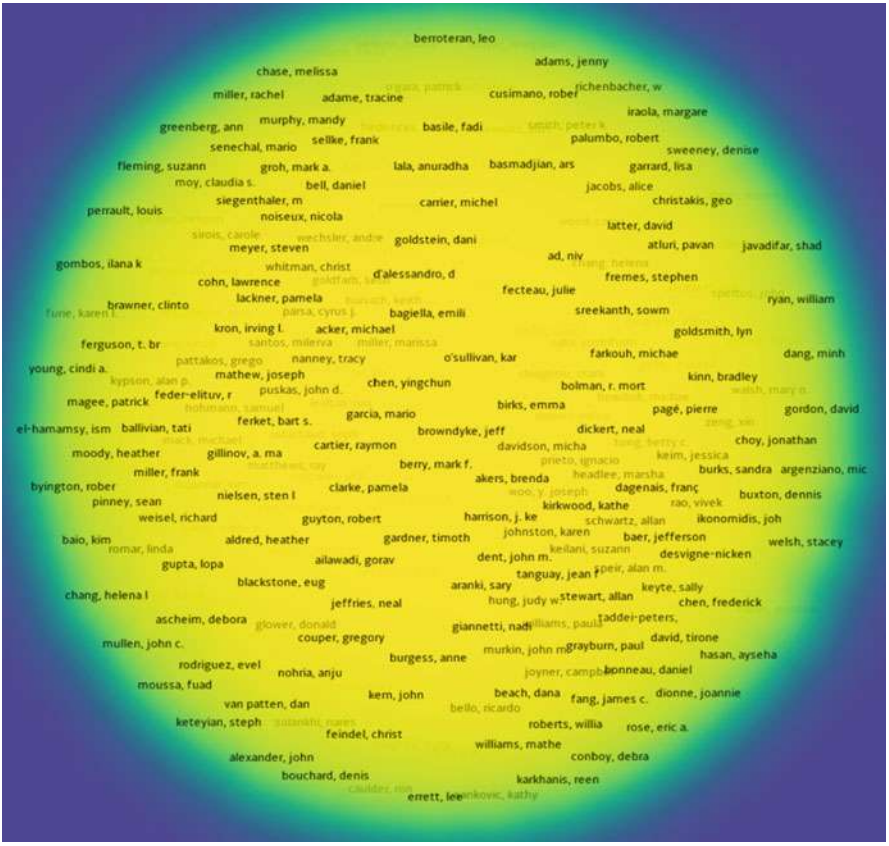


**Fig. 1.5** Density visualization from the most relevant cluster with 250 authors

learning, big data, data science, decision-making, and analytics. For the data analysis, we used the association strength method and a minimum cluster size of 10 by merging the small clusters, where were deleted for a better visualization resolution.

From the verified selected keywords, the ones with more occurrences were machine learning ($n = 34$, total link of strength = 59), big data ($n = 28$, total link of strength = 47), and data science ($n = 40$, total link of strength = 45). The previous order was dictated by the total link of strength from the selected keywords.

From the current literature, we can also conclude that the connections and linkage between data science and advanced analytics are still not completely clear, where advanced analytics have not been presented with a solid strength level from the current literature.

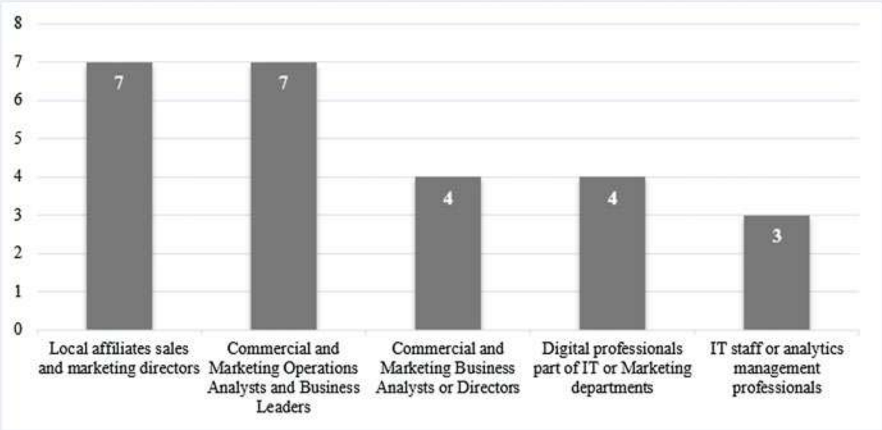


**Fig. 1.6** Stakeholder categories and number of participants

### *1.3.2 Focus Group*

Resulted from the systematic literature review, also ten questions were developed to act as key support to the focus group research stage.

The key focus areas during the focus group discussions and raised questions were experiences with DS and AA, opinions regarding business use cases, opportunities, models, and techniques from DS and AA.

The focus group participants were according to the selection criteria aimed to have a good representation of pharmaceutical professionals performing directly or indirectly tasks, activities, or projects connected with DS and AA.

The focus group participants ($n = 25$) were selected from the following stakeholder categories: commercial and marketing business analysts or directors; IT staff or analytics management professionals; digital professionals part of IT or marketing departments; commercial and marketing operations analysts and business leaders and Local affiliates, and sales and marketing directors.

Participants represented a wide diversity of positions including senior directors, directors, and associate directors; managers; business analysts; and technical or IT specialists (see Fig. 1.6). We conducted a total of ten sessions using the Zoom technology starting from September 5th, 2020, to September 22nd, 2020, sorting participants into smaller groups with similar titles and responsibilities. The sessions were 60–90 minutes in length, and PowerPoint slides were used to guide the interviews and facilitate the sessions.

As part of the focus group strategy, we defined three main phases (planning for analysis, information collection and management, and interpretation), where each of those phases had related steps. This process had the main intention to produce quality and remove any bias from all collected information and analysis and ultimately produce the best focus group outputs possible (see Fig. 1.7).

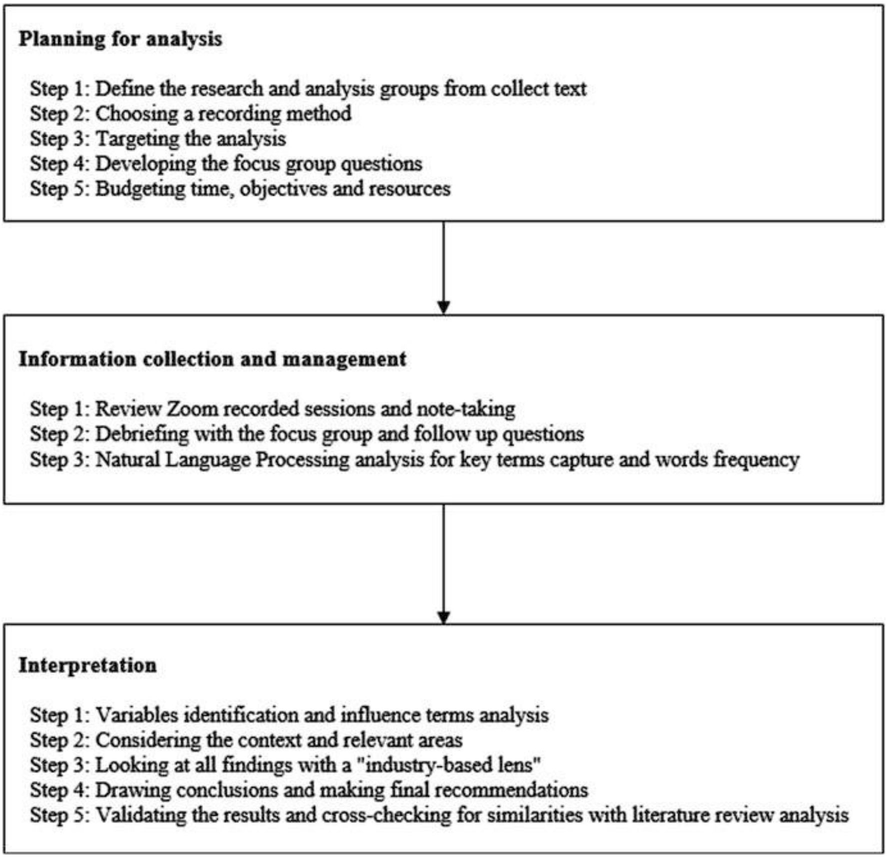


**Fig. 1.7** Focus group analysis process

#### 1.3.2.1 Focus Group Questions

A list of ten questions was developed to guide the discussions from the focus group sessions where the participants received the questions in advance of their scheduled session to have a better preparation and to support the participants in terms of reflecting as pre-read the major considerations and opinions to the different topics. Since the composition of each group varied by job duties and titles, several perspectives were represented in their responses (see Table 1.1).

**Table 1.1** Focus group questions

| Focus group areas | Focus group questions |
|---|---|
| Added-value of data science and advanced analytics to commercial pharma | What are the strategies to increase the awareness of the added value of data science and advanced analytics in your department/in your organization? Can you tell examples of where both concepts have been used in value-generated processes? |
| Relevant techniques and models | What are the examples and use cases in data science and advanced analytics that have been used in your organization? |
| Data sources | Tell us examples of data sources in pharma and how to secure their quality and safety? |
| Data governance | Tell us examples where your organization promotes open use and sharing of data science and advanced analytics models? |
| Applications and purposes | Can you describe examples of your organization and department's usage of data science and advanced analytics? |
| Data analysis | Identify the potential of data science and advanced analytics, and where analytical and data science methods are used to better optimize your organization decision making processes and other internal processes |
| Data access and usage | Explain current procedures to ensure security and availability for data usage and directly connected with the use of data science and advanced analytics for commercial purposes |
| Standards | Detail all existing standards for data science and advanced analytics and examples of its application and interoperability |
| Financial resources | Describe all forms of investment in data science and advanced analytics projects and programs with financial and human impacts |
| Legal aspects and privacy regulations | Describe all procedures and considerations for legal and privacy regulation of data science and advanced analytics impacting commercial processes and projects |

#### 1.3.2.2 Focus Group Results and Process Conclusions

From the focus group discussions and after deep analysis from all group participants, all answers were grouped into major groups for a more consistent and logical analysis of all collected comments, observations, and notes.

The below table list describes and highlights the key topics to each of the presented questions with also analysis in terms of the most used and frequent words in the provided answers.

The below table is a summary of all collected answers from the focus group discussions and is grouped by four major columns: questions, main categories, most relevant discussed topics, and keyword frequency with more than five recurrent words analysis (see Table 1.2).

Results of the focus group analysis revealed the above major findings. The next section aims to provide a generic overview of the key highlights and key takeaways to the most pressing topics.

#### 1.3.2.3 Focus Group Conclusion

The consensus of the focus groups was that both models (AA and DS) allow pharma to better predict the best tactics and actions to sales and marketing activities.

There was a consensus that more than ever pharma companies have as well more responsibility to automate analytics, data governance, and analytics standards to support the decision-making processing, and AA will be an integral part of different departments to assure the necessary capacity and capability to meet the needs for decision-making processing and insights generation.

It is important to highlight in this section that two participants mentioned some initial concerns with DS and AA: "Our company still doesn't know how to operate with advanced analytics as we have constant challenges from compliance and data privacy"; "to analyze huge data amounts ( . . . ) and benefit to our internal processes"; "although modern concepts like data science offer high performance, data privacy, and consent gathering from our customers is still an issue." This initial feedback points out the importance of pharmaceutical organizations managing customer and patient reference data as a global strategic asset and the importance of customer data to support life sciences strategic initiatives. Throughout the focus group discussions, it was also clear that most of the participants reported that customer data is essential to launching new products or manage effectively a sales model, where most of the organizations are not satisfied with the quality and service they receive from their legacy customer data provider or have the right customer data foundation to fully support digital transformation.

Some of the most used data science models were highlighted during the discussions with a special focus on the following models: natural language processing, logistic regression, discriminant analysis, data mining, and exploratory analysis.

The focus group data show that decision-making processes and data governance are vital skills for AA and DS within pharmaceutical. To continue answering the initial and primary research question, we also understood from the focus group discussions that most opportunities to DS and AA to commercial pharma relies on the following points:

- *Process automation and data-driven predictive insights*: Concrete and future ability to change how commercial decision-makers perform strategic decisions and manage financial performance across all commercial areas. The business needs and applicable use cases are increasing the number of real opportunities for AA in several different contexts.

**Table 1.2** Top-ranked categories, relevant topics, and keywords

| Focus group questions | Main categories | Most relevant discussed topics | Keywords and frequency (more than 5) |
|---|---|---|---|
| Added-value of data science and advanced analytics to commercial pharma | DS and ADD allow to measure the business impact of commercial campaigns and events<br>We can ensure our organization is making the right investments, decisions to achieve the best business objectives and results<br>Both models allow pharma to better predict the best tactics and actions to sales and marketing activities | Sales and marketing time series data help the industry to qualify what we called before intuition. Now, it's fact-based<br>We have more responsibility now to automated analytics, data governance, and analytics standards to support the decision-making processing<br>Measure incremental sales contributions and predict the future impact from tactical and brand planning | Prediction ($n = 54$)<br>Governance ($n = 34$)<br>Data requirements ($n = 22$)<br>Sources ($n = 12$)<br>Insights ($n = 7$) |
| Relevant techniques and models | *Advanced analytics*: The majority of respondents state that their organization views customer reference data as a global strategic asset<br>*Data science*: Data visualization, prescriptive analytics, data mining, data processing, time series, linear and logistic regressions, K-means clustering, tree-based methods, random forests<br>*Most used data science models*: Natural language processing, logistic regression, discriminant analysis, data mining, exploratory analysis | Commercial tactical planning, pharma products commercialization, net sales and gross margin data, and HCP management<br>Forecasting is a key need for advanced analytics as well as market share and performance analysis<br>Clearly articulating the business needs and understand key goals with KPIs that "tells" the story and outline a clear vision<br>Gathering data from internal systems and external sources with qualitative lenses to predict future actions<br>Applying linear and nonlinear analytics modeling to drive new insights | Decision making ($n = 32$)<br>Data analysis ($n = 24$)<br>Knowledge ($n = 17$)<br>Market ($n = 15$)<br>Metrics ($n = 11$)<br>Performance ($n = 11$)<br>Scorecard ($n = 8$)<br>Insights ($n = 6$) |

(continued)

**Table 1.2** (continued)

| Focus group questions | Main categories | Most relevant discussed topics | Keywords and frequency (more than 5) |
|---|---|---|---|
| Data sources | *Data sources and types*: Events, market share, market and competitors, tenders, patient, sentiment from HCPs and patients, cost activity, sales (units, vials, blisters, packages), wholesalers and distributors, patients generated, medical images<br>*New data sources*: Smartphones, payer records, patient portals, generic and public databases, EHRs, wearable devices<br>*Others*: Social media listening, observational data, market research, public data, net promoter score, market research, competitive intelligence | Profit and revenue-generating logic measures that have a value meaning to all involved stakeholders<br>Data-driven decisions with solid decision-making processing<br>Be active in competing in a data-driven world<br>Support the commercial transformation and drive results<br>Key focus on commercialization excellence<br>Ensuring the efficiency of field force is pivotal to the growth and local success | Performance ($n = 17$)<br>Market ($n = 7$)<br>Competitive intelligence ($n = 5$)<br>Competitors ($n = 5$)<br>Wholesalers ($n = 5$) |
| Data governance | Components and services network and protocols<br>*Publications and clinical research*: PubMed, ResearchGate, ClinicalTrials.gov, Google scholar, IQVIA<br>Covid-19 brought new challenges in key account management, customer engagement, and supply chain readiness<br>Incorporate customer-centricity and agility against key competitors to competitive advantage | Tenders and contracts monitoring and review<br>Context and forecasting models representation<br>Financial and production forecasting<br>Solid view of sales & financial positioning | Sales ($n = 15$)<br>Social media ($n = 13$)<br>Tenders ($n = 12$)<br>Pricing ($n = 12$)<br>Public data ($n = 7$) |

(continued)

**Table 1.2** (continued)

| Focus group questions | Main categories | Most relevant discussed topics | Keywords and frequency (more than 5) |
|---|---|---|---|
| Applications and purposes | Analytical techniques: Modeling, simulation, machine learning, visualization, data mining, statistics, web mining, optimization, text mining, forecasting, and social network analysis<br>Effective market engagement models and competition overview<br>Multichannel and marketing tactics review and salesforce effectiveness and customer engagement strategy | Research improvements<br>Technological improvements<br>Reporting and evaluation<br>Monitoring and prediction/simulation | Analytics ($n = 21$)<br>Forecasting ($n = 14$)<br>Data types ($n = 22$)<br>Business outcomes ($n = 12$)<br>Insights ($n = 7$) |
| Data analysis | Leading companies are using their capabilities not only to improve their core operations but to launch entirely new business models<br>The business model transformation highlights the need for improved decision-making tools and strengthening its commercial foundation is a key need | Influencer profiling<br>Commercial dashboards are key in steering the business<br>Market understanding in harmonized market & data definitions<br>Driven through data transparency & aligned KPIs<br>Monitor how we turn market share and market growth into gross sales | Measure ($n = 34$)<br>Objectives ($n = 31$)<br>Analytics ($n = 21$)<br>Strategies ($n = 11$)<br>Outcomes ($n = 10$)<br>Management ($n = 8$) |

(continued)

**Table 1.2** (continued)

| Focus group questions | Main categories | Most relevant discussed topics | Keywords and frequency (more than 5) |
|---|---|---|---|
| Data access and use | Standardization<br>Better data access to improve sales force effectiveness<br>Ensure data quality for accurate reporting/analytics<br>Ability to easily match all channel data to master data | Dynamic insights driven by personas and business needs<br>Predictive analytics<br>Analytics based on multiple data sources<br>Strong governance across dissimilar data sources | Governance ($n = 24$)<br>Data usage ($n = 17$)<br>Time ($n = 12$)<br>Matches ($n = 6$) |
| Standards | Data richness<br>Data completion<br>Defining targeting, segmentation, and alignments<br>Developing accurate analysis and reporting | Unstructured data integration<br>Security best practices for non-relational data stores<br>Risk modeling<br>Customer segmentation<br>Recommendation engines and models<br>Real-time predictive analytics | Automation ($n = 13$)<br>Risks ($n = 9$)<br>Procedures ($n = 6$)<br>SOPs ($n = 6$) |
| Financial resources | New technologies like SaaS and social media monitoring<br>Digital supply chain and blockchain<br>Global and local performance tracking | Operational management need intuitive ways of finding root causes<br>Explain deviations from target to mitigate the impact<br>Ad hoc reporting enablement<br>Integrating sales & activity data<br>APIs and data integration<br>Unstructured data and data modeling<br>Data warehousing | Dashboards ($n = 16$)<br>Risks ($n = 9$)<br>Technologies ($n = 7$)<br>Costs ($n = 5$) |
| Legal aspects and privacy regulations | Data regulations (e.g., GDPR, HIPPA)<br>Supporting GDPR and other regulatory compliance requirements<br>Enable reps to engage with new HCPs with real-time access to a database of all HCPs | Certifications for data privacy regulations<br>New balance between benefits of big data and data protection<br>Trust and permission management mechanisms<br>Integrate training on data privacy<br>Take advantage of security tools | Privacy ($n = 24$)<br>Consent ($n = 22$)<br>Data protection ($n = 21$)<br>Anonymization ($n = 15$)<br>Trust ($n = 12$)<br>Training ($n = 7$) |

- *Business decisions*: DS and AA have nowadays a unique opportunity to drive business decisions and bring a consistent value premise across the value chain in the organization.
- *Business and technology decision-makers*: Pharma commercial analytics leaders are also learning how to create and capitalize on new opportunities derived from DS and AA. Organizations are moving from traditional mindsets to data-driven mentalities. Those leaders are also increasing their comprehensiveness and therefore the resulted value from DS and AA, where several pharma organizations are already adding data and analytics to their decision-making processes.

Regarding the key challenges, we collected the following information:

- *Data and information*: several of the focus group participants focused on several challenges in how the data quality, data security, and data integration are managed and control, where it brings more complexity to any DA and AA initiative.
- *Technology and infrastructure*: currently, the available knowledge and technical architectures don't offer all the necessary confidence and solidity to several of the participating companies in having the correct scalability of analytics and correct resources in terms of advancing into a systematic approach to several DS and AA initiatives.
- *Processes integration*: most of the DS and AA projects fail due to the lack of processes optimization and governance that are not capable to offer ad advanced perspective to both concepts.

In that manner, the focus group was able to provide concrete details to the initial research question and to help us to identify general benefits and constraints from AA and DS projects that most influence commercialization processes and capabilities within the pharmaceutical industry. In terms of the collected information from the focus group, we were able to understand the following conclusions to both research questions.

Throughout the focus groups, participants noted a list of applicable use cases of DS and AA:

- Trend analysis and HCP's behaviors/needs/preferences patterns understanding
- Evolution index analysis: manufacturer sales relative to the market growth with short-/medium-/long-term variations in sales, profits, customer satisfaction, loyalty building, and customer relationship management
- Market/sales data analysis and sales forecasting and competitive intelligence-associated data
- Data capture and analysis from KOLs and other influencers
- KOL classification and profiling models
- KOL-centric models data analysis for HCPs and KOLs responses analysis to medical surveys (via CRM or other systems) and medical interactions over time. This enables commercial to understand not only the feedback HCPs and KOLs
- Text interpretation and analysis using natural language processing techniques

- Marketing channels analysis and trends capture face to face, website usage, visual aiding/eDetailing, digital publications, social media, conferences and congresses tracking, etc.
- Sales incentive schemes, pay-mix, sales target vs budget, and pay-out conditions analysis
- Financial performance reporting with different consumption levels of PnL report with brand-specific insights
- Cash flow report with drivers for locked capital with market dynamics reporting with in-market trends
- Advanced reports with key tender insights, driving, e.g., timely response and efficient call plan and subnational sales reporting
- Multichannel view of marketing performance
- Utilization tracking of promotional content across channels and content monitoring
- Determining disease awareness across social media platforms
- Product and supply chain metrics across the value chain & product geo-mapping

## 1.4 Conclusions

### *1.4.1 Practical Implications*

This article provides several practical implications for organizations' decision-makers and managers. One of the conclusions resulted from this study is management needs to have a strategic approach to creating a culture and capabilities for tracking novel data science (DS) and advanced analytics (AA) models, technologies, processes, and skills to better empower their commercial departments and structures and develop better outcomes frameworks and insights models.

Nowadays, several pharmaceutical companies have preconceived ideas and plan to have systematic and regular procedures for the design and implementation of DS and AA models and processes.

Typically and also as highlighted in the discussions with the focus group participants, the ability from the industry to test and piloting new AA and DS technologies and processes will mean new capabilities in terms of concrete and practical implementation of use cases and techniques and how to align them to organizations' structures and processes.

The research methodologies selected and designed indicated clear insights and valuable research inputs for future research activities and a better understanding of the presented topics in different industries. The data sources, databases, and data collection methods were used, whereas this bibliography study on applications of data science and advanced analytics in the commercial pharmaceutical context presents good opportunities to conduct future analysis and applicability frameworks for constructive knowledge built in systematic DS and AA implementations within the selected industry.

### 1.4.2 Limitations

The research study was created and designed to better understand two specific areas in a pharmaceutical context where the presented conclusions and observations provide already solid evidences but are recommendable to exist a more broad research activity in terms of a possible large-scale empirical testing and validation of the discussed techniques, models, and processes.

Resulted from all data analysis and conclusions, we can also conclude that due to the relatively reduced population of involved companies and departments in this study, some of the conclusions might not be able to represent fully the view of the industry and professionals on the presented topics.

### 1.4.3 Conclusions

This research study presented a combined methodology that allowed us to better understand several different topics to the proposed research questions. One of the major conclusions from this study is the underlying principles behind a DS and AA model that brings an enormous amount of potential information that uncovers hidden information that might accelerate the corporate capacity to gain competitive advantage and better market positioning in terms of new advances in decision-making processes. Another conclusion was that AA and DS techniques are currently already present in commercial pharma but still require several steps to be capable to improve decision-making by reducing the complexity of exponentially increasing amounts of data.

Resulted from the focus group discussions, we are also able to understand that as a result of the rapid evolution of DS and AA, pharma commercial analytics and commercial excellence have flourished, where sales activities have also taken advantage of both terminologies to provide improved services to their key stakeholders and customers. Specific applications of DS and AA for the management and analysis of commercial pharma data might include business and social media and as we saw from the focus group discussions a broader scope of data sources and metrics.

The conclusions and data analysis results from the systematic literature review also presented clear results in terms of the current usage of DS and AA in different industry-specific processes and showed relationships between DS and AA with different technologies and process areas like AI and machine learning.

The focus group discussions further emphasize the need for pharma organizations to bring more analytical, data management, and leadership skills, and enthusiasm for practicing them, within the workplace environment.

Using this hybrid approach (systematic literature review and focus group) composed of database search and interviewing relevant professions resulted in a very successful approach with a rich set of collected data.

In conclusion, the potential of DS and AA within commercial pharmaceuticals also serves to increase the organizational competitive advantage and innovation and allows more analytical and innovation capabilities with clear impacts on the business performance and profitability levels.

According to the collected data and conclusions from both methodological approaches, this research study was able to demonstrate the value that DS and AA have in leveraging and evolving data-driven decisions and more analytical capacity in combination with business operations and related processes, where the benefits and advantages of having systematic processing of insight generation and business pieces of evidence to support decisions are clear gains from both DS and AA.

Therefore, the findings present in this research paper indicate an increase in new DS and AA models, techniques, and systems applying new analytical and data management techniques to large quantities of data and new decision process problems. For future research objectives, a large-scale AA and DS case study or research for current use cases and development frameworks would be useful to better understand in the future and as described in the previous section points.

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# Chapter 2
# Smart TV-Based Lifelogging Systems: Current Trends, Challenges, and the Road Ahead

**Mumtaz Khan, Shah Khusro, and Iftikhar Alam**

## 2.1 Introduction

The phenomena of lifelogging can be described as “to digitally record the people’s daily-life activities and events in varying amounts of detail” [1]. The lifelogging systems use various tools, applications, and devices, such as desktop computers, laptops, smartphones, wearable smart devices, biometric devices, and process the data for explaining the individual’s daily-life activities [2]. This recorded information can offer the potential to mine or infer knowledge about life experiences and used for a variety of purposes including contextual recommendation, e-commerce, monitoring, memory augmentation, linking, summarization, contextual retrieval, browsing, the judicial system, searching, adaptive user interface, and analyzing user profiles [3]. Usually, these personalized devices captured a single user’s events to help predict and find out different patterns, such as healthcare services, social network services, intelligent mirror services, and recommendation services. Moreover, a user must be actively involved during the lifelogging [4].

Lifelogging is a form of pervasive computing. Users can digitally record, capture, store, archive, and process the individuals’ complete life experiences in the form of multimodal through different sensors [5]. The main idea of lifelogging to enhance the way people record and exchange their data, information, communication with others, and log into tools or devices [6]. Besides, the concept of lifelogging, to gain knowledge and data about someone, is just like automated biography. However, the lifelogging applications/tools of these devices have been used for single-user life experiences. For example, lifelogging applications and computer tools, such as Latent [7], have their own perspective of live experiences. However, these

M. Khan · S. Khusro (✉) · I. Alam
Department of Computer Science, University of Peshawar, Peshawar, Pakistan
e-mail: Mumtaz.ksu@uop.edu.pk; khusro@uop.edu.pk; iftikharalam@uop.edu.pk



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lifelogging tools and applications can find a single-user life experience's patterns and behavior.

Similarly, various lifelogging tools and applications have been developed for smartphones, used for multiple-user experiences such as Google Fit, Samsung S-Health, and Huawei Health. In contrast, wearable devices such as google glass, smartwatch, FitBeat, Fitabase, Beddit, BedScales, Sensecam, and Nike+ Sportband use various lifelogging applications and tools in different domains of lives experiences [8]. These tools and applications gather the data and information of a single user and find the analytics and usage behaviors.

In contrast to personalized devices, such as a computer, smartphone, wearable devices, the smart TV is not a single-user device having modern technological computing capabilities. It is a shared device and hybrid of a computer and traditional TV. The activities and events of viewers on smart TV such as watching contents, viewing behaviors, searching behaviors, user interaction behaviors, and interaction modalities are different from the computer and smartphone. However, as discussed, it is a shared device used by the whole family members, and therefore, the interaction and usage style are different from the smartphone and computer [9]. It provides advanced computing and connectivity capabilities, storage, processing, Web 2.0 features, embedded sensors, and other peripheral devices support, with access to online services, such as video on demand, online games, sports, TV shows, personalized content recommendation, web browsing, face recognition, voice control, contents downloading, cloud computing environment, cloud storage, N-screen support, and social media and healthcare activities. Besides, smart TV comes with an operating system, third-party applications, middleware, and different development platforms. A smart TV operating system can manage hardware, software, communication, interaction, processing, and connectivity [10–12]. These technologically advanced features and functions have made smart TV very attractive to the viewers, customers, and gain high market value worldwide. According to a research-and-market report, a smart TV unit is expected to increase from around 209.3 million in 2019 to 266.4 million in 2025 with a compound annual growth rate of 4.1% [13]. According to the American Time Use Survey conducted by the US Bureau of Labor Statistics in 2017, most Americans spend leisure time watching TV to browse entertainment, movies, sports, and news channels [14]. This incredible growth rate shows that each household will soon have a smart TV [10–12]. The integration of these advanced features and functionalities, smart TV made-up smarter and more intelligent, could be used for smart-TV lifelogging systems to capture and store the daily-life interactions, preferences, activities, watching behaviors, and events of the users/family members. Smart TV is a shared device that can assist individuals in capturing, storing, processing, analyzing, and visualizing daily-life events of a family/ group of users [15]. This captured and lifelogging data can be used for various fields and domains of our life experiences (see Sect. 2.3 for more details). Various personalized services of smart TV have been proposed, such as recommendation services for TV programs, channel recommendations, commercials, consumer content, and group-based recommendation [16–18]. In these services, various types of lifelogging data are used. It includes watching histories, browsing histories, user interaction, time of the day, location, and static attributes like gender, age, and hobby [19]. However, these various lifelogging data types are handled individually for each service, device, and user. Besides, they are not communicated efficiently among service applications and individuals. Suppose smart TV-based lifelogging systems are developed and store daily-life activities, events, watching behaviors, preferences, and interaction. In that case, it can be used across various service applications. Using a smart TV-based lifelogging system can provide more valuable personalized services, new trends, and new services to improve the relationship among family members, such as a service provided to the parent to be aware of their children. The detailed various applications, areas, and domains of smart TV-based lifelogging are discussed in Sect. 2.3. Despite multiple applications and advantages of a smart-TV lifelogging system, research in this domain is still broader and needs proper attention to develop such a system. However, the development of such system has some issues and challenges, which are discussed in Sect. 2.4. Therefore, it is necessary to develop a high-quality smart TV-based lifelogging system to capture the daily-life activities, events, watching behaviors, preferences, and interactions of the users/family members.

This chapter may help researchers and experts further extend this work on dominant issues and challenges in the smart TV-based lifelogging system. The contributions of this chapter are (1) to discuss the state-of-the-art lifelogging tools and application of desktop computer, smartphone, and wearable devices and compare their features with smart TV; (2) to identify the various application areas and domains of smart-TV-based lifelogging systems; (3) to determine the various issues and challenges in the design and development of smart-TV lifelogging system; and (4) to present the future trends and research guidelines that may help in handling with these issues and challenges for the developing of a reliable and fine-tuned smart-TV-based lifelogging system.

The rest of the chapter is divided into five sections. Section 2.2 is a literature review. Section 2.3 highlights the applications of lifelogging systems. Section 2.4 is about issues and challenges, and Sect. 2.5 are the recommendations. Section 2.6 concludes the paper. References are enlisted in the last section.

## 2.2 Related Work

The notion behind lifelogging is not new; instead, it has a long human history of research and development. Since ancient times, people have tried to record daily-life activities, events, and personal activities within a community using cave painting, diaries, letters, books, and calendars. The new forms of lifelogging data such as photos, sounds, and videos were added to the last century's mentioned list. The rapid growth, technological development, and broad propagation of personal computers have made users keep records and personalize their services, preferences, accounts, and applications in the 1980s. With the advent of the Internet and Web 2.0, personal data such as login accounts, favorite web pages, email account, gaming data, documents, digital photo albums, web services, and applications are stored in personal devices. Lifelogging has a long history of research and development, as discussed above. Still, its idea and the origin of digital lifelogging system can be traced back to 1945, when Vannevar Bush gave the concept of Memex that users can compress and store all of their data, information, records, and communications providing an "enlarge intimate supplement to one's memory," an automated diary or personal Internet of sorts [20]. The lifelogging system's central concept is to enhance the way people record and exchange their data, communicate with others, and log into applications or devices. Due to the rapid technological development, lifelogging systems have been developed for various devices, such as computers, smartphones, and wearable devices used in different life experiences. Today, several state-of-the-art lifelogging systems are used, which can be categorized into desktop-based, wearable devices, smartphone-based, and smart TV-based. Here, we investigate and compare the desktop computer, wearable devices, and smartphone features with a smart TV.

### *2.2.1 Desktop-Based Life-logging Systems*

The collection and management of information is the essential property of human behavior. However, the users' local and online storage spaces get overloaded day-by-day with information accumulated from unfolding their life experiences. This rapid increase of user information creates information overload, making storage space, arrangement, and retrieval of information difficult [21]. To minimize the problem of information overload, various computer-based personal information management systems (PIMS) have been developed to assist individuals in managing their personal information (PI) space for facilitating their daily-life tasks and accomplishing their required needs [22]. The notion of PIMS has been trace back to 1945 when Vannevar Bush proposed the idea of Memex that users can compress and store all their lifetime data (i.e., information and communications) and retrieve them instantly and flexibly [20]. He believed that applying technology to Memex would increase human memory to assist knowledge and promote information exchange [23]. The technological advancement in computer technologies, such as storage capacity and CPU speed, significantly increased, storing digital and conventional information, including pictures, music, videos, and documents [24]. To overcome the problem of information overload of individuals for personal computer, various research initiatives aims towards a Memex such as semantic desktop [25], Haystack [26], Gnowsis [27], IRIS [28], MylifeBits [29], and NEPOMUK [30]. These applications support individuals in their daily-life activities and augment their memory and intellect.

Similarly, various standalone and web-based lifelogging applications and tools have been developed for the personal computer that has used for the different domain of life experiences and provide a variety of protentional area of benefits such as content-based information retrieval, retrieval of context, browsing, searching, linking, summarization, user interaction behavior, memory augmentation, contextual recommendation, health monitoring, social network analysis, psychological studies, and adaptive user interfaces. However, these lifelogging tools and applications can find the patterns and usage behavior of a single user.

### *2.2.2 Smartphone-Based Lifelogging Systems*

The technological advancement in smartphone technologies plays a vital role in our modern daily-life activities [31]. According to a report by Statista, 3.3 billion users worldwide have used smartphones that become 42.63% of the world's population, showing the smartphone's value and importance [32]. The smartphone performs a wide range of functionalities and services such as messages, email, audio and video call, storage facility, personal calendars, gaming console, connectivity, Web 2.0 features, embedded sensors, development platforms, social networking, and browsing, and the consumer can accomplish a variety of tasks for the intended purpose [33]. Besides, smartphones come with built-in operating systems, third-party applications, middleware capabilities, and various development platforms. The operating system of a smartphone has the capabilities to manage hardware, software, communication, interaction, processing, and connectivity. With the integration of these features, the smartphone becomes like a mini-computer, and users can easily carry it anywhere without any restrictions that creating the opportunity of a lifelogging platform [33]. Nowadays, several lifelogging tools and applications have been developed and proposed for the different domain of live experiences, using the rich sensing capabilities and advance technological features of smartphone for determining the various cues of daily-life activities and events, such as where we go, what we do, who we communicate with, and what data and information we consumed. For example, some of the available smartphone-based tools are Nokia Lifelog project [34], Reality Mining [35], CenceMe [36], MyExperience [37], UbiqLog [33], Sense-Seer [38], Digital Diary [39], Experience Explorer [40], Memento [41], StudentLife [42], and EPARS [43].

### *2.2.3 Wearable Device-Based Life-logging Systems*

The development of wearable devices is a relatively novel, emerging, and multifaceted technology, to be worn or carried by users on the body or attached to clothing to perform specific tasks or function to track daily-life activities. Wearable devices have many forms including a smartwatch, smart eyewear, fitness trackers, smart jewelry, smart clothing, implantable devices, head-Mounted displays, wearable camera, and wearable medical devices, which contains various embedded sensors and apps that have the capability to capturing data, storing, and transmitting data for dissemination purposes [44–46]. The evolution of wearable devices is a promising and emerging technology, used for a variety of fields of life experiences, such as entertainment, healthcare, sports, big data analytics, public safety, military, posture tracking, financial services, e-commerce, monitoring, law enforcement, and political campaigning [47–50]. These devices have used a variety of lifelogging tools and apps for the various domain of life experiences. For example, the lifelogging and tracking tools and applications of wearable devices for healthcare, such as Amiigo, Autographer, Beddit, Bedscales, Nike+ Sportsband, BodyMedia FIT, Fitbit, WakeMate, Runkeeper, SenseCam, SenseWear, ReadiBand, SmartRun, and Smart Belt, identify the disease and disorder symptoms, general vital signs, fitness, steps count, distance travelled, calories burned, stress level, etc. The key advantages of wearable devices are to enhance efficiency, productivity, connectivity, health, and wellness. However, these devices have limitations, such as social acceptability, limited battery life, ergonomics, security, and privacy. Besides, these dedicated and customized lifelogging devices need other devices to log the daily-life activities, which sometimes overwhelms the user in some scenarios.

### *2.2.4 Smart TV-Based Lifelogging Systems*

Smart TV is a fusion of computers and traditional TV; it comes in various shapes and sizes, including set-up boxes. It has modern technological features and functions, including computing/processing, storage, connectivity, Web 2.0 features, face recognition, gesture recognition, motion control, voice control, N-screen support, automatic content recognition, gaming support, social networking, content recommendation, embedded sensors like camera, speaker, Bluetooth, Wi-Fi, ambient light sensor/Eco sensor, motion sensor, IR sensor, and other peripheral device support, with access to online services, such as video-on-demand, online games, sports, TV shows, personalized content recommendation, web browsing, content downloading, cloud computing environment, cloud storage, social media, electronic program guide, interactive advertising, traditional broadcast TV channels, and healthcare activities [10, 17]. Some smart TVs support special features and functionalities such as smart home management, ThinQ AI, SmartThings, Google Assistant, and HomeKit. It also supports integrating a variety of sensors for various purposes like smart home management sensors, healthcare management system sensors, home security management systems sensors, ambient intelligence systems sensors. [51–53]. The amalgamation of these features and functionalities has made smart TVs become one of the most popular entertainment devices and has made this device attractive to viewers and researchers alike [10, 54]. Therefore, it is possible to make smart TV more advanced and intelligent for various life experience domains with current state-of-the-art smart technologies [9]. Besides, the integration of these technologically advanced features and functionalities that make up smart TVs smarter and intelligent could be used for a smart TV-based lifelogging system to store and capture the daily-life interactions, preferences, and activities watching behaviors and events of the users/family members.

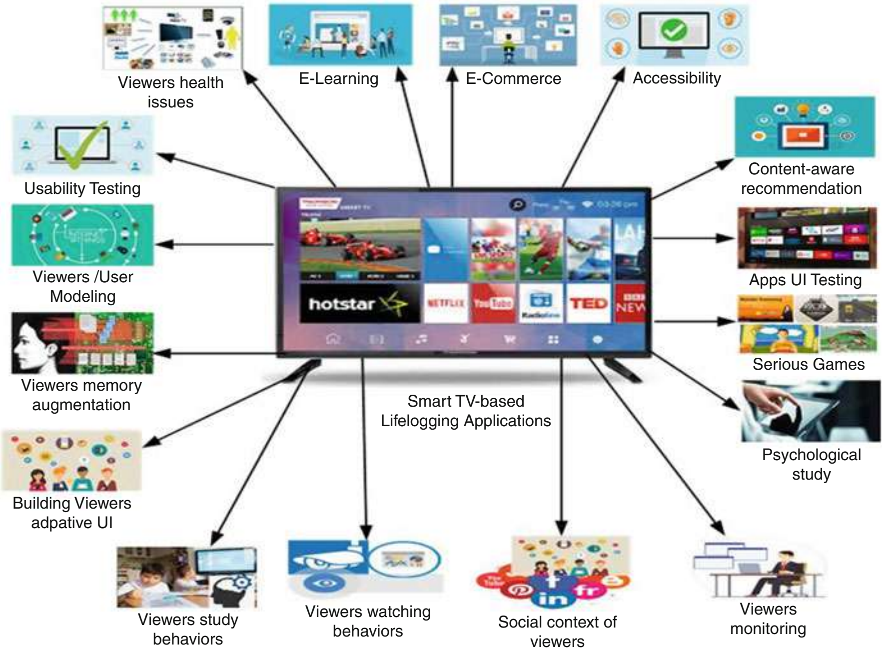


**Fig. 2.1** Possible applications of smart TV-based lifelogging

Smart TV is used for entertainment and is a central hub that manages other activities, such as managing smart home devices, healthcare, and home security. The report of Statista shows that 200 million smart TV were sold in worldwide 2018, and it is predicted that approximately this number will rise to 250 million units in 2024 [55]. This incredible growth rate shows that each household will soon have a smart TV [10–12].

As discussed, the smart TV also has advanced technological features and functions that make it intelligent and can be used for smart TV-based lifelogging systems to capture and store the daily-life interactions, preferences, activities, watching behaviors, and events of the users/family members. Furthermore, smart TV is a shared device with the facilities to assist individuals in capturing, storing, processing, analyzing, and visualizing daily-life events of a family/ group of users. This captured and lifelogging data can be used for various fields and domains of our life experiences, shown in Fig. 2.1. Numerous personalized services of smart TV have been proposed, such as recommendation services for TV programs, channel recommendations, commercials, and consumer content [16–18]. In these services and applications, various types of logged data are used. It includes watching histories, browsing histories, user interaction, time of the day, events of the year, location, and static attributes like gender, age, hobby, likes, and dislikes [19]. However, these various logging data types are handled individually for each service, device, and user. Besides, they are not communicated efficiently among service applications and individuals. Similarly, in the domain of smart TV, some partial lifelogging systems and architecture have been proposed. For example, lifelogging aggregation architecture for smart TV has been proposed [56] to collect lifelogging data from various sources like smartphones, sensing devices, and service servers. They claimed that we could create a new service that is much more useful than existing services by aggregating lifelog data from multiple sources. A smart TV logging system [57] consisting of a smart TV, a smartphone, and a smartwatch has been proposed that received signal strength indication (RSSI), an accelerometer, and a gyroscope data from smartwatches be used to track user activities and determine whether the user is located in the smart TV watch area. In addition to these users' data, smartphone app-use information was used to figure out what users did while watching TV. Another smart TV logging system has been proposed [58] consisting of a Beacon system, a smartphone, and a camera. This system's main purpose is to precisely determine the user viewing activities and viewer behavior in a household. The proposed logging system uses the camera to record the TV content of the screen. The beacon device is used to check the viewers' location in the household, and the smartphone is used to collect the viewer's usage logs using an app usage tracker. Similarly, another data-driven approach [59] has been proposed to identify household members' viewing behavior. The proposed system collects various TV-related behavioral data using an implemented data logger that includes infrared (IR) TV remote controller logs, internet protocol television (IPTV) packets and programmed information, Bluetooth signal tracker, and near-TV photo-resistance brightness data. However, most of the available proposed system has not fulfilled the requirements of various areas' applications domains for the lifelogging aspects for the household viewers and developers, researchers, and manufacturers. Besides, most of the system has been developed in a controlled environment where viewers have followed the specific instructions and given full attention to a smart TV. If the smart-TV lifelogging system is developed and store daily-life activities, events, watching behaviors, preferences, interactions, etc. of the users/family members/household, then it could be used across various service applications or individuals. Using a smart TV-based lifelogging system can provide more valuable personalized services, new trends, and new services to improve the relationship among family members. A service will be provided to the parent to be aware of their children because children spent most of their time in front of smart TV while watching cartoons, playing games, and doing their school assignments near the smart TV. Therefore, the camera of a smart TV can capture their watching behavior and their surrounding environment. Thus, this logging of data can support the parents to look after and monitor their children easily. Similarly, a smart TV is used as a smart IoT device in a healthcare system that collects data from various sensors and data sources. This logging and data collection can provide various aspects of users' healthcare and monitoring services [9, 52]. Despite various applications and advantages of smart TV-based lifelogging systems, research in this domain is still broader and needs proper attention to develop such a system. However, the development of such a system has some issues and challenges discussed in section. Therefore, it is necessary to develop a high-quality plugin-able smart-TV lifelogging system to capture the daily-life activities, events, watching behaviors, preferences, and interactions of the users/family members.

## 2.3 Applications of Smart TV-Based Lifelogging Systems

A smart TV is a lean-back and shared device and enjoyed by the whole family members. Various lifelogging tools and applications have been developed for smartphones, computers, and wearable devices that capture an individual's life events and activities, as discussed in the previous sections. These tools and devices are developed for the domain-specific purpose and individual users that determine the particular user's various aspects, not the whole family members.

A smart TV is a shared device used by the whole family members. Thus, interaction style and usage are different from other devices such as smartphones, computers, and wearable devices. The integration of Web 2.0 features, processing capabilities, storage, Internet connectivity, development platforms and technologies, built-in operating system, third-party platforms, media player, voice and face recognition, automatic content recognition, social networking, embedded sensors like camera, microphone, ambient light sensor, IR sensor, Bluetooth, and speaker, support integration of other sensors, support peripheral devices, and integration support for additional smart devices with smart TV has resulted in more advance, attractive, and entertainment device in the world [10, 54]. Furthermore, smart TV's operating system has the full capability to manage hardware, software, communication, interaction, processing, and connectivity. Today's smart TV supports some unique features and functionalities, including ThinQ AI, SmartThings, smart home management, Google Assistant, and HomeKit. It also supports integrating various sensors and smart devices for multiple purposes, such as sensors and smart devices for smart home management, healthcare management system, home security management systems, ambient intelligence systems, etc. These functionalities and features could make smart TV more advanced, intelligent, and smarter. However, this can be achieved to develop a smart TV-based lifelogging system. Table 2.1 shows the comparisons of smart TV features with computers, smartphones, and wearable devices.

Table 2.1 depicts that smart TV has almost the same features and functionalities, just like other smart devices, including smartphones and computers. The smart TV can log the data and information of multiple users at the same time. In contrast, personalized devices can log the data and information for a single user. Smart TV has more advanced capabilities and functionalities to capture the whole family members' lifelog during the watching, interactions, and data that provide different aspects of the family users. They can be used for a variety of purposes. This diverse information and data of smart TV-based lifelogging system (smart-log) may be genuinely used in the following applications areas, depicted in Fig. 2.1.

**Table 2.1** Comparison of smart TV features with other devices

| Features/functions | Devices<br>smart TV/TV box | Smartphones | Smart wearable devices | Computer/laptop |
|---|---|---|---|---|
| Primary interactive devices | Remote control, small keypad, voice, gesture, touch | Touch, keypad | Small keypad, buttons, pen, gesture | Mouse, keyboard |
| CPU | ✓ | ✓ | ✓ | ✓ |
| Operating system | ✓ | ✓ | ✓ | ✓ |
| Storage | ✓ | ✓ | ✓ | ✓ |
| Apps | ✓ | ✓ | ✓ | ✓ |
| Browning | ✓ | ✓ | ✓ | ✓ |
| Wi-Fi | ✓ | ✓ | ✓ | ✓ |
| Bluetooth | ✓ | ✓ | ✓ | ✓ |
| IR receiver | ✓ | ✗ | ✗ | ✗ |
| Motion sensor | ✓ | ✓ | ✓ | ✗ |
| Ambient light sensor | ✓ | ✓ | ✓ | ✗ |
| Microphone | ✓ | ✓ | ✗ | ✓ |
| Eco sensor | ✓ | ✓ | ✗ | ✗ |
| Camera | ✓ | ✓ | ✓ | ✓ |
| Sensors support | ✓ | ✓ | ✓ | ✓ |
| Peripheral devices support | ✓ | ✓ | ✓ | ✓ |
| Interfaces/ports | ✓ | ✓ | ✗ | ✓ |
| Internet support | ✓ | ✓ | ✓ | ✓ |
| Multiple users support /shared device | ✓ | ✗ | ✗ | ✗ |
| Web 2.0 feature | ✓ | ✓ | ✓ | ✓ |
| Personalization | ✗ | ✓ | ✓ | ✓ |
| Logging support | ✓ | ✓ | ✓ | ✓ |
| Development Platforms | ✓ | ✓ | ✓ | ✓ |
| Interactivity | ✓ | ✓ | ✓ | ✓ |

### *2.3.1 Viewers Watching Behaviors*

Due to the emergence of Web 2.0 features and Internet technologies, a smart TV is changing the TV viewership patterns to a large degree [60]. The technological development and advancement of computing capabilities make the smart TV become the most prominent entertainment device in the world [61]. The emergence of these features dramatically alters the audio-video market for smart TV. The players of the marketing are aware of the concept that changes in viewer routine and usage patterns are the essential rules to redefine the business model for the next coming years; due to this, the demand for user behavior, experiences, and usage patterns are growing [62]. Different approaches such as computer vision, machine learning, recording and observing in the lab environment, human interaction, surveys, and content analysis have been used to measure the viewers' behavior patterns [63–68]. The data collected through the logging system is more robust and authentic than the qualitative research studies such as surveys and interviews [58]. Therefore, the development and use of smart TV-based lifelogging systems (smart-log) are one of the best choices to analyze and identify household family members' various watching behavior patterns.

### *2.3.2 Social Context of Viewers*

Smart TV viewers' watching tastes varied from one another in different contexts and times [69]. Some viewers are interested in watching the news, sports, comedy movies/clips alone, or other viewers or family members. The social context and time are significant factors during the watching of the smart TV environment. For example, watching a smart TV in the office may help protect contents in-home [70, 71]. Therefore, the development of smart TV-based lifelogging systems (smart-log) is probably one of the most promising areas to provide benefit and support in contextual recommendations.

### *2.3.3 Viewers Memory Augmentation*

The field of lifelogging has been used to help recall the viewers with dementia and provide episodic memory impairment [72, 73]. To overcome cognitive overload and augment human memory, different external memory aids such as photos, calendars, alarms, social media posts, application usage logs, and activity logs are often used to help recall important events in our past and future [1, 74]. However, these can overcome the cognitive overload of a single user. But the use of a smart TV-based lifelogging system (smart-log) can enhance the memory augmentation of the whole household for various purposes.

### *2.3.4 Viewers Monitoring*

One of the primary purposes of logging is to help viewers collect self-monitoring and reflection [75]. The real-time identification and tracking apps enable the monitoring and consumption of TV contents or other devices for the viewer through tracking pixels and cookies [76]. The smart TV-based lifelogging system (smart-log) can provide the parents' facilities to monitor and track children and kids' activities that what they are watching and viewing on the smart TV. Besides, from this logging data, several types of patterns and behaviors are concluded to help the parents and smart TV firms, content providers, and apps developers recommend the users' required contents and apps.

### *2.3.5 Viewers Study Behaviors*

A smart TV is used for entertainment and browsing; reading papers, books, newspapers, and magazines; and playing audiobooks online and offline. However, a smart TV is not a single-person device but used by the whole family members. The characteristics of individuals in the family vary from one another, such as their age, gender, education level, preferences, time of the day, and week of the day. Due to these characteristics, each individual's reading behavior and pattern may differ from one another in the household. Therefore, the smart TV-based lifelogging system (smart-log) can provide the facilities to find the different study behaviors and patterns of each individual that may help household viewers, vendors, and service providers.

### *2.3.6 Viewer/User Modelling*

User modelling is already applied in various areas, such as information retravel, filtering and extraction systems, adaptive user interfaces, educational software, and advertising [77]. Therefore, the smart TV-based lifelogging system (smart-log) of smart TVs can provide the facility with a dynamic and adaptive user model for the household viewers based on their interaction history, usage, and viewing behaviors.

### *2.3.7 Context-Aware Recommendations*

Different approaches such as content-filtering, collaborative-filtering, hybrid-filtering, preference-based, behavior-based, Profile-based, ontology-based, multiple viewer-based, context aware-based, time-based, and user model-based have been proposed for the recommendation of items and contents for the smart TV domain [16, 78–85]. Several works have proven that contextual information can significantly increase and improve the recommendation process [86–90]. Using a smart TV-based lifelogging system (smart-log) may have rich data and reports of viewers. Therefore, it can significantly improve the context-aware recommendation process to the viewers in the smart TV environment.

### 2.3.8 E-Learning

A smart TV is used not only for entertainment purposes but also for e-learning. It can be widely used for foreign languages or any other online course. The smart TV-based lifelogging system can help in judging the nature of the children during the course and can facilitate parents to understand their weaknesses [91–94].

### 2.3.9 E-Commerce

Many companies are using smart TVs for e-commerce during live video channels, apps, and browsing. They are using different factors for the advertisement/e-commerce such as implicit feedback (such as watching duration, watching time, time-of-the-day, and demographic information) and explicit feedback (such as like, dislike, and rating) of the viewers [95, 96]. However, a smart TV is a shared device and enjoyed by the whole family members, and most of the time, some irrelevant advertisements are displayed during the watching of smart TV. Household members have different tastes of watching, watching behaviors, social status, and characteristics, educational background, etc. Besides, most of the advertisements are not targeting the individual in which the company is impressive. Therefore, a smart TV-based lifelogging system can make smart TV more intelligent and smarter. It can store every interaction and behavior of the viewers that make advertising more contextual and relevant to the viewers' characteristics and behaviors.

### 2.3.10 Building Viewer Adaptive UI

Several types of research and European initiatives such as GUIDE [97], AdaM [98], and CASAS [99, 100] have addressed the challenges of accessible smart TV/setup-box applications. Besides, they have also solved the issues of UI to some degree. The viewers of the household have not the same characteristic, knowledge, experience, technicality, etc. Therefore, smart TV-based lifelogging can capture the interaction, usage, and watching behaviors of the viewers, making it possible to develop an adaptive user interface for smart TV viewers according to their needs, preferences, and skills.

### 2.3.11 Viewer Health Issues

The researchers have developed various apps, wearable devices, smartphones, and sensors to collect their own health-related daily-life activities and events data.

These devices and technologies can be adopted in various places such as smart homes, smart healthcare that improve patients' rehabilitation process [101–106]. Nowadays, smartphones are also commonly preferred devices due to their mobility, user-friendly interface, and rich available resources such as CPU, embedded sensors, memory, and battery that can easily monitor human life activities and events [107]—however, these devices and technologies collect the data of the single individual. But the development and using the smart TV-based lifelogging system can easily manage the daily-life activities and events of the whole family members, enabling the users and healthcare organizations to identify the household family members' health-related issues. Besides, it may help the apps developer and a broadcaster/content provider recommend the household members' required contents according to the viewer's mode and situations.

### 2.3.12 User Interface (UI) Testing

Several android GUI testing tools and libraries such as Appium, MonkeyTalk, and UiAutomator are available in the literature [108, 109]. However, the UI of smart TV apps is facing some challenges, such as user interaction issues, an intermediate device for interaction, and user distance issue from a smart TV [110]. Hence, a smart TV-based lifelogging system could allow the facility to identify and test the user interface (UI) related issues of various household viewers and can easily handle and improve the UI for smart TV viewers.

### 2.3.13 Accessibility

A smart TV has a wide range of user groups such as kids, adults, elders, technical users, and non-technical users. However, the needs and usage of everyone are different from one another. Almost the development and designing of smart TV apps follow the rules and guidelines of smartphone apps. Still, a smart TV is the other device in the context of usability, accessibility, usage, and lifetime [110, 111]. Besides, it rarely follows the rule of accessibility for designing and development. Therefore, it is essential to follow the rules and guidelines of the user-centric approach to developing smart TV apps. In such cases, the smart TV-based lifelogging could improve the accessibility of smart TV apps.

### 2.3.14 Usability Tests

Usability evaluation and testing is the primary step during the design process of an interactive system such as software, web application, or any service [112, 113]. It allows the facility to measure the functionality and degree to which the software is effective, efficient, and positive attitudes and responses [114, 115]. Thus, a smart TV-based lifelogging system could enable the different apps' usability test during different users' usage (child, kids, adults, aged people). It can store and capture the other interaction behaviors of the viewers during the usage of apps that can provide the facility with the developers, vendors, and researchers to test the usability of various install apps of smart TVs.

### *2.3.15 Psychological Studies*

Smart TV-based lifelogging systems can be captured and stored in household members' comprehensive data such as interaction history, watching history, and viewing behaviors. Therefore, smart TV-based lifelogging can help in the psychological study of the individual such as viewing habits, considering timing, emotion, behavioral research [116], personality study [117], health issues [118], and user performance [119].

### *2.3.16 Serious Games*

Millions of viewers playing games on smart TV like smartphones and computers. Several types of games have been developed for different domains, such as health, education, training, and military. These games are used for a wide range of characteristics such as in health serious games to analyze viewers' behavioral capability with mental or learning abilities. Similarly, severe educational games help analyze students' learning and psychological capabilities and so on [120–123]. Therefore, the smart TV-based lifelogging system could provide more in-depth insight into the gameplay dynamics.

## 2.4 Issues and Challenges of Smart TV-based Lifelogging System

Although there are protentional applications of the smart TV-based lifelogging system in many valuable domains of our lives—the applications and advantages have been discussed in the previous section—however, there are still some key challenges available for the developing of smart TV-based lifelogging system. These challenges include updating a user profile, browsing, searching, user characteristics, privacy, security, storage, and processing.

### 2.4.1 Updating User Profile Issue

A smart TV is not a personalized device like a smartphone or a computer. It is a shared device which is watched and enjoyed by the whole family members. The profile of the individual viewer can be easily handled. However, the dynamic updating of group viewers may create hurdles during combined watching [18]. Besides, older citizens and children often observe the continuous decline of capabilities over time. As long as these users use a device, they update their profile as capabilities and priorities will change, not only on a day-to-day basis but also specific time to time. This dynamic updating needs a complex algorithm, programming skills, and management system with a dedicated infrastructure to handle this issue.

### 2.4.2 User Privacy and Security Issues

To gain the full benefits from smart TV, it must be connected to the public network (Internet), creating security and privacy for hackers and spammers [124]. However, privacy and security issues are critical problems in a smart TV. According to this report [125], smart TVs capture and send user viewing information to the manufacturer, service provider, and the third-party application that can determine every moment of the viewers, using automatic content recognition technology. In [126], the author demonstrates the software-based attacks and mentioned that security and privacy are high risks than computers and smartphones. In [127], the researchers highlighted the various privacy and security aspects and issues in a smart TV environment. Therefore, considering these concerns, there may be chances that hackers, spammers, or others steal the smart TV's lifelogging data. However, the concept of confidentiality, integrity, and availability (CIA) triad endured and agreed by [128, 129] can be applied for security and privacy.

### 2.4.3 User Preferences

The preferences of each user are different from one another. In this situation, each user's preference and watching activity will be considered for the combined family. These preferences will be stored in all family members' profiles and their respective logging files. Besides, typically, each user's preferences, choices, taste, and natures are different from each other. Due to these reasons, one user's selection may affect another user's preferences, resulting in different issues such as recommendation, indexing, summarization of contents, and adaptive user interface. However, user preferences may be treated using anonymous profile generation techniques [18] to store the importance of each family/group in the corresponding user/group profile.

### 2.4.4 User's Characteristics/User's Taste

The characteristics and tastes of each user in the household are varying from one another. The viewers' watching habits, perspectives, and patterns are different from one another. The viewing habits can predict and identify the characteristics, tastes, or desires of viewers. However, identifying and predicting a specific viewer/individual in the smart TV environment is challenging [130]. Some researchers have recently proposed identifying users in front of a smart TV through the camera that determines the gender, the age, and the number of users. But these studies limited identifying the characteristics and tastes of various users in the household (like kids, adults, and senior citizens).

### 2.4.5 Storage (Local and Cloud-Based)

Smart TVs can store an adequate amount of data for an individual. However, it includes sensors, such as a microphone and camera that can record the single viewer's data and the whole family members' data, which are a rich life-experience archive. The lifelogging application generates many data such as video, images, text, or sensor data in a nonintrusive manner that may produce storage [131]. However, according to Moore's and Kryder's law [132] [133], it is correct and reasonable that storage drive densities will continue to increase. Besides, this large generated may be stored locally or cloud-hosting. So, in the future, the memory of smart TVs can be enriched. However, the lifelogging data is stored on cloud-hosting; it may create privacy and security problems.

### 2.4.6 Processing and Presentation Issue

According to [134], once a lifelog is created, it is our attention to using, access, and process this lifelog data. Lifelogging of smart TV can record continuously and passively a wide range of aspects about the whole household/family members. These captured aspects/events (maybe in the form of audio, video, text, picture, interaction history, watching history, and preferences) that may be related to some sort of time of our lives. The audio and video data will be in the form of segments, shots, and scenes. The meaningful extraction, semantics, and presentation of this vast lifelog data due to nonintrusive recording manner that produces a large volume and variety of data such as videos, images, text, or sensor data can cause the issue of processing and presentation. The capability of the smart TV related to processing and meaningful representation of various modalities are limited. But with technological advancement, the processing capability can be enhanced like a computer. Smart TVs have provided the peripheral support of additional memory.

### 2.4.7 Accessing and Searching Issue

Lifelogging tools and applications of wearable devices, smartphones, and computers have generated numerous personalized archives that contain the rich details of our life experiences in different modalities such as videos, images, text, and numeric or sensor data [134]. These personalized archives contain details of individuals' life experiences such as watching history and user interactions. These archives day-by-day enriched, which create difficulties for the individuals, including how to extract meaningful information and summarize and search for this rich data [135]. These tools and applications can store and archive the various information of individual users, and researchers have already initiated some work on this issue, such as NTCIR-14 [136] and LifelogTask [137]. However, the lifelogging of smart TV can have the capabilities to store the richer details of our life experiences of individual family members and the group form. This substantial life-experience archive of viewers may create accessing and searching issues like the other lifelogging application and tools developed for wearable devices, smartphones, and computers. To handle these issues, smart TV's lifelogging can capture and store the optimized life experiences of viewers and remove the raw/irrelevant data from lifelogging data using deep learning approaches. In addition, it needed a powerful processing, computation, and complex algorithm for information retrieval.

## 2.5 Recommendation and Research Guidelines

The issues and challenges of smart TVs have been critically investigated and discussed in the previous section. Here, some guidelines and recommendations are given that might help develop and design smart TV-based lifelogging systems in light of these issues and challenges. These guidelines and recommendations will mitigate and handle the issues and challenges including updating user profile issues, user privacy and security issues, user preference issues, user characteristic/user taste issues, storage issues, processing and presentation issues, and accessing and searching issues. These recommendations and guidelines are discussed one by one as follows:

### 2.5.1 Updating a User Profile

The dynamic updating of each user/group profile in the household is cumbersome in the smart TV-based lifelogging system. A smart TV is a shared device and enjoyed by the whole household family members. Each home has various types of users, such as kids, adults, and senior citizens. Each user/group profile is different due to nature, taste, age, gender, technicality, preferences, usage history, and interaction. Each user's profile has various types of data/information, such as implicit and explicit data. Typically, household family members use one profile for content searching, browsing, accessing, and watching, leading to wrong content recommendations, summarizations, and adaptations to the individuals/ viewers. However, the profile updating ambiguity can be solved using automatic recognition of user profile(s) through the embedded camera that identifies the age, gender, and numbers. Using the proposed formula for the profile generation [18], for example, if there are two users (U1, U2) in the household, then the possible profile arrangements of the household family members are U1P1, U2P2, U1P1, and U2P2. So, if a user one (U1) is watching the smart TV, then the user profile one (U1P1) will be recognized, and their activities such as watching and searching will be updated in their corresponding user profile (U1P1).

Similarly, if user two (U2) watches the smart TV, then user profile two (U2P2) will be recognized. Their activities, such as watching and searching, will be updated in their corresponding user profile (U2P2). Similarly, if user one (U1) and user two (U2) combine watching the smart TV, then the combined profile (U1P1U2P2) of user one and user two will be recognized. Their activities, such as watching and searching, will be updated in their corresponding combined user profile (U1P1U2P2).

### *2.5.2 The Security and Privacy Issues*

Security and privacy are the main problems of smart TV-based lifelogging systems for household members while watching smart TV. A smart TV is a shared device and enjoyed by the whole family members. Each household has various types of the user, such as kids, adults, and senior citizens, and their interaction, watching, and searching behavior are different from one another. Hence, content searching, browsing, streaming, interaction, and watching are not secured and might lead to security and privacy issues. However, this issue may be solved by using profile generation and recognition techniques [18]. According to this technique, various anonymous profiles generated for the household members and each profile are secured. One profile member cannot see the other profile information, watching history, and interaction history. Similarly, using the privacy principles, including confidentiality, integrity, and availability (CIA) triad can be applied for security.

### *2.5.3 Preferences of Each User*

One of the issues and problems in a smart TV-based lifelogging system is the preferences of each user. A smart TV is a shared device and watched by the whole family members. So, the watching, searching, browsing, or any other activity on smart TV of any user can be considered for all family members. These preferences will be stored in each user profile. However, watching, searching, browsing, or any other activity of each user in the household on a smart TV is different. Hence, user preference can affect another user's preferences, resulting in various issues such as recommendation, indexing, summarization, and adaptive user interfaces. However, each user profile ambiguity's importance can be solved using automatic recognition of user profile(s) through the embedded camera that identifies the age, gender, and numbers discussed in the dynamic updating user profile issues. Using this procedure and approach in the smart TV-based lifelogging system, each user's preferences can easily store their respective user profiles.

### *2.5.4 Exact Identity of Viewers*

Another issue in the smart TV-based lifelogging system is that the exact identification of user characteristics or taste is challenging. A smart TV is a shared device and enjoyed by the whole family members. The characteristics/taste of each user in the household varies from one another. But this issue can also be used to automatically recognize user profile(s) through the embedded camera that identifies the age, gender, and numbers as discussed above in the dynamic updating user profile issues. Using this approach in the smart TV-based lifelogging system, each user's characteristics/taste can easily store in their respective user profiles that might help identify and predict specific viewers/individuals in the household environment.

To minimize storage, smart TV-based lifelogging systems need to filter out the information of the viewer(s) before storing it into a storage device. A smart TV is a shared device that is seen by not only the single viewer but also all family members. These family members have rich life-experience data, which need further preprocessing to find meaningful information before storing them into storage devices. It would be better, and smart TV-based lifelogging systems have a classifier that filters out the necessary information and events before storing them into a storage device.

Smart TV-based lifelogging systems can capture the whole family members' wide range of data related to some part of the viewer's events and life experiences (s). These events and life experiences of the viewers would be depicted and interpreted by meaningful semantic annotation, where semantic annotation can be organized to extract meaningful information from the smart TV-based lifelogging systems and answers the question of the daily-life routine (for example, who, what, when, where) using advanced information retrieval approaches complex semantic query technologies and deep learning approaches.

### *2.5.5 Removal of Irrelevant Data*

Smart TV-based lifelogging systems can generate various types of personalized archives that may contain the rich information of the multiple viewers of the household and may create issues in searching and accessing the desired contents in these archives. However, this issue could be handled to store the viewers' optimized life experiences and remove the irrelevant data from the lifelogging data. Furthermore, it needed, powerful processing, computation, and complex algorithms for information retrieval.

## 2.6 Conclusion and Future Work

The technological advancement and the rapid growth of smart TV technologies are increasing day by day due to the usage of diverse sets of contents from different data sources, including live channels, videos, games, video-on-demand, and social networking and full support of Web 2.0 features. Introducing more advanced and technological computing features like smartphones and computers can be made up smart TV more intelligent and smarter for capturing and storing the daily-life activities and interactions, preferences of the individual viewers, and overall household members. This logged data could be used for diverse life experiences and purposes, including contextual recommendation, adaptive user interface, usability testing, and memory augmentation. The detail applications have been discussed in the section of applications of a smart TV-based lifelogging system and depicted in Fig.2.1. Despite various smart TV-based lifelogging system applications, interest in this domain is needed proper attention to design and develop such an approach to facilitate the end-user and the practitioners, developers, and manufacturers of a smart TV. However, the development and designing of such a system have faced some issues and challenges discussed in the issues and challenges of smart TV-based lifelogging systems. But these issues and problems could be handled to follow the standard guidelines and rules of the lifelogging system. In this chapter, we have outlined some dominant difficulties and challenges that are addressed to avoid what has been done and what needs to do in the context of various research opportunities. This chapter provides some guidelines that may help in the latest problems including user privacy and security issues, updating user profile issues, user preferences, user taste, storage, processing and presentation issues, and accessing and searching issues. Moreover, we are working on a lifelogging framework that may help researchers further extend his/her research in smart TV-based lifelogging systems.

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# Chapter 3
# Knowledge Management in Marketing

**Ricardo Jorge Gomes Raimundo, Albérico Manuel Fernandes Travassos Rosário, and Ana Luísa Marques Rocha**

## 3.1 Introduction

The success in adapting to globalization and the unpredictable path of the economy can be considered in the light of knowledge as a strategic resource, whereas the most important determinant of technological advancement may be the gathering of knowledge and acquisition of intellectual capital. Indeed, KM has emerged as a promising area of research at the interface of diverse management areas [1].

The central to KM research are issues related to business management; businesses must build their own data system gathered from stakeholders to keep growing, mainly in the new era of the digital revolution with the rise of multiple automation services. KM can be deemed as a process of creating, using, and managing the knowledge and information of an organization [2]. It embraces company data related to customers, products, working systems/structures and consists of two main types of knowledge. On the one hand, explicit knowledge can be simply understood, and thus easily disseminated to others and, on the other hand, tacit knowledge, which is difficult to transfer to others. Through KM, organizational knowledge is stored and constructed in due course so that anybody can use it. It, therefore, comprehends a strong link to organizational goals and strategies and can add value by ameliorating the relationship and data quality between provider and customer [3].

R. J. G. Raimundo (✉) · A. L. M. Rocha
IPAM-The Marketing School, Matosinhos, Portugal
e-mail: ricardo.raimundo@universidadeeuropeia.pt; ana.rocha@universidadeeuropeia.pt

A. M. F. T. Rosário
GOVCOPP, ESGTS – IPSantarém, Aveiro, Portugal
e-mail: alberico.rosario@esg.ipsantarem.pt

 
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The problems related to KM upon marketing are explored in this piece of writing over 32 articles that emphasize the issues of information not shared well, or not properly managed over time [4]. For example, if knowledge is not shared with others at once, it will be hard to extend the idea and grow the business [5]. Likewise, if new employees have no idea about that knowledge, it will be difficult to keep a high and constant level of service, as part of the team is unaware [6]. In short, by making use of KM, companies manage to deliver products/services to more customers, which enhances ensuing marketing efficiency. For example, computing adaptive technology, and intelligent filtering tools present an enormous impact for codifying knowledge, and improving marketing campaigns and customer experience by enabling to understanding how customers react [7].

Hence, the way KM impacts marketing is essential to business performance. As Al-Dmour et al. [2] posit, marketing knowledge management is paramount for business performance with respect to corporate capabilities. Research on the topic has grown in the past decade and demonstrates several characteristics.

First, while KM is broadly positioned at the interface of marketing and production and operations [8], existing studies have drawn from a wide range of theoretical insights, including developing contexts [9], marketing organizations as boundary spanners [10], innovation [11], indigenous knowledge [12], branding [13], dynamic capabilities [14], electronic marketing [15], conceptual maps [16], and social media [17], by using different methods to study different contexts. While this may indicate the turbulence of the field, it is important to take stock of the work to date by a systematic literature review (SLR) and identify key research themes to provide an overview of KM literature on marketing for further research to build upon.

Second, in addition to the characteristic of the variety of KM research, its highly fragmented nature and ensuing definitional incongruence. For example, although KM is often referred to as improvement of work based on the use of employee knowledge [2], it can also be deemed as a business attitude, which considers knowledge and marketing innovation as its strategic advantages [7]. In fact, KM comprises knowledge creation, storing, transfer, and utilization. It is a discipline that promotes the creation, sharing, and utilization of organizational knowledge [6]. While we recognize that the variety and inconsistency reflect individual researchers' ontological, epistemological and methodological background, it is central to examine KM literature on marketing and identify the key research gaps and challenges for future research.

Third, the rise of KM research has refreshed marketing research by focusing on the knowledge creation and developmental process of marketing [18] and integration with firms' strategy [19]. As Chai and Nebus [20] posit upon knowledge reuse efficiency, organizations continue to struggle with low returns on knowledge management (KM) investments. Past KM research partly ignored business performance in terms of marketing effectiveness. Thus, more research is needed to understand the role of KM in marketing [2] and the way KM can help to understand the key challenges in the marketing literature and to cross-fertilize KM and marketing literature.

This study aims to help to fill those research gaps by focusing on three key objectives. On the one hand, we conduct a systematic analysis of KM literature in marketing studies to examine the theoretical and empirical development and identify KM research themes. We aim to provide an overview of KM research on marketing and a foundation for future researchers to build on. On the other hand, we discuss those main trends of KM literature on marketing that deserve more attention in future research, the key research gaps identified, and at the center of the debate. To sum up, our main aim is to take stock of KM research on marketing to provide a foundation for future KM research, while recognizing its current variety.

## 3.2 Methodological Approach

We carried out a review of the Systematic Bibliometric Literature (LRSB) of knowledge management in marketing following the suggestions of Rosário et al. [21] and Rosário and Cuz [22]. An LRSB improves: (i) the validity of a review, providing a clear set of steps that can be followed if the study is replicated; (ii) the accuracy of a review, providing evidence to support arguments closely related to research issues; and (iii) the generalizability of the results, allowing for the synthesis and analysis of accumulated knowledge. In view of the above, we consider the LRSB as a "guiding instrument," which allows us to shape the review according to our research objectives, rather than a methodology with a concrete set of rigid rules.

Thus, LRSB allows a comprehensive knowledge of the subject, as well as its evolution over time, identifying researchers, publications, and the nature of the most relevant articles [21–23]. In this case, KM is the methodological object of analysis, on which we have collected, selected, and synthesized information based mainly on academic databases and their research engines.

As suggested by Rosário et al. [21]; Rosário and Cuz [22]; Sacavém et al. [23], it allows a comprehensive knowledge, consisting of the identification, selection, analysis, and synthesis of existing research on a given theme, with the presentation of the main issues and results emerging from the research, which may be conceptual or empirical. This revision model is dedicated to the study of scientific documents with the aim of predicting theory, with its main limitation being the fact that it is necessary to remove and interpret information from documents.

The study continues as follows: (i) definition of the research question; (ii) location of studies; (iii) selection and evaluation of studies; (iv) analysis and synthesis; (v) presentation of results; and (vi) discussion and concussion of results. This methodology ensures that the review is comprehensive, auditable, and replicable and responds to specific research questions, following the main LRSB procedures [21–23].

This LRSB was conducted in September 2020 through the SCOPUS database, as it is considered the most significant peer-reviewed database of scientific articles in an academic context. The study presents therefore the limitation of using only the SCOPUS database while excluding other academic sources. It uses “knowledge management” and “Marketing” as keywords in a comprehensive manner (title, abstract, and keywords), and limited to peer review literature on business, management, and accounting topics over the past ten years (2010–2020).

LRSB aims to generate insights into recent developments in the field, analyze research to date, and identify opportunities for future research. This study aims to facilitate the discussion of knowledge management in Marketing. We have obtained a set of 32 scientific articles cited, 1 open access article, and 31 other types of access.

## 3.3 Literature Analysis: Themes and Trends

Peer-reviewed articles on the subject were screened from 2010 to 2020. Over the period under the review, 2016 was the year with the largest number of peer-reviewed articles on the subject, with seven publications. Figure 3.1 analyzes the peer-reviewed publications published for the period 2010–2020.

The publications were sorted out as follows: Current Issues In Tourism; International Journal Of Innovation and Learning; Vine Journal Of Information and knowledge management with two publications, and the remaining journals with one publication each (Annals Of Applied Sport Science; Construction Management And Economics; European Journal Of Economics Finance And Administrative Sciences; IEEE Transactions On Engineering Management; IEEE Transactions On Professional Communication; Industrial Marketing Management; International Business Management; International Journal Of Contemporary Hospitality Management; International Journal Of Culture Tourism And Hospitality Research; International Journal Of Emerging Markets; International Journal Of Enterprise Information Systems; International Journal Of Project Management; International Journal Of Services Technology And Management; International Journal Of Supply Chain Management; International Journal Of Technology Management; International

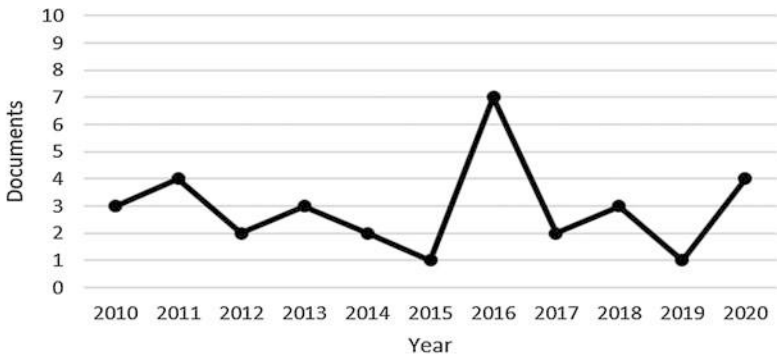


**Fig. 3.1** Documents by year. (Source: Own elaboration)

Journal Of Tourism Research; Journal Of Manufacturing Technology Management; Journal Of Retailing And Consumer Services; Journal Of Travel Research; Knowledge-Based Systems; Management Research Review; Research Technology Management; Service Industries Journal; Technology Analysis And Strategic Management; Technology In Society; and World Review Of Entrepreneurship Management And Sustainable Development).

We can say that between 2010 and 2020, there has been an interest in research on knowledge management in marketing.

In Table 3.1, we analyze for the Scimago Journal & Country Rank (SJR), the best quartile, and the H index by publication. The current issues in Tourism is the most quoted publication with 1.40 (SJR), Q1, and H index 64. There is a total of 13 journals on Q1, ten journals on Q2 and four journals on Q3. Journals from best quartile Q1 represent 46% of the 29 journal titles, best quartile Q2 represents 36% and finally, and best quartile Q3 represents 14% of the 29 journal titles.

As evident from Table 3.1, the significant majority of articles on nascent entrepreneurship rank on the Q1 best quartile index.

The subject areas covered by the 32 scientific articles were business, management, and accounting (32); social sciences (12); computer science (8); engineering (7); decision sciences (4) economics, econometrics, and finance (2); and energy; environmental science; health professions; and medicine—psychology (1). The most quoted article was "The impact of knowledge management on innovation: An empirical study on Jordanian consultancy firms" from Obeidat et al. [24], with 77 quotes published in the Journal of Business Venturing with 0.51 (SJR), the best quartile (Q2), and with H index (47). The published article hangs itself in the study in the processes of knowledge management and in the approaches of knowledge management about innovation in consulting companies.

In Fig. 3.2, we can analyze the evolution of citations of articles published between 2010 and 2020.

The number of citations shows a net positive growth with an R2 of 87% for the 2010 to 2020 period, with 2019 peaking at 105 citations.

The H index was used to ascertain the productivity and impact of the published work based on the largest number of articles included that had at least the same number of citations. Of the documents considered for the H index, 13 have been cited at least 13 times.

In Fig. 3.3, a bibliometric analysis was carried out to analyze and identify indicators on the dynamics and evolution of scientific information using the main keywords. The analysis of the bibliometric research results using the scientific software VOS viewer aims to identify the main keywords of research in knowledge management in marketing studies.

The linked keywords can be analyzed in Fig. 3.4, making it possible to clarify the network of keywords that appear together/linked in each scientific article, allowing us to know the topics analyzed by the research and to identify future research trends.

In Annex 3.I, the citations of all scientific articles from the 2010 to 2020 period are analyzed; six documents were not cited until 2020, 2011, 2; 2012, 11; 2013, 19; 2014, 24; 2015, 24; 2016, 36; 2017, 43; 2018, 58; 2019, 99; and 2020, 105 with

**Table 3.1** Scimago Journal & Country Rank impact factor

| Title | SJR | Best quartile | H index |
|---|---|---|---|
| Current Issues in Tourism | 1.40 | Q1 | 64 |
| Construction Management and Economics | 0.87 | Q1 | 88 |
| IEEE Transactions on Engineering Management | 1.07 | Q1 | 89 |
| Industrial Marketing Management | 2.08 | Q1 | 125 |
| International Journal of Contemporary Hospitality Management | 2.20 | Q1 | 76 |
| International Journal of Project Management | 2.66 | Q1 | 134 |
| International Journal of Technology Management | 0.41 | Q1 | 54 |
| International Journal of Tourism Research | 1.03 | Q1 | 51 |
| Journal of Manufacturing Technology Management | 1.17 | Q1 | 65 |
| Journal of Retailing and Consumer Services | 1.37 | Q1 | 75 |
| Journal of Travel Research | 3.01 | Q1 | 122 |
| Knowledge-Based Systems | 1.75 | Q1 | 107 |
| Research Technology Management | 0.84 | Q1 | 63 |
| Vine Journal of Information and Knowledge Management Systems | 0.37 | Q2 | 28 |
| IEEE Transactions on Professional Communication | 0.38 | Q2 | 42 |
| International Journal of Culture Tourism and Hospitality Research | 0.47 | Q2 | 228 |
| International Journal of Emerging Markets | 0.37 | Q2 | 26 |
| International Journal of Enterprise Information Systems | 0.40 | Q2 | 24 |
| International Journal of Supply Chain Management | 0.36 | Q2 | 13 |
| Management Research Review | 0.51 | Q2 | 47 |
| Service Industries Journal | 0.63 | Q2 | 62 |
| Technology Analysis and Strategic Management | 0.63 | Q2 | 64 |
| Technology in Society | 0.57 | Q2 | 47 |
| International Journal of Innovation and Learning | 0.22 | Q3 | 26 |
| Annals of Applied Sport Science | 0.18 | Q3 | 2 |
| International Journal of Services Technology and Management | 0.13 | Q3 | 22 |
| World Review of Entrepreneurship Management and Sustainable Development | 0.22 | Q3 | 14 |
| International Business Management | 0.13 | Q4 | 17 |
| European Journal of Economics Finance and Administrative Sciences | –[a] | –[a] | 15 |

Source: Own elaboration
Note: [a]Data not available

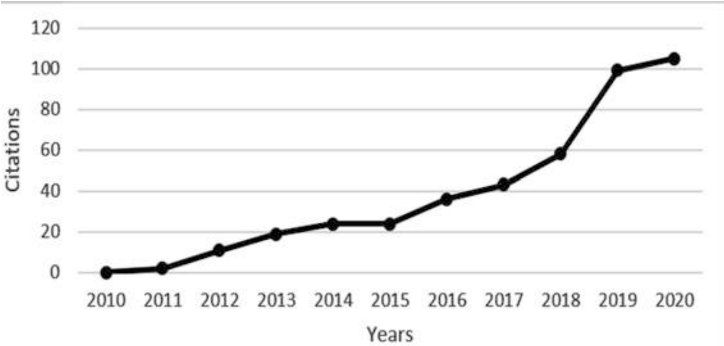


**Fig. 3.2** Evolution of citations between 2010 and 2020. (Source: Own elaboration)

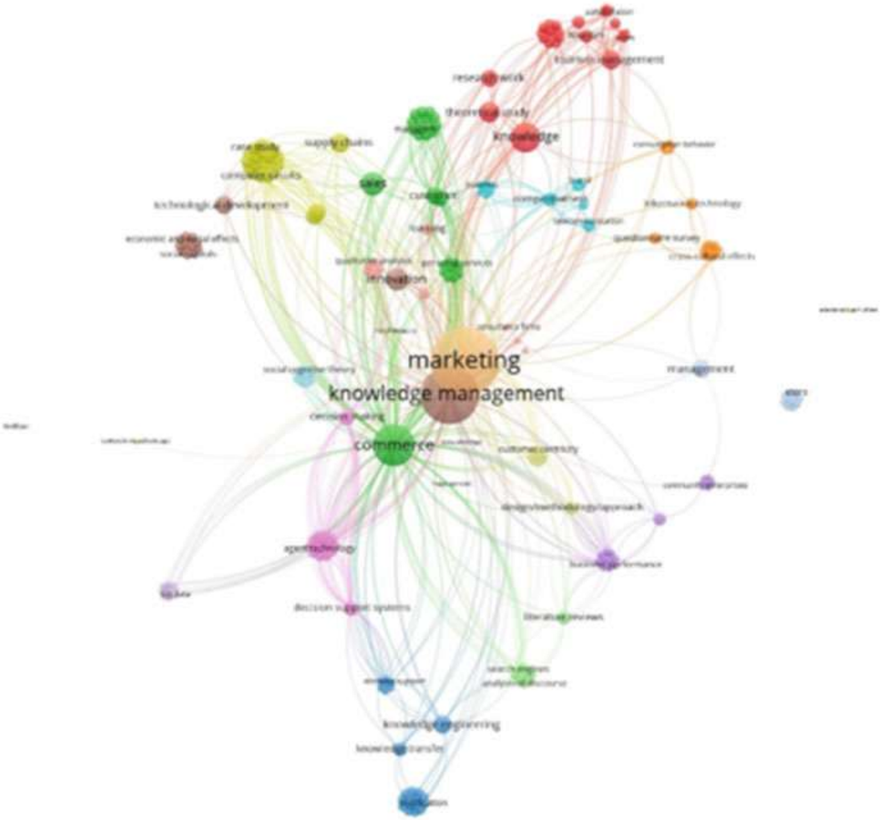


**Fig. 3.3** Network of all keywords. (Source: Own elaboration)

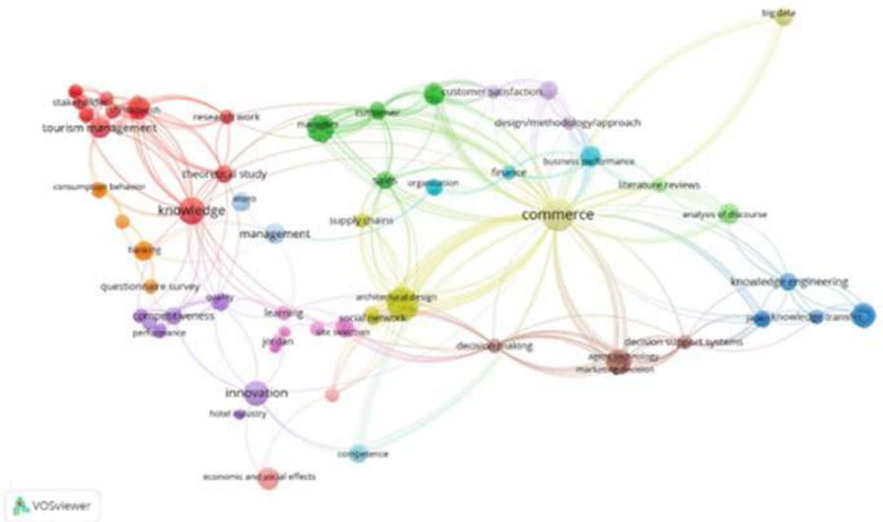


**Fig. 3.4** Network of linked keywords. (Source: Own elaboration)

a total of 421 citations. Annex 3.II examines the document self-citation during the period 2010 to 2020, of the 32 articles, 12 were self-citation for a total of 352 self-citation "The impact of knowledge management on innovation: An empiric . . . "was self-citation 21 times

Of the 32 scientific papers, six have not been cited until the time of writing of this paper (Table 3.2) (two papers from the same VINE Journal of Information and Knowledge Management Systems).

The article "A case study of hybrid strategies to create value for a contracting business in the education sector in England and Wales" by Cheung et al. [25], 0.87 (SJR), Best Quartile Q1 and H index (88) were also not cited.

## 3.4 Literature Analysis: Themes and Trends

The analysis is based on a total of 32 articles out of a Scopus search, centered on the keywords "knowledge management" and "marketing." The analysis follows the aforementioned thematic objectives, focusing on those key trends of literature. This leads to the identification of four main topics on "knowledge management on marketing," discussed below

**Table 3.2** Documents without quotes until 2020 (2010–2020 period)

| Documents | Investigator | Title | SJR | Best quartile | H index |
|---|---|---|---|---|---|
| A case study of hybrid strategies to create value for a cont ... | Cheung et al. (2016) | Construction Management and Economics | 0.87 | Q1 | 88 |
| Validation of the impact of marketing knowledge management o ... | Al-Dmour et al. (2020) | VINE Journal of Information and Knowledge Management Systems— | 0.37— | Q2— | 28— |
| Knowledge transfers as the basis of decision support for dru ... | Ahmed et al. (2018) | | | | |
| Knowledge as an important factor in the process of ... | Vukasović (2020) | International Journal of Innovation and Learning | 0.22 | Q3 | 26 |
| Rural community enterprises in Thailand: A case study of par ... | Wongadisai (2020) | World Review of Entrepreneurship, Management and Sustainable Development | 0.22 | Q3 | 14 |
| The effects of economic factors and knowledge management pra ... | Pooncharoen (2016) | International Business Management | 0.13 | Q4 | 17 |

Source: Own elaboration

### 3.4.1 Developed and Developing Context

The role of KM cannot be appreciated outside of the contextual characteristics of its environments, in which they demonstrate distinct demands while showing varying depths of change in its outcomes [24]. KM is therefore relational, envisioning, exploring future opportunities while conducting daily management [10]. This study emphasizes the role of KM on regional innovation milieus [26]. The majority of research in the topic addresses the effect of KM in terms of the acquisition, knowledge sharing and knowledge utilization, and knowledge management in developing contexts and through approaches based on the social network [24]; in terms of contextual nuances that feed corporate strategy, as in the case of KM in inter-agency collaboration and communication in what comes to disaster response [26].

Although some studies were carried out in developed contexts (as in New Zealand, for example), in the way contextual nuances impact marketing strategies [26], most of the studies focus on less developing or intermediate contexts. Indeed, most of the studies on KM were carried out to fulfill the demand from less developed regions in themes such as agriculture, in the way knowledge management, along with agricultural practices concur to the productivity of Thai farmers. In particular, to ascertain the factors that affect the productivity of the small farmers and to study the role of knowledge management, namely acquiring, storing, adjusting, sharing, and creating knowledge practices on this [27]. KM studies also covered community platforms of enterprises, regarding knowledge management and marketing in Thailand, concluding that community enterprises, of bottom-up, polycentric approach to management, are a tool to support sustainable community development, in which required knowledge, management, and marketing skills are often lacking [5], as well as the need to link up indigenous knowledge management structures and the correspondent technology-supported systems in less favored contexts, in facilitating the community in preserving and transferring their indigenous botanical knowledge through proper documentation processes, e.g., designing cultural protocols, developing ICT tools, and clarifying the roles of stakeholders with process flow diagrams [12].

Other studies discuss the positive relationship between supply chain management, knowledge management, and competitive advantage in manufacturing on Indonesian manufacturing firms [28]. Some articles favor other geographies such as the Arabic world in analyzing the impact of marketing knowledge management (assets and capabilities) on business performance, via the mediating role of digital financial innovation in Jordanian commercial banks, in which digital financial innovation acted as partial mediators in this relationship [29]. Moreover, the issue of factors such as management, knowledge, customer relationship and dtrategies, underlying electronic marketing in developing countries is also carried out in Iran, in particular identifying of effective factors on development of the electronic marketing capacity of professional sports federations of Iran [15].

Other studies go even further in attempting to contrast developing and developed context regarding the relationship quality between provider-customer through marketing orientation, perceived relationship investment, and knowledge management while examining a conceptual model using a comprehensive management approach that includes those dimensions, thus contributing to better understanding the continuity of customer–firm relationships in cross-cultural relationship marketing literature [30].

### 3.4.2 Marketing and Production and Operations

Another string of literature discusses the support of KM to the interplay between marketing and other functional areas, in order to achieve competitiveness. Some use an integrated approach to examine key determinants of firm competitiveness along with three keys; positive influencing, capability-based constructs of quality marketing, and KM systems [31]. Also, business relationships through KM, in which management of the relationship between provider and supplier has an interaction between the valuation systems of the counterparts that might be understood through the lens of knowledge management, KM assists in the dissemination and co-creation of knowledge, whereas it allows us to represent and better manage the knowledge aspects of a relationship [8]. And, in the relation to providers, the user feedback with respect to customizing marketing communication by new strategies to make free services sustainable and profitable in the long term enables companies to capture value from user-sourced data [32].

In contrast, other studies emphasize a contingency model of strategies of knowledge reuse efficiency from KM investments, in order to achieve better returns on KM investments and optimize agendas during a knowledge exchange, in particular organizational knowledge reuse efficiency [20].

A recurrent concern of KM literature has been the customer with respect to making the right management decisions. In order to provide an effective KM, by monitoring environmental changes and acquiring, storing, retrieving, and using such up-to-date knowledge, properly assisted marketing decisions using agent technology are needed [33]. Furthermore, to provide an improved KM design that increases service level by an inter-disciplinary and client-centered approach and the ensuing enhanced customer satisfaction, better interaction production/marketing is needed [6]. Finally, regarding KM in construction marketing, adopting an interpretive inquiry approach while attempting to capture multiple views in successful strategic programs, enhances interactions through intense customer engagement [25].

Furthermore, other studies emphasize the need to connect supplier and sales knowledge management through KM, as the knowledge acquired during the sales phase is very important for suppliers. In this case, it is worth linking the knowledge a project manager has acquired before the project starts to the corresponding sales phase, to avoid funnel-like sales processes and volatile projects' situations [34]. In addition, some studies investigate knowledge transfer in terms of pharmaceutical marketing of drugs' information and with regard to practitioners' prescriptions behavior, in the way drug knowledge transfer facilitates to change general practitioners' (GPs) prescribing decision [35]. Others, always centered on the customer, apply KM to the forecasting of sales from potential store development opportunities by quantitative modeling techniques, by detailing how tacit knowledge is synthesized with codified knowledge, to affect the decision making of senior management in retail firms, to improve local marketing and to do product ranging that can be drawn for subsequent forecasting [7].

Another customer-centered string of literature is customer relationship management (CRM) benefits for customers and customer satisfaction in marketing companies, in terms of personalized service, responsiveness to customers' needs, customer segmentation, customization of marketing, multichannel integration, time-saving and improving customer knowledge, enhancing customer satisfaction while significantly improving marketing performance [36]. CRM was related to the strategic marketing of tourism products to augment loyalty programs, keeping customers returning and yielding a large volume of transactions [18].

### *3.4.3 Boundary Spanners*

Despite some recognition of the role of destination marketing organizations (DMOs) in crisis management, limited attention has focused on their role as boundary spanners in managing knowledge across diverse stakeholder groups and domains, namely during crises by transferring, translating, and transforming knowledge across boundaries, which is emphasized by Blackman et al. [37]. Other studies explore the unique position of being a boundary spanner between the internal destination environment and the external competitive environment that requires higher capabilities in knowledge management. In so, the successful DMO will be able to identify, engage, and learn from disparate stakeholders, therefore acquiring, filtering, analyzing, and prioritizing data and information from various sources to create knowledge and maximizing KM capabilities, with respect to marketing strategies formulating [10].

### *3.4.4 Innovation*

On the one hand, innovation is a constant in KM literature, explicitly the positive relationship between marketing knowledge innovation and companies' multiple dimensions of performance, and mostly carried out in intermediate economies (e.g., Jordan) [9]. On the other hand, other literature, as well in developing countries (e.g., Turkey) relate innovation with a competitive advantage, in particular the way innovation components impact KM processes and performance, to augment competitive advantage, concluding that KM processes affect all innovation components in which marketing, product, and process innovation are mediators [38].

### 3.4.5 Branding

Companies utilize and transfer knowledge to processes and activities related to branding, therefore rendering the role of knowledge in the process worthwhile. Some pieces of literature discuss marketing and destination branding through a literature review that intends to embrace destination branding research and practice as a whole around nine central papers and in the last 12 years [13]. In turn, other studies examine the role of KM in creating brand equity and combining both implicit and explicit knowledge, therefore enhancing the importance of it in the process of both creating brand equity and augmenting competitiveness [39].

### 3.4.6 Media and Content

Social media provide a wide array of interactive functions which allow users to share and comment on content and personal status. Some strands of literature identify factors that increase social media participation with regard to content sharing and ensuing consequences of social media participation such as the obtaining of social support and social capital through social media participation, in which altruism expected reciprocal benefit, and expected relationship are significant determinants of knowledge sharing intention [17]. Others aim at integrating content strategy with marketing communication as a content strategy through literature review. The focus on the production of web-based materials for customers or managing the data and documentation of an enterprise has become the latest in a series of methods that have sought to ameliorate the integration of professional and technical communication with the marketing, training, and business processes of organization [19].

### 3.4.7 Dynamic Capabilities and Conceptual Maps

An interesting stream of literature analyzes the positive effect of management strategy dimensions and dynamic capability issues on firms' growth, also predominantly in intermediate countries (China). These pieces of writing and drawing on the economic growth and social cognitive theory, investigate the impact of management strategies-based dimensions (e.g., KM process competence and innovation capability) and dynamic capabilities-based features (e.g., rewards system and marketing) on firms' growth in high tech companies [14]. Yet, the way learning capability influences the knowledge resources on marketing innovation (e.g., in the hospitality sector), in particular the influence of knowledge resources on marketing innovation, in which learning capability mediates it, has attracted great attention. It was found that collective knowledge has a direct influence on marketing innovation and an indirect effect through the learning capability [11].

Another literature string has focused on tools able to ascertain tacit knowledge contained in people's minds, so it can be shared. Concept maps are such a tool that can gather knowledge from individuals and groups, facilitate its creation, and assist in the distribution of knowledge and learning processes within an organization. Therefore, some aim at improving an organizational KM system based on conceptual maps, which ease participants to use it for knowledge acquisition and distribution [16].

## 3.5 Conclusion

This study highlights the interplay between organizational functions such as production and operations, influential developed/developing context, organizations' boundary spanners, branding, media, and content creation, innovation dynamic capabilities and conceptual maps and marketing in the light of KM, based on a literature review of relevant articles. The way those issues interplay has been enhanced through the KM lens. The context was overemphasized, as it plays a central role, leading to distinct needs to feed effective marketing strategies in terms of KM. Less developed contexts present contextual characteristics that contribute to a lack of performance, comparing to endowed regions that enjoy supportive institutional contexts, therefore demanding efficient KM systems. Moreover, some key themes studied such as innovation or media and content production were carried out in developing contexts, as well. The contribution of KM systems to better optimize the interplay between marketing and other organizational functions such as production and operations was also emphasized. KM systems that optimize the socio-technical dynamics within the organization are deemed crucial.

Furthermore, this study shows that KM is paramount to corporate competitiveness by improving innovation, internal knowledge dissemination, dynamic capabilities, branding equity, and the production of media content. Finally, KM substantially enhances knowledge gatekeeping and boundary spanning in terms of knowledge absorption and dissemination throughout organizations. While doing so, KM tools both ameliorate organizational behavior and the firm's competitiveness. Therefore, disparate contexts, organizational capabilities, and KM tools positively interplay one to another.

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# Annexes

**Annex 3.I** Overview of document citations period 2010–2020

| Documents | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Antecedents and gains of user participation in social media ... | 2020 | – | – | – | – | – | – | – | – | – | – | 1 | **1** |
| Impact of supply chain integration on competitive advantage | 2019 | – | – | – | – | – | – | – | – | – | 1 | 1 | **2** |
| Exploring the mediating role of innovation in the effect of ... | 2018 | – | – | – | – | – | – | – | – | – | 3 | 6 | **9** |
| Relationship quality as an antecedent of ... | 2018 | – | – | – | – | – | – | – | – | 2 | 3 | 4 | **9** |
| Factors affecting the development of the electronic marketin ... | 2017 | – | – | – | – | – | – | – | – | – | – | 3 | **3** |
| Give away your digital services: Leveraging big data to Capt ... | 2017 | – | – | – | – | – | – | – | 1 | 1 | 10 | 11 | **23** |
| The use of intelligence in tourism destination management: A ... | 2016 | – | – | – | – | – | – | – | 3 | 7 | 15 | 6 | **31** |
| Antecedents and outcomes of marketing innovation: An empiric ... | 2016 | – | – | – | – | – | – | – | 1 | 3 | 5 | 9 | **18** |
| Content strategy: An integrative literature review | 2016 | – | – | – | – | – | – | 1 | 3 | 3 | 6 | 2 | **15** |
| Knowledge management and tourism recovery (de)marketing: The ... | 2016 | – | – | – | – | – | – | 3 | 8 | 7 | 8 | 14 | **40** |
| The impact of knowledge management on innovation: An empiric ... | 2016 | – | – | – | – | – | – | – | 7 | 10 | 30 | 30 | **77** |
| Knowledge lost: Challenges in changing project manager betwe ... | 2015 | – | – | – | – | – | 2 | 1 | 3 | 3 | – | 1 | **10** |
| Research note market centricity and producibility: An opport ... | 2014 | – | – | – | – | 1 | 1 | 2 | – | 1 | 1 | – | **6** |

(continued)

**Annex 3.I** (continued)

| Documents | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A study towards the relation of customer relationship manage … | 2014 | – | – | – | – | | 1 | 1 | – | – | – | – | **2** |
| Knowledge-collector agents: Applying intelligent agents in m … | 2013 | – | – | – | – | 1 | 1 | 1 | 1 | 1 | – | 3 | **8** |
| Knowledge management, organisational learning and memory in … | 2013 | – | – | 2 | 1 | 4 | 3 | 4 | 3 | 4 | 2 | 2 | **25** |
| Augmenting indigenous knowledge management with information … | 2013 | – | – | – | 1 | 2 | 4 | 1 | – | 2 | 1 | 1 | **12** |
| Personalization or codification? A marketing perspective to … | 2012 | – | – | – | 1 | 2 | 2 | 2 | 4 | 1 | – | 2 | **14** |
| The influence of quality, marketing, and knowledge capabilit … | 2012 | – | – | 2 | 4 | 1 | 2 | 4 | 1 | – | – | – | **14** |
| Affirmation, assimilation, and anarchy: Critical undercurren … | 2011 | – | – | – | 1 | 2 | 1 | 2 | – | – | – | – | **6** |
| Knowledge management: The missing link in DMO crisis managem … | 2011 | – | – | 2 | 3 | 4 | 1 | 4 | – | 1 | 7 | 2 | **24** |
| The determinants of corporate growth: Evidence from Chinese … | 2011 | – | – | – | 1 | – | – | – | – | 1 | – | – | **2** |
| Customer relationship management in tourism: Management need … | 2011 | – | 1 | – | 5 | 3 | 2 | 1 | 5 | 3 | 3 | 4 | **27** |
| 25Mapping the values in B2B relationships: A sy16stemic, knowled … | 2010 | – | – | 3 | 2 | 2 | 2 | 7 | 1 | 6 | 2 | – | **25** |
| The effect of marketing knowledge management on organization … | 2010 | – | 1 | 2 | – | 1 | 2 | 1 | 2 | 2 | 2 | 3 | **16** |
| The value of maps concept for knowledge management based on … | 2010 | – | – | – | – | 1 | – | 1 | – | – | – | – | **2** |
| | **Total** | 0 | 2 | 11 | 19 | 24 | 24 | 36 | 43 | 58 | 99 | 105 | **421** |

Source: Own elaboration

**Annex 3.II** Overview of document self-citation period 2010–2020

| Documents | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Relationship quality as an antecedent of customer relationsh … | 2018 | – | – | – | – | – | – | – | – | – | 1 | – | **1** |
| Give away your digital services: Leveraging big data to Capt … | 2017 | – | – | – | – | – | – | – | – | – | 9 | 2 | **11** |
| Knowledge management and tourism recovery (de)marketing: The … | 2016 | – | – | – | – | – | – | 1 | 3 | 1 | 3 | 2 | **11** |
| The impact of knowledge management on innovation: An empiric … | 2016 | – | – | – | – | – | – | – | – | 1 | 18 | 2 | **21** |
| Knowledge lost: Challenges in changing project manager betwe … | 2015 | – | – | – | – | – | – | – | – | 1 | – | – | **1** |
| Knowledge management, organisational learning and memory in … | 2013 | – | – | – | 1 | 2 | 1 | – | 1 | 3 | – | 1 | **8** |
| Augmenting indigenous knowledge management with information … | 2013 | – | – | – | – | – | – | – | – | – | 1 | – | **1** |
| The influence of quality, marketing, and knowledge capabilit … | 2012 | – | – | 1 | 3 | – | – | – | – | – | – | – | **4** |
| Affirmation, assimilation, and anarchy: Critical undercurren … | 2011 | – | – | – | – | – | – | – | 1 | – | – | – | **1** |
| Knowledge management: The missing link in DMO crisis managem … | 2011 | – | – | 1 | – | – | – | – | – | – | 3 | – | **4** |
| Mapping the values in B2B relationships: A sy16stemic, knowled … | 2010 | – | – | – | – | – | 1 | 1 | 3 | | 1 | 1 | **7** |
| The effect of marketing knowledge management on organization … | 2010 | – | – | – | – | 2 | – | – | – | – | – | – | **2** |
| | **Total** | **–** | **–** | **2** | **4** | **4** | **2** | **2** | **8** | **6** | **36** | **8** | **352** |

Source: Own elaboration

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# Chapter 4
# Game-Based Interventions as Support for Learning Difficulties and Knowledge Enhancement in Patients with Dyslexia: A Systematic Literature Review

**Aliza Saeed, Khubaib Amjad Alam, Awais Azam, Maria Khalid, and Osama Tauni**

## 4.1 Introduction

Dyslexia is among the most prevalent specific learning difficulties (SpLDs). The word *dyslexia* has its origin from a Greek word meaning having problem in the language-based processing functionality of a person, which affects learning power, ability to spell and recognize words, phonology, and short-term memory [1]. Dyslexia is labeled as a learning impairment. When a person reads, the brain is required to perform the functionality to link shown alphabets to their sounds, put those sounds in an organized form and then arrange the words into sentences and paragraphs making them readable. Dyslexic patients face difficulty in creating a match between the letters shown to them and their sounds. It is also known as a reading disability.

There are many ways to classify dyslexia. Numerous authors group dyslexia as per the symptoms it addresses. As types of dyslexia do not share symptoms, we can classify it based on symptoms. Based on symptoms, dyslexia can be classified into three categories, namely, *(i) visuospatial difficulties, (ii) speech sound difficulties*, and *(iii) correlating difficulties* [2]. In visuospatial difficulties, patients have problems recognizing letters and distinguishing between them. They try to remember the alphabet's shape and end up confusing them. Patients also try to read the words in reverse order. In speech sound difficulties, patients suffer in creating sentences and decomposing words into syllables as they face difficulty to understand spoken language. In correlating difficulties, the dyslexic patients face

A. Saeed (✉) · K. A. Alam · A. Azam · M. Khalid · O. Tauni
Department of Computer Science, National University of Computer & Emerging Sciences (FAST-NUCES), Islamabad, Pakistan
e-mail: aliza.saeed@nu.edu.pk; khubaib.amjad@nu.edu.pk; awais.azam@nu.edu.pk; f190805@nu.edu.pk; f190809@nu.edu.pk



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problem in writing as they are unable to match letters and speech sounds especially the monosyllabic words [2]. Dyslexia can also be categorized based on whether it is inherited or occurred due to an incident. In this case, there are two types of developmental dyslexia, which is inherited from parents and the other one is acquired dyslexia, which is suffered due to trauma or injury. Development dyslexia is the most common type and carried in hereditary material. This type is categorized as a phonological difficulty. Acquired dyslexia is caused by trauma, accidents, or stroke. This is further categorized into deep (semantic difficulty) and surface (problem with sight words) dyslexia.

Previously, game-based interventions have been used to attract users to specific tasks. These interventions are interactive computer applications that engage the user by providing entertainment and amusement, but side by side, these games are fulfilling the target with less effort. These games do not typically follow a common arrangement of rules, which limits replication [2]. Explicit human behavior and skills can be easily developed and advanced with the help of game-based interventions as they provide an exciting and playful atmosphere. Gamification and serious games, which are the use of game elements in a non-game context, have been effectively applied to propel users to do required exercises in various fields.

Game-based intervention methods have been used in the medical field and clinical settings to increase the required output. Game elements are the required components of the games used. They may include scoring points, badges, storyline, plot, success, or failure. Game components give a mix of challenge and learning result too. These game elements can help to improve the learning capability of the students or users suffering from dyslexia by motivating them to learn and helping them to memorize things. Games for dyslexic patients usually implement a group of activities using different game elements, which are connected to a single visual screen [3].

A systematic literature review is conducted to examine the use of game elements in enhancing the learning power of dyslexic patients following the Kitchenham guidelines [4]. Initial primary studies are selected from six databases and oogle scholar engine in a fair and unbiased manner. Inclusion and exclusion criteria are then applied to these studies to extract relevant literature. This document consists of four sections. Section 4.2 reports the related work. Research methods are discussed in Sect. 4.3. This review is concluded in Sect. 4.4.

## 4.2 Related Work

This section reports the reviews already conducted in the domain of game-based intervention for dyslexic patients, which will conclude the need for this proposed research.

A systematic literature review [5] has been conducted in 2019 covering game-based interventions for neuropsychological diseases. It does not report any research question. Quality assessment criteria is not defined. Moreover, it is focusing on neuropsychological diseases overall. There exists a preliminary study [6] covering an interactive system for the improvement of dyslexic patients using games. It does not include any research question.

A review [7] published in 2018 also presents reporting intervention methods for dyslexia. It is not covering game-based interventions in detail. It includes studies published from 2000 to 2016. There is an existing review [8] of the role of computational technologies in the detection of dyslexia published in 2016. It is not covering game base interventions in detail. It does not have any research questions.

A review was published in 2018 reporting dyslexia in China [9]. It does not cover GBI in detail. A review on IOS and an android application was published in 2017 [10]. It reports the use of apps including their game resources for dyslexia. No research question is reported in it and it covers the articles published before the year 2017. A systematic literature review discussing e-learning for patients with cognitive disabilities has been published in 2019 [11]. It reports four research questions, but not covering game elements in detail. This review is not targeting dyslexia disease in detail; rather, it is discussing cognitive disabilities as a whole.

A systematic review on the modalities of computer-based intervention for autism spectrum disorder has been published in 2019 [12]. It is focusing on a cognitive disability just like dyslexia. It reports all CBIs including game elements. There exists a gap in conducting a review on game-based intervention methods for dyslexia patients. Therefore, this objective is fulfilled by the conducted research.

## 4.3 Research Methods

A systematic literature review is a method employed for exploring a domain. It is categorized as evidence-based software engineering. For carrying out this review in an unbiased and fair manner, Kitchenham guidelines are used [4]. These guidelines consist of three phases divided into seven steps. Figure 4.1 below shows these phases divided into steps. Three phases of the SLR process are planning, conducting, and reporting. In the planning phase, some of the pre-review activities are performed which include defining research questions, formulation of search strings, selection of electronic databases, formation of inclusion/exclusion, and quality assessment criteria. This phase involves the development of a review protocol. Activities of study selection and data synthesis are performed in the conducting phase. In the last phase, results are documented.

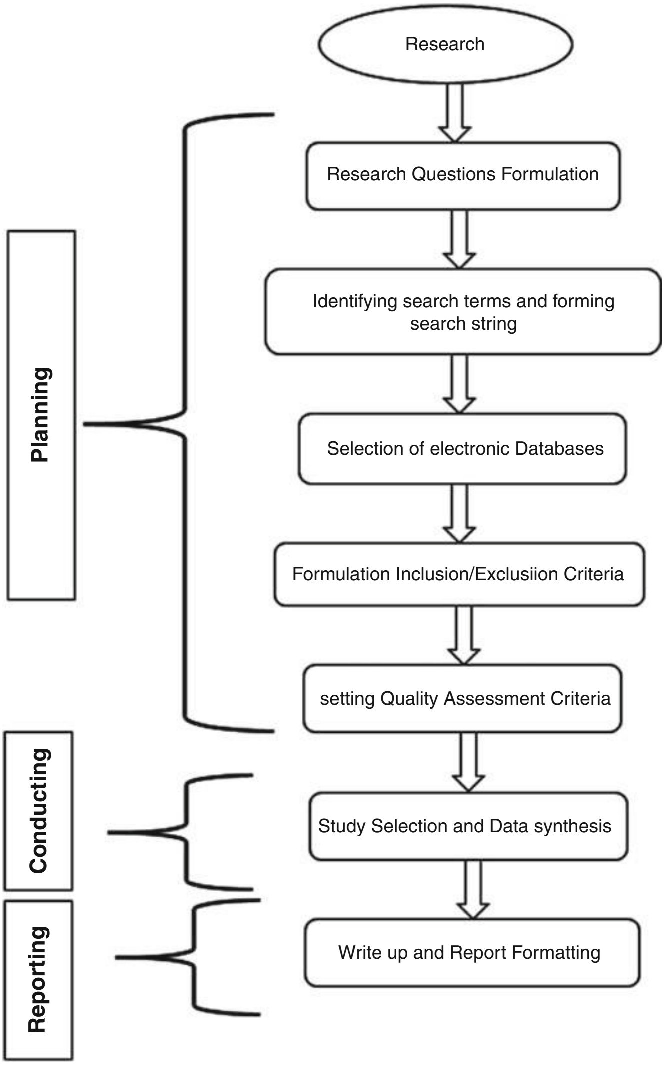


**Fig. 4.1** SLR process [4]

### *4.3.1 Research Question*

Four research questions have been formulated to conduct this systematic review.

- *RQ1:* How effective are game-based intervention methods as behavioral medicine for dyslexic patients?
- *RQ2:* What are the existing dyslexic errors?

- *RQ3:* What type of game-based intervention methods have been proposed in existing literature as behavioral medicine for dyslexic patients?
- *RQ4:* What is the overall research productivity in this domain?

### *4.3.2 Electronic Databases*

Primary studies for this systematic research have been selected from six databases. Some studies have been extracted from the Google scholar engine also. Table 4.1 below shows the selected databases.

**Table 4.1** Electronic databases

| Database | URL | Queries |
|---|---|---|
| ACM | http://dl.acm.org/ | [[Publication Title: dyslexia] OR [Publication Title: dyslexic] OR [Publication Title: dyslectic]] AND [[Abstract: "game based"] OR [Abstract: game] OR [Abstract: "serious games"] OR [Abstract: "gamif*"] OR [Abstract: gbi]] AND [Publication Date: (01/01/2010 TO 01/31/2020)] |
| IEEE Xplore | http://ieeexplore.ieee.org/ | ("Document Title":'game based' OR 'serious game' OR game OR 'gamif*' OR GBI) AND ("Abstract":dyslexia OR dyslexic OR dyslectic) |
| Science Direct | http://sciencedirect.com/ | Title, abstract, keywords: (Dyslexia OR dyslexic OR dyslectic) AND ("game-based" OR game OR "serious game" OR gamification OR GBI)) |
| Springer Link | http://link.springer.com/ | ("game OR based" OR "serious OR game" OR game OR "gamif*" OR GBI) |
| Wiley | https://onlinelibrary.wiley.com/ | "”game based“ OR game OR ”serious games“ OR ”gamif*“ OR GBI" in Title and "dyslexia OR dyslexic OR dyslectic" in Abstract |
| PUBMED | https://www.ncbi.nlm.nih.gov/pubmed/ | (((((((“game based”[Title/Abstract]) OR game[Title/Abstract]) OR "serious game"[Title/Abstract]) OR "gamif*"[Title/Abstract]) OR GBI[Title/Abstract]) AND dyslexia[Title/Abstract]) OR dyslexic[Title/Abstract]) OR dyslectic[Title/Abstract] |

**Table 4.2** Search terms

| | |
|---|---|
| P | Dyslexia, dyslexic, dyslectic |
| I | Game-based, game, serious game, gamif*, GBI |

### 4.3.3 Search Terms and String

Search terms and a generic string are created by following Kitchenham's PICO structure [4]. They are given below.

- *Search term* (Table 4.2)

- *Generic string*
  (Dyslexia OR dyslexic OR dyslectic) AND ("game-based" OR game OR "serious game" OR gamif* OR GBI)

### 4.3.4 Study Search Procedure

Figure 4.2 shows a flow chart of PRISMA guidelines followed to carry out this review. The four-phased process has been followed as guidelines. The phases involved are identification, screening, eligibility, and inclusion. In the first phase, relevant studies have been extracted from above mentioned six databases and duplication among studies has been removed. Initial results are mentioned below in Tables 4.3 and 4.4. Then, the title-based and abstract-based screening is done in the second phase. Studies are screened based on inclusion and exclusion criteria as well as quality assessment criteria in the eligibility phase. Full texts of articles screening are done, and relevant primary studies are included.

### 4.3.5 Inclusion Criteria and Exclusion Criteria

Inclusion and exclusion criteria have been formulated to filter primary studies for the conduction of this review. These criteria are listed below in Table 4.5.

### 4.3.6 Quality Assessment Criteria

In this section, the quality assessment criteria have been described. This criterion helps to maintain the quality of selected primary studies. This criterion is shown below in Table 4.6. A scale with three parameters (1, 0.5, 0) is set to rank selected studies.

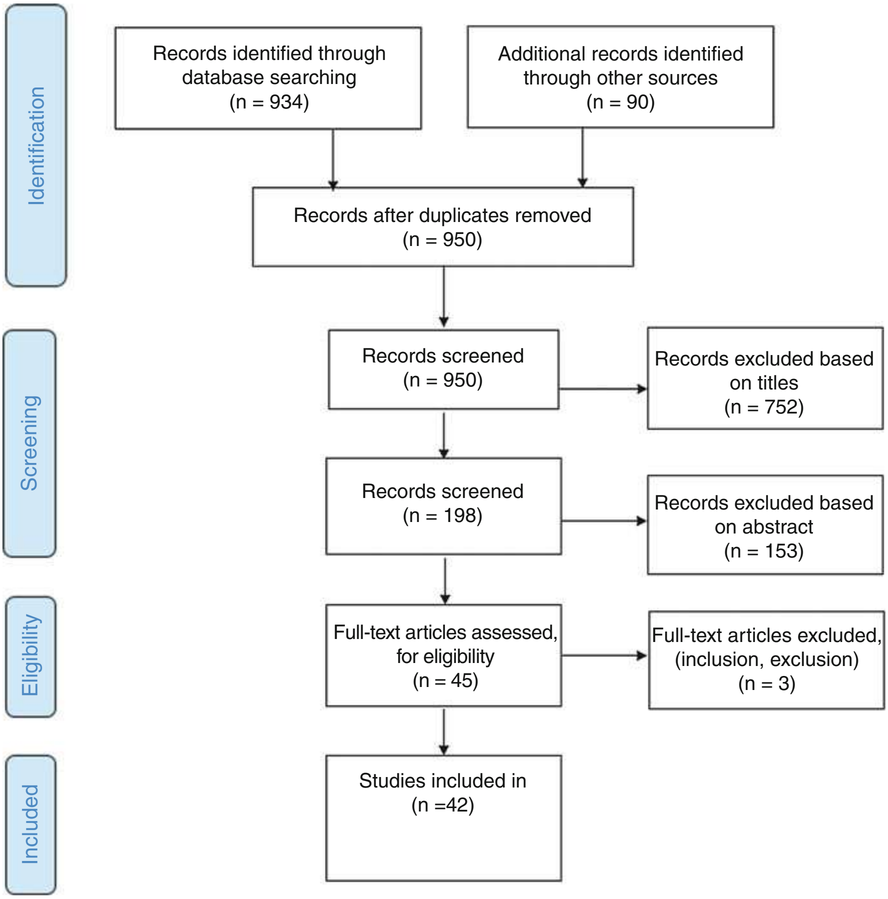


**Fig. 4.2** Study Selection Procedure

**Table 4.3** Initial results from databases

| Electronic database | Initial result |
|---|---|
| PubMed | 794 |
| IEEE Xplore | 27 |
| ACM | 21 |
| Science Direct | 15 |
| Wiley | 26 |
| Springer | 51 |

**Table 4.4** Initial results from manual search

| Manual search | Initial result |
|---|---|
| Google scholar engine | 50 |
| Others | 40 |

**Table 4.5** Inclusion & Exclusion Criteria

| | **Inclusion criteria** |
|---|---|
| IC1 | The article explicitly focusing on game-based intervention methods for dyslexia. |
| IC2 | Articles that are peer reviewed. |
| IC3 | Articles that address one or more research questions. |
| IC4 | Recent study if there exist several studies on the identical concept from the same author. |
| IC5 | Articles published during the period of (2010–2020). |
| | **Exclusion criteria** |
| EC1 | Articles not written in the English language. |
| EC2 | Articles that are not validated and novel. |
| EC3 | Data acquired from short papers, posters, editorials, abstracts, thesis, patents, extended abstracts, blogs, or Wikipedia. |
| EC4 | Articles whose full texts are not accessible. |

**Table 4.6** Quality assessment criteria

| | |
|---|---|
| QC1 | Statement of limitations should be clearly specified |
| QC2 | Context and objectives ought to be clearly indicated |
| QC3 | Research design and conclusion should support the goals of the research |
| QC4 a) | Core ranked conferences<br>A* or A >1point<br>B or C >0.5 points<br>others >0 points |
| QC5b) | Journal ranking<br>SCI/SCIE > ranked as 1<br>ESCI/scopus/dblp/ei compendex >ranked as 0.5<br>Others> ranked as 0 |

## 4.4 Discussion & Results

- *RQ1: How effective are game-based intervention methods as behavioral medicine for dyslexic patients?*

Dyslexia is one of the learning disabilities that is affecting 3–10% of the present population [13]. It is usually diagnosed when one is unable to develop fluency in reading skills. Besides having normal IQ and intelligence, a person suffering from dyslexia has to face severe problems during studies. Dyslexic people have to face unwanted outcomes such as loss of self-confidence and self-belief because of their inability to read during knowledge acquisition [14].

Recently, game elements and game-based intervention methods have been used in the medical field as medicine to increase the cure rate. Existing literature caries a lot of evidences and examples that prove that game-based interventions and different game elements can be used as behavioral medicine for patients suffering from dyslexia and helps them to improve their disability. These game elements help them in education attainment as they provide a means of entertainment, which reduces their frustration and anxiety caused by an inability to read and remember phoenix. These game-based intervention methods increase the patient's interest in knowledge attainment [15]. These games should be visually attractive and catchy so that patients play these games with interest and attraction [16, 17].

A case study approach was adopted to view the effect of games on dyslexic children [15]. A set of nine mini-games are used encompassing seven identified skills including finding syllables, vowels, consonants, blends and letter patterns, suffixes, prefixes, and confusing letters. Difficulty levels are defined, and to introduce flexibility in gameplay according to the patient's IQ level, a set of nine games are introduced. Each mini-game covers one skill. Tutors are appointed to guide and interact with children. This whole session is for 10 weeks. Game logs and videos of student-tutor interaction are used to examine the effect of GBIs used. The findings have shown that these games have improved social engagement, sense of competition, morale, self-confidence, interactions and learning through voice aloud of game situations, and learning through tutor intervention. These games also improve a sense of teamwork.

Letter phoenix binding problem is detected in [13] and the effect of the instructional method of learning of letter speech binding. An experiment was conducted with 62 participants with dyslexia and 64 participants with average and above-average reading skills. Participants were given training involving games and then statistical tests were performed. Results show that dyslectics suffer from reading and letter-speech mapping disability. Implicit training along with explicit preparation results in a positive effect on learning capability.

Speed of reading, memorizing, and phoenix decoding can be increased by AVG training [18]. Eighteen dyslexic children were selected for this clinical video game training session under the supervision of psychologists. Each participant was trained for two weeks consisting of 12 sessions each composed of 60 minutes. Each child had to play one of the two selected action video games. Game score improvement was judged for individual players. The median score was calculated which was used as a model for comparison of individual scores. Reading ability improvement was measured using a non-parametric test and notable improvements were recorded. Memory skills were measured using the statistical test to examine the results and significant improvements were seen.

In [19], a study was conducted to examine the effect of games designed for people with phonological disability on students suffering from reading problems. Only a short period of three hours proved that these sorts of intervention methods have a very positive effect on people with dyslexia. Patients who took part in playing the game improved in all learning-related exercises like speech-to-sound mapping and syllable finding.

The research was conducted to enhance the phoenix skills of dyslexic patients [20]. A sample of 12 students belonging to the age group six to 12 years participated in the research. They were divided equally among the two groups, experimental and control, and the quasi-experimental scientific method was used. T.E.D.E. test with the pre-test and post-tests was adopted as methodology. A total of 15 sessions were conducted. The research result highlighted significant differences in experimental subjects after using gaming techniques. A video game named Jelly is developed to help patients affected by dyslexia [21]. Proof of concept was conducted with ten dyslexic children which was used as a foundation to develop the prototype. The developed prototype is then tested with 22 dyslexic students and 22 non-dyslexic students which were considered as a control group. The results showed that game is highly engaging.

"Maghzineh" cognitive video game is used to improve the learning skills of students suffering from dyslexia. A quasi-experiment having a pretest-posttest design was conducted to examine the effectiveness of playing this game on the reading skills of the patients [22]. Twenty students with learning impairment were selected and were randomly divided into experimental and control groups with ten students each. For a period of a month, the experimental group was trained with a "Maghzineh" cognitive video game. The other group received no training. Reading performance was then measured with the NEMA test. The analysis of gathered data was done using Multiple Analysis of Covariance (MANCOVA). Findings show prominent improvement in the reading performance of students with dyslexia.

Word exercises are introduced to improve the spelling of dyslexia patients [23]. The experimental group performed these exercises for four weeks. Pre and post-tests were performed. Two tests namely Mann–Whitney U test and Kolmogorov–Smirnov test were conducted and the results show a positive effect on dyslexics. There is a significant decrease in incorrect answers of the experimental group than the control group. Computer-based intervention is used for improving the spelling skills of dyslectics [24]. The learning progress of dyslexic patients is first compared with their progress during working with other older software and then their progress is compared with the group without dyslexia. The results have clearly shown that children with dyslexia have significant improvement from the phonological cue and phoneme-based student model.

A mobile game is introduced to help dyslexia patients [25]. After using six weeks, a promising effect on the learning capability of dyslectics can be seen. The spelling and reading performance of the patients improved a lot. Speeded reading comprehension tests have shown the best improvement among all. A study to measure the efficacy of phonetic and rhythmic approaches for enhancing the ability of dyslexic patients is conducted [26]. Thirty-three dyslexic patients participated in this study and were divided into three groups. The duration of the intervention is 6 weeks. Both techniques resulted in equally significant gains in phoenix's knowledge. Combining both techniques may offer an advantage to people suffering from developmental dyslexia significantly. An educational game is developed to enhance the capabilities of dyslexic patients [27]. This game is tested with 46 pupils including five dyslectics. T-tests were conducted to check the effect of the game on subjects. Results highlighted significant change saying that reading and spelling skills of participants. Grapho-Game GG is used as a supportive tool for people with dyslexia [28]. The Finnish version of GG is used in this article. This game is tested in African countries. This game not only improves the patient's learning ability but also increases teacher's and parent's knowledge about awareness of reading skills.

A game named "FunLexia" is developed to improve the lacking capabilities of dyslexic patients [29]. Eleven dyslexic children from the 8–12 age group and some field specialists were involved in this study. Questionnaire results show that children find this game interesting and specialists feedback suggest that this game is a supportive tool to enhance the reading skills of children with reading disabilities. The Gamification technique is used as a supportive tool for people with dyslexia [30]. It can be concluded for results that gamification and proposed framework can effectively enhance the abilities of dyslectics.

- *RQ2: What are the existing dyslexic errors?*

Dyslexics make many errors and mistakes while reading, writing, speaking, etc. due to their disabilities. These errors are being explained in Table 4.7 below.

The dyslexic error can be grouped into four categories namely substitution, deletion, insertion, and transposition. Table 4.8 below shows types of dyslexic errors, their description, example, and frequency [31].

- *RQ3: What type of GBIs have been used in existing literature as behavioral medicine for dyslexic patients?*

One of the specific learning disorders is dyslexia which is a learning disability hindering a smooth pathway to become literate. It is a persistent deficit to reach a

**Table 4.7** Dyslexic errors

| | |
|---|---|
| Reading errors | Reads the word on one page, however, does not remember it on the following<br>Learn phonics however cannot sound out a new word.<br>May add or miss letters in words, for example, cold to could and stair to star<br>May disturb the sequence of identical letters in a word like they may change bowl to blow<br>May ignore and skip punctuation<br>May confuse letter directionality. For example, letters p and q<br>Change similar-looking words. For example, horse for house<br>May skip or change word endings, e.g., talk for talked, reading for the reader |
| Spelling errors | Incorrect use or skipping of vowels.<br>Spelling mistakes |
| Writing errors | Ignoring punctuation rules<br>Add extra or skip space between the word |

**Table 4.8** Error categories

| Error name | Description | Example | Frequency |
|---|---|---|---|
| Substitution | Changing one letter with other | Really to **reelly** | 58.84 |
| Deletion | Omission of letter | Approach to **approach** | 26.30 |
| Insertion | Insert an extra letter or space | Apple to **applle** | 13.40 |
| Transposition | Substituting the sequence of two adjacent letter | Really to **raelly** | 1.45 |

**Table 4.9** Game types

| Paper identifier | Game type | Count |
|---|---|---|
| [3, 15, 19, 20, 23–30, 32–45] | Word game | 26 |
| [13, 14, 18, 46–50] | Action video game | 8 |
| [22, 51, 52] | Strategy game | 3 |
| [21] | Adventurous game | 1 |
| [53] | Educational game | 1 |
| [54] | Narrative game | 1 |
| [55] | Puzzle game | 1 |

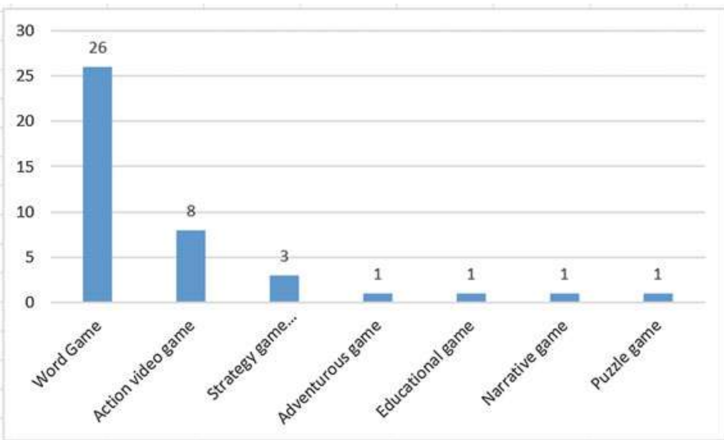


**Fig. 4.3** Game types

normal reading level. As a result, patients become demotivated and frustrated. GBIs are developed to entertain as well as to enhance their learning capabilities. Existing literature reports different kinds of GBIs for dyslectics including word games, action video games, puzzle games, games involving some animals like dinosaurs, and chess. Table 4.9 given below shows the list of these games in existing literature from 2010 to 2020.

Figure 4.3 signifies that most of the relevant research work has been done in the first category of word games. In total, 26-*word* games have been reported in the existing literature followed by *action* video games with the count of eight. In addition, three *strategy* games have also been reported in the extant literature.

- *RQ4: What is the overall research productivity in this domain?*

Some of the characteristics of selected primary studies were inspected which include publication trends, authorship data, publication forums, and citation impacts of selected papers.

– *Publication Trends*

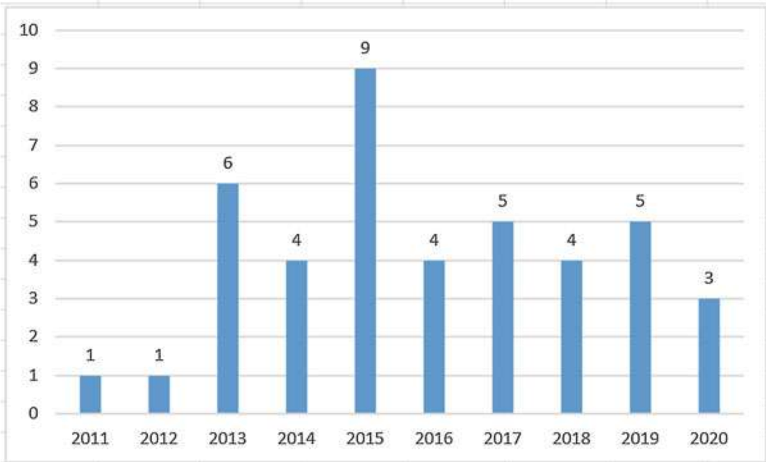


**Fig. 4.4** Publication trends

During the period of 2010 to 2020, 42 studies were selected following the criteria mentioned above. Figure 4.4 below shows the progress of literature related to the topic. It can be seen from Fig. 4.4 that the research was very active in the year 2015 with nine publications covering different dimensions of dyslexia and GBIs to enhance the learning power of dyslectics. Six studies have been published in 2013. Years 2017 and 2019 produced five research papers. Four research papers are produced during the years 2014, 2016, and 2018. Three studies covering different areas of research related to GBIs for dyslectics are published in 2020. 2011 and 2012 have produced one research article each.

– *Citation Impact*

Citation statistics of the selected primary studies are shown in Fig. 4.5 given below. Google scholar engine is used as a source to obtain these citation counts therefore can vary at any instance. Figure 4.5 shows that there exist only two articles with above 100 citations each [14, 26]. There are six studies with citations in the range of 50–100 [13, 19, 24, 28, 32, 50]. All other studies among selected papers have below 50 citations.

– *Publication Forums*

Existing literature has been published in 21 different journals, 18 conference proceedings, followed by 1 workshop proceedings and 2 symposiums proceeding. Figure 4.6 below shows that the most active contributor in our selected primary studies is journals followed by conferences with 18 conference proceedings.

Table 4.10 below shows the list of active journals that participated in producing the literature relevant to the topic. Among 42 studies, 21 are journal publications. Most active among these 21 journals are including Neuropsychologia, Annals of

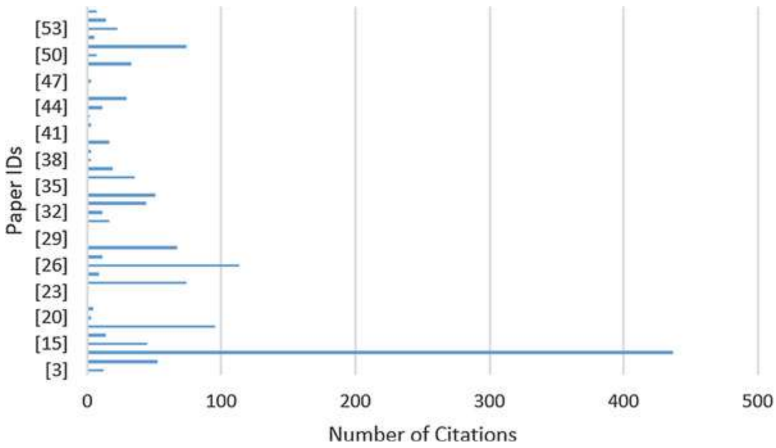


**Fig. 4.5** Number of citations

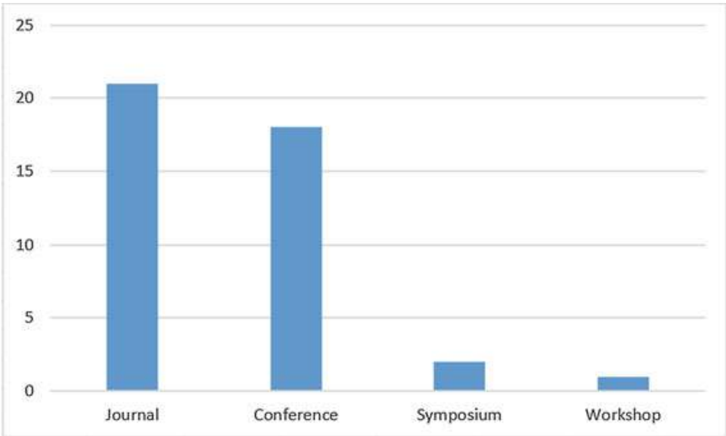


**Fig. 4.6** Publication forums

Dyslexia, Education and Information Technologies, and Scientific Reports producing two publications each. Others include International Journal of Information Science and Technology, Informatics, Research on Education and Media, Language Resources and Evaluation, Computer and Education, Current biology, Journal of Experimental, Child Psychology, Brain Research, Frontiers in psychology, Cortex, Journal of Computer, Assisted Learning, Procedia Computer Science, and Reading and Writing with one publication each related to the topic.

Table 4.11 given below enlists the active proceedings. Eighteen conference proceedings published papers relevant to dyslexia and related GBIs. The most active among these 18 conferences are International ACM SIGACCESS Conference on Computers & Accessibility with three published studies, International Conference

**Table 4.10** Active journals

| Venue | Count |
|---|---|
| Neuropsychologia | 2 |
| Annals of Dyslexia | 2 |
| Education and Information Technologies | 2 |
| Scientific Reports | 2 |

**Table 4.11** Active conferences

| Venues | Count |
|---|---|
| International ACM SIGACCESS Conference on Computers and Accessibility | 3 |
| International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES) | 2 |
| International Conference on Information, Intelligence, Systems and Applications (IISA) | 2 |

**Table 4.12** Authorship information

| Name | Count |
|---|---|
| Luz Rello | 7 |
| Sandro Franceschini | 4 |
| Clara Bayarri | 3 |
| Simone Gori | 3 |
| Andrea Facoetti | 3 |
| Sara Bertoni | 3 |
| Maria Rauschenberger | 2 |
| Asimina Vasalou | 2 |
| Rilla Khaled | 2 |
| Daniel Gooch | 2 |
| Luca Ronconi | 2 |
| Jeffrey P. Bigham | 2 |
| Marie Lallier | 2 |
| Manuel Carreiras | 2 |

on Games and Virtual Worlds for Serious Applications (VS-GAMES), International Conference on Information, Intelligence, Systems and Applications (IISA) with two publications each.

– *Authorship Information*

Table 4.12 given below enlists the authors along with their study count who participated in producing the literature related GBIs for dyslexic patients to enhance their learning capabilities. Among all the authors, the most prominent is Luz Rello with seven publications. Then there are four publications by Sandro Franceschini. Clara Bayarri, Simone Gori, Andrea Facoetti, Sara Bertoni have produced three studies each. Eight authors from the list have published two relevant studies. All other writers have produced one article each.

## 4.5 Conclusion

Dyslexia is a neuropsychological disease that affects the brain segment processing alphabets and words. Patients suffering from dyslexia have learning-to-read difficulties and ultimately to write. Game-based interventions have been found to be quite effective as therapeutic support to address these learning difficulties. This study highlights the use and effectiveness of game-based intervention methods for dyslexic patients. This is the first secondary study dealing with game-based interventions for dyslexic patients suffering from learning disabilities. Results of this SLR suggest that game-based intervention methods help dyslexic patients by enhancing their learning capabilities. Dyslexic errors have been grouped into four categories namely substitution, insertion, omission, and transposition. Among all the existing GBIs, most of the developed games are word games. Different game elements help the patients to do hectic tasks in a playful manner and side by side, the task of increasing learning power is accomplished. Future research efforts can be directed towards the incorporation of essential gaming elements and solid theocratical foundations of the game design.

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# Chapter 5
# Knowledge and Data Acquisition in Mobile System for Monitoring Parkinson's Disease

**Tetiana Biloborodova, Inna Skarga-Bandurova, and Illia Skarha-Bandurov**

## 5.1 Introduction

Parkinson's disease (PD) is a slowly progressive chronic condition that develops gradually and tends to be asymptomatic for a long period of time. Early detection, treatment, and delivering the correct combination and dose of a drug enable to extend the primary stage and prevent severe cognitive disorders in future. An adequately prescribed dose of medication enables to return the correct movement control within a few hours. However, as the disease progresses, the motor complications increase. Conversely, drug resistance often develops during PD treatment making it difficult to determine the correct medication dose. The reduction in effectiveness of a medication can seriously impair the quality of PD patient's life. Timely detected drug resistance makes it possible to adjust the forms and quantity of dopaminergic medication, which in turn has positive impact on the motor response fluctuations and reduces long-term side effects.

It is well known that, to improve any condition, we must first measure it. Obtaining accurate information about the progression of the motor symptoms and their short-term fluctuations is crucial to assign a therapy for patients with PD and evaluate the results of clinical trials correctly. There are many clinical

T. Biloborodova (✉)
Volodymyr Dahl East Ukrainian National University, Severodonetsk, Ukraine
e-mail: biloborodova@snu.edu.ua

I. Skarga-Bandurova
Volodymyr Dahl East Ukrainian National University, Severodonetsk, Ukraine

Oxford Brookes University, Oxford, UK

I. Skarha-Bandurov
Luhansk State Medical University, Rubizhne, Ukraine

 
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scales that have been developed to assess symptoms of Parkinson's disease. The most widely known PD rating scales are Hoehn and Yahr scale [1], the Unified Parkinson's Disease Rating Scale (UPDRS) [2], and its extension MDS-UPDRS [3]. The Hoehn and Yahr scale enables to measure PD symptoms' progress and the level of disability. The UPDRS scale comprises of five parts and evaluates different aspects of Parkinson's disease, including modified Hoehn and Yahr stages, complications of therapy, motor symptoms, mental and behavior impairment, as well as patient's complaints of complications during daily routines (activities of daily living). Relatively new version, entitled the MDS-sponsored revision of the UPDRS (MDS-UPDRS) [3], represents a comprehensive questionnaire-based assessment with modified non-motor section and four groups of PD symptoms.

Meanwhile, these measuring procedures are not used routinely. People with PD usually visit a specialist no more than once or twice a year; they need to have notes or rely on their memories that make evaluation very complex, subjective, and inaccurate. The lack of comfortable, user-friendly tools for regular objective assessment makes it all the harder to track the disease progression and results in a situation where both efficiency and side effects of medication can be unnoticed timely.

Since the smartphones have become an essential tool for day-to-day life, their integration with electronic patients' diaries that leverage the elements MDS-UPDRS could be a natural way of retrieving information about symptoms and their severity in the PD patients. Long-term home monitoring and automatic data analysis can help physicians and healthcare providers have a better grasp on the impact of PD on daily habits, even in the early stages, assess the patient's response to therapy, evaluate the motor symptoms, and compare effectiveness with the prescribed treatment. Penetrating in real life any digital health solutions faced with a challenging task to capture useful disease indicators and achieve long-term statistics [4]. To solve this task, we develop an affordable and easy-to-use solution for long-term remote monitoring of patients with Parkinson's disease, designed in form of electronic patient diary. The present work is an extended version of our conference paper [5] with focus on predictive healthcare data analytics, in capturing early signs of PD as well as assessing the development of parkinsonian symptoms over time. The idea of this approach involves a combination of well-known methods for testing patients with PD, namely, specially designed tests built in as an application in a smartphone which enable to perform analysis of data in a different time and population scales.

## 5.2 Background

Smartphones are used extensively daily in many different ways. The everyday interaction of individuals with their smartphones enables to achieve the specific behavioral indices, built in a dynamic and personalized way across the short sessions of interaction. There are two options for PD monitoring via smartphone: (1) the active or task-specific sessions when a patient has to open an application and execute tests and (2) passive session when the application collects data (voice jitter, specific sound waves, tracking accuracy, speed and pressure on the virtual keyboard, etc.) directly from everyday routines and analyzes them in long-term dynamics. In some mental or physical conditions, using active sessions is attended with great difficulties, especially for elderly patients; in this case, special non-obtrusive, passive sensing features could be beneficial. The last involves leveraging different types of modalities raised from a variety of embedded internal sensors. Given this, the current study steps further by developing a multimodal smartphone-based system for long-term PD patient monitoring.

During the preparation stage, we analyzed a set of recent smartphone applications such as mPower [6], PDLens [7], PDMove [8], SmT [9], and cloudUPDRS [10], together with techniques used for PD symptoms assessment via smartphones. A comprehensive review of techniques for assessing PD motor malfunctions can be found in [11]. Many previous studies addressed using different internal measurement units (IMU) of smartphones to evaluate an individual's daily activities such as walking, standing, running, falling, etc. Several recent papers devoted to smartphone-based assessments are focused on measuring more specific PD motor symptoms such as tremor [12–15], postural instability [16], gait [17, 18], and bradykinesia [8, 19]. For this study, we also topped up dysarthria and dysphonia (detected by Mantri and Morley [20]) to the set of core characteristics for prodromal and early Parkinson's disease symptoms like bradykinesia, rigidity, tremor, and postural instability from MDS-UPDRS [3]. Table 5.1 summarizes information about the IMU and smartphone camera and their current operational capability to perform both task-specific testing and daily activity monitoring.

- *Accelerometer*: It is the most common smartphone sensor used for assessing parkinsonian tremor. The smartphone's accelerometer and gyroscope signals are processed to compute a set of metrics and quantify a patient's tremor symptoms [11, 21]. These applications are ubiquitous due to various advanced onboard sensors (accelerometers alone or accelerometers combined with gyroscopes or magnetometers) and wireless connections. They are also much easy to use compared with most wearable solutions previously developed for this purpose. An example of leveraging the smartphone's accelerometer for differential diagnosis between Parkinson's disease and essential tremor is discussed in [21].
- *Camera*: Tremor detection is also possible by applying a camera [22]. Wong et al. [23] have recently used smartphone videos to determine the presence of bradykinesia. The video frames were segmented into pixels corresponding to a participant's hand. The segmented frames were converted into an optical flow field, in which magnitude is scaled by the number of pixels in the hand region of interest and used for further feature extraction.
- *Microphone*: Tracy et al. [24] used recorded voice as a biomarker for early PD symptoms detection and developed a voice analysis technique. The study includes extraction of paralinguistic features and training a set of machine learning models to predict level of the PD severity. In [22], Wang et al. proposed to use speakers and microphone of smartphone for tracking hand and detecting

**Table 5.1** Using IMU and camera of smartphone for PD monitoring

| IMU | Task/test | Time | Target symptom | Type of monitoring |
|---|---|---|---|---|
| Accelerometer [11, 13] | Hold the phone flat in the hand | 4 min | Tremor | Task- oriented |
| Accelerometer [16] | Turn-to-sit and sit-to-stand tasks | 30 s | Postural instability | Task-oriented |
| Camera [14] | Finger-tapping tasks | 10–20 s | Bradykinesia | Task- oriented |
| Camera [15] | Contralateral hand opening-closing (Froment's maneuver) | 30 s | Rigidity | Task- oriented |
| Camera [15] | Hand and arm extension to the front and to the side | 30 s | Tremor | Task- oriented |
| Microphone [26] | Voice-based tests (syllable alternating motion rate) | 30 s | Dysphonia | Task- oriented |
| Microphone [23] | Smartphone conversation | 10 min | Dysarthria | Daily life activities |
| Microphone [24] | Smartphone conversation | 10 min | Early PD biomarker | Daily life activities |
| Microphone [22] | Hand movements (extracting the phase of sound waves reflected by the hand) | 30 s | Tremor | Task- oriented |
| Sensor screen [27] | Finger-tapping tasks | 30 s | Tremor | Task-specific |
| Sensor screen [25] | Finger-tapping tasks | 20 s | Bradykinesia | Task-specific |
| Sensor screen [25] | Routine typing activities using virtual keyboard | 5 min | Tremor | Daily life activities |

tremors. The acoustic sensing is executed through the low-latency acoustic phase methodology deployed on the smartphone application.

- *Sensor screen*: Study [25] shows possibility of quantitative assessment of resting tremor and bradykinesia in PD using touchscreen during finger-tapping tasks.

Combining information from multiple sources to create complex models offers significant benefits for accurately identifying symptoms of Parkinson's disease. Data fusion enables extracting useful information from a set of input modalities and achieving greater accuracy and reliability of inferences than it could be reached with one data source. There are several studies dedicated to data fusion methodology applied for PD data captured through smartphone application [6, 17] and machine-learning approaches for effective classification [18]. Although many improvements have been shown, there is still a shortage of systems that enable efficient fusing of different modalities and delivering a trustworthy validation of PD status [28]. Because of the data’s temporal and spatial heterogeneity, fusion in mobile and cloud-based systems still faces challenges, especially in heterogeneous regions. Temporal heterogeneity emphasizes static and dynamic data. Dynamic data is the stream data received by several data sources simultaneously and continuously or at ample time intervals. Static datasets are snapshots of events at a point in time. When there is a spatial discontinuity, data reflects spatial features in one or several dimensions. Thus, the main challenges of data fusion can be described as follows: (i) spatial and temporal data alignment, (ii) out-of-sequence measurements, and (iii) data correlation [29]. For this research, the following three levels of data fusion were analyzed [30]:

1. Data-level fusion. This type of multi-sensor fusion assumes the raw data from smartphones, and special wearable sensors are combined directly. This approach enables the achievement of the highest level of information details, but because of the absence of preprocessing, it is highly susceptible to noise and failures.
2. Feature-level fusion works with features achieved from preprocessed information instead of raw signal and is the second level of fusion abstraction with moderate information details and less sensitive to noise and failures.
3. Decision-level fusion is the highest level of abstraction that can utilize raw data, features, and patterns defined at the feature-level fusion. This type of fusion is the most common in multimodal applications and is highly resistant to noise and failures.

Following [31], possible inputs and outputs at each fusion level could be represented as data in-data out, data in-feature out, feature in-feature out, feature in-decision out, and decision in-decision out (Fig. 5.1).

In the context of the further system improvements [32], we propose a novel smartphone-based system that involves multimodal decision fusion and knowledge and data acquisition and provide useful recommendations for PD patients. The system gathers signals from smartphone sensors.

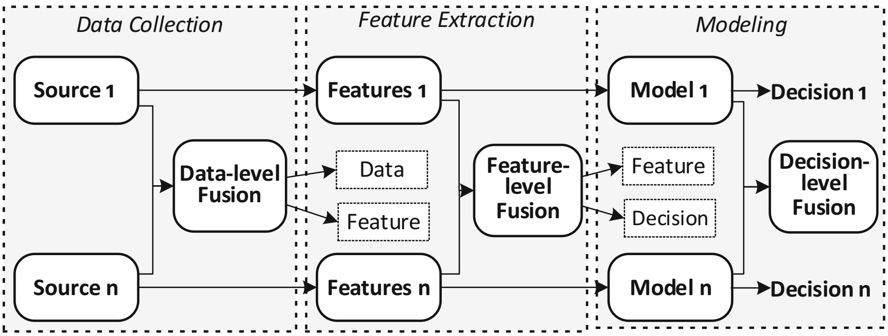


**Fig. 5.1** Data fusion modes

## 5.3 Base Components of Knowledge and Data Acquisition

### *5.3.1 The MeCo System Components*

The MeCo is a personal PD monitoring system that utilizes the built-in sensors and data fusion methodology [33]. The MeCo service is designed to deliver scalable performance with microservice architecture [34] and includes the following components:

- A smartphone application for patients with functions of active and passive symptoms tracking. During the task-specific sessions, a user can take a set of motor performance tests, execute a self-assessment questionnaire, and securely send results of measurements to the cloud storage.
- A web application to secure and remote access to data.
- A cloud-based service for data collection, management, and sharing.

Data stored on the smartphone never leave the device; only scores and weights are transferred to the cloud. The weights and scores can be shared, and model parameters are fused, averaged in the cloud, updating a global model returned to users' smartphones. The data-mining package for PD analytics includes statistical instruments for short-term and long-term analyses, clustering and classification algorithms, and tools for data visualization.

The MeCo realizes the complete workflow for audio, video, and textual information to guide patients and their careers and conduct the tests at home unsupervised by a clinician.

### *5.3.2 Knowledge and Data Acquisition Pipeline*

Functional system architecture provides a means for data acquisition and transmission from the smartphone sensors and extracting valuable information. The raw data collected from sensors are processed and used to assess the current PD state. This process is mainly composed of four steps: collection, processing, analysis, and fusion. These steps are explained below.

Figure 5.2 shows a diagram of main knowledge and data acquisition processes in MeCo system supplemented by quiz data with consideration of the data preprocessing, processing, and feature extraction. The data analytics pipeline and fusion stages are also included.

Since test data are gathered from several sensors, the time steps of their transmission may differ. Therefore, to this moment, we utilized data fusion for static data only, such as exercises and quiz data for the PD state assessment. In general, data from smartphones are pushed to data storage, where the data mining process is carried out. In the case of lost internet connection, data are aggregated in the smartphone. Several processes are executed during the data processing stage as data

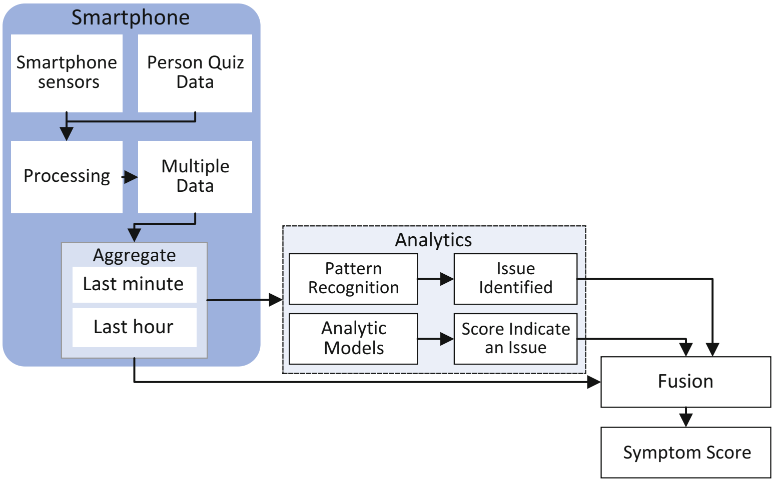


**Fig. 5.2** The base knowledge and data acquisition processes in MeCo functional architecture

cleaning, data imputation, segmentation, and feature extraction. The segment size can also be different. Next is the analytics stage, where the currently active model runs algorithms and assesses the targeted scores. Further, data fusion is conducted separately for quiz and sensor nodes. Finally, fused scores are aggregated to obtain a general score for PD symptom severity and then get the symptom rating value.

#### 5.3.2.1 Data Collection

MeCo 2.4 app collects data remotely. Subjects from Ukraine provide multimodal pseudo-anonymized data (e.g., voice, movement sessions) via downloading the mobile app from the application web site [35] and registering for the study. Written informed consent was obtained from all subjects before they participated in research and procedures conducted under institutional and international guidelines on adult-led research. Subjects can recall the process at any time using the available option in the application and even request the removal of the collected data.

#### 5.3.2.2 Data Processing

The data processing steps are similar to classification works and include the preprocessing, segmentation, feature extraction, and analytics stages. The main difference of this work is that we use various techniques to preprocess data. The MeCo is able to receive and process at least four different types of data from microphone, accelerometer, sensor screen, and questioner.

It enables to proceed with sensor data independently and form the complex score for several smartphone sensors.

1. Segmentation: At the end of the data collection session, all data gathered from the smartphone is extracted and passed through the data processing pipeline. A technique for data processing stands on the task and type of IMU used for the study. For example, data corresponding to key-press is extracted and segmented as well. One segment is considered as the entire duration between a key-press and a key-release.
2. Feature extraction: each segment is used for feature extraction depending on the task and type of data source. Each feature can either be a sensor-specific feature or a temporal one [36].

#### 5.3.2.3 Data Analysis

At this stage, extracted features are used as input for models. Models are chosen depending on the tasks and enable PD symptoms detection, classification, tracking, and estimation. The symptom level assessment problem is considered a supervised classification task where dataset's subsequences are fed into a machine learning classifier. Thus, once the features for every user's key-press are extracted, we use tenfold cross-validation for model training for sensor screen data. We employed machine learning algorithms, such as Random Forest, k-Nearest Neighbor, XGBoost, and support vector machine. We evaluated various classifiers and found that the accuracy obtained using XGBoost classifier is the highest. Therefore, XGBoost model was used for this research as a classifier.

#### 5.3.2.4 Data Fusion

In MeCo, each classification model achieved on previous level is trained separately for each feature set. When training is completed, individual results (classifier scores) are fused into a final decision. For late fusion, the system utilizes a traditional approach for combining multiple classifiers by summating weighted individual classifier scores.

## 5.4 Symptom Score Methodology Via Sensor Data

The PD symptom score methodology for PD symptom scoring is based on gradient tree boosting algorithm and includes stages of segmentation and feature extraction, symptom estimation to generate decisions on individual level, and data fusion.

### 5.4.1 Segmentation and Feature Extraction

Feature extraction starts from segmenting sensor data into non-overlapping one-second windows where each represented particular symptom patterns [37, 38]. The details of the extracted features are provided in [5]. As a result, we obtain a set of feature vectors $\left(\overrightarrow{f\upsilon} \in \mathbb{R}^{N_{Tr}}\right)$, where $N_{Tr}$ is the number of features per segment which is organized as $D_{Tremor} = \left\{\left(F^{(d)}, y^{(d)}\right)\right\}_r^{N_R}$ with $\left(F^{(d)} \in \mathbb{R}^{N_W^{(d)} \times N_{Tr}}, y^{(d)} \in \mathbb{R}\right)$ and $F^{(d)} = \left[\overrightarrow{f\upsilon_1}\,\overrightarrow{f\upsilon_2} \ldots \overrightarrow{f\upsilon_t} \ldots \overrightarrow{f\upsilon_{N_W^{(d)}}}\right]$, where $N_W^{(d)}$ denotes the number of 1-s windows in test $d$ and $N_R$ is the total number of tests. $y^{(d)}$ denotes a symptom rate to the corresponding feature vectors $F^{(d)}$.

### 5.4.2 Symptoms Estimation

To set a symptom rate $y^{(d)}$ with its corresponding feature vectors $F^{(d)}$, the gradient tree boosting algorithm [39] is used.

Firstly, each $\overrightarrow{f\upsilon_t}^d$ in test $d$ is assigned to the symptom rate $y^{(d)}$. Then, the method estimates the output $\hat{y}$ applying an ensemble of $N_t$ weak regression trees $\left(\{f_i\}_{i=1}^{N_t}\right)$, according to (5.1).

$$\hat{y}_t^{(d)} = \sum_{i=1}^{N_t} f_i\left(\overrightarrow{f\upsilon_t}^{(d)}\right), \tag{5.1}$$

where $f_i\left(\overrightarrow{f\upsilon_t}\right) = w_{q\left(\overrightarrow{f\upsilon_t}\right)}$ is the space of regression tree $i$ with $L$ leaves, $q\left(\overrightarrow{f\upsilon_t}\right)$ is the structure of the tree that maps $\overrightarrow{f\upsilon_t}$ to an index and represents the corresponding tree leaf, and $w \in \mathbb{R}^L$ is the leaf weights.

The regression tree learning is conducted through the additive strategy. According to this technique, at each iteration, one tree can be learned via minimization of an objective function. The objective function is comprised with the first and second gradient statistics of a loss function. It is calculated as the difference between the estimated symptom rate $\hat{y}_t^{(d)}$ and the symptom score $y^{(d)}$ of test $d$. The trained model is applied for symptom score evaluation for all feature vectors in one test. Finally, the average of the estimated symptom rates in one round is computed and used as the estimated symptom score of each test $\hat{y}^{(d)}$.

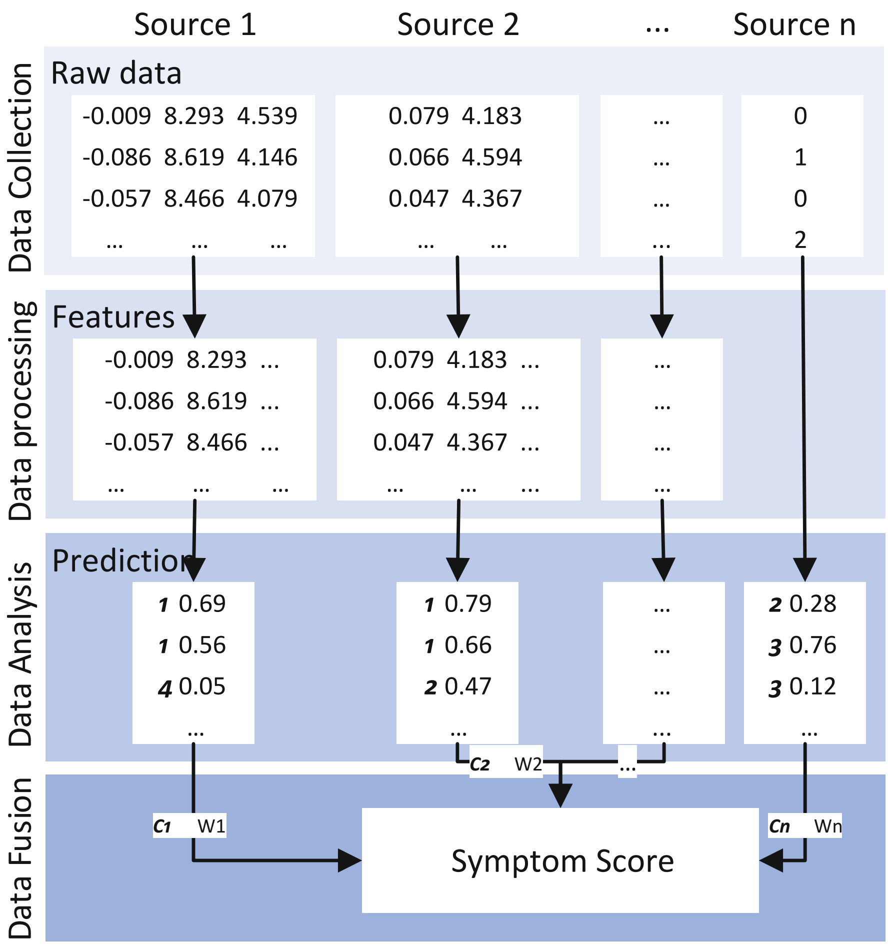


Fig. 5.3 Data fusion step flowchart for different sources

### 5.4.3 *Symptom Scoring Based on Decision Fusion*

Symptom score assessment is a final stage of the methodology. Symptom score module fuses results achieved form numerous classifiers for the same problem and generates predictions, a unique solution as it is presented in Fig. 5.3.

Each classifier provides an individual result for each segment of the features extracted from the test data. Combining the results of the classification for individual segments and then fusing the results for both hands at the decision level enable to obtain a more comprehensive symptom's score basis. In XGBoost model, after each boosting step, we obtain the weights of new features. The classification results

**Table 5.2** Symbol description

| Source 1 ($S_1$) = sensor data | Source 2 ($S_2$) = quiz data |
|---|---|
| Weight of $S_1 = W_1$ | Weight of $S_2 = W_2$ |
| Threshold of $S_1 = V_1$ | Threshold of $S_2 = V_2$ |
| Class label of $S_1 = C_1$ | Class label $S_2 = C_2$ |

**Table 5.3** Test cases for decision level fusion

| IF | THEN |
|---|---|
| ($W_1 \geq V_1$ **AND** $W_2 \geq V_2$) | IF ($W_2 \leq W_1$)<br>Then Final Class Label = $C_1$<br>Else Final Class Label = $C_2$ |
| ($W_1 \geq V_1$ **AND** $W_2 < V_2$) | Then Final Class Label = $C_1$ |
| ($W_1 < V_1$ **AND** $W_2 \geq V_2$) | Then Final Class Label = $C_2$ |
| ($W_1 < V_1$ **AND** $W_2 < V_2$) | Then $W_1 = w_1 * W_1$ and $W_2 = w_2 * W_2$<br>IF ($W_2 \leq W_1$)<br>Then Final Class Label = $C_1$<br>Else Final Class Label = $C_2$ |

include the level of symptom severity $Cn$ and weight $Wn$. The description of the data used at the fusion stage is given in Table 5.2.

Table 5.3 shows the options for fusion the results of the symptom assessment, based on the weights obtained during the exercise and the survey. The thresholds for each data source are defined manually. The fusion parameters are used to merge the classification results within one test and to fusion the classification results of several tests.

Here $w_1$ denotes the weights assigned to each data source in addition to the resulting weight $Wn$ achieved after classification.

## 5.5 An Example for Accelerometer Data Processing

### *5.5.1 Data Collection*

The signal $T_s$ used for this example was obtained from routine procedure assessments employing a smartphone placed in the hand. Test exercises had a different duration. Each hand was tested separately. The testing part included three tasks related to finger touches. All tests were intended to reflect the most common types of interaction individuals have with the smartphone touchscreen.

1. Basic finger tapping: a person follows a spiral on the screen by finger trying to repeat it. The mode with appearing and disappearing spiral is also available.
2. Sequential finger tapping: a person taps the squares appearing and disappearing on-screen.
3. Double finger tapping: a person switches off an alarm by tapping twice on a 15-mm circle.

**Table 5.4** The fragment of accelerometer data

| Time stamp | *X* | *Y* | *Z* |
|---|---|---|---|
| 1,604,821,250,168 | −1533 | 3241 | 9538 |
| 1,604,821,250,176 | −1617 | 3129 | 9728 |
| 1,604,821,250,183 | −1624 | 3014 | 9912 |
| 1,604,821,250,191 | −1634 | 3014 | 10.125 |
| 1,604,821,250,199 | −1677 | 3079 | 10.070 |
| 1,604,821,250,206 | −1737 | 3107 | 10.180 |

User actions during the first test comprise the sequence of the following steps. Participant touches the Start button. At first, they need to follow the spiral line on the screen by the index finger. When the line is ended, press the Finish button. Then second round starts. After clicking the Finish button, the spiral starts to disappear and appear, and the participant needs to run their finger along the spiral and click the Finish button.

Each exercise for tremor detection using smartphone holds as follows. The phone must be in the person's outstretched hand for 10 seconds. User actions during the first exercise comprise the sequence of the following steps. Participant reads the short recommendation and touches the Start button. After 10 seconds, exercise is finished and data is pushing up to the cloud storage. The result scores follow MDS-UPDRS [3]. This rating includes five levels of symptoms severity: 0-Normal, 1-Slight, 2-Mild, 3-Moderate, and 4- Severe. This rating is used for data labeling for model training and symptom scoring.

The result of each exercise, the time stamp, and accelerometer data are obtained in three axes (Table 5.4).

In addition to objective motor assessment tests, we developed a quiz based on standard clinical rating scales. For quiz developing, the clinical rating system used for PD is the Unified Parkinson's Disease Rating Scale (MDS-UPDRS) [3], Part I: Non-Motor Aspects of Experiences of Daily Living (nM-EDL). The quiz consists of seven questions about user experiences of daily living. This one is about sleep problems, daytime sleepiness, pain and other sensations, urinary problems, constipation problems, light headedness on standing, and fatigue. Answers were scored from 0 to 4 (0 = normal, 1 = slight, 2 = mild, 3 = moderate, 4 = severe).

### *5.5.2 Data Processing*

#### 5.5.2.1 Segmentation

Data from sensors were segmented in a non-overlapping one-second window as it is shown in Table 5.5.

**Table 5.5** The fragment of segmented accelerometer data

| **Timestamp** | 1,604,821,250,168 | 1,604,821,250,176 | 1,604,821,250,183 | 1,604,821,250,191 | 1,604,821,250,199 | 1,604,821,250,206 | 1,604,821,250,214 |
|---|---|---|---|---|---|---|---|
| ***X*** | −1.533 | −1.617 | −1.624 | −1.634 | −1.677 | −1.737 | −1.789 |
| ***Y*** | 3.241 | 3.129 | 3.014 | 3.014 | 3.079 | 3.107 | 3.138 |
| ***Z*** | 9.538 | 9.728 | 9.912 | 10.125 | 10.070 | 10.180 | 10.238 |

**Table 5.6** The extracted features of accelerometer

| Feature name | Used signals | Number of features |
|---|---|---|
| Mean (Mn) | $X, Y, Z$ | 3 |
| Standard deviation (SD) | $X, Y, Z$ | 3 |
| Energy of the sequence (En) | $X, Y, Z$ | 3 |
| Pearson's correlation (PC $XZ$) | $X$ and $Z$ | 1 |
| Pearson's correlation (PC $XY$) | $X$ and $Y$ | 1 |
| Pearson's correlation (PC $YZ$) | $Y$ and $Z$ | 1 |

#### 5.5.2.2 Processing

Data processing is carried out on a non-overlapping one-second window. For each segment, the features are calculated. Extracted features are listed in Table 5.6 from each segment. $N_{Tr} = 12$ for accelerometer data is the number of features per segment.

After this stage, we obtain 12 variables for each sample window. A fragment of the dataset is presented in Table 5.7.

The classification of each hand accelerometer data is carried out using labeled data with five output classes: 0 (no tremor), 1 (slight tremor), 2 (mild tremor), 3 (moderate tremor), and 4 (severe tremor).

### *5.5.3 Classification*

The processed tremor exercise data was classified using train and test datasets. Classification is carried out using the GXBoost algorithm.

The evaluation of the classification was carried out using correctly classified and misclassified scores.

The dataset consists of data of 12,250 timesteps from 10 exercises using accelerometer. Data have been processed as it is described.

The processed dataset consists of 100 extracted feature segments. The class labels include 20 cases of each class in each dataset and uniformly distributed. When training and testing the model, the dataset is randomly divided into training and test sets in a ratio of 75/25 feature segments, respectively. Observation class is determined by the maximum probability for each observation, as shown in Table 5.8.

ID represents the feature segment number; Prob_Class 0, Prob_Class 1, Prob_Class 2, Prob_Class 3, and Prob_Class 4 represent the probabilities of the classes Tr0, Tr1, Tr2, Tr3, and Tr4, respectively; Max_Probab is the value of the maximum probability for this observation; and Pred_Class is the predicted class. The maximum probability value, rounded to 3 decimal places, is further used as the class weight values.

**Table 5.7** Extracted features from segmented accelerometer data

| Mn $X$ | Mn $Y$ | Mn $Z$ | SD $X$ | SD $Y$ | SD $Z$ | En $X$ | En $Y$ | En $Z$ | PC $XY$ | PC $YZ$ | PC $XZ$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| −0.77335 | 1.97856 | 9.588816 | 1.290633 | 0.97255 | 1.283998 | 69.96643 | 464.4552 | 11126.67 | −0.15024 | −0.38828 | 0.567455 |
| −0.11847 | 2.410264 | 9.728048 | 0.422734 | 0.200946 | 0.66973 | 2.142768 | 700.2699 | 11406.69 | −0.35152 | 0.164927 | −0.01178 |
| 0.420432 | 2.316016 | 9.749856 | 0.121046 | 0.092993 | 0.197247 | 21.51734 | 647.1169 | 11496.68 | 0.023095 | −0.29819 | −0.15589 |
| 0.422016 | 2.396536 | 9.706584 | 0.101095 | 0.079066 | 0.121336 | 21.56881 | 694.2002 | 11402.45 | 0.426961 | −0.30433 | −0.04237 |
| 0.42448 | 2.533664 | 9.667704 | 0.083002 | 0.123725 | 0.131883 | 21.92921 | 777.9884 | 11311.75 | 0.300872 | −0.47068 | −0.0287 |

**Table 5.8** Fragment of obtained class probability

| ID | Prob_Class 0 | Prob_Class 1 | Prob_Class 2 | Prob_Class 3 | Prob_Class 4 | Max_Probab | Pred_Class |
|---|---|---|---|---|---|---|---|
| 76 | 0.115531 | 0.279782 | 0.135393 | 0.309714 | 0.15958 | 0.3097 | 3 |
| 95 | 0.130082 | 0.130555 | 0.350543 | 0.242499 | 0.146321 | 0.3505 | 2 |
| 46 | 0.127879 | 0.139272 | 0.344607 | 0.128183 | 0.260058 | 0.3446 | 2 |
| 21 | 0.21559 | 0.192925 | 0.206293 | 0.192684 | 0.192508 | 0.2156 | 0 |
| 14 | 0.407075 | 0.167919 | 0.142537 | 0.1413 | 0.14117 | 0.4071 | 0 |
| 7 | 0.418131 | 0.145319 | 0.146408 | 0.145137 | 0.145004 | 0.4181 | 0 |
| 48 | 0.147325 | 0.160451 | 0.397009 | 0.147675 | 0.14754 | 0.3970 | 2 |

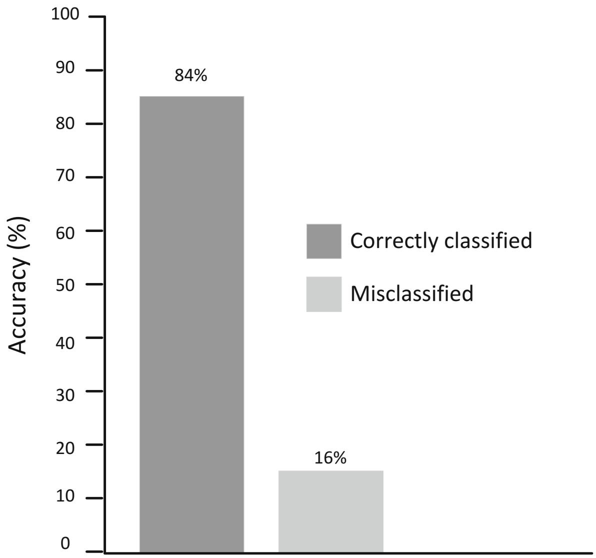


**Fig. 5.4** Classification accuracy for test dataset

Out of 25, 21 right-hand observations are correctly classified, and classification accuracy is 84%, which is shown in Fig. 5.4.

Figure 5.4 shows the correctly classified and misclassified cases obtained on test data.

### *5.5.4 Fusion Strategy*

The weight values obtained from the classification of the test data are used to set up the threshold value for the selection of classified feature segments. Based on observations, the threshold value was determined to be 0.22.

The stage of data fusion was demonstrated drawing on the example of detection of the degree of tremor for the right and left arms to obtain a general assessment of the tremor degree. Right-hand data were obtained with tremor amplitude from 1 to 3 cm, which corresponds to class 2 = mild. Left-hand data were obtained with a tremor amplitude of 3–10 cm, which corresponds to class 3 = moderate. Right- and left-hand exercise data were acquired and processed, and feature segments were classified as described above. The results obtained for the segments of the attributes of the exercise and the class and weight of the class for the right and left hands are presented in Table 5.9.

The result shows a classification accuracy of 90% for both hands. Combining the classification results of the feature segments of one exercise is carried out in accordance with the following rules

**Table 5.9** Result of right- and left-hand exercise data segments

| Right hand | | | Left hand | | |
|---|---|---|---|---|---|
| Segment ID | Weight | Predicted class | Segment ID | Weight | Predicted class |
| 1 | 0.3927 | 2 | 1 | 0.3378 | 3 |
| 2 | 0.2199 | 1 | 2 | 0.2534 | 3 |
| 3 | 0.3927 | 2 | 3 | 0.3446 | 3 |
| 4 | 0.3680 | 2 | 4 | 0.2156 | 2 |
| 5 | 0.3418 | 2 | 5 | 0,4071 | 3 |
| 6 | 0.2262 | 2 | 6 | 0.4181 | 3 |
| 7 | 0.3970 | 2 | 7 | 0.3970 | 3 |
| 8 | 0.3463 | 2 | 8 | 0.3960 | 3 |
| 9 | 0.4181 | 2 | 9 | 0.4182 | 3 |
| 10 | 0.3320 | 2 | 10 | 0.3032 | 3 |

**IF** ($W_1 \geq V_1$ **AND** $W_2 \geq V_2$) **THEN** IF ($W_2 \leq W_1$) Then Final Class Label = $C_1$ Else Final Class Label = $C_2$($W_1 \geq V_1$ **AND** $W_2 < V_2$) Then Final Class Label = $C_1$

for the right hand, starting from the first segment as below

(0,3927 ≥ 0,22 AND 0,2199 < 0,22) Then Final Class = 2 with weight = 0,3927
(0,3927 ≥ 0,22 AND 0,3927 ≥ 0,22) Then Final Class = 2 with weight = 0,3927
(0,3927 ≥ 0,22 AND 0,3680 ≥ 0,22) Then Final Class = 2 with weight = 0,3927
(0,3927 ≥ 0,22 AND 0,3418 ≥ 0,22) Then Final Class = 2 with weight = 0,3927
(0,3927 ≥ 0,22 AND 0,2262 ≥ 0,22) Then Final Class = 2 with weight = 0,3927
(0,3927 ≥ 0,22 AND 0,3970 ≥ 0,22) Then Final Class = 2 with weight = 0,3970
(0,3970 ≥ 0,22 AND 0,3463 ≥ 0,22) Then Final Class = 2 with weight = 0,3970
(0,3970 ≥ 0,22 AND 0,4181 ≥ 0,22) Then Final Class = 2 with weight = 0,4181
(0,4181 ≥ 0,22 AND 0,3320 ≥ 0,22) Then Final Class = 2 with weight = 0,4181

According to the results of combining these segments of the right-hand exercise attributes, Final Class = 2 with weight = 0.4181. In the same way, we combine the data of the segments of the attributes of the exercise of the left hand and we get Final Class = 3 with weight = 0.4182. Next, we combine the data at the decision-making level about the overall degree of hand tremor using the following rule

**IF** ($W_1 \geq V_1$ **AND** $W_2 \geq V_2$) **THEN** IF ($W_2 \leq W_1$) Then Final Class Label = $C_1$ Else Final Class Label = $C_2$

**IF** (0,4181 ≥ 0,22 **AND** 0,4182 ≥ 0,22) **AND** (0,4181 ≤ 0,4182) **THEN** Final Class Label = 3.

As a result, at the decision-making level, a general assessment of the degree of hand tremor was obtained, which corresponds to the class 3 = moderate.

## 5.6 Conclusion and Future Work

The MeCo system is designed to help people with Parkinson's disease to monitor their health status in time. It includes two types of activities related to interaction of people with the smartphones, the active or task-specific sessions and passive sessions, and enables to acquire large-scale data from users' everyday patterns through human-smartphone interaction, patient-reported outcomes, and physical activity data. The connection settings developed for the system proved to be efficient when sensor data were transmitted from the smartphone to database storage. The time required to transfer data to the database is less than 1 s. The fusion technique is proposed for PD symptom assessment. The technique consists of four steps: smartphone sensor data collection, processing, analysis, and fusion. Data processing includes segmentation and feature extraction. Analysis is provided with machine learning algorithms. These steps can have a different mode depending on task and data. The fusion step combines several classifier results into a general assessment of PD symptoms such as hand tremor, as presented in the experiment. Further research on multimodal data analysis and comparison with data from a control group of healthy participants is needed in order to validate the system and to test its reliability. This would improve the accuracy of multimodal data classification for parkinsonian symptom assessment.

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# Chapter 6
# How to Manage Knowledge within Hotel Chains in the Era of COVID-19

**Sofia Almeida, Maria José Sousa, and Susana Mesquita**

## 6.1 Introduction

Over the last months, since being declared as a pandemic by the World Health Organization (WHO) on March 11, 2020, the impacts on the political, social, and economic system, with no precedents, caused a global crisis to which the world is trying to respond in order to recover from a crisis that remains unpredictable due to the high contagiousness characteristic of the virus [1].

According to WHO, the virus has spread to 115 countries, and almost 4,300 people have died in two months and on March 11, 2020, COVID-19 is called a pandemic disease [2]. Humanity was suspended for a couple of months, in the so-called lockdown. People stayed at home and the economy went through one of the most complicated periods ever. The tourism sector has stopped its activities due to business and leisure travel cancellations. Hotels closed doors, for the first time, since they had open to the public. Planes, instead of filling the skies, filled the airport parks. Tourism professionals start to work from home using technologies to continue their activities. Tourism is very rewardable to crises, like diseases, financial breakdowns, or wars in complex times. It is one of the activities that suffer the most of the direct and indirect impacts of these crises. In 2020, the world met a brand-new pandemic in the twenty-first century [3], so now it is important to

S. Almeida (✉)
Universidade Europeia, and CEG-Territur Universidade de Lisboa, Lisbon, Portugal
e-mail: salmeida@universidadeeuropeia.pt

M. J. Sousa
Instituto Universitário de Lisboa (ISCTE-IUL), Business Research Unit (BRU-IUL), Lisbon, Portugal

S. Mesquita
Universidade de Aveiro, Aveiro, Portugal

 
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reunite all the efforts to let tourism keep being one of the world's fastest-growing markets. Specifically, the hospitality and the hotel sector are highly susceptible to this kind of health-related crisis. The linked points are the high volume of patrons, large staff work teams, exposure to intra-regional and international travelers, the potential for contagion through cross-contamination, and multiple pathogen delivery mechanisms (e.g., surfaces, cutlery and crockery, food) [4]. The tourism industry has just suffered one of the biggest hits ever with more than a million deaths over the past few months. The hotel professionals have shown in the past a willingness and resilience to overcome other crises and natural disasters, such as 9/11, bird flu, SARS, or swine flu, which hotel occupancy has recovered pre-crisis levels in less than two years [5].

Hall et al. [6] pinpointed that the threat of a pandemic has increased in the present century due to the way how humanity is dealing with its ecological footprints. Connolly et al. [7] and Hall et al. [6] presented several reasons to explain this pandemic risk, namely; the growing mobility of the population and urbanization, the industrialization of food production processes, and the expansion of global transport networks which contributes to the transmission of pathogens.

The tourism sector is reacting in different ways to this pandemic crisis. Researchers have been doing an effort to identify these reactions in a more local paradigm and also into an international one. Hao and Chon [8] researched the impacts of COVID-19 on China's Hotel Industry and verified that in a post-pandemic era, the hotel industry in China will be affected under four major aspects: multi-business and multi-channels, product design and investment preference, digital and intelligent transformation, and market reshuffle. Hu et al. [3] analyzed how companies are implementing protocols to guarantee the health and security of their employment. Carr [9] studied how the indigenous population is responding to this crisis; [2] is studying how tourists are reacting to all these cancellations through the analysis of the TripAdvisor website.

Fitch [5] is expecting that the coronavirus pandemic will cause a drop of more than 60% in revenue per available room (RevPAR), which will not be recovered until 2023. However, according to the same source, the magnitude of the coronavirus outbreak caused most of the evaluations under pressure with negative EBITDA during 2020 for most hotel groups, thus delaying their ability to restore. Corporate travel will take longer to recover, as video conferencing has been seen as a suitable replacement for face-to-face meetings. On one hand, hotel companies, especially large brands, are adjusting their cost structures to mitigate revenue pressures and protect their profits. On the other hand, hotel chains with many assets are also reviewing and cutting back on their investment plans. They only cover the minimum maintenance investment, and all new developments, expansions, and major renovations are canceled or postponed to 2021.

The paper begins by reviewing literature in knowledge management and COVID-19 in the tourism and hotel sector then followed by the methods. The findings are discussed in line with the key concepts and relationships between different actors. Finally, theoretical and practical implications are provided.

## 6.2 Literature Review

### *6.2.1 Knowledge Management*

Knowledge is defined as the sharing of information and relevant experiences in organizations, allowing an increase of resources within a company and reduction in time lost in the attempts/errors. Davenport and Prusak [10] pinpointed that knowledge is a fluid mix, blending experience, values, contextual information, and the insights of specialists who formulate a model for evaluating and incorporating new experiences and information and is applied in the minds of connoisseurs. Larsson et al. [11] refer to the importance of the process of knowledge development, specifically in strategic alliances, mentioning that transparency and reciprocity are important for the development of knowledge, unlike "power," "opportunism," and "asymmetric learning strategies" that are barriers to the transmission of knowledge. Other reference authors like [12] associate knowledge with action. Authors referred that knowledge is the ability to act. Nonaka and Takeuchi [13] explain that knowledge is created by the flow of information associated with the beliefs and commitment of those who possess it. As pinpointed by [14], knowledge sharing is considered a precious intangible resource and contributes to the creation of a company's competitive advantage. Wong et al. [15] research about the performance of virtual teams and the sharing of knowledge in the relations of competition supported by the measurement items of [16].

Polanyi [12] proposes a useful classification, distinguishing between implicit knowledge, and explicit knowledge. Both knowledge is present as the most important resource to overcome business challenges and to obtain a competitive edge [17]. In addition, individual knowledge or group knowledge may be knowledge. Individual awareness is what literature terms implicit knowledge and is seen as an individual property. Via experience and experiences between people and between people and systems, tacit information is contextual, kept informally, and acquired [18]. It is embedded in the behavior, experience, participation in a particular sense of organizational participants, and includes all dimensions of cognitive and technical awareness [13]. The cognitive tacit understanding is characterized as a collection of mental models that affect the actions and decisions of a person. The opinions of a salesperson on what would appeal to a customer will be an example of this [19]. Knowing what might appeal, however, is not sufficient to allow the individual to make the sale. The technical component of tacit knowledge is defined as the know-how relevant to a particular situation [13].

Sharing knowledge within the organization enables valuable assets to be preserved: studying new strategies, solving problems, and creating essential skills [12]. Process creation, formal language, technical manuals, and information systems facilitate the sharing of explicit knowledge among workers. Face-to-face contact, on the other hand, is the primary means of communicating implicit information and its achievement, the desire and capacity of individuals to express what they know and use what they understand [20]; implicit knowledge is based on human experience [12]. Difficulties resulting from the sharing of implicit knowledge include the ability of co-workers to communicate and/or use this kind of knowledge, the restricted understanding of each individual's implicit knowledge, and the complexity in other contexts of applying this knowledge [21]. However, in the process of knowledge sharing, these obstacles can be resolved by relationships of trust between individuals. Wang and Wang [22] want to understand the perceptions of their respondents in their research about the difference between sharing implicit and explicit knowledge between workplace teams.

Research has, however, made it clear that a team of communicating people may have information that independently transcends the knowledge of each one of them [23]. Organizational knowledge is multidisciplinary, difficult to formalize, and developed in discussions with competing points of view, according to [24]. This third organizational knowledge categorization is an effort to acknowledge this understanding of knowledge and to integrate the knowledge of both individuals and groups. The term "knowledge structure" is used by [23] to describe a "mental blueprint" that is used to give form and meaning to a complex information environment. In order to allow subsequent understanding and intervention, information systems are based on previous experiences and are used to store data. Individual knowledge is thus concerned with personal systems of knowledge, while collective knowledge is related to organizational structures of knowledge. Group knowledge can be described as the knowledge and skills that individuals who have been exposed to similar work-related situations collectively acquire [25]. People within organizations can easily share this information.

Organizations' knowledge-based viewpoint means that the combination of tools and organization uses to deliver its products/services is a function of the knowledge of the company [19]. This perspective raises the question of how best to treat the resource of information, including how to promote behaviors that exchange knowledge. This requires a broader conception of knowledge than the conventional view of knowledge as an entity that can be codified and transmitted beyond the person [18]. This form of knowledge [13] is also referred to as explicit knowledge. In the last decade, several organizations have started to understand the value of the storehouse of information that resides within their organizational members' heads and experiences, while at the same time recognizing that it is difficult to distinguish from the initiating person [14]. This indicates that knowledge can also be seen as rooted in individual behaviors and communications [18], and is also related to implicit knowledge. The integration can result from the experiences of the individuals or the workgroups to which they belong, as well as from work practice interpretations and routinization [19].

Extensive literature offers many examples of knowledge-sharing organizations [26], but most of these case studies do not thoroughly examine why these organizations have been active in this endeavor. It is probably important to understand what factors tend to impact knowledge sharing to fully understand how to develop this ability. The following five factors that could impact knowledge sharing were presented in the literature within the knowledge domain:

(i) Relational channels of two-way human-to-human touch, frequency, and depth [27].
(ii) Similarity of spouses, degree of similarity between individuals (i.e., interests, history, or education) [28, 29].
(iii) Depreciation after sharing, lack of information [30]; [31].
(iv) Organizational understanding of oneself, what people know and use [27].
(v) Divergence of interests and congruency between individual and organizational objectives [32, 33].

Nonetheless, a large number of authors say that many businesses suffer from substantial obstacles, impeding the sharing of information and eventually reducing organizational effectiveness (e.g., [34]). It is possible to organize the traditional obstacles to information sharing found in the literature into three groups:

(a) Individual obstacles centered on information sharing, process members for both the receiving and the transmitting parties. This category involves a wide range of challenges such as fear of losing personal competitive advantage, confusion and misunderstanding, group thinking, preference for one's own ideas rather than someone else's, e.g., [34].
(b) The organizational structure, the communication system, and the organizational culture decide the infrastructural (organizational) obstacles [35, 36]. For instance, [35] note that an organization must reinforce the importance of trust, both among employees and between an employee and the organization, and encourage free flows of information and error tolerance to efficiently share knowledge.
(c) Ontological obstacles that deal with knowledge itself and emerge from the problems of implicit transfer of knowledge [13] as well as from the perceived meaning of knowledge [37] are also not recognized at all by participants who exchange knowledge [36].

### *6.2.2 Knowledge Sharing Applied to Hotel Sector*

Knowledge management practices are present especially within hotel chains, as they have to deliver high levels of quality standard [38]. The tourism and hospitality sector are one of the bigger users of ICT and some important chains are implement the knowledge management system based on three different components: IT-based knowledge accumulation, access to IT KM system, and motivation to use and create knowledge [39].

The importance of using knowledge is recognized by hotel chains as continuous development and improvement of business. However, this industry has some difficulty to adapts to KM due to its complexity which requires high levels of data mining skills, statistics, and knowledge of the sector itself [40]. Concerning the hotel sector and according to [41] the main components of knowledge are; (i) the human capital knowledge, skills, and experience; (ii) systems capital, operational knowledge of the firm, (e.g., processes, policies, and procedures) and (iii) customer capital (related with the value of the brand and the ability to attract and retain customers). Hotel chains implement knowledge systems based on different components. Some well-known hotels have developed a learning culture by encouraging and offering a consistent approach to training for team members by using e-learning technology. The need for knowledge in the hotel sector has increased due to customer demand. The transformation of tacit knowledge into explicit knowledge is not easy to achieve as normally as the first one is used automatically [39].

The hotel sector with a large hierarchy can opt to implement some strategies in order to minimize the impacts of the pandemic like developing work teams and project-based groups using knowledge [42]. The creation of a knowledge system to allow answers to this crisis both using internal and external sources and the creation of a tourism crisis communication center are according to [43] a solution to deal with crises. The crisis team, according to the author, is composed of representative stakeholders. This model is rather simplistic as the authors believe that crises have familiar patterns and occur in a linear manner.

One of the key drivers to competitivity in the twenty-first-century economy is without any doubt knowledge [44].

### *6.2.3 Knowledge Management in Times of Crisis*

This section aims to explore knowledge management for the tourism crisis in a chain of hotels in the era of COVID-19. The actual coronavirus (COVID-19) pandemic has a worldwide dimension, affecting all countries equally although the policies adopted differ from country to country. This aspect is relevant as large firms especially the international ones have to deal with different politics and laws that can have tremendous negative effects upon a wider range of stakeholders.

Knowledge management is crucial in tourism management in order to react quickly and to minimize the impacts of crises such as disasters [45]. The definition of tourism crisis was first presented by World Tourism Organization as something unexpected that interferes with the travelers' confidence affecting either their destination and either the ability to continue performing normally [46]. In addition to this idea, we must add the fact that a tourism crisis cannot be addressed only on the demand side but also on the supply side. In other words, the challenges businesses face in their daily operations must be also considered. Thus, a crisis can seriously affect business operations even leading the business to extinction. Crises are not a novelty to tourism however the impact of COVID-19 has no precedents in world history [2]. This, like all other crises, according to several authors [47], is an opportunity and a way to reinvent tourism. In the last years, the tourism industry and research have provided a large amount of knowledge concerning some important topics related to how to manage crisis recovery and how to build resilience to deal with future crises. What is still missing is an answer to how can a crisis help to sustain industry changes and how can we transform a problem into an opportunity using, for example, an innovation ([36, 48]).

One of the most important topics that are stated as improving the chance of surviving is a rapid change in a business environment to come out of a crisis [43].

The aim of knowledge, according to some authors is to gain a competitive edge by developing innovative products. Thus, the definition present in this study of Knowledge management is that present by [45] as "a systematic and continuous process to audit, develop, and transfer knowledge of tourism crisis." Since 2001, research regarding crisis management had increased due to terrorism, especially in 2001 in the 9/11. The way a hotel deals with catastrophic events depends on different variables such as location, size among others [45]. Collaboration becomes an essential aspect of the tourism crisis as it "leads to dialog, negotiation, and building of mutually acceptable proposal about how tourism should develop" [49].

In a short period of time, companies had to adapt in order to overcome the difficulties that emerged from the COVID-19. Although China's hotel industry was the first receiver of the pandemic's ramifications, it took timely measures to cushion the economic loss and secure its employees and customers. Security is also a recurrent theme in COVID-19 research. Hu et al. [3] pinpointed how organizations facilitate employees' deep compliance with healthy procedures. This research is focused on the health and wellbeing of employees through safety requirements and protocols in response to this unprecedented health crisis. Long-term changes in tourism are expected due to COVID-19. The current pandemic has highlighted the importance of sustainability and the need for cooperation among different stakeholders to produce knowledge to transform the post-Covid degrowth in opportunities [50].

The hotel sector suffers from booking cancelations around the world, although the process of traveling begins with the booking of the transports. So, travel insurance has become a hot topic, which may be a way of reanimating the industry by offering travel packages, including travel insurance services [2]. Many countries prohibit foreigners from entering the country and close their external borders, so this situation started a huge process of cancelations around the world. Authors used one of the largest forum travel platforms to identify comments of travelers and travel planners about the Covid 19-Results allows to present the decisions and reactions of individual tourism actors because of this pandemic. This study aimed to present the decisions and reactions of individual tourism actors and tourists because of the pandemic trends outlined. Specifically, this study focused on revealing the effects of the COVID-19 pandemic on global tourism in the light of the comments of travelers and travel planners. The forums on the world's largest travel platform (tripadvisor.com) have been examined. The most extracted phrases are coronavirus, travel insurance, wear face mask, and confirmed case. The most extracted topics are cancelling the trip; march; stay home, high risk; test positive, patient; full refund, ticket, and flu, people die. Couto et al. [51] research about COVID-19 impacts in the perspective of residents in Azores Island. Obrenovic et al. [52] conceptualized an innovative approach to COVID-19 from the perspective of organizational characteristics, operations, digital transformation, and financial planning in China and Croatia in Uzbekistan.

The COVID-19 had social and economic impacts which will negatively impact the tourism sector around the world while positive impacts on the environment result from the pandemic situation. Tourism demand decrease due to the health risk on human mobility [53]. The COVID-19 has produced several impacts on the tourism sector leading to transformations by the stakeholders who had to act quickly to the pandemic [48].

## 6.3 Methodology

### *6.3.1 Bibliometric Analysis*

The methodology of this study is firstly based on quantitative bibliometric analysis, and secondly, a qualitative analysis was made based on interviews performed with the top management of the two main hotels chain in Portugal.

The bibliometric study was made based on [54] principles. They state that "the fitting process necessarily starts, or in some cases restarts, with some level of awareness of the state of prior work in an area of interest. Ideally, a researcher develops a reasonably good understanding of major streams of work in one or more bodies of research literature." This bibliometric review was performed using the main search keywords knowledge + impacts of Covid + hospitality and tourism, on the scientific search engine b-On, which aggregates and accesses all major scientific databases, was performed to evaluate the research patterns of the study. The research was carried out since 2019 (Table 6.1):

The final number of papers for analysis is 216 ($n = 216$) for current research, after applying the criteria specified in Table 6.1.

The study of the results of the bibliometric search was carried out using the VOS viewer scientific program to visualize the keyword networks and to co-author the papers considered for this analysis. This analysis was guided by the two following research questions; RQ1: What were the main research keywords in the articles selected? RQ2: Who were the main authors of the articles? And RQ3: How hotel

**Table 6.1** Number of articles found according to criteria of exclusion

| |
|---|
| Keywords: Knowledge + impacts of Covid + hospitality and tourism |
| 118,751 scientific papers in journals since 2019 |
| Exclusion criteria: Equivalent terms and search in the whole text: 450 |
| Integral text: 317 |
| In English: 228 |
| Duplicates removed: 12 |
| Peer reviewed: 216 |

companies are managing knowledge to give answers to their employees and also to their clients?

### *6.3.2 Case Study*

To answer research question 3, the authors used a literature review about the hotel sector, knowledge management and COVID-19, and a case study. According to [55] the case study method involves the study of an example of a phenomenon spatially and temporally delimited. In the case study, a diversity of types of data and analysis are used. The same author refers to six main particular merits of using a case study approach and even if it offers flexibility, it is however essential that the researcher takes the same initial steps on the planning of the research project. In the same line, [56] defining a case study as a qualitative approach in each of the researcher explores a time and space-bound phenomenon. In the present study, the cases presented were deliberately chosen to illustrate the particular situation of how CEOs deal with the present pandemic times in terms of materializing their knowledge and transform it into important strategies to deal with this crisis. In a case study in methodology, diverse methodological approaches may be used to show a complexity of a certain problem that is being studied [56].

The authors analyzed a case study about the COVID-19 impacts in the hotel sector, using an example applied to Portugal. CEOs of the two of the large chain of hotels were interviewed about economic, financial, operational, organizational, and technological impacts on their business and in the hotel sector. Pestana Hotels and Vila Galé Hotels are the largest chain of hotels operating in this country, according to the ranking of Atlas da Hotelaria, 2020. These interviews took place in July, before the high season and new rules and procedures presented by the Government in Autumn. The following presents the best theoretical practices (literature review) and managerial practices (cited quotes from practitioners) about the way how companies share implicit and explicit knowledge to better take decisions and run their results.

### *6.3.3 Operationalization of Implicit and Explicit Knowledge*

Demonstration of how explicit and implicit knowledge is managed in the hotel sector, in times of COVID-19.

Musulin et al. [39] identify the difficulty to transform implicit knowledge into explicit knowledge once that the first one is used automatically. That is one of the big challenges of companies. Explicit knowledge is easy to be identified, more formal, and tangible. Implicit is more difficult because is more informal, comes from conversations, exchanging experiences. Being an important source as the first one is more difficult to capture and transform into tangible communications supports. After analyzed quotes of the CEOs, explicit and implicit knowledge concepts were operationalized to identify how this knowledge can be shared by companies with internal and external targets and transformed into the best practices.

(i) explicit knowledge e.g., the collection and use of formal documents and reports [57]; sharing market information files, databases and training manuals and training and personal development programs [62] and information technology systems [58]. Process creation, formal language, technical manuals, and information systems facilitate the sharing of explicit knowledge among workers. Based on human experience [12].
(ii) implicit knowledge (e.g., sharing information at professional events, fairs, and workshops) [58] sharing employee experience, professionalism, and lessons learned from mistakes in the past [20, 21]). Face-to-face contact, on the other hand, is the primary means of communicating implicit information and its achievement, the desire and capacity of individuals to express what they know and use what they understand [20].

## 6.4 Results

### *6.4.1 Bibliometric Analysis*

To answer research question 1, (RQ1: What were the main research keywords in the articles selected?) a network of all keywords is represented in Fig. 6.1. It shows that the main research keywords of the articles analyzed are COVID-19, pandemic, coronavirus, sars-CoV-2, and public health, among others.

Figure 6.2 represents only the clusters of keywords which link the articles, being the keywords associated represented in the network (the colors represent the strength of association between keywords). This will help to visualize and explain the issues addressed by field research and define patterns in research.

As we can see in the following Table 6.2, the main keywords with the most occurrences are COVID-19, pandemic, coronavirus, sars-CoV-2, being the ones with more link strength:

A representation of the co-authorship network is provided in Fig. 6.3 to address research question 2 (RQ2: Who were the main authors of the articles?), since 2019, being a profusion of co-authorships defined by all colors except grey, as these authors are not connected in co-authorships, which implies an effort of collaboration between the authors researching in this area. Moreover, the different colors represent clusters of authors linked by co-authorships.

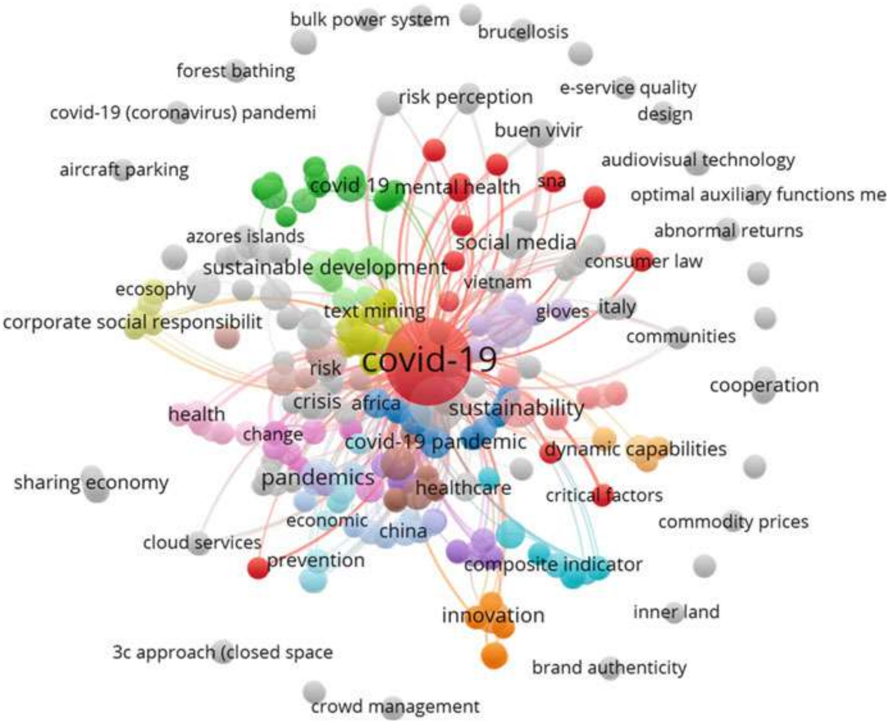


**Fig. 6.1** Network of all keywords

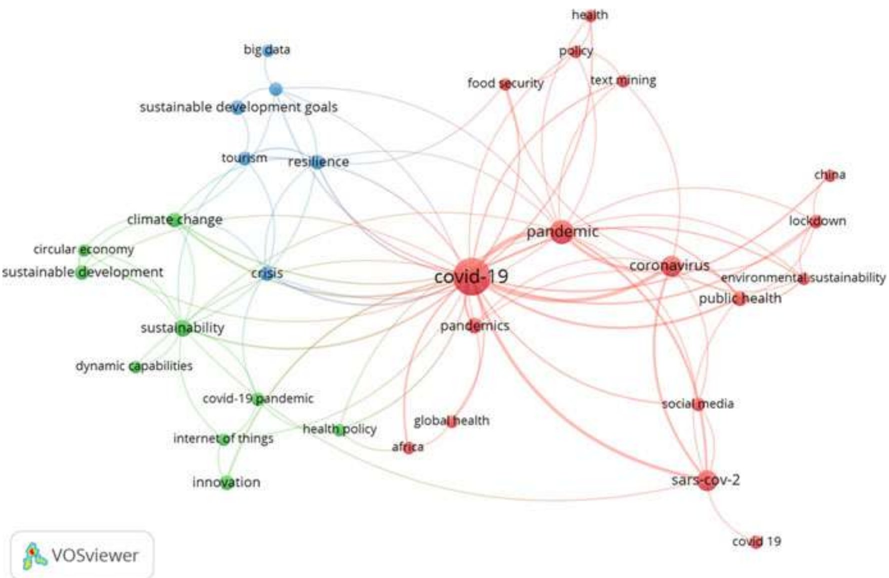


**Fig. 6.2** Network of linked keywords

**Table 6.2** Main keywords

| Keyword | Occurrences | Total link strength |
|---|---|---|
| COVID-19 | 78 | 66 |
| Pandemic | 20 | 38 |
| Coronavirus | 15 | 29 |
| Sars-cov-2 | 14 | 21 |
| Public health | 5 | 12 |
| Climate change | 5 | 10 |
| Sustainability | 7 | 8 |
| Pandemics | 6 | 7 |
| Resilience | 5 | 7 |
| Crisis | 5 | 6 |
| Innovation | 5 | 3 |
| Sustainable development | 5 | 3 |
| Sustainable development goals | 5 | 0 |

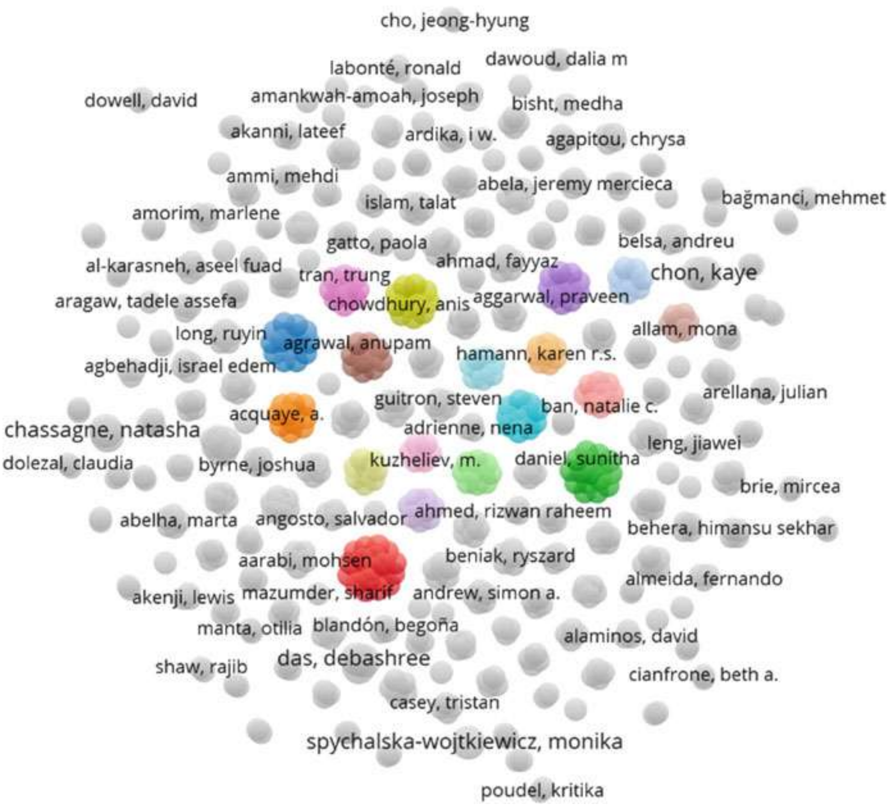


**Fig. 6.3** Co-authorships

### *6.4.2 Case Study and Implicit and Explicit Knowledge*

A table was designed to operationalize the best practices of explicit and implicit knowledge accordingly, literature review, and the use of a case study. Table 6.3 shows how hotel companies absorbed knowledge from the market, governance, stakeholders, and transform it to delivery to their main targets (internal – employees) and external (guests), and replies to research question 3 (RQ3: How hotel companies are managing knowledge to give answers to their employees and also to their clients?)

The way how company's delivery knowledge can be done in two ways, using explicit knowledge e.g., formal documents, reports, files, databases, training manuals, ([57, 58, 62] and implicit knowledge e.g., sharing knowledge through a conversation; physical and virtual meetings; exchanged experiences, and learn from the past [20, 21, 57, 58]. The following table will present the explicit and implicit knowledge practices in COVID-19 times by the CEOs of the chain of hotels (practitioners) and also literature review as previously shown.

## 6.5 Conclusion

This research made a contribution to the state of the art regarding the COVID-19 in the hotel sector and the way how this sector is managing knowledge inside and outside companies.

The bibliometric analysis concludes that there are several patterns of research being the keywords with more occurrences distributed in four clusters with relation to the main keyword COVID-19 on each one of them. Other keywords with a strong association are pandemic, coronavirus, sars-CoV-2, and public health. Regarding the 754 authors' analysis, ten of them have more than one article published in 2020 regarding COVID-19. Also, there are 19 authors with 171 links in these articles. As the theme is very recent, there are efforts of the researchers to understand how knowledge sharing among the actors of tourism field is contributing to deal with potential negative impacts in the life of hospitality organizations in respect to the different processes, relationships of the professionals with the sector, and with the public health questions.

Regarding the explicit knowledge (easier to codify), authors used CEOs' quotes from the case study and literature review to analyze this type of knowledge and the way how it is materialized in the sector. Authors verified that inside hotel companies, explicit knowledge appears upstream from the Government and Hotel Associations in the form of rules, standards, decree-laws; financial measures to boost the economy, [52] and recommendations about travelling and destinations. Explicit knowledge appears downstream when companies transform it and present it to their employees through meetings, workshops, training actions, healthy procedures, [4] and manuals. Themes are about safety and hygiene measures, technological

Table 6.3 Explicit and implicit knowledge in times of COVID-19

| | |
|---|---|
| **Explicit knowledge** unlike implicit knowledge is easier to transmit, encode, and communicate within companies and is found in the form of documents, databases, files, and other media. | |
| (i) | Reinforcement of the safety and hygiene regulations and standards through training actions and awareness-raising actions (Practitioners 2020) |
| (ii) | Strengthened the use of digital media in the departments of reservations and purchases (Practitioners 2020) |
| (iii) | Meetings with government agencies to identify the measures to be implemented, the reopening of hotel units and reinforcements in the organization" (Practitioners 2020) |
| (iv) | "The group has redesigned its loyalty program, the new Pestana Guest Club, for easier, enhanced advantages, and deals" (Practitioners 2020). |
| (v) | Creation of an App for mobile devices, "Checking in and checking out online, filling out online questionnaires, checking your account, seeing the news, and giving feedback. It's almost ready" (Practitioners 2020). |
| (vi) | "New measures include strategically planned out and well-marked ways in which to move around the hotel properties to control people traffic flow and ensure social distancing" (Practitioners 2020). |
| (vii) | "My Vila Galé was launched and new digital platforms are being considered in the area of purchases" (Practitioners 2020)? |
| (viii) | "The company invested in digital education, on broad areas such as management, leadership, digital marketing, or soft skills" (Practitioners 2020) |
| (ix) | One of the main solutions for combating the COVID-19 and reopening tourism and the economy are for example apps to trace mobility, robotized-AI, touchless service delivery, digital health passports, identity controls, social distancing and crowding control technologies, big data for fast and real-time decision-making, humanoid robots delivering materials, disinfecting and sterilizing public spaces, detecting or measuring body temperature, providing safety, or security [48]. |
| (x) | Enterprises need to rely on IT infrastructure, enterprise resource planning systems, digital libraries, knowledge management systems (KMS), inventory report systems, as well as know-how, software, tools and apparatus, applications, computational logarithms, hardware, technological, and cognitive capital [59] |
| (xi) | Creation of a tourism crisis communication center (a knowledge system to deal with crisis [43] |
| (xii) | A crisis management team is pointed as crucial to prepare society for crisis disasters [60]. The capacity and competency to take different and difficult responsibilities, assignments, and initiatives is a skill of highly trained emergent leaders who can cope with stressful situations and react rapidly by combining all the relevant information from all the organizational key nodes and transforming them into the most optimal actions [52] |
| (xiii) | Organizations facilitate employees' deep compliance with healthy procedures [3]. |

(continued)

**Table 6.3** (continued)

| | |
|---|---|
| **Implicit knowledge** which is harder to encode and communicate to others, is in the form form of information or experience and is more difficult to digitize. | |
| (i) | Telework (Practitioners 2020) – people communicate and work in a virtual way. |
| (ii) | Human contact continues to exist, but they will try to overlook the bureaucratic and administrative part of the check ins and reception of guests" (Practitioners 2020) |
| (iii) | "The Telework model brought on by the crisis will be integrated in the new management model – even if at a different level – and in particular for our shared services" (Practitioners 2020) |
| (iv) | Integrate online communication platforms, use intranet and social media into daily routines, in order to help establish trust and build bonds with employees, stakeholders, and customers during and post-crisis [52] |
| (v) | Specialization of products such as ecotourism, cultural tourism for niches, and new segments (Practitioners, 2020). Use the expertise to create packages. |
| (vi) | Developing work teams and project-based groups, using knowledge [42] |
| (vii) | Shared leadership like transferring certain activities and jurisdiction to selected members, especially in the domains where managers do not possess specialized expertise [52] |
| (viii) | "Dialog, negotiation, and building of a proposal to develop tourism" [49] |
| (ix) | Leaders should bring together the entire system in one place and engage the participants in a dialogue, collect various viewpoints, experiences, and visions regarding the events before reaching clear consensus [61] |
| (x) | Engaging staff in the information exchange, which takes the form of a "conversation-for-action" formula. Such initiative must be the first step of leaders while forming a more resilient organization [52] |
| (xi) | Research on tourists' experiences, reactions, and cancellations through the analysis of the TripAdvisor website [2] |

Source: Adapted from literature review and the case study

education, teleworking, layoff measures, and confinement rules. One of the best examples is the implementation of safety and cleanness staples. The creation of a crisis communication center [43].

Companies also externalize this knowledge by directing it to their customers, retaining the actual ones, and attracting potentials in the creation of new applications, namely the QR code for reading restaurant and spa menus, new tourist packages to promote niches attractions, and the abandonment of masses. Implicit knowledge appears upstream through the form of seminars, meetings, change experiences with other members of the sector, and learning with other peers about crisis situation from the past. Concerning the downstream perspective, companies transmit implicit knowledge to their targets through informal conversations, changing experiences, and learning with other procedures implemented in past crises. Their materialization is about new rules of social distancing, security and cleanliness rules inside hotel companies, and improving new ways of communicating using the digital channels, namely Intranet, social media, and online communication platforms [52].

In theoretical contribution, hopefully, this research will enrich the body of knowledge about this pandemic crisis that has been shaking the world and causing uncalculated costs and prejudices for human life, and also for the economy. In addition, this contributes to the development of implicit and explicit knowledge construction. Using the theory about knowledge management, COVID-19 and recent pandemic literatures identify inputs to show real examples of how hotel companies can materialize their knowledge and transform it in actions to develop their strategy during pandemic times.

With respect to the managerial contribution, this research can give directions to practitioners to deal with the impacts of the COVID-19 in the hospitality sector, regarding the knowledge they can use and share to minimize the impacts on the sector, and on the professional's situations. The research analyzes not only the patterns in research, but mainly the perceptions of top managers of two main hotel chains, and the recommendations that can arise from this is related to how can they minimize the impacts in the processes, in services, and also in future strategies for the sector.

This research tried to analyze the literature review on the most recent publications about COVID-19, knowledge, and the hotel sector. Hopefully, this bibliometric analysis will help future research identifying the most used concepts, giving directions for new studies, and contributing to the development of a theoretical framework. The research also analyzes the links that are created among the authors that are studying a new theme and creating critical mass, to help future researchers in the search for new knowledge, finding new possibilities for a sector that is strategic for Europe and for the world.

For further research, it will be important to make an analysis of how the knowledge created and shared during the year 2020 can be used to define new strategies for the future of the hospitality and tourism sector. Moreover, the identification of new tourism services in a world more and more digital, and how the clients can be engaged using that technology. Also, a new strategy for the hospitality sector needs to be defined and studied, considering that public health is the main criteria for those services in the future, and will determine the directions for this sector of activity.

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# Part II
# Decision Support Systems in IoT

# Chapter 7
# An Efficient Supervised Machine Learning Technique for Forecasting Stock Market Trends

**Asad Khattak, Adil Khan, Habib Ullah, Muhammad Usama Asghar, Areeba Arif, Fazal Masud Kundi, and Muhammad Zubair Asghar**

## 7.1 Introduction

The stock market plays an important role in a country's economic prosperity. If the stock market is strong, a country's economy is considered stable [1]. Predicting stock market trends has been an important and active field of research in computational intelligence [2]. Due to the lack of stationary and clean data pertaining to stock, estimating the trends in the stock market is considered a difficult task [3].

### *7.1.1 Problem Formulation*

Stock exchanges is an integral part of any stock market and play an important role in measuring and financing a country's economic growth. This is facilitated with stock trends forecasting which is an important application area of computational

A. Khattak (✉)
College of Technological Innovation, Zayed University, Dubai, UAE

A. Khan
Department of Computer Science, University of Peshawar, Peshawar, Pakistan
e-mail: adil@uop.edu.pk

Department of Computer Science, SZIC, University of Peshawar, Peshawar, Pakistan
e-mail: adil@uop.edu.pk

H. Ullah · M. U. Asghar · A. Arif · F. M. Kundi · M. Z. Asghar
Institute of Computing and Information Technology, Gomal University, Dera Ismail Khan, Pakistan
e-mail: zubair@gu.edu.pk



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intelligence. Existing research work [1, 3, 4] on stock trend forecasting has shown poor performance on noisy datasets (due to the lack of clean data availability) used on various machine learning classifiers. Therefore, in order to get an efficient stock trend, forecast, it is necessary to reduce the dimensionality of the stock data. To address this problem, the stock trend forecasting system based on machine learning is designed to emphasize the stock market to accurately predict the stock trend. This research work mainly targets to perform and achieve stock trend prediction using K-nearest machine learning classifier by improving the work performed by Ghazanfar et al. [3] in 2017.

**Research Questions:** ***RQ.1:*** How to apply K-nearest neighbor for effective prediction of a stock trend? ***RQ.2:*** How to minimize data sparseness in the acquired dataset using outlier detection for efficient stock trend prediction? ***RQ.3:*** What is the efficiency of the proposed model with respect to the other baseline methods?

### *7.1.2 Research Contributions*

To conduct stock pattern expectation by applying managed AI strategies on the stock related datasets, we have chosen base-line work carried out by Ghazanfar et al. [3] and we suggest extensions, having a significant impact along following dimension of the study: (i) efficient and effective prediction of stock trends using K-nearest neighbor machine learning classifier on various datasets of stocks, (ii) reducing data sparsity in the acquired dataset by applying outlier detection for efficient stock trend prediction, and (iii) comparing the proposed system performance with other machine learning classifiers in addition to the base-line study to analyze and assess the efficacy of the proposed system.

The rest of this chapter is organized as follows. Section 7.2 presents a review of existing literature in this domain. In Sect. 7.3, the proposed methodology is described in detail, and Sect. 7.4 presents experiments, results, and discussion on the achieved results. Section 7.5 concludes the research work and lists future directions.

## 7.2 Literature Review

In this section of the chapter, we present a review of related studies performed on stock trend prediction. This review is categorized as (i) machine learning, (ii) deep learning, and (iii) others (see Fig. 7.1)

**Supervised Machine Learning**

Different studies on stock trend prediction are conducted using machine learning, which are summarized as follows: Ghazanfar et al. [3] presented machine learning techniques to forecast the future stock market. The required datasets of six months were collected from Karachi stock exchange (KSE) and Saudi stock exchange

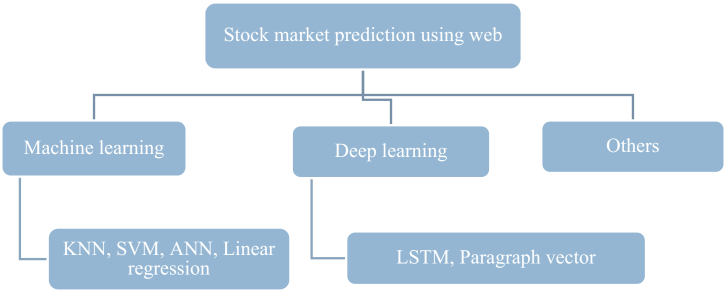


**Fig. 7.1** Classification of literature review

(SSE). The result obtained on the datasets collected is good, yielding low error (MAE = 0.0904 and RMSE = 0.2402). The study also has a limitation of small datasets size and data sparseness. However, for obtaining more efficient results, the work can be expanded by conducting experiments on a larger dataset. In another study, the role of the stock market in the country's economy is investigated [4]. The economy would be stable if the stock market is bullish, otherwise unstable daily stock market closing prices were extracted from a financial website of Yahoo finance. The neural network model is trained on the available data. Results show a strong correlation between stock prices and returns. The limitation of the study includes the weak correlation between stock returns and differences in T-bill rate. The system can be enhanced by including a higher frequency of stock returns. While working on the stock movement prediction, Khedr et al. [5] proposed a model to determine the movement in the stock market on daily basis. The data was collected from news sentiment and from historical stock prices. After applying the Naïve Bayes and K-NN classifier, the prediction accuracy was 89.80%. The limitation of this study was avoiding the use the textual financial information. This work can be enhanced by including technical analysis indicators.

The prediction of the stock market and trends in the stock market is a challenging task due to the complicated nature and structure in terms of the normalization factor [6]. Initially, stock-related sentiments are collected from Twitter, then pre-processing steps are performed on the collected data. Finally, the SVM model is trained on the pre-processed data to make the stock prediction. The limitation of the study includes obtaining more promising results by incorporating an additional feature set. In a similar study, Ruan et al. [7] proposed a Linear Regression model to perform a comparative analysis of the relation between people sentiments expressed and the financial stock market using microblogs. The linear regression model is trained on historical abnormal stock return to establish the relationship between sentiments and abnormal stock return. The limitation of the work is that it deals with only a single dataset rather than multiple datasets, spanning over different time intervals. Testing on multiple datasets over periods of time is a part of future work.

**Deep Learning**
In [8] Zhang et al. presented their model to analyze and evaluate the impact of social media and internet on financial market. A dataset was acquired using web crawlers from the network news. Long-term short-term memory (LSTM) model was used for training purpose. The prediction results achieved were not very satisfactory, i.e., ranging 40.3% to 50.6% from their experiments. The limitation of the study was that the time series process was not fine-tuned, and it was required to improve the results of emotion extraction algorithm by incorporating additional useful features to train the model. In another study on deep learning-based stock prediction, Akita et al. [9]. states that the economy of a country greatly depends on its stock prices. Different deep learning techniques like paragraph vector and LSTM were used. The result obtained from various experiments performed was promising. However, in this study, only news titles were considered. To improve their results, more technical indices i.e., Moving Average (MA) and the Moving Average Convergence Divergence (MACD) are highly recommended.

**Others**
Presently internet is widely used by people to get information and give their own opinions about an event [10]. In [10], they acquired data from the Weibo website (China) and experimented with a hybrid Back Propagation Neural network (BPNN) using the time series dataset and received a prediction accuracy of 92.99%. The presented work was limited to a time series dataset rather than the features of online public opinions. However, enhancements in the model are recommended for obtaining more efficient results. While investigating the role of sentiment analysis in stock prediction, Li et al. [11]. reported that analysis of social media content using sentiment analysis techniques is an emerging area in stock prediction. A dataset of around 200 million tweets was extracted and correlated with other models. The system achieved a prediction accuracy of 70%. To improve the accuracy of prediction, long textual data and other sources, such as Facebook, are highly recommended.

The aforementioned studies on forecasting stock market trends, make use of different techniques, like supervised machine learning, deep learning, and other approaches. However, it is required to investigate the applicability of efficient supervised machine learning techniques on a historical dataset for the efficient forecasting of stock market trends.

## 7.3 Proposed Methodology

This section of the chapter presents in detail the proposed system/model for stock trend prediction using supervised machine learning techniques, i.e., K-Nearest Neighbor (KNN) classifier. The proposed system architecture is shown in Fig. 7.2.

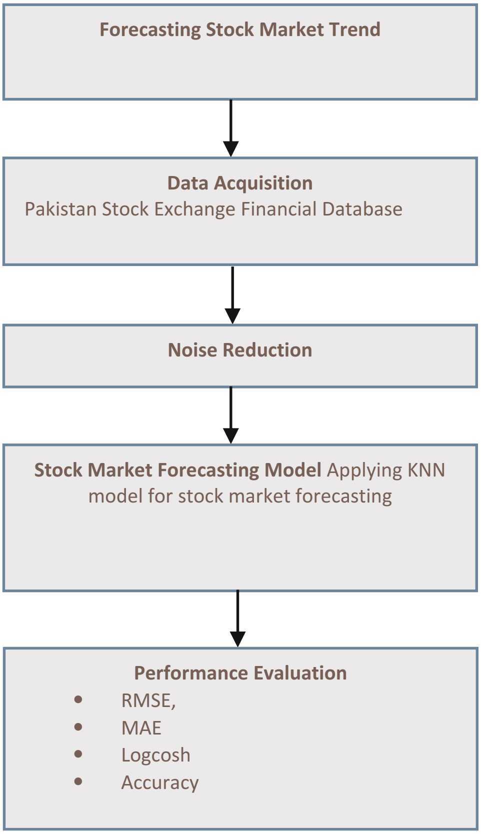


**Fig. 7.2** Proposed Architecture

### 7.3.1 *Dataset Collection*

The benchmark dataset for conducting experiments on stock trend prediction is acquired from the work conducted by Asghar et al. [1]. The three datasets are described in Table 7.1. The following attributes are included in the acquired dataset: Open, High, Low, Close, Volume, and Return (see Fig. 7.3). Our dataset consists of 24 months of data starting from 2014 to 2015 and trains the model on the previous 24 months data. After detailed training of the proposed model, it can forecast stock returns for the next months while using the previous 24 months historical transactions.

A partial listing of KSE-100 index dataset is shown in Table 7.2 which is as follows.

**Table 7.1** Detail of multiple datasets

| Dataset | Title | Detail |
|---|---|---|
| D#1 | Karachi stock exchange (KSE) 100 index | KSE 100 company stock indices, available at www.ksestocks.com/QuotationData |
| D#2 | Lucky cement | Lucky cement company stock data available at www.ksestocks.com/QuotationData |
| D#3 | Engro fertilizer limited | Engro fertilizer limited dataset, available at www.ksestocks.com/QuotationData |

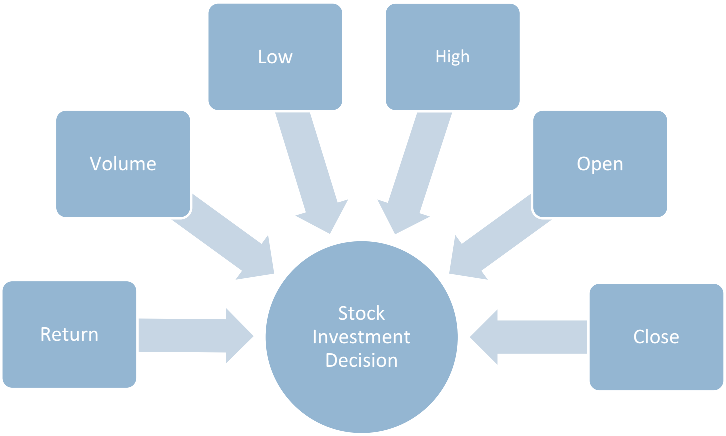


**Fig. 7.3** Variable relationship

## *7.3.2 Data Normalization*

This stage of the proposed system involves various data derivation steps applied to the different attributes of the dataset. The variations are applied for efficient processing by the proposed prediction model as data sparsity may (in most cases) ultimately degrade the prediction results [2].

**Why Data Normalization is Used**
To overcome the issue of data sparseness, and to achieve high-quality prediction results, we have normalized the dataset in order to detect the outliers by utilizing normal distribution techniques. Data normalization aims at deriving relevant information from existing attributes and is used as an input parameter to train the multiple regression model.

The data normalization aims at getting applicable data from the current attributes, the derived data is then utilized as an input parameter to train the KNN model. The data normalization phase is subdivided into the following tasks: (i) computation of stock return, (ii) computation of z-score, (iii) applying Z-score for outlier detection,

**Table 7.2** A Partial Listing of KSE-100 index dataset

| Symbol | Open | High | Low | Close | Volume |
|---|---|---|---|---|---|
| KSE-100 | 25261.66 | 25628.41 | 25261.7 | 25608.85 | 198,346,580 |
| KSE-100 | 25615.12 | 25979.06 | 25615.1 | 25962.18 | 257,114,700 |
| KSE-100 | 25968.76 | 26136.28 | 25968.8 | 26046.71 | 170,698,120 |
| KSE-100 | 26052.69 | 26299.69 | 26052.7 | 26169.83 | 149,219,040 |
| KSE-100 | 26172.73 | 26289.33 | 26051.2 | 26259.57 | 200,616,520 |
| KSE-100 | 26265.01 | 26432.02 | 26,265 | 26341.08 | 188,892,540 |
| KSE-100 | 26343.68 | 26566.73 | 26305.5 | 26373.24 | 250,510,720 |
| KSE-100 | 26374.06 | 26518.36 | 26270.3 | 26488.32 | 139,377,180 |
| KSE-100 | 26496.23 | 26633.09 | 26496.2 | 26590.69 | 108,150,460 |
| KSE-100 | 26591.92 | 26876.71 | 26591.9 | 26761.78 | 198,426,560 |
| KSE-100 | 26770.19 | 26900.66 | 26629.8 | 26730.24 | 226,041,900 |
| KSE-100 | 26803.53 | 26973.11 | 26803.5 | 26913.85 | 235,856,160 |
| KSE-100 | 26925.44 | 27069.59 | 26,836 | 27000.95 | 177,204,080 |
| KSE-100 | 27063.74 | 27180.72 | 27035.1 | 27104.7 | 166,487,100 |
| KSE-100 | 27106.44 | 27213.21 | 26948.6 | 27015.12 | 243,786,980 |
| KSE-100 | 27023.1 | 27204.55 | 26997.9 | 27064.34 | 248,174,520 |
| KSE-100 | 27072.05 | 27097.33 | 26867.8 | 27002.89 | 143,333,620 |

and (iv) implementation of outlier removal using pandas' code. Details of all subtasks are given below.

**Calculate Z-score**

Standard deviations from the mean are also called the "Standard Score," "sigma," or "z-score." To convert a value to a Standard score ("z-score"), we first subtract the mean, then divide it by the Standard deviation. The process is called "standardizing." Table 7.3 shows Z-score computations.

**Detection of Outliers**

An outlier in a dataset distinctly stands out from the rest of the data. It is usually the highest or smallest value in a dataset. This can alter your result and leads to inaccurate calculation. Table 7.4 shows outlier detection.

**Removal of Outliers through Pandas Code**

Detected outliers are removed from dataset using panda code. Details of these steps are given in Algorithm 7.1.

**Table 7.3** Computation of Z-score

| Std dev of close | Z-Score open |
|---|---|
| 12919.92 | −1.372710079 |
| **Std dev of open** | −1.370433599 |
| 12927.85 | −1.351300487 |
| **Std dev of high** | −1.346822558 |
| 13001.27 | −1.346317446 |
| **Std dev of low** | −1.341558728 |
| 12838.54 | −1.340946871 |
| **Std dev of return** | −1.34277316 |
| 0.009379 | −1.34154171 |
| **Mean of open** | −1.331938412 |
| 27257.94 | −1.333175277 |
| **Mean of high** | −1.333157486 |
| 27422.89 | −1.332859679 |
| **Mean of low** | −1.344012345 |
| 27096.27 | −1.344182521 |
| **Mean of return** | −1.349737195 |
| 0.000659 | −1.349635864 |
| **Mean of close** | −1.355356846 |
| 27253.55 | −1.356683439 |

**Table 7.4** Outlier detection

| Std dev of Close | Z-Score Open | Open_New | Z-Score High | High_New |
|---|---|---|---|---|
| 12919.92 | −1.372710079 | Outlier | −1.382603392 | Outlier |
| **Std dev of open** | −1.370433599 | Outlier | −1.365910407 | Outlier |
| 12927.85 | −1.351300487 | Outlier | −1.354690734 | Outlier |
| **Std dev of high** | −1.346822558 | Outlier | −1.354476909 | Outlier |
| 13001.27 | −1.346317446 | Outlier | −1.35365622 | Outlier |
| **Std dev of low** | −1.341558728 | Outlier | −1.350409614 | Outlier |
| 12838.54 | −1.340946871 | Outlier | −1.352916292 | Outlier |
| **Std dev of return** | −1.34277316 | Outlier | −1.349705836 | Outlier |
| 0.009379 | −1.34154171 | Outlier | −1.353932347 | Outlier |
| **Mean of open** | −1.331938412 | Outlier | −1.343684117 | Outlier |
| 27257.94 | −1.333175277 | Outlier | −1.339882181 | Outlier |
| **Mean of high** | −1.333157486 | Outlier | −1.339288393 | Outlier |
| 27422.89 | −1.332859679 | Outlier | −1.345711611 | Outlier |
| **Mean of low** | −1.344012345 | Outlier | −1.354373073 | Outlier |
| 27096.27 | −1.344182521 | Outlier | −1.354662275 | Outlier |
| **Mean of return** | −1.349737195 | Outlier | −1.359032618 | Outlier |
| 0.000659 | −1.349635864 | Outlier | −1.360047134 | Outlier |
| **Mean of close** | −1.355356846 | Outlier | −1.367521019 | Outlier |
| 27253.55 | −1.356683439 | Outlier | −1.368008664 | Outlier |
| 27257.94 | | | | |

**Algorithm 7.1** Steps of data normalization in Python

```
Input: Stock data
Output: Preprocessed data (without outliers)
## data structures for data
SET data to [] []
SET P data to [] []
## Reading stock data from file
Read "data-file" data
## dimension of stock data
SET LENGTH (data) to N
SET COLUMN (data) to C
For I = 0 to C-1
## calculating mean and standard deviation of each column
SET AGV to MEAN (data [:] [I])
SET STD to STDEV (data [:] [I])
For J = 0 to N-1
## calculating Z-score
Z = (data [I] [J] - AVG) / STD
## excluding values beyond these limits
IF (Z < = 1 OR Z > −1) then
## storing outlier-free data
P data [I] [J] = data [I] [J]
End IF
NEXT J
NEXT I
```

After applying some normalization techniques, the dataset is split into training and testing set by using Sci-kit learn "train_test_split" technique. The main objective of the training set is to train the model in a way that it will be capable to learn the data. The test set is used for computation of the overall performance of the proposed model. Figure 7.4 illustrates the code for train and the test split of dataset.

### 7.3.3 *Applying K-Nearest Neighbor Classifier*

K-nearest neighbor is an easy algorithm which stores all possible cases and identifies new cases depending on a measure of resemblance (e.g., distance functions).

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.20, random_state=42)
  model = KNeighborsRegressor(n_neighbors=n)
    model = model.fit(X_train,y_train)
    prediction = model.predict(X_test)
```

**Fig. 7.4** Training and Testing set of data

**Table 7.5** Given training data

| Open | High | Low | Close |
|---|---|---|---|
| 14985.61 | 15040.89 | 14951.45 | 15000.08 |

KNN has been used in measurable estimation and examples verification and acknowledgment since the start of 1970's as a non-parametric method [12]. The K-nearest neighbor uses different input parameters (independent/predictor variables) for prediction.

In this research study, we have used a KNN classifier to effectively and accurately predict the stock trend. The model is best fit to evaluate financial terms, and it is less prone to noise or data overfitting [1]. It is computed as follows.

$$y = \frac{1}{K}\sum_{i=1}^{k} yi \tag{7.1}$$

In Eq. 7.1, $y$ is the outcome (Root Mean Square Error), $K$ is the selected distance, $yi$ is the ith example, and i is the counter for iteration performed. After selecting $K$ value, we can make a prediction based on the KNN. For regression, KNN prediction is the average of the k-nearest neighbor outcome. In this case, stock return is the target variable, and open, high, low, close, and volume are dependent variables.

We apply Eq. (7.1) on our data as follow:

**Example:** As shown in Table 7.5, given training data (open, high, low, close, and return). Total no of predictors 4 and one target variable "return."

**Objective:** We want to predict the return for data in Table 7.5.

**Step1:**
Calculate the distance of the above test data from all examples of training data using the Euclidean formula.

$$\text{Euclidean Distance} = d\,(x, y) = \sqrt{\sum_{i=1}^{n} (xi - yi)\,\hat{}2} \tag{7.2}$$

$$d\,(x, y) =$$

$$\sqrt{\begin{array}{c}(14422.37 - 14985.61)^2 + (14629.04 - 15040.89)^2 + (14422.37 - 14951.45)^2 + \\ (14612.28 - 15000.08)\,\hat{}2\end{array}}$$

$$d\,(x, y) = \sqrt{(-563.24)^2 + (-411.85)^2 + (-529.08)^2 + (-387.8)\,\hat{}2}$$

**Table 7.6** Sample Computation results

| Return | Distance | K-value |
|---|---|---|
| 0.0101940928727384 | 223.0643 | 5 |
| 0.00395387061535146 | 75.69683 | 2 |
| 0.00194710682636279 | 0 | 1 |
| 0.00536463805526366 | 123.64 | 3 |
| 0.00274326864736363 | 202.53 | 4 |

$$d\,(x, y) = \sqrt{(317239.29) + (169620.42) + (279925.65) + (150388.84)}$$

$$d\,(x, y) = \sqrt{917174.2065}$$

$$d\,(x, y) = 957.6921$$

This is the distance similarly we can calculate for each one and so on.

**Step2:**
Select first kth smallest distances in our case $k = 5$. Sample computation results are depicted in Table 7.6.

**Step3:**
Calculate average of return values against these five distances which is

$$Sum\ yi = a1 + a2 + a3 + a4 + a5 \tag{7.3}$$

In Eq. (7.3), $a1$ to $a5$ are the return values against five distances.

$$\begin{aligned} Sum\ yi &= 0.010194093 + 0.003953871 + 0.001947107 \\ &+ 0.005364638 + 0.002743269 \end{aligned}$$

$$Sum\ yi = 0.01871644$$

Now
Average of return value in our case is

$$Y(mean) = \left(\frac{sum\ of\ distances\ of\ return}{total\ number\ of\ distances}\right) \tag{7.4}$$

$$Y(mean) = \frac{0.01871644}{5}$$

$$Y(mean) = 0.00374328$$

This is the prediction of KNN at $k = 5$. Working steps of KNN are depicted in Algorithm 7.2.

**Algorithm 7.2** Working steps of KNN implementation

```
1. Data acquisition (training/test data)
2. Set the value of K
3. For each point in test data
Find the Euclidean distance to all training data points
Store the Euclidean distance in a list
4. Chose the first K-smallest distance print from the list
Assign a target value to the average of the K-point
corresponding first K-smallest distances
5. End
```

**Developing a Code for Machine Learning Classifier**

Fig. 7.5 is carrying a code of the KNN classifier used for experimentation. In order to perform stock trend prediction on the KSE-100index dataset, the KNN classifier is used as follows.

```
from sklearn.neighbors import KNeighborsRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error
from sklearn.metrics import mean_absolute_error
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.20, random_state=42)
sselist ={}
mae={}
skmae={}
logcosh ={}
for n in range(5,45,6):
    model = KNeighborsRegressor(n_neighbors=n)
    model = model.fit(X_train,y_train)
    prediction = model.predict(X_test)
    sse = mean_squared_error(y_test,prediction)
    skmae[n]=mean_absolute_error(y_test,prediction)
    sselist[n]=sse
    ss = sum(prediction-y_test)/len(y_test)
    mysselist[n]= math.pow(ss,2)
    sae =sum(abs(prediction-y_test)/len(y_test))
    mae[n]=sae
    loss = np.log(np.cosh(prediction-y_test))
    logcosh[n]=np.sum(loss)
print(sselist)
print("MAE")
print(mae)
print("SKLearn MAE")
print(skmae)
print("LOG Cosh")
print(logcosh)
```

**Fig. 7.5** Code of machine learning Classifier (KNN)

## 7.4 Results and Discussion

**Metrics Used**
There are various metrics that are utilized to gauge accuracy like root mean square error (RMSE), mean absolute error (MAE), and exactness. Their numerical formulation is given as follows:

RMSE: To compute the average magnitude of forecasting error in the stock market prediction, we use RMSE as a quadratic value. It is computed as follows:

$$\text{RMSE} = \frac{\sqrt{\sum_{t=1}^{n} (forcast(t) - actual(t))^2}}{n} \tag{7.5}$$

**MAE:** It depicts the mean of errors while predicting indices for the stock market. It is computed as follows:

$$\text{MAE} = \frac{\sum_{t=1}^{n} |forcast\ (t) - actual\ (t)|}{n} \tag{7.6}$$

In the above formulas, "*n*" shows the number of estimated values, where estimated and actual values are depicted by *recast* (*t*) and (*t*) respectively.

**Log-cosh:** It measures prediction error in terms of logarithm of the hyperbolic cosine.

### *7.4.1 Answer to RQ.1: "How to Apply K-Nearest Neighbor for Prediction Stock Trend?"*

To answer RQ1, we have applied the KNN classifier to predict the stock trend. Results obtained for the different iterations are presented in Table 7.7, depicting that the optimal results that our classifier achieved are based on the first iteration

We have used the collected dataset in our proposed model (KNN) for training and to check the results. After the training phase of the proposed model, we have checked the results for each iteration. Iteration 1 has produced very low RMSE,

**Table 7.7** Evaluation of the proposed model's performance using the number of iterations

| Iteration | RMSE | MAE | Log-cosh |
|---|---|---|---|
| 5 | 4.42E-05 | 0.004892914 | 0.003716503 |
| 11 | 6.07E-05 | 0.005722075 | 0.005097995 |
| 17 | 6.31E-05 | 0.005944986 | 0.005303328 |
| 23 | 6.64E-05 | 0.006160232 | 0.005573119 |
| 29 | 6.71E-05 | 0.006216439 | 0.005634309 |

**Table 7.8** Setting parameter of the proposed KNN model

| |
|---|
| **n_Neighbors**: *integer, optional (default)* |
| **Algorithm:**{*'brute', 'kd_tree', 'ball_tree', 'auto'*}, *optional* |
| **leaf_Size:***integer, optional (= 30)* |
| **p:***integer, optional (= 2)* |
| **Metric:***callable or string, 'minkowski' default* |
| **n_Jobs**: *None or integer, (default = None) optional* |

MAE, and Log-cosh which are promising results as compared to the subsequent iterations.

Setting parameters for experiments is an important task, and the proposed KNN model (used for stock trend prediction) is presented in Table 7.8.

#### 7.4.1.1 Why KNN?

The KNN has yielded the best performance in different domains including financial forecasting like stock markets [2]. The reason why the KNN accuracy is high is that the determination of the new data class is based on a voting majority system, in which the proximity between data is taken into account, which is acceptable when the distance of each nearest neighbor is closer against the distance from the test data [13], which is the main reason why KNN classifiers give high accuracy in our work.

### *7.4.2 Answer to RQ.2: How to Minimize Data Sparseness in the Acquired Dataset Using Outlier Detection for Efficient Stock Trend Prediction?*

This research question was answered by conducting experiments on normalized and un-normalized data to find and evaluate the prediction efficiency of the proposed model.

#### 7.4.2.1 Applying KNN Regressor on Raw Dataset

Initially, KNN Regressor is applied on the un-normalized dataset. Table 7.9 presents the prediction results obtained. The prediction results for all iterations are quantified using RMSE, MAE, and Log-cosh.

Table 7.9 shows high values of RMSE, MAE, and log-cosh, resulting in poor prediction [13].

**Table 7.9** The prediction results of the KNN model using the un-normalized dataset

| K-value | Root mean square error | Mean absolute error | Log-cosh |
|---|---|---|---|
| 5 | 202955735.8 | 11976.81202 | Inf |
| 11 | 188881104.5 | 11746.46341 | Inf |
| 17 | 180075597.2 | 11570.63793 | Inf |
| 23 | 174864623.6 | 11430.98562 | Inf |
| 29 | 173025251.2 | 11378.50613 | Inf |
| 35 | 171312709.5 | 11335.03967 | Inf |
| 41 | 169612906.4 | 11275.85507 | Inf |

#### 7.4.2.2 Applying KNN Regressor on Processed Dataset

In these experiments, the normalized (preprocessed) dataset has been used with KNN Regressor. Table 7.10 shows the prediction results obtained in the performed experiments. The prediction results for all iterations are quantified using RMSE, MAE, and log-cosh.

The results presented in Table 7.10 show the low values of RMSE, MAE, and log-cosh, resulting in a better prediction [13].

Tables 7.11 and 7.12 show the prediction error rate before and after noise reduction, and it is obvious that the error rate has reduced significantly after performing noise reduction.

**Table 7.10** The prediction results of the KNN model using the normalized dataset

| K-value | Root mean square error | Mean absolute error | Log-cosh |
|---|---|---|---|
| 5 | 4.42E-05 | 0.004892914 | 0.003716503 |
| 11 | 6.07E-05 | 0.005722075 | 0.005097995 |
| 17 | 6.31E-05 | 0.005944986 | 0.005303328 |
| 23 | 6.64E-05 | 0.006160232 | 0.005573119 |
| 29 | 6.71E-05 | 0.006216439 | 0.005634309 |
| 35 | 6.94E-05 | 0.006315764 | 0.005827321 |
| 41 | 7.05E-05 | 0.006379043 | 0.005918586 |

**Table 7.11** Prediction result without noise reduction using KNN

| K-value | Root mean square error |
|---|---|
| 15 | 2.57137E+15 |
| 21 | 2.55606E+15 |
| 27 | 2.55152E+15 |
| 33 | 2.60533E+15 |
| 39 | 2.64669E+15 |

## 7.4.3 *Answer to RQ3: What Is the Efficiency of the Proposed Model with Respect to the Other Baseline Methods?*

### 7.4.3.1 Comparison of Proposed Model with Other Classifiers

The preprocessed (normalized) data has been used in experiments of Decision Tree and SVM classifiers for results comparison. The Decision Tree has produced low values of RMSE, MAE, and log-cosh which are not in the acceptable range. We have then used the dataset the SVM Regressor and receive low values for RMSE and MAE; however, results are still not promising enough. Finally, the dataset has been used in experiments with the KNN model that resulted in very low RMSE, MAE, and log-cosh values compared to SVM and Decision Tree as shown in Table 7.13.

Quantitative Evaluation

The comparison of root mean square error, mean absolute error, and log-cosh for the KNN model is shown in Fig. 7.6. The y-axis in the figure represents the error and the X-axis represents the K-value starting from five with a difference of six. We split the graph and separate the root mean square error from mean absolute error and log-cosh, because there is a minor distinction between square Root Error and Mean Absolute Error and the graph is not clear due to overwriting on one another. At K-value = 5, the root mean square error = 0.00005, mean absolute error = 0.004, and log-cosh = 0.005, which are very low compared to other K-values. With the increasing K-value, the root mean square also increases, and at k-value = 40, we get a very high error.

### 7.4.3.2 Comparison of Proposed Model with Baseline Method

This section presents the comparison of the performance results of our proposed model with the baseline studies. The results are shown in Table 7.14.

**Using Asghar et al. [1] work**, we used the dataset (six months) of the Karachi stock exchange (KSE-100 index). Multiple regression algorithms have been applied

**Table 7.12** Prediction result after noise reduction using KNN

| K-value | Root mean square error |
|---|---|
| 15 | 6.31E-05 |
| 21 | 6.69E-05 |
| 27 | 6.77E-05 |
| 33 | 6.90E-05 |
| 39 | 6.97E-05 |

**Table 7.13** Comparison of the proposed model with other classifiers

| Classifier | RMSE | MAE | Logcosh |
|---|---|---|---|
| SVM | 0.0000691 | 0.006358753 | 0.005806286 |
| Decision tree | 0.000064953 | 0.005623272736 | 0.005168238520 |
| **KNN (proposed)** | **0.000044246** | **0.004892914** | **0.003716503** |

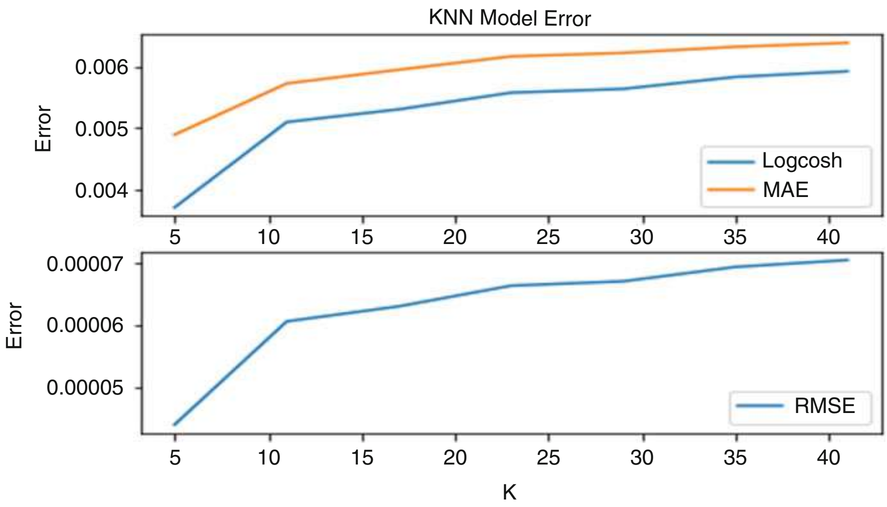


**Fig. 7.6** KNN regression graph

**Table 7.14** Comparison of proposed KNN classifier with baseline method

| Study | Technique | Dataset | Result | | |
|---|---|---|---|---|---|
| | | | MSE | MAE | Log-cosh |
| Asghar et al. [1] | Machine learning. Multiple regression. | KSE | 0.31402 | 0.038 | – |
| Proposed | Machine learning. KNN. SVM. Decision tree. | KSE | 0.00005 | 0.005 | 0.004 |
| | | LUCK | 0.00006 | 0.006 | 0.005 |
| | | Engro fertilizer | 0.00013 | 0.012 | 0.011 |

to predict the stock trade volume. The experimental results are good with low error i.e., MSE = 0.31402 and MAE = 0.038.

**Proposed Work:**
The proposed model has produced better results compared to our previously conducted similar research work [1]. In addition, the proposed model (KNN) classifier

**Table 7.15** Different models' accuracy before and after noise cleaning

| Dataset | Prediction accuracy (before noise cleaning) | Prediction accuracy (after noise cleaning) |
|---|---|---|
| KSE | 92% | 95% |
| Luck | 85% | 89% |
| Engro | 89% | 93% |

**Table 7.16** Results of the t-test

| t-value | p-value |
|---|---|
| −4.6572 | 1.4371E-0.4 |

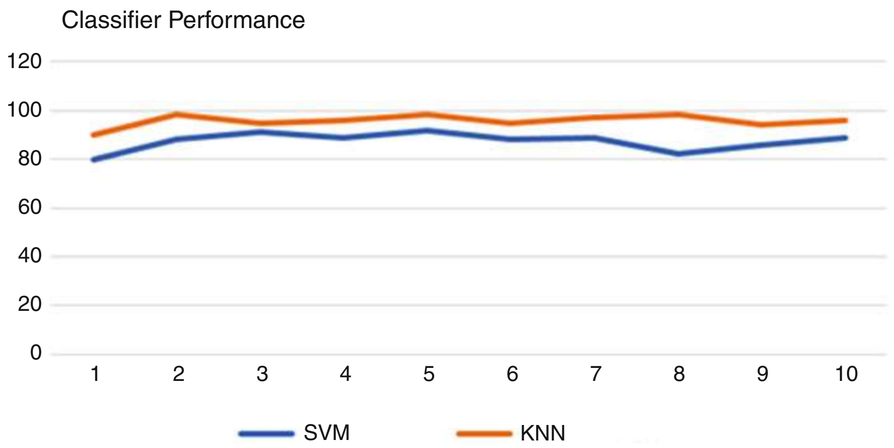


**Fig. 7.7** Classifier Comparison

achieved better results with very low error (i.e., MSE = 0.00005, MAE = 0.005, and Logcosh = 0.004) on KSE dataset compared to existing classifiers.

Table 7.15 shows the prediction accuracy of the proposed model before and after applying a noise reduction. It is evident that, after applying a noise reduction, prediction accuracy is improved on different stock forecasting datasets

T-Test Implementation

To check whether the KNN classifier is the best classifier when compared to the other classifiers, for example, SVM, T-test has been utilized for the difference between the compared classifiers. For this reason, the T-test is applied to the correctness of both (best) classifiers, in particular, "KNN and SVM." It is seen that the difference between the classifiers has statistical significance. The outcomes are depicted in Table 7.16 and also shown in Fig. 7.7.

## 7.5 Conclusion, Limitations, and Future Work

In this research work, we have introduced the stock trend prediction system by applying the KNN regressor model. It uses a historical dataset to explore the model of stock trend prediction. We have performed various experiments on un-normalized datasets and on normalized datasets to evaluate the root mean square error, mean absolute error, and log-cosh of our proposed prediction model (KNN). The proposed system has the following integral parts; (i) acquisition of the historical dataset from the Karachi stock exchange (i.e., data acquisition module). (ii) The acquired dataset is normalized using normal distribution techniques for further processing (i.e., normalization module). (iii) The acquired dataset is divided into training and testing with an 80:20 ratio (i.e., dataset splitting module). (iv) Training the KNN regressor model on the training data and then the performance of the KNN model is evaluated with the testing data (i.e., training and testing module). The proposed model summary has shown exciting results on relationship parameters, root mean square error, mean absolute error, log-cosh, and overall model fitness. The results achieved demonstrate that using the KSE-100 index dataset to train the model the forecast performance and accuracy are better.

### *7.5.1 Limitations*

It is clear from the experiments and results presented in this research work that the proposed model (KNN) is better compared to the baseline study; however, the following limitations still exist. (i) Our prediction error (root mean square error, mean absolute error, and log-cosh) are very high at an un-normalized dataset. (ii) Only daily stock return is predicted by our proposed model (KNN). (iii) The dataset is composed of numerical values only. (iv) The dataset is from a local stock exchange. (v) We checked the results of our proposed model against three loss functions.

### *7.5.2 Future Work*

There are various ways of extending this work in the future, such as (i) the prediction error can be reduced further, if data are normalized and more predictors are added in KNN regressor, (ii) the monthly and weekly stock return prediction can also be investigated instead of daily stock return predictions, (iii) social media (tweets) data can also be taken into account, in addition to historical information in stock trend forecast, (iv) the dataset can be extended for a longer time period, and acquired from foreign stock exchange for further experiments.

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# Chapter 8
# Artificial Intelligence Trends: Insights for Digital Economy Policymakers

**Maria José Sousa, Gabriel Osório de Barros, and Nuno Tavares**

## 8.1 Introduction

In recent years, academics and practitioners have become increasingly interested in artificial intelligence (AI), and concepts such as machine learning (ML), deep learning (DL), and others are now commonly used [22, 49].

AI is a technology that has improved the performance of the manufacturing and service industries while maintaining a huge promise for future applications.

Two factors motivate this research on AI: to give an overview of the concept and applications of new entrants in the field of AI (Brooks [5], Gamberger and Lavrac [17], Patel-Schneider and Sebastiani [39]) and to generate in researchers from all disciplines and companies a greater interest in AI, as well as the potential of the research to provide insights for policymaker decisions.

Regarding AI's previous work, other bibliometric studies and reviews have been produced, such as Lee and Siau [27] working on data generation using data mining (DM) techniques, including statistics, artificial intelligence, decision tree approach, genetic algorithm, and visualization. Vishnoi et al. [46] studied the technology integration into business domains (techno-centrism) and the insights of AI technologies in aiding marketing processes and organizations. Further, it

M. J. Sousa (✉)
Instituto Universitário de Lisboa (ISCTE-IUL), Business Research Unit (BRU-IUL), Lisbon, Portugal
e-mail: mjdcsousa@gmail.com

G. O. de Barros · N. Tavares
Gabinete de Estratégia e Estudos do Ministério da Economia e Transição Digital, Lisbon, Portugal

 
T. Guarda et al. (eds.), *Information and Knowledge in Internet of Things*,
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https://doi.org/10.1007/978-3-030-75123-4_8

attempts to explain the AI-marketing nexus and build a basic understanding of how their fusion is the future of successful business organizations. Additionally, Moudud-Ul-Huq [34] refers that AI is one of the most advanced technologies and, with his research, demonstrates how AI is helping in the development of an accounting system, in the context of the impact of expert systems on organizational contexts. Moreover, they studied the application of AI to decision-making, as accounting involves structured, semi-structured, and unstructured decisions, based on the uncertainty caused by risks and lack of information. They conclude that AI has an impact on factors that ultimately improve productivity. Li et al. [28] studied the applications of AI technology in the manufacturing industry, which is changing the models, means, and ecosystems of the manufacturing industry. Furthermore, they propose an intelligent manufacturing system architecture and an intelligent manufacturing technology system, based on the integration of AI technology with information communications, manufacturing, and related product technology. Besides, Sousa et al. [11] analyzed the benefits in the provision of public services, based on the adoption of AI systems. Albeit, research on AI is still scarce, and the advance of this technology in the public sector, as well as the applications and results of this strategy, needs to be systematized. Martínez and Fernández-Rodríguez [31] studied AI applied to project success, to understand how to minimize the negative economic impact of delay in projects, so AI can help with alternative tools for project success prediction to estimate project success or identify critical factors of success. In another perspective, Dhamija and Bag [12] studied the role of artificial intelligence in the operations environment. Finally, von Krogh [47] refers in his study that AI in organizations provides new avenues for decision-making and problem-solving, signifying that this current research is even more necessary.

Analyzing all these studies, we concluded that there is still space in this field to study how AI is related to decision-making processes, for policymakers to create public policies with value for the industry and citizens. This is a link that is missing from the literature and is the main innovation of our research. The study presents a holistic review of the literature, namely, theoretical frameworks, and practical AI experience. It reports on the state of the art for AI, based on a bibliometric analysis regarding the research made in the last 5 years and indexed in the two major scientific databases: Scopus and Web of Science. The sample is made of the papers that include the keyword "artificial intelligence," and from this research, we intend to answer the following research questions:

RQ1: What are the main keywords present in the studies of artificial intelligence?
RQ2: Which areas of research are being studied in artificial intelligence studies?
RQ3: Which technologies are related to artificial intelligence?

The study is organized as follows: the second section presents a conceptual approach to AI, and the third section presents the decision-making processes related to AI. The following section provides a bibliometric analysis, and the final section is devoted to policy insights and conclusions.

## 8.2 Artificial Intelligence Conceptualization

AI is related to the ability of machines to think as human beings and to have the power to rationally and intelligently learn, reason, perceive, and make decisions.

AI areas are classified into several categories [7]:

(a). Reasoning research has emerged from the following dimensions: case based (CBR), non-monotonic, model, qualitative, digital, spatial, temporal, and universal sense; in CBR, a collection of cases stored in a case base is the primary source of information. Cases reflect personal knowledge within a problem-solving context rather than general laws. The main activities for problem-solving with cases are described in the case-based reasoning cycle. This cycle proposes four steps: relieve, reuse, revise, and retain; the solution in this retrieved case is reused to solve the new problem with a unique solution obtained and presented to the user, who can verify and possibly revise the answer; the revised case is then retained for future problem-solving (Bukht and Heeks, [6]).

(b). Genetic algorithm, which is a search algorithm focused on natural selection principles and natural genetics.

(c). An expert system, which is a computer software that uses information and reasoning techniques generally associated with a human expert to solve a narrowly defined set of problems.

(d). Natural language comprehension or natural language generation (NLG) systems are computer software systems, generating texts in English and other languages, mostly from nonlinguistic input data.

(e). Knowledge representation (KR), bases of knowledge that are used to model applications and facilitate access to information.

AI-based technologies include machine learning, deep learning, natural language processing, and others. Machine learning involves machines that learn to achieve the results autonomously from the data introduced in them and with a minimum of programming [20, 21].

Machine learning allows data to build a mathematical model, including a large number of variables that are not known in advance [49]. The parameters are configured as you go through a learning phase, which uses sets of training data to find and classify links. The various methods of machine learning [21] are chosen by the designers according to the complexity of the tasks to be carried out (grouping, decision tree). Usually, these methods are classified into three categories [2]: human-supervised learning, unsupervised learning, and reinforced unsupervised learning; these three categories combine different techniques, including neural networks, deep learning, and others.

Deep learning is one of the most used techniques, and it occurs when machines use complex algorithms to mimic the neural network of the human brain and learn an area of knowledge with virtually no supervision (Arel, Rose, and Karnowski, 2010). Another technique is natural language processing (NLP), a machine learning technique used to find patterns in large data sets and recognize the natural language [29], for example, the application of NLP to the analysis of feelings, where algorithms can look for patterns in publications in social networks to understand how customers feel about specific brands and products.

Technologies such as robotization, cloud computing, and Internet of things (IoT) include AI, enabling a smarter machine, a smarter factory [11], and a smarter ecosystem [25]. Additionally, AI is driven by the combination of nearly limitless computing power in the cloud, the digitalization of our world [8], and breakthroughs in how computers can use this information to learn. All of those technologies are shaping a new society and also industry and services, and from these analyses emerge the second and third research questions: (RQ2) Which areas of research are being studied in artificial intelligence studies? (RQ3) Which technologies are related to artificial intelligence?

When leveraging innovative AI techniques such as machine learning and cognitive systems toward data from the production cycle (UNCTAD [45]), a value-added dimension of visibility into the data may be gained [36]. This allows operational efficiencies to be improved, production to be accelerated, equipment performance to be optimized, waste to be minimized, and maintenance costs to be reduced. AI innovations even open opportunities for a blended society in which humans and computers operate together. According to IDC Technologies, in 2020, 60 percent of G2000 manufacturers' plant floor staff would operate alongside support technologies that allow automation, such as robotics, 3D printing, AI, and AR/VR.

Artificial intelligence is reshaping business [41] and makes it more efficient, and new possibilities are opening up for new business, in the perspective of the integration of human-computer interaction, in dealing with large quantities of data [23], to make them useful for the decision-making process for managers of organizations [10, 15].

Moreover, Bolton et al. [3] researched the human-machine collaboration, in the context of business automation, for a smarter economy, putting machines in tasks that are routines but also in tasks that need precision and accurate movements to achieve the goals faster and with high levels of quality. In this context, several types of jobs will disappear [48], but another type of job will be created by artificial intelligence, regarding more conceptual tasks and including creativity and emotions, only being expressed by humans, and with a change of values in organizational culture, it will promote diversity [9].

All of this revolution emerged from AI and will impact society and organizations [30], at several levels, not only regarding new jobs but also new work practices, new types of relationships in organizations, and new management models and leadership strategies [19], being the human trust in AI a major factor for these changes.

## 8.3 Decision-Making Complexities Linked to AI

Strategic decisions are "important, regarding actions taken, the resources committed, or the precedents set" ([33], p. 246). Selznick [42] differentiates the (critical) strategic decision from the routine one. Core choices fell into three categories: the first grouping contains mission and role concepts; the second is to make and shape "character defining," the purpose and institutional embodiment that includes building policy into the structure or deciding on the means to attain the desired ends; and the third category is for maintaining integrity. Drucker [13] underlines that strategic decisions are multidimensional decisions that will impact the institutions' future. Braybrooke and Lindblom [4] emphasize the difficulty of decision-making processes and demonstrate that the incorporation of knowledge pieces is a rather complicated mechanism that may decide the growth or creation of dominance of an area.

Newell and Simon [35] approach problem-solving research by analyzing the shift from asking how searches are conducted in problem spaces to asking how problem spaces – internal representations of problems – are built up in human minds. Through neural networks, AI will help to facilitate the problem-solving processes, as the possibility of processing big quantities of data [14] in a few seconds will be a major support for humans' decisions and problem-solving situations. Jarrahi [26] highlights the complementarity of humans and AI and examines how each can bring their strength to organizational decision-making processes [24], typically characterized by uncertainty and complexity. AI systems have a processing capacity and an analytical approach to complex problems, whereas humans can still offer a more holistic, intuitive approach in dealing with uncertainty and equivocality in organizational decision-making, improving the organizational strategies through AI applications [1, 38]. The idea of intelligence augmentation prevailing – as AI systems – means they should be designed to augment human contributions [40, 43].

## 8.4 Methodological Approach

The methodology of this study is firstly based on a quantitative bibliometric analysis to allow having a perspective of the scientific production on Web of Science and Scopus about AI.

This methodology was chosen based on Edmondson and McManus [16] studies and ideas about the best methodology to analyze the problem of the research trends about AI. They state that "the fitting process necessarily starts—or in some cases restarts—with some level of awareness of the state of prior work in an area of interest. Ideally, a researcher develops a reasonably good understanding of major streams of work in one or more bodies of research literature," and the bibliometric analysis helps to identify prior research regarding the field of AI.

According to Tague-Sutcliffe [44] and Garousi [18], a bibliometric analysis is a collection of mathematical and statistical techniques and procedures that enable, inter alia, the calculation of the dissemination and dissemination of scientific information in a particular subject and the evaluation of science output by a form of publication (books, documents, papers), countries, etc. The second step was a literature study coupled with a comprehensive analysis of literature to locate relevant research that established AI patterns, leading innovations, procedures, and performance.

The bibliometric analysis was conducted to answer the three research questions that guided this study and to provide a synthesis and interpretation of the results: (RQ1) What are the main keywords present in the studies of artificial intelligence? (RQ2) Which areas of research are being studied in artificial intelligence studies? (RQ3) Which technologies are related to artificial intelligence?

The aim is to select, classify, and incorporate the research studies to provide a comprehensive and accurate description of the topic under examination.

### *8.4.1 Description of the Research*

In July 2019, the data for this bibliometric analysis was collected, using Boolean operators to limit the research according to several inclusion and exclusion criteria, in two large multidisciplinary databases, Clarivate Analytics' Web of Science (WOS) and Elsevier's Scopus.

The research only included scientific papers in both databases, and the term *"artificial intelligence"* was searched in all scientific dominions. All publications were surveyed between 2015 and July of 2019, to cover the last 5 years, as the development of AI technologies and its adoption by organizations has been increasing. This is confirmed by Pan [37] stating that "during the first six months of 2016, investment in AI exceeded that realized throughout 2015, and 200 AI-related companies have raised 1.5 billion dollars in the stock market."

To compare the articles collected in the WOS and Scopus, we identified the main authors, the number of publications and the trends considered over the years, the leading journals, main organizations/universities and research centers, countries, and main languages used in the publications, and research areas. Following McKinnel et al. [32] criteria, the papers needed to be "either a peered review conference or journal paper and published in the English language."

### *8.4.2 Stages of Data Collection*

This research was split up into two phases. The term "artificial intelligence" was the first criterion for searching WOS and Scopus, delimiting the period from 2015 to


**Fig. 8.1** Stages of research. (Source: authors' elaboration)

**Table 8.1** Number of publications on Web of Science and Scopus

| Terms | Web of Science | Scopus |
|---|---|---|
| "Artificial intelligence" | 17.179 | 108.778 |

Source: WOS database and Scopus database, 2019

July 2019. Then, the general features of the publications were examined. In stage two, the most cited publications were compared with the authors who published the most in the same period (Fig. 8.1).

### *8.4.3 Search Strategy*

This study will be guided by the overarching question, *"what research has been conducted regarding artificial intelligence in the industry from 2015 to 2019?"* This question is broken into six elements that were chosen for analysis based on the research questions: (1) keywords, (2) sectors, (3) outcomes, (4) technologies, (5) processes, and (6) countries of study.

## 8.5 Data Analysis and Discussion

The results of the search will show up at this point. The search was carried out based on the appropriate Boolean operators for refinement to expand the scope of the research and to encompass as many results as possible. The search gave back 125,957 scientific papers distributed by WOS and Scopus, as shown in Table 8.1.

### *8.5.1 General Characteristics of the Publications*

The following are the general characteristics of the publications related to the theme *"artificial intelligence,"* namely, (1) type of publications, (2) main research areas, (3) author's affiliations, (4) main sources, (5) main countries, and (6) main funding institutions.

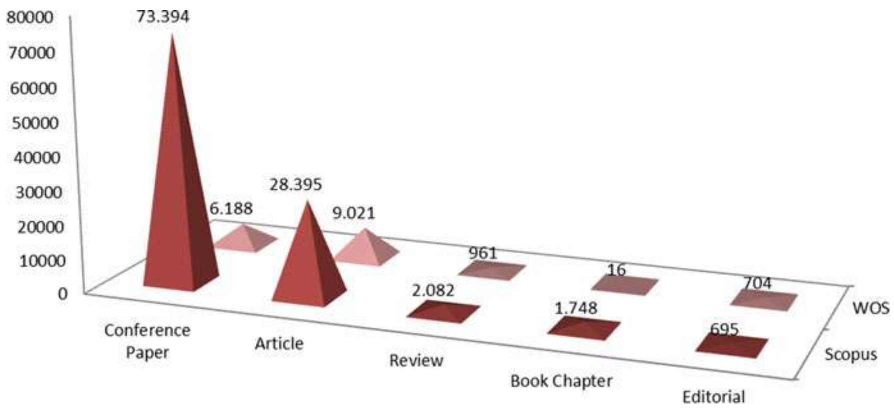


**Fig. 8.2** Distribution of articles by type of publication. (Source: WOS database and Scopus database, 2019)

#### 8.5.1.1 Type of Publications

When the distribution of the publications in WOS and Scopus is analyzed, we can state that the number of conference papers indexed by Scopus is very high (73.394) in comparison with the other type of publications (Fig. 8.2). Regarding the WOS journal articles are the highest indexed publication (9.021).

#### 8.5.1.2 Main Research Areas

The main research areas explored by the publications indexed by Scopus are computer science (84.828), engineering (30.568), mathematics (29.626), followed by decision sciences (5.866), and medicine (5.861) (Fig. 8.3).

Regarding the WOS, the main research areas are *computer science* (6.920), *engineering* (5.629), *telecommunications* (1.033), followed by *science technology other topics* (892), and *automation control systems* (723) (Fig. 8.4).

#### 8.5.1.3 Authors' Affiliations

Tables 8.1 and 8.2 present the number of publications by the author's affiliations on the topic *"artificial intelligence,"* in the two databases, during the period considered (Table 8.3).

The most published authors have 77 publications in Scopus (Tao, D.) and 68 publications in WOS (Zhang J.). Portugal is represented in Scopus by the *Universidade do Minho* (68th position), *Universidade do Porto* (83rd position), and *Universidade de Lisboa* (85th position), regarding authors' affiliations.

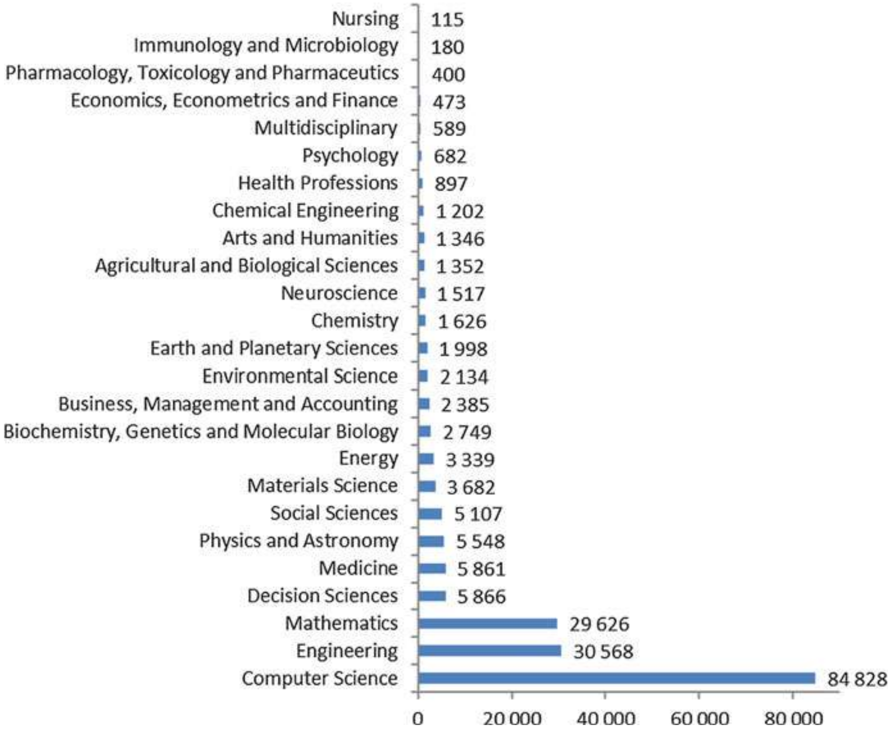


**Fig. 8.3** Research areas – Scopus (Top 25). (Source: Scopus database, 2019)

#### 8.5.1.4 Main Sources: Journals and Conferences

The top 25 primary sources (journals and conferences) on the subject both in WOS and in Scopus are represented in Figs. 8.5 and 8.6.

In the Scopus database, the five main sources are Lecture Notes in Computer Science including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics (14577), Advances in Intelligent Systems and Computing (3385), ACM International Conference Proceeding Series (1909), CEUR Workshop Proceedings (1675), and Procedia Computer Science (980).

Moreover, in the WOS database, the five main sources are Science (229), Studies in Health Technology and Informatics (220), Procedia Engineering (219), Advances in Intelligent Systems Research (186), and Artificial Intelligence Review (111).

#### 8.5.1.5 Main Countries

The distribution of scientific publications by country is presented in Fig. 8.7.

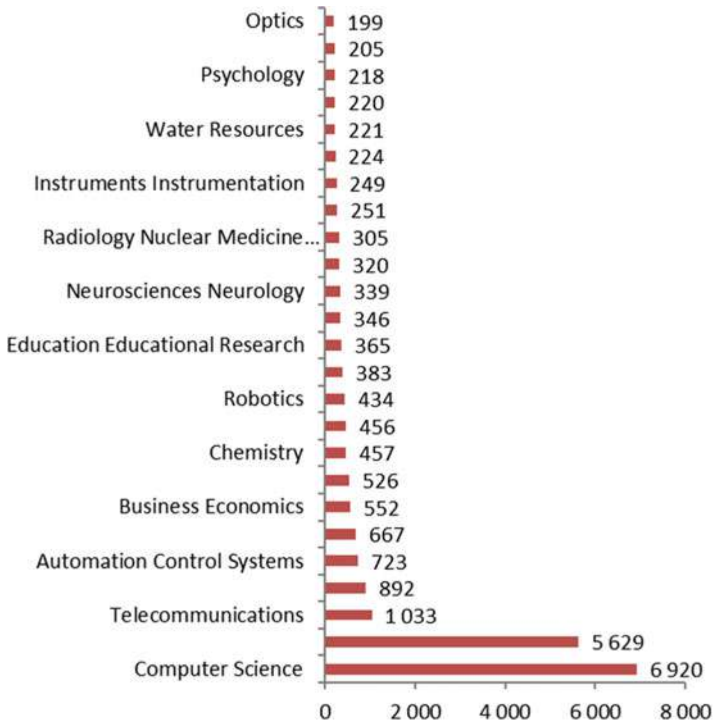


**Fig. 8.4** Research areas – WOS (Top 25). (Source: WOS database, 2019)

Most of the scientific publications have been published in the United States, China, India, the United Kingdom, and Germany, indexed in both WOS and Scopus. Portugal is in the 20th position with 1.369 scientific publications indexed in Scopus and the 26th position with 178 scientific publications indexed in WOS, between 2015 and July 2019, on artificial intelligence.

#### 8.5.1.6 Main Funding Institutions

The main institutions that allocate funds to research and promote the scientific publication related to "artificial intelligence" are presented in Fig. 8.8.

The funding of science is a very important issue and is related to the country's strategy for research and development (R&D). The *National Natural Science Foundation of China* is the institution that has contributed the most to the scientific publications indexed in both databases, Scopus (7433) and WOS (978), and far from the institution that comes in second place.

**Table 8.2** Authors affiliations – Scopus (Top 20)

| Rank | Affiliation | Scopus |
|---|---|---|
| 1 | Chinese Academy of Sciences | 1396 |
| 2 | Centre National de la Recherche Scientifique (CNRS) | 1044 |
| 3 | Carnegie Mellon University | 1001 |
| 4 | Tsinghua University | 916 |
| 5 | Ministry of Education in China | 761 |
| 6 | Massachusetts Institute of Technology | 619 |
| 7 | Nanyang Technological University | 590 |
| 8 | University of Oxford | 551 |
| 9 | Stanford University | 539 |
| 10 | Shanghai Jiao Tong University | 519 |
| 11 | Peking University | 508 |
| 12 | University of Chinese Academy of Sciences | 483 |
| 13 | Georgia Institute of Technology | 472 |
| 14 | Harbin Institute of Technology | 461 |
| 15 | University of California, Berkeley | 457 |
| 16 | Beihang University | 446 |
| 17 | Microsoft Research | 444 |
| 18 | University of Tokyo | 437 |
| 19 | Zhejiang University | 423 |
| 20 | Beijing Institute of Technology | 422 |
| 68 | **Universidade do Minho** | **268** |
| 83 | **Universidade do Porto** | **233** |
| 85 | **Universidade de Lisboa** | **232** |

Source: Scopus database, 2019

## 8.6 Trends in Artificial Intelligence

To investigate future trends in AI, we based our analysis on three research questions:

RQ1: What are the main keywords present in the studies on artificial intelligence?
RQ2: Which areas of research are being studied in artificial intelligence studies?
RQ3: Which technologies are related to artificial intelligence?

To answer these questions, the first stage was to perform a literature survey. The number of papers found with several queries is presented in Table 8.4. The final number of articles considered for the analysis was 333.

Analyzing the first research question (RQ1): What are the main keywords present in the studies of artificial intelligence?

It is possible to verify through Table 8.5 analysis that artificial intelligence, machine learning, predictive analytics, artificial neural network, deep learning, and robotics are the most common keywords.

**Table 8.3** Authors affiliations – WOS (Top 20)

| Rank | Affiliation | WOS |
|---|---|---|
| 1 | Chinese Academy of Sciences | 313 |
| 2 | University of California | 223 |
| 3 | Harvard University | 187 |
| 4 | University of London | 181 |
| 5 | Islamic Azad University | 178 |
| 6 | Centre National de la Recherche Scientifique (CNRS) | 177 |
| 7 | Indian Institute of Technology | 129 |
| 8 | State University System of Florida | 121 |
| 9 | Tsinghua University | 111 |
| 10 | University of Texas | 111 |
| 11 | University of Chinese Academy of Sciences | 110 |
| 12 | Universiti Teknologi Malaysia | 105 |
| 13 | University of Oxford | 105 |
| 14 | Massachusetts Institute of Technology (MIT) | 102 |
| 15 | VA Boston Healthcare | 100 |
| 16 | Pennsylvania Commonwealth System of Higher Education (PCSHE) | 93 |
| 17 | Stanford University | 90 |
| 18 | University College London | 88 |
| 19 | University System of Georgia | 88 |
| 20 | University of Tabriz | 82 |

Source: WOS database, 2019

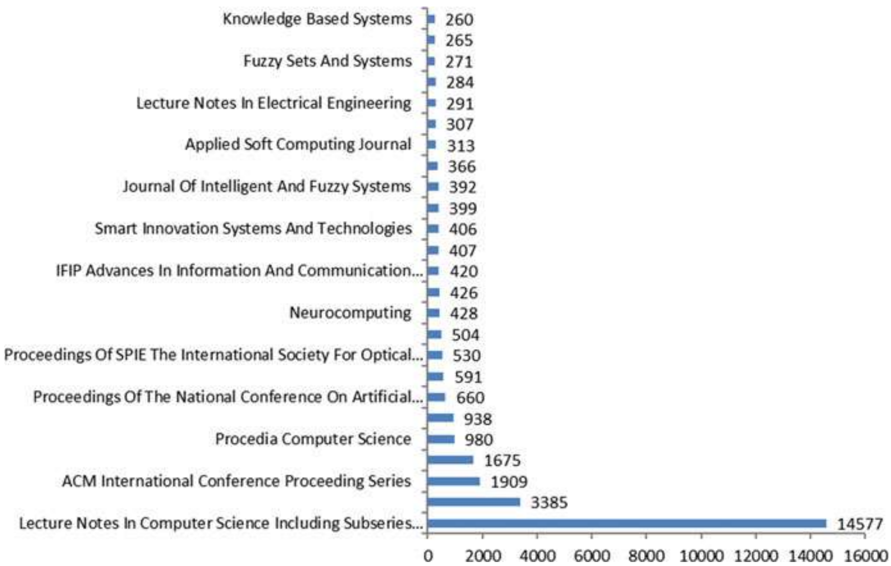


**Fig. 8.5** Main sources – Scopus (Top 25). (Source: Scopus database, 2019)

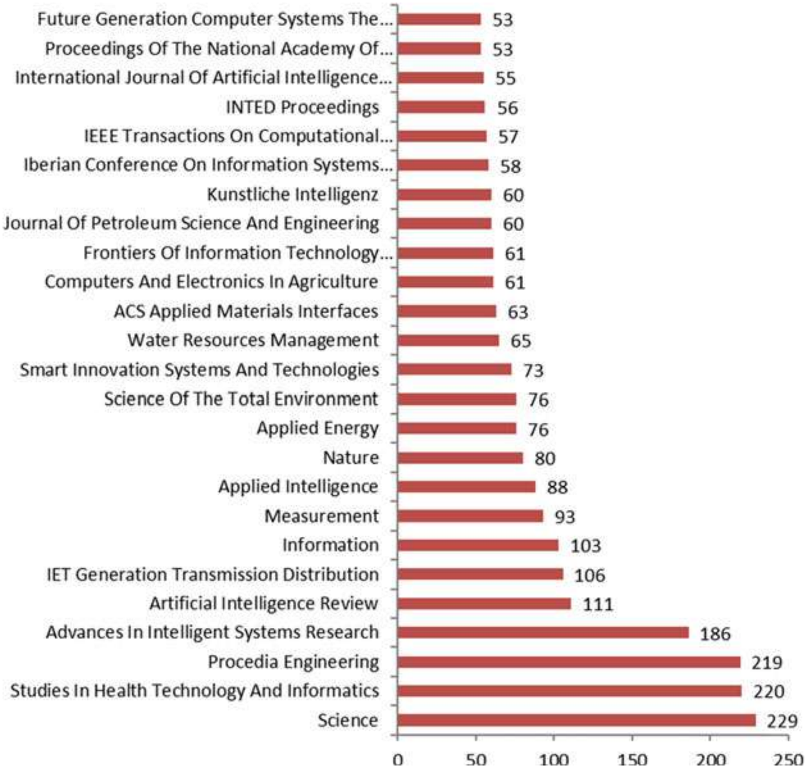


**Fig. 8.6** Main sources – WOS (Top 25). (Source: WOS database, 2019)

Moreover, Fig. 8.9 shows the network of the main keywords being studied (including the ones only mentioned once in the papers considered in this study).

As presented in Table 8.5 and Fig. 8.9, the main keywords in the articles analyzed are artificial intelligence, machine learning, predictive analytics, artificial neural network, and deep learning. These keywords are followed by others less addressed by the researchers but that show the complementarity of the field of AI with other fields, namely, social media (the most studied), accounting, agriculture, healthcare, energy, and other industries that are including AI technologies in their production processes, as well as services systems.

**RQ2: Which areas of research are being studied in artificial intelligence studies?** As Table 8.6 and Fig. 8.10 show, the main sectors that are being studied regarding AI technology penetration are health, computer and engineering, safety and environment, emergent technologies, energy, and industry.

**Regarding the RQ3: Which technologies are related to artificial intelligence?** The literature review has enabled us to identify and verify the profusion and advancement of technologies (Wang & Shin, 2015), through the analysis of the

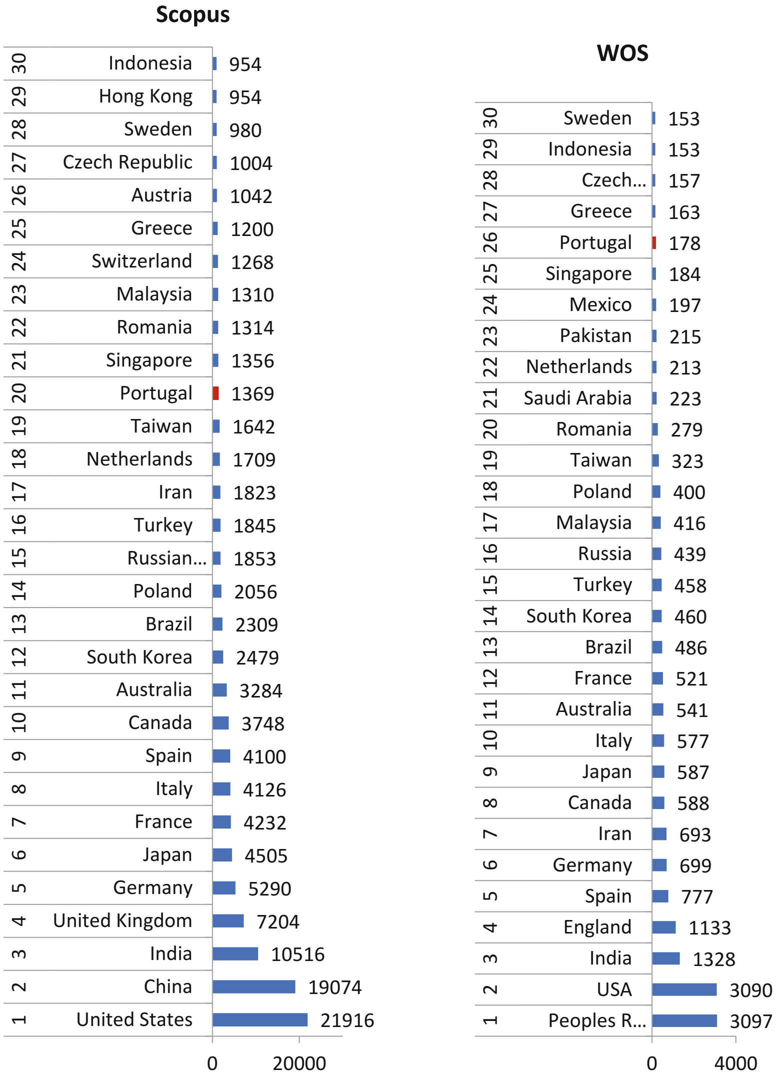


**Fig. 8.7** Distribution of articles by country (2015–2019). (Source: WOS database and Scopus database, 2019)

findings present in the abstract of the articles considered in the final search. The evolution of technology occurs at high speed, redefining world economies and, in a more microanalysis, businesses and how they are managed, produced, and interact with the market. The most important contemporary technologies (Aydin & Parker, 2018) have integrated AI, which is the capacity of robots to think like human beings – to have the power to rationally and intelligently understand, interpret,

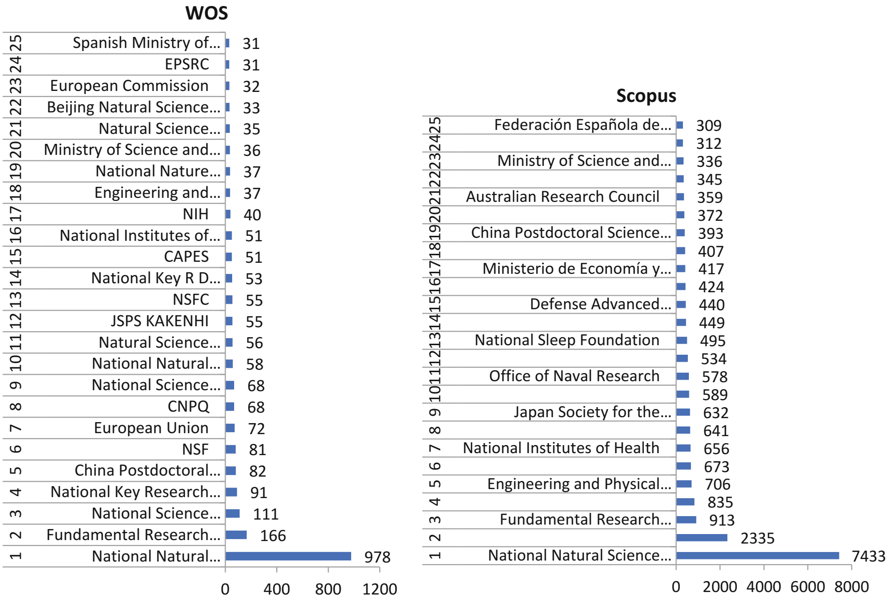


**Fig. 8.8** Main funding institutions – WOS/Scopus. (Source: WOS and Scopus database, 2019)

**Table 8.4** Number of articles found per query – keyword "artificial intelligence"

| |
|---|
| Keyword: artificial intelligence |
| Scientific papers in journals from 2015 to 2019: 274,226 |
| No expanders: 92,385 articles |
| Peer review and full text: 53,246 |
| Academic reviews: 40,103 |
| Subject: artificial intelligence, 20,399 articles |
| Language: English, 19,925 |
| Science direct: 5045 articles |
| Publication: artificial intelligence, 333 articles |

perceive, and determine. AI systems in their digitalization phase are various at the business level, for example, virtual assistants or chatbots.

Big data and analytics systems often carry with them the opportunity to utilize modern methods, frameworks, and methodologies to evaluate different kinds of knowledge (Holmström et al., 2016; Melnyk et al., 2018), such as sensors, audio, and video, to which conventional information management platforms may not react.

New advanced analytical methods are expected to classify market patterns and predictions automatically, incorporating analytical models into the management processes of businesses that play a central role in the design of corporate strategies, with a major effect on the design of organizations where new roles appear (Adebanjo, Teh, & Ahmed, 2018).

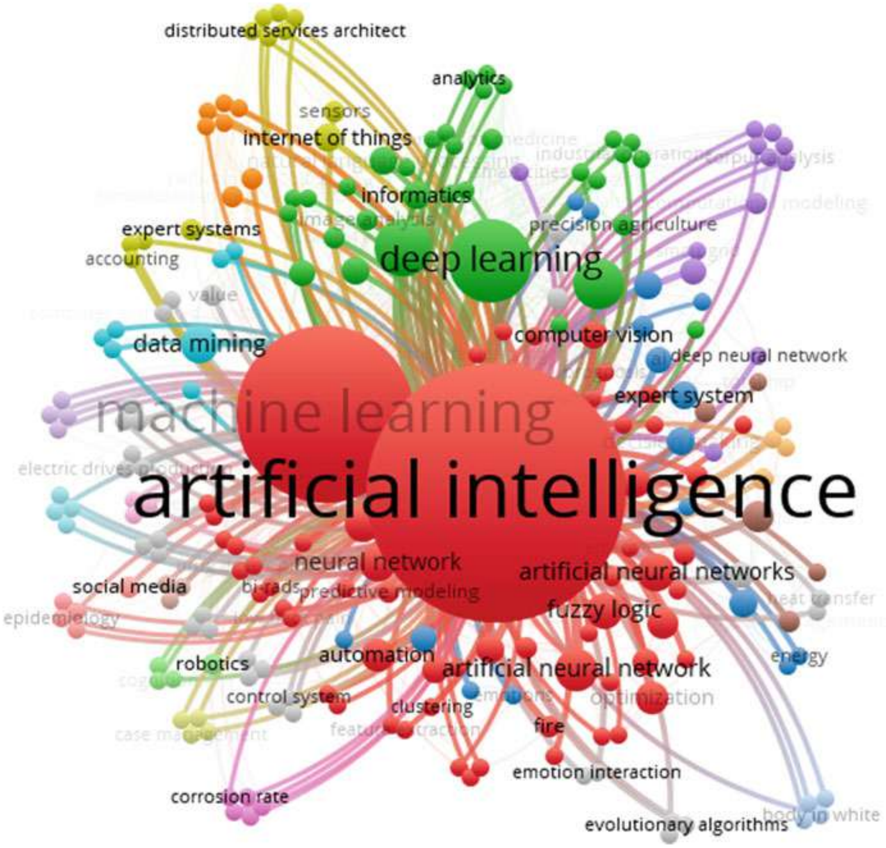


**Fig. 8.9** Network of publications by main keywords

**Table 8.5** Main keywords in artificial intelligence studies

| Keywords | Number of publications |
|---|---|
| Artificial intelligence | 144 |
| Machine learning | 61 |
| Predictive analytics | 37 |
| Artificial neural network | 24 |
| Deep learning | 22 |
| Robotics | 19 |
| Big data | 9 |
| Data science | 3 |
| Smart cities | 3 |
| Blockchain | 2 |
| Total | **324** |

The IoT as a network of billions of digitally connected devices that collect data and communicate with each other is another critical technology for companies.

**Table 8.6** Sectors being studied in artificial intelligence studies

| Research areas | Number of publications |
|---|---|
| Health | 110 |
| Computer and engineering | 79 |
| Safety and environment | 39 |
| Emergent technologies | 32 |
| Energy | 30 |
| Industry | 13 |
| Business and management | 8 |
| Citizen privacy and law | 5 |
| Smart cities | 4 |
| Public sector | 3 |
| Tourism | 1 |
| Total | **324** |

Source: WOS database and Scopus database, 2019


**Fig. 8.10** Sectors being studied in artificial intelligence studies. (Source: WOS database and Scopus database, 2019)

Its application to the different sectors of activity is an added value, as it enables processes to be more efficient and more effective. The implementation of IoT is comprehensive and difficult in establishing parameters, ranging from tracking the manufacturing cycle to detecting problems influencing the final product output, allowing corrective measures to be enabled in real time, increasing system performance and other tasks (Chandrasekaran et al. 2015; Holmström et al. 2016).

Moreover, virtual reality (VR) that combines visible reality with artificial reality and augmented reality (AR) overlaps digital elements with physical reality, and both facilitate the acquisition of new abilities, immediate task resolution, and the visual

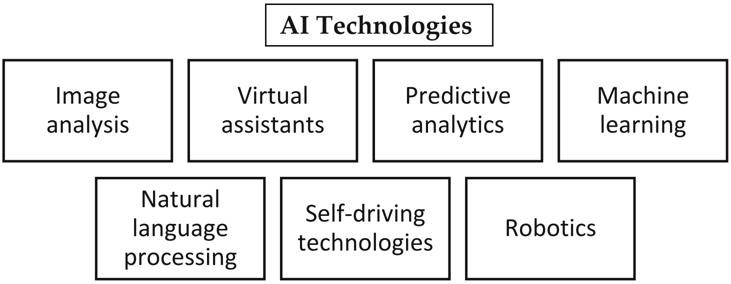


**Fig. 8.11** Most trendy AI technologies. (Source: Melnyk et al., 2018)

perception of processes, leading to greater decision-making performance. Additionally, robots and drones can perform the work of a human through programmed processes – robotic process automation (Aydin & Parker, 2018).

Additionally, the use of drones is one of the symbolic elements of Industry 4.0 and has revolutionized how equipment, locations, and specific situations are monitored. The use of drones in the industry enables greater accuracy and versatility in the large-scale inspection of facilities, collecting information, and enabling decision-making data (McAdam et al., 2017).

3D printing (or additive manufacturing) (Chan et al., 2018) also redefines how the production techniques, machinery, and components are used to produce a 3D item.

In Fig. 8.11, the trendiest technologies are presented, according to Melnyk et al. (2018).

According to the results of Melnyk et al. (2018), predictive analytics is one of the most important systems that includes AI technology, namely, using mathematical algorithms to assess the probability of possible events (i.e., when a delivery truck is expected to break down or when it might encounter road congestion). Furthermore, image analysis is very important in the field of healthcare, aeronautics, and marine sciences, as it helps scientists and physicians to improve the quality of their decisions. Virtual assistants are used by all companies, regarding call centers, but also to help the clients in their relationship with the companies. Machine learning is important for all fields, as it improves the performance of the systems, such as robots, because they are in a continuous process of learning new ways of problem-solving, new solutions, and new ways of accomplishing goals. Natural language processing with the goal to facilitate the interactions between computers and human language is also important, making it easier to program computers and to process and analyze data. Self-driving technologies and robotics, besides the ethical issues, are emergent technologies that can be applied to the industry and to the personal lives of citizens.

(a) Which are the main applications of AI technologies?

**AI Applications**

| | | | |
|---|---|---|---|
| Predictive analytics | Real-time operations management | Customer services | Risk management and analytics |
| Customer insight | Customer experience | Research and development | Supply chain, procurement or logistics optimisation |
| Human Resources Management | Fraud Detection | Knowledge creation | Pricing and promotion |

**Fig. 8.12** AI applications. (Source: WOS and Scopus database, 2019)

The applications of AI are innumerable at the firm level and in their process of digital transformation, as in the marketing functions through the processing of a significant number of data coming from purchase interactions, which allows for a simpler mapping process of consumer tendencies and behaviors; increased cybersecurity through a greater ease in detecting security intrusions and threats to enterprise systems; and improving service and customer service through the generalization of the use of virtual assistants (chatbots).

Some of the themes that are associated with AI are the application of robots to the industry and services, seeking to improve citizen assistance (especially in the area of health); cooperation and coordination between machines/robots, intelligent sensors, and robotics; and autonomous transport, machine learning, and predictive systems (Fig. 8.12).

The main applications of AI identified in the studies analyzed are as follows:

- Predictive analytics, risk management and analytics, fraud detection enabling the creation of real-time reporting with accuracy, and processing of large volumes of quantitative data to make crucial decisions;
- Real-time operations management, supply chain, procurement or logistics optimization algorithmic trading, adaptive intelligence, automation into all of the processes;
- Customer services, customer experience, customer insight, pricing and promotion related to online stores and offer of high-tech customer support;
- AI-enabled customer assistants answering simple questions such as the status of an order, helping in finding a particular product based on a description, and chatbots providing upselling opportunities through a personalized approach;

**Table 8.7** AI applications by industry identified in the literature

| | Financial services | Government/ public sector | Healthcare/ life sciences | Manufacturing | Main authors analyzed |
|---|---|---|---|---|---|
| Predictive analytics | X | X | X | X | [1, 3, 6, 7, 9–12, 14, 19, 23, 24, 26–28, 30, 31, 34, 38, 40, 41, 43, 46–48] |
| Real-time operations management | X | X | | X | |
| Customer services | | X | X | X | |
| Risk management and analytics | X | | X | X | |
| Customer insight | | | | X | |
| Customer experience | | | X | X | |
| Research and development | X | | X | X | |
| Supply chain, procurement, or logistics optimization | | | | X | |
| Human resource management | X | X | X | X | |
| Fraud detection | X | | | | |
| Knowledge creation | X | | X | X | |
| Pricing and promotion | X | | | X | |

Source: WOS and Scopus database, 2019

- Research and development, knowledge creation, and human resource management, as AI, through a complex technology that involves many research areas, such as computer science, philosophy, mathematics, physics, biology, psychology, engineering, linguistics, and logic.

Its development requires a wide range of knowledge and relatively high R&D investment, and ultimately it requires new competencies and that companies invest in high-level employees (Table 8.7).

## 8.7 Insights for Policymakers' Decision Processes

AI research has advanced rapidly over the past years, because of the adoption of these technologies. In the literature two perspectives can be found, a more pessimistic one stresses that the rapid advances in AI can transform society with a significant loss of jobs (Stevenson 2018), and with complex ethical questions associated to the application and use of those technologies, while a more positive perspective focuses on the fact that AI can contribute to a better quality of life, mainly regarding life science developments, thus enhancing productivity in industry.

Policy decisions regarding the introduction of AI in industry and society are likely to play an important role, namely, (a) regulatory policy that can contribute to increasing the speed of diffusion of the technology and (b) privacy policy that has a direct impact on the ability of organizations to build and implement AI. However, a high level of privacy regulation means that organizations will have difficulties in using data to innovate and potentially slows technology adoption and innovation (Goldfarb and Tucker 2012).

This research gives policymakers knowledge to help them to decide on creating an ethical framework for a more trusted, ethical, transparent, and unbiased use of AI. Additionally, there will be a reinforcing of trust with initiatives to understand emerging standards and norms. Moreover, it will be necessary to decide how to develop policy regarding issues, such as ownership of intellectual property rights in AI-generated outputs, liability, and data privacy. In this regard, future liability decisions will also impact the diffusion of AI (Galasso and Luo 2018) as it affects the trust of organizations in investing in the development of AI technologies (i.e., the case of autonomous vehicles).

The decision on the creation of policies to address inequality is also nuclear as AI is likely to be skill biased (Acemoglu and Restrepo, 2018). Policymakers need also to take decisions considering AI in both business cycles and education policy as workers need to develop those kinds of skills (Cockburn et al., 2018; Agrawal et al. 2018) to respond to the digital economy challenges.

Policy decisions should be designed to help businesses explore technology and to upskill and reskill the labor force. The digital and data-driven world pushes all areas of the economy forward, and policy decisions can speed up the adoption, making AI more accessible and affordable.

## 8.8 Conclusions, Limitations, and Future Research

Artificial intelligence is transforming the economy and the way organizations and citizens face and adopt technological innovations. Artificial intelligence can bring substantial benefits in healthcare regarding prevention, diagnosis, and the treatment of disease, as well as access to care; manufacturing through the robotization of factory environments and of the production management systems; the finance sector, mainly in cybersecurity and fraud detection; and public services, regarding digital government and the way services are delivered to the citizen.

However, AI is in the dawn of its development; some questions related to regulations, ethics, and even digital competencies are contributing to the difficulty to spread this technology further, and this is a significant policy challenge to be addressed by European countries.

The consequences will be the elimination of several types of jobs as AI and robotics are redefining the market. Global trade is becoming more and more digital, business is led in digital value chains, and in distributed models, where AI plays a fundamental role, regardless of the impact on the labor force, which will need to redefine itself, to create new avenues for performance in organizations, new activities, and new jobs, more skilled and more related to human specificities, that cannot be substituted by an AI system.

Despite the above, the fact that artificial intelligence, robotics, and augmented reality are the future is undeniable, and its application in all sectors is a driver for the innovation and development of the digital economy.

The study has several limitations that can be an opportunity for future research, as we used only one keyword – artificial intelligence – and related keywords naturally would have opened the research to a wider analysis.

Another limitation is in having used only Thomson Reuters's Web of Science (WOS) and Elsevier's Scopus; in further studies one might include EBSCO, PsycInfo, and EconLit.

Nevertheless, this research contributes immensely to creating knowledge for policymakers' decision processes, regarding the introduction of AI in industry and in society. The decision process depends on the knowledge, ability, and level of responsibility of the policymakers. Thus, concerning complex AI problems, including ethics, job loss, and skill development, it is hard to determine which decision is best.

In respect to future research, some questions arise related to human-AI interactions: What are the main factors that enable human-AI interactions? What are the main factors which make human-AI interactions difficult? Do these difficulties disappear when users continually interact with AI technology and experience their benefits?

It is also very important to analyze AI capabilities, namely, autonomy, communicating, and learning, and this can be expressed by the research question: what is the effect of AI capabilities on user interaction?

Regarding ethics, it is fundamental to study if an ethical and transparent AI system has positive impacts on users' decision-making behavior, operationalized by the following research questions: What type of ethics principles must be considered for the application of AI to industry? What type of ethics principles must be considered for the application of AI interactions with workers?

Finally, it is also important to study the AI systems' appearance, namely, if the virtual (avatars) and physical (robotic) appearances positively affect users' perceptions, transposed for the research question: What is the correlation between the AI system's appearance and users' positive perceptions?

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# Chapter 9
# Methodological Proposal for the Construction of a Decision Support System (DSS) Applied to IoT

**Geovanna M. Chela, Miguel Flores, Tania G. Gualli, and Roberto Andrade**

## 9.1 Introduction

In recent years, the amount of data generated by organizations has grown exponentially due to the advancement of technology. Concepts such as Internet of things (IoT), cloud computing, and social networks have allowed this to happen. Today it is frequent to hear that data is "the new currency" or "the new oil," that "they play an essential role in decision-making," or that "information is money"; in short way "our world is becoming data" [1]. As indicated by the authors [2], we must develop systems that use, infer, and work with the information that is stored but adapting it to the style of the person or persons in charge of decision-making. Every day, human beings use information to make decisions, complete transactions, and carry out all the activities that run a business. Applications come and go, but the information generated from those applications remain. This is the point where the quality of the information comes into play [3]. It is difficult to take into account the factors that go into a decision; therefore, it is very important to find some ways to decompose those factors and allow decision-makers to think through the implications of each factor in a rational way. The problems that are generated after a decision have several characteristics that describe their nature and provide several alternatives for their solution. This is why decision theory is an analytical and systematic approach to study decision-making [4]. Today, decision support systems (DSS) occupy a leading

G. M. Chela (✉) · T. G. Gualli · R. Andrade
Escuela Politécnica Nacional, Quito, Ecuador
e-mail: geovanna.chela@epn.edu.ec; tania.gualli@epn.edu.ec; roberto.andrade@epn.edu.ec

M. Flores
Grupo MODES, SIGTI, ADIAAC, Departamento de Matemática, Facultad de Ciencias, Escuela Politécnica Nacional, Quito, Ecuador
e-mail: miguel.flores@epn.edu.ec



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position in the decision-making of an organization by providing timely and relevant information to decision-makers. DSS has become a key to the success or survival of many organizations [5]. Knowledge should play a bigger role in decision-making. Shim et al. [5] emphasized that DSS researchers and developers should (i) identify areas where tools are needed to transform uncertain and incomplete data, along with qualitative knowledge, into useful knowledge, (ii) be more prescriptive about the effective decision-making using smart systems and methods, (iii) exploit advanced software tools to improve work productivity and decision-making time, and (iv) help and guide DSS professionals to improve their core knowledge of effective decision support.

Design science studies have shown a significant number in recent years in DSS research. This research stream has expanded rapidly with a range of new topics, encouraged by technological advances and methodological innovations [6]. The remainder of this work is structured as follows: Section 9.2 presents the research methodology of the systematic literature review Expansion of acronym (SLR). Section 9.3 describes the features for developing DSS. Section 9.4 presents a proposal of the methodology for developing DSS. Section 9.5 describes DDS applied to IoT systems. Finally, Section 9.6 concludes this study.

## 9.2 Methodology

This section describes the research methodology used to illustrate the importance for the development of a DSS. Three phases are considered in this methodology: first, a review of the literature related to DSS development methodologies; second, generate a methodological proposal for the construction of a decision support system (DSS); and, third, make an adaptation to be applied to the Internet of things (IOT).

For the first phase, a systematic literature review (SLR) was performed. The following academic databases were chosen: IEEE Xplore, ACM, Scopus, ScienceDirect, and Web of Science. The research has been limited to the publication date from 2000 to 2020. It is in accordance with the established inclusion and exclusion criteria, shown in Table 9.1.

## 9.3 Development of DSS According to Analysis of SLR

Decision support is a set of tools and methods to support institutional decision-making. Most of these methods and tools focus on one or more of the main aspects of institutional decision-making problems. When these decision methods are implemented without considering these aspects, the developed solutions are practically infeasible [7, 8].

Decision support systems should be defined as a broad category of information systems to inform and support those responsible for decision-making. DSS are

**Table 9.1** SLR criteria

| Population | Organization |
|---|---|
| Intervention | Decision support system (DSS)<br>Recommender system<br>Framework decision support system<br>Decision support<br>Balanced score card<br>Expert system |
| Results | Methodology<br>Framework<br>Process<br>Requirement<br>Benefits or prototype |
| Context | Organization or decision |
| Inclusion criteria | ISO 27000<br>Business intelligence<br>Data mining<br>Machine learning<br>CSIRT<br>Issues and challenges<br>Agile |
| Exclusion criteria | Geospatial data or spatiotemporal |
| Selection criteria | Written in English/Spanish<br>With framework/procedure described<br>Having obtained results and difficulties<br>Unique (no duplicates)<br>Since 2000 |

intended to improve and accelerate the processes by which people make and communicate decisions. Defining decision support systems needs conceptual, technical, and concrete levels. Managers and designers of DSS need to understand the different categories of decision support systems, in order to provide better communication methods to decision-makers [9–11].

Some studies [2, 5, 8, 12–14] provide a logical framework for understanding the components of DSS. A brief analysis to identify the components of a DSS based on these studies is shown in Table 9.2.

Mission-critical group decision-making has some important characteristics that are different from conventional group decision-making [15–17]. Among we can mention: (i) decision-makers have to make decisions in near real time; (ii) the mission-critical decision-making problem is unstructured, confusing, and unexpected; and (iii) the information available for decision-making. In some cases, decision-makers cannot always be accurate because complete information may not be collected in a short time, so decision-makers can only rely on incomplete information to make decisions [18]. Due to the aforementioned, it is of great importance to take into account that a process must be followed to reach the optimal decisions, as shown in Table 9.3.

**Table 9.2** DSS components

| Studies | [10] | [2] | [13] | [9] | [14] | [5] |
|---|---|---|---|---|---|---|
| | Components | | | | | |
| Data | DataComponent | | Data management | Language system (LS) | Data | Data management system |
| Models | Model component | Model | Model management | | B model | Model management system |
| Knowledge | | Knowledge base | | Knowledge system (KS)<br>Problem processing system (PPS) | Processes | Knowledge engine |
| Communication | User interface | Component of the dialogue | Dialogue | Presentation system (PS) | Communication | User interface<br>DSS architecture and network |

**Table 9.3** Decision-making process

| Studies | [4] | [16] |
|---|---|---|
| Decision-making process | (a) Defining the problem<br>(b) Finding alternatives<br>(c) Evaluation of alternatives<br>(d) Choosing one of the alternatives<br>(e) Determination of the action plan<br>(f) Communication of the decision<br>(g) Implementation of the decision<br>(h) Control and evaluation | (a) Define the problem<br>(b) Identify the decision criteria<br>(c) Distribute weights to criteria<br>(d) Develop alternatives<br>(e) Evaluate the alternatives<br>(f) Select the best alternative |

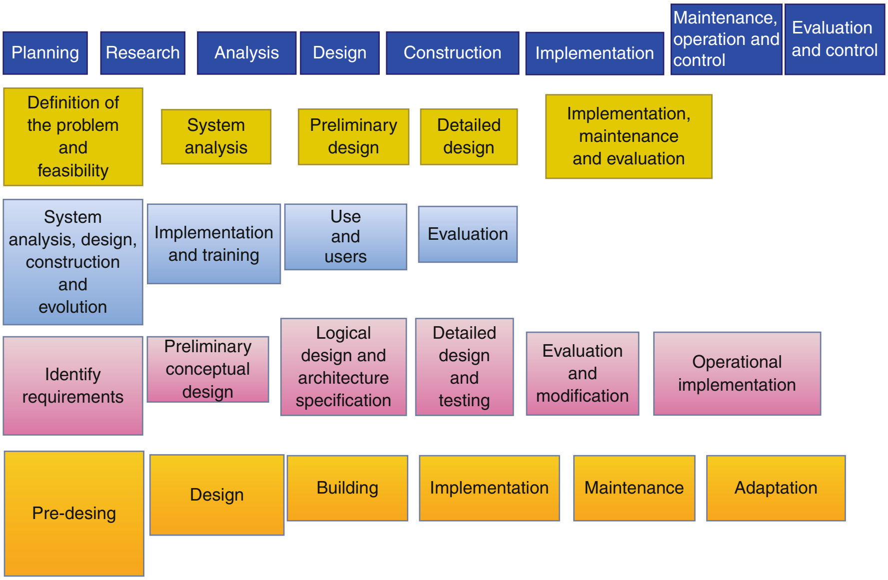


**Fig. 9.1** Comparison of traditional DSS methodologies

The review of the DSS literature reveals that there is no standard framework related to the implementation of a DSS. Figure 9.1 indicates the stages for some DSS development methodologies [2, 5, 12, 13].

## 9.4 Proposal Methodology for the Development of DSS

We present a methodological proposal for the development of a DSS. The proposal is based on the methodology outlined in the book Executing Data Quality Projects: Ten Steps to Quality Data and Trusted Information [19–24], which provides a systematic approach to improve and create quality data and information within any organization with a methodology that combines a conceptual framework to


**Fig. 9.2** DSS proposal methodology (own elaboration)

**Table 9.4** Proposed methodology stages and objectives

| Stage | Objectives |
|---|---|
| Initial analysis | Identify key decisions<br>Identify key information needs |
| Situational analysis | Understanding the organizational environment<br>Understanding the processes<br>Understanding user characteristics |
| Design system | Logical design<br>Building the system<br>System evaluation |
| Implementation | Demonstration<br>Training |
| Deployment | Deployment |
| Communicate actions and results | Document and communicate the results of key decisions, improvements made, and the results of those improvements. Communication is so important that it is part of every step |

understand the quality of information with the techniques, tools, and instructions to improve and create quality information. The proposed methodology development under agile methodology [25–29] is shown in Figure 9.2 and consists of six stages, which are shown in Table 9.4.

Table 9.5 provides a quick reference to the main objectives, inputs, outputs, and checkpoints for each of the six stages and will be the guide for specifying each step.

Screen layouts should be aesthetically pleasing. Decision-makers and designers must evaluate the DSS user interface in terms of balance, symmetry, proportion, and layout. A DSS can be a subsystem of a larger information system, and a specific DSS can have multiple types of decision support subsystems. The goal of business intelligence is to study historical patterns and performance to predict the future and improve the organization's response to future events. That means the data should represent practical indicators of what is happening in the organization, indicators of when changes occur, and indicators of when and how action should be taken. Models are simplifications of real situations that act as vehicles to learn about those situations; it is required to select a model that helps to answer the questions posed by decision-makers. Table 9.6 shows a quick stage guide for developing user interface, data, and model components of the DSS.

Well-defined and well-communicated DSS architecture helps developers work together, improves planning, increases the development team's ability to communicate system concepts to management, increases the team's ability to communicate

**Table 9.5** Quick stage guide: initial analysis for DSS

| Step | Description | Quick guide |
|---|---|---|
| Objective | **What am I trying to accomplish?**<br>Expected objective or results | Identifying and prioritizing the main information needs are the focus of the project<br>Identify and prioritize key decisions<br>Describe the high-level information environment: data, processes, people/organizations, and technology associated with the business situation<br>Plan and start the project using good project management practices |
| Purpose | Why **should I?**<br>Why activity is important | Ensure that the project has business value<br>Clarify the project's approach and agree on expected results<br>Provide the initial high-level snapshot of the information environment<br>Establish the project and approach to solve problems |
| Tickets | **What do I need to perform the step?**<br>Information required to execute the step; entries from other steps | Business information needs, objectives, strategies, problems, and opportunities<br>Problems in current decision-making |
| Technology and tools | **What will help me complete the process?**<br>Techniques, tools, and practices to support or facilitate the process | Interviews and investigations<br>Project management practices<br>Organization chart<br>Cost matrix vs profit<br>Prioritization techniques<br>Communication plan |
| Outputs | What **happens as a result of this step?**<br>Step results (most steps contain examples or templates) | Clearly agree and document the needs to be addressed and the relationship with the project<br>Description of high-level data, processes, people, and technology related to decision-making<br>Project plan<br>Initial communication plan |
| Checkpoint | **How do I know if I'm ready or ready to move on to the next step?**<br>Guidelines for determining the integrity of the step and the willingness to proceed to the next step | Determine that the objectives of the project are clearly defined, understood, and supported by stakeholders<br>Document and understand the processes, data, people/organizations, and high-level technology associated with the problem<br>Document the project plan<br>Document the communication plan |

Adapted from [3, 12]

**Table 9.6** Quick stage guide: user interface, data, and model for DSS

| Feature | User interface | Data | Model |
|---|---|---|---|
| Objectives | Develop user interfaces | Build data repositories, and fill them with the information required in the decision-making process, as well as by the models | Implement the models required for decision-making |
| Purposes | Ensure that the user interfaces for the selected case contain the characteristics identified in the initial analysis and at the design stage | Ensure that the data required for the decision-making process is available and with the necessary quality | Ensure that the models required for the decision-making process are built |
| Tickets | Decision diagrams<br>Screen diagrams<br>Validated diagrams with users | Identification of indicators and perspectives<br>Identification of the level of granularity<br>Conceptual data models | Identification of required models<br>Identification of required data in models |
| Tools and techniques | The decision-making process<br>Front-end development tools<br>Data visualization tools<br>Validate results with users | Database engines<br>Data quality tools<br>Methodologies for building data warehouses | The decision-making process<br>Data mining tools<br>Data analytics methodologies (CRISP-DM) |
| Outputs | End-user screens that allow you to interact and obtain the information, model, etc., required for decision-making<br>Functionality testing with users | Data repositories (relational, multidimensional databases, NoSql databases, etc.)<br>Data extraction, transformation, and loading processes<br>Data cleansing processes | Preparation of data required in the model<br>Implementation of models<br>Model evaluation |
| Checkpoint | Phase evaluation:<br>Has the functionality of the tools been validated with end users?<br>Have the results obtained been completed and documented? | Phase evaluation:<br>Have the results obtained been completed and documented?<br>Has the communication plan been updated?<br>Has communication been completed up to this point? | Phase evaluation:<br>Are the results of the model evaluation appropriate?<br>Have the results obtained been completed and documented? |

Adapted from [3, 12]

needs to potential vendors, and increases the ability of other groups to implement systems that should work with DSS. One of the keys to ensuring that the system provides the desired types of information appropriately is to use DSS prototypes throughout the analysis and design. Designers should work with the organization to establish a climate that encourages an honest discussion of the advantages and disadvantages of the current system and allows for brainstorming of possible solutions and opportunities [12]. Table 9.7 shows a quick stage guide for developing architecture, implementation, and deployment for DSS.

Communication is essential to the success of any DSS project. Table 9.8 shows a quick stage guide for communication for DSS.

## 9.5 DSS Applied to the Internet of Things (IoT)

IoT is a key element in the development of smart cities that seek to be an alternative in the decision-making processes by city managers. One of the benefits to create a smart city is the ability to make decisions based on data generated in real time from different components of the city, such as streetlights, traffic lights, and garbage collectors. IoT allows generating a level of abstraction of the physical variables of the city to the digital world; later this generated data can be managed according to the DSS methodology described previously in this study to generate value for decision-makers.

The methodology used in the DSS is carried out through six key stages: (1) Detect if an area exceeds the critical level of atmospheric pollution. (2) Identify the latitude and longitude of the critical area. (3) Find the road that has the highest volume of traffic that is both upwind and within a specified distance of the critical area. (4) Decide on a mitigation strategy to implement. (5) Implement the mitigation strategy. (6) Exclude the critical site from immediate future analysis so that the treatment has time to work.

A much smarter methodology would focus on existing and/or emerging policies, current and historical data, predictive analytics results, contextual awareness, forecast data, anticipated weather, and community events such as festivals to ensure that the smart decision can be made.

Finally, a goal of the DSS is that all the required information could be relatively easily acquired for different locations, and therefore, the DSS would not be limited to a single location and could be easily generalized to other cities. The developed IoT-based DSS prototype provides a solid foundation for further work that focuses on accounting for vehicle interactions in the underlying traffic model and improving the atmospheric dispersion model by enabling simulation of more complex areas.

A case of use of an IoT-based DSS application can be used to monitor and mitigate air pollution in smart cities. The infrastructure of a smart city provides an element to inform decisions, taking advantage of the data from low-cost sensors that report information in a timely, reliable, and accurate manner. Therefore, in this application, a DSS is proposed to allow the analysis of different mitigation strategies to reduce pollution. DSS is used to detect a critical level of air pollution and then respond by implementing road closures and informing policy makers of when and where mitigation treatments should be applied to obtain the best result. The DSS

**Table 9.7** Quick stage guide: architecture, implementation, and deployment for DSS

| Feature | Architecture | Implementation | Deployment |
|---|---|---|---|
| Objectives | Implement the technology infrastructure required for the DSS | Identify the aspects required for users' use of DSS (licenses, role assignment, access controls, etc.)<br>Generate manuals or user guides<br>Train users in the use of DSS | Institutionalize the use of DSS<br>Evaluate the use of DSS |
| Purposes | Have the technology infrastructure required to support the DSS | Ensure that the environment required for DSS operation is correct<br>Provide the necessary documentation and training to users | Manage the change for the use of the implemented DSS<br>Assess whether the developed DSS has managed to be of business value |
| Tickets | DSS architecture component specification<br>Databases<br>Model or models<br>Hardware platforms and operating systems<br>Communication capabilities needed to connect hardware platforms<br>Security aspects to consider | DSS in proper operation<br>Identifying DSS users and roles | Information needs, objectives of the implemented DSS<br>DSS usage metrics |
| Tools and techniques | Back-end development tools<br>Servers<br>Database engines<br>Permits in different work environments<br>Monitoring tools<br>Document the implementation of the DSS architecture | DSS policies and production guides | Interviews for feedback<br>Tools to get DSS usage metrics |
| Outputs | DSS architecture components in operation<br>Databases<br>Hardware platforms and operating systems<br>Communication capabilities needed to connect hardware platforms<br>Security aspects | Trained users with appropriate roles and accesses | Feedback documentation on the use of DSS<br>Identification of improvements or changes identified by users<br>Definition of actions required to manage, change, and institutionalize the use of DSS, if applicable |

(continued)

**Table 9.7** (continued)

| Feature | Architecture | Implementation | Deployment |
|---|---|---|---|
| Checkpoint | Phase evaluation:<br>Do DSS architecture components work correctly?<br>Have the results obtained been completed and documented?<br>Has the communication plan been updated?<br>Has communication been completed up to this point? | Have accesses and roles assigned to users been validated?<br>Have users been trained?<br>Have the results obtained been completed and documented? | Has DSS usage feedback been obtained?<br>Are DSS usage metrics available?<br>Have the results obtained been completed and documented? |

Adapted from [3, 12]

**Table 9.8** Quick stage guide: communication for DSS

| Feature | Communication |
|---|---|
| Objective | Communicate results and progress as appropriate throughout the project |
| Purpose | Educate and raise awareness of the importance of a DSS in the business<br>Obtain and maintain management support throughout the project<br>Provide visibility, and maintain the support of all those impacted by the project<br>Get and maintain support for the resulting action plans and improvements<br>Show results |
| Tickets | Results of any of the steps |
| Tools and technologies | Communication plan template<br>Any communication or presentation technique that is useful in your environment |
| Outputs | Communication plan and schedule<br>Presentation and training materials<br>Communications completed according to the calendar and communication plan |
| Checkpoint | For each step of your project, have project progress, results, and standardization been reported?<br>At the end of your project, have the results of the project been documented and properly communicated to the necessary hearings?<br>Have additional activities and/or projects resulting from your project been identified?<br>Are the support and resources compromised?<br>Is the necessary support received? If not, what additional communication is needed to get what is required? |

Adapted from [3, 12]

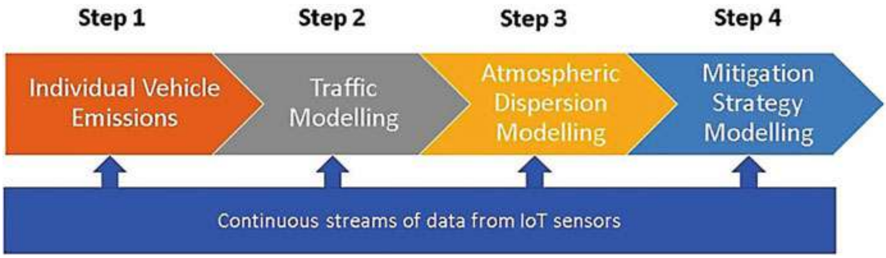


**Fig. 9.3** Measures taken during the development of the DSS [30]

must use real-time data from IoT devices and then use a decision-making process that focuses on the following four areas, as can be seen in Figure 9.3.

Another case of use is to detect cybersecurity attacks to smart city; these attacks could be considered of high impact in economic, social, and environmental axis of the city. Some attacks such as Distributed denial-of-service (DDoS) could affect to critical infrastructures [30]. In this context, DSS could help cybersecurity analyst to select the best defense strategy to minimize the cybersecurity risk. DSS focusing on cybersecurity attacks to IoT could be based on scoring systems. For instance, Dahiya et al. [31] propose a mechanism for DDoS attack mitigation based on reputation score policy and Bayesian game theory.

## 9.6 Conclusions

Specifically, with this study, the following has been achieved: (i) Know the state of the art regarding the characteristics of DSS, which allowed us to reach concepts such as decision-making processes, components, and methodologies. The clarity in these concepts contributed to a better understanding of the process of building a DSS in any area. (ii) Identify factors that directly affect the success or failure of a DSS, which must be known and properly managed. (iii) Propose a methodology with clear stages applicable to any context. In each stage, specific guides were defined that contemplate techniques and tools for what should be done in each one. In addition, it was indicated that the steps are iteratively sequenced, which means that the process can iterate to a previous phase if the results of the current phase are not satisfactory.

It is important to mention that a DSS achieves better decision-making in a given situation, analyzing various scenarios, but finally the one who has the last word is the people.

Finally, we hope that the approach described in this paper provides a basis for researchers and practitioners to develop and implement it in different contexts.

IoT is presented as an emerging technology that provides a large amount of data and that is applicable in the different verticals of the city, such as health, education, mobility, or environment. These data need to be adequately addressed, so that they can be used as a key input in the decision-making processes. The focus of this work was based on proposing a methodology for the development of DDS that can be applied in the context of IoT, for which a methodology and a set of tools have been defined.

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# Chapter 10
# IoT-Based Pervasive Sentiment Analysis: A Fine-Grained Text Normalization Framework for Context Aware Hybrid Applications

**Asad Habib and Arslan Ali Raza**

## 10.1 Introduction

The proliferation of Web 2.0 has altered the general styles of research and academia. The Internet of things (IoT) is one of the core IT fields in the current arena, as it transforms the physical objects into sensor-based virtual intelligent objects. There exist millions of physical objects that are interlinked with sensor-based devices in order to mimic the real-world intelligence. The IoT industry is taking benefit of big data sentiment classification in reshaping and improving the sensor-based integrated information processing systems. Sentiment analysis (SA) proved to be the backbone in orientation and betterment of IoT technology. Opinion mining is the problem of natural language processing (NLP) and field of data mining and machine learning. The goal of opinion mining is the identification of public sentiments, feeling and appraisals. Opinion mining is the significant research area in this new arena of web mining and text classification. It draws great attention in the last few years due to social media sites and their usage. Proliferation of internet applications has changed the public communication trends. Online users adopt social media sites for communication and collaboration. Most valuable communication channels are Twitter, Facebook, Tumbler and Plurk. There exist various classes of web-based application for communication, i.e. discussion forum, blogs, review sites and

A. Habib (✉)
Institute of Computing, Kohat University of Science and Technology, Kohat, Pakistan
e-mail: asadhabib@kust.edu.pk

A. A. Raza
Institute of Computing, Kohat University of Science and Technology, Kohat, Pakistan

Department of Computer Sciences, Faculty of Sciences, COMSATS University Islamabad, Vehari, Pakistan
e-mail: arslan@ciitvehari.edu.pk



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microblogs. Blogs and discussion forums are long text communication channels, while microblogs are short text communication channels. The web application, which allows short text for communication, is considered as a microblogging website. Commonly known microblogging websites are Twitter, Tumbler, etc. Twitter is the most popular microblogging websites created by Jack Dorsey, Evan Williams and Biz Stone in 2006 [1]. It is web-based application that allows its registered users to communicate publicly. These kinds of sites impose restriction over text size. Twitter allows up to 140 characters for publishing a message or tweet to its users. Mostly celebrities, actors, politicians and sportsmen use Twitter for sharing their posts and suggestions. People utilize these sites for sharing their feelings, appraisal, opinions and attitudes towards various entities. The entities widely discussed on these sites are product, events, political agents and movies. The individuals and organization are always interested in knowing what other people think, but in the past, these opinion and sentiments were not analysed for analysis, due to unavailability of mining services and classification techniques. Sentiment analysis and opinion mining are the right choice for these issues. Mining is the process of identifying and extracting desired data or text [1, 2]. Opinion mining is the aim of extracting and identifying the polarity of public opinions towards desired entities. The term opinion mining and sentiment was first used in 2003. Nasukawa and Dave used these terms for the first time [2, 3]. Basically, opinion mining is the subfield of data mining. Data mining is the problem of identifying useful information about concerned entities from huge amount of publicly available contents. Data mining techniques are used to implement and solve different types of research problems. The research-related areas in data mining are text mining, web mining, image mining, sequential pattern mining, spatial mining, structure mining and graph mining. Text mining is the process of deriving or extracting concerned information from text.

Opinion mining is the branch of text mining and the problem of natural language processing. The public opinions are marked as positive or negative through supervised or unsupervised classifiers. The supervised classifier needs training and testing data for labelling public opinions as positive or negative, while the unsupervised classifier does not need training and testing data for marking public opinions. In fact, unsupervised classifiers use various dictionaries and lexicons for mining public opinions. This research aims to handle the problem of input text preparation by removing the noise and stop words from extracted contents and preprocessing input through parts of speech tagging and lemmatization. However, the novelty of proposed research is provision of definitions to informal terms (a.k.a slangs) and subject tags identification for efficient sentiment analysis.

The basic aim of this research is to prepare quality text for effective sentiment analysis. The following tasks are needed to achieve these objectives through proposed framework.

1. To extract text for performing effective preprocessing
2. To handle noisy, unstructured and informal nature of text
3. To lemmatize the inflected form of terms
4. Provision of definitions to unstructured and informal opinionative terms

## 10.2 Literature Review

The information technology has brought about rapid improvements in the field of science and technology in general and the computational sciences in particular. A number of information management and analysis method are now being utilized to support and store a huge data, commonly referred to as big data, in local and remote databases via the Internet and computing grids. The stored data is invaluable for utilization in different tasks for various purposes, such as its usefulness in data mining of various intrinsic insights and differential data analytics. Data mining is now successfully being used with other disciplines, such as statistics, database management systems, World Wide Web, natural language processing, information retrieval, etc. Beside the popularity of mining the data, there are also some challenges in finding ways for further development in the field of data mining.

In the same manner, the emergence and rapid growth of research and development in the field of Internet of things have positively affected the research trends due to the integration of cloud computing, 5G and big data sentiment classification [67, 68]. It would be appropriate to mention that the IoT industry is taking benefit of big data sentiment classification in reshaping, analysing and improving the sensor-based integrated information processing systems [68, 69]. Sentiment analysis is computational processing of public views and opinions. It is a problem of natural language processing, which itself has a strong influence on the fields of data mining and artificial intelligence (AI). It aims to detect the public opinion shared about various real-world entities over social networking websites. Figure 10.1 illustrates a generic and broad spectrum about how the Internet of things have been incorporated in our everyday life, i.e. control and management of heterogeneous software and hardware resources ranging from smart homes, offices, hospitals to other geospatial locations for intelligent and optimized commuting over 24/7 real-time high-bandwidth physical networks.

The recent boom and rapid technological advancements in social networking websites have changed the general trends of communication and shopping, where users freely share their opinions about various services and products they sell and purchase. Opinion mining and sentiment analysis aim to predict and analyse these opinions for better decision-making. The term opinion mining was first used by Dave Lawrence [2], and sentiment analysis was introduced by Nasukawa in 2003 [3]. Basically, sentiment analysis and opinion mining assign digital score to opinionative words shared about different desired entities. The terms opinion [4], appraisals [5], polarity [6] attitude [7], sentiment [8] and semantic orientation [9, 10] are used to describe similar but not the same idea. Although there exist various techniques [5, 11–13] for sentiment analysis of social media text, it is observed that most of the existing methods have not produced satisfactory outcomes just due to the quality of text.

There are various applications of sentiment analysis for which different methods are suggested, which observed some common characteristics [5, 11–13]. These characteristics can help to understand the differences between applications and

**Fig. 10.1** The Internet of things (IoT)

methods and also enable application to be developed in ethical manner. One main property of text is high dimensionality that makes text preprocessing very important in text classification problems, including sentiment analysis [14–16]. The function of preprocessing is to transform unstructured text into a machine process able to input for text classifier. Most of the researchers discussed that text preprocessing has high effect on improving the classification accuracies [17–19]. The widely used approach for text classification is machine learning approach [14, 19–21]. Many other methods of text preprocessing are also combined to classify sentiments of movie reviews. With some experimental results, it is demonstrated that sentiment analysis accuracies using support vector machine significantly improved with the help of appropriate feature selection and representation.

High dimensionality in texts is one of the text's main properties that make text preprocessing very important in text classification problems, including sentiment analysis [14, 15].

As discussed before, sentiment analysis is comprised of two main approaches: supervised and unsupervised. Supervised method needs training and testing of data. Algorithms and classifiers are first trained using training dataset and then tested on unseen data. Machine learning methods are based on a set of selected features for a specific mission and then test on another set whether it is able to detect the right features and give the right classification. A lexicon-based method depends on a predefined list or corpus of words with a certain polarity. An algorithm is then searching for those words, counting them or estimating their weight and measuring the overall polarity of the text [22]. Lastly, the linguistic approach uses the syntactic characteristics of the words or phrases, the negation and the structure of the text to determine the text orientation. This approach is usually combined with a lexicon-based method [23]. The raw data in the form of text files is collected from online resources. The data is converted in to xml files and stored in database. The preprocessing usually includes converting xml documents into text document, removing undesired tags, stop word, performing Part-of-speech tagging, word stemming, lemmatization and coreference resolution. Undesired tags and stop words frequently used common words like 'and', are', 'this', etc. not useful in the classification of documents. So, they must be removed. Part-of-speech tagging is a process in which concerned grammatical categories are assigned to each target token for an efficient sentiment analysis, while stemming and lemmatization [22, 24] are the process in which inflected form of word is reduced into base form, and coreference resolution is the task of finding all expressions that refer to the same entity in a text. Coreference resolution is the task of finding all expressions that refer to the same entity in a text.

To access and generate information, local language computing is necessary. The most culturally and linguistically diverse continent in the world is Asia. More than 50 countries and 2200 languages are spoken in Asia. To gain the computing experience in local language and culture, we need localization process. This localization computing needs to provide a solution for input, output and process data in local language. It is also necessary that the processing, input and output are in the cultural acceptable standard form, e.g. formatting direction and writing direction (left to right, right to left). This localization process required a lot of work because Asian language and convention are not in the standard form as required for computing process.

Modelling linguistic background of a language is an important part of localization. Much clear linguistic phenomena are required for proper modelling of computational. Before forwarding the localization process, some time linguistic analysis is required. The same problem also exists in cultural conventions about which we know but usually not documented. So, it is necessary to involve local experts in the localization process.

Text preprocessing is the primary step in sentiment analysis and opinion mining. It is the process of cleaning text from undesired symbols and tags to make a valuable input. In fact, preprocessing is a kind of normalization in which unstructured text is transformed into machine understandable input. Social media text is of different dimensionality, which is one of the main reasons behind the requirement of preprocessing as each social networking website has different nature, so it is not possible for a system to automatically process all kinds of text without any preprocessing for the sake of prediction and analysis [14, 15]. Little work had been done to unfold opinions before 2003, but the advent of microblogging websites has given birth to the concept of analysing public opinions from microblogging websites, especially Twitter as it is considered as a word-of-mouth service. The main hurdle in exploring social networking text is the quality of input text. In the past, numbers of methods were proposed for cleaning input text as Rehab Duwairi (2013) [25] has investigated the representation and quality of text for Arabic sentiment analysis. It investigated many features, like several alternatives of text representation, feature correlation, effects of stemming, n-gram models for Arabic text on SA, the behaviour or three classifiers (SVM, naïve Bayes and K-nearest neighbour classifiers with SA, and the effects of the characteristics of the dataset on sentiment analysis were also analysed. El Kourdi et al. [26] used naïve Bayes classifier for automatic detection of Arabic sentiments. A corpus of 1500 text documents related to 5 different categories was utilized, in which each category held 300 text documents. The extracted tokens are first converted into root form, and a 2000-term corpus was created as a result. They used cross-validation for evaluation and achieved 92% accuracy over Arabic text. Motaz K. Saad [17] presented and evaluated the impact of preprocessing on Arabic text using different text classifiers. The classifiers they evaluated are decision tree, K-nearest neighbours, support vector machine and naïve Bayes along with its variations. Various term weighting schemes and morphological analysis are used to preprocess Arabic text. They integrated machine learning tools like Rapid Miner and Weka with morphological analysis. Text classification algorithms are implemented on seven different corpora. Tajinder Singh et al. [27, 28] examined the impacts and importance of text preprocessing for tweets having slang and informal words. They proposed a system for identifying the informal words and translating these slang words into formal form for better evaluation of sentiment. Conditional random field (CRF) and bindings are identified using n-gram in order to examine the importance of slang words. The system's performance is evaluated through experiments of sentiment orientation, and they stated that the proposed system achieved promising results with support vector machine. Giulio Angiani et al. [29, 30] evaluated the significance of preprocessing over Twitter datasets. Their main focus was to explore the best suited technique for preprocessing and to discover the features involved in effective preprocessing.

Lin et al. [63] eliminated noisy characters, such as noise, punctuations and other non-alphabetic values. Haddi et al. [64] observed that classification accuracy can be enhanced by removing stop words, stemming and negation identification. Similarly, Duwairi et al. [65] claimed that stemming and feature correlation enhance the overall classification efficacy. Emoticon and acronym detection improves the classification outcomes in sentiment analysis and opinion mining [66]. Although we have mentioned few preliminary steps of preprocessing, there exist some others issues too, e.g. removal of white spaces, online text cleaning, abbreviation extension and handling negative words. White space removal is responsible for removing or eliminating undesired or incorrect white spaces just to make text meaningful and clear. Online text cleaning is used to remove ambiguous data from text. It makes text clear and unambiguous. Abbreviation extension is the processes of defining acronyms and slangs. In this phase, acronyms are replaced with complete definitions. Negation handling is used to overcome the misinterpretation of sentences and paragraph. Negation symbols are used to reverse the sense of sentence. For instance: Nawaz Sharif is not a sincere leader. Here, the polarity of the whole sentence is negative just due to the term 'not'. Orientation of negators is key to efficient analysis. So, handling negation is an unavoidable task. Similarly, HTML Cleanup is used [31, 32, 33] to remove the html tags. Similarly, Document Object Model and the Apache HTML Unit are also used for parsing the HTML-specific features and generate an object-based structure.

### *10.2.1 Levels of Sentiment Analysis*

Sentiment analysis can be performed in one of the three levels: document-level, sentence-level and phrase- or word-level sentiment analysis [5, 11, 46, 52] (Fig. 10.2).

In document-level sentiment analysis, the whole document is considered as the unit for sentiment analysis [53, 54]. Generally, such analysis is performed for reviews, financial news and blog posts. Sentence-level sentiment analysis is finer in comparison with document-level sentiment analysis. In this level of analysis, a single sentence is treated as the unit for sentiment analysis [12, 55–57].

The general assumption of sentence-level sentiment analysis is that here each sentence holds at least one sentiment about target domain. Subjectivity classification is performed in sentence-level sentiment analysis. The process of classifying or distinguishing subjective and objective text is called subjectivity classification. The text which contains one or more opinionative tokens is considered as a subjective or opinionative text, and similarly text which does not contain opinionative words is considered as an objective text. Objective text is comprised of factual information, which is not useful in analysing opinionative text. The third most useful level of sentiment analysis is word- or phrase-level sentiment analysis. This level of sentiment analysis is useful in classifying Twitter data into positive, negative and neutral. Phrase-level sentiment analysis is also known as aspect-based sentiment analysis. Aspect-based sentiment analysis actually determines the associated features for better evaluation of sentiments. Aspect-based sentiment analysis can be defined as quintuple: (Ei, Aij, Sijkl, Hk, Tl). Here, 'E' is entity, A is the aspect of entity, S shows the sentiment on aspect of entity, whereas H represents the holder of opinion and T shows the time of opinion when expressed. The sentiment Sijkl can be


**Fig. 10.2** Levels of sentiment analysis

negative, neutral and positive based on the expressed sentiments. Generally, aspect-level sentiment analysis can be represented as fine-grained sentiment analysis. It is obvious that sentiment analysis is performed on clean and normalized text. There exist three main tasks of analysis: preprocessing, subjectivity classification and sentiment analysis. Preprocessing is the process of cleaning and normalizing text, while subjectivity analysis is the art of decomposing and classifying text into subjective and objective. Subjective text is a text which contains one or more subjective opinionative tokens, while objective text contains factual information. Subjectivity classification is one of the core tasks of sentiment analysis. One cannot assign proper score without knowing whether a tweet/sentence is subjective or objective. Bing Liu [58] stated that nouns, phrases, verbs, adverbs and adjectives are used in aspect-level sentiment analysis. Kim Houy [58, 59] performed aspect-level sentiment analysis using aspect, entity, sentiment time and holder and performed sentiment analysis of comparative sentences. In comparative sentences, explicit opinions are not present, while analysis is performed using comparative expressions, e.g., Samsung works better than Nokia. There exists a case, whereas subjective sentence may not express a sentiment or opinion. For example, 'I think that he went to Lahore'. Similarly, 'I want a mobile phone that can make good phone calls'. On the other hand, objective sentences can employ opinions, for example, 'Motor pump stopped working in just 2 days'. So, handling such complex expressions may result in unclear outcome. So, we must need proper preprocessing and normalization of text.

### *10.2.2 Approaches Towards Opinion Mining and Sentiment Analysis*

Sentiment analysis can be performed by three main approaches: supervised machine learning-based methods, lexicon-based approaches and linguistic analysis [34] as shown in Fig. 2.1 (Fig. 10.3).

Supervised machine learning-based methods need testing and training of data in which classification and clustering are performed through supervised classifier. In supervised classification, the dataset is arranged in testing and training set. Training set is used to learn classifier, and testing set is used to evaluate the performance of trained classifier. Lexicon-based approach uses dictionaries and lexicons for the classification and clustering of opinionative text. Lexical approaches do not use training and testing of data. Lexical methods are good for informal opinion-bearing text and domain-independent sentiment analysis. These methods rely on constructing lexicons 'which is dictionary of words/ tokens with associated tags', whereas these tagged words are considered as lexical items [35]. Basically, lexicon-based approach is unsupervised in nature, and these lexical items are used to analyse the pubic sentiments. The third approach used for sentiment analysis is linguistic analysis, in which various linguistic clues are used for scoring public sentiment

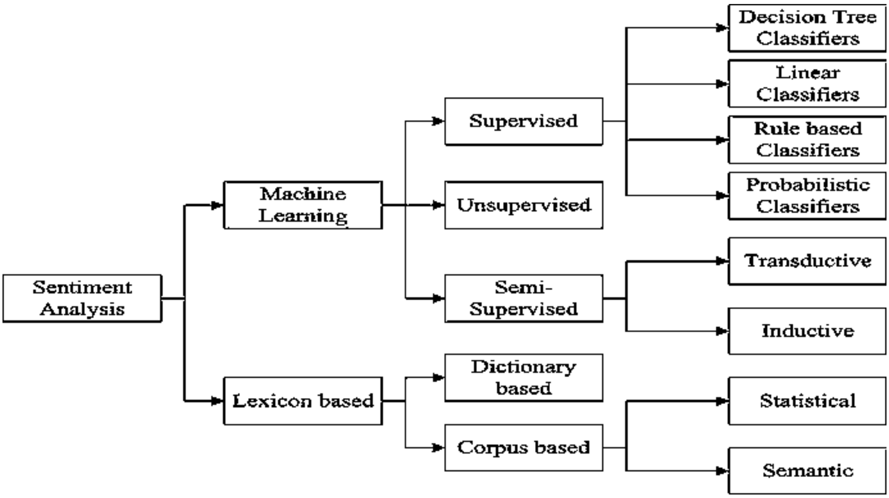


**Fig. 10.3** Sentiment analysis approaches and techniques

into positive, negative and neutral. In fact, this approach uses lexical information of words, phrases, negation and formalism of text to capture the semantic orientation of expressed opinions. Generally, such approaches are the combination of lexicon and natural language strategies [12, 34, 36, 51]. Mostly, linguistic techniques are based on parts of speech tagging, lemmatization, stop word removal and coreference resolution [35, 37, 38]. Generally, parts of speech used for classifying public sentiments are verb, adverbs and adjectives [39, 40].

#### 10.2.2.1 Machine Learning (ML)

ML-based systems tailed the well-known ML algorithms to address the opinion mining as text classification problem by utilizing syntactic and semantic information. Text classification aims to assign appropriate labels to each record from a set of given records R = {$R_1$, $R_2$, ..., $R_n$} based on the corresponding class label.

Supervised Learning

Supervised learning needs training and testing of data for a given set of documents. It is actually based on labelled/annotated training datasets. In the past, numerous supervised classification algorithms have been employed for the semantic orientation of public sentiments shared in the form of text. Here, we presented the brief summary of frequently used supervised classifiers for SA and OM.

*Decision Tree Classifiers* A decision tree (DT) utilizes decision control structure by ensuring hierarchical classification of training instances. It follows a treelike structure to decompose the data. Word existence is tuned as condition, whereas in sentiment analysis, DT is used widely to detect the aspect of sentiments by following the recursive procedure as decision trees are primarily based on recursive hierarchical structures.

*Linear Classifiers* In the area of machine learning and data science, linear classifier is used to classify the text based on linear combination of features. Each object has its own set of attributes also known as feature values. These feature values are provided to machine in the form of vectors. Although there exist a number of linear classifiers, support vector machine has gained noticeable attention in semantic orientation of user-generated text [41]. It is widely used in text categorization, information retrieval and author profiling [42]. Linear classifiers work well for practical problems, such as text classification and document categorization.

*Rule-Based classifiers.* A rule-based classifier used to adopt several combinations of rules, in which left side of the dataspace represents the condition on a feature set, whereas label of class is placed at the right side. Rules are generated based on several criteria during the training process of data. Support and confidence are preferred as base for making criterion. Support signifies the occurrence of rule in database, whereas confidence assesses the number of time a given rule is correct.

*Probabilistic Classifiers* In data mining and sentiment analysis, a probabilistic classifier is used to calculate sentiment labels based on probability distribution. It is useful in combining classification algorithms into ensembles. Probabilistic classifiers can also be referred as generative classifiers. The well-known probabilistic classifiers are maximum entropy (ME), naïve Bayes (NB) and Bayesian network (BN).

#### Unsupervised Learning

Unsupervised learning used to learn patterns from unlabelled set of data. It doesn't need training and testing of data. The major concern is to categorize data into a certain number of classes and assign appropriate labels on the bases of dictionary terms and lexicon. Raza et al. [43] employed unsupervised lexicon-based framework in the semantic orientation of user's opinion about news articles.

#### Semi-supervision

It is not always possible to collect labelled instances in supervised classification of sentiments. In order to utilize the supervised strategy with unlabelled instances, a semi-supervised classification is proposed. It is useful in many applications, such as text annotation, classification and categorization. Socio-monitoring framework is proposed in the classification of public sentiments [44].

*Transduction* is the ability of a system to learn and reason from training to test case specification, while on the other hand, induction can be defined as the ability of a system to learn from observed-training cases to general rules. These rules are then applicable at different levels for test cases.

#### 10.2.2.2 Lexicon-Based Approach

The key to sentiment analysis process is the existence of opinion-bearing terms. These opinionative terms can also be referred as subjective labels of a publisher. The opinionative contents can express some kind of positive or negative sentiments towards the target entity. Subjective (opinionative) terms are collected and stored in the form of dictionary or lexicon. These lexicons are then used in the orientation of sentiments. In the past, traditional methods were used for collecting the existence of positive and negative opinion of a user. Data mining came with novel strategies to gather, process and use the opinion-bearing terms. These automated mechanisms are listed below.

##### Dictionary-Based Approach

Dictionary-based approach (DBA) followed an unsupervised way of collecting opinionative information. Subjective terms and lexical items are collected and labelled with an appropriate semantic score. Dictionary can be extended by searching the synonyms and antonyms of the previously compiled resources as WordNet [47] and other rich resource thesaurus [48]. These synonyms are then labelled and added in the seed word list. In a similar way, iterative process is employed to search and label synonyms of the previously compiled corpora. In addition, a manual inspection needs to performed to cope with errors. These errors are then removed to improve the quality of dictionary. Domain independency and lack of contextual orientation are the limitations of dictionary-based approach.

##### Corpus-Based Approach

The limitation of dictionary-based approach is resolved with corpus-based mechanism as it allows domain-specific orientation of public opinions. This approach provides an appliance to gather context-oriented opinion words. Syntactic patterns are adopted and employed in collecting the subjective information from a large corpus. Usually the TF-IDF (term frequency and inverse document frequency) is applied to compile a corpus. Hatzivassiloglou and McKeown [49] applied seed word list collection of opinionative adjectives and practiced few linguistic clues to discover the new adjectives along with their relevant placement in terms of semantic information.

*Statistical Approach* This approach follows the analogy of co-occurrence rate and the existence of an opinion-bearing term. Statistical rules are applied in terms of posterior polarities along with the occurrence pattern of a target terms. Fahrni and Klenner [50] stated that the co-occurrence of an adjective in corpus can be derived with posterior polarities of target adjective terms. Statistical approach can also be useful in comprising a dictionary based on the entire web indexed document as resource corpora. Early research on aspect-level analysis is done via statistical-based sentiment analysis systems. Similarly, "runs test" (statistical test of randomness) can be conducted to detect review manipulation.

*Semantic Approach* The approach uses semantic relations to assign sentiment labels to any single subjective term. It follows several predefined principles to assess the semantic relation between the terms. Further, semantically related terms are labelled with the same orientation. Semantic approach is proved as a significant mechanism in lexical orientation of verbs and adjectives [50].

## 10.3 Methodology

Sentiment analysis approaches and classifiers are introduced for helping organizations, individuals and companies. The input text for classification purpose is extracted from social media sites, but extracted text is not suitable for classification, as there are numbers of tags, symbols and undesired data associated with it. Text must be preprocessed before going towards the classification process. The efficiency of sentiment classification is based on the quality of text. Text preprocessing is the essential phase of each sentiment classification process. We can't mine public moods accordingly if the source text is not clean. Preprocessing is performed to target the following reasons: to eliminate the incompleteness, to eliminate the noise, to make data consistent, to speed up classification task, to devise efficient output and to produce fine-grained polarity result. Online text is comprised of a lot of noisy and uninformative part, such as HTML tags, scripts and ads. Similarly, contents also have some words that are irrelevant and do not have an impact on the orientation of opinions. So, considering these terms during classification process results in error, since each term in the text is treated as a separate dimension. Data must be preprocessed to reduce the noise in the text; preprocessed text improves the performance of sentiment analysis classifiers. The text preprocessing also improves the classification speed. In this research, we have proposed a framework for generating better and efficient input text for mining public opinions more effectively. The proposed framework is comprised of eight basic phases. The phases included in this framework are as follows:

(i). Data extraction
(ii). Noise reduction
(iii). Stop word removal

(iv). Slang definition
(v). Stemming and lemmatization
(vi). PoS tagging
(vii). Coreference resolution
(viii). Tags identification

Although the proposed preprocessor is based on eight sequential steps, all these steps are not the novel contribution of the proposed study; instead, a few of them are existing preprocessing tasks, which are the prerequisite to novel phases of the proposed preprocessors. The novelty in the proposed study is the incorporation of slang and tag identification. In the past, these two key opinion indicators were ignored just due to their abstruse and unclear nature.

### *10.3.1 Data Extraction*

The social media contents are actually the source text, which is to be evaluated for the analysis of the concerned subject or topic. The growing nature of social communication has provided a vast amount of text, so the desired text must be fetched or extracted before going to further phases. As sentiment analyses are performed on textual opinions, we need an appropriate domain related text for analysing the impact of a particular entity or object. In this research, the first phase of proposed framework is data extraction. In this phase, the data is fetched/extracted from social media (microblogging) sites. We have used APIS and 80legs web crawler for crawling desired text. The Twitter data is extracted using word analyse and Twitter API, while blogs text is extracted through 80legs web crawler. The extracted text is saved in a separate file for further preprocessing. This saved file is then passed to the preprocessing phase for the removal of undesired tags and symbols. The *scope and constraints* of data considered are as follows: The contents having opinionative clues, both formal and informal, are in the scope of data, whereas the absence of such visible as well as invisible (informal) clues is treated as data constraint.

### *10.3.2 Noise Reduction*

It is obvious that social sites contain a lot of undesired and unwanted tags and URLs, so proper preprocessing is needed for handling and producing quality text for analysis. The extracted text is full of noise. A lot of undesired symbols and tags are attached with target information. To achieve the desired target information, noise must be removed. So, the text file is passed to the noise reduction phase for the elimination of URL, tags and other undesired symbols. In this phase of preprocessing, noise is removed for generating quality text. In this research, HTML parser is used for removing undesired tags from extracted text. Python and publicly available parsers are used for removing undesired symbols and tags [45].

### *10.3.3 Stop Word Removal*

Most common words of vocabulary are considered as stop words or words, which have very high frequency in documents. Such frequent words have no role in text classification, summarization and information retrieval, so such frequent words are removed in order to reduce the text size for fast and efficient processing of data. Stop word removal enhances the processing speed, but sometimes it reduces the classification accuracy. We used Python language [60, 61] and the natural language toolkit for removing the frequently used or common words from the extracted text.

### *10.3.4 Slang Definition*

The communication trends from the last few years have adopted novel style in which various microblogging and linguistic features are used for collaboration and conversation. Moreover, punctuations and other linguistic tokens are used for representing facial expressions. Emotion icon is also the prominent opinion indicator of social media, and almost every user adopts such punctuations and symbol during opinion sharing process. Subject, topic or hashtag is also one of such important indicators, which gained great attention by social media users. Hashtags are actually used for referring the context, subject or topic of shared tweet, e.g. *Love the battery timing of Nokia 1100 #sarcasm* and *well played team Pakistan 17/5 #angry #irony*, as both these sentences convey negative feelings with positive words.

If we ignore hashtags during classification, then accuracy will be sacrificed; so, to achieve fine-grained and efficient outcomes, we must have to incorporate hashtags in the classification approach. In this study, we proposed a novel strategy of handling context or sarcasm. Sarcasm indicators sometimes alter the meaning, context and polarity of conversation from positive to negative, and vice versa (Fig. 10.4).

In the proposed framework of efficient preprocessing, the third phase of tag identification is used for deciding whether the extracted tweets or messages are sarcastic or not, while in this phase, the identified sarcastic tokens/words and tweets are defined according to meaning and context. In this phase of preprocessing, Python NLTK with WordNet and Urban dictionary is used for defining the sarcastic, ironic and informal terms according to sense and meaning.

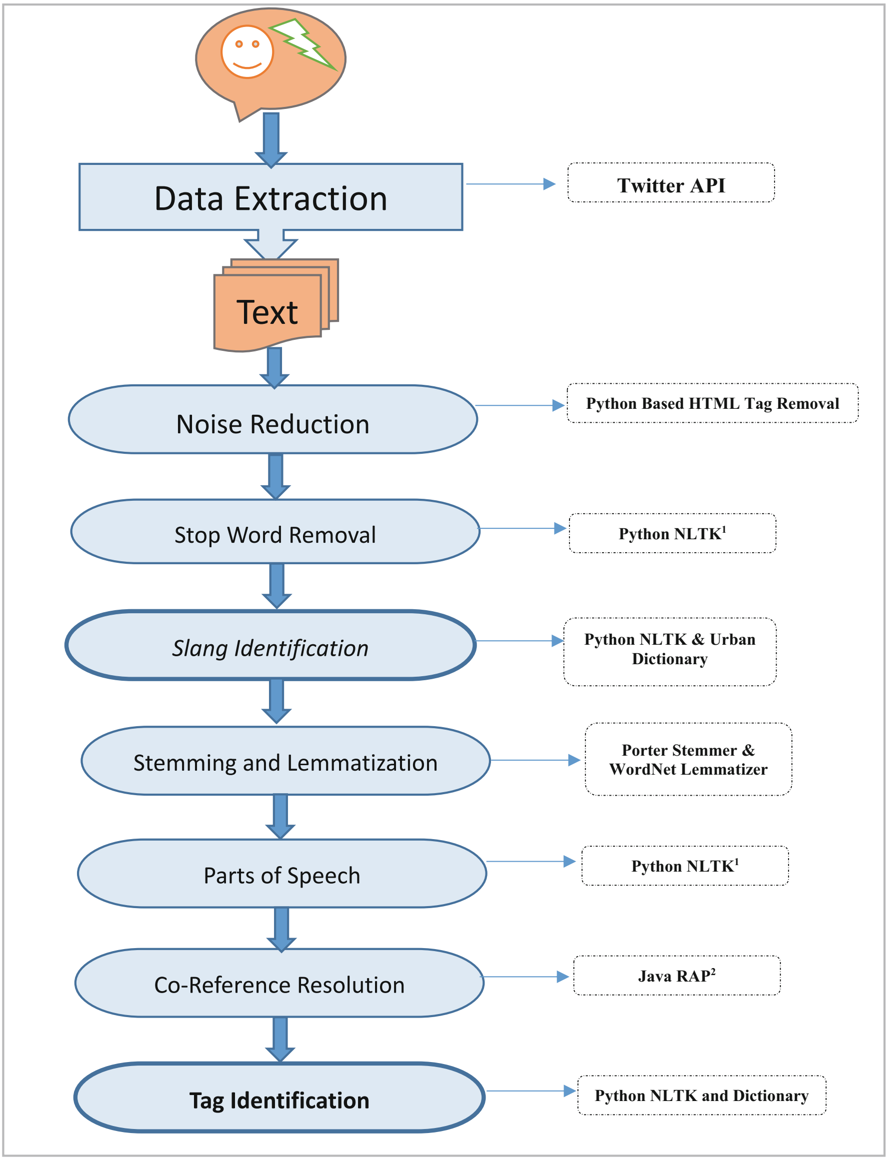


**Fig. 10.4** Mechanism for fine-grained text normalization of opinionative text

## *10.3.5 Stemming and Lemmatization*

The social networking users post their views and opinions over social sites without care of the grammatical constructs, spelling and morphological forms and language constructs. To achieve the desired useful information from publicly shared text, proper preprocessing steps are performed. Stemming or lemmatization is one of them. In this phase of preprocessing, all inflected forms are converted into base form and root form. Stemming and lemmatization are the two fundamental principles of preprocessing phase. Stemming is the process in which inflected forms are converted into root form. For example, 'automatic' and 'automatically' are converted into root form 'automate'. The operational speed of stemming is fast as compared to lemmatization, but its accuracy is not much promising. The stemming process is performed through stemmer. Stemmer is a software or tool first published in 1968 by Julie Beth Lovins, and porter stemmer was first designed by Martin Porter in 1980. Although stemming lowers the precision, it helps in the fast processing of text. Python NLTK comes with Porter and Lancaster algorithms. On the other side, lemmatization is the process of converting inflected forms into base form with the help of an additional dictionary. Lemmatization is better in performance than stemming due to the addition of an extra dictionary for meaningful lemma. Lemmatization is used in replacing words into their base form with the help of an additional dictionary. In this research, all the extracted tokens are converted into root and base form through Porter stemmer and WordNet Lemmatizer. Both these actions are performed sequentially in order to reach the most relevant opinionative tokens. Python NLTK [45, 60] provides stemming and lemmatization algorithms for converting inflected forms into their base and root forms. We used Python 3.5.0 with natural language toolkit for converting inflected forms into base and root forms.

### *10.3.6 Part-of-Speech Tagging*

The most essential phase of a proposed framework is part-of-speech tagging. In this phase, the extracted noise-free text is labelled with proper grammatical tags. The part-of-speech tagging label needs words on the bases of grammatical category and context. The purpose of assigning part-of-speech tags is the contextualized orientation of opinions.

Adjectives mostly contain more opinions than verbs and adverbs, so part-of-speech tags suggest which term is more opinionative and which one is not. The efficiency of sentiment analysis result is based on the fact on how positively a targeted token is tagged. We assigned part-of-speech tags to each token through Python natural language toolkit. Part-of-speech tags are cross-validated via SentiWordNet (SWN). SWN is a publicly available resource for semantic orientation, tagging and scoring of sentiments and emotions. It assigns labels on the bases of grammatical sense. A ternary classifier was used in the development of SWN.

### *10.3.7 Coreference Resolution*

It is the sixth and dominant phase of preprocessing in which co-occurred instances are resolved. The occurrence of two or more than two shortcuts that subject to single object or entity is considered as coreference, and the process of finding which shortcut is related to which object and which object is related to which shortcut is considered as a coreference resolution. For example, Imran Khan is a cute and intelligent politician but he is not much experienced. In this tweet, 'he' is used to refer the entity Imran and mining classifiers are not much intelligent to identify and resolve the co-references, so we have introduced an additional phase in the proposed framework for handling and resolving co-references. Coreference resolution is also considered as an anaphoric resolution as it is the task of natural language processing. Here, coreference resolution is performed only for one-statement-based sentences due to need of high morphological rules. Anaphoric terms considered in this research are proverbs, such as he, she, his, her, etc. In the past, Long Qiu et al. [62] used Java RAP (Resolution of Anaphora Procedure) to tackle anaphora resolution in which they offered an algorithm for resolving the anaphoric expression. Therefore, part-of-speech tagging, parsing and Java RAP algorithm [10, 62] are used to identify the relation between addressed part-of-speech tags along with subject terms.

### *10.3.8 Tag Identification*

Microblogging sites have introduced the novel communication features, such as target (@) sign, retweet and subject (#) sign, for fast and efficient communication. The tag identification phase is responsible for recognizing tags associated with each extracted tweet. Tags uncover the actual context of tweet. In this research, we have used subject (hash) tags for the identification and orientation of context of tweets. Python natural language toolkit along with the manually compiled list of subject tags is used for the recognition and orientation of context and subject in opinions.

## 10.4 Evaluation Parameters

The text prepared through proposed framework is experimented with both supervised and unsupervised machine learning approach. Preprocessed text is evaluated via lexicon-based sentiment analysis system and also publicly available classifier SentiStrength is used to capture the quality of data. This chapter elaborates and explains the effectiveness of framework. The parameters used in evaluating performance of framework and algorithms are mentioned below.

**Table 10.1** Contingency table

| Actual class | Predicted class | | |
|---|---|---|---|
| | | Positive | Negative |
| | Positive | Correctly identified Positive (CIP) | Incorrectly identified Negative (IIN) |
| | Negative | Incorrectly identified Positive (IIP) | Correctly identified Negative (CIN) |

**Table 10.2** Classification of opinionative and non-opinionative tweets

| **Total tweet = 1000 (before preprocessing)** | |
|---|---|
| Positive | 643 |
| Negative | 357 |
| **Total tweet = 1000 (after preprocessing)** | |
| Positive | 564 |
| Negative | 436 |

## *10.4.1 Contingency Table*

The contingency table is two-dimensional arrays comprised of rows and columns, in which rows represent human annotated instances while columns show machine predicted instances (Table 10.1).

Contingency table, also considered as a confusion matrix, is actually used to compute the number of incorrectly identified instances. Basically, it is an error matrix which represents the performance of proposed framework.

Table 4.2 CIP is used to show the correctly identified positive which means machine predicted correctly, while IIP represents the incorrectly identified positive which means machine didn't predict the class correctly. While on the other hand, CIN is used to show the correctly identified negative, which means machine marked correctly the instances as negative, and IIN presents the incorrectly identified negative, which shows that the machine labelled the instance incorrectly as negative (Table 10.2).

In this research, we have collected 1000 tweets from microblogging services. The obtained results are illustrated in Table 4.2. All collected tweets are classified into positive and negative. We performed these tasks twice. The above table shows that the results produced before preprocessing are actually weak as compared to the outcomes produced after preprocessing. Before performing preprocessing, the tweets classified as positive are 643 while 357 as negative while; on the other hand, after preprocessing, 564 tweets are marked as positive, whereas 436 are labelled as negative (Table 10.3).

Table 4.3 shows the confusion matrix of results produced with implementation experiments. It is clear that proposed framework achieved promising results.

**Table 10.3** Contingency matrix of proposed framework

| Before preprocessing | | | |
|---|---|---|---|
| Actual class | Predicted class | | |
| | | Positive | Negative |
| | Positive | 324 | 176 |
| | Negative | 319 | 181 |
| After preprocessing | | | |
| Actual class | Predicted class | | |
| | | Positive | Negative |
| | Positive | 394 | 106 |
| | Negative | 170 | 330 |

## *10.4.2 Precision*

The precision is used to assess the performance of proposed framework by evaluating positive predicted value. The lower precision indicates that high numbers of negative tweets are labelled as positive, while a higher precision means less numbers of negative tweets are incorrectly labelled as positive. So, the high precision reflects high accuracy of CIP. Mathematically, it is represented as:

$$Precision,\ p\ (Positive) = \frac{CIP}{CIP + IIP}$$

Table 4.3 shows the number of correctly predicted tweets as well as incorrectly predicted tweets.

$$Precision,\ p\ (positive) = \frac{324}{324 + 319} = \frac{324}{643} = 0.51 = 51\%$$

**After preprocessing:** $Precision,\ \ p\ (positive) = \frac{394}{394+170} = \frac{394}{564} = 0.69 = 69\%$.

Table 4.3 also shows the number of the correctly identified negative tweets as well as the incorrectly identified negative tweets.

$$Precision,\ p\ (negative) = \frac{CIN}{CIN + IIN}$$

$$Precision,\ p\ (negative) = \frac{181}{181 + 176} = \frac{181}{357} = 0.50 = 50\%$$

**After preprocessing**: $Precision,\ p\ (negative) = \frac{330}{330+106} = \frac{330}{436} = 0.756 = 75.6\%$

### 10.4.3 Recall

The recall is used to assess the sensitivity of proposed framework by evaluating positive cases classified correctly, or we can say that recall is used to measure the correctly classified tweets from the total numbers of tweets classified. The higher recall indicates that less numbers of positive tweets are incorrectly labelled as negative. Mathematically, it is represented as:

$$Recall, r\ (Positive) = \frac{CIP}{CIP + IIN}$$

Table 4.3 shows the number of the correctly identified positive tweets as well as the incorrectly identified negative tweets.

$$Recall, r\ (positive) = \frac{324}{324 + 176} = \frac{324}{500} = 64.8\%$$

**After preprocessing:** $Recall, r\ (positive) = \frac{394}{394+106} = \frac{394}{500} = 78.8\%$

$$Recall, r\ (negative) = \frac{CIN}{CIN + IIP}$$

Table 4.3 also shows the number of the correctly identified negative tweets as well as the incorrectly identified positive tweets.

$$Recall, r\ (negative) = \frac{181}{181 + 319} = \frac{181}{500} = 36.2\%$$

**After preprocessing:** $Recall, r\ (negative) = \frac{330}{330+170} = \frac{330}{500} = 67\%$

### 10.4.4 F-Measure

The F-Measure is an assessment which follows the harmonic mean of recall and precision. F-Measure mathematically is represented as:

$$F - Measure = \frac{2rp}{r + p}$$

$$F - Measure\ (positive) = \frac{2CIP}{2CIP + IIP + IIN}$$

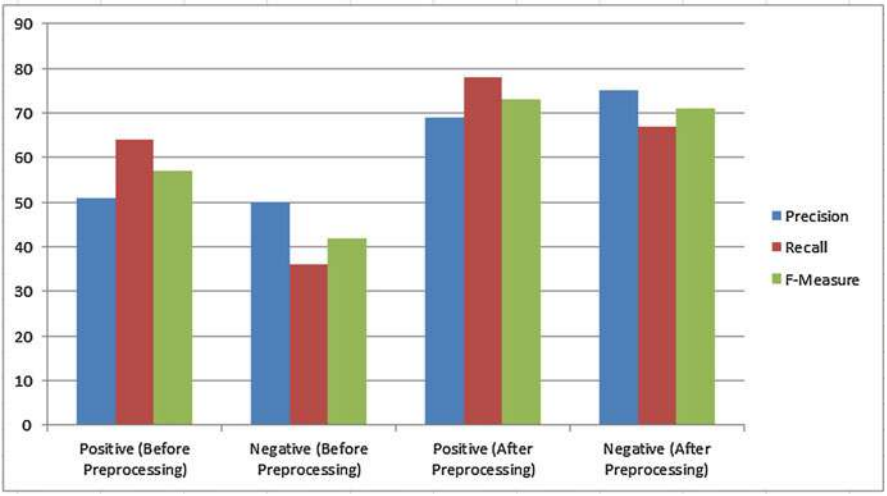


**Fig. 10.5** Impacts of preprocessing (precision, recall and F-measure)

$$F - Measure\ (positive) = \frac{2(51)64}{51 + 64} = \frac{6528}{115} = 56.76\%$$

**After preprocessing:** $F - Measure\ (positive) = \frac{2(69)78}{69+78} = \frac{10764}{147} = 73.22\%$

$$F - Measure\ (negative) = \frac{2CIN}{2CIN + IIN + IIP}$$

$$F - Measure\ (negative) = \frac{2(50)36}{50 + 36} = \frac{3600}{86} = 42\%$$

**After preprocessing:** $F - Measure\ (negative) = \frac{2(75)67}{75+67} = \frac{10050}{142} = 71\%$

### *10.4.5 Accuracy*

Experiments demonstrate that proposed framework improved the overall accuracy. We have achieved an average accuracy of 72.40% (Fig. 10.5).

$$Accuracy = \frac{CIP + CIN}{CIP + CIN + IIN + IIP}$$

$$Accuracy = \frac{324 + 181}{324 + 319 + 176 + 181} = \frac{505}{1000} = 51\%$$

**After preprocessing:** $Accuracy = \frac{394 + 330}{394 + 170 + 106 + 330} = \frac{724}{1000} = 72.4\%$

The precision, recall and F-Measure for positive instances have not led to a promising level due to the following reasons: *inapplicability of sarcasm detection* (i.e. opinionative contents relevant to political domain contain sarcastic and ironic behaviour), domain *Independency* (domain independency sometimes lost the actual orientation of a sentiment carrier) and inoperativeness of proper inclusion/exclusion strategy of opinionative contents in terms of context.

## 10.5 Conclusion

The rapid growth of microblogging sites has transformed the public styles of communication and collaboration. This fast change has given birth to new communication channels. One of the buzzwords in recent advancement is Internet of things (a.k.a. IoT). There exist millions of physical objects that are interlinked with sensor-based devices in order to mimic the real-world intelligence. The IoT industry is taking benefit of big data sentiment classification in reshaping and improving the sensor-based integrated information processing systems. The IoT is employing advantage of big data sentiment analysis. People from different geographical areas are using these services for sharing their interests. They mostly share sentiments and opinions about different real-world entities. Analysts and observers are always curious about knowing the popularity of product, so they used computational methods for the purpose of analysis. Computational study of public sentiments about desired entities is called opinion mining. Sentiment analysis (SA) is the subfield of text mining (TM) and problem of natural language processing (NLP). In the recent past, sentiment analysis, also known as opinion mining, is proved as one of the active research areas as different supervised and unsupervised methods are applied for analysing public sentiments, but new informal style of communication has produced various challenges for researcher in the form of noisy text. Sentiment analysis can't be applied directly over informal and noisy text. Preprocessing is an essential step for performing sentiment analysis and opinion mining. Although numerous methods have been applied for removing noise and preparing quality text, still these techniques are lacking in performance. Keeping in view this specific need, we have proposed a framework for efficient preprocessing of microblogging text in sentiment analysis. The system is comprised of few essential steps: noise reduction, tag identification, PoS tagging, stop word removal (SWR), stemming, lemmatization, coreference resolution and slang identification. The extracted text is passed to preprocessing framework, in which all these steps are performed incrementally. Each single phase is the input for the next phase, and the performance of proposed system is applied over existing Twitter datasets. In this research, we have prepared a dataset of 1000 tweets related to movies and politics from which 500 are positive and other 500 are negatives. Result clearly demonstrates that after preprocessing with the proposed system, we have achieved better results than without preprocessing. It is observed that effective preprocessing has a great impact on the accuracy of sentiment analysis. These experiments explored that the proposed system outperformed the existing methods by achieving 72.4% of an average accuracy without consideration of the domain specificity. Domain specificity improves the overall efficacy of the sentiment analysis process. Based on these experiments, we have faced two limitations; the proposed system needs much time as each step of preprocessing is the input for the next step, so one can't process all the steps in parallel. The second limitation is inapplicability of system over tweet having problem in the first few steps.

This study clearly explores that effective preprocessing has high impact over accuracy of sentiment analysis and opinion mining, especially for microblogging and Twitter data. As Twitter limits the size of text for communication, mostly users post informal, ambiguous, slangy and non-standard text for sharing their views, suggestions, appraisals, sentiments and opinions about real-world entities. Such noisy text can only be handled via effective preprocessing techniques and methods. We are hopeful that this framework will benefit the IoT community in effective big data sentiment analysis.

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# Part III
# IoT Sensing Technology and Applications

# Chapter 11
# Stadium 2.0: Framework to Improve Sports Fans' Experience in Stadium Through IoT Technology

**Miguel Filipe Beatriz and Vítor Santos**

## 11.1 Introduction

Lately, it is possible to see several changes in the way people act and behave because we live in an online world that reduces the distance between people and objects [1]. The reasons for that are related to the number of devices with Internet access that is increasing every year. In 2021, it is expected to have two billion people using smartphones [2].

This increase will continue, when we account the possibility of the data being accessible from online systems being represented by objects. This concept is called *Internet of Things* (IoT) and essentially describes a network of physical objects ("things") embedded in several technologies (e.g., sensors, actuators, software) for the purpose of connecting and exchanging data with other devices and systems over networks, as for example, the Internet [3].

The usage of IoT systems allowed to improve and connect people with information systems in several quotidian areas: smart houses, smart cities, environment, industry, e-health, and e-government.

Besides the IoT categories mentioned above, there is one with an increasing development and investment: smart sports. This area has recently become more important in terms of developments and investments due to the positives impacts that it can bring for sports stakeholders [4].

The role of IoT in smart sports can be categorised by three main branches:

– **Team's and athlete's development**: will allow to improve training sessions and athletes' performances during the matches. It uses several sources of data

M. F. Beatriz (✉) · V. Santos
NOVA Information Management School, Lisboa, Portugal
e-mail: m20180378@novaims.unl.pt; vsantos@novaims.unl.pt



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with advanced analytics from sensors and matches videos so that the coaches and athletes can obtain in real time key performance indicators (KPI), patterns from the match events. This allows the improvement of athletes' performances, analysis of opposing teams, scouting process, and match strategy.

– **Athletes' health safety**: This category allows physiotherapists and doctors to reduce the number and time of athletes' injuries. Through devices connected to the athletes, it is possible to track in real time their health status to provide information to health specialists so that they may take the best decisions about them.
– **Sports Fans' Experience**: This area is also called as *smart stadiums* and is focused on improving the relationship between the digital world and the sports fans. The stadium of the future allows the spectators to be connected in a closer way to their favourite athletes/teams and to the stadium in order to improve their experience.

From these three main branches, the sports fans' experience is the one that needs the most development, in comparison with the others and taking into account the potential of IoT usage in other quotidian fields [5]. Although there exist some investments from sports clubs organisations that aim to improve sports events' experience, there is a need for a mindset change in sports clubs management to overcome the challenges this area faces today.

Currently, there is an increasing distance between sports fans and their clubs' venues. This happens because of the existence of alternative ways to watch a sports event, for example, television broadcasts or streaming services. These alternatives are more economic and more comfortable and provide a set of technologies to provide an immersive experience to the spectators. In order to challenge this, the sports stadium must innovate and improve the sports fans' experience in order to be more competitive through the use of IoT technologies [5].

According to the article *Stadium of the future: a revolution for the fan experience in sport* [6], there are already some examples from sports clubs being aware about this topic, for example, the new Tottenham Hotspur F.C. football stadium (2019), Football World Cup in Qatar (2022), and Atlanta Falcons American football stadium. Based on these examples, it is clear the usage of technologies to improve sports events' experiences becomes an important topic to be covered by sports managers' stakeholders.

Taking this into consideration, it is necessary to improve the sports fans' experience in stadiums through the usage of IoT technologies. This chapter presents a framework to address this challenge with the following objectives:

– Allow the spectators to have a more attractive and immersive experience with better quality.
– Allow sports club managers/directors to improve and innovate their venues to have more people in stadiums and increase revenues.
– Create a standard to assess the sports fans' experience quality through the technology used in a venue. It can be used by leagues, federations, associations,

and event to determine if a certain stadium is eligible for a certain event or competition.

The contributions of this framework are: (1) mapping between the available IoT technologies and their benefits for sports fans' experience and other sports stakeholders; (2) analysing sports fans' experiences preferences in a stadium and how IoT can have a positive impact on them; and (3) sports venue classification based on IoT technology implemented and their benefits.

## 11.2 Sports Fans' Experience in Stadiums

Sports have always been part of our culture and everyday life since primitive forms of football in China or the gladiator shows in Rome. Therefore, sports and entertainment leaders over time have always had in mind the importance of sports events' experience to engage spectators [7, 8].

However, the current sports venues need to handle competition of alternative ways to watch these events, for example, television broadcasts or streaming services. These alternatives provide better viewpoints of the match, the use of augmented/virtual reality, and other multimedia experiences integration. Furthermore, the monetary and time cost of going to the stadium remains high in comparison with these alternatives and, because of that, the attendance to the stadiums has had a slight decrease. However, sports clubs' revenues have been growing because of television broadcast revenues [8].

The current venues' infrastructures are not enough for a spectator who prefers to watch a match at a stadium instead of at home. In order to attract new or occasional viewers, sports leaders cannot only focus in the spectators' basic expectations, but rather need to make this experience unique and differentiating to increase the emotional connection between fans and their teams. There are four basic expectations for a sport fan in a stadium [8]: safe, comfortable, and clean stadium; good visibility from venue's seats; high-quality match; a positive, exciting, and engaging atmosphere. The positive atmosphere in a stadium depends on three factors [7, 9]: spectators, match, and event organisation.

Once a sports fan spectator comes to a stadium to watch a game, it is important to go beyond the basic expectations by providing an experience that makes the fan want to come again and also to spend time and money on other associated channels, for example, food/drinks or merchandising concessions. There are some points relevant to improve viewers' experience [10]: personal identification with the sports club; the ability to have a unique experience in a venue; personalised experiences; real-time entertainment before, during, and after the event; opportunity to sit with viewers that share the same interests.

In addition to these points that allow to retain spectators and improve their identification with sports clubs, there is a need to innovate through differentiating factors, and it is necessary to take into account that there are different interests based on demographic strata. For example, the *Millennial* generation has a growing interest in mobile devices' integration in sports events [8].

In order to measure sports fans' experiences in venues, there are several mathematical formulas based on a set of metrics [11, 12]. These satisfaction metrics include: stadium infrastructure, security and accessibility, sports club team quality, sports club management, stadium services, staff quality, entertainment, merchandising, stadium atmosphere, and sports club identity and tradition.

Taking into consideration these factors, the *state-of-the-art* stadiums should be designed to increase sports fans' experiences through the usage of new technologies: augmented or virtual experiences, interactive seats, wireless infrastructure, custom mobile content, competitions for the spectators inside the stadium, and wide screens that go beyond the home experience [13]. The implementation of these improvements increases the involvement, engagement, retention, and interest of the spectators to go to the stadium.

## 11.3 IoT to Improve Sports Fans' Experience in Stadiums

The usage and implementation of IoT technologies in sports fans' experience in stadiums allow to handle effectively various types of challenges according to the following categories [14]:

- **Outdated stadium**: There is a risk of older infrastructures and technologies becoming obsolete. A sports stadium must be seen as a platform with the purpose of linking team, athletes, and their spectators.
- **Fan engagement**: With the increase of ticket prices and home experience to watch a sports event, it is possible to see a decrease in the attendance of stadiums. It is necessary for sports management leaders to be aware of the importance of the fans' attendance in a sports event and attract them with new experiences.
- **Decentralised data**: Sports clubs and their teams collect information from players and fans from several sources, but they are not integrated and managed effectively to provide results on business decisions.

Based on these factors, there is an increasing concern and awareness of the importance to invest in IoT technology to improve sports fans' experience with more investment from sports clubs or organisations [14]. According to a market study published by *Allied Market Research* [15], in 2017, the global market for smart stadium area was 4192.1 million dollars, and for 2025, a value around 22,100 million dollars is projected. This increase happens because sports leaders have a larger focus on improving spectators' experience, infrastructure energy efficiency, and security of the stadiums.

In terms of impacts that IoT can have in this area, there are four main categories [14, 16–18]:

– **Improved spectators' experience**: This category focuses directly on sports fans' experience, including the following activities: social media integration, WiFi infrastructure, and usage of mobile or wearable devices to provide information about the event.
– **Event management efficiency**: It includes activities such as spectators' traffic management with queue analysis and forecast to improve the stadium's accessibility, logistics, and security; mobile applications that track in real time the waiting times in venue's concessions; operational costs optimisation (e.g., energy, maintenance, infrastructure) or security/infrastructure improvements.
– **Personalised experience**: It includes activities related to the use of technology to make the viewer's experience as personalised as possible, for example: suggestion of entertainment activities within venue, custom advertisement, mobile applications that allow sports fans' interactions with entertainment games, real-time statistics and metrics of the athletes, or match event.
– **New revenue sources**: Usage of IoT technologies to increase advertising sales and sponsorship or broadcast rights; revenue increase from ticket purchases and existing venue's concessions (food, beverage, and merchandising) through mobile applications; selling of data obtained by sensors to sponsors/partners; expense reduction due to the optimisation of resources used in the venue.

## 11.4 The Framework

In order to improve sports fans' experience through IoT usage, in this section, a framework is proposed based on three pillars presented in Fig. 11.1:

– Existing state of the art related with spectators' experience, IoT technologies, and its usage for smart stadiums
– Questionnaire targeted for sports fans to prioritise the best experiences in a stadium
– Classification system to assess sports fans' experience based on the two previous points

The result of these three artefacts contains a reference model that allows to classify a stadium with a certain level by evaluating which IoT technologies are currently implemented. With this level, there is a set of benefits for the spectators in a sport venue and also a list of recommendations of IoT technologies to be implemented in order to level up.

In the following subsections, it will be explained with more detail the main concepts of the framework: questionnaire, classification system, and finally the reference to improve sports fans' experience.

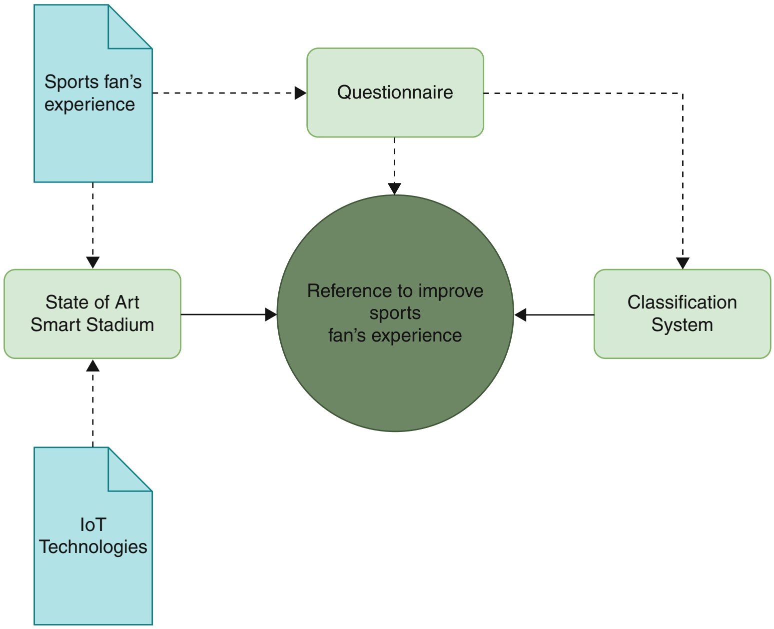


**Fig. 11.1** Framework proposed to improve sports fans' experience through IoT technologies

### *11.4.1 Questionnaire*

For supporting the creation of this framework, a questionnaire was made to understand how the sports fans' experiences can be improved and which types are most important for them in a venue.

This questionnaire was completed by 205 sports fans to provide feedback from a list of sixteen experiences in a stadium according to four levels of classification: Not Important (1), Low Importance (2), Important (3), Very important (4). The questionnaire's list of sports fans' experiences is listed below:

1. Safe, comfortable, and clean venue
2. Good viewpoints of the event in existing seats
3. Exciting game with high quality and a positive atmosphere
4. Compliance with game rules through the use of technologies (e.g., Hawk Eye, Virtual Assistant Referee)
5. Analysis of game, teams, and athlete's data through mobile applications or augmented reality
6. Entertainment activities in sports venue using IoT technologies (e.g., competition for the most audible applause, kiss cam)
7. Access to the different viewpoints of the game in the stadium through mobile applications or augmented/virtual reality

8. Access to the athletes' point of view through mobile applications or augmented/virtual reality
9. WiFi infrastructure in sports venue
10. Sports tickets online booking
11. Food, beverage, and merchandising online reservation through mobile applications
12. Food, beverage, and merchandising delivery to the spectator's seat through technology
13. Efficient accessibility with an optimised distribution of people and vehicles accessing to the sports venue
14. Efficient accessibility with an optimised distribution of people accessing restaurants, stores, and concessions in the stadium
15. Usage of contactless or biometric ticket for entry into the stadium
16. Eco-friendly processes in sports venue through technology usage

In Table 11.1 are presented the questionnaire's results for each experience. The results include the absolute frequency for each level of classification and an average classification value. Therefore, the obtained results were grouped in several experience levels, according to their similarity degree and qualitative importance from sports fans, resulting in a total of five different groups of sports fans' experiences. These five groups are listed below:

1. **Basic expectations**: 1, 2, 3
2. **Compliance with game rules**: 4
3. **Data-driven experience**: 5, 7, 8
4. **Enhanced services in sports venue**: 9, 10, 11
5. **Entertainment and accessible experience**: 6, 12, 13, 14, 15, 16

Subsequently, in order to prioritise these aggregates, the average importance of these experiences was calculated based on the questionnaire results and weight factor from the state-of-the-art study. This weight factor considers in first place spectators' basic expectations when going to a sport venue, improvements in match itself, improvements related to the match, and finally sport venue's enhancements.

Through this calculation, a set of levels was created that allows the construction of the proposed classification system. In Table 11.2, the questionnaire results are presented with the order of the five groups with the associated fans' experiences, importance, average result obtained from sports fans, weight value, and finally weighted average.

### *11.4.2 Classification*

The proposed model classifies a sports venue based on the existing IoT technologies used to improve sports fans' experience in a stadium in several levels. Each level contains a list of IoT technologies that must be implemented to be classified with a certain value and the associated benefits for the spectators' experience.

**Table 11.1** Sports fans' experience preferences questionnaire results (absolute frequency, average)

| Experience/classification | Not important (1) | Low importance (2) | Important (3) | Very important (4) | Average |
|---|---|---|---|---|---|
| Safe, comfortable, and clean venue | 1 | 6 | 65 | 133 | 3.61 |
| Good viewpoints of the event in existing seats | 1 | 9 | 70 | 125 | 3.56 |
| Exciting game with high quality and a positive atmosphere | 1 | 23 | 73 | 108 | 3.40 |
| Compliance with game rules through the use of technologies | 10 | 38 | 86 | 71 | 3.06 |
| Analysis of game, teams, and athlete's data through mobile applications or augmented reality | 15 | 66 | 88 | 36 | 2.71 |
| Entertainment activities in sports venue using IoT technologies | 46 | 57 | 67 | 35 | 2.44 |
| Access to the different viewpoints of the game in the stadium through mobile applications or augmented/virtual reality | 10 | 55 | 83 | 57 | 2.91 |
| Access to the athletes' point of view through mobile applications or augmented/virtual reality | 41 | 76 | 60 | 28 | 2.37 |
| WiFi infrastructure in sports venue | 29 | 63 | 68 | 45 | 2.63 |
| Sports tickets online booking | 5 | 20 | 75 | 105 | 3.37 |
| Food, beverage, and merchandising online reservation through mobile applications | 39 | 75 | 57 | 34 | 2.42 |
| Food, beverage, and merchandising delivery to the spectator's seat through technology | 29 | 72 | 64 | 40 | 2.56 |
| Efficient accessibility with an optimised distribution of people and vehicles accessing to the sports venue | 9 | 41 | 99 | 56 | 2.99 |

(continued)

**Table 11.1** (continued)

| Experience/classification | Not important (1) | Low importance (2) | Important (3) | Very important (4) | Average |
|---|---|---|---|---|---|
| Efficient accessibility with an optimised distribution of people accessing restaurants, stores, and concessions in the stadium | 17 | 58 | 87 | 43 | 2.76 |
| Usage of contactless or biometric ticket for entry into the stadium | 11 | 40 | 92 | 62 | 3.00 |
| Eco-friendly processes in sports venue through technology usage | 12 | 31 | 86 | 76 | 3.10 |

**Table 11.2** Questionnaire results (classification levels, sports fans' experiences, average, weight, and weighted average)

| Levels | Sports fans' experiences | Average | Weight | Weighted average |
|---|---|---|---|---|
| 1 | 1–3 | 3.52 | 0.3 | 4.58 |
| 2 | 4 | 3.06 | 0.25 | 3.83 |
| 3 | 5,7,8 | 2.66 | 0.2 | 3.19 |
| 4 | 9–12 | 2.74 | 0.15 | 3.16 |
| 5 | 6, 13–16 | 2.86 | 0.1 | 3.14 |

For a certain stadium to be able to reach a certain level of classification, it must implement and use a set of IoT technologies. This process can be repeated until the venue has implemented all existing actions in the framework reference and therefore reaches the maximum level of the classification.

Through a classification model, it is possible for a certain sports club management agent to quantify the spectators' potential level of satisfaction in a venue and also allow to compare experiences between two or more sports venues.

In the following list and in Fig. 11.2, the various levels of the classification are presented:

- **Level 1 (Basic)**: This level must guarantee the basic expectations of a sports event spectator in a stadium: a sports venue with good safety conditions, comfortable, clean; good viewpoint visibility from every venue's seat; an exciting and high-quality game with a positive and engaging atmosphere.
- **Level 2 (Fair Game)**: In this level, it is necessary to implement and use IoT technologies that allow to improve game fairness to enforce sports rules, for example, *Hawk Eye* or *Video Assistant Referee* technologies.
- **Level 3 (Immersive Game)**: A venue must implement and use IoT technologies focused on making sports fans' experiences more immersive. In this category, the following technologies are included: mobile applications or augmented reality


**Fig. 11.2** Classification system to assess sports fans' experience in stadiums

technologies to provide statistics from athletes and teams involved in the event; relevant news from the sports' fan club or competition; access to different viewpoints from the sports venue or athletes.

- **Level 4 (Intelligent Service and Marketing)**: It consists on the ability of IoT technologies to automate and improve the sports fan's experience in relation to the existing services, stores, or concessions in a stadium. The implementation of IoT on this level includes: the ability to schedule a food, drink, or merchandising delivery through a mobile application to a spectator's seat during the sports event; personalised advertising targeted to the spectator based on their interests; online ticket venue's seat booking and parking seats; ticket upgrade systems based on customer's loyalty; WiFi infrastructure within the venue.
- **Level 5 (Stadium 2.0)**: For a sports venue to reach this level, it must have all IoT technologies in this framework implemented and thus be considered as a Stadium of the Future. In order to complete this last level, the improvements are mainly focused in the stadium's accessibility for the spectators in existing queues, stores, or concessions; optimisation and maintenance of the resources used in the venue; social media integration; and entertainment activities before, during, and after the sports event.

### *11.4.3 Reference to Implement IoT Technologies in Sports Venues and Benefits to the Sports Fans' Experience*

Table 11.3 presents the relationship between each classification level and a set of recommendations through IoT usage to improve the classification level and sports fans' experience in a venue.

**Table 11.3** Reference to implement IoT technologies in sports venues and benefits to the sports fans' experience

| Level | Benefits to the sports fan's experience | IoT technologies to implement for a venue to level up |
|---|---|---|
| Level 1 - Basic | • Sports venue with security conditions, comfortable, and clean<br>• Good view of the event in venue's existing places<br>• Exciting and high-quality game with a positive atmosphere | • High-speed cameras to provide correct decisions in all match situations<br>• Sensors (accelerometer, gyroscope, motion and proximity sensor, GPS, and RFID) to collect data to provide correct decisions during the match<br>• Software applications or wearables that allow the referee to evaluate correctly the match decisions and the sports fan to watch all game events with more detail |
| Level 2 - Fair Game | • Ensure an effective compliance to the rules of the match event<br>• Capability to review all match events that may be subject to the discussion of the match rules | • High-speed camera to collect data from players, the match, and their several points of view<br>• Embedded cameras in athletes<br>• Sensors (accelerometer, gyroscope, motion and proximity sensor, GPS, and RFID) to collect data from athletes and match<br>• Mobile applications to provide match and player's statistics collected by the sensors and cameras<br>• Augmented, virtual technologies, and devices (e.g., software, actuators, VR glasses) |
| Level 3 - Immersive Game | • Review of statistics and match events from the teams, players, and competitions through mobile applications and augmented reality<br>• Wide screens in venue with statistics and match events<br>• Visualisation of the several cameras of the match and from the point of view of each athlete | • Wi-Fi infrastructure in venue<br>• Applications that allow the scheduling of services in real time for the customer (e.g., food, drinks, merchandising, tickets)<br>• Applications to collect personalised data from spectators<br>• Artificial intelligence to provide a set of services and marketing custom campaigns for each venue spectator<br>• Identification/localisation systems (e.g., RFID, GPS) that allow the identification of the customer's position during the event |

(continued)

**Table 11.3** (continued)

| Level | Benefits to the sports fan's experience | IoT technologies to implement for a venue to level up |
|---|---|---|
| Level 4 - Intelligent Services and Marketing | • Wi-Fi infrastructure in the venue<br>• Online reservation of food, drinks, merchandising, tickets or parking with custom scheduling, and delivery to the customer (e.g., customer's place or restaurant)<br>• Advertising and marketing sales campaigns targeted to the customer<br>• Customer loyalty campaigns (e.g., gamification) | • Cameras and sensors in sports stadium entrances to optimise accessibility<br>• Contactless devices (e.g., mobile device, NFC) or biometrical devices as admission ticket<br>• Sensors to measure the energy resources consumed in the venue<br>• Cameras and sensors to track maintenance level in all existent places in the venue<br>• Social media integration<br>• Software applications, cameras, and sound speakers to entertain the spectators |
| Level 5 - Stadium 2.0 | • Intelligent and efficient access to the venue with optimisation of waiting time in the entrance<br>• Intelligent and efficient access to all services and concessions existent in the venue<br>• Entrance to the venue through a contactless admission ticket (e.g., mobile or biometrical device)<br>• Eco-friendly processes (e.g., temperature, air, humidity sensors) that allow an efficient usage of resources in the venue<br>• Predictive analysis of risk behaviours inside and outside of the venue<br>• Entertainment activities and social media integration during the match to improve sports fans' atmosphere | • Guarantee the usage of all technologies and actions from all levels |

For each classification level in this reference, there is a set of benefits in sports fans' experience and also a set of IoT technologies implementations to allow a venue to proceed to the next level.

In order to define a classification level for a stadium, it is necessary to assess which IoT technologies are currently implemented and maps with the framework's classification. For example, a basketball venue that contains safety conditions and seats with good visibility and uses several IoT technologies that ensure the compliance with game rules (e.g., cameras, motion, and location sensors, Virtual Assistant Referee) should be classified as *Level 2 (Fair Game)*.

Besides the experience improvements, this framework can also have a positive impact on other stakeholders:

– **Sports Clubs**: New sources of revenue through entertainment activities; increase of advertising and sponsorship rights revenue; increase of revenues from tickets, concessions (food, beverage, and merchandising); customer data sale collected by sensors to the partners and sponsors; reduction of expenses due to the optimisation of resources used in stadium.
– **Sponsors and concessions**: Revenue due to the increase in stadium attendance; more effective and personalised advertisement; increase of concession's revenues due to the existence of mobile applications that allow the delivery of food, beverage, and merchandising to the customers in real time in a personalised way.
– **Leagues, Federations, and Government**: Existence of a standard to classify the sports fans' experience through IoT technologies, which allows leagues, federations, and governments to ensure that competitions organised by them have the necessary quality level to host the event. For organisations managing sport events on a continental or worldwide context (e.g., World Cup, Olympic Games), this framework allows the classification of which sports venues are eligible candidates to host these events. In addition, this classification allows centralised support mechanisms to provide the necessary investment to all sports clubs within a competition.

Regarding the implementation of IoT technologies, for a venue to be able to level up in classification there are several points to consider by a sports club or organisation.

The first point focuses on economic viability of IoT technology implementation and usage in a sports venue. It is necessary to consider some criteria to decide how much investment should be made by sports clubs. For instance, the sport, competition, or league's venue attendance and return of investment. In sports clubs where investments cannot be so high, they should focus on the necessary requirements to implement the framework's first two levels because they cover the basic expectations of sports fans in a venue. If a sport club decides to achieve the framework's higher classification levels, there must exist an impact and return of investment assessment to decide it.

In addition, this technology investment can also be made by sports associations or organisations. In order to improve their sports competitions and allow competition fairness between clubs, the framework allows these organisations to define if a certain recommendation should be implemented across all clubs in a certain competition/organisation or if it should be implemented individually by a club. Based on the proposed model, it is considered that lower classification levels (Levels 1, 2, 3) can also be implemented at the level of associations, organisations, or federations because they allow an improvement across all organisations' clubs.

The last point focuses on legal requirements. It is necessary to consider the framework's proposals that need to store any personal data from sports spectators.

The General Data Protection Regulation *GDPR* law, for example: GPS location, personalised data. In order to implement technologies that need personal data, it is necessary to request an authorisation from spectators to approve personal data storage and usage.

## 11.5 Evaluation

In order to assess the importance and applicability of the framework in a real context, a set of interviews was carried out. These interviews had focus on understanding if the framework's reference and classification levels system based on IoT recommendations and their benefits could be a good way to improve spectators' experience in a sport venue, if it could be an efficient way to assess a stadium based on IoT technologies implemented, and if they are suitable to the financial context of sports clubs, federations, or organisations.

To proceed with these interviews, it was necessary to identify the relevant stakeholders who will benefit with the implementation of the framework's artefacts. The main benefits of this framework are sports fans' experience improvements and increasing of source revenues of sports clubs, and because of that these interviews were conducted within two groups of individuals: sports fans and sports events management staff (sports clubs, national sports federations). These two groups were chosen to understand the two existent viewpoints in a sports event experience.

The first group corresponds to individuals who are spectators of sports events. The objective was to assess if the implementation of this model will improve experience quality to be unique, differentiating, and attractive. In this group, there was a distribution in terms of sports interests (e.g., football, basketball, handball, volleyball) and frequency to attend a sport event (occasional, frequent) in order to understand if this framework can be applied to several types of spectators.

The second group targets individuals who work in sports areas or sports events management including sports clubs and national sports federation management. The interviewees are from several types of sports, for example, football, volleyball, basketball, and handball. This type of interview aimed to understand whether the proposed model is feasible in a practical and real context in the various existing sports.

These interviews were conducted through video conference calls with a presentation of the proposed framework and related concepts and therefore a set of questions based on the target group. The questions presented in the interviews are listed below:

- *Personal Identification (Name, Age, Professional Activity)*
- *How often do you attend a sports event in a stadium?* (**Only for sports events spectators**)
- *Which sports and respective venues have you attended?* (**Only for sports events spectators**)

- *What are the sports you manage in your professional position?* (**Only for sports events management staff**)
- *Do you consider the benefits proposed in the framework positive to the fan's experience in a venue?*
- *Do you consider the proposed IoT technologies could be implemented in a venue?*
- *Do you consider the proposed framework could be positive in a financial perspective for the sports clubs? (e.g., new/increased revenue sources, new marketing/advertisement agreement)* (**Only for sports events management staff**)
- *Have you implemented any of the proposed actions/technologies in a venue managed by your sports association? If so, can you list some of these actions/technologies?* (**Only for sports events management staff**)
- *Do you consider the proposed framework through a level classification to assess a certain venue and sport fans' experience a good way to evaluate it?*
- *Do you have any suggestions to the proposed framework?*

### *11.5.1 Results*

In the following subsections, the results obtained from the two groups of interviews are discussed and their respective considerations.

**Sports Venue Spectators** In this group, a total of six interviews were conducted with different types of spectators (occasional or frequent).

The interviewees considered that the proposed experiences in the framework can be real improvements on their experience in a stadium. For occasional spectators, they consider that it is a way to make the sports event experience more dynamic and interactive. Because of that, they feel more integrated and immersed in the experience. As for the case of more frequent spectators, they emphasise the improvement of the sports experience in a stadium as a way to make it unique, differentiating and generally better comparing to watching the game through a television broadcast. They considered the framework's most impacting benefits the existence of match statistics and different viewpoints, technologies to enforce match fairness (e.g., Video Assistant Referee, Hawk Eye), existence of food, drinks, and merchandising services with delivery to a stadium seat through mobile devices, and contactless ticketing system.

Regarding framework's IoT implementation recommendations, the interviewees consider that a high level of investment is necessary to implement some of these technologies and to achieve higher levels in the framework classification and, as such, not all sports clubs have positive financial conditions to do it or have high enough stadium assistance to make the investment profitable. However, they refer that since the framework contains a set of levels to be achieved, it is a better way for sports clubs with less financial conditions to try to implement some of the recommendations with a lower investment. It was also suggested that there could be a central entity or organisation (e.g., a league or federation) to provide financial investment to the clubs and to implement the proposed recommendations to improve the quality of the clubs and their competitions.

The interviewees considered the proposed model a good way to evaluate sports venues in terms of sports fans' experience because the existing classification levels are well defined in terms of experience benefits and the proposed actions to be implemented. It was also considered that with the existence of levels there does not exist a polarised definition between an interactive stadium or not, and sports fans' experience can be incrementally improved over time and investment.

**Sports Management Staff** In this group, a total of four interviews were conducted with different types of staff in different sports (top sports clubs management and national federations) to guarantee the practicability of this framework in several sports in a real context.

This group of interviewees considered the proposed activities in the framework as beneficial to the sports fans' experience because they feel that currently there is a lack of focus on spectator experience based on the sports clubs investment. In addition, according to General Director of Sports in Sporting CP,[1] these activities allow the sports fans an attractive, diverse, and differentiating experience that goes beyond a simple sports experience in a stadium.

However, the interviewees emphasise the applicability of this framework to all clubs or sports may not be easy to implement. The first point is regarding financial conditions, since all the sports clubs do not have the same conditions, and normally only the top division clubs have enough budget to include technological development and investment in their plan. The main focus of the majority of sports clubs is based on the success of their teams because the next season budget depends on it. However, the interviewees think this framework can provide a new perspective to the sports club's management to have other types of investments with focus on sports fans' experience.

The second point regards to the popularity of the sport target of this framework, for example, football. According to the Sporting Braga interviewee's feedback,[2] the first division clubs can handle this type of technical investments in their budgets. In handball, according to a national federation's feedback,[3] it is possible to implement some of these recommendations if they were included as a regulation for the participant clubs in their competitions to improve sports fans' experience through technology usage. However, in the case of volleyball, according to the feedback of a national federation,[4] it is necessary to adapt the proposed model based on target sports because in this case financial conditions do not exist to implement

[1] Bruno Silva—General Director of Sports in Sporting CP.

[2] Álvaro Portela—Technical Director Sporting Braga.

[3] Ricardo Andorinho—Portuguese Handball Federation.

[4] Leonel Salgueiro—Portuguese Volleyball Federation.

the majority of the recommendations and, because of that, the proposed framework should have less technological requirements to be implemented.

Besides these two points, the interviewees stated there are already some initiatives in their clubs and federations to improve technologically their sports venues through recurring meetings and new regulations to enforce all sports clubs to have implemented a set of basic technological requirements in their stadiums.

Regarding the question if the proposed model can be economically beneficial to the sports clubs, the interviewees consider that in certain sports clubs with a good assistance average in stadium, it can be very beneficial. However, for lower-level division clubs where the spectators usually watch the game just for affinity/identity and not so much for the sports event experience itself, perhaps not so many financial benefits exist for the clubs. In addition, since the presented model is progressive, it allows the clubs to have sustained growth of necessary investment in their budget, so instead of trying to implement all the existing framework's recommendations, a business plan should exist, which grants a progressive investment that allows the implementation of the proposed technological recommendations and access to some financial return.

The interviewees considered the proposed level classification system a very positive model because it works as a tool for sports clubs to assess themselves in terms of technological evolution in their stadiums and spectators' experience quality. According to the national federations, they consider it a very important tool that can be used as a standard to the sport clubs participating in their national competitions, which would lead to the technological evolution of clubs, organisations, and federations and to the improvement of the sports clubs competitions' attractiveness to the spectators. It also allows for all clubs associated a certain competition to improve themselves together instead of only individually. In addition, these improvements can be done in a centralised way through investments done through league or federation organisations funding. In conclusion, they consider that this framework can also be used as an instrument for sports venue certification by continental or worldwide institutions to consider a certain venue as a Stadium 2.0 and to be eligible for continental/worldwide competitions (e.g., Continental Championships, World Cup, Olympic Games).

As for suggestions to improve the proposed framework, the following points were mentioned: extend reference to include if a certain recommendation should be implemented by all sport clubs in a certain competition/federation or if this can be implemented by the club itself; define an interconnection of this framework with television broadcast experience to attract more television sports fans to attend their favourite sports in the stadiums.

## 11.6 Conclusion

This chapter presented a framework to improve sports fans' experience in a stadium through the usage of IoT technologies. There is a great challenge for sports stakeholders in how it is possible to improve the experience in venues because there exist alternative ways to watch a sports event, for example, television broadcasts or streaming, that allow the spectators to watch a match at home with lower costs in a more comfortable way and with higher quality.

In addition, the current sports venues' infrastructures have not been sufficient to keep up the other alternatives and, because of that, this option is not a differentiating factor compared to attracting more spectators to the stadiums.

There is an increasing need for sports stakeholders to not focus only on spectators' basic expectations in a sports event, but rather to innovate and invest in unique and differentiating factors that allow them to attract more sports fans to their venue.

Addressing these issues, the proposed framework presents a classification model with five levels, which allow the improvement of sports fans' experience. This classification contains several benefits to the spectator's experience through the usage and implementation of IoT technologies.

In order to assess the importance and applicability of this framework in real context, a set of interviews was carried out with two groups: spectators of sports events and sports events management staff (sports clubs, national sports federations). It was concluded that the actions proposed can really improve the spectator's experience quality in a stadium and that they also have a positive impact on clubs and sports associations that aim to attract more sports fans to the venues and increase revenues. In terms of applicability, this framework is easier to be implemented in sports clubs with better financial conditions. However, since this model is based on classification levels, it allows other clubs to develop some of the actions proposed.

In conclusion, according to the feedback from sports clubs and federations, the proposed framework stands out as a promising classification model to assess the quality of a sports venue in terms of technology used and the benefits in sports fans' experience that can be used as a standard, certification or regulation mechanism to be used by sports organisations to classify their venues.

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# Chapter 12
# Smartphone-Based Lifelogging: Toward Realization of Personal Big Data

**Shaukat Ali, Shah Khusro, Akif Khan, and Hayat Khan**

## 12.1 Introduction

The advancements in computing technologies have paved the way for the development of lifelogging technologies [1] addressing the "memories for life" grand challenge of computing research [2]. A common definition of lifelogging is as follows: "a form of pervasive computing, consisting of a unified digital record of the totality of an individual's experiences, captured multi-modally through digital sensors and stored permanently as a personal multimedia archive" [3]. In other words, lifelogging refers to using computer technology for digitally archiving peoples' lifetime experiences in multimedia format for different purposes [4, 5]. The lifelogging system has to operate both continuously and passively to automatically capture content and contextual data with no explicit users' input [6]. A lifelogging technology creates a rich lifelog personal big dataset by capturing and recording various information from different sources, such as Web pages browsed, sent and received emails and SMSs, electronic calendar entries, dialed and received phone calls, downloaded and listened audios and videos [7], captured or viewed photographs, as well as contextual and environmental information captured via sensors (e.g., ambient noise or locations using GPS [8]).

S. Ali (✉) · S. Khusro · A. Khan
Department of Computer Science, University of Peshawar, Peshawar, KP, Pakistan
e-mail: shoonikhan@uop.edu.pk; khusro@uop.edu.pk; akif@uop.edu.pk

H. Khan
Department of Computer Science, National University of Computer & Emerging Science, Peshawar, KP, Pakistan
e-mail: p177509@nu.edu.pk



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The lifelogging can be classified into *total capture* and *selective capture* [9]. The total capture lifelogging (also called extreme lifelogging) focuses on capturing life experiences from all available sources without predefined use-cases at the beginning of lifelogging. The selective capture or targeted lifelogging [9] focuses on capturing experiences about a particular aspect of a person life with clear predefined objectives and applications. For both types, the lifelogging can provide complementary digital assistance particularly to human memory [10, 11].

The easy availability of computing technologies and the proliferation of capturing devices have encouraged the development of new hardware and software systems for turning the vision of lifelogging into reality. Most lifelogging systems employ wearable technology, relying on external capturing and sensing devices to automatically record peoples' daily life activities and contextual information [12–14]. Despite their benefits, wearable lifelogging systems tend to provide limited features, which in turn may overload users with extra devices.

The advent of ubiquitous computing technologies has shown the possibility and affordability of capturing and storing a person's total life experiences for providing a digital memory [10, 15, 16]. The occurrence and independence of noticeable events and activities from specific time and space makes the application of ubiquitous computing devices necessary for lifelogging. The smartphone (SP) is a ubiquitous computing device, which can be easily found with almost every person in the world today [17]. According to Gartner, 366 million SPs are sold to the end users globally in the third quarter of 2020. They are our constant companions and know us well, beyond our imagination, by collecting a wide variety of information on many aspects of our lives [17, 18]. The SP's portability, built-in features, and capability of integration with other technologies have made it a de facto lifelogging device [18–20]. A SP has advanced computing technologies in terms of sensors, processor, storage, or networking. The advanced sensors enable SP for continuous and unobtrusive capturing of content and contextual information regarding peoples' daily life operations, activities, and surroundings [10, 21, 22]. The advanced processing power enables SPs to process large amount of data and complex algorithms in short time. The large storage empowers SPs to store and access voluminous data for lifetime. The different networking capabilities enable SP to connect to a vast computing and storage media for extensive data processing and storage [19]. The SP-based lifelogging research is majorly focused on developing applications, emphasizing on exploiting smartphone capabilities to fulfill the objectives of lifelogging. However, the technological advancements make SP-based lifelogging scope wider than other lifelogging technologies and could be a step toward capturing and recording of voluminous totality of life experiences information into a lifelog dataset.

A SP-based lifelog dataset is a personal big data archive because SP-based lifelogging can potentially confirm the four elements of a big data scenario (i.e., volume, variety, velocity, and veracity) [5]. The size of personal big data typically depends on the type of lifelogging and the number of information sources used. Certainly, the size of personal big data will grow with time, thus providing opportunities for the big data analytics. The personal big data analytics opportunities include information mining and cross-referencing; correlating and merging; data mining and semantic extractions from different sources; learning, sharing, and transferring; and querying and visualizations in appropriate manner for decision-making on personal as well as enterprise levels. The big data technologies can use personal big data and provide certain advantages to the SP-based lifelogging applications, for example, bringing changes in behaviors of the people by analyzing past behaviors, finding peoples' preferences for dinning in a region, and enabling people to remember names of previously visited places. In addition to human memory augmentation, the big data analytics on personal big data can find several big data applications in different domains, such as healthcare, commerce and business, society and public sector, learning, and scientific research. However, for SP to fulfill the design requirements of lifelogging personal big data systems (i.e., seamless incorporation in daily life, efficient in resources utilizations, protection of privacy and security, long-term storage and preservation of personal big data, and instant information retrieving from personal big data), a number of challenges are needed to be solved [19]. The challenges are mainly regarding capturing, processing, storing, index, retrieval, and visualization of huge personal big data archives, which will be continually addressed by the advancements in sensor technology and computer science and information technology. In addition, a real challenge is the using of personal big data in the big data analytics.

To date, we have a few research attempts from academia and organizations, who have articulated about using SP for lifelogging [19, 23, 24]. However, none of them has provided insight knowledge about its core potentials and functionalities to produce personal big data, relationship and placement in the big data paradigm, supporting big data technologies and applications, and opportunities and challenges. This is the reason that has motivated us to present a comprehensive survey of SP-based lifelogging from big data perspectives. To the best of our knowledge, this paper is the first comprehensive review on SP-based lifelogging and highlighting its potential applicability as source of personal big data. The contributions of this paper are the following:

- Unpacking the technological capabilities of smartphone to capture, process, store, and visualize different types of content and contextual information and their potential applications/contributions in SP-based lifelogging systems for harnessing personal big data archives
- Providing a survey of the available SP-based lifelogging systems by studying their architectures, principal components, sensors, deployments, and lifelog organization
- Demonstrating SP-based lifelogging as a big data application and producing novel taxonomies to classify SP-based lifelogging research and identify research gaps for strengthening the personal big data concept
- Presenting a general architecture for SP-based lifelogging systems using big data systems design principals to increase personal big data trend

- Highlighting potential personal big data applications, opportunities and challenges, and research directions/recommendations in SP-based lifelogging from personal big data perspectives to motivate and help young researchers in finding new research dimensions

Section 12.2 will present a compact discussion of lifelogging history. Section 12.2 will present detailed analysis and review of SP-based lifelogging research. Firstly, the SP technological developments to capture and record daily life experiences and contextual information into a potential personal big data will be highlighted, and technological comparison of SP with dedicated lifelogging devices will be presented. Secondly, an analysis of SP-based lifelogging research/systems producing potential personal big data archives will be presented, and taxonomies of SP-based lifelogging research/systems will be presented to highlight potential research gaps and avenues. Section 12.3 will present SP-based lifelogging as a source of personal big data using big data perspectives. Firstly, the capability of SP-based lifelogging as a big data application and conformance to big data scenarios will be discussed. Secondly, we will introduce a generalized architecture for SP-based lifelogging systems using big data systems design principles. Thirdly, we will highlight opportunities and challenges for harnessing personal big data archives. Finally, we will highlight several future research directions/recommendations to provide research topic to the researchers for increasing personal big data trend. In Sect. 12.4, the conclusion will be drawn.

## 12.2 Lifelogging: Background

Human memory augmentation using technology is not new, rather, it has roots since first drawing is created and first word is written [4]. The earliest lifelogging techniques were based on human manual efforts and were in the form of cave paintings, storytelling, books, and personal diaries. With the passage of time, several automatic lifelogging technologies are introduced for enhancing human memory augmentation, such as Kodak camera in 1888. However, the advent of digital technologies has realized the realm of human memory augmentation and accelerated its practicality and worldwide acceptability. Moreover, the developments and wide availability of computing technologies (e.g., wearable devices and smartphones) have enabled to automatically and digitally keep track of our habits, locations, purchases, routines, social interactions, and sentiments in a variety of formats. The digitally archived personal big data from peoples' behaviors can potentially present new opportunities to gain insight into their behaviors and use the insights to provide effective solutions to the problems facing by the normal people as well as people with memory impairments (e.g., forgetting, distortion, and failure in encoding) [25]. This section gives a brief discussion of the efforts performed in the field of lifelogging to produce personal big data using computing technologies.

### 12.2.1 History of Lifelogging

In 1945, Vannevar Bush published an article "As We May Think" and tossed the idea of an imaginary mechanized device called Memex (memory extender) [26]. Bush postulated Memex as "enlarged intimate supplement to one's memory," which technically means for a mechanized device for organizing lifetime information in similar to human brain and hints for the first lifelogging system [5]. He determined Memex as human memory prosthesis, which will enhance peoples' lives by enabling them for recording, organizing, searching, and exchanging large amount of information produced during their daily life experiences [4, 27]. He also introduced the concept of "camera hound," allowing individuals with head-mounted cameras to capture pictures according to their interests for storing and indexing by the Memex. The Memex proposal was presented almost at the end of the Second World War, which could not be rationalized due to the unavailability of technology at that time. However, researchers rationalized the idea of Memex with the advent and availability of digital technologies. In 1962, Dough Engelbart published the article "Conceptual Framework for Augmenting Human's Intellect," where he cited some of the Memex ideas, such as links between the data objects [28]. He argued that the computer can be used to augment human intellect. The LifeLog project was initiated by the American Advance Project Agency (DARPA) to find ontology-based solution for lifelong information capturing. The prime objective of the project was enabling to trace threads of peoples' life experiences information of event, states, and relationships and combining the information into a timeline [29]. The project was seen worrying and criticized due to DARPA's involvement and its aim to compile a massive database for storing information about peoples' activities and relationships, including purchases via credit card, Web sites browsed, details of phone calls and emails, scans of faxes and postal mails, books and magazines read, television and radio selections, and physical locations recorded via wearable GPS sensor. The LifeLog project was canceled in 2004 due to the criticism from the civil libertarians regarding its privacy implications [29].

### 12.2.2 Lifelogging via Desktop Computing

The advancements in local and online storages have enabled people to accumulate and store vast information regarding their daily life activities, which results into information overload problem and makes storing, arranging, managing, and retrieving of required information increasingly difficult [20, 30]. The Personal Information Management Systems (PIMs) are developed to assist people in collection, management, and retrieving their daily life information and facilitate them in performing their day-to-day tasks to accomplish their needs. The lifelogging systems are inherently PIM systems having the same objectives, but the application of ubiquitous and pervasive computing technologies makes lifelogging different from the PIM systems [20, 30].

Desktop computer has been the prime focus of researchers to produce lifelog archives consisting of detailed record of users' activities on their desktops. The desktop-based lifelogging applications enable the acquisition, management, and organization of users' desktop information and activities and provide effective search mechanisms to retrieve users' lifetime data swiftly. Researchers have hypothesized that recording of desktop activities can bring several benefits, including information access optimization, learning and projecting users' behaviors, time management, helping and facilitating users' processes of searching and browsing their personal information, and assisting users in their reminiscence. In 2001, Gordon Bell of Microsoft started a research project "MyLifeBits" to realize the Memex vision with the aim to create a user's digital archive of all of the information that can be found on his/her PC [1]. He found that one terabyte storage is enough to digitally record a user's lifetime data [1]. The storage module of the system supported various functionalities, including annotations, hyperlinks, queries, reports, search, and clustering. However, the algorithms required excessive explicit users' interventions to annotate different events. With the passage of time, researchers, organizations, and academicians have suggested different approaches and methodologies for effective lifelogging of users' activities on desktops such as LifeStream [31], Stuff I've Seen [32], SemanticLife [33], iMemex [34], DARPA's LifeLog [35], and Advance Soldier System and Information Technology (ASSIST) [36]. The semantic desktops (e.g., NEPOMUK [37], Gnowsis [38], SemanticLife [33], Haystack [39], and IRIS [40]) have leveraged Semantic Web technologies for organizing, managing, and searching data on users' desktop computers and computers in a network. The desktop search engines (e.g., Beagle++ and Stuff I've Seen (SIS) [32]) enable users to quickly search and retrieve their required personal information from their desktop computers and computers in an enterprise network, using a single query in the same way as Web search engines are used for locating information on the Web. However, the desktop-based lifelogging applications are limited to lifelogging desktop activities information, whereas occurrence of significant daily life activities is independent of space and time [20].

Apart from desktop-based lifelogging systems, a number of Web-based lifelogging applications are developed for desktop computers to capture lifelog information from different perspectives and provide facilitation in content-based and context-based information retrieval, summarization, linking, behavior monitoring, memory augmentation, health monitoring, and social network analysis. The Web-based lifelogging applications include ActivityWatch, Semantic Logger, Toggl, RescueTime, and TimeCamp.

### *12.2.3 Lifelogging via Wearable Computing*

Wearable computing, also known as body-worn computing or bearable computing, refers to a set of practices of designing and developing miniature electronic devices. The wearable devices could be worn constantly above or under the cloths to seamlessly extend both mind and body of a user while performing both the general purpose and specific purpose – new and previously unexpected – functions [41]. The idea of wearable computing concentrates on the continuous archival and retrieval of personal experiences (CARPE) approach of lifelogging. Steve Mann tossed the idea of wearable computing and focused on developing small wearable devices with enhanced sensing, capturing, and displaying capabilities for the lifelog information manipulation [42, 43]. He urged using of wearable life-capturing technologies for "sousveillance," which refers to using digitally captured life experiences for self-surveillance. To address problems in wearable lifelogging technologies, Steve Mann produced miniaturized wearable camera technologies such as personal imaging [44] and EyeTap system [45], which served as the foundation for the Google Glass. Visual lifelogging – a subtype of lifelogging paradigm – represents a special type of personal lifelogging, which is fulfilled by using wearable cameras for capturing photos and videos of everyday activities [46]. A wearable lifelog agent system is designed and developed to continuously capture video from wearable camera and data from several other sources (i.e., sensors, and applications) to contextualize the captured videos and make retrieval faster [47]. It is observed that context-based triggering of video recordings and indexing the recorded videos using contexts descriptions can facilitate memory retrieval [47]. A smart wearable goggle system called "Cyber Goggles" is developed to continuously record video of everything that a weaver sees, identify objects in the video and assign names to them, and create an easily searchable database of the recorded videos [48]. In the "CyborGlogger" lifelogging project, Mann and his colleagues have developed a mobile phone application to capture lifelog objects (i.e., videos and pictures), using mobile phone camera, and store and share the captures, using a user's social networking sites or personal homepages in real time [49]. To demonstrate audio lifelogging, a wearable device is developed for creating memory prostheses by recording audio conversation and related contextual information as per users' intentions [50]. The audios of personal experiences are continuously recorded and experimented to show the automatic analysis, indexing, and visualization of the captures [51]. The integration of microphone in glasses and camera in a necklace is demonstrated to record an individual's view of the world [52]. The "Memory Glass" system has used microphone and camera for recordings, and laptop and headphones for output (i.e., both audio and video), and found that time and location contextual information provide valuable clues about users' activities [53]. A semiautomatic system called "familiar" has used sensors (i.e., camera, microphone, and accelerometer) to continuously record data, machine learning algorithms for extracting high-level features form sensors data, and cluster the data and extracted information into events, such as going home, being at work, and shopping [54].

Apart from laboratory research, several commercial wearable lifelogging devices are also floated in the market in the past several years. SenseCam [12] is a ubiquitous wearable camera to capture a series of images automatically for creating a digital record of a wearer daily life experiences using assistance of a number of built-in sensors (i.e., accelerometer, light intensity meter, thermometer, GPS, and passive infra-red (PIR)). The sensors are used to control the images capturing process, and the images are stored in the local storage along with GPS coordinates and timestamps. The SenseCam is rebranded with Vicon Revue, which has additional features of interface for querying and presenting captured information. The Narrative Clip is another commercial lifelogging device that incorporates a small wearable camera for capturing more than a thousand photos in a day using assistance of built-in optical sensor and forwards the captures to the narrative cloud-based server for event segmentation and analysis. A number of projects have used visual lifelogging tools including SenseCam [12] and the most advanced Google Glasses and found them significantly useful for the people with memory disabilities in improving their memory recalls [6, 55]. Several inexpensive wearable commercial products (e.g., Fit Bit OneTM, Nike FuelBandTM, and LarkTM) are available to monitor specific aspects of an individual's life. They integrate basic sensors (i.e., accelerometer, magnetometer, gyroscope) to monitor and log activity levels (e.g., steps count, distance travelled, and caloric output) onboard and subsequently forwards the captures wirelessly to a cloud service via laptop or PC.

Wearable devices have provided a new frontier to the realm of lifelogging and have been justified useful for memory augmentation by the several researchers [55, 56]. However, using wearable devices for lifelogging also faces with certain problems and shortcoming (e.g., uni-functionality) because of either video-based or audio-based, overburdening users that would create hurdles in mobility and performing daily life activities and interactions, increasing cost by purchasing extra devices/hardware and services, and suffering with societal criticisms. In addition, wearable lifelogging solutions are designed to work in a restricted environment (e.g., home, office, etc.). However, the occurrences of most of the daily life events are independent of space and time. Therefore, they cannot fulfill vision of capturing the totality of life experiences. Furthermore, they are constrained in capturing lifelog information (e.g., using of limited number and inappropriate sensors, hard mobility, and no omnipresence) and might not be able to capture relevant information from a reality due to complexities of the physical world [3]. Therefore, they produce personal little data by capturing only a portion of information instead of complete information about an event [57]. It was required that lifelogging functionality should be integrated in devices that are already have the required technologies and are in common use of the people to support capturing and processing of totality of life experiences – personal big data [58].

## 12.3 Smartphone-Based Lifelogging

A SP combines the features of mobile phone and personal digital assistant (PDA) [2]. SPs can fulfill Memex vision and provides capabilities and opportunities to capture "totality of life experiences" by ubiquitously and unobtrusively recording almost every aspect of an individual's daily life actions and events (i.e., incoming and outgoing calls, sent and received messages, images captured, and music listening) and constructing and preserving a lifelong digital memory (i.e., personal big data) [15]. Realizing the technological developments and potentials of SP, a few researches have demonstrated that SP has several advantageous characteristics over dedicated wearable devices (e.g., SenseCam [12]). They have used SP as a de facto lifelogging platform and have developed SP-based lifelogging systems for monitoring lifestyles and activities [18, 58]. Nokia Lifeblog project [23] was the first among the SP-based lifelogging systems. Nokia Lifeblog provided inspiration for many of the subsequent research efforts that resulted into different SP-based lifelogging systems with increasing sensing and logging capabilities, such as Pensieve [59], MyExperience [60], Experience Explorer [17], etc. Each of the research agrees on voluminous capturing and long-term preservation of lifelog information. However, none of them have provided insights of SP as lifelogging device for producing personal big data.

### *12.3.1 Smartphone Technological Developments*

The SP is tremendously improved technologically in the past few years. The SP weight is reduced to improve mobility and portability, while the display size is increased for improved visualization. The battery power is improved to meet the excessive power needs of the SP applications and underlying platforms. The increased battery power enables developers to develop sophisticated applications that are exploiting full potential of SP to solve the complex real-world problems. The SP provide easier and advanced graphical user interfaces that are fully multimedia loaded, easy to navigate, easy to understand, touch-enabled virtual keyboard, and user-friendly. The multi-touch technology is available in the SP to track more than one touch at the same time [61]. The SP processor is improved, and octa-core processors are integrated in SPs to execute complex applications and process large amount of data. Similarly, SP is integrated, with graphical processing unit (GPU) to execute graphical calculations and transformations, and reduces the burden of the central processing unit (CPU) for enhancing performance of the device. The SP mostly has internal data storage capacity up to 512 GB, which is much larger as compared to storages of a few years back and can log digital data about a user's activities, contacts, and calendar data. A SP with 512 GB storage (e.g., Samsung Galaxy Note20 Ultra 5G) provides enough space to store images of personal big data if images are taken with rate of 1.65 million/year for 5 years [2]. The continued advancements and miniaturization in storage technologies have enabled the development of slim, lightweight, and high-volume removable storage metaphors (e.g., microSD, microSDXC, and small form-factor disks) for the SPs. As it was predicted in 2006 [62], the removable storage capacity has reached up to 2 TB in a single card, which is large enough to store digital personal big data of a person's life [1]. The advancements in networking capability have enabled SP to access and exploit the free storage and processing capabilities offered by various cloud services for transferring, storing, and processing excessively a variety of personal big data to create digital memories [18, 19]. In addition to large internal and removable storages, today's SP also supports RAM up to 12GB. The increase in RAM capacity not only contributes in enhancing speed of SP but also provides room for the execution of complex applications/algorithms, including machine learning for big data analytics.

Today's SP is embedded with a significant set of sensors of the same quality and sophistication as external sensors and new sensors are expected to be included in the SPs in the near future [22]. Technically, the sensors can record huge personal big data, whose storing, processing, and transferring are now cheap and affordable due to the advancements in SP. The sensors turn SP into a life-centric sensor to capture different types of content and contextual information to effectively show individuals' daily life activities and events, such as where we go, what we do, who we meet and communicate, and what information we use [22]. For example, accelerometer, magnetometer, and gyroscope can monitor physical activities and body movements; GPS and RSS can measure indoor and outdoor locations with acceptable accuracy; camera can capture images and videos; Bluetooth can provide information about other devices/objects in a vicinity (i.e., whom we near); microphone can infer what is happening around people; RFID can provide information about objects in contact [63, 64]. SP sensors can be divided into four broad categories: physical sensors, logical sensors, informational sensors, and application sensors [65]. Physical sensors are hardware components physically provided in a SP, such as accelerometer, gyroscope, GPS, Bluetooth, WiFi, etc. Logical sensors are software sensors that are formed by fusing data from more than one physical sensor, such as e-compass is formed by combining magnetometer and accelerometer. Informational sensors (also called desktop sensors) are SP applications, which contain information about users' activities and events, such as calendar app and Personal Information Management (PIM) applications. Application sensors represent a wide variety of applications, which are used to produce lifelog objects and store information about users' interactions, such as applications for Web browsing, SMS, voice calls, contacts, email, weather reporting, and audio/video recording. However, it is very difficult to clearly distinguish sensors belonging to the different categories. There is a strong possibility that sensors might be belonging to different categories but could be used for the same purpose. For example, WiFi and GPS are inherently different sensors; however, both of them can be used for users' localizations. The SP sensors has several advantages over wearable sensors [22, 66] including the following: (1) small and combined into a single holistic device that will not interfere with our everyday activities, (2) supported by enough battery power to work continuously for at least a day, (3) robust and unobtrusive to work in hard environmental conditions such as moisture and humidity, (4) tolerant to drifts in calibrations, and (5) onboard enough storage support to hold data for days at least. An overview of the physical sensors commonly available in SPs is shown in Table 12.1. Apart from these sensors, smartphone models have explicit logical sensors, such as iPhone and Huawei have Face ID

**Table 12.1** Comparison of sensors available in smartphones

| | Net. tech[a] | | | Sensors[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Smartphone model | A | B | C | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Apple iPhone 12 Pro Max | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ |
| Samsung Galaxy Note 20 Ultra 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Samsung Galaxy S20+ 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| OnePlus 8 Pro | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Google Pixel 4A 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Motorola Moto G9 Power | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ |
| VIVO V51 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Huawei P30 Pro New Edition | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Alcatel 3X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Oppo A33 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Realme C15 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ |
| Xiaomi Poco X3 NFC | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✗ | ✓ |
| Asus ROG Phone 3 ZS661KS | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Samsung Galaxy S20 FE 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Huawei Mate 40 Pro | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Samsung Galaxy A51 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| LG Wing 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Sony Xperia 5 II | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Asus Zenfone 7 Pro ZS671KS | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✓ | ✓ | ✓ |
| Xiaomi Mi 10T Pro 5G | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

[a]*Networking technologies*: A-4G/5G, B-Bluetooth, C-WiFi
[b]*Sensors*: 1-microphone, 2-camera, 3-A-GPS, 4-accelerometer, 5-proximity, 6-compass, 7-barometer, 8-gyroscope, 9-fingerprint, 10-GLONASS

sensor; Samsung has ANT+, pedometer, and SpO2 sensors; and Huawei and Sony have a color spectrum sensor. An overview of the potential applications of SP sensors for capturing lifelog information is shown in Table 12.2. A comprehensive survey of potential applications of SP sensing capability for solving variety of real-world problems in different domains is articulated in our previous work [66].

The advancements in capturing, processing, and storing enable SP-based lifelogging to generate and long-term preserve personal big data by fulfilling the four fundamental elements of a big data scenario: (1) gathering of a large volume of data; (2) handling a variety of heterogeneous data sources (e.g., primary data from sensors and secondary data from semantic analysis of the primary data); (3) tolerating and affording and noticing minute variations in patterns occurring in a data stream or information source, and identifying patterns and changes in real time; and (4) identifying and esteeming accuracy of the captured data, which may be introduced due to the issues of calibration and drift in sensors. Thus, SP can provide an effective platform to create and route personal big data to gain real-world advantages.

**Table 12.2** Potential applications of smartphone sensors for lifelogging

| No | Categories | Sensors | Applications in SP-based lifelogging |
|---|---|---|---|
| 1 | Position sensors | Proximity sensor | Perceives occurrence of any object without being in physical contact in different systems such as logging of navigation patterns and obstacle detection especially for blind people in a closed proximity |
| 2 | Acceleration sensors | Accelerometer sensor | Measuring/capturing of position using acceleration forces, both static and dynamic, and orientation using angular momentums (i.e., roll, pitch, and yaw) for logging a powerful array of information about multitude of physical activities (i.e., jogging, walking, running, driving, stair up and down, etc.), traffic accidents, games, and falls |
| | | Gyroscope sensor | |
| 3 | Thermal sensors | Temperature sensor | Measuring of temperature changes (i.e., heat, and cold) generated by an object or in the external environment for logging information about body heat of users in performing physical activities such as jogging and running, environmental heat relevant to an event such as image or visit of a place |
| 4 | Optical sensors | Camera sensor | Capturing still photos or videos of users or objects in surrounding environment for logging visual information about an event such as farewell party of a senior student in a university |
| 5 | Light sensors | Ambient light sensor | Mimics human eye to work under ambient light conditions by measuring light intensity of surrounding environment for logging information about an event such as tour to a historical place or help other sensors such as camera sensor to adjust light while capturing a photograph |
| | | Back-illuminated sensor | |
| 6 | Localization and comm. sensors | NFC sensor | Establishing communication between mobile devices by either touching or bringing them very close to each other for sharing lifelog data (e.g., photos, videos, and audios) locally and logging information about indoor users' localizations or electronic payments |
| | | WiFi sensor | Capturing information about nearby WiFi access-point and GSM cell tower finger prints (e.g., signal strength, cell tower ID, and SSIDs.) for sharing lifelog data remotely and logging information about indoor and outdoor battery effective users' localizations and tracking movements of users |

(continued)

**Table 12.2** (continued)

| No | Categories | Sensors | Applications in SP-based lifelogging |
|---|---|---|---|
| | | GSM sensor | |
| | | GPS sensor | Capturing geo-location and time information from GPS satellites for logging information about indoor and outdoor users' localization |
| | | Bluetooth sensor | Capturing of identity information about other Bluetooth-enabled objects in a user's proximity, logging information about indoor user localization, and sharing of lifelog data locally |
| 7 | Direction sensors | Digital compass sensor | Capturing of information about the strength and direction of north of a smartphone to give the right direction with respect to the north-south pole of Earth by using Earth's magnetic field for logging information about directions of events, such as directions of users' physical activities (e.g., running, and driving) |
| 8 | Altitude sensors | Barometer sensor | Measuring of atmospheric pressure information above the sea level for logging information about short-term weather changes and altitude about events such as tracking of a hike in an unfamiliar territory |
| 9 | Medical sensors | Heart rate sensor | Measuring of users' physiological information for logging information about heart rate, breathing, blood pressure, blood oxygen level, skin temperature and condition, and pulse rate |
| | | biosensor | |
| 10 | Acoustic sensors | Microphone sensor | Measuring/capturing of voice information either produced by objects in a proximity or by users for logging voice information about events such as voice conversations, environmental noise pollution, and traffic accident |
| 11 | Time sensors | Clock sensor | Capturing of timing information from smartphone internal clock for logging information about events such as time of image capture |

## *12.3.2 Context Sensing*

The user context represents a set of information describing the condition or position of a user, such as location, activity, environment, and preferences [21]. Devices capable of understanding users' contexts fit into the vast framework of context awareness. Context awareness refers to the capability of a system to automatically adopt itself according to a user's context, by providing appropriate information and services without requiring his/her active interactions [21]. Technically, lifelogging systems are context-aware pervasive systems with certain extensions [18, 19] that emphasize on passive and continuous capturing of contextual information from users' environments for assisting users in recalling their past experiences information. However, features of archiving lifelog data for long-term access and always running in the background to not miss anything important make lifelogging a step ahead than context-aware systems [19]. A context can be either subjective or objective. Subjective context refers to information related to a person's feelings, interests, and attentions. For example, physiological data about heart rate, skin conductivity, and brain wave. Objective context refers to information about outer world around a person. For example, data about spatial-temporal, objects, behaviors, comments, and documents. Memory prostheses believe in the importance of context over content and have articulated that wise capturing of variable contextual information can provide powerful cues about users' activities and actions. These cues provide human memory augmentation and indexing of lifelog information automatically to ease the recall of past experiences information from our personal digital memories/libraries [67, 68].

The lifelogging systems have used sensors as the core component to capture contextual information [19]. As discussed earlier, the sensors extend the capability of SP-based lifelogging systems to capture both the contents (i.e., lifelog objects) and contextual as well as environmental information to generate a huge personal big data. Specifically, a wide variety of contexts can be captured by SP-based lifelogging systems using sensors, including textual information, multimedia information (i.e., pictures, audios, and videos), environmental information (i.e., light, temperature, humidity, and pressure), bio-information [69, 70] (i.e., heart rate, galvanic skin response, and blood pressure), spatial information (i.e., location, cellular location, Bluetooth proximity, WiFi signal, etc.), and motional information (i.e., acceleration and orientation) [71]. The captured contextual and environmental information can be used by the lifelogging systems to automatically annotate and structure the recorded data to facilitate user-friendly retrieval [63]. A comprehensive survey of using SP sensing capability for contexts capturing and context awareness is presented in our previous research work [21]. The research has mainly used individual SP sensors for identifying simple primary contexts (e.g., temperature and humidity) and has fused data from multiple independent SP sensors for identifying complex primary contexts (e.g., activities and events). Similarly, secondary contextual information can also be identified by using dependent contextual information from other people, if available and accessible. For example, the state of a person at home can be identified by using contextual information of his wife. However, fusing sensors' data requires careful data cleansing, alignment, and temporal normalization [5]. The following paragraphs present a swift discussion of the research, which have used SP sensors for capturing different types of contents and contextual information for harnessing personal big data.

#### 12.3.2.1 Passive Video and Audio Contexts

The most widely used capturing device in lifelogging system is the digital cameras (i.e., visual lifelogging), which are used as wearable devices to capture still images and videos [23, 45, 72, 73, 74]. Researchers have recognized that the use of

**Table 12.3** Overview of using SP sensors for passive visual and audio contexts capturing

| Publication | Sensors | Context |
|---|---|---|
| [17] | Camera | Pictures |
| [23] | Camera | Pictures |
| [79] | Camera | Pictures |
| [59] | Camera, microphone | Pictures, audios |
| [58, 76] | Microphone | Audios |
| [15] | Camera, microphone | Pictures, audios |
| [19] | Camera, microphone | Pictures, audios |
| [18] | Camera, microphone | Pictures, audios |
| [24] | Microphone, camera | Pictures, audios |

images and videos can be very useful for people to remember the contexts of memories [75]. Using SP camera and microphone sensors for visual and audio lifelogging, respectively, is as effective as using of specialized or proprietary lifelogging devices [23, 58, 76]. Images captured using smartphone camera are found as valuable as images captured using SenseCam [58], and a real-time visual lifelogging solution using SP is developed by [77]. Lifelogging systems with audio-based recording devices (i.e., microphone), either built-in smartphone or wearable, are also employed in some research to continuously record audios of events and activities [14, 78]. The recorded audios include speeches, music, conversations, and environmental sounds. To reduce the time-consuming task of searching a specific segment of sounds in a long recording, the researchers have conducted experiments of dividing a large audio clip into smaller ones and performing speech recognition transcripts. The clips are annotated with required semantic tags for indexing and are compressed for archiving into large database without sacrificing user comprehension [14, 78]. Researchers have promoted that audio logging can be helpful in recognizing objects (e.g., location, type of activity, and individuals in a proximity) using voice pattern matching or words/phrases used in a conversation [5]. A swift overview of the research that used SP sensors for passive visual and audio contexts capturing is shown in Table 12.3.

**Location Context** Location information, despite of its insufficiency to completely describe the semantics of an event, still have attracted attention of the researchers as reported in [80]. Location is a primitive context that can be used by computing agents to determine a user's current task and could be potentially used to develop a predictive model of his future movements. The Active Badge system has used location information for the design of memory aid systems and could provide powerful cues for prosthetic memory [81]. The smartphone includes a rich set of sensors (i.e., GPS, WiFi, and GSM) for determining location of a user accurately. Among all of the location tracking devices, Global Positioning System (GPS) is the preferred choice of researchers due to its accuracy and infrastructure-free nature [47, 82]. Researchers have found that using of GPS for estimating users' location contexts is not only useful in memory reconstruction but also in correct and flexible responses to different types of lifelog information retrieval queries [6, 47, 83] from a personal big data archive. Another potential application of GPS is building detection, which could be interpreted by the absence and presence of GPS signals. To overcome the problems associated with GPS (i.e., satellite signals weakness, unavailability inside buildings and vehicles, and greater battery power consumption), WiFi-based and GSM-based localizations have been introduced [83, 84]. However, obtaining accurate location information from WLAN scanning and cellular tower identification is complicated due to a number of shortcomings, including signal strength, multipath distortion due to number of cell towers within a range, connectivity with multiple cell towers at the same time, and time duration of stay at a location. To solve these issues and the power consumption issue, location is estimated by combining different ways of localizations techniques for indoor and outdoor [17, 64]. Bluetooth sensor is suggested as an indoor localization indicator, by detecting nearby devices/objects and people in a proximity, and can be used to gather social presence information [84, 85]. Information from either GSM cell tower or GPS can be used in combination with Bluetooth information for accurate localizations, both indoor and outdoor [79, 84]. In addition to localization, information obtained from Bluetooth scanning can be used as contexts of the people in proximity [71]. In an experiment in MIT, event similarities and deep social patterns in users' activities are diagnosed by analyzing Bluetooth presence, duration, and familiarity. A combination of all of the localization techniques (i.e., GPS, WiFi, GSM, and Bluetooth) is also suggested for fine-grained localizations even in case of absence of GPS [17]. An abstract view of the different localization techniques used by the different relevant research is shown in Table 12.4.

**Table 12.4** Abstract view of localization techniques using SP sensors

| Sensors | Publication | Platform | Localization scope |
|---|---|---|---|
| GPS | [86] | Garmin Model 35-LVS GPS | Outdoor |
| GPS | [47] | Not mentioned | Indoor and outdoor |
| GSM | [83] | Smartphone Nokia s60 | Indoor and outdoor |
| WiFi and GSM | [87] | Smartphone | Indoor and outdoor |
| GSM and Bluetooth | [84] | Smartphone Nokia 6600 | Indoor and outdoor |
| Bluetooth | [85] | Smartphone | Indoor |
| Bluetooth and GPS | [82] | Smartphone and SenseCam | Indoor and outdoor |
| GPS, WiFi, and GSM | [80] | Smartphone Nokia N95 | Indoor and outdoor |
| GPS, WiFi, Bluetooth, and GSM | [17] | Smartphone | Indoor and outdoor |
| GPS | [6] | SenseCam and eTrax Legend HCx GPS unit | Outdoor |
| GPS and WiFi | [15] | Smartphone Nokia N95 | Indoor and outdoor |
| GPS and Bluetooth | [79] | Smartphone Mobile Phone | Indoor and outdoor |
| Accelerometer Gyroscope Magnetometer | [88] | Smartphone | Indoor |
| Accelerometer Gyroscope Magnetometer Camera | [89] | Samsung Galaxy S8 and LG G6 | Indoor |

**Physical Activities Context** Recognizing human physical activities or special motions is one of the most important concerns in lifelogging systems that can be essentially used for automatic annotation of lifelog information [63]. Automatic activity recognition has been the topic of research since years, and researchers have demonstrated its feasibility using wearable sensory technology. However, attaching multiple sensors to the body could produce hurdles in physical activities' performance and cumbersome to use too. The integration of sensors in SPs has provided a novel platform for the researchers, and a variety of methods are proposed over the time with effective results. Out of the plethora of research, accelerometer has been proven as the most information rich and most accurate sensor for automatic activity recognition. Accelerometer has been used in most of the SP-based human activity recognition and classification research due to its inexpensive and effective characteristics. The accelerometer is either used individually for simple activities recognitions or is used in conjunction with other SP sensors (i.e., microphone, gyroscope, magnetometer, GPS, and pressure sensors) to recognize complex activities effectively. Data from multiple sensors is fused either at raw level or at higher level to recognize activities depending on an application's objectives. For example, data from accelerometer, light, microphone, and GPS can be fused to identify the sleeping activity of a person. Furthermore, SP capability of connectivity with external sensors in smart homes can also capture and infer information about users' presence in homes using infrared sensors and pressure sensors in chairs and beds and indoor activities by monitoring electricity, gas, and water consumption in homes [5, 90]. A number of classifier algorithms are implemented by the researchers in SP-based human activity recognition systems. Some researchers have used a single classifier, whereas others have used multiple classifiers to create multilayer or hierarchical classification scheme. A comprehensive review of SP-based human activity recognition research is presented in [91] and [92]. An abstract level comparison of SP-based activities recognition research is show in Table 12.5.

**Personal Biometric and Environmental Contexts** There are several contexts that can provide key indicators about a user body, behavior, and environment during his/her daily life activities and actions. However, their nature varies from domain to domain. For example, automatic health monitoring systems would be interested in capturing physiological subjective contexts (e.g., number of steps taken, distance travelled, caloric expenditure, and sleep duration and quality) for presymptomatic testing, whereas automatic air pollution monitoring system would be interested in capturing objective contexts (e.g., level of CO in the air) for determining ambient air quality.

The SP sensors (i.e., accelerometer, magnetometer, and gyroscope) are used for automatic and continuous sensing of accessing mental health, academic performance, and behavioral trends of a person [93]. In addition to SP sensors, several domain specific sensors are available (i.e., sensors for heart rate, blood pressure, ECG, and NOx) that can capture respective information from users' subjective or objective contexts and provide to SP for processing, analysis, and decision-making. For example, a number of SP-based health monitoring systems are developed, which

**Table 12.5** Abstract level comparison of SP-based activity recognition research

| Publication | Sensors | Activities | Classifier | Platform |
|---|---|---|---|---|
| [96] | A | WL, RUN, WU, WD, STI, BI, DR | DET | Samsung Galaxy Y |
| [97] | A | WL, ST, SIT, RUN, BI, DR, PH | DET | Samsung Galaxy Mini |
| [98] | A, G, M, GS, LA, OS | WL, ST, SIT, RUN | NB | Google Nexus S |
| [99] | A | WL, ST, SIT, RUN, WU, WD, LA | SVM | Samsung Galaxy S2 |
| [100] | A | WL, JOG, WU, WD, BI | SVM and KMC | HTC Nexus |
| [101] | A | WL, ST, RUN, WU, WD, JM | PNN | LG Nexus 4 |
| [102] | A, M | WL, JOG, WU, WD, STI, BI, ELU, ELD | DET and PNN | Samsung Nexus S |
| [103] | A, G, M | WL, RUN, WU, WD, STI | SVM | Android Smartphone |
| [104] | A, PS, Mic | WL, RUN, WU, WD, BI, DR, VH, JM, ELU, ELD, VA, WTV | SVM | LG Nexus 4 |
| [105] | A, G, LA | ST, JOG, SIT, BK, TY, WR, WL, WU, WD, CF, TL, SM, ET | KNN and DET | Smartphone |
| [106] | A, G | WL, WU, WD, SIT, ST, LA | SAE | Samsung Galaxy S II |
| [107] | G, A, T, H | SIT, WL, JOG, LA, WU, WD, CY, ST, SQT, FL | | |
| [108] | A, CS, G | LA, SIT, ST, WL, WU, WD | RF and MRF | Smartphone |
| [109] | A, GPS | SIT, WL, RUN, CY, VH | CNN and RF | Smartphone |
| [110] | A, G | WL, WU, WD, SIT, ST, LA | DET, SVM, KNN, EC | Smartphone |
| [111] | CA | WL, JOG, RUN, BX, HW, HC | CNN and SVM | Smartphone |
| [112] | A, M, G, B | STI, WL, WU, WD, ELU, ELD, UE, DE | CNN | Smartphone |
| [113] | A, G, M | ST, SIT, LA, WL, RUN, CY, BT, WU, WD, ELU, ELD, SOT, STOT, VH | Ontology | Nexus 5X and LG Watch |

*Sensors:* A-accelerometer; M-magnetometer; Mic-microphone; G-gyroscope; PS-pressure sensor; GS-gravity sensor; LA-linear acceleration; OS-orientation sensor; B-barometer; T-temperature; H-humidity; CS-compass; GPS-Global Positioning System; CA-camera
*Activities:* WL-walking; ST-standing; SIT-sitting; JOG-jogging; RUN-running; WU-walking upstairs; WD-walking downstairs; STI-still; BI-biking; DR-driving a car; VH-in vehicle; JM-jumping; ELU-elevator up; ELD-elevator down; VA-vacuuming; LA-laying; PH-phone on table/detached; WD-washing dishes; IR-ironing; BT-brushing teeth; HD-hair-drying; FTT-flushing the toilet; SQT-squatting the toilet; BD-boarding; WTV- watching TV; UE-up escalator; DE-down escalator; TR-turning; CY-cycling; SOT- sitting on transport; STOT-standing on transport; FL-fallen down; BK-biking; TY-typing; WR-writing; CF-coffee; TL-talking; SM-smoking; ET-eating; BX-boxing; HW-hand waving; HC-hand clapping; unknown
*Classifier:* DET-decision tree; SVM-support vector machine; KNN-K-nearest neighbor; NB-naive Bayes; KMC-K-medoids clustering; PNN-probabilistic neural network; CNN-convolutional neural network; RF-random forest; MRF-modified random forest; SAE-stacked autoencoder; EC-ensemble classifier

are using SP sensors in combination with specialized medical sensors (biometric sensors) to help users in collecting information about their physiological changes that occur during various times of a day and during various daily life activities for detecting any abnormality and symptoms, such as MobiCARE Cardio [94], UbiFit [95], etc.

Similarly, SP sensors provide indicators about environmental conditions and phenomenon present and happening in a user environment, for example, identifying temperature value using temperature sensor, identifying people in vicinity using SP Bluetooth sensor, and continuous audio and video recordings to track peoples' activities in an office or home.

**Communication Activities and Interactions Contexts** SP supports several communication activity types, such as SMS messages, MMS message, audio phone calls, video phone calls, social networking activities, and email messages. Together, recording them can constitute a big part of a personal big data. Support of the general-purpose operating systems enables developers to develop numerous tools for digital recording of contents and information about communication activities on SP. There are several applications available to support recordings of SMSs, phone calls, Web browsing, and social networking histories. An advantageous characteristics of communication activities logging is that the information to be captured is already in the text format, therefore having less semantic gap between its contents and meanings. Apart from these, monitoring and capturing of users' general activities and interactions on smartphones can also constitute a part of their lifelogs' personal big data. SP apps can capture users' general SP activities and interactions using keystroke inputs and via screenshots to measure and analyze their intellectual activities, for example, monitoring and logging Web access and activities information.

### *12.3.3 Smartphone Versus Dedicated Lifelogging Devices*

The use of Microsoft's SenseCam [56] in the preventive medicine has produced promising results. However, the widespread adoptability of SenseCam is affected due to its purchase, maintenance, and operating procedures. It was proposed that large-scale adoptability of lifelogging trend would be improved, if SenseCam functionalities are integrated in devices, which are already prevalent and users are accustomed of charging and maintaining them. As discussed earlier, an obvious choice in this regard is the SP technology. Gurrin et al. [58] have experimented of using SP as SenseCam replacement in 2012. It is observed that the reduction in size and weight of SP has reached its "wearability" to SenseCam. In the experiment, they have developed a SP application that works similarly to SenseCam by taking pictures during daily life activities accurately and meaningfully. Similarly, annotation data is sampled from SP built-in rich set of sensors and external sensors as compared to SenseCam. Furthermore, the processing and storage capabilities

**Table 12.6** Comparison of Narrative Clip 2 and Samsung Galaxy Note20 Ultra 5G smartphone

| Properties | | Narrative Clip 2 | Samsung Galaxy Note20 Ultra 5G |
|---|---|---|---|
| Camera | Sensor | 8MP | 108MP |
| | Aperture | f/2.2 | f/1.8 |
| | Resolution (aspect ratio) | 3264 x 2448 pixels (4:3) | 1440 x 3088 pixels (21:9) |
| | Output format | JPEG | JPEG, PNG |
| | Video capture | Full HD 1080p | 8K@24fps, 4K@30/60fps, 1080p@30/60/240fps, 720p@960fps, HDR10+ |
| Body | Dimensions (mm) | 36 × 36 × 12 | 164.8 × 77.2 × 8.1 mm |
| | Weight (g/oz) | 19/0.67 | 208/7.34 |
| Connectivity | | USB, WiFi, Bluetooth | USB, WiFi, Bluetooth, GSM, NFC |
| Memory | Internal | 8GB | 512GB |
| | Removable | No support | 1TB |
| Battery | | 315 mAh | Li-Ion 4500 mAh |
| Sensors | Accelerometer | Built-in | Built-in |
| | GPS | Built-in | Built-in |
| | Magnetometer | Built-in | Built-in |
| | Gyroscope | Built-in | Built-in |
| | Microphone | No support | Built-in |

of SP are used to provide the analysis power for supporting a broader range of lifestyles and behaviors. The captured pictures were found of sufficient quality, and analyzing them using automated machine-vision technique resulted in the identification of a range of lifestyle concepts. Conclusively, results of the experiment showed feasibility of enhanced replication of SenseCam functionalities on SP. However, improvements in the SP's battery power and camera technologies were highlighted at the time of experiment (i.e., 2012), which has been significantly improved. For example, Samsung Galaxy Note20 Ultra 5 g has 4500 mAh battery and 108MP rear camera and 10MP front camera. Certainly, today's SP is much faster and sophisticated as compared to a year-old SP. Therefore, based on the argument, repeating the same experiment using today's SP would definitely produce much better results over SenseCam and other visual-lifelogging metaphors (e.g., Narrative Clip 2). Narrative Clip 2 is the advanced version of SenseCam. A compact resource-wise comparison of Narrative Clip 2 and Samsung Galaxy Note20 Ultra 5G SP is shown in Table 12.6. SP has rich list of features; however, comparison is restricted to dedicated lifelogging device features only. The comparison shows that SP has far more superior qualities than Narrative Clip 2, hence making SP a suitable replacement of dedicated lifelogging devices for lifelogging.

### *12.3.4 Smartphone-Based Lifelogging Research*

Realizing the technological advancements of SP, a few researchers have presented SP-based lifelogging solutions by either exploiting the entire set of capabilities (i.e., sensing, processing, storing, and networking) of SP or using SP in conjunction with wearable devices or remote computing infrastructures. SP users have already witnessed the first generation of SP lifelogging apps (e.g., Saga, Moves, and Rove) developed by the different organizations/researchers for passive capturing and archiving of specific types of life experiences and contextual and environmental data. For example, Saga and Move passively capture and generate lifelog of users' daily life activities data only but do not capture visual contents. In addition, several apps (e.g., Instant, Loca, FitTime, Sleepy, and RescueTime) can be downloaded from the app stores, which are mainly logging users' daily life information about fitness, locations and places visited, sleep duration, weather, and tracking programs usage on device.

**Smartphone-Based Lifelogging Systems** This section presents a quick discussion of the SP-based lifelogging systems by describing their functionalities, composition of the personal big data produced, and the retrieval methods used. However, the discussion is limited to the systems that are available in the research publications, and apps are not included due to the unavailability of their technical details. A satellite view comparison of the on-hand SP-based lifelogging systems is shown in Table 12.7.

*Nokia Lifelog Nokia Lifeblog is an earliest SP-based lifelogging system that was developed by Nokia as a commercial application for PCs and Nokia N-series SPs* [23]. *Nokia called it "multimedia diary" that automatically records personal multimedia contents (*i.e.*, images, videos, text and multimedia messages, and sound clips) and enhances them with reliable metadata information. The electronic diary is expected to help users in collecting, finding, organizing, sharing, and archiving personal contents in an effortless way. SP is used for life data recording, enhancing, viewing, and sharing tool. The personal computer is used for enhance data archiving, viewing, and searching tool. Nokia Lifeblog automatically collects metadata and contextual information for each of the collected items (*i.e.*, data, time, description, cellular network information, country name, calendar events, and full contact information), which is stored in a database along with lifelog contents information. All of the collected items are organized into a timeline using the metadata and contextual information to facilitate their browsing and searching. Personal digital contents can be shared from timeline to online images album (*i.e.*, Flicker) and blogging service (*i.e.*, Typepad).*

*iRemember iRemember* [76] *is audio-based memory tool and assumes that fragments of recorded data can be used to trigger forgotten memory for solving everyday memory problems. Software is developed for PDAs (Personal Digital Assistants) to continuously record users' everyday audio conversations from built-in as well as external microphones. The recorded sounds are transmitted to large capacity server*

**Table 12.7** Satellite view comparison of smartphone-based lifelogging systems

| Publication | Sensors | Contexts | Contents | Annotations | Storage | Sharing | Retrieval |
|---|---|---|---|---|---|---|---|
| Experience Explorer [17] | GPS, WiFi, GSM, Bluetooth, camera | Location, time, neighborhood, keywords | Pictures | Semiautomatic | Database – MySQL | Yes (Flickr photo service) | PC – Timeline |
| Nokia Lifeblog [23] | GPS, camera, metadata | Time, location, object name, phone number | Pictures, videos, SMS, MMS, notes, blogs | Automatic | SQLite | Yes (Typepad) | Mobile phone and PC – timeline |
| Memory Book [79] | GPS, Bluetooth, camera, metadata | Location, time, neighborhood | Pictures, text | Automatic | RDF | Not available | WWW – timeline |
| Pensieve [59] | Camera, Mic | location, time, metadata | Pictures, audios | Semiautomatic | Lucene Indexer | Yes | PC – Web UI |
| iRemember [76] | Mic | Time | Audios | Automatic | Not available | No | PC – timeline |
| Mobile Lifelogger [15] | Accelerometer, GPS, camera, Mic, WiFi, rotation | Location, time | Pictures, audios, activities | Semiautomatic | Not available | No | WWW – Timeline |
| UbiqLog [19] | Not available | Location, time | apps, SMSs, pictures, calls | Semiautomatic | Not available | Yes | Smartphone – timeline |
| SenseSeer [18] | Not available | Not available | Not available | Not available | Cloud | Yes (cloud) | Smartphone, WWW |
| Digital Diary [24] | GPS, camera, infrared | Location, neighborhood | Pictures, audios | Automatic | SQLite | Yes (cloud) | Smartphone – timeline |
| SoundBlogs [14] | Mic, GPS | Location, time | Audios | Automatic | Not available | Yes | Smartphone |

*(a user's computer) wirelessly where all audio recordings as well as associated data are archived and converted into text using automatic speech recognition (ASR) tool. The recordings are augmented with the related metadata (*i.e., *location, calendar event, email, local weather, and news services) to improve their quality for memory recall. Using PC as a retrieval tool, users can perform keyword-based searching to locate required information in the entire collection of recorded data and results are displayed as a ranked list and on a timeline.*

*Pensieve* *Pensieve* [59] *augments human episodic memory by capturing experiences cues. Users manually capture experiences by taking pictures and recording audios using SP's camera and microphone. The recorded data is annotated with date and time automatically and location manually. The metadata is extracted from the captures for dividing them into context and more fine-grained sub-context groups as a result of connecting SP with a PC. The captures are processed using optical character recognition (OCR) and speech recognition engines to extract text and additional information. The captures are annotated with the collected and extracted information, applications are updated accordingly (*e.g., *entering of event in calendar, and to-dos lists), and indexed in Lucene. Users can query the index for searching and browsing the relevant captures. Pensieve also includes sharing features by enabling users to share their information with others for advantages such as social tagging.*

*Experience Explorer* *Experience Explorer* [17] *uses SP sensors and interfaces to collect contextual information in addition to user-generated content using the device's camera. The contextual information collected includes: location* via *GPS coordinates, proximity information* via *Bluetooth, indoor location* via *WLAN, cellular network cell ID, and date-time. The context information is periodically uploaded to context database on a network. User-generated contents are hosted form SP on online social media sharing service (*e.g., *Flicker) to be shared with a user's social connections. User interface is provided on PCs for requesting and visualizing the content-context relation form the explorer service. Explorer service collects context and content metadata information from context database and media sharing service for answering clients' retrieval requests.*

*Mobile Lifelogger* *Mobile Lifelogger* [15] *provides digital memory assistance by indexing a large lifelog dataset using activity language. Activity language formed using sensory data. The framework consists of mobile client, application server, and user interface. The mobile client application is developed for Symbian-based Nokia N95 SPs which are mounted on a user's helmet. The client records various sensors data including accelerometer, GPS, camera, microphone, WiFi signal strength, and rotation sensor. The sensory data is recorded along with their timestamps. The application server consists of components for preprocessing, mapping sensors data into activity language, saving data in database, activity corpus indexing, hierarchical activity segmentation, and finally retrieving and labeling of the similar current and past activities of a user. The Web Interface enables users to browse and search their lifelog information.*

*MemoryBook MemoryBook* [79] *automatically generates lifelogging narratives from the large and varied lifelogging data and enriches narratives by extracting information from the Semantic Web knowledge stores for showing additional information about people, places, and things. A narrative generated would be composed of information relevant and associated with an event such as geographical locations and images. Imouto is a lifelogging system developed for SPs and PDAs for collecting sensors data (*i.e.*, GPS, Bluetooth, and WiFi) for inferring locations of a subject. Viewer application processes the raw data by segmenting it into events and extracts information from datastores (*i.e.*, DBPedia, GeoNames, and YAGO2) in LOD to produce rich visualization of events in a user's day. MemoryBook has a Web-based interface that allows users to query RDF data using time range (*i.e.*, days, weeks, or months) for generating narratives and output would be displayed as a Web page comprising of narratives along with related images, maps, weather information, and hyperlinks.*

*SoundBlogs SoundBlogs* [14] *enables to continuously record audios of long and short durations. Long duration audios can be feed into PC for feature extraction, segmentation into chunks of smaller clips, annotating clips with relevant semantic and audio tags (*i.e.*, location, movement patterns, data, time, and calendar appointments), and archive sound clips along with related tags. The archived clips can be searched using keywords search and resultant sound clips are displayed as icon on a map using the location information. Selecting icon would prompt for listening of audio clip provides a brief description of audio clip, and sharing of the audio clip. Searching for a specific audio clip will not only display the audios that match the keyword but will also display the other audios recorded on the day with their locations. The archived audio recordings can be instantly blogged and shared with friends and colleagues.*

*UbiqLog UbiqLog* [19] *is a generic, lightweight, configurable, and extendable lifelogging framework for SPs. The framework emphasizes on sensors as core component of the lifelogging process and offers a novel open architecture which is flexible in terms of enabling users to configure sensors (*i.e.*, enabling/disabling of sensors and changing sensors settings) and adding/removing of sensors according to their needs. A specifically designed data model for lifelogging is proposed to further aid the flexibility feature of the framework. The architecture is generic and relives from the difficulties associated with custom-built systems. The developers are enabled to develop applications using the framework on any device having computing features such as e-book reader, smart TVs, tablets, and SPs for different use-cases. Using the proposed framework, an Android based prototype is developed with data capturing, visualization, and searching features. The implementation is evaluated and results are found promising. The framework, however, has emphasized on data collection stage of lifelogging and has not considered semantic analysis of the gathered data and users' digital reflection methods.*

*SenseSeer SenseSeer* [18] *is a generic mobile cloud-based framework which uses SP for data collection and stores data on a cloud server. The framework extends* *the design principles of UbiqLog* [19] *with back-end side with customizable analytic services for persons sensing, understanding semantics of life activities, and easy deployment of analytic tools with new interfaces. The framework is divided into three engines: collection engine, capture engine, and semantic engine. Collection engine is similar to UbiqLog* [19] *and collects multi-sensors data for uploading to the cloud. Capture engine is a Web service in the cloud for storing received data from SPs into correct format and organization. Semantic engine is another Web service which uses a number of reasoning, machine learning, and statistical algorithms for data analytics and semantic extraction. SenseSeer can provide services in different domains including personal health monitoring, location tracking, and lifestyle analysis. Semantic extraction is emphasized in the framework but no proper mechanisms or technologies have been defined for semantic extraction to evaluate viability of the framework.*

*Digital Diary* *Digital Diary* [24] *is a SP- based system that performs both the functions of capturing and retrieving lifelog information. The system captures lifelog information in the form of images and audio clips. A picture is taken after every half minute and a sound clip of 10 seconds is recorded in every minute. The captured lifelog information are stored temporarily locally and is uploaded to a cloud storage. To help in retrieving, the captured lifelog information is associated with three context elements: location, nearby person, and nearby objects. Location is estimated using a SP's GPS, nearby person is identified using external infrared, and nearby objects are identified by employing computer vision techniques on a camera captured image. Evaluation showed that context elements are very help in recalling past experiences. However, nearby person is most desirable context element for recalling memories of meetings with the people around them.*

**Taxonomies of Smartphone-Based Lifelogging Research** Using information of the previous sections, this section presents detailed taxonomies of the SP-based lifelogging research. The taxonomies are proposing categorization methods for SP-based lifelogging research using various attributes/aspects, such as basic architecture, role of SP, scope of lifelogging, and sensor placement and sensing mechanism. The taxonomies are aimed at providing a complete reflection of the present SP-based lifelogging personal big data property and the possible future personal big data prospects. The proposed taxonomies could also be helpful to evaluate and identify research gaps in the available SP-based lifelogging research. In the taxonomy figures, the solutions reported by the researchers are represented with rectangles, and the unreported solutions are represented with rounded rectangles, which could be potentially new areas for the future research.

*Sensors Deployment and Role* *Using the sensors deployment and role of SP, the available solutions can be categorized roughly into* in situ *systems and wearable systems (see* Fig. 12.1*). Using of wearable technologies has been the prime target of researchers since years where sensing devices are portable and carried by the weavers. However, a few researchers have demonstrated using of SP technology as alternative to the available wearable technologies (*e.g.*, SenseCam* [12]*) such*

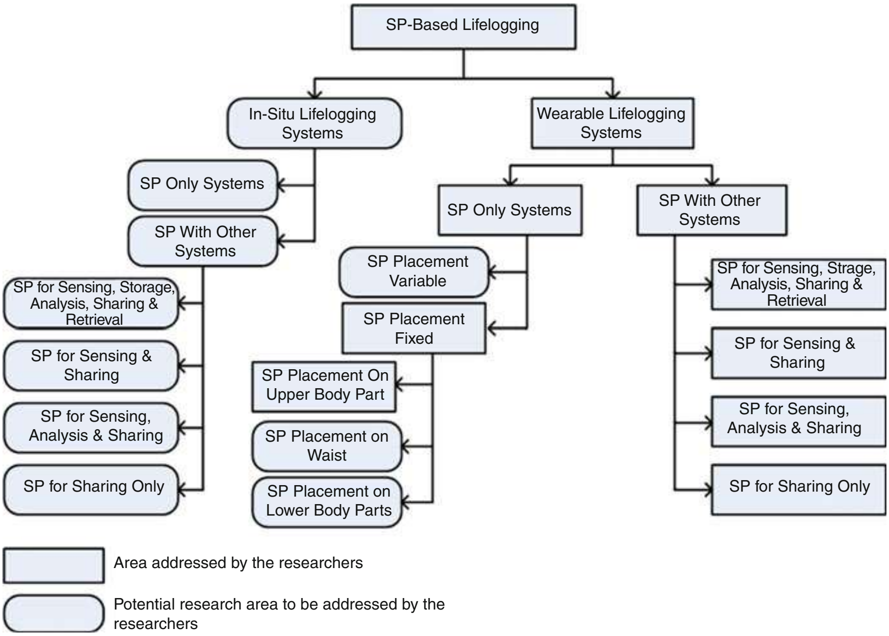


**Fig. 12.1** Taxonomy of SP-based lifelogging systems using sensors deployment and role of SP in the lifelogging process

*as* [58]. *This is usually done by harnessing the weaver with a SP. A SP either alone can be used as a wearable device or can be used in conjunction with other computing devices that could be wearable sensing devices (*e.g., *Google Glasses) or body-mounted computers/laptops for resources intensive processing, and retrieval. Researchers have reported using SP alone as wearable by mounting it on upper part of body (*i.e., *worn in a helmet on the head* [15] *or in a lanyard round the neck* [58]*); whereas, other potential placement areas (*i.e., *placement on waist and lower part of body) needs to be investigated and explored for potential applications and results. Researchers have greatly promoted using of SP with other systems, where a SP could have different roles of sensing, storage, analysis, sharing, and retrieval. However, these types of systems could overburden users that could affect their performances and requires uses to have explicit devices and communication channels that collectively increases cost.* In situ *lifelogging means lifelogging in an instrumented environment (called smart environment), where capturing of lifelog information is highly dependent on sensors installed in a local infrastructure. However,* in situ *SP-based lifelogging solutions can either rely fully on SP built-in sensors or sensors already deployed in an environment or any combination of them, with the varying roles of a SP related to sensing, storage, analysis, sharing, and retrieval. This criterion would eliminate users from wearing any type of wearable devices or sensors that would advantageously enable users to move*

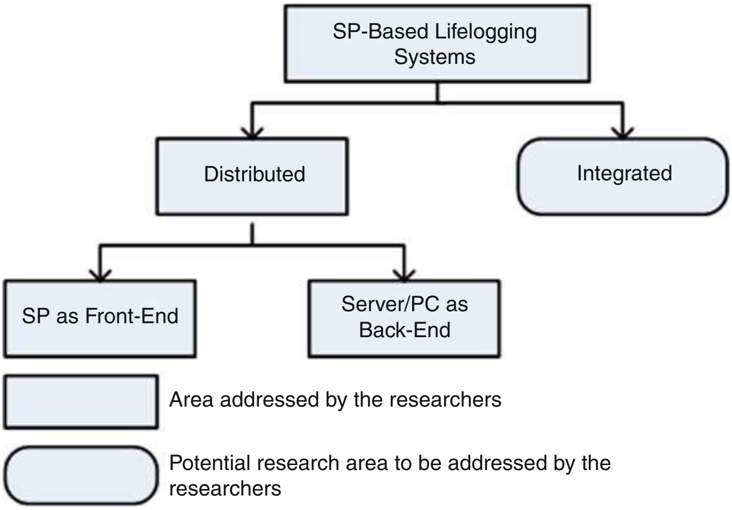


**Fig. 12.2** Taxonomy of SP-based lifelogging systems using architecture

*freely and perform their daily life activities and actions. However, operations of* in situ *SP-based lifelogging systems would be strictly restricted and dependent on the instrumented environment.* In situ *SP-based lifelogging can track peoples' lives in detail but no research attention has been paid to it to date. Comparatively, all of the SP-based lifelogging solutions are developed using wearable technology by requiring users to keep their SPs close to their bodies at a certain position. However, using SP in combination with both (*i.e., *wearable and* in situ *technologies) and placing SP at different body parts can provide effective and voluminous personal big data opportunity.*

*Architecture. Architecturally SP-based lifelogging systems can be divided into distributed and integrated categories (see* Fig. 12.2*). In distributed approach, SP-based lifelogging system's functionalities are distributed across SP and a remote server or PC, where SP is majorly used as a front-end device for capturing lifelog and contexts data or for low-level data processing and storage, and remote server or PC is used as back-end for resources intensive processing, analysis, indexing, storage, and retrieval of lifelog information from personal big data. The data captured by a SP would need to be transferred to remote server using Internet or cellular networks technologies or by physically connecting SP to PC. The distributed approach is best suited for big data scenarios and has been the preferred choice by the researchers due to resources constraints nature of SP (*i.e., *low processing power, battery power, and storage) in the past. However, this approach can have several problems that can reduce significances of SP-based lifelogging: (1) transmission delay can take place which could be problematic for real-time monitoring systems; (2) data uploading would be difficult in areas where network connectivity is not available; (3) heavy data transmissions can waste battery power* *rapidly; and (4) uploading and storing lifelog personal big data remotely can induce privacy and security issues. The integrated approach attempts to exploit the potentials and functionalities of SP for performing all of the lifelogging operations. The integrated approach solves the problems of distributed approach by combining all of the operations in a single place. None of the available SP-based lifelogging solutions supports integrated approach in its complete essence. However, a few (*i.e.*, UbiqLog* [19] *and Digital Diary* [24]*) are a bit closer to it. It is not hard to believe that recent technological advancements in SP can attract researchers' interests in developing solutions using integrated approach. However, to fulfill objectives of big data, SP-based lifelogging should combine both distributed and integrated approaches to provide effective platform for personal big data development and big data analytics.*

*Lifelogging Scope* *Using the lifelogging scope, SP-based lifelogging research can be classified into two broad categories: total capture and selective capture (see* Fig. 12.3*). Indeed, both of these approaches produce personal big data; however, the size of personal big data will depend on the type of lifelogging. The selective capture records experiences information regarding a particular aspect of a user's life (*e.g.*, exercise level, and health indicators) in a few data types (*e.g.*, audios, videos, images, message, and notes) with predefined applications at the beginning of lifelogging. This type of lifelogging is common and has got market traction due to mining of immediate value from the focused data. The total capture is the creation of a unified digital record of multi-modally captured data of totality of life experiences in a variety of data types. Total capture has a broad spectrum and can support a number of use-cases. Total capture is, however, complex and requires sophistication in gathering, storing, and processing into semantically meaningful and retrieval information for supporting various use-cases. None of the available SP-based lifelogging solutions supports total capture. However, the recent technological improvements and wide availability of apps for performing daily life activities in SPs can attract researcher interests for total capturing of life experiences. The total capture can produce comprehensive personal big data as compared to selective capture and provides effective environment for big data analytics to solve a variety of real-world problems in different fields.*

*Storage* *Using storage for personal big data, SP-based lifelogging research can be classified into two categories: database and ontology (see* Fig. 12.4*). The database has been the primary choice of researchers for storing lifelogging information since years. They have successfully demonstrated storing and retrieval of information from database partly local on SP and majorly on remote backend storage servers. However, a database has fixed schema and cannot cope with the problem of accommodating new events and information that could emerge with the changing lifestyles of people over the time. Furthermore, the rational databases are found expensive and technically unwieldy for storing, indexing, and retrieving voluminous personal big data* [114]. *The set-based retrieval model of relational database becomes quickly unworkable as the size of a lifelog archive increase in size. The huge and growing size of a personal big data from different data sources could*

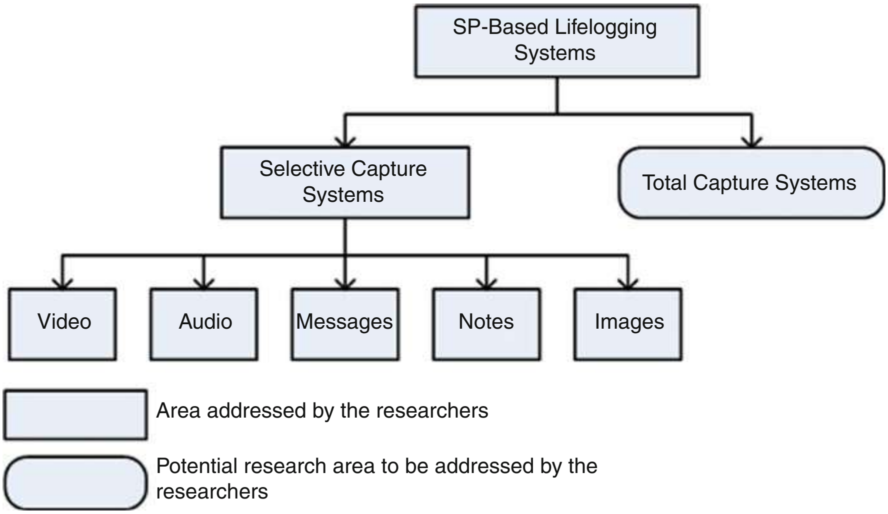


**Fig. 12.3** Taxonomy of smartphone-based lifelogging systems using scope of lifelogging

*make databases suspicious for inconsistent, incomplete, and noisy data. Thus, storage technologies (*e.g., *Hadoop, and NoSQL) are explicitly developed to store and manage big data. The schema less databases have big data applications. However, daily life information in a personal big data is related with each other in multiple semantic ways, which cannot be projected exactly in the schema-less and relational database technologies. Representing lifelog information in personal big data in similar semantics to their existence in the world will be helpful in interlinking diverse lifelog information, and developing retrieval models and big data applications. The ontology is a Semantic Web technology that enables to develop a semantically enriched model for lifelog information in personal big data, which would be more flexible and scalable by adding/modification of new/existing lifelog information and relationships, reasoning and inferencing of new information on the basis of existing information, and covering a wide variety of relationships and data sources. In addition to semantically modeling and organizing lifelog information, the ontology would provide powerful constructs to use and manage personal big data such as querying using SPARQL. A few of researchers have used ontology formalism for lifelog information management in desktop environment such as* [33, 115]. *However, none of the SP-based lifelogging research has paid attention to using ontology for lifelog information modeling and could be a potential research area for the researchers.*

*Sharing and Retrieval* *Apart from the above classification taxonomies, the available SP-based lifelogging research can be classified in other numerous ways as well such as sharing, and retrieval. Lifelog information has two aspects that are private and public. The private aspect underpins that personal big data remains in the user ownership and should not share with others; whereas, public aspect*

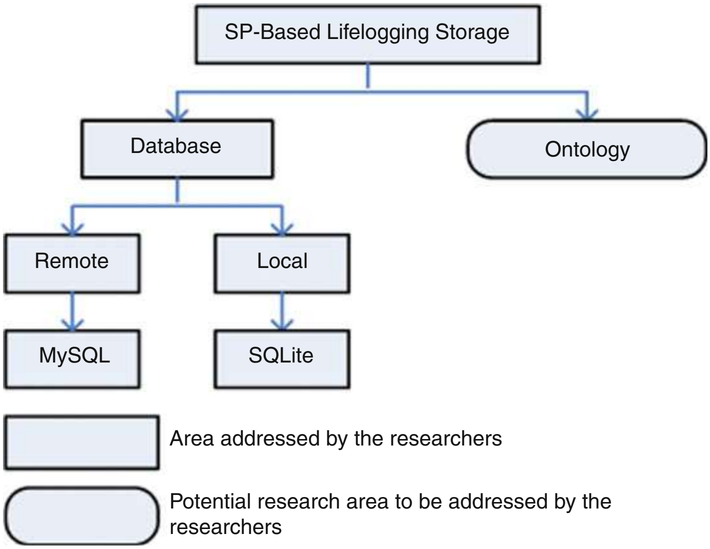


**Fig. 12.4** Taxonomy of smartphone-based lifelogging systems using storage modeling

*is related with sharing of personal big data using consents of the users. Most of the researchers have presented methodologies of sharing lifelog information from SP with their Web interfaces; whereas, a few have postulated sharing on social media such as Flicker. The sharing of personal big data is mandatory to support several effective big data analytics and applications. However, security and privacy should be ensured while sharing personal big data. Similarly, the effective SP-based lifelogging practices should provide methods for the implicit swift real-time retrieval of lifelog information to augment human memory and other variety of needs. The effective retrieval requires defining and using of big data techniques* (e.g., *data mining, machine learning, and visualization approaches) depending on applications. Most of the researchers have postulated retrieval using contextual information and timeline display either directly on desktop computers or with the assistance of the Web, which is explicit and not in real-time. The advancements in SP can attract attentions of the researcher to provide big data dependent retrieval methods to do things like combining, correlating, cross-referencing, leveraging, data mining from heterogeneous sources, learning, and presenting in appropriate and passive manner.*

## 12.4 Smartphone-Based Lifelogging: Personal Big Data

The term "big data" is applied to data sets, which have the characteristics of high volume, high velocity, high verity, and high veracity [5]. Typically, a big data includes voluminous amount of structured, semi-structured, and unstructured data that can be potentially mined for information [114]. However, the size of big data is not specific and could be in terabytes and zettabytes. The big data can be generated from various sources (e.g., sensors, devices, video/audio, networks, log files, transactional applications, Web, and social media) in real time and in a very large scale. The big data applications are believed to confirm the four characteristics of a big data scenario and have found space in various complex and interdisciplinary scientific disciplines, such as Web, e-commerce, astronomy, atmospheric science, medicine, genomics, biologic, biogeochemistry, etc. [116]. A prominent source of big data is sensors, which can generate large volume of complex sensory data that can be analyzed by real-world applications such as intelligent transportation system. Generally, the lifelogging uses sensors as core component and has shown conformance to the big data characteristics [5]. However, SP-based lifelogging has widened potential than traditional lifelogging; therefore, big data technologies can bring certain advantages to the SP-based lifelogging applications. Using knowledge of the previous sections, in this section, we will examine SP-based lifelogging confirming the four characteristics of big data or not.

The SP-based lifelogging essentially captures and generates lifelogs of personal experiences (i.e., personal big data) from different information sources in different data types, formats, and mostly unstructured. For example, data from sensors, information accesses, and communications. The myriad of sensing technologies enables SP to sense a person, his/her subjective and objective contexts, and the environment in which he/she is situated. The primary lifelog information sources include physiological data (e.g., heart rate, blood pressure, respiration rate, and galvanic skin response), movement and activities data, location data, nearby objects in a vicinity, images and audios, communication and data activities, temperature and environmental data, and WiFi and cellular networks and signal strength. The secondary lifelog information can be derived from the semantic analysis of the primary lifelog information. All these information sources and the information derived are substantially varied and different from each other in several aspects. However, in SP-based lifelogging, the variety across data sources is to be normalized and eliminated, and the information from varied sources is to be merged and combined into a holistic lifelog. The variety of data sources makes SP-based lifelogging a big data application by providing opportunities for efficient solving of real-world problems and posing challenges for lifelog information management and retrieval.

The SP-based lifelogging data sources have high velocity because of high speed at which data is emanating and occurrence of subtle changes in patterns in diverse data sources and datasets. The sensors have varied capturing frequency (i.e., samples per second), resulting into varied amount of data captured. For example, SP accelerometer sensor has a capturing frequency ranging from 1 to 102 Hz with a size 12 bytes per sample, and GPS has a maximum capturing frequency of 1 Hz of 24 bytes [2]. The SP is technologically improved and provides opportunities of advanced analytic techniques (i.e., text analytics, machine learning, predictive analysis, data mining, and statistics), of low level on the SP locally and of high level on the cloud remotely. The SP-based lifelogging can incorporate real-time pattern analysis and processing to identify patterns and changes of untapped data sources independently or together with enterprise data for gaining new insights for better results and solving real-world problems, such as contextual information retrieval, healthcare monitoring, and real-time intervention.

The SP-based lifelogging can realize extreme lifelogging by real-time continuous generation and capturing of life experiences and contextual information of a person from the different data sources, without requiring any user explicit interactions. The passive and continuous capturing characteristics of SP-based lifelogging enable generation of voluminous lifelog (i.e., personal big data) in a very limited span of time. Technically, as the number of capturing technologies and data sources increases, the amount of data captured into a lifelog would be increased accordingly. The volume of lifelog will be small initially but will constantly increase with the passage of time and increase in the number of people lifelogging. An overview of using SP to produce lifelogs of different personal information is shown in Table 12.8. Theoretically, the volume of lifelog of a single individual would be a major challenge for the PIM but would be a small challenge for the big data analysis. However, the central storage of lifelogs of many people (i.e., thousands perhaps millions) by a service provider (e.g., cloud) would produce a large volume of personal big data, which would be certainly a real big data challenge.

Finally, the veracity determines the accuracy of the data collected in a lifelog (i.e., personal big data). It is believed by the large number of organizations that the collected data could be imprecise and uncertain due to problems in the collection and processing devices and methodologies. In SP-based lifelogging, most of the lifelog information is captured using sensors, which could be erroneous due to noise and troublesome due to sensors' calibrations and drifts [5]. In sensor-based domain (e.g., wireless sensor networks in environmental monitoring), frameworks are developed to tackle the issue of captured data correctness, such as reputation-based framework for high integrity sensor networks [117]. However, to date, the SP-based lifelogging poses personal big data challenge because of lacking of addressing data veracity issue. The data accuracy and data quality can be increased by incorporating the processing steps (i.e., sensors data cleaning and integration, fusing sensors data, and semantic analysis and organization of lifelog information) in the SP-based lifelogging.

Fulfilling the 4 V's of big data makes SP-based lifelogging (i.e., personal level or enterprise level) produce a form of personal big data. The personal big data can be an effective big data application by extracting/discovering information, which are not directly possible from an information source. For example, deep mining sensors data streams to extract patterns, linking and cross-referencing information sources at personal level or enterprise level, and using machine learning can be helpful for deducing new knowledge to learn about users' behaviors and actions such as improving Web searching users' experiences by tracking their click through behaviors and interactions with a search engine. It is believed that the widespread adaptation of SP-based lifelogging will enable lifelogging to find personal big data applications by providing facilities to extract useful and meaningful semantics

**Table 12.8** Overview of using smartphone to produce lifelog personal big data

| Content type | Hours/day | Volume in day | Volume in month (30 days/month) | Volume in year | Volume in 60 years |
|---|---|---|---|---|---|
| Full HD (1080p) | 10 | 110 GB | 3300 GB | 39.2 TB | 2.3 PB |
| Audio (CD audio) | 10 | 6.06 GB | 181.7 GB | 2.16 TB | 129.53 TB |
| Accelerometer (102 samples/second) | 10 | 42.02 MB | 1.23 GB | 15.00 GB | 898.7 GB |
| Picture (JPEG 640*480 32-bits/sample) | 10 (picture after each 5 seconds) | 702 MB | 20.57 GB | 250.22 GB | 14.7 TB |
| GPS locations (1 sample/second) | 10 (location after each 5 seconds) | 168.75 KB | 5.0 MB | 60.15 MB | 3.6 GB |

from the lifelog information of diverse nature. The applications will not only enable creation of effective surrogate memories but will also fulfill the lifelogging challenge of swift and accurate retrieval of lifelog information from personal big data.

### *12.4.1 General Architecture for Smartphone-Based Lifelogging*

As discussed earlier, SP-based lifelogging can tremendously increase peoples' ability to obtain personal big data for aiding themselves and providing valuable big data applications in the various fields. The SP-based lifelogging systems are architecturally different from each other and having no compliance with big data systems design principles. The lack of standard guidelines for SP-based lifelogging freed researchers to propose solutions using their own experiences and methodologies. Thus, creating separate islands is wastage of resources and time. Taking SP-based lifelogging in the big data perspectives will produce several big data problems and challenges of data capture, storage, searching, sharing, analysis, and visualization [116], which will change the trend of both hardware and software development [116]. Therefore, we have proposed a general architecture for SP-based lifelogging systems using big data systems designing principles [116] that will minimize the problems, improve systems' interoperability, and incorporate effective big data analytics. Technically, using SP for end-to-end personal big data generation and processes is a complex phenomenon and involves many challenges [65]. However, the whole phenomenon can be substantially divided into four modules/layers (see Fig. 12.5): data collection engine (DCE), software middleware (SM), semantic extraction and organization (SE&O), and retrieval and sharing (R&S). The proposed architecture is used in the development of SP-based semantic lifelogging application, namely, SLOG in our previous research work [20].

**Data Collection Engine** Data collection engine collects lifelog information from a user's personal information (PI) space. A user's PI space is composed of lifelog objects (e.g., pictures, documents, contacts, emails, and calls), which are created and manipulated by SP applications, SP applications maintaining information about user, and contextual and environmental information captured by the sensors. Information from a user's PI must be made accessible to a SP-based lifelogging system for instrumentation, automation, and querying. To create a personal big data of life experiences, DCE captures data about user from different types of sensors (i.e., smartphone sensors, wearable sensors, and environmental sensors) and applications, and relays the captured information for further analysis and storage. However, the type of lifelogging determines the number and types of applications and sensors to be used. As discussed earlier, focused lifelogging (i.e., selective capture) will use a few sensors to record life experiences; however, extreme lifelogging will use several sensors to record lifelog information from all possible sources to create a

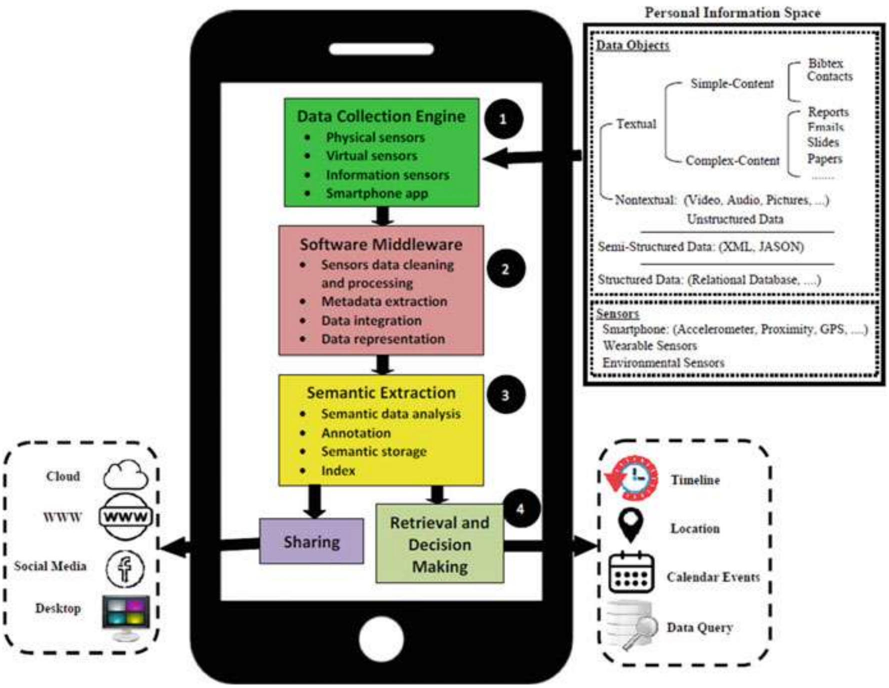


**Fig. 12.5** General architecture for SP-based lifelogging systems using big data systems design principles

perfect record of life experiences in detail [5]. For example, body-worn wireless ECG sensor would be used by a real-time ECG processing system but a fall monitoring system would use SP's built-in accelerometer, microphone, and camera sensors. DCE would capture information from information sources either reactively on event-based or proactively on polling-based. In reactive capturing, information would be captured as a result of occurrence of an event (e.g., arriving of a SMS). In proactive capturing, information would be captured from managed information resources continuously/periodically after regular time intervals. However, event-based capturing is effective for SP to not waste battery power.

**Software Middleware** Lifelog data, especially the heterogeneous sensory data provided by DCE, is in the raw format with no semantic descriptions, which cannot be used directly and needs further processing for storing into useful lifelog information. Software Middleware (SM) would provide components, which could use big data techniques (e.g., statistical methods, machine learning, and deep learning) to preprocess raw sensory data and lifelog items numerously, such as aligning data both temporally and spatially, cleansing data from noise, fusion of data into uniform object, computing and utilizing the trust and provenance or reliability of the data streams, and transforming unstructured data into a structured format to improve quality of the captured data, transform the captured data into useful information, and merge/combine the captured information into a consistent structure.

Functionality of SM depends on the applications for efficient representation, access, and analysis. However, the raw sensory data (e.g., voice data from microphone) received from DCE would be segmented (i.e., using time) to extract features, which could be used for classification, identifying daily activities, and other contextual information. The captures would be divided into fine-grained context and sub-context groups using context information, for example, first division into context groups using time information and next division into sub-context groups using location information. In addition, information about a context can also be retrieved from relevant applications such as user's calendar. Similarly, metadata associated with lifelog objects by the parent applications can also provide additional contextual information and is needed to be extracted for enhanced annotations. The lifelog, contextual, and metadata information should be fused and organized in a holistic consistent structure (e.g., JSON) for further processing and analysis. Very little research attention has been paid to this area of SP-based lifelogging to date. However, research experience from the other fields (e.g., SP-based activities recognition and fall detection) can be potentially used for learning about data quality, trust, and reputation.

**Semantic Extraction and Organization** Semantic extraction and analysis (SE&A) will provide semantic glue to organize and relate lifelog information in a personal big data archive in similar semantics as their existence in the world and stored in the human biological memory. In SP-based lifelogging, to fill the space between raw sensory data and people understandability needs employment of effective semantic extraction techniques and several of semantic modeling and reasoning, and machine learning and statistical analysis methods for identification and generation of semantic constructs out of lifelog information, for example, using of speech recognition for the extraction of a person's name, email address, and cell number from an audio conversation or using of OCR engine to extract objects and background information from an image. However, the extraction of high-level semantics from huge information and organizing information semantically are the key challenges for big data analytics and information retrieval. The semantic analysis involves several of the structuring, organizing, and summarization processes for mapping lifelog information into more discrete and meaningful data units (e.g., event). Organizing lifelog information into discrete units could be used by the mining pattern process for determining their singularity and regularity in a lifelogger's lifestyle. Event is, however, not essentially an optimal lifelogging data unit, but it has received most of the research attention, to date such as [118]. Semantically enriching lifelog data at the event level involves annotation using contextual and metadata information, received form SM, to describe and relate lifelog information in a more meaningful way that will not only increase data representations and understandability but will also enhance retrieval of specific lifelog information from personal big data. The semantic organization and annotation of lifelog information would also enable fine-grained enriching of personal big data with the data from the Semantic Web knowledge store (e.g., Linked Open Data). All of the lifelog information and annotations in personal big data can be indexed (i.e., using Lucene) for improved retrieval/discovery performances (i.e., improving recall and precision). As discussed earlier, the semantically organized personal big data can be effectively used for the different big data analytics as compared to relational and schema-less databases. SE&O is an important activity for SP-based lifelogging to completely exploit the gold ores of personal big data but has not received significant research attentions to date.

**Retrieval and Sharing** Once a semantically enriched personal big data is created, an appropriate retrieval model is needed to be defined for the swift retrieval of specific lifelog information instantly and completely for effective decision-makings. A SP-based personal big data should provide primitives of querying implicitly and explicitly numerously (i.e., content-based information or context-based information) for searching, browsing, summarization, and recommendation using a number of information, such as time, location, calendar event, and proximity to support a number of use-cases (i.e., both identified and unidentified). A retrieval model typically depends on a use-case; however, potential use-cases of personal big data can be inspired from the 5Rs of memory access proposed by [9]: recollecting, reminiscing, retrieving information, reflecting, and remembering intentions. In addition, access methodology and HCI factor should be considered while defining a use-case. The traditional information retrieval techniques are slower for the exponentially increasing personal big data, especially solving real-time problems. Therefore, collecting detail trace of users would enable the development of a retrieval model to know the user in detail and provide information to them to answer information need query or using a real-time context-aware recommendation engine. The SP-based lifelogging has personal and social aspects. To fulfill the social aspect, lifelog information from personal big data can be shared with friends, colleagues, and family members for numerous purposes. The lifelog information can be shared using a number of techniques such as cloud due to storage limitation of SP and providing global access to personal experiences information, online social networks for exchanging life experiences and legacies, Web blog for creating personal digital diaries, and desktop for long-time preservation of personal life experiences. However, privacy and security measures should be considered while defining personal big data sharing policies.

### *12.4.2 Personal Big Data Applications*

The potential applications of SP-based lifelogging depend on users' interests, where some would be interested in recording information about themselves for their own benefits, some would like to record information for sharing with others, and some would be interested in building a repository of life experiences in similar to maintaining a diary. Nearly all of the studies have emphasized on using SP-based lifelogging as memory aid tool due to no clear identification and availability of its applications. The big data analytics on personal big data can highlight varied and broad SP-based lifelogging applications, which would become clear as the technology becomes more popular by motivating people to gain benefits. It could change the meaning of being human by changing the way we work and learn, unleash our creativity, improve our health, and maintaining our relationships with our loved ones either dead or alive. The potential applications of SP-based lifelogging in the big data paradigm can be tailored from the book "Total Recall" [119], which believes in lifelogging to revolutionize healthcare, learning, productivity, and social society. The SP ability of automatic and effortless logging of personal big data and combining with appropriate analysis tools can improve understanding of the people on why certain things are happening (e.g., behavioral changes and shopping trends). In this section, we are listing some of the potential personal big data applications, mainly extracted and aligned with the relevant literature.

**Memory Augmentation and Assistance** Memory augmentation is the use of technologies to increase one's ability to retain and retrieve information from memory accurately and reliably. Information about life events is stored in human episodic memory and annotated with time and location information to facilitate event retrieval from the memory [120]. Continuing the legacy, a significant personal big data application could be helping patients having episodic memory impairments, such as Alzheimer's and other dementias. The available SP-based lifelogging systems have already demonstrated the development of lifelog archive for the human episodic memory augmentation. In the research, it is found that contextual information stored as part of lifelog personal big data archive can provide valuable clues to assist people in their memory recalls. For example, reviewing of an image lifelog captured via SP camera and annotated with date, time, and location can enhance short-term cognitive functioning. The detailed memory augmentation and assistance applications can be accomplished by defining big data analytics in accordance to the 5'Rs of human memory access [9]. Each of the 5'Rs postulates different reasons and requirements of people inclination to access their episodic memories and by inferencing their personal big data.

**Medicine and Healthcare** The continuous recording and long-term preservation of an individual's biological data is also lifelogging [65]. The SP sensors in connection with biometric sensors can give accurate data about physiological changes (e.g., pulse rate, blood pressure, and skin conductivity) of people that happen amid different circumstances and activities [64]. Recording key biological signs benefit users in increasing their self-understandings about their health status, enriching their health record, and helping to figure out how to affect their biological parameters consciously (biofeedback exercises). The biofeedback exercises are proven helpful in improving users' health [121, 122]. The personal big data can have significant functionality in medicine and healthcare by using information captured in SP-based lifelog archives. An individual's lifelog consisting of his/her biological, treatment, medicines, and history data could be exploited by the big data analytics to retrieve information helpful for a physician on-hand analysis. For example, using the information, a physician can prescribe medicines to a patient without visiting the patient by knowing his heartbeat and temperature. The stack holders in pharmaceutical industry can mine and analyze personal big data to obtain insights about treatment effectiveness in a particular condition and identify pattern related to drugs' side effects and information related cost reduction.

**Commerce and Business** A significant part of an individual life is composed of commerce and business events while performing activities like buying and selling of consumer products, visiting restaurants for dinning, and shopping groceries. The capturing and recording of information about these activities also falls within the scope of SP-based lifelogging. The data generated by the individuals can help business in highlighting new business and charging models. The retail industry has already shown interest in establishing data warehouses for demonstrating big data applications in commercial purposes. For example, Hewlett Packard has used Wal-Mart for the establishment of data warehouse of 4 petabytes [116]. The companies are interested in collecting consumer preferences and purchases' data by extracting data from different sources, including surveys, purchases, Web logs, product reviews, and phone conversations with customers. However, personal big data could be a valuable addition in the sources, providing the required data in high volume and velocity at ease. Using big data analytics on this huge volume of personal big data will be valuable for the companies in discovering hidden knowledge, which could be helpful in improving their pricing and advertisement strategies. The companies can spot trends and develop an understanding of why certain products succeed and other fail. The product manufacturers can exploit data from SP-based lifelogging service to gain competitive advantages by introducing higher level of context awareness and personalization of services.

**Government and Society** The public administration can benefit from personal big data composing of information regarding behaviors, attitudes, and opinions. The SP-based lifelogging can capture and record huge volume of behavioral and attitude information, which could be helpful to the government agencies in improving understanding of different actions, relations, and causes. Applying big data analytics, government and society can profit from personal big data, mainly in decision support for improving productivity and higher level of efficiency and effectiveness. For example, a population lifelog data could be helpful for the medical investigations or national health infrastructure promotion campaigns in detecting early warnings of disease outbreaks. Similarly, the impacts of social networking and social media on the public affairs are evident. Capturing and recording social networking and social media activities can potentially provide valuable input information to the government agencies to understand public opinion and influence policy-makings to various political and social issues. The personal big data functionalities and tools can be helpful for governments in improving productivity and public services within specific budget constraints [116].

**Scientific Research** The developments of computer science have made several scientific fields highly data driven [123]. The generation of multi-type large volume of data in the scientific fields (e.g., social computing, bioinformatics, and computational biology) enables data-intensive scientific discoveries in the fields. As discussed earlier, the intensive SP-based lifelogging can generate data about individuals, contexts, and environments. The huge personal big data can have enormous data to facilitate the scientific research in the different fields, such as healthcare, transportation, and environmental pollution, For example, using temperature and humidity information from the lifelogs of a population, the meteorological departments can accurately determine the weather condition and other environmental parameters. The semantic organization of personal big data and connecting with vast collection of semantic data on the Linked Open Data (LOD) can provide big data analytic opportunities to accelerate research activities in the different fields. However, to probe knowledge from the large-scale personal big data archives is itself a big data problem, which needs development of effective big data analytics and retrieval models. The big data analytics should correlate, cross-reference, identify patterns, merge, and combine data from the various personal big data archives to provide efficient and effective datasets for the execution of scientific research tests.

### *12.4.3 Opportunities and Challenges*

Like any other new technology, SP-based lifelogging can potentially excite and inculcate worries and concerns [65]. For example, the first generation of different technologies (i.e., Kodak camera, mobile phones, pagers, Sony Walkman, and more recent Google Glass) faced serious sanctions from the US government. Moreover, new technologies are initially seen as elitist and would not eradicate worries until they become affordable and have mass adaptation. SP-based lifelogging creates unique opportunities of creating comprehensive personal big data by digitally recording peoples' daily life experience. However, one can legitimately ask why SP-based lifelogging has not made to the mainstream market yet and how knowledge hidden in a personal big data can be highly valuable for the different stockholders (i.e., government agencies, organizations, society, and individuals). As discussed earlier, the effective harnessing and use of personal big data can provide opportunities in several ways, including increasing a person's operational efficiency, enhanced customer service and experiences for businesses, identifying and developing new products and services to gain competitive advantages, identifying new markets according to user's behaviors, and complying with law-and-order regulations. However, opportunities are followed by challenges.

Using knowledge gained in the previous sections, it is not hard to determine that SP-based lifelogging studies have a number of challenges, which could limit our ability to describe its consequences once it has been widely adapted by the peoples. Lack of complete development of the technology (i.e., SP-based lifelogging) is by itself a big challenge, making it difficult to describe clearly the legitimate use of the technology by the stockholders. Functions of the technology are uncertain and not clearly described to date, including controlling functions of the technology and owning the produced personal big data, effects of the lifelogging using the technology on an individual's identity and behaviors and functions, and the interoperation between technological memory and biological memory. These uncertainties will pose serious challenges to the developers and individuals, off course. In short, there are several challenges in SP-based lifelogging from big data perspectives regarding capturing, storage, searching, analysis, sharing, and presentation/visualization. Some of the challenges in the technology will be discussed in the following paragraphs.

**Data Capturing and Merging** The personal big data will grow exponentially in size because of gathering data from multiple sources mainly using sensors. The available SP-based lifelogging solutions have either used a single sensor (e.g., microphone [14]) or combination of a few sensors (e.g., GPS and camera [23]) for capturing and annotating the lifelog information according to their own interests. Similarly, certain personal big data contents might not be possible from single sensor readings; therefore, data from multiple sensors and sources needs to be fused. Technically, using a broad range of sensors can provide a large-scale personal big data by capturing and recording rich content and contextual information about different aspects of life events. Eventually, performance of a SP-based lifelogging system would be enhanced by providing more semantics to the information for advance querying and exploration of personal big data. However, fusing/merging data from either multiple sensors or fusing sensors data with other information sources is crucially a difficult task. The fusing sensors data require careful data cleansing, alignment, and temporal normalization [5]. Therefore, knowledge and research efforts from sensors data fusion domain [124, 125] can be used to develop effective schemes for fusing data from various SP sensors and other sources of information for improved information (i.e., cheaper, qualitative, and highly relevant) for accurate estimations of contexts and contents. However, care should be taken that sensors' usages should not be at the cost of resource consumption. Instead of using a static combination of sensors, adaptive and dynamic selection of sensors and their sampling rates should be employed to produce more energy-efficient solutions. In addition to sensors, relevant information can also be captured from other sources, for example, using phone number to extract information (e.g., name, address, etc.) from the phone contacts and using location coordinates (i.e., latitude and longitude) to extract location information (e.g., known name, postal code, etc.) from online repositories (e.g., Google and Linked Open Data). However, specialized techniques should be produced for meaningful information merging from the different and diverse sources into compact information.

**Targeting Fine-grained Data Events and Activities** The tasks in a typical SP-based lifelogging system involves the following: (1) determining a set of target events and (2) associating sensory data and other inputs as contexts to the events. Extreme lifeloggers argue for digitizing every possible aspect of human daily life experiences. However, such approach would result into a very large personal big data, which would be difficult to handle and maintain (i.e., searching, mining, interlinking, and security). The available SP-based lifelogging solutions have claimed reasonable retrieval rate due to addressing a small set of coarse-grained events and activities in personal big data. However, such approaches would be of little use due to their limited scopes, such as automatic diary (i.e., personal big data), and would be incomplete if it could not recognize meetings in an office environment. Therefore, the legitimate question is what would be the effective set of daily events and activities that should be recognized and recorded in SP-based lifelog personal big data for empowering potential applications. There are three potential reasons of defining a potential set of common activities for all of the people. Firstly, human life is dynamic and changes with the passage of time, making peoples' interactions and activities different from each other. Secondly, the integration of new technologies in SP (e.g., sensors and applications) can emerge new opportunities of lifelog information in personal big data. Finally, SP-based lifelogging can have potential big data applications of diverse nature. Nevertheless, identifying and defining a set of common daily life events and activities could benefit in setting objectives and guidelines for research efforts.

**Data Processing and Storage** The big data has changed storage devices and their architectures and information access mechanisms [116]. The available SP-based solutions are mainly implemented in centralized architecture, where SP is used for data collections and back-end servers on the Web (i.e., cloud) or PCs are used for the personal big data storage and processing. The storage technologies for servers and PCs are improved both in storage and I/O speed. For example, solid-state drives (SSDs) have replaced hard disk drives (HDDs). Similarly, networked-attached storage (NAS) and storage area network (SAN) are the commonly used architectures for enterprise storage. However, centralized architecture will require users to have explicit network connections and devices to store and review their personal big data. This increases the overall cost, security and privacy issues, and bandwidth bottleneck in case of large volume of communication. The performance of data-intensive applications can be increased by optimizing data access techniques, including data replications, migration, distribution, and access parallelism [116]. Therefore, processing and storage technology advancements are needed to be extended to SP for implementing distributed data centric storage. Advantageously, this would enable to replicate personal big data on SP and would ensure users' control on the lifelog information, ubiquitous and omnipresent access to lifelog information, and data archiving without relying on additional technologies.

**Data Curation** The data curation aims at authentication, archiving, management, long-time preservation, quality assurance, and retrieval of data [116]. The available SP-based lifelogging solutions emphasize on storing and indexing personal big data using database technologies. The existing database management tools cannot handle personal big data that grows exponentially in size and complexity. As discussed earlier, a database has fixed schema and cannot deal with the dynamic nature of lifelog information by accommodating directly the insertion of new types of lifelog information (i.e., events and activities) and relationships, which emerge with the changing lifestyles. A slight change in the requirements would require restructuring of database schema. In addition, using database technologies cannot rationalize the sharing aspect of lifelogging because API access would be required for importing, exporting, and accessing of personal big data. Furthermore, the set-based retrieval (used by the relational databases) becomes quickly unworkable with the growing size of a big data [5]. The NoSQL and Hadoop provide distributed database design and management for processing and storing voluminous data in parallel across a grid of commodity servers. These implementations are non-relational and do not support relational functionalities (e.g., fixed relation schema, join(s) operations, and lower consistency) for storing and managing unstructured data. The advantage of schema-free database is the empowerment of developers to change the structure of data without rewriting tables and greater flexibility if data is heterogeneously stored. Using relational and schema-free databases can leave semantic gap between the lifelog information stored and their occurrence in the world. The lifelog information is related with each other in different semantic ways in the world, which could not be exactly represented by the database technologies due to their limitations of features and constructs. Therefore, more scalable and flexible, high performance, and low-level access storage methods for personal big data are needed to be investigated, which should store information about any type of lifelog items and their relationships in a subtle way. Semantic Web technologies can solve this problem by formulating lifelog information using ontologies and storing them in RDF triple format for advance query, exploration, and connections with other lifelog information at any other place (e.g., Linked Open Data).

**Data Analysis and Visualization** The volume of personal big data is scalable and will grow with the passage of time, which will make its increasingly difficult for the big data analysis tasks. To deal with the problem, research contributions in the domain of big data can be incorporated in SP-based lifelogging. In the past few years, researchers have highlighted effective analysis algorithms to tackle the growing size of a big data, and the processor speed is increased following the Moore's Law [116]. The increment algorithms have acceptable scalable characteristic for big data analytics techniques as compared to other machine learning algorithms [116]. Technically, despite of introducing core technology in the smartphone's processor, the processor clock speed is still highly lag behind due to the expected scaling of size of the personal big data much faster than the processor speed. However, the problem can be handled by the development of parallel computing in SP. Another potential solution could be cloud computing, which could combine multiple disparate workloads into a large cluster of processors.

The personal big data visualization is to represent and convey the information/knowledge from a complicated and large dataset easily and more understandably. However, the SP-based lifelogging systems have data visualization approaches of very low performance in functionalities, scalability, and response time. Therefore, the personal big data visualization approaches are needed to be revised and to develop new data visualization tools to cope with the problems. For example, eBay is using Tableau (i.e., a big data visualization tool), which transforms complex and large data set into intuitive pictures for helping eBay employees to visualize search relevancy and quality, by monitoring latest customers feedbacks, and perform sentiment analysis [116].

**Societal Acceptance** Each new technology has witnessed increased negative responses from the society in the beginning. Lifelogging and associated technologies has undergone the same concerns and responses. For example, response for the Google Glasses, which is not a lifelogging technology in its integrity but could be used as potentially powerful lifelogging tool if apps developers desire to port lifelogging technology to glassware [5, 65]. However, SP is a commonplace and can be used by the people in different places and situations openly and freely. In this regard, SP-based lifelogging for personal big data harnessing can have high degree of societal acceptance as compared to its predecessors. However, SP-based lifelogging as a new technology will be acceptable by the society when it finds space in the mainstream. The increasing understandings and highlighting of positive benefits of personal big data harnessing, sharing, analytics and applications can turn peoples' thoughts and can result into its high-level adaptation. The realization and availability of useful personal big data applications could be handy in this regard, which would put SP-based lifelogging into social debates by disclosing its positive benefits.

**Violations of Privacy** A number of privacy concerns need to be solved as SP-based lifelogging becomes more commonplace. Privacy detrimental depends on the types of SP-based lifelogging. SP-based selective capture lifelogging (i.e., quantified-self-analysis) would be of less security concern due to small personal big data formed by collecting data toward an individual at a particular space and time. But, SP-based total capture lifelogging would be of more privacy concern due to large personal big data formed by collecting data from inwards, outwards, and sharing. Certainly, the ubiquity and powerful nature of SPs enables lifeloggers to capture their life experiences in any level of interest. However, the increased capturing can be tailored with increased privacy implications. Privacy in SP-based lifelogging is puzzling with no clear definition. Some of the researchers have regard privacy with control over information in personal big data and have developed their own concepts of privacy, and others have aimed of offering recommendations for the developers [5]. In this section, we are highlighting some of the privacy concerns that could be raised by the SP-based lifelogging in relation with the individuals, bystanders, and society.

- *Information ownership.* Regarding privacy, the important challenges in SP-based lifelogging are ownership and access of personal big data [5, 65, 126]. Solutions are needed to be developed to answer legitimate questions. Examples include the following: Where the personal big data would be stored? Who will have the ownership a stored personal big data? What will be the lifetime of stored personal big data? Who can potentially access a stored personal big data? Technically, personal big data storage location greatly implicates the development of SP-based lifelogging solutions. The SP storages are still limited to archive large amount of personal big data and would require usage of external storage infrastructures. Peoples will have separate opinions about the facility of storing huge archives on a cloud-based storage. For some people, it is not acceptable because of the private nature of personal big data, whereas others accept it if appropriate data hosting, backup, security, and retrieval facilities are ensured by the service providers. Practically, self-hosting of the personal big data is desirable by most of the lifeloggers with the choice of sharing a part of their digital memories securely. However, sharing information can have unclear consequences. A person might have control of choosing information to share, but he/she would not be able to decide how self-publicized information should be used and interpreted. Furthermore, user consent is also an important related challenge, which needs great consideration while defining any of the personal big data control, access, and monitoring policies [126].

- After logging. It is straightforward that personal big data would remain within the lifeloggers' ownership during their lifetimes. However, the legitimate question is why and how long personal big data should be retained when the data gatherer dies, commonly referred as "after-logging" challenges [5]. The possibilities could be either the deletion of data or passing to a trusted relative. However, if passed then other concerns arise about keeping personal big data forever or for certain (i.e., one or more) generations. A past person's personal big data could contain valuable historical contextual information, and society may emphasize greatly on keeping the data for potential applications. Advance digital storages can potentially retain personal big data indefinitely with low cost. However, a personal big data may contain a detailed digital trace of life, which may raise privacy concerns even when the lifelogger is dead.
- Bystanders. SP-based personal big data harnessing can potentially pose privacy challenges to not only the individuals but also to the peoples around at the time of lifelogging that are commonly referred as bystanders. The total capture SP-based lifelogging can create privacy consequences for the people beyond a lifelogger by capturing them without their consents. For example, using SP to take pictures or record audios at a common place can capture the presence of other people as well without their consents. This could produce sever consequences, if the captures containing some sensitive materials are publicized such as shared using a social media. Thus, SP-based personal big data privacy challenges are not only from lifelogger perspectives but also from the bystanders encountered by a lifelogger.
- Surveillance. Surveillance is another SP-based personal big data harnessing privacy challenge, where citizens could be vulnerable to baneful surveillance by either government authorities or organizations. The relationships among citizens and government, and employees and organizations could be seriously impacted by rich personal big data because of providing excessive information for monitoring individuals' activities and behaviors. SP-based lifelogging can turn users into recreational spies by revealing confidential information. Recreational spies refer to the people investigating with lack of professionalism and professional ethics and having no concerns with the legal and moral obligations of their targets [126].
- Ethics. Another key privacy issue in SP-based lifelogging is the ethics of lifelogging. Information captured in SP-based personal big data would not only

be related to lifelogger but would also contain abundance of information about people and situations happening around a lifelogger spatially and temporally. For example, if someone is captured while practicing a crime, then should the lifelogger report it or not? It is very crucial to highlight and analyze ethical, legal, and social issues, which may rise from the technological and scientific developments of SP-based lifelogging.

The privacy concerns to the lifeloggers, society, and bystanders would be more highlighted as SP-based lifelogging applications become more mainstream activity. The SP-based lifelogging systems should be developed by integrating privacy concerns in each and every stage of development. Privacy by design [127] framework is suggested for ubiquitous computing and has foundation in seven principles from Cavoukian [128], where privacy and data protection are considerably embedded in the entire development process and use of a system. The seven principles could be used as a starting road map for producing privacy-enabled SP-based lifelogging solutions. However, privacy by design has received critics of being complex and could affect meeting of functional requirements of a system [5]. Therefore, a trade-off has to be settled between privacy and functionality for SP-based lifelogging. More or less, privacy by design has to be incorporated in SP-based lifelogging application development and also to be tailored by the information retrieval developers while developing personal big data retrieval tools.

**Tasks Standardization** SP-based lifelogging is not standardized due to lacking of considerable amount of systematic research efforts to date. As discussed earlier, researchers and developers have developed the available solutions using their own methodologies without any mutual consensus. To date, none of a specific methodology has been defined for SP-based personal big data generation, showing the essential components, sequencing and interactions of components, inputs and outputs of events, description of functions of components, and identification of usable technologies. A generalized architecture for SP-based lifelogging systems using big data systems design principals is presented in Section 12.4.1. Lack of standardization can be due to a number of reasons.

- Data Collection Technologies Immaturity. Although a modern SP is integrated with a rich set of sensory devices to record contents and contexts information for building a rich personal big data. However, they are still limited to capture the dynamic information from all of the possible prospects of an individual's life. For example, for capturing an individual's healthcare information, one cannot rely on SP sensors only but also has to take help from external specialized health related sensors as well. In addition, the integration of every possible sensor in SP platforms might be theoretically possible but not technically as their usage could have sever effects on the overall SP operations such as depleting battery power and jeopardizing SP normal operations. Furthermore, some of the SP sensors (e.g., camera) are far behind in performance and sophistication than other commercially available sensor-enabled devices. Wearable lifelogging has made significant improvements in this regard by building specialized lifelogging devices (e.g., SenseCam, Memento, and OMG Autographer), which have valuable lessons for SP-based lifelogging solutions' developers.

- Human Life Dynamics. Tomorrow never dies resulting into new requirements taking birth due to human life dynamics. A rich prosthetic memory (i.e., personal big data) would be constructed if each and everything about a person's life is captured in real time. Technically, the available wearable lifelogging systems and SP-based lifelogging systems are either using built-in sensors or in conjunction with body-worn sensors to capturing a subset of well-defined lifelog events and activities (i.e., attending party, office meeting, and conversations); however, they cannot scale dynamically for new events to constitute real reflection of an individual's life experiences. The approach of total SP-based lifelogging is deemed to solve the problem. However, the approach is not feasible and practical due to a number of reasons to date: (1) it requires extreme use of additional technologies, which are not possible to be predicted that what would be integrated in the future SPs; (2) SP-based lifelogging applications, at present, are not technologically feasible to build, which would predict tomorrow's new activities and events; and (3) peoples' interests in daily life events vary considerably where some events would be of high worth and others would not be of that worth. However, semantically organizing and interlinking information in diverse personal big data archives can infer identification and handling of future events' information using existing information. Similarly, using of effective machine learning techniques can also be helpful in identifying patterns in personal big data archives for predicting future events and activities.
- Test Collection and Evaluation. Research in SP-based lifelogging is in short of publicly available personal big data datasets and reference test beds. The available solutions have developed their custom methodologies for test collections and result evaluations. However, none of the test collections is made publicly available for using in other applications' evaluations and ensuring the claimed results of a research. Gathering a dataset of real-time contexts and events information is a complex process and may encounter a number of problems. Firstly, developing a robust application to run for hours on SP requires valued programming skills and experiences. Secondly, technical (i.e., both hardware and software) issues may hinder problems in data collection. Thirdly, organizing and collecting an effective group of participants as an accurate sample of a population is a tedious and time-consuming task. Finally, logging life experience requires dedication, devotion, and active participants' involvement and reporting. It should be ensured that participants may not report sparse or erroneous information due to not charging or forgetting to carry their devices, etc. Publicizing personal big data datasets would enable repeating of a lot of experiments for an accurate determination of any progress in the domain of SP-based lifelogging and others. People may be reluctant about publicizing existing personal big data datasets due to privacy issues as they may have logged their personal contextual information (i.e., location, contacts, and activities), whose potential misuse could be devastating and may raise legitimate question about their security. However, anonymized versions of the personal big data

datasets could be helpful for SP-based lifelogging in comparing the existing systems on the same test bed. Examples and lesson could be learned from the reality mining [84] and CRAWDAD initiatives in this respect.

- Information Retrieval. SP-based lifelogging systems are supposed to provide omnipresent access to personal big data for retrieving required and related events spatially and temporally and other big data analytics/applications. The existing SP-based lifelogging researchers have developed custom-build very basic types of information retrieval methodologies by displaying information in timeline or clustering information into events and sub-events using time and maximally location information. Searching and mining in such organizations is tedious, and retrieving a particular piece of information would require one to review all of the events of personal big data of a day, at least. More sophisticated types of information retrieval methods can be developed by leveraging and learning lessons from the information retrieval technologies developed for semantic memory (i.e., facts, Web pages, and documents) retrieval domain. However, a significant body of research is needed in SP-based lifelogging area to clearly describe how and what far traditional semantic memory retrieval techniques developed over the decade can be refined and made applicable for searching and retrieving of episodic personal big data.

**Personal Big Data Impeding Forgetting** Theoretically, a SP-based lifelogging personal big data would be desired to contain the totality of a person's life experience. However, a legitimate question can be about its dealing with the issue of forgetting where people would like to forget or surpass their past bad experiences. Forgetting of past bad experience is important for individuals to live healthy and peaceful lives as well as to be integrated as a useful part of a society [126]. Firstly, clean slate concept, which means allowing a person to completely forget his past and move beyond his/her past deeds. Secondly, forgetting can be helpful in self-development by enabling people to change their opinions about things in the world. Thirdly, constant recalling of bad experience can potentially threat reconciliation among the people. Finally, not forgetting can severely effect one's mental and intellectual growth. Therefore, forgetting is important for humans and is a natural function. A person would control his memory intrinsically and could lose control if a personal big data triggers memory that he/she actually want to forget. A legitimate question is as follows: Does SP-based lifelogging personal big data contravene the forgetting ability or does it support the facility of retrieval upon demand? They are biologically and technologically interlinked, making it difficult to separate them. Therefore, SP-based lifelogging researchers would be divided on the concept of forgetting where some would be in the favor of forgetting while others would be antithesis of forgetting. However, both storing and deleting of life experience could have good and harmful effects on individual's memory and society, which might not have been noticed so far. Therefore, a critical analysis of storing and deleting of life experience in personal big data requires the researchers' attentions.

**Impairing Memory and Health** Another aspect of SP-based lifelogging is providing omnipresent access to information stored in personal big data for solving real-world problems. However, it would create negative effects on the peoples' health by increasing their dependencies on their personal big data archives. Peoples' relying heavily on their lifelogs instead of their memories could be the root cause of creating cognitive laziness and would harm their abilities and capacities to remember. The human memory is malleable, and leaving certain portions of memory unused could result into losing their functionalities. Therefore, artificial memory is not essential for human memory enhancement but could potentially reduce the biological memory capabilities. Furthermore, using technology in place of biological memory for constructing one's personal identity and awareness could result into autism or schizophrenia [129]. A personal big data can be the source of pathological rumination by facilitating ponderings for sufferers from bipolar and unipolar depression. Similarly, recalling events from personal big data can be harmful as well. For example, a recalling of a bad experience can increasingly deteriorate the post-traumatic stress disorder. However, finding more personal big data applications can reduce the remedy of effecting biological memory capabilities.

### *12.4.4 Future Directions/Recommendations*

As discussed earlier, SP-based lifelogging technology for building personal big data is in its early stages and certainly needs extensive research efforts to attract attentions of the governments, organizations, and individuals. In the preceding section, a number of challenges are described, each of which is of significant importance and needs attentions. From big data perspective, a number of research directions are highlighted in [116] for the improvement and advancement of processing and storage technologies, which equally apply to the personal big data. Notwithstanding these, and with extreme caution that it is just the start of exploring the concept and possibilities of SP-based lifelogging personal big data, we will propose a few of the future directions/recommendations specifically for strengthening the idea of personal big data generation and usability. The research directions are aimed to solve majority of the challenges identified in the previous section.

#### 12.4.4.1 Smartphone Limitations for Lifelogging

SP-based personal big data harnessing will witness high adaptability, if the technology functions according to the standard, which is passive and continuous capturing of lifelog information to the totality of life experiences. Wearable lifelogging technology suffers with a number of limitations, which are supposed to be addressed by the SP-based lifelogging paradigm. It is not hard to believe that recent advancements have enabled SP to be used as an alternative to traditional wearable lifelogging devices such as SenseCam [58]. However, SP as a compact lifelogging platform is still far behind technologically than other competitive technologies such as PCs or laptops. State-of-the-art SP needs improvements from processing power and storage capacity perspectives to capture and store comprehensive personal big data archive such as approximately 1 TB of storage would be required to store a person's lifetime data [1]. Furthermore, complexities of the physical world make capturing of relevant information about all aspects of a reality increasingly difficult. In this respect, SP's capturing devices have several challenges of effective capturing. For example, capturing devices would need specific orientation and positioning for accurate capturing of a phenomenon. In addition, capturing devices also need improvements in quality and quantity for capturing information about a reality. In addition, improvements are needed in SP networking and bandwidth technologies. Although they have been improved significantly, they can create problems while transferring and access a large volume of personal big data.

Sensing capabilities integrated in modern SPs are relatively fundamental to date. However, the existing sensing capabilities enable users to capture a spectrum of information regarding their' environments, activities and participations in social gatherings, a plethora of what they visualize and hear, and some of about their interest and likes/dislikes. The available solutions have primarily focused on using of visual and acoustic sensing technologies for lifelogging. However, collectively they can capture only a snapshot of a person's life experiences into personal big data. Therefore, advanced sensing technologies are needed to be integrated in SPs for detailed sensing and capturing of the human life semantics by recording sentiments, moods, and emotions. The list of SP physical sensors should be extended with more advanced sensors [22], and advanced sensors data fusion techniques should be explored to capture lifelog information, which are not possible from physical sensors. The integrations of advanced capturing technologies will harness comprehensive personal big data archives and will shift the technology from logging episodic memory into logging of both episodic and semantic memories.

#### 12.4.4.2 Scope of Smartphone-Based Lifelogging

Theoretically, the scope of SP-based lifelogging for personal big data harnessing has not been defined to date on how far it should capture daily life experiences. Historically, as discussed earlier, there are two schools of thoughts regarding lifelogging: extreme lifelogging and targeted lifelogging. The extreme lifelogging creates comprehensive personal big data but raises the issues of processing, storage, maintenance, and more importantly retrieving. Similarly, it is also tedious to create huge personal big data, and only a few of the extreme lifelogging collections are witnessed to date such as MyLifeBits by Gordon Bell [130]. The targeted lifelogging creates restricted personal big data and could solve the problems associated with extreme lifelogging. However, things seeming unimportant at the capture time could be of more significance and importance in the future. Similarly, data missed to capture at the first hand cannot be recaptured with the emergence of new semantic tools and use-cases. A legitimate question is as follows: Where SP-based lifelogging stands? Conceptually, SP is perceived as extreme lifelogging device; however, the available SP-based lifelogging solutions have used SP as a targeted lifelogging device. It is observed that available SP-based lifelogging solutions have shown variability of data capturing due to the absence of standard guidelines. Therefore, standard procedures should be defined to indicate scope of SP-based lifelogging to generate personal big data composing of information to fulfill the needs of the current use-cases as well as the future.

#### 12.4.4.3 Unit Identification

Unlike other information retrieval systems, a generally acceptable atomic unit of retrieval is not defined in SP-based based lifelogging. Most of the research has defined units of retrieval according to use-cases. By the law, lifelogging systems use raw data originated from sensors, which could not be queried by the users or any information retrieval system to extract data from a personal big data. The concept of segmenting continuous sensor recordings into manageable unit called an event is now a widely acceptable practice in lifelogging domain for easy indexing and retrieval of personal big data. However, event would not be an appropriate lifelogging unit for all of the use-cases such as in some situations like quantified-self-analysis a summarized or aggregated data will be useful than a list of events [5]. Therefore, big data techniques should be used to convert the raw unprocessed continuous stream of lifelog data from the sensors (i.e., using analysis of the content) into meaningful atomic units to facilitate big data analytics and applications including retrieval. In addition, research experiences from related domains can be implicated for personal big data segmentation into more meaningful and manageable units such as segmenting of lifelog information into activities using the nearest sounds [131], segmenting video into clips using time of fixed duration [132], time constrained clustering for segmenting data [118, 133], and event identification using sensors data [118]. The lifelog data segmentation will not only help in efficient retrieval but will also semantically interlink and infer related information from diverse personal big data archives.

#### 12.4.4.4 Data Analysis and Semantic Extraction

The extraction of meaningful semantics from a multiyear personal big data is a key big data challenge. The available solutions have primarily focused on data collection into a personal big data and have considered data analytics and semantic extraction as a second-priority activity [18]. In SP-based lifelogging, semantic extraction and semantic organization of the lifelog data from heterogeneous sources, including text, multimedia, and sensors, are least advanced that require the development of sophisticated data analysis and semantic extraction techniques for generating more meaningful annotations for lifelog information in personal big data. Semantically annotating personal big data can bridge the semantic gap between sensors data and users' understandings and information needs. Once lifelogging units (e.g., events) have been identified, meaningful semantics can be generated out of them for helping users in their exhaustive searching efforts. Research experiences from the other domains (i.e., using of machine learning techniques for activity recognitions) can be implicated for data analysis and semantic extractions such as extracting features and recognizing events from sensors data.

#### 12.4.4.5 Annotating Events

A SP-based lifelogging personal big data represents a flat collection of units (e.g., events), where each would be represented and interpreted by textual annotation as semantically meaningful metadata. People would have different meanings of semantic concepts due to differences in their lifestyles and looking into things. Therefore, semantic annotation can be performed either internally (automatically) by a system or in parallel by allowing users to manually annotate lifelog units (e.g., annotation in YouTube and Flicker) [5]. Contextual information and semantically extracted information can be advantageous for annotation. The annotations will be helpful in interpreting and interlinking multisource lifelog information in a personal big data to answer everyday questions (i.e., who, what, when, and where). The fundamental types of contextual information providing annotations could be information regarding location, time, identity, and activity [134]. In addition, annotating lifelog personal big data (i.e., automatically, manually, or both) can be useful in creating indexes on each of the annotating element to support search and retrieval from personal big data. Furthermore, annotations can be used to create meaningful narratives to represent contents, for example, MyLifeBits creates narratives using time and location information [1].

#### 12.4.4.6 Semantic Organization

The flat and non-related collection of daily life information in a lifelog personal big data has low usability and applicability from lifelogging and data science perspectives [5]. As discussed earlier, even the relational and hierarchical data structure also cannot effectively represent a personal big data. The lifelog information is related with each other in different relations, where the semantic interpretation of relationships depends on human interactions with the real world. Typically, a personal big data would be a densely linked archive of daily life experiences where linking lifelog information in multitude of ways provides a graph. An important baseline rule for a useful personal big data would be organizing lifelog information in a semantic model/structure similar to human episodic memory. However, for complete reflection of a person high-level semantics, advanced semantic modeling techniques are needed to be used to semantically model a person's entire set of information (i.e., events information, context information, annotations, and semantically extracted information) to facilitate retrieval and inferencing for new semantic knowledge. In addition, the semantic modeling would not only relate relevant lifelog information semantically but would also help in developing appropriate retrieval models that would support a number of big data use-cases depending on big data analytics. The Semantic Web technologies (i.e., ontology) are now developed enough to develop effective and more subtle semantic models for personal big data, which will not only match the real world but also support a variety of personal big data applications.

#### 12.4.4.7 Use-Cases and Retrieval Tools

An annotated and semantically enriched personal big data is needed to be provided through an interface to support a number of applications for solving real-world problems. A personal big data would have varied and broad big data use-cases, which will become more clear as the technology becomes more popular. Whichever might be the big data use-cases, this new technology should be developed and mapped into our lives instead of changing our lives for the technology. As discussed earlier, most of the studies have emphasized on using personal big data as memory aids due to no clear availability of its use-cases. Unfolding more use-cases will instigate the need of development of novel capture technologies to tackle new data sources and will also indicate information needs of real-world users for retrieval. However, guidance can be taken from the book "Total Recall" [119] to identify potential personal big data use-cases. Importantly, the personal big data would have the new search challenges, where the new use-cases will require the development of new search and access methodologies providing opportunities for redefining and reexamining of the available big data analytics techniques. The personal big data analytics will provide an appropriate retrieval model and correlate, combine, cross-reference, mine data from heterogeneous sources, learn, and make knowledge discoverable and presentable. Moreover, due to lacking of development of formal personal big data retrieval models, effective access tools should be developed for enabling the stakeholders to retrieve the required piece of information from a personal big data easily and trustfully as one searches the Web.

#### 12.4.4.8 Anonymization of Lifelog Personal Big Data

The SP is a highly portable device and has strong probability of being lost or damaged. With privacy concern raised in mind, if a SP with a rich personal big data is lost, it could be devastating for a lifelogger. Similarly, a personal big data may also contain information about unknown passersby, which could deteriorate the picture of individuality. In these and many other respects, the issue of anonymizing of personal big data in SP will receive research attention. We believe that anonymization should be implemented at access time, dynamic process, and dependent on user access policies instead of being nonreversible capture time process.

#### 12.4.4.9 Humanizing Technology

As discussed earlier, the SP-based lifelogging could produce an extensive personal big data in a very short span of time, which would be humanly infeasible and cumbersome to handle manually. To reduce user intervention in the sensing and recording, a lifelogging system needs to run in the SP background inconspicuously 24/7. However, users need to have an appropriate understanding and control over the SP-based lifelogging systems. Therefore, users' interventions should be limited to sensors configuration, adjusting sensors reading, and starting and stopping the service. Furthermore, the systems should use lifelogging technology to provide human-like interface in semblance of episodic memory or personality. Valuable research experiences from other domains (e.g., development of humanoid robotics) can be used in making SP-based lifelogging more humanized.

## 12.5 Conclusion

The big data has started a new era of scientific revolution with new frontiers of innovation, competition, and productivity. The personal big data is a subfield of big data and is potentially generated by the SP-based lifelogging. The SP-based lifelogging produces a comprehensive personal big data by ubiquitous and passive capturing and storing of content and contextual information about individual's daily life operations and events in a precise and fair manner. In this review, we have given a detailed overview of SP-based lifelogging from big data perspectives and guidelines. We have presented that SP-based lifelogging confirms 4 V's characteristics of big data scenarios, and SP technological developments can realize the development of personal big data archives.

There is no doubt that the concept of personal big data is relatively new; however, it is powerful enough to excel the big data research and applications to new avenues by providing information for solving problems, which are impossible before and otherwise. Like any big data, the development of specialized personal big data techniques and tools will boost the interests and investments from research community, government agencies, and organizations into this scientific discipline to achieve competitive advantages from the personal big data. The advancements in hardware (e.g., SP sensors and architectural developments, easy and high speed access to the data intensive computing platforms on cloud, etc.) and software (e.g., personal big data semantic organization and retrieval tools) technologies, development of efficient privacy and security preservation techniques, and introduction of useful personal big data use-cases will attract attentions of the researchers from academia and organizations for the development of useful personal big data solutions and retrieval applications for solving real-world problems. To fulfill the objective of personal big data, we need big systems, which will pose big challenges and problems to achieve big profits. Therefore, extensive research efforts from the stockholders are needed in this subfield to resolve its problems and increase its trend.

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# Chapter 13
# Development of a Mobile IoT Device for Supervision and Alert BPM Problems

**Luis Chuquimarca, Dahyana Roca, Washington Torres, Luis Amaya, Jaime Orozco, and David Sánchez**

## 13.1 Introduction

At present, remote monitoring systems in people are being considered important advances in telemedicine [1]. According to the World Health Organization, among the major causes of death worldwide is heart disease [2]. In this way, it is considered that it should be a relevant issue in terms of permanent monitoring in people who present this type of health problems. As is known, the cardiovascular diseases (CVDs) that present a higher death rate worldwide are cardiac arrhythmia, heart attacks, coronary artery problems, heart failure, etc. [3].

That is why the group of people with these diseases must have continuous monitoring by a family member or directly by the treating doctor, in addition to being able to review their condition and establish the necessary treatment, in addition to a family member or guardian being constantly monitored and can be alerted in the event of an emergency. For several years, the standard way in which various health data such as blood pressure levels and the heart could be measured has been done through traditional testing interventions in specialized health centers. With the help of the advancement of technology, today there is a great variety of sensors that acquire vital signs data, which have been used for the elaboration of various electronic equipment such as bracelets that measure blood pressure and monitor heart rate. Even some devices that emit a digital electrocardiogram allow

L. Chuquimarca (✉) · W. Torres · L. Amaya · J. Orozco · D. Sánchez
Universidad Estatal Península de Santa Elena, La Libertad, Ecuador
e-mail: lchuquimarca@upse.edu.ec; wtorresguin@upse.edu.ec; lamaya@upse.edu.ec; jorozco@upse.edu.ec; dsanchez@upse.edu.ec

D. Roca
Facultad de Sistemas y Telecomunicaciones (FACSISTEL), Universidad Estatal Península de Santa Elena (UPSE), Santa Elena, Ecuador



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patients to constantly track their vital signs. The Internet of Things is currently being applied much more to the care and monitoring of patients which is common in the area of health, in such a way that there is an improvement in terms of the quality of life of people; likewise it is essential to constantly store the results issued daily so that they can be subject to medical studies.

For the proposed project, it has been considered that for the emission of the signal through the heartbeat, it is carried out by means of a heart rate sensor, which acquires the signal and transforms it so that the microcontroller can process said information, in addition to resorting to other electronic designs such as the filtering and amplification system. When a heartbeat abnormality occurs, a pop-up alert is sent through a text message using the SIM808 communication module, in addition to storing the data on the ThingSpeak web platform [4, 5].

This document is divided into three sections: IoT as a solution for the bpm monitoring and alert system, in addition to the content used for the development of the project. Finally, conclusions of the development, design, and benefits of the project are presented.

## 13.2 IoT as a Solution for the Supervision and Alert BPM System

Currently, various mobile health and healthcare applications have been developed to improve, assist, and aid in health, which have been of great help to users. The Internet of Things increasingly allows the integration of devices capable of connecting to the Internet and at the same time providing information on the health status of patients in certain cases in real time to treating doctors. It is evident that chronic diseases such as diabetes, heart disease, and blood pressure, among others, stand out as a problem at the global economic and social level [6, 7].

The present work is made up of blocks. First, when you press the touch button, the connection is generated. The processes to acquire information are as follows: (1) the ATmega32u4 microcontroller is used, (2) the data acquired by the heart pulse sensor is presented on the organic light-emitting diode (OLED) screen, and (3) subsequently communication is established with the second ATmega32u4 microcontroller and the SIM808 module that contains the Global System for Mobile Communications (GSM), the General Packet Radio Service (GPRS), and the Global Positioning System (GPS) networks that constitute the communication system (see Fig. 13.1).

The information received continuously through the integrated sensor MAX30100, used for its physical characteristics, since it has a reduced size, as well as a lower energy consumption in the system. To process the acquired signals, the amplification and filtering systems are used through the libraries of the MAX30100 cardiac pulse sensor [9], in such a way that these acquired data are treated by the microcontroller; for this, the programming algorithm for the information acquisition

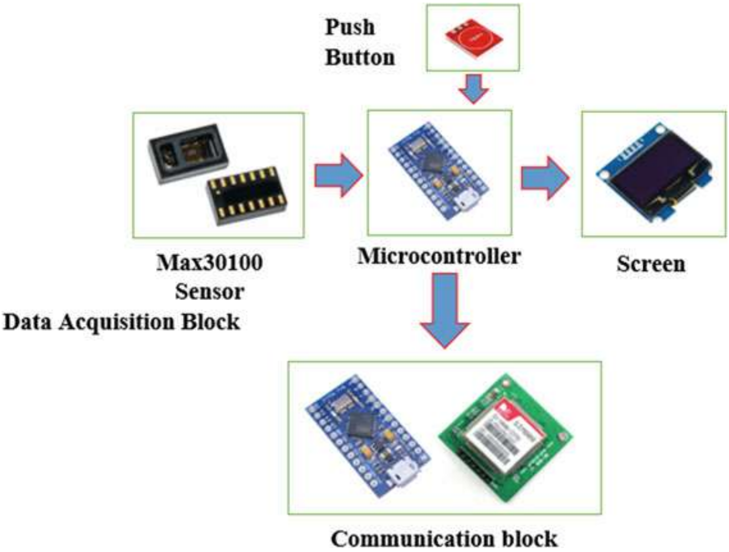



**Fig. 13.1** Processes to acquire information [8]

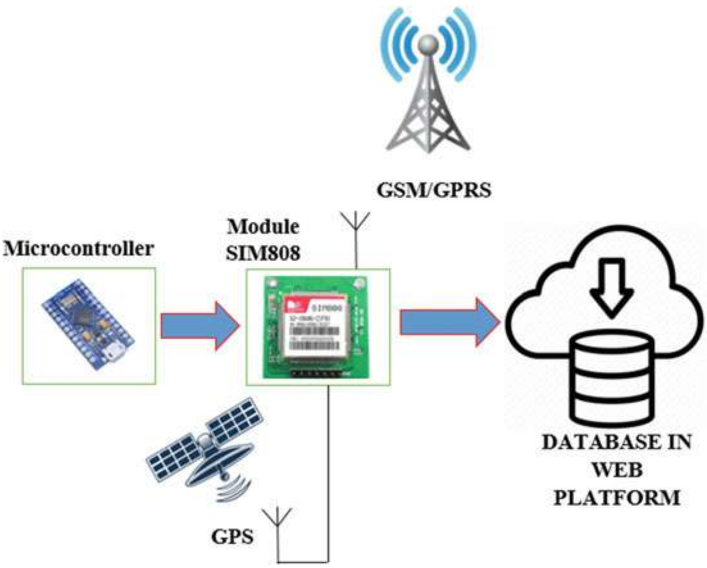



**Fig. 13.2** Communication system [8]

system has been developed. This process is complemented through the serial Inter-Integrated Circuit ($I^2C$) protocol, to comply with the purpose of the monitoring and alert device for cardiac pulsations (see Fig. 13.2).

The connection of the system that allows to acquire the data emitted by the pulse sensor and the communication system (see Fig. 13.2) or the connection between both systems and the serial ports of both microcontrollers is used for the transmission/reception of the information acquired, while the ports of communication for sending the data frame received by the sensor are the transmission/reception ports established by the manufacturer of the microcontroller. The alert system is activated when there is a variation in the nominal range of the heart rate; an SMS alert message is sent which contains the heart rate data acquired by the sensor, including the satellite location through the GPS module [10].

## 13.3 Content

### *13.3.1 Heart Pulse Oximeter Sensor*

A heart pulse oximeter is basically a device that can measure heart pulses and oxygen saturation in the blood. For the oximetry measurement, a device that allows real-time monitoring that is compatible with the microcontroller is required; for this a comparative analysis is carried out with the various cardiac pulse oximeters (see Table 13.1).

**Table 13.1** Comparison of oximetry sensors

| Pulse oximetry sensor | | | |
|---|---|---|---|
| Technical parameters | MAX30102 | MAX30100 | Keyestudio FR-4 |
| |  |  |  |
| Accessibility | Certain geographical areas | Certain geographical areas | Certain geographical areas |
| Acquisition methods | Pulse oximetry | Pulse oximetry | Pulse rate |
| Internal device | Maxim integrate MAX30102 | Maxim integrate MAX30100 | FR-4 |
| Dimensions | 12.7 × 12.7 mm | 23.5 × 19 mm | 33 × 25 mm |
| Operating voltage | 3.1–5.25 V | 5 V | 5 V |
| Power consumption | 600 μA | 600 μA | 20 mA |

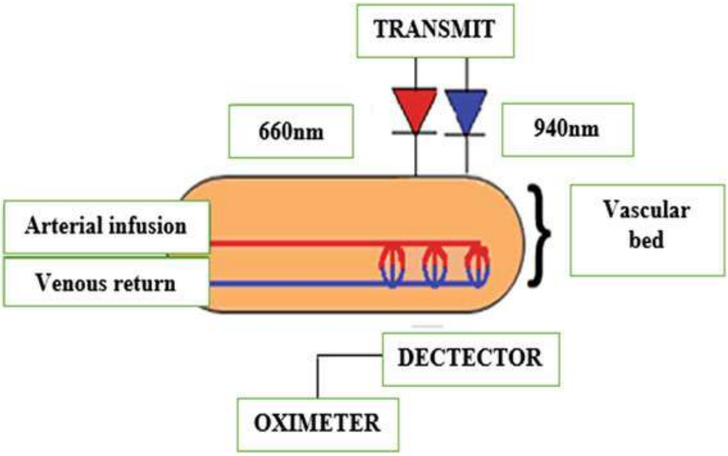



**Fig. 13.3** Pulse oximeter sensor [8]

The acquisition of the data emitted by the MAX30100 sensor consists of two LEDs that emit light, one in the red spectrum 650 nm and the other in the infrared 950 nm (see Fig. 13.3). The sensor works by means of a 5 V power supply, voltage regulated through an electronic design of a module voltage regulator [11]. The sensor is configured through the libraries established by the manufacturer; the digital data received is stored in the serial access memory used for data recording called "First In, First Out" (FIFO) [9, 12].

For data acquisition which consists of measuring the heart rate in the person, the process of alteration in blood flow is perceived in the parts of the skin where it is not so thick. In addition, by reading the blood flow and with the transformation of the signal, the heart rate information and the oxygen saturation of the blood are obtained (see Fig. 13.3) [11].

### *13.3.2 Filter and Amplification of the Signal Captured by the Sensor*

To synthesize the operation of the filtering system that contains the pulse sensor used for the development of the project, pulse oximetry is cracked taking advantage of the changes that are generated in the process of absorption of the light found in hemoglobin in its oxygenated form and deoxygenated states of blood flow. As the blood flow change occurs, the typical pulse oximeter design operates at low acquisition rates, respectively. The design of the sensor will activate the red and infrared (IR) LEDs successively at low frequency and with a minimum duty cycle in such a way that there is a minimum energy consumption; from another perspective, the execution of low duty cycles also occurs in baseline measurement of ambient

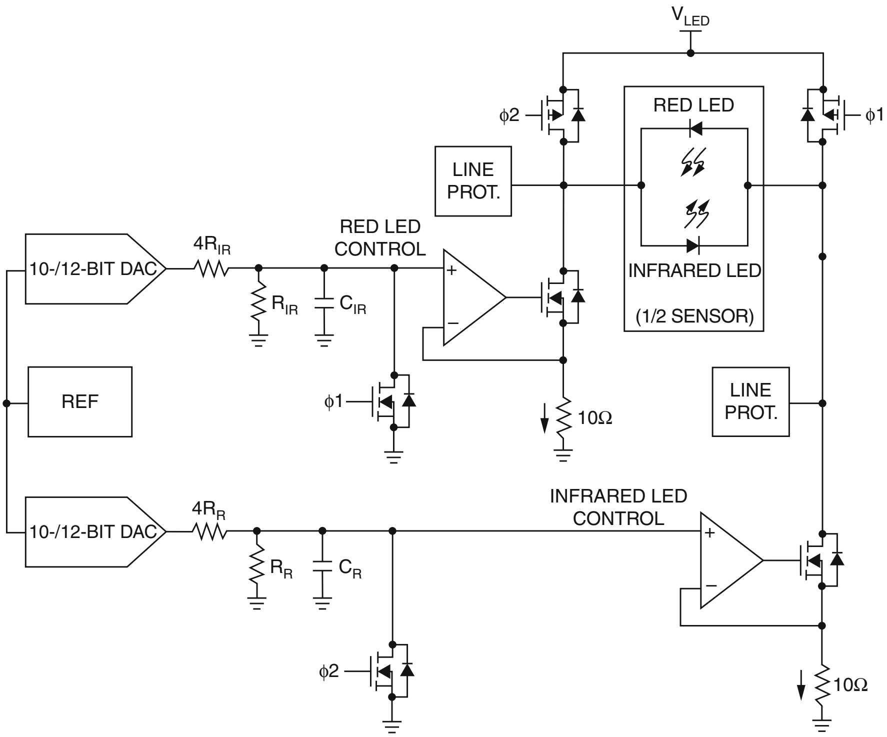



**Fig. 13.4** The pulse oximeter electronic design [13]

light while both LEDs are off. However, by activating the LEDs, noise is minimized while supplying pulses of current at the appropriate levels for each of the LEDs. Therefore, by synchronizing the current pulses of the red and IR LEDs, the integrity of the measurement is controlled and maintained so as not to affect the data obtained by the sensor (see Fig. 13.4).

For the electronic design of the filtering and amplifying stage, knowing that the manufacturers developed a current controller independently for the LED and the IR, also the complexity can be reduced by using a single DAC, but this modification can generate noise in the output side in addition to eroding the signal-to-noise ratio (SNR) on the input side, producing a problem that leads to signal degradation and therefore poor sensor performance. For MAX30100 sensor, lower signal noise is advantageous since data can be obtained faster [13]. For these types of biosensors like the MAX30100, a lower noise in the signal facilitates a faster time to report the results. Therefore, a device with a higher SNR improves the user experience by shortening the time to report human vital signs while increasing the accuracy of the results.

For the sensor amplification stage, the pulse oximeter measures red and IR light using two general approaches. One approach performs the measurement primarily

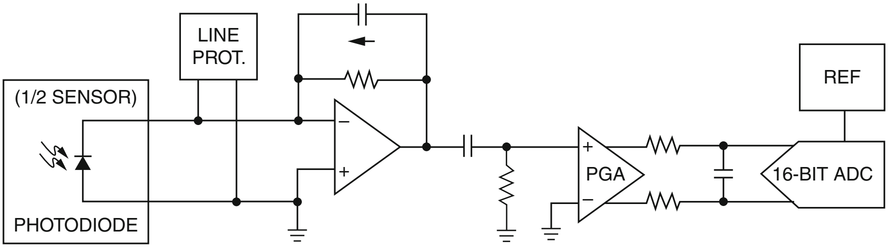



**Fig. 13.5** Transimpedance amplifier, filter, programmable gain amplifier, and analog to digital converter [13]

in the analog domain, using a dedicated ADC for each wavelength, or a single high-resolution ADC synchronized with the LED drivers to measure the results at each wavelength. Alternatively, you can perform measurements primarily in the digital domain. This approach simplifies hardware design, with the compromise being a modest increase in software complexity. At the heart of either approach, a transimpedance amplifier (TIA) converts the photodiode output current into voltage for measurement by the ADC [13].

The pulse oximeter detects transmitted or reflected light using a single photodiode and associated signal chain comprising a transimpedance amplifier, filter, programmable gain amplifier (PGA), and ADC (see Fig. 13.5).

To maximize SNR, the TIA needs to exhibit very low inrush current and noise. Typically, a high-pass filter is used to remove the ambient source component from the signal. Finally, a programmable gain amplifier is configured to use the full dynamic range of the ADC for optimal signal conversion resolution. Some external components need to be added to implement a pulse oximeter subsystem capable of providing heart rate data to a microcontroller [13].

### *13.3.3 Atmel Microcontroller*

A microcontroller is an integrated circuit that contains a very large-scale integration (VLSI); internally it has a central processing unit (CPU) and other components. Atmel has multiple microcontrollers with different characteristics; for the development of the project, the comparative process of the following ATmega Arduino cards was carried out, taking into account the accessibility, technical parameters, and the support that provide the best performance for the development of the project (see Table 13.2).

The Arduino ProMicro board has several ways of communicating with a computer, Arduino or other microcontrollers, through the serial ports it can contain or UART TTL ports. The following image details the ports that have been used and their functionality (see Fig. 13.6) [14].

**Table 13.2** ATmega Arduino board comparison

| Controller | | | |
|---|---|---|---|
| Technical parameters | Arduino ProMicro | Arduino ProMini | Arduino nano |
| |  |  |  |
| Microcontroller | ATmega32u4 | ATmega328P | Atmega168 |
| Operating voltage | 5 V | 5 V | 5 V |
| Supply voltage | 7–12 V | 7–12 V | 7–12 V |
| Operating frequency | 16 MHz | 16 MHz | 16 MHz |
| Input and output pin current | 40 mA | 40 mA | 40 mA |
| EEPROM | 1KByte | 1Kbyte | 1KByte |
| SRAM | 2.5KByte | 2Kbyte | 2KByte |
| Flash memory | 32KByte | 32Kbyte | 32KByte |
| Communications | SPI/I2C/UART | SPI/I2C/UART | SPI/I2C/UART |
| Dimensions | 32.02 mm × 17.78 mm | 30.0 mm × 18.0 mm | 18.5 mm × 43.2 mm |

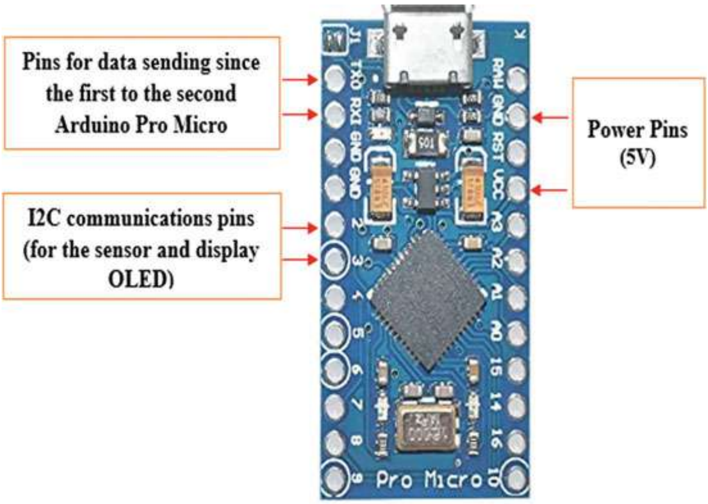



**Fig. 13.6** Arduino ProMicro, data communication ports [8]

## *13.3.4 Communication Module*

The communication module SIM808 is based on the SIMCOM SIM808 chip; it has a quad band, in addition to the functionalities of sending and receiving GSM/GPRS data (that of 2 g mobile phones) and GPS satellite navigation technology. With the SIM808 module using a SIM card, it is possible to send and receive calls and SMS,

**Table 13.3** Sim808 module with features and benefits

| Features | Advantage |
|---|---|
| Telephone bands 850/900/1800/1900 MHz | It allows to obtain connection to work in the regulated frequencies in the operators of the country |
| 37 × 37 mm dimensions | The reduced size |
| Low power consumption | It has a lower power consumption compared to the other SIM808 cards that the manufacturer has |
| Power supply from 5 to 10 V | The module contains a MIC29302 regulator that controls the voltage necessary for the operation of the module |
| IPEX connector (uFl) for GPS and GSM/GPRS antennas | These connectors allow easy antenna connections to be made |
| Global Navigation Satellite System (GNSS), with −165 dBm sensitivity and <2.5 m accuracy | Satellites allow to obtain positioning and location in the diverse places of the terrestrial globe |
| GPRS transmission speed of 9.6 kbps | The module transmission speed, which is sufficient to send information to the platform |
| TCP/UDP protocol | The module supports both communication protocols |

connect to the Internet, and know our coordinates and the Coordinated Universal Time (UTC) [15].

This module establishes access to the connection of the GSM/GPRS networks, in addition to being that works with the frequency bands of the GSM network, which are established in the radio electric spectrum in the country. The SIM808 module allows you to combine GPS technology and acquire a latitude and longitude position. In this SIM808 model, it has the advantage of incorporating lower power consumption; unlike other models, it also offers the ease of being powered by a rechargeable battery such as lithium [16]. For the programming algorithm developed for the communication module, the use of AT commands is considered, by enabling the Tx and Rx serial pins between the SIM808 module and the micro-controller. The power supply for the SIM808 module is from 5 to 10 V. When the module turns on, the indicator LED starts to blink slowly until it registers the network of the operator that we are using [17]. The characteristics of the SIM808 module are observed in the table (see Table 13.3).

### *13.3.5 IoT ThingSpeak Platform*

Currently, the use of IOT platforms has increased, and therefore its use is applied in different ways in the daily environment, using devices that allow the acquisition of data in real time; for this, it is considered that the devices work correctly, in addition to considering new technological updates [18].

IoT is a term in the area of innovation and technology, for this arise the various IoT platforms that are currently found, such as: ThingSpeak, Ubidots, etc., are tools that allow the exchange of messages between the components of an IoT system, in order to create a connection environment that allows for affordable management, as well as easy data analysis and visualization [18]. That is why IoT web platforms are considered as the growth to new technological sources. The IoT application covers environments or various “smart” spaces in domains such as transportation, construction, lifestyle, health care, emergency, medical care, user interaction, culture and tourism, environment and energy, etc.

ThingSpeak is an IoT analytics platform service from MathWorks, the makers of MATLAB and Simulink. It allows adding, visualizing, and analyzing data flows provided by electronic devices or equipment in real time on the platform; in addition ThingSpeak accelerates the development of IoT systems, mainly those that require information analysis; it also allows creating IoT systems without configuring servers or developing web software.

ThingSpeak allows the sending of data or information to the cloud; the said information is stored in a private or public channel; when the data is stored in a public channel, they allow information to be shared with other users. When the information is stored in a private channel, it can be viewed and analyzed, to obtain new information in order to interact with other devices or web services.

The web platform used for the project is ThingSpeak, in which the data obtained by the sensor, which are bpm and SpO2, are stored. In addition, through the graphical interface offered by the web platform, it is possible to visualize the data acquired in real time (see Fig. 13.7) [19, 20].

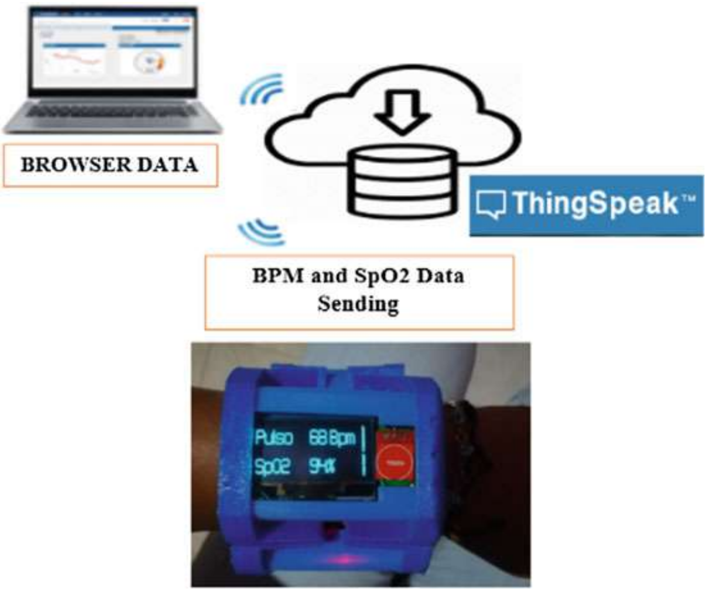



**Fig. 13.7** Scheme of the process of sending data to the ThingSpeak platform [8]

To send data to the IoT platform, the use of the TCP/IP communication protocol is used; it provides reliable communication between pairs of processes using host modules connected to the different interconnected communication networks, in this way that a control of the data issued by users to be stored and viewed on the ThingSpeak platform.

## 13.4 Methodology

The operation of the device is detailed in the flow diagrams, which contain and explain in a general way the processes involved in the fulfillment of the project objectives [21].

### *13.4.1 System Algorithms*

The operation of the device is detailed in the flow diagrams, which contain and generally explain the processes involved, flow diagram of the data acquisition system (see Fig. 13.8), and communication system flow chart (see Fig. 13.9).

### *13.4.2 Device Design and Dimensions*

The physical design of the cardiac pulse detection device has the following dimensions – 40 mm long, 52 mm wide, and 12 mm thick – in its design of each of the four parts that are interconnected for their functionality (see Fig. 13.10).

The structural design was prepared in the SketUp software [22], after which each part of the device was printed in polylactic acid (PLA) material, in such a way that it is a comfortable device for the end user [22] (see Fig. 13.11).

### *13.4.3 Configuration of Parameter*

Regarding the consideration of the pop-up alert which is triggered when a drastic change in heart rate is generated in people, that is, when the range of their bpm exceeds the normal values that oscillate between 60 and 100 bpm [23]. The configuration parameters of the device that are stored in the memory of the microcontroller can be changed by the user if necessary. These parameters are the telephone numbers of the people who will receive the pop-up alert and the Apikey ID of the ThingSpeak platform where the information will be stored (see Fig. 13.12). Said configurations are made directly on the device by pressing the configuration

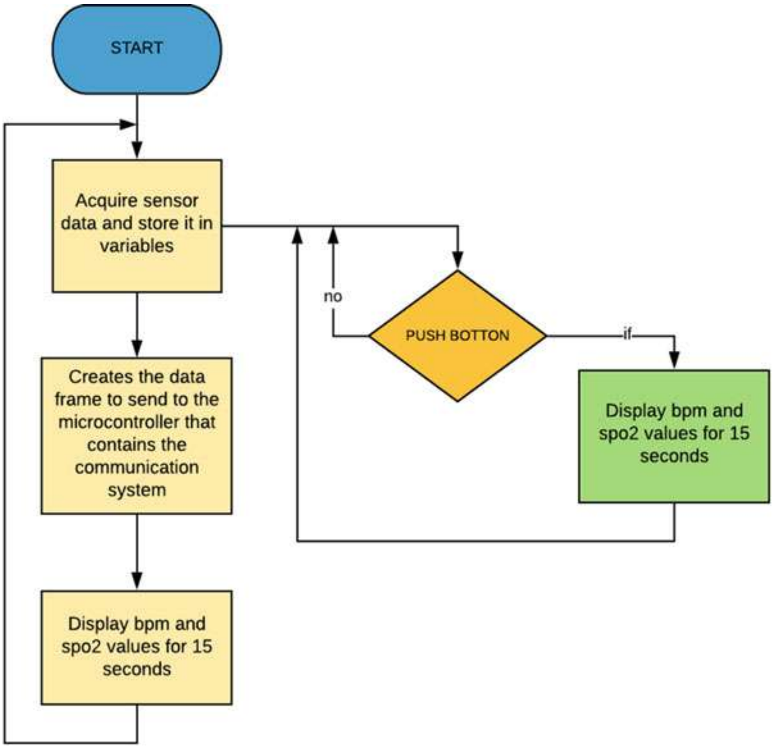



**Fig. 13.8** Flow diagram of the data acquisition system

button that is kept for 80 seconds in the configuration menu, in which the new registration of the telephone numbers or ID will be made del Apikey, by sending a text message to the number that contains the mobile device.

## 13.5 Results

### *13.5.1 BPM Data Comparison*

Through the data and measurements obtained from the "Scian" device, the following results are presented in such a way that the correct functionality is verified through the data comparison (see Fig. 13.13) [24].

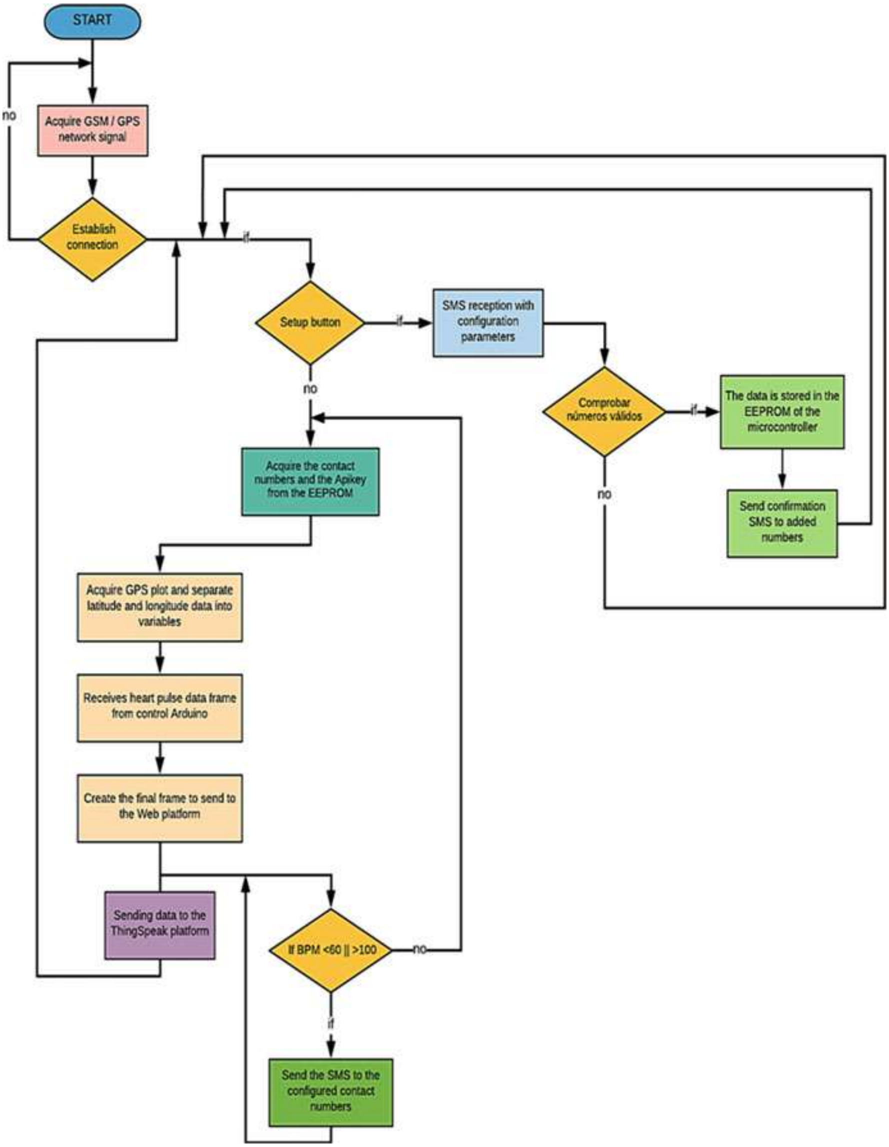



**Fig. 13.9** Communication system flow chart

## *13.5.2 Energy Consumption*

The cardiac pulse detector device, alerting and sending to an IoT web platform, is powered by a LiPo battery that supplies a voltage of 3.7–4.2 V when fully charged, with an amperage of 1800 mA. Therefore, the device consumes a lower current than

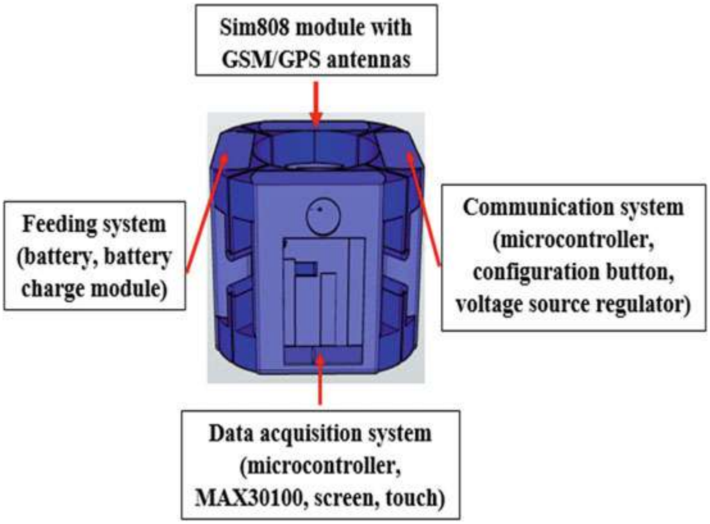
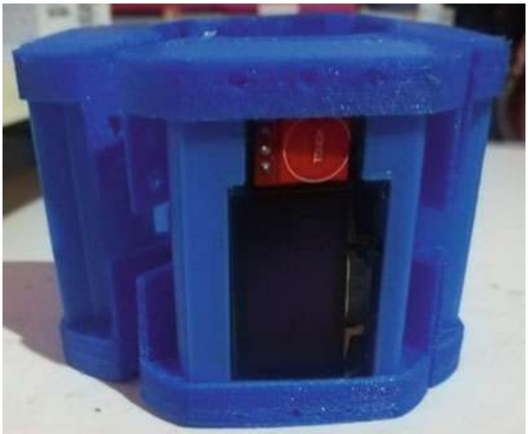



**Fig. 13.10** Device design and dimensions [8]

**Fig. 13.11** Physical design of the device [8]



that supplied and in this way the time of use of the device is provided. Through the following formula, we can calculate the operating time (see Eq. 13.1):

$$t = \frac{1800 \text{ mAh}}{200 \text{ mA}} \tag{13.1}$$

$$t \approx 9 \text{ operating hours.}$$

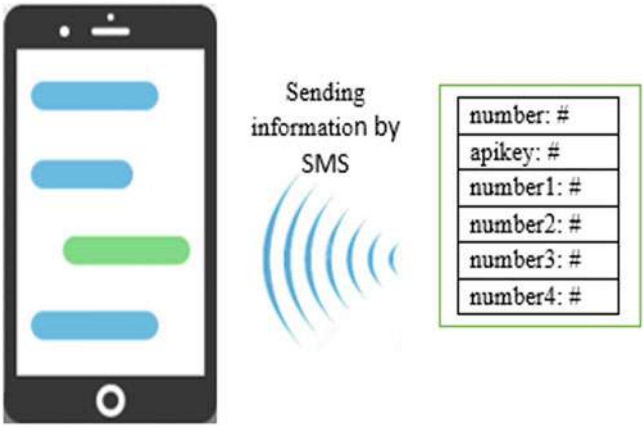



**Fig. 13.12** Setting parameters for recording data in the device [8]

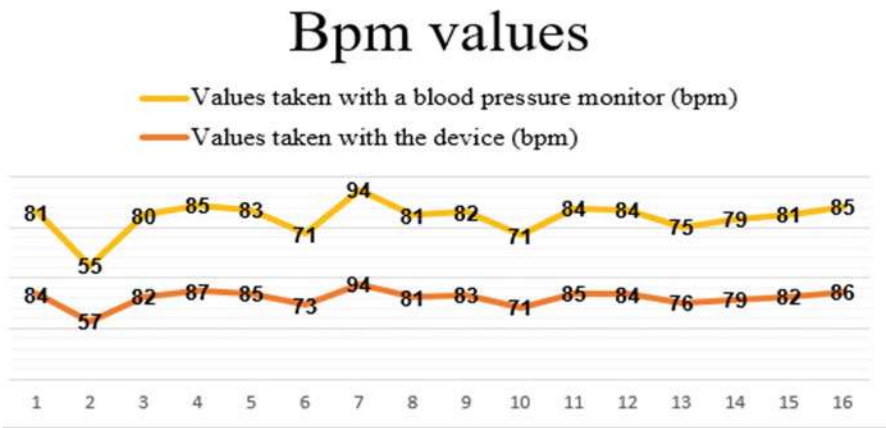



**Fig. 13.13** Comparison of receiving data between the device and a “Scian” device [8]

### *13.5.3 Alert Messages*

According to the development of the project, one of the proposed objectives refers to a system of alerts that are issued through text messages to two numbers registered in the device, when its bpm values are altered.

In the alert message, the values of bpm, SpO2, and the direct link to link with the Google Maps service are presented, in which the location of the person is established, in order to provide immediate medical help (see Fig. 13.14).

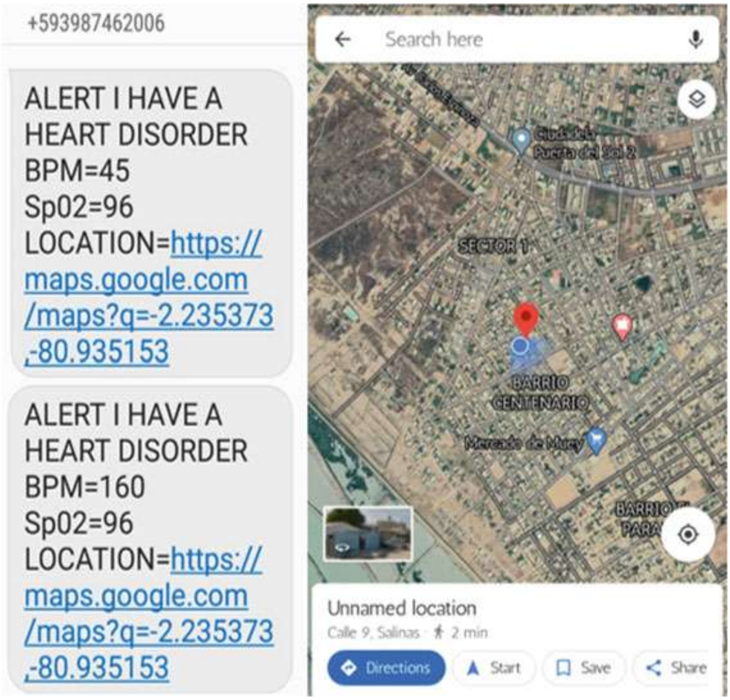



**Fig. 13.14** Parameters that are observed in the alert message [8]

### *13.5.4 IoT Platform and Data Send*

As it has been considered, the data emitted by the heart pulse sensor are sent to an IoT analysis services platform; they are stored in a private channel to be able to visualize them and in recurring cases analyze them (see Fig. 13.15).

For sending data to the ThingSpeak platform, they are carried out in an interval of 48 seconds.

### *13.5.5 Mobile Data Consumption*

The consumption of mobile data according to the data sent in a period of 1 hour of functionality was approximately 123.70 Kbytes. When carrying out the approximate calculation of consumption per day, a consumption of 2.9688 Mbytes is obtained.

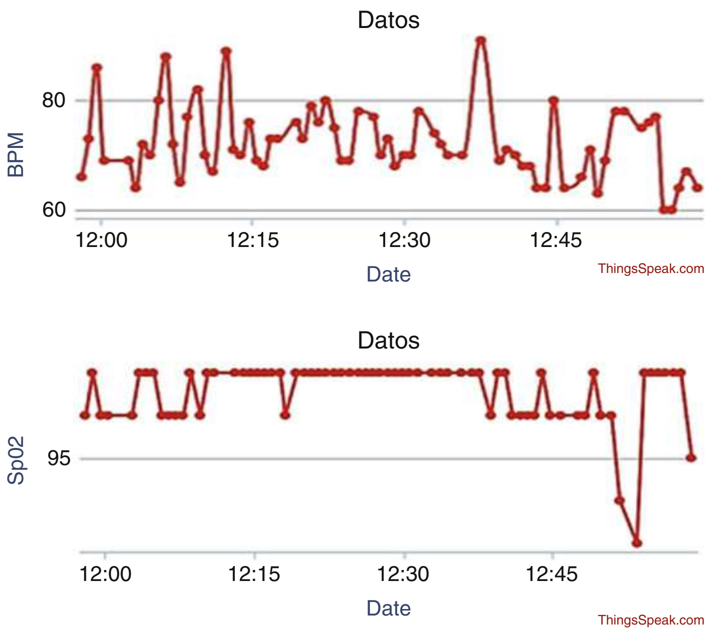



**Fig. 13.15** Recording of bpm and SpO2 data on the ThingSpeak platform [8]

## 13.6 Conclusion

The system for monitoring people with heart problems based on the Internet of Things is an alternative used to help patients or people with this type of disease. In the same way, it is a solution that improves people's quality of life, through monitoring and the alert system in case of an emergency. The experimentally developed device is focused directly with telemedicine in such a way as to allow continuous monitoring of heart rate in real time, in the event of an emergency, in the event that the heart rate values show alterations, an alert is automatically activated that consists of sending a text message to the phone numbers registered in the device, the message contains the bpm and SpO2 values in addition to the location of the satellite where the person with the heart problem is located. For the development of the device, the use of the MAX30100 sensor was used, considering the size and opting for a better performance in terms of the acquisition of the person's heart rate data; additionally among the characteristics, it has to work with a wavelength of 660 nm to improve its efficiency. Finally, between the implementation of the device, the data is sent to a ThingSpeak web platform which allows through its graphical interface to visualize the data in real time in such a way that it allows data analysis and visualization.

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# Chapter 14
# Evaluation of Data Transfer from PLC to Cloud Platforms-Based Real-Time Monitoring Using the Industrial Internet of Things

**Luis Chuquimarca, Alba Asencio, Washington Torres, Samuel Bustos, José Sánchez, and Carlos Saldaña**

## 14.1 Introduction

The internet of things (IoT) is basically a modification of the connectivity technology for information exchange Machine to Machine (M2M) using limited Internet connectivity [1]. The connection of IoT devices has evolved over time, since 1999, the objective of new technological levels is to combine the digital and physical world, whereby all the devices that surround us can be linked, collected, and transmitted through the IoT and permit data analysis in real time [2]. This technology has been applied in the industrial areas of manufacturing, energy consumption, smart cities, telemedicine, and health, giving way to continuous technological innovation and the industrial internet of things (IIoT) [3].

Although the IIoT is the strategic future of most large companies, nowadays it is considered one of the fundamental pillars of Industry 4.0 (Fig. 14.1), improves manufacturing in smart industrial processes with the easy accessibility of data by enabling the interconnection between devices and hardware operating in the industrial sector. Monitoring and controlling this technology improves the link between the operators and the industrial process, and consecutively the scalability, interoperability, reduction of waiting times, and the saving of costs that are unnecessary for an industrial company involving foreseeable maintenance, improved safety, and greater operational efficiency in real time without the need to be physically in the industrial area [4, 5].

L. Chuquimarca (✉) · A. Asencio · W. Torres · S. Bustos · J. Sánchez · C. Saldaña
Universidad Estatal Península de Santa Elena, Facultad de Sistemas y Telecomunicaciones, Santa Elena, Ecuador
e-mail: lchuquimarca@upse.edu.ec; wtorres@upse.edu.ec; sbustos@upse.edu.ec; jsanchez@upse.edu.ec; csaldana@upse.edu.ec

 
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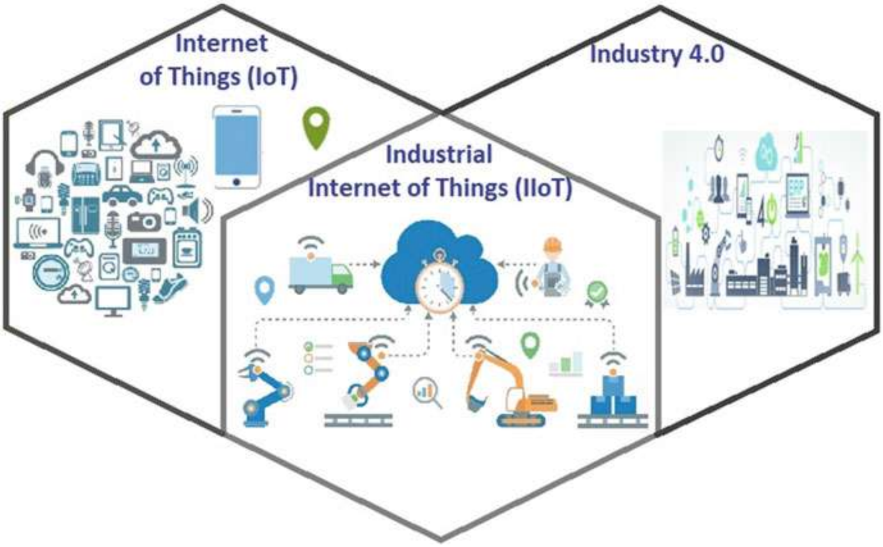


**Fig. 14.1** Industry internet of things (IIoT) is the integration of the internet of things and Industry 4.0

An important aspect in the implementation of IIoT is data gathering from devices connected to the system, different protocols used for transmission, and the reception of automated processed data. The Message Queue Telemetry Transport (MQTT) transmission protocol has become a standard that is very important for IIoT; basically, it is a means of transporting messages of little weight, and therefore it supports devices or sensors of basic use [6]. However, recently, the interface that is more frequently used and recommended for interaction in smart industry is Open Platform Communications Unified Architecture (OPC-UA), proposed as the successor to classic OPC [7].

This project presents a study on the quality of connection in agreement with delayed data collection from the production area to the Cloud through the internet and vice versa, using architecture OPC-UA. In the proposed work this configuration is used to transmit and receive data between Siemens PLC and the Simatic IIoT device in real time via Profinet according TCP/IP protocols [8]. It is clear that technological advances have revolutionized the industrial world, a way of connecting in order to collect data is the communication protocol Machine to Machine (M2M), as part of OPC-UA and is very well accepted in industry. Therefore, this protocol enables an adaptable interface where production machines are automatized to obtain the best manufacturing quality and performance [9].

The systems arrive at a higher level with the use of Scada, through monitoring software that allows interconnection between control/management equipment and simultaneously communication between the operator and the industrial process. This System depends on levels and structures for data collection for increased performance in the industry, are linked up PLC to PLC, SCADA to SCADA to realize interoperation and effect vertical and horizontal data integration. Actually, these levels (supervisory and control local/remote with PLC) are presented from the IIoT point of view for smart industry [7, 10].

Local process controls using PLC have evolved, focusing on the IIoT with new systems. First, the classic OPC is included for PCs, for example, KepServerEx OPC [7], and then the OPC-UA servers were introduced onto the HMI and PLC. Also, the communications tests of PLC Siemens S7-1200 adopt Profinet Ethernet for the configuration connection of systems with hardware Raspberry Pi 3, Siemens IoT2040, and file manager WinSCP [7] (Fig. 14.2).

Storage space is an important topic; this is quite limited when collecting data on industrial processes using the controller system. An alternative solution is the implementation of the Cloud platform coupled with the System PLC S7-1200 and Siemens IoT2040 [11] (Fig. 14.3).

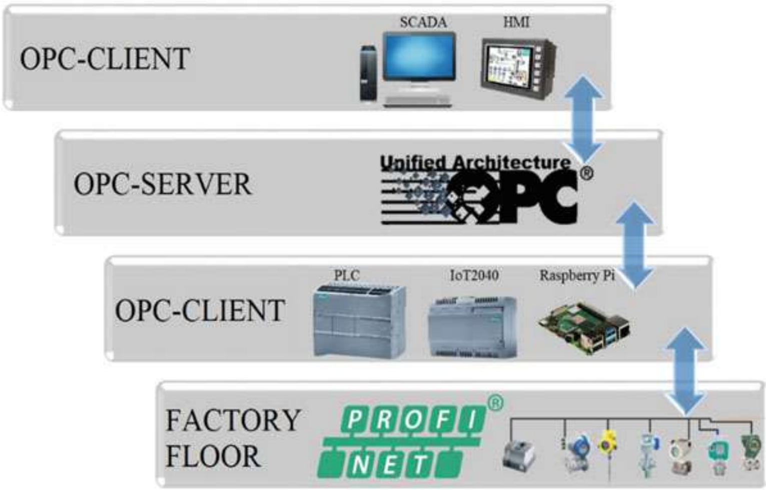


**Fig. 14.2** OPC-UA communication architecture application

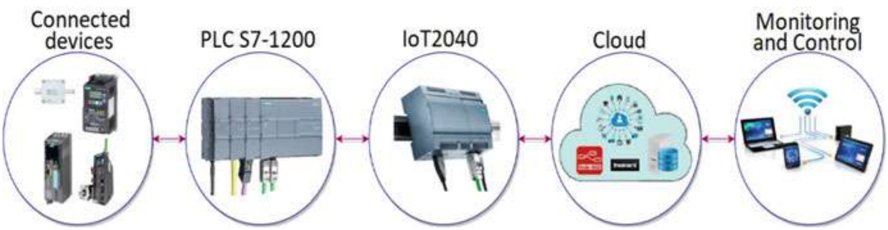


**Fig. 14.3** Implementation of a system with Cloud platform, PLC S7-1200, and Siemens IoT2040

## 14.2 Proposed System

This work is about devices controlled by remote access, the transmission/reception of data from the PLC and IoT Gateway (Fig. 14.4). For communication between these devices or machines, the web programming tool Node-Red is used. This tool allows you to configure and program through a web browser, the programming is totally graphical with nodes [4].

One of the advantages of this technology is the inquisition of data backup copies when making transfers to the Cloud; with these data two-way communication is used when sending and receiving data, which allows control of the PLC. Remote monitoring and control are commonly done on laptops, tablets, or cell phones through the specific Freeboard web platform. This platform allows variables to be controlled and monitored (bool, word, int) directly from the Cloud previously configured on the Dashboard [4].

### *14.2.1 Hardware Description*

Siemens Simatic IoT2040 is a connection interface between the PLC S7-1200 and the Cloud of the freeboard web platform, with internet access and a web application using programming languages such as Python, C++, or Java, and the communication protocol that is most frequently used, MQTT [12], also processes and stores data remote from a PLC [4].

### *14.2.2 Software Description*

Node-Red offers a graphical programming language for nodes and Freeboard a configuration and design with widgets. These software applications allow the

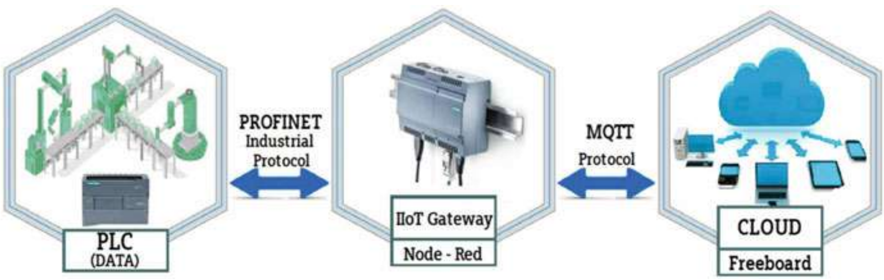


**Fig. 14.4** Transmission and reception of data between the PLC and the IoT Gateway with an Internet connection

remote monitoring and control system, which is composed of the Siemens PLC S7-1200 and Gateway IoT2040, to be built. It also includes the software for the Control, Supervision, and Data Acquisition (SCADA) system, along with its efficient network architecture, Virtual Private Network (VPN) [13].

### *14.2.3 Communication System Description*

Technology has also advanced in the field of industrial equipment communications, as Profinet (Industrial Ethernet). This is a reliable and efficient protocol in high-velocity data exchange [12] (Fig. 14.5).

The OPC-UA has become a master protocol that facilitates the communication of automated systems based on different designs of industrial communication networks [14, 15].

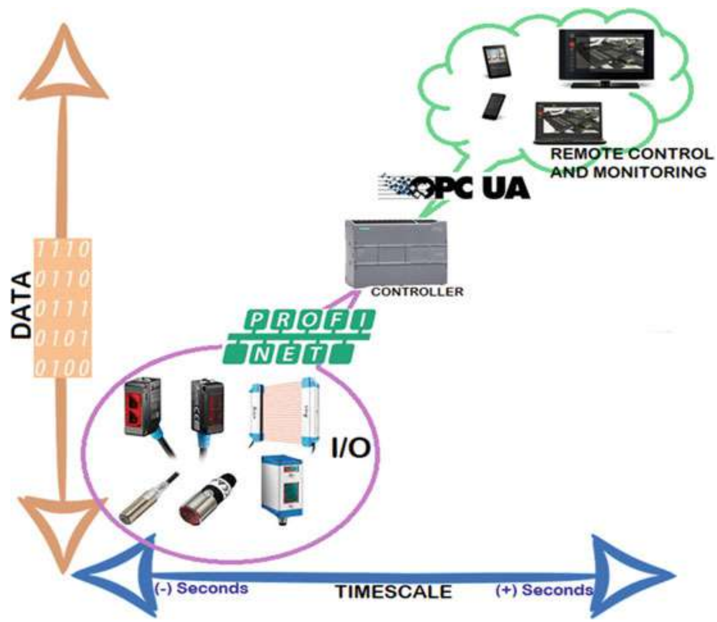


**Fig. 14.5** Profinet communication protocol, a fast and reliable connection, reduces the delay in data transmission

## 14.3 Content Development

The development system allows the control and monitoring in real time of the automatization of the industrial process, based on the control programming in the memory of the PLC S7-1200 controller, which is the device of monitoring and communication [4].

### 14.3.1 System Devices

The Programmable Logic Controller, PLC S7-1200, is an industrial process control unit. By means of logic programming it allows the automation of processes and stores the data of the different connected devices as sensors and actuators using communication protocols [16].

The Man–Machine Interface, HMI, allows interaction through an interface with the operators, which is used to supervise and control variables and verify the history of the industrial processes in real time from a process controlled by a PLC, by means of operation screens with touch buttons [17].

Supervisory Control and Data Acquisition (SCADA) is a system that allows the supervision, control, and acquisition of data in real time of control devices. It is an interface that performs monitoring in order to make decisions, acquisitions, warning alarms, and specifically the visualization of data states [18]. The system SCADA uses is KepServerEx, a platform as a server in a PC through the OPC standard that communicates the SCADA system with PLC and allows real-time monitoring and control of devices or machines used in industrial processes [19].

### 14.3.2 Protocols of Communication

To adapt to the different communication protocols of the field devices, therefore, an exchange of process data is based on the protocol OPC Client/Server. The OPC Server interprets the data received from PLC or HMI and OPC Client requests data from the server for processing. The protocol PROFINET is the communication standard used in the industrial field, owing to the high-speed transmission/reception of data, which ensures the high quality of IIoT technology [13, 20] (Fig. 14.6).

The data system transfers the information of the automated industrial process to the respective PLC controller and also the Cloud platform, with their respective software programs Node-Red and Freeboard, used by the PLC S7-1200 and IoT2040 interconnected from to the industrial network [12] (Fig. 14.7).

The development of the supervisory system through the PLC S7-1200 sends information to the IoT2040 and is finally visualized on the web platform; instead

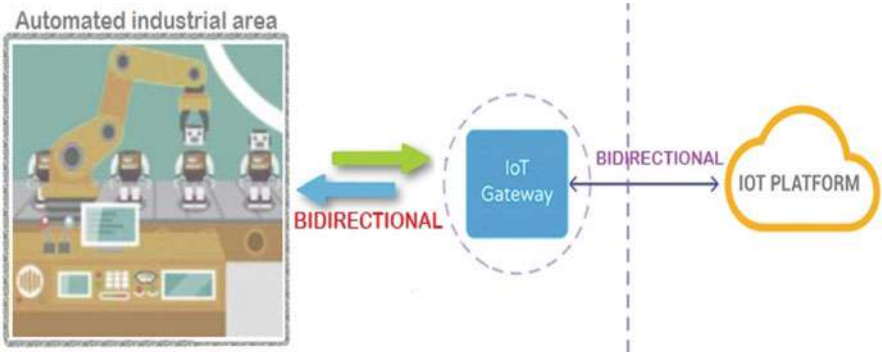


**Fig. 14.6** Bidirectional communication, high data transmission/reception speed

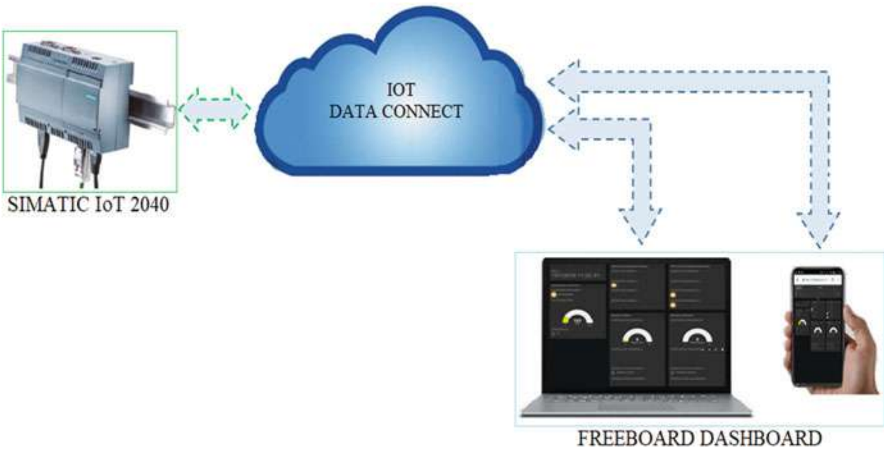


**Fig. 14.7** Communication between the Simatic Iot2040 Gateway and the Freeboard Platform

for the process control system a signal is sent from the web platform to the PLC S7-1200 for activation of the devices connected to the system (Fig. 14.8).

There is communication between the PLC S7-1200 and Simatic Iot2040 Gateway via the Node-Red tool, whose programming nodes access the PLC S7-1200; therefore, various properties are specified such as the Rack Number, Slot, IP address, and the enabling of PUT/GET protection, configured in the TIA software portal, which allows communication between these devices [4].

## 14.4 Methodology

The empirical method is applied, which allows the system of industrial data information, the data transfers of a system between the control equipment and the

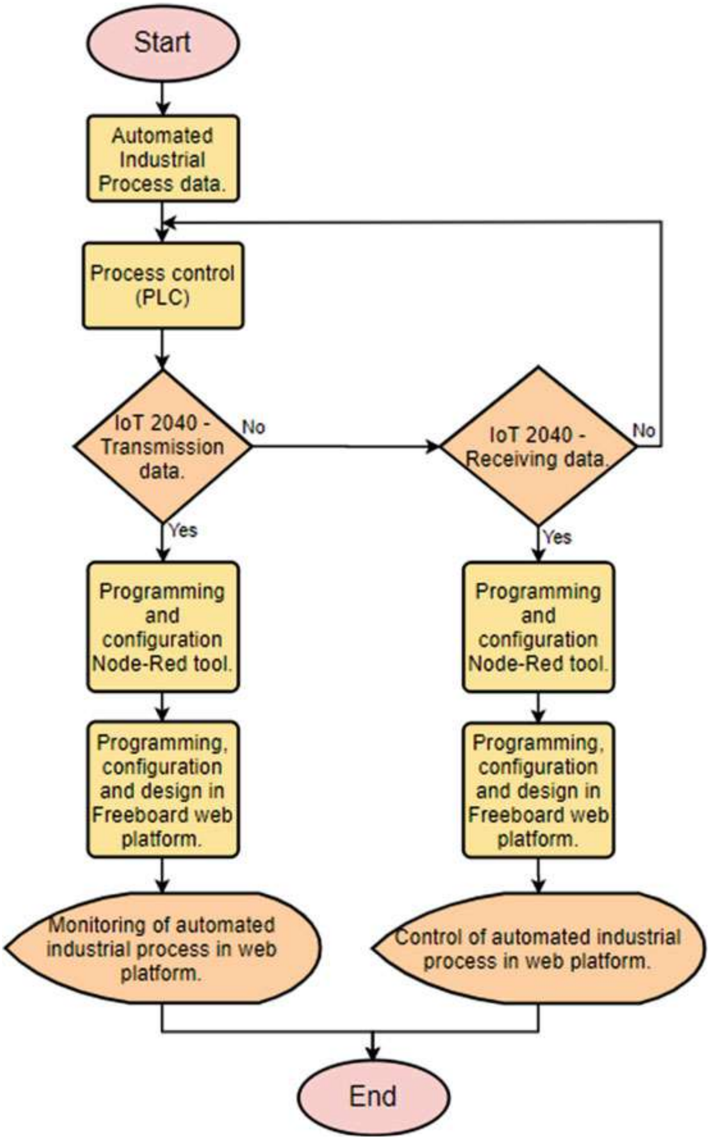


**Fig. 14.8** Logical diagram of the system for collecting and storing data received from the PLC and sent to the web platform for remote control through a web application

IoT, to be determined, taking into consideration the time delays of the industrial communication network. Certainly, the application of IIoT technology is considered less complicated than IoT applications, as the devices used in the automated area transfer data to the Cloud These data are processed to determine their storage, and then the requirement to send data from the Cloud to the field devices is analyzed.

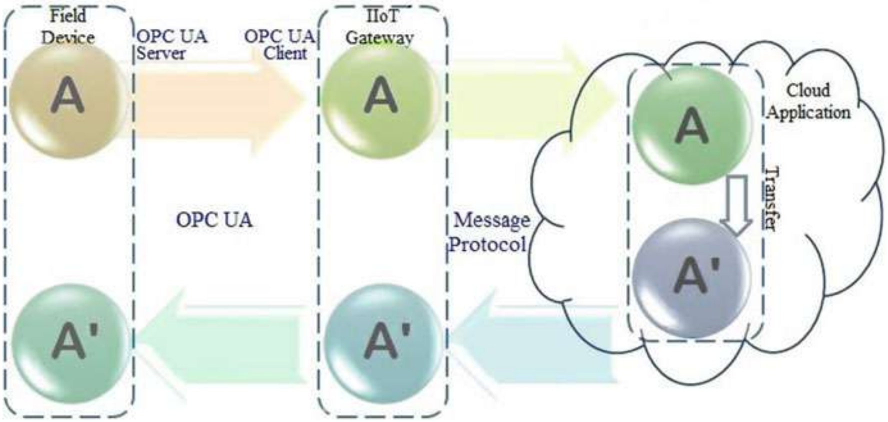


**Fig. 14.9** Communication configuration between field devices, the IoT Gateway with OPC-UA interface and Cloud platform with Message Protocol

The system consists of three elements such as the field devices, the controller system, the IIoT gateway, and the Cloud platform using the OPC-UA protocol [21] (Fig. 14.9).

The Client/Server architecture belongs to OPCUA because the servers are used to provide information to clients, whereas clients acquire information from the server system. Therefore, the data addresses of the controller device and supervisory system are configured [14].

The platform Node-Red is used to communicate various devices through a graphical programming of nodes with accessibility to different standards that allow industrial communication. The node S7 in the Node-Red tool is an OPC Client used to acquire the data stored in the OPC Server (PLC S7-1200), and the node dweetio sends the information to the Freeboard web platform for storage [14].

Freeboard communicates with the Simatic IoT2040 through the Node-Red tool. On the web platform, the graphic screen is configured and designed with the different widgets that show information from the different devices connected to the automated system [14].

## 14.5 Results

The controller of the automated system uses OPC-UA communication, while the Simatic IoT2040 is used as a gateway; it allows the reception of data from the PLC S7-1200, data information sent later to be displayed through widgets on the Freeboard web platform. The equipment is configured with an address that is on the same network as the system, to analyze the time delays produced by the industrial controllers and communication devices.

Results are obtained of the communication between the different pieces of equipment and devices, and it is possible to verify the sending and responses of data packets with their respective times. They are shown in Tables 14.1, 14.2, 14.3, and 14.4.

As shown in Fig. 14.10, the data are sent from the PLC S7-1200 to the IoT2040 and vice versa; later, the results obtained by industrial communication are analyzed, of which the time delay of sending is extensive compared with the process of downloading.

With regard to the time delay of the communication between the IoT2040 device and the Freeboard web platform and vice versa, the results obtained indicate how high the latency of sending data to the Cloud is compared with download data (Fig. 14.11).

**Table 14.1** Data sending information from PLC S7-1200 to the IoT2040 Gateway and verification of the sending and response of the data packet with its respective time

| PLC S7-1200 to gateway IoT2040 | | | |
|---|---|---|---|
| Data packet | | Time (ms) | |
| Sent | 60 | Minimum | 3 |
| Received | 60 | Maximum | 14 |
| Lost | 0 | Medium | 6 |

**Table 14.2** Data sending information from the IoT2040 Gateway to PLC S7-1200 and verification of the sending and response of the data packet with its respective time

| Gateway IoT 2040 To PLC S7-1200 | | | |
|---|---|---|---|
| Data packet | | Time (ms) | |
| Sent | 35 | Minimum | 1 |
| Received | 35 | Maximum | 8 |
| Lost | 0 | Medium | 1 |

**Table 14.3** Data sending information from the IoT2040 Gateway to the Freeboard web platform and verification of the sending and response of the data packet with its respective time

| Gateway IoT 2040 To Freeboard Web Platform | | | |
|---|---|---|---|
| Data packet | | Time (ms) | |
| Sent | 30 | Minimum | 2 |
| Received | 30 | Maximum | 9 |
| Lost | 0 | Medium | 2 |

**Table 14.4** Data sending information from Freeboard web platform to the IoT2040 Gateway and verification of the sending and response of the data packet with its respective time

| Freeboard Web Platform to Gateway IoT 2040 | | | |
|---|---|---|---|
| Data packet | | Time (ms) | |
| Sent | 30 | Minimum | 1 |
| Received | 30 | Maximum | 5 |
| Lost | 0 | Medium | 1 |

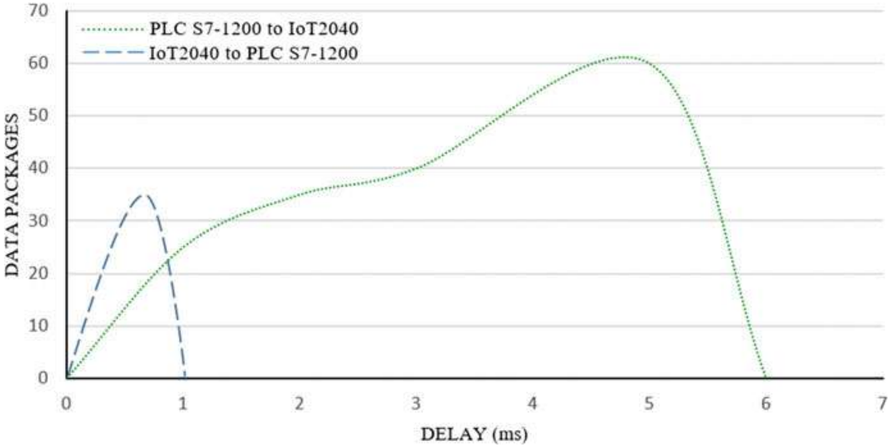


**Fig. 14.10** Comparison of data latency in PLC S7-1200 and IoT2040 communication

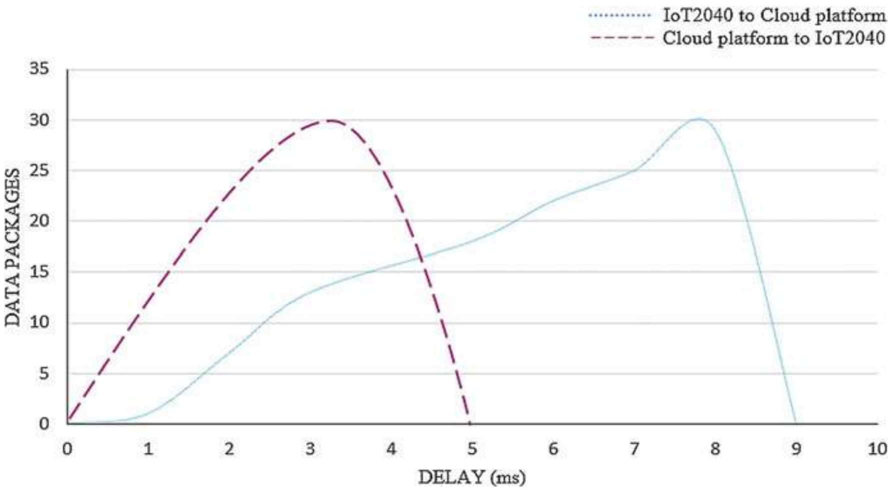


**Fig. 14.11** Comparison of data latency in IoT2040 and Freeboard web platform communication

For the programming of Node-Red, the nodes coordinate the data that the PLC needs to control and monitor the system. Therefore, the connection between the PLC S7-1200 and Node-Red includes important data such as the IP address, the PLC mode, and the rack number and slot. The declaration of read/write variables has the same addresses as those previously declared in the configuration of the PLC S7-1200 (Fig. 14.12).

For visualization of the data of the automated system, the Freeboard web platform is used for acquiring data through the configuration in Node-Red. With the configuration of the dweetio node, the data are transferred to the web platform via widgets in real time.

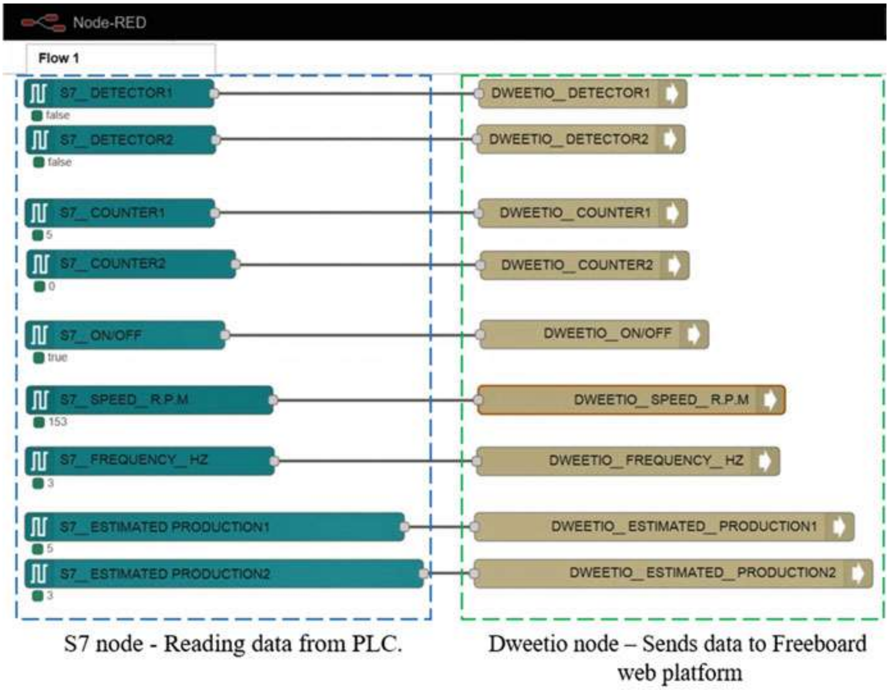


**Fig. 14.12** Use of S7 and dweetio nodes in the graphical programming of the Node-Red tool

In the Freeboard configuration the variables are imported to the data source through the command (dweet.io). Later, they are declared to be variables with the same name that the platform Node-Red has. Finally, the interface is configured using the widgets whose visualization of the data is presented on the web platform, such as indicator lights, gauge type, trend graphs (Fig. 14.13).

## 14.6 Conclusion

The future of the industrial network is Industry 4.0, which requires innovative solutions for the communication in real time of the industrial device, also reducing time delays. In the work, the OPC-UA architecture was used in different devices, such as PLC S7-1200, the IoT2040 Gateway with the platforms Node-Red and Freeboard, obtained excellent processing, storage, and transfer of data to the Cloud, considering a low of latency for industrial systems communications.

The time data transmission mensurated from the PLC S7-1200 to the Simatic IoT2040, with a minimum response time of 3 ms to a maximum 14 ms; the communication system obtained an average of 6 ms, with zero lost data packets.

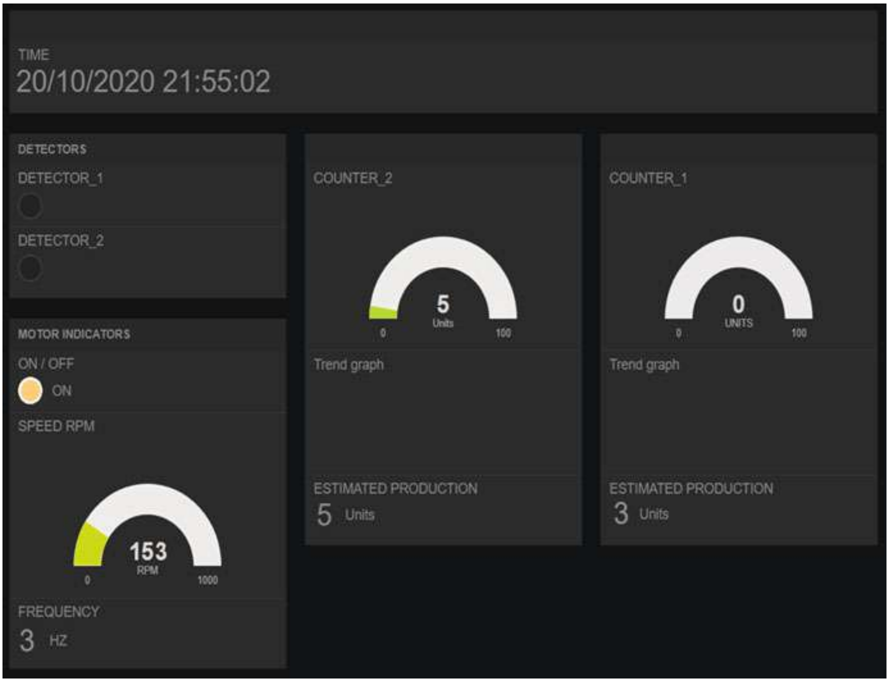


**Fig. 14.13** Data visualization in the Freeboard web platform

Instead, the time data transmission mensurated from IoT2040 to the PLC S7-1200 a minimum response time of 1 ms to a maximum 8 ms; the communication system obtained an average of 1 ms with zero lost data packets. Therefore, it is concluded that the duration of data transmission to the Cloud is much longer than that of the data downloaded from the web platform.

For future studies on the data latency in IIoT, other web platforms, such as MindSphere, and various controller devices could be considered.

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# Chapter 15
# Relationship of Body Mass Index to Body Composition and Somatotype of Infantry Personnel from the Ecuadorian Air Force

**Luis Palacios and Rosalba Rodríguez**

## 15.1 Introduction

Nowadays, the Internet has become an important tool in all aspects of our lives; the regular development of everyday activities is surrounded by different online platforms which help us to complete our tasks. Military aspects are no exception; the numerous sites available on the web have contributed to fulfill academic objectives in this area as well as to obtain data regarding military training. It is imperative to mention that all military personnel must be able to carry out their duties which mostly depend on their specific combat physical condition [1] since their "performance and body composition are key elements in all military operations" [2] and must always be ready as combatants even if the conditions demand a high-level physical performance and a balanced morphology [3].

The body composition of a person is formed by the distribution of body mass between three separate compartments: fat-free tissue or lean body mass, extracellular water, and adipose tissue, being fat the main source of energy storage which demands a high concentration of calories [4]. Likewise, for the classification of body composition, it is important to consider the research presented by Sheldon in 1940, in his first attempt to divide the human body using a continued scale; he called his technique "somatotype" [5]; this technique was modified, and currently the somatotype classification is one of the most used tools in the sports world, and as for the nutrition, it is the one introduced by Health-Carter which comprises the following: ectomorph, a tall and skinny person who does not accumulate fat

L. Palacios
Fuerza Aérea Ecuatoriana, Sangolqui, Ecuador

R. Rodríguez (✉)
Universidad de las Fuerzas Armadas – ESPE, Sangolqui, Ecuador
e-mail: rmrodriguez5@espe.edu.ec

 
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EAI/Springer Innovations in Communication and Computing,
https://doi.org/10.1007/978-3-030-75123-4_15

or develops muscle and his or her metabolism is fast; mesomorph, a person who is more balanced, relatively muscular, and well-built, with a high metabolism and responsive muscle cells; and finally, the endomorph, a person who is big, with high body fat, is often pear-shaped, and with a high tendency to store body fat [6].

Nevertheless, genetics plays a crucial role in height, body composition, and somatotype; therefore, it is the instructor's duty to establish these basic characteristics during the diagnosis and consider them to be a factor to modify diet and exercise [7]. Body mass index (BMI) is a simple calculation using a person's height and weight to determine overweight or obesity. However, these tables do not provide a reliable information regarding body composition or relative weight of an individual [8].

Consequently, it is necessary to determine the body morphology, considering the anthropometric variables which are a fundamental part of the military evaluation, since there are results of studies presented by Armed Force members of Colombia [9], Peru [10], and Chile [11] which prove that the relation of weight and height is not applicable for the military personnel.

## 15.2 Methodology

This research has a quantitative approach, because there were analyzed documents regarding the state of the art; they contained results from previous investigations related to the somatotype and military training in Peru, Chile, and Colombia; in Ecuador, there is only one study that shows results from the Army Soldiers Training School (ESFORSE). The group selected for this investigation was from 60 members of the Combat Wing 223 of the Ecuadorian Air Force; the methodology applied is the one established by the International Society for the Advancement of Kinanthropometry (ISAK) [12]; it is non-experimental research with a cross-sectional design since the samples were only taken once. This investigation was divided in different phases as presented in Fig. 15.1.

There are various instruments which can be used to obtain effective deductions; these can be ultrasounds and densitometers, among others; however, this involves investment which may be expensive. The kinanthropometric method is considered to be the most useful because it allows instructors to optimize time; it is defined as "the quantitative interface between anatomy and physiology, or between human structure and function, it is a scientific specialization that employs measurements to appraise human size, shape, proportions, composition, maturation and gross function" [13]; for this reason the measurements are simpler to use and they allow instructors to get values closer to real body composition of large groups.

Anthropometry "is the study of human body measurements especially on a comparative basis" [14]; that is why, anthropometric tools were used to analyze the individuals who were part of the study; these instruments are easy to manipulate and they provide accurate measures; in addition, they must be endorsed by international organizations. The basic components used in this research to obtain the measures

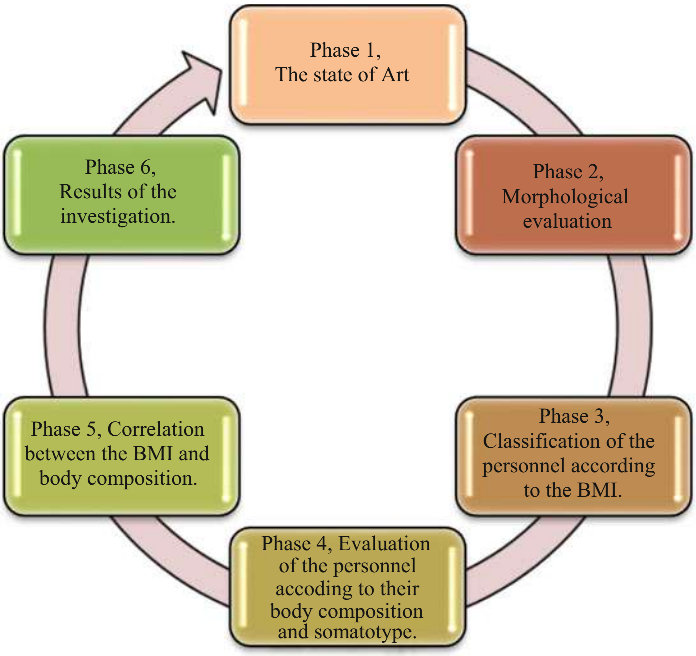


**Fig. 15.1** Phases of the research

from the Infantry personnel were the anthropometer, personal scale, spreading caliper, pelvimeter, sliding caliper, soft metric tape, and caliper; through the use of these instruments, it was possible to get lineal measures of height; the diameter of cuffs, humerus, and femur; the perimeter of calf and arm for the circumferential measures; and the mass measurement of weight and the skinfold calipers: triceps, supraspinal, abdominal, and thigh.

The anthropometric measurements of the military personnel were taken by the researcher and registered on a database that included personal information; this formation was stored on a Google Form, processed, and analyzed using a Microsoft Excel worksheet to generate the BMI measures and body composition to locate them on an anthropometric chart.

### *15.2.1 Body Mass Index (BMI)*

Body mass index is a calculation using the height and weight of an individual. The formula is BMI = kg/m$^2$ where kg is a person's weight in kilograms and m$^2$ is their height in meters squared [15]. The formula to be applied is:

$$\text{BMI} = \text{Weight (kg)} / [\text{height (m)}]\,2 \tag{15.1}$$

Body mass index is a measure of body fat and is commonly used within the health industry to determine whether the weight of a person is healthy. BMI applies to both adult men and women and is the calculation of body weight in relation to height, and the World Health Organization has established the classification presented in Table 15.1.

It is important to highlight that according to kinanthropometry, each measure has a specific methodology to be applied; that is why there are some basic rules to be considered to ensure effectiveness when collecting data. The individual who is part of the study must be wearing light clothes and no shoes, the surfaces for all the measurements must be level, and all the anthropometric tools have to be frequently calibrated.

### *15.2.2 Body Composition*

Faulkner technique is the most used and it was developed with the Olympic Canadian team; it is based on the measurements of skinfolds of five anatomic parts: triceps, subscapular, supraspinal, abdominal, and thigh. Two formulas to obtain these measures in this study were applied:

$$\%G = \left(\sum \text{skinfolds : T, SE, SI, AB}\right) \times 0.153 + 5.783 \tag{15.2}$$

$$\text{P.G} = \frac{\%G \times \text{Total weight}}{100} \tag{15.3}$$

To determine the lean body mass (LBM) and the healthy weight (HW), it was taken into consideration the studies of De Rose in professional Brazilian athletes. Two formulas were applied:

$$\text{LBM} = \text{Total weight} - \text{fat weight} \tag{15.4}$$

**Table 15.1** Classification of weight status

| Weight status | Body mass index (BMI), kg/m$^2$ |
|---|---|
| Underweight | <18.5 |
| Normal range | 18.5–24.9 |
| Overweight | 25.0–29.9 |
| Obese | ≥30 |
| Obese class I | 30.0–34.9 |
| Obese class II | 35.0–39.9 |
| Obese class III | ≥40 |

*Source:* WHO [16]

$$HW = LBM \times 1.12 \tag{15.5}$$

According to Von Dobelen, the height, cuff, humerus, and femur diameter is taken into consideration as variables to determine bone mass (BM), and a formula to obtain the BW was applied:

$$BM = 3.02\left(\frac{H^2 \times R \times F \times 4}{1000000}\right)^{0.712} \tag{15.6}$$

The residual weight corresponds to the 24% of the total weight in men and 21% in women.

Once the residual weight was calculated, it was possible to determine the muscle mass which corresponds to the active muscle mass (AMM); in order to get this measure, it was taken into consideration the bone mass (BM), fat mass (FM), and the residual weight (RW), and the formula applied was:

$$AMM = \text{Total weight} - (BM + FM + RW) \tag{15.7}$$

### *15.2.3 Somatotype*

The three types of somatotypes established by Health and Carter were previously explained and are represented in Fig. 15.2 [17].

This graphic is divided into three exes which are intercepted in the center and form angles of 120°, each exe representing a component. The somatotypes are located in the graphic: endomorphic vertex (7-1-1), mesomorphic vertex (1-7-1), and the ectomorphic vertex (1-1-7).

It is necessary to detail the different formulas applied to determine the typology of an individual through the method of Health and Carter. According to Baldayo and Steele [19], the formulas for each somatotype are:

**Endomorphy (Endo)** It describes the fat tissue in the human body and it was possible to determine it through the equation which included skinfold measures of triceps (TR), subscapular (SE), and supraspinal (SI) in the following formula:

$$\text{Endo} = -0.7182 + 0.1451(X)–0.00068\left(X^2\right) + 0.0000014\left(X^3\right) \tag{15.8}$$

$$X = \sum \text{skinfolds (TR, SE, SI)} \times 170.18/\text{Height}$$

in which:

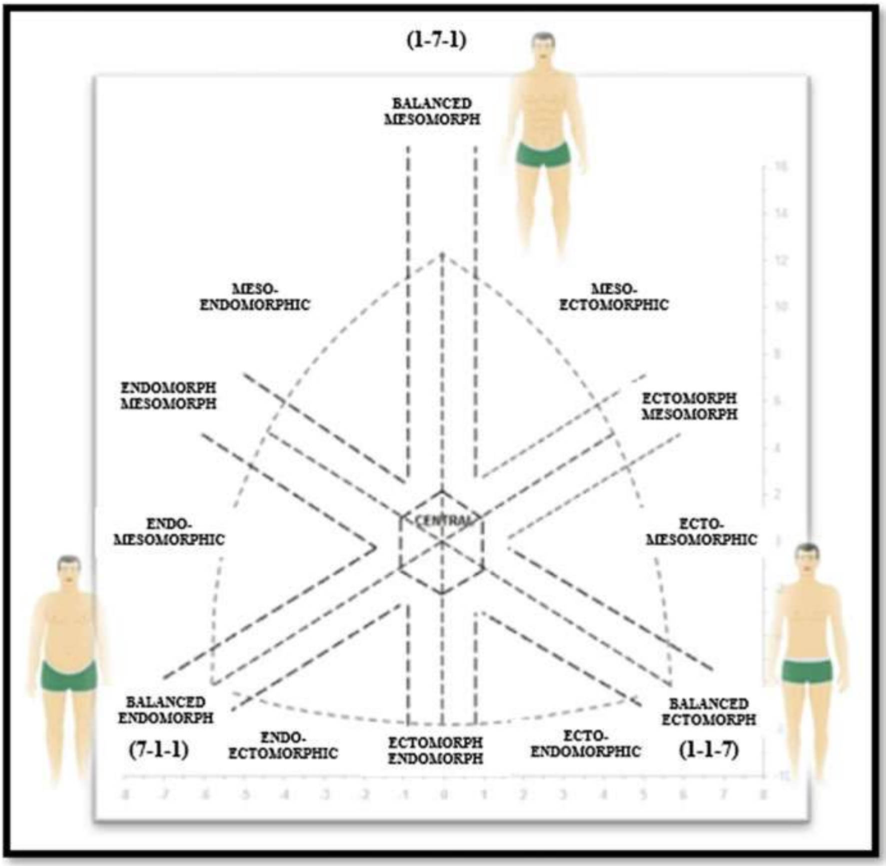


**Fig. 15.2** Classification of somatotypes by Franz Reuleaux. (*Source:* EFDeportes [18])

Σ skinfolds = belongs to the addition of all the skinfold measures of triceps (TR), subscapular (SE), and supraspinal (SI); this result is corrected by multiplying it with the phantom value which is 170.18 cm.

**Mesomorphy (Meso)** It represents the development of the skeletal muscle mass and it is calculated by applying the formula:

$$\begin{aligned} \text{Meso} = (0.858 \times U) + (0.601 \times F) + (0.188 \times B) \\ + (0.161 \times P) - (E \times 0.131) + 4,50 \end{aligned} \tag{15.9}$$

in which:

$U$ = Biepicondylar breadth of the humerus in centimeters
$F$ = Biepicondylar breadth of the femur in centimeters
$B$ = Corrected upper arm girth

$P$ = Corrected leg perimeter
$E$ = Height

The corrections, which are proposed to exclude the fatty tissue from the muscle mass, are done by subtracting the value in centimeters from the skinfold values, and the formulas are:

$$B = \text{PB} - (\text{DT}/10) \tag{15.10}$$

$$P = \text{PP} - (\text{DP}/10) \tag{15.11}$$

in which:

PB = Upper arm girth
DT = Triceps skinfold measure in millimeters
PP = Leg perimeter
DP = Leg skinfold measure in millimeters.

**Ectomorphy (Ecto)** It is the relative physical linearity of individuals; it evaluates the shape and grade of distribution of the previous components. These values depend on the Ponderal Index (PI), and the formulas to obtain these values are:

$$\begin{aligned} &\text{ECTO} = 0.732 \times \text{PI} - 28.58, \ \text{ if the PI is greater} \\ &\quad \text{than or equal to } 40, 75 \end{aligned} \tag{15.12}$$

$$\begin{aligned} &\text{ECTO} = 0.463 \times \text{PI–17.63}, \ \text{ if the PI is less than } 40.75 \\ &\quad \text{and greater than } 38.25 \end{aligned} \tag{15.13}$$

$$\text{ECTO} = 0.1, \text{ if the PI is less than or equal to 38.25} \tag{15.14}$$

in which:

$$\text{PI} : \text{Ponderal Index} = (\text{Height/mass}) \ 0.333$$

Once the results of the endomorphy, mesomorphy, and ectomorphy are established, these values must be located in a somatotype chart, represented in a two-axis ($x$, $y$) Cartesian system [20].

**Coordinate Calculation ($X$-$Y$)**
Carter proposes a model in which the central point is represented by zero in both coordinates, determining ($X$) by the points −6 in the ENDO vertex, +6 in the ECTO vertex, and ($Y$) is determined by the point +12 in the MESO vertex, as it is explained in the following formulas:

$$X = \text{Ectomorphy–Endomorphy} \tag{15.15}$$

$$Y = 2\ \text{Mesomorphy} - (\text{Ectomorphy} + \text{Endomorphy}) \quad (15.16)$$

Eventually, some different somatotypes as 5-5-5, 4-4-4 or 3-3-3 may be located at the same point in the somatotype chart; for this reason DUQUET suggested a special model in which each exe $X$, $Y$, $Z$ corresponds to a component.

All these somatotype values lead to the following classification [21]:

Classification of one dominant category and the other two equally balanced:

- Balanced endomorph: endomorphy is dominant and mesomorphy is greater than ectomorphy and endomorphy and ectomorphy are equal (or do not differ by more than one-half unit).
- Balanced mesomorph: mesomorphy is dominant and endomorphy and ectomorphy are equal (or do not differ by more than one-half unit).
- Balanced ectomorph: ectomorphy is dominant and endomorphy and mesomorphy are equal (or do not differ by more than one-half unit).

Classification in which two categories are equally dominant and the third is lower:

- Mesomorphic-endomorph: endomorphy is dominant and mesomorphy is greater than ectomorphy.
- Mesomorphic-ectomorph: ectomorphy is dominant and mesomorphy is greater than endomorphy.
- Endomorphic-ectomorph: ectomorphy is dominant and endomorphy is greater than mesomorphy.

The other six positions are named after the prefix of the category with lower values and a suffix as the dominant category.

- Meso-Endomorph
- Endo-Mesomorph
- Ecto-Mesomorph
- Meso-Ectomorph
- Endo-Ectomorph
- Ecto-Endomorph

It is important to remark that this research was carried out based on male values since there are no women in charge of Infantry operations.

### *15.2.4 The Applicability of the Internet of Things (IoT)*

There were found various programs for the analysis of body composition. The first is a software developed by MedicalExpo, which also distributes technological medical supplies; this software may also be applied to determine body composition, body mass index, and adipose mass; it is presented in Fig. 15.3.

**Fig. 15.3** Body composition software 115. (*Source:* MedicalExpo [22])

**Fig. 15.4** Anthropometry software. (*Source:* Informatics and Sports [23])

**Fig. 15.5** Anthropometry software program. (*Source:* Anthropometry Software Program [24])

**Fig. 15.6** Body composition software. (*Source:* Body composition software [25])

BodyMetrix is another option available to measure body composition; this software is more complete since results are presented in a somatotype chart. Its logo is displayed in Fig. 15.4.

Nutri solver is the first software that gives customers the option of calculating the nutritional status with emphasis in anthropometry, body composition, and energy consumption; it can be used in students, teachers, and professionals. Its logo is displayed In Fig. 15.5.

This is an application that can be used from any devices; it is a fast program based on scientific research about body composition. Its logo is displayed in Fig. 15.6.

MUSEUMIS 2020 is another application for body composition assessment; it is only available for mobile devices, it is practical, and data can be modified at any


**Fig. 15.7** MUSEUMIS 2020 home page

time. There is a variety of options which can be used, and the most common features are displayed in Figs. 15.7 and 15.8.

## 15.3 Results

The data of 60 members of the Infantry Group 223 of the Ecuadorian Air Force was processed; the information collected was age, body mass, height, body mass index (BMI), breadth, length, and subcutaneous skinfolds; it was also considered the thickness of adipose, bone, residual, and muscle tissues, the lean body mass, waist hip index (ICQ), the somatotype, and the relation between body mass index and body composition; these values are described in Table 15.2.

Table 15.2 contains the results of the mean, standard deviation, and minimum and maximum values of the basic variables: age 27.07 ± 6.72 years; body mass 79.00 ± 30.39 kg; height 170.50 ± 5.14 cm; BMI 27.02 ± 10.01 kg/m$^{2;}$ addition of subcutaneous skinfolds 68.00 ± 23.7 mm; variables of breadth: biepicondylar 5.5 ± 0.3 cm, humerus 6.8 ± 0.6 cm, and femur 9.8 ± 0.8 cm; lengths: calf 38.0 ± 2.8 cm, arm 31.3 ± 3.1 cm, waist 90.3 ± 10.3 cm, and hip 100.0 ± 14.0 cm; and subcutaneous skinfolds, triceps 9.5 ± 5.6 mm, subscapular 14.0 ± 6.0 mm, supraspinal 14.0 ± 6.6 mm, abdominal 18.0 ± 7.0 mm, and leg 6.0 ± 3.0 mm.

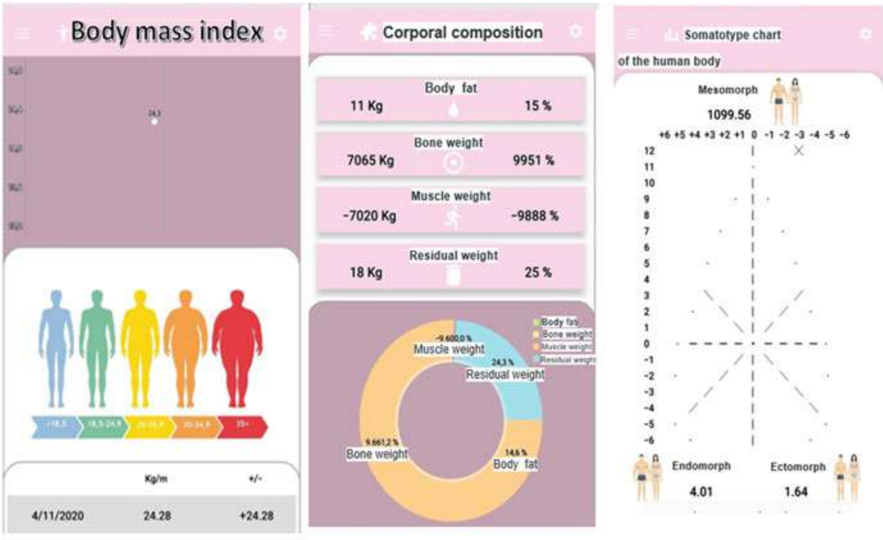


**Fig. 15.8** A somatotype chart available on the app MUSEUMIS 2020

**Table 15.2** Basic measurements and variables of breadth, length, and subcutaneous skinfolds

| Variables | PCP $n = 60$ | | | | |
|---|---|---|---|---|---|
| | Mean | | DE | Min | Max |
| Age (years) | 27.07 | ± | 6.72 | 22.05 | 51.04 |
| Body mass (kg) | 79.00 | ± | 30.39 | 59.00 | 220.00 |
| Height (cm) | 170.50 | ± | 5.14 | 156.00 | 186.00 |
| BMI (kg/m$^2$) | 27.02 | ± | 10.01 | 21.36 | 75.24 |
| $\sum$5 skinfolds (mm) | 68.0 | ± | 23.7 | 18.0 | 140.0 |
| *Breadth (cm)* | | | | | |
| Biepicondylar | 5.5 | ± | 0.3 | 5.00 | 6.50 |
| Humerus | 6.8 | ± | 0.6 | 5.80 | 9.50 |
| Femur | 9.8 | ± | 0.8 | 8.70 | 13.00 |
| *Length (cm)* | | | | | |
| Calf | 38.0 | ± | 2.8 | 32.00 | 45.50 |
| Arm | 31.3 | ± | 3.1 | 27.00 | 41.00 |
| Waist | 90.3 | ± | 10.3 | 70.00 | 130.00 |
| Hip | 100.0 | ± | 14.0 | 10.10 | 120.00 |
| *Subcutaneous skinfolds (mm)* | | | | | |
| Triceps | 9.5 | ± | 5.6 | 2.00 | 32.00 |
| Subscapular | 14.0 | ± | 6.0 | 6.00 | 30.00 |
| Supraspinal | 14.0 | ± | 6.6 | 3.00 | 30.00 |
| Abdominal | 18.0 | ± | 7.0 | 5.00 | 40.00 |
| Leg | 6.0 | ± | 3.0 | 2.00 | 18.00 |

The BMI percent is presented in Fig. 15.9.

The BMI of the population are as follows: zero participants are underweight, which represents 0%; 22 participants have a healthy weight, which is the 36%; 23 participants are overweight, which represents the 38%; ten participants are obese I, which is 17%; one participant is obese II, which represents 2%; and four participants are obese III, which represents the 7%.

The results of the body composition are presented in Table 15.3.

The results of the mean, standard deviation, and minimum and maximum values of body composition in percentage and weight in kilograms are presented in Table

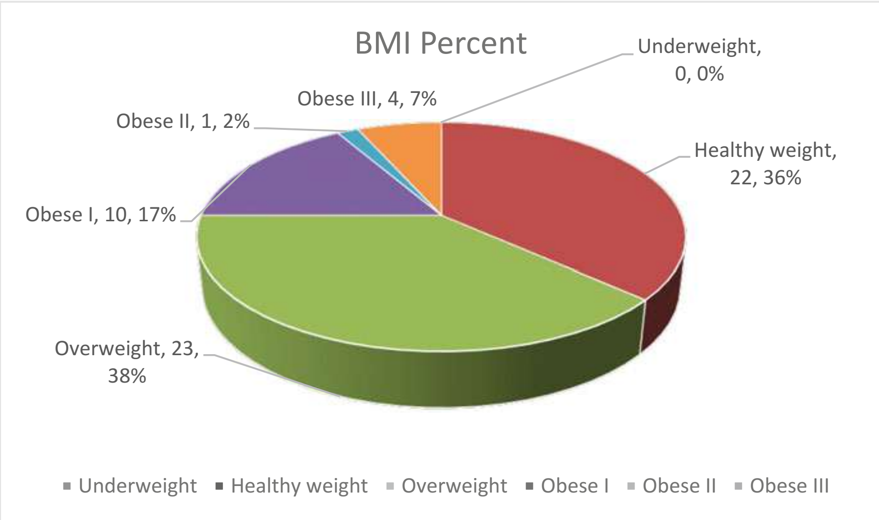


**Fig. 15.9** Results according to the body mass index (BMI) of the participants

**Table 15.3** Body mass composition

| Variables | Measure | PCP $n = 60$ | | | | |
|---|---|---|---|---|---|---|
| | | Mean | | DE | Min | Max |
| Body composition by Carter and Heath (1999) | | | | | | |
| Adipose tissue | % | 15.19 | ± | 3.26 | 8.23 | 24.45 |
| | (kg) | 11.70 | ± | 6.49 | 4.86 | 36.62 |
| Bone tissue | % | 16.68 | ± | 3.01 | 5.55 | 22.58 |
| | (kg) | 13.01 | ± | 1.56 | 10.62 | 18.03 |
| Residual tissue | % | 24.0 | ± | 0.0 | 24.0 | 24.0 |
| | (kg) | 19.0 | | 7.3 | 14.2 | 52.8 |
| Muscle tissue | % | 45.0 | ± | 3.8 | 35.6 | 53.8 |
| | (kg) | 35.0 | ± | 17.1 | 22.4 | 118.4 |
| Lean body mass | (kg) | 67 | ± | 25 | 50 | 183 |
| ICQ | | 0.9 | ± | 1.0 | 0.8 | 8.4 |

15.2. The results are as follows: adipose tissue 15.19 ± 3.26%, 11.70 ± 6.49 kg; bone tissue 16.68 ± 3.01%, 13.01 ± 1.56 kg; and residual tissue 24.00 ± 0.0%, 24.00 ± 0.0%, 19.0 ± 7.3 kg.

The results of Table 15.3 are also presented in Fig. 15.10.

As for the results of the somatotype, they are presented in Table 15.4.

In Table 15.4, the somatotype results of the mean, standard deviation, and minimum and maximum values of the variables: endomorph 4.8 ± 1.6; mesomorph 5.9 ± 1.6; ectomorph 0.8 ± 1.5; Ponderal Index (PI) 39.9 ± 3.0; $X$ coordinate −4.0 ± 2.7; $Y$ coordinate 6.2 ± 3.3, which corresponds to the category of mesomorph-endomorph because the component II is dominant and greater than component III.

The somatotype results are also represented in the somatotype charts displayed in Figs. 15.11 and 15.12.

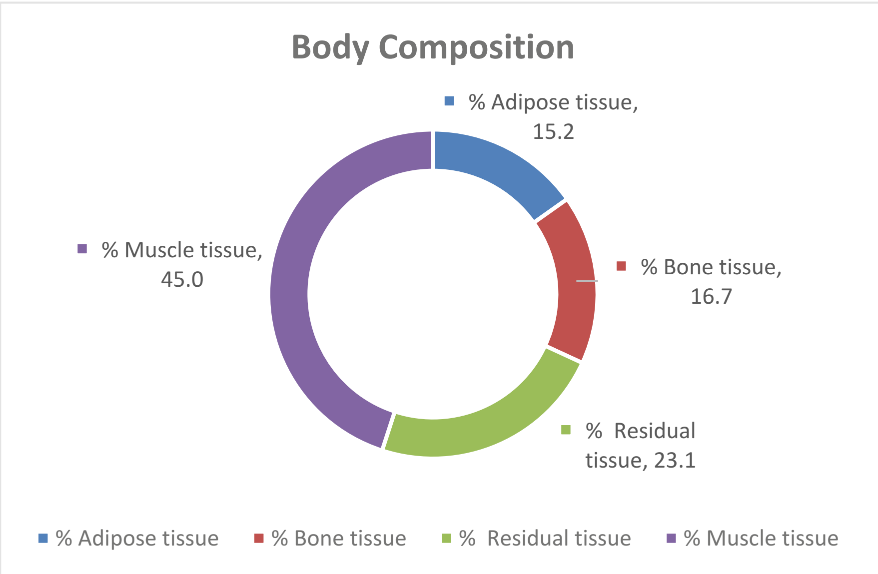


**Fig. 15.10** Percent of body composition

**Table 15.4** Somatotype results

| | | PCP $n = 60$ | | | | |
|---|---|---|---|---|---|---|
| Variables | Measure | Mean | | DE | Min | Max |
| Somatotype by Carter and Heath (1999) | | | | | | |
| Somatotype | Endomorph | 4.8 | ± | 1.6 | 1.1 | 8.4 |
| | Mesomorph | 5.9 | ± | 1.6 | 2.4 | 10.8 |
| | Ectomorph | 0.8 | ± | 1.5 | −4.5 | 3.6 |
| | PI | 39.9 | ± | 3.0 | 28.3 | 43.9 |
| | $X$ | −4.0 | ± | 2.7 | −9.7 | 1.3 |
| | $Y$ | 6.2 | ± | 3.3 | −1.8 | 15.8 |

In Table 15.5, it is presented the relationship between the BMI and body composition (above and under the average) from the participants of this research (PSP).

In Table 15.5, there are the results of the percentage relationship of BMI and body composition (above and under the group average) of 60 military members; the results indicate that there are no participants who are underweight; from 22 participants who have a healthy weight, four, which is the 18%, are above the average of adipose tissue; from 23 participants who are overweight, nine, which is the 39%, are under the average of adipose tissue, ten of them, which is the 43%, are above the average of the muscle tissue, and 15 of them, which is 65%, are above the average of lean body mass; ten participants are considered to be obese I, one of them, which represents the 10%, are under the average if the adipose tissue, four of them, which is the 40%, are above the average of muscle tissue, ten of them, which represents 100%, are above the average of lean body mass; one participant who is considered to have obesity II is above the average of lean body mass; from four participants who are considered to be obese III, three of them, which represents the 75%, are above the muscle tissue, and four of them, which represents the 100%, are above the average of lean body mass.

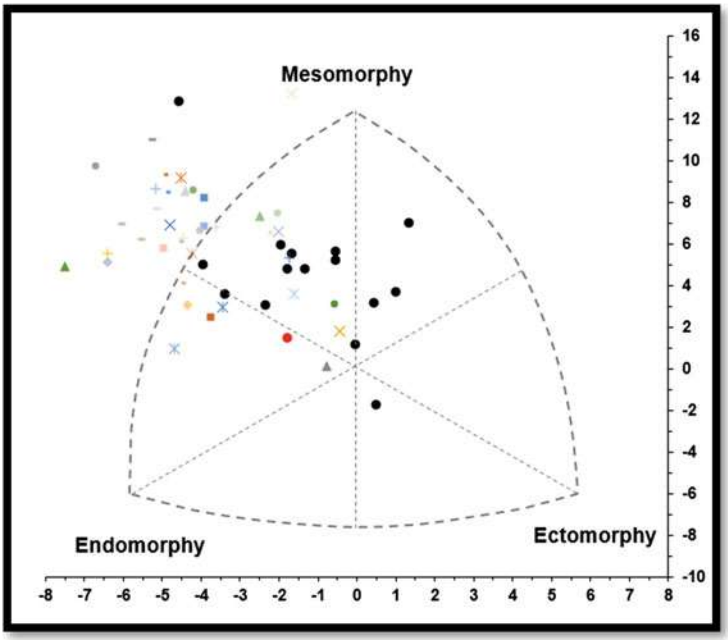


**Fig. 15.11** Variety of somatotypes found in the study

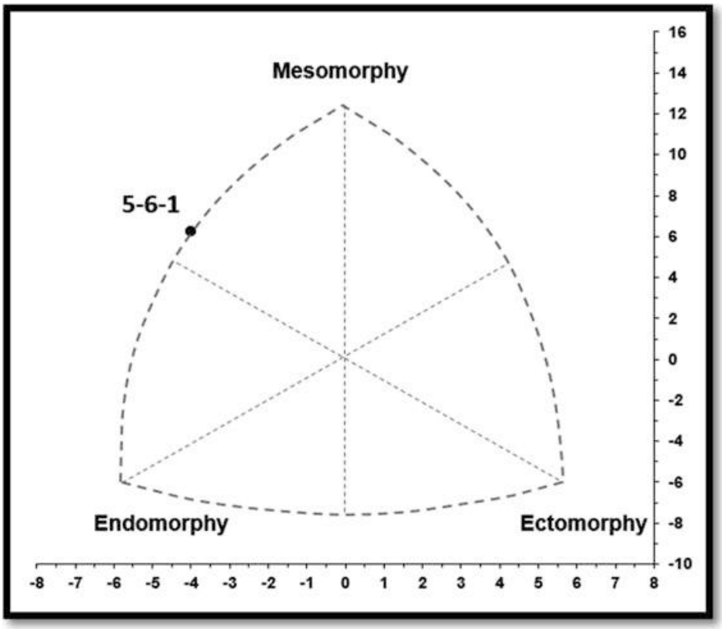


**Fig. 15.12** Somatotype average

## 15.4 Discussion and Conclusions

With the anthropometric characteristics of the Chilean male military personnel [26], in which the average age is 33.83 ± 7.96 years old, with a BMI of 28.64 ± 3.56 kg/m$^2$, compared to the results of the current study of 27.07 ± 6.72 years old and a BMI of 27.02 ± 10.01 kg/m$^2$, it is possible to state that the BMI is directly proportional with the age in the military personnel. Likewise, the average of the adipose tissue in the Chilean study which is 28.48 ± 6.04% the average of the muscle tissue, which is 43.87 ± 5.12% compared to the results of the current research, which are 15.19 ± 3.26% for the adipose tissue and 45.0 ± 3.8% for the muscle tissue, shows that the adipose tissue increases and the muscle tissue decreases with the age. Finally, the location of the somatotype average from the Chilean military personnel is placed in the somatotype chart with endomorph values of 5.09 ± 1.64, mesomorph values of 6.05 ± 1.24, and ectomorph values of 0.77 ± 0.78, compared to the results of the current investigation which are endomorph 4.8 ± 1.6, mesomorph 5.9 ± 1.6, and ectomorph 0.8 ± 1.5, confirming that there is a minimal difference between the two studies, locating the participants of both researches under the category of mesomorph-endomorph.

Based on the percentage relationship of BMI and body composition of 22 participants, who are categorized as healthy weight, four of them, which represents

**Table 15.5** The relationship between the BMI and body composition

| BMI | PCP $n = 60$ | Mean | % fat | PCP $n = 60$ | % bone | PCP $n = 60$ | % | Muscle | PCP $n = 60$ | % | PCP $n = 60$ | Lean body mass | PCP $n = 60$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Under weight | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Healthy weight | 22 | Above | 18 | 4 | 95 | 21 | 24 | 5 | 1 | 59 | 13 | 0 | 0 |
| | | Under | 82 | 18 | 5 | 1 | 24 | 95 | 21 | 41 | 9 | 100 | 22 |
| Overweight | 23 | Above | 61 | 14 | 35 | 8 | 24 | 61 | 14 | 43 | 10 | 65 | 15 |
| | | Under | 39 | 9 | 65 | 15 | 24 | 39 | 9 | 57 | 13 | 35 | 8 |
| Obese I | 10 | Above | 90 | 9 | 10 | 1 | 24 | 100 | 10 | 40 | 4 | 100 | 10 |
| | | Under | 10 | 1 | 90 | 9 | 24 | 0 | | 60 | 6 | 0 | 0 |
| Obese II | 1 | Above | 100 | 1 | 0 | 0 | 24 | 100 | 1 | 0 | 0 | 100 | 1 |
| | | Under | 0 | | 100 | 1 | 24 | 0 | | 100 | 1 | 0 | |
| Obese III | 4 | Above | 100 | 4 | 100 | | 24 | 100 | 4 | 75 | 3 | 100 | 4 |
| | | Under | 0 | 0 | 0 | 4 | 24 | 0 | 0 | 25 | 1 | 0 | 0 |

the 18%, who are above the group average of the adipose tissue, it is possible to establish that this category is not decisive to define body weight.

Based on the percentage relationship of BMI and body composition of 23 participants who are considered to have overweight and ten of them who are part of the obese I group and nine and one participant from these groups are under the average of the adipose tissue, it is possible to state that these categories do not discriminate the percentage of predominant fatty mass to be in the healthy weight category.

Based on the percentage relationship of BMI and body composition of 23, ten, and four participants who are categorized as overweight, obese I, and obese III, respectively, and ten, four, and three of them are above the average of muscle tissue, it is possible to state that these categories do not discriminate the percentage of predominant muscle mass to be in the healthy weight category.

Based on the percentage relationship of BMI and body composition of 23, ten, and four participants who are categorized as overweight, obese I, and obese III, respectively, and 15, ten, and four of them are above the average of lean body mass, it is possible to determine that these categories do not discriminate the percentage of predominant lean body mass to be in the healthy weight category.

The body mass index of the military personnel who participated in this research is not determined to define exactly the weight categories which may lead them to have health issues, since the BMI only relates the total body weight to the height, and in some cases the average of the adipose tissue is low and the muscle tissue is high because of the physical activity that a military personnel has.

There are different programs and applications available on the web to register and process the data collected from the anthropometric measures; in this research, the information was stored on a database which was developed on a Google Form, a tool that is part of the package of Google Docs Editors; all the information gathered was synchronized with a worksheet of Microsoft Excel to generate body composition values as well as statistical graphs to represent the results of the research in a somatotype chart in real time.

In conclusion, the applicability of the IoT to control body composition and somatotype permanently results to be a practical and dynamic method which allows users to keep track of their health, especially in the military field, in which the physical shape plays an important role during operations.

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# Part IV
# Smart Environments

# Chapter 16
# Water Management in the Territorial Development Organization Plans of the Provinces of Bolívar and Cañar

**Marcelo Leon, Jessica Ayala, Leidy Alexandra Lozano, and Juan Pérez-Briceño**

## 16.1 Introduction

In recent years we can see that most of the objects that we use in our environment and daily life such as televisions, washing machines, refrigerators, and air conditioning, among others, are interconnected through the Internet. This interconnection is known under the term Internet of Things (IoT) introduced in 1999 by Kevin Ashton, Executive Director of the Auto-ID Center at the Massachusetts Institute of Technology [1, 2].

Within this IoT environment, we also find sensors for the collection of environmental variables, such as temperature, humidity, atmospheric pressure, noise, flow, solar radiation, air quality, and gases, among others [3].

All this has led us to be able to monitor and manipulate things remotely through the Internet and has allowed us to produce large volumes of data that when processed allow analysis and use in decision-making [4].

M. Leon
Universidad Tecnológica Empresarial de Guayaquil, Guayaquil, Ecuador

J. Ayala
Universidad de las Fuerzas Armadas del Ecuador, Quito, Ecuador

L. A. Lozano (✉)
IS-PCE S.A.S, Bogotá, Colombia

J. Pérez-Briceño
Universidad Técnica de Ambato, Ambato, Ecuador
e-mail: jc.perez@uta.edu.ec



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The case of water is not alien to the benefits of the IoT since it makes it possible to maintain detailed control of information on water resources and allows a more optimized and efficient use and management by being able to base decisions on real and updated data [5].

Likewise, when using IoT, the increase in the efficiency of water use in all sectors is favored, even in the total purification of wastewater, thus expanding recycling and reuse and the liberalization of agricultural water for other functions of the ecosystem [6].

At a global level, efforts are being made in management models for the efficient use of water resources due to their scarcity. In South Africa, Cape Town will be the first city to run out of water due to climate change, so its management is based on rationalization and control of its consumption by each inhabitant [7, 8]. In America, Brazil, and Los Angeles, the water scarcity problem occurs due to excessive use and climate change [9].

The annual availability of water reported by the World Bank until 2014, worldwide, was 5932 $m^3$ per inhabitant, while in Ecuador the estimated annual availability of water was 27,733 $m^3$ per inhabitant, that is, Ecuador has a rate 4.6 times higher than the world average [10].

In Latin America, the Territorial Development Organization Plans (PDOTs) with respect to water resources are considered as an instrument for the prevention of contamination and sustainable management of resources [11]. In Ecuador, the integral management of water resources is carried out by hydrographic units under the directive of the Single Water Authority, and the provincial and municipal decentralized autonomous governments (GADs) must coordinate water management with this entity and have the responsibility of including projects in their management plans and activities to prevent water contamination and promote efficiency of use, according to Article 42 of the Organic Law of Water Resources Uses and Use of Water published in RO No. 305 on August 6, 2014 [12].

The problem at the local level of water resources in the province of Bolívar and Cañar is diverse, and the main causes are due to deforestation, destruction of protective vegetation due to the expansion of agricultural activity, lack of solid waste management, and water discharges served.

The province of Bolívar is located in the central-western zone of the inter-Andean region, occupying the basin of the Chimbo River on the outer slopes of the Western Cordillera of the Andes. It has an area of 3944.86 $km^2$. The relief of the province is rugged and mountainous, with altitudes ranging from 180 m.a.s.l. to 4000 m.a.s.l. The hydrographic system of the Bolívar province is divided by the Chimbo mountain range, which runs longitudinally from north to south. Among the productive activities of the province are sheep, cattle, pig, and poultry farming, metal mining, and hydroelectric projects. The province is divided into seven cantons: Guaranda, Chimbo, Bolívar, Chillanes, Echeandia, Caluma, and Las Naves.

The province of Cañar is located in the south central region of Ecuador. It has an area of 4106.76 $km^2$. The hydrographic system of the province is framed on the Pacific slope and the Amazon slope; it has different altitudinal floors, and the area belonging to the highland has a mountainous and steep relief, while the area belonging to the coast has low relief and little steep. The economic activities of the province are agriculture, small-scale cattle ranching, commercial activities, and handicrafts. Its cantonal political division corresponds to La Troncal, Suscal, Cañar, El Tambo, Biblian, Deleg, and Azogues [13].

The objective of this study was to identify the current situation of territorial management in relation to water resources in the provinces of Bolívar and Cañar with respect to their needs and deficiencies in the PDOTs and to propose improvements in their environmental management at the local level, taking advantage of the benefits of the IoT.

Water is the basis of sustainable development. Poverty reduction, economic growth, and environmental sustainability are based on water resources and the range of services they provide. From food and energy security to human and environmental health, water contributes to improving social well-being and inclusive growth, affecting the livelihoods of billions of human beings [14].

The problem at the local level of water resources in the province of Bolívar and Cañar is diverse, the main causes are due to deforestation, destruction of protective vegetation due to the expansion of agricultural activity, lack of solid waste management and water discharges served (Fig. 16.1).

The objective of this study was to identify the current situation of territorial management in relation to water resources in the provinces of Bolívar and Cañar with respect to their needs and deficiencies in the PDOTs to propose improvements in their environmental management at the local level.

## 16.2 Methodology

For the diagnosis of the water resource in the PDOTs, the qualitative method was used applying an analytical investigation of land use plans of the provinces of Bolívar and Cañar obtained from the National Information System until 2013, in addition to information on environmental information indicators of municipal GAD of the INEC 2017 and 2014. The topics to be investigated were:

- Situation of the rivers
- Water use, drinking water coverage, and sanitation
- Environmental management

The seven cantons studied in the province of Bolívar were Guaranda, Las Naves, Echeandia, Caluma, Chimbo, San Miguel, and Chillanes. From the province of Cañar, the evaluated cantons were La Troncal, Suscal, Cañar, El Tambo, Biblian, Deleg, and Azogues (Figs. 16.2 and 16.3).


**Fig. 16.1** Province of Bolívar and Cañar

## 16.3 Results

### *16.3.1 River Situation*

Ecuador has shown significant progress in terms of environmental legislation; however it is not the most appropriate, and it is not in accordance with current times and the seriousness of the problem of environmental damage; hence environmental legal regulations must include relative provisions to safeguard the normal functioning of nature in order to maintain, preserve, and conserve it and legally establish environmental rights not only as an object of legal protection but also to consolidate the recognition of the legal personality of nature as established by the current Constitution [17, 18].

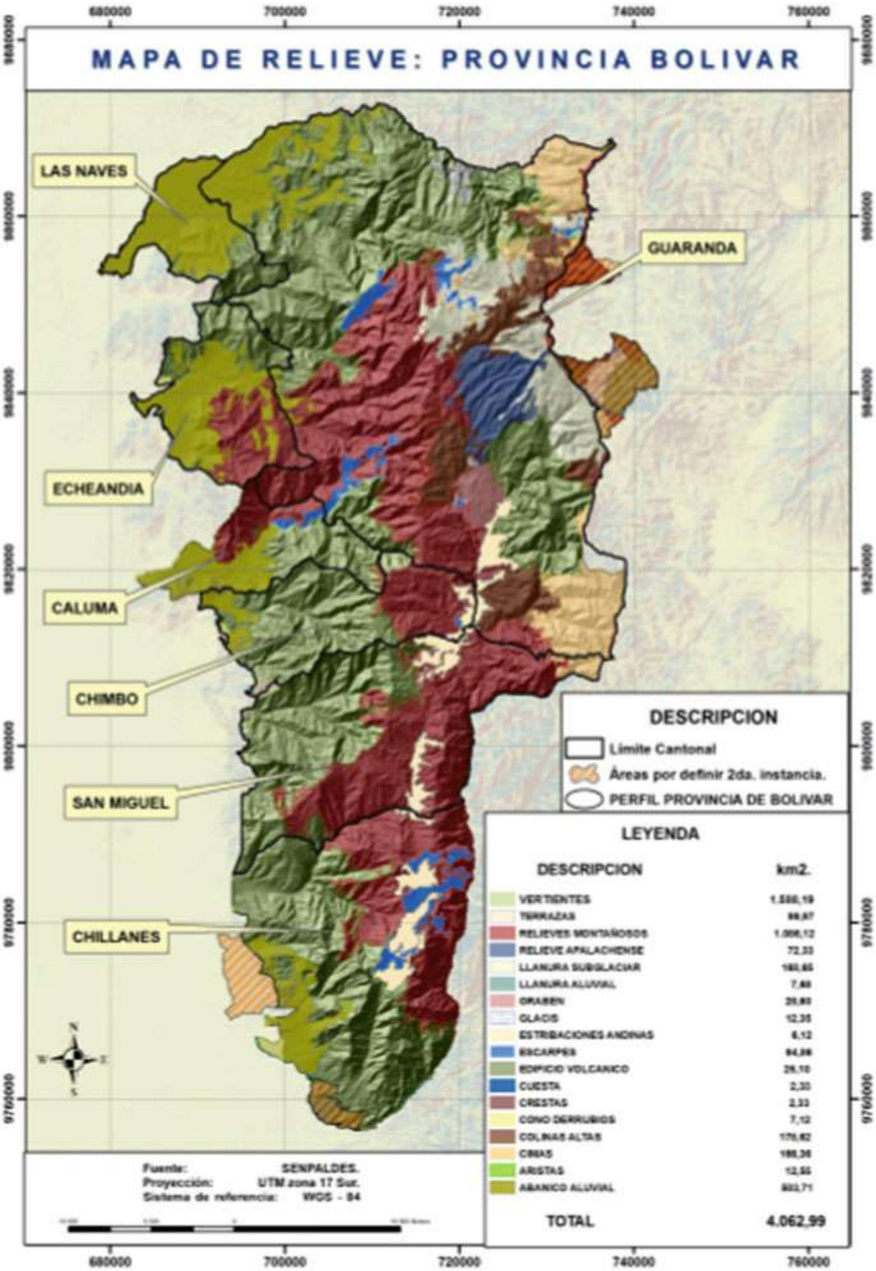


**Fig. 16.2** Cantons of the province of Bolívar. (Source: [15])

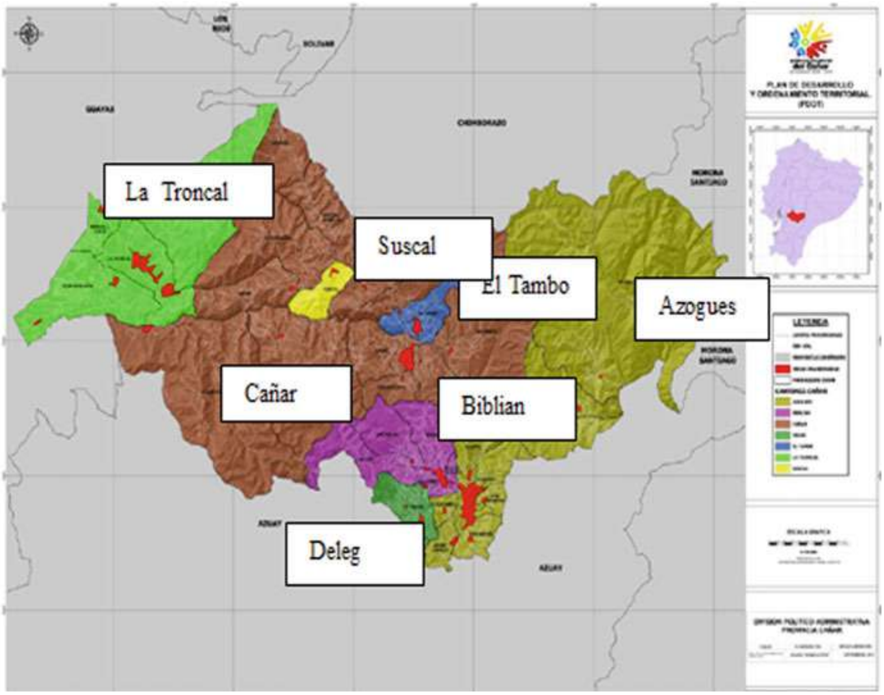


**Fig. 16.3** Cantons of the province of Cañar. (Source: [16])

In Bolívar province, there are four factors that affect pollution: sewage discharges or poor maintenance, organic waste and open dumps, bad agricultural practices, and deforestation (Fig. 16.4).

River pollution comes from small industries, producing 50% of the total pollution (small artisan industries, such as the production of textiles and dairy products that are the main source of labor and employment in rural communities that settle on the banks of the Guaranda River and use its waters for washing process, tanning, and dyeing, among others). Another factor is the city's wastewater, which is made up of sewage that flows directly into the Guaranda River without any treatment, leading to environmental contamination. Another factor of weight is the rubbish dumps located on the riverbank, since there is no true control and strategic planning over the location of the rubbish dumps; these dumpsters have become an active source of generation of environmental pollution that directly harms the population that lives on the banks of the Guaranda River. Deforestation is also an important factor.

In the case of Cañar province, these are the factors that impact the environment: sewage discharges (29%), organic waste (21%), and unidentified factors/no data (21%) (Fig. 16.5).

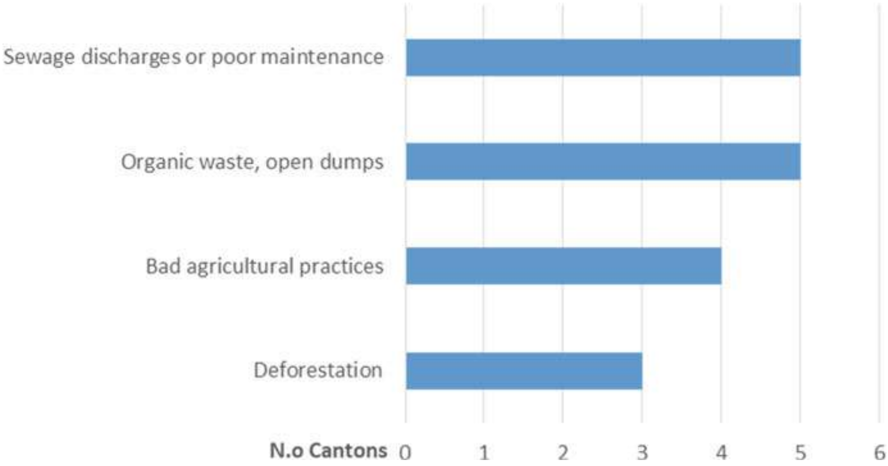


**Fig. 16.4** River pollution problems in the province of Bolívar. (Source: [15])

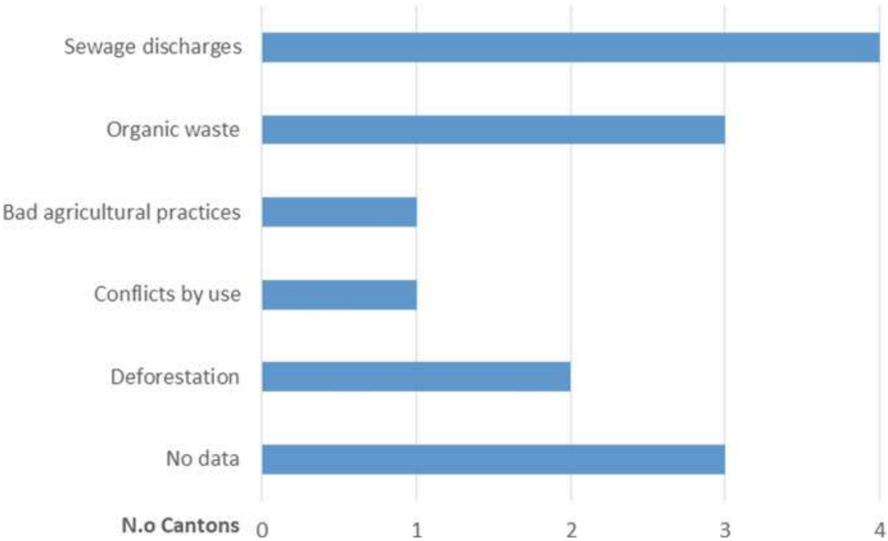


**Fig. 16.5** River pollution problems in the province of Cañar. (Source: [16])

### *16.3.2 Use of Water, Drinking Water Cover, and Sanitation*

The main uses of water in the province of Bolívar are distributed in the following way: hydroelectricity (in the cantons of Echeandia, Chillanes, and Guaranda), irrigation (in the corners of Chimbo, San Miguel, Caluma, and Guaranda), domestic (Caluma, Chimbo, and San Miguel), and industry (in the canton of Chimbo) (Fig. 16.6).

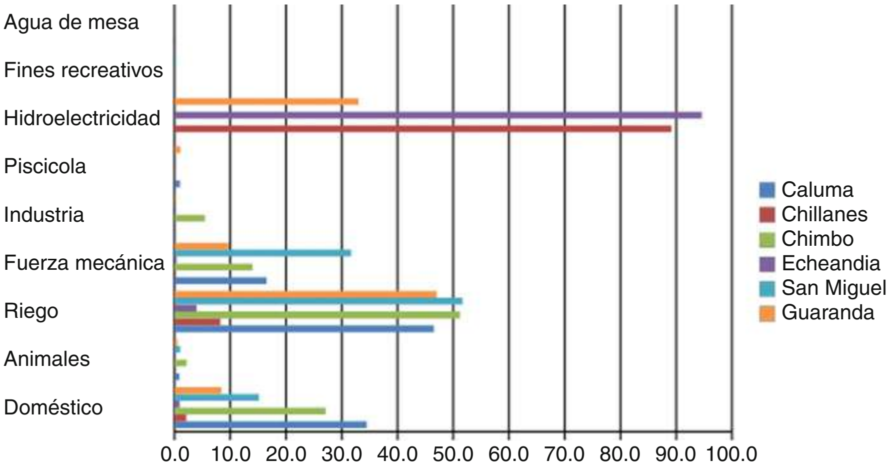


**Fig. 16.6** Uses of water in the province of Bolívar. (Source: [15])

**Table 16.1** Environmental indicators for water in the provinces of Bolívar and Cañar

| Indicator | Bolívar | Cañar |
|---|---|---|
| Urban area drinking water coverage (%) | 42–56 | 69–81 |
| Drinking water coverage in rural area (%) | 22–40 | 59–76 |
| Purification treatment system (%) | 85.7 | 100 |
| Consumption ($m^3$/month consumer) | 112.43 | 117.68 |
| N ° municipalities that have sewerage | 6/6 | 7/7 |
| N ° municipalities that have wastewater treatment | 1/7 | 5/7 |
| N ° municipalities that reuse treated water | 0 | 1/5 |
| Final disposal of waste cell emergent or sanitary landfill | 4/7 | 7/7 |

Source: [19]

The water environmental indicators of the Bolívar and Cañar provinces are shown in Table 16.1. A better performance has been verified at the level of PDOT projects in the Cañar province.

### *16.3.3 Environmental Management*

To solve the problems detected and improve the environmental indicators for water, the PDOTs of the provinces of Bolívar and Cañar propose the projects shown in Figs. 16.7 and 16.8.

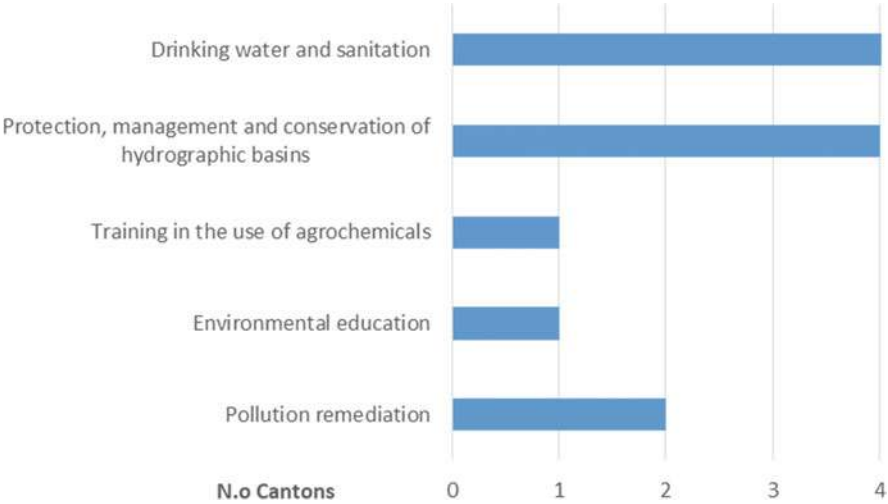


**Fig. 16.7** Environmental management projects of the province of Bolívar. (Source: [15])

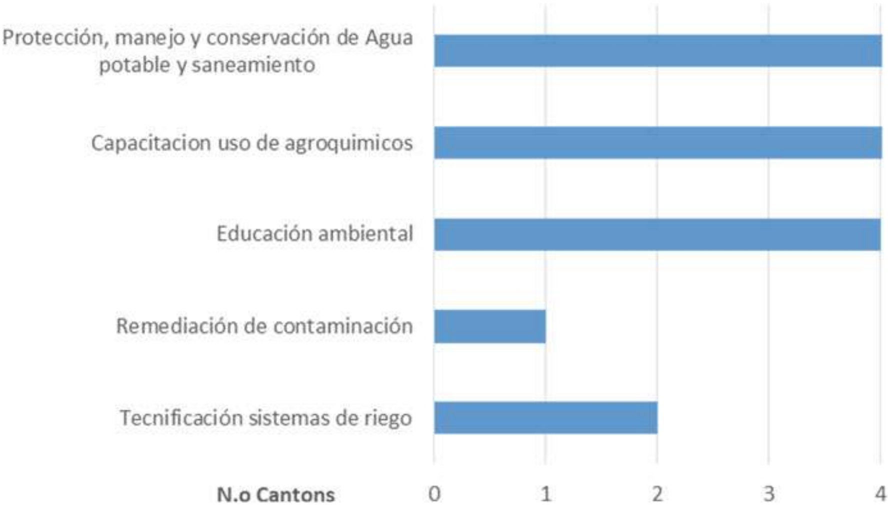


**Fig. 16.8** Environmental management projects of the province of Cañar. (Source: [15])

## 16.4 Discussion of Results

### *16.4.1 River Situation*

The pollution problems of rivers and watersheds that were identified in the PDOTs in periods before 2013 were due to deforestation, domestic water discharges, solid waste, and poor agricultural practices. The study carried out in Ecuador by SDFG

[20] corroborated the presence of pollutants in rivers such as organic loads, toxic substances, hydrocarbons, and pathogenic microorganisms.

Regarding the uses of water in the province of Bolívar, the main source of pollution of the rivers is due to agricultural activity, so actions were taken in the PDOTs aimed at training in good agricultural practices and irrigation systems and were so far successful. In the province of Cañar, there are no quantitative data on uses from economic sectors, but the actions are also successful in terms of environmental education in the management of moors, irrigation systems, and good agricultural practices.

### *16.4.2 Use of Water, Drinking Water Cover, and Sanitation*

The main use of water in the province of Bolívar and Cañar is for electricity, irrigation, and domestic use.

The coverage of drinking water in the cantons studied in the urban area is high, while in the rural area there are particular situations where you do have access to water but it is not drinkable. In these cases, it is necessary to identify the supply sources and the conditions of the physical-chemical parameters for domestic use and irrigation and implement local projects.

The PDOT projects in the province of Bolívar were planned for sanitation, that is, the sewerage of rainwater and sewage. The treatment of domestic water is a pending task to include in the planning of the PDOT; only a few included projects of this type in their planning. It is suggested to prioritize projects at discharge points that influence other water uses in low-lying areas. Currently, the use of technological tools can facilitate these studies.

### *16.4.3 Environmental Management*

The geographical location of the province of Bolívar stands out for having several important ecosystems of hydric recharge sources such as the very humid pre-montane forest, very humid montane forest, pre-montane humid forest, and low pre-montane humid forest. The environmental management of the cantonal PDOTs is oriented in projects aimed at the conservation of forests and environmental education of its inhabitants [15].

In the province of Cañar, environmental management has progressed with respect to the conservation of ecosystems, prevention of river pollution, water reuse, training in good agricultural practices, and optimization of irrigation systems [16].

The land use planning should include environmental projects in coordination and collaboration with the administrations corresponding to the local water planning units. The province of Bolívar corresponds to nine hydrographic units of level 5,

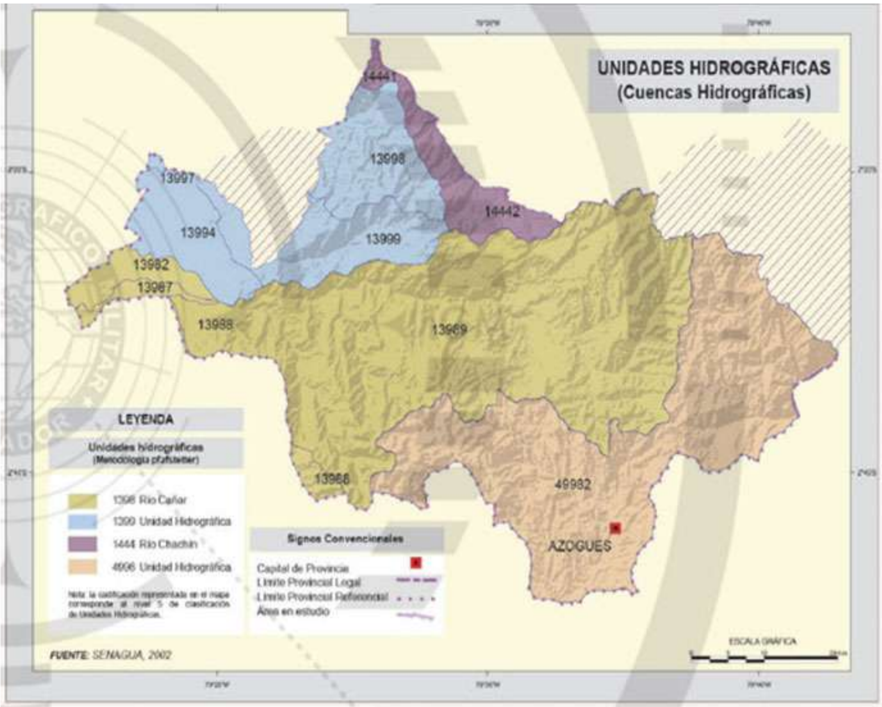


**Fig. 16.9** Thematic maps and indicators: hydrographic units in the province of Bolívar. (Source: [21])

while the province of Cañar corresponds to four hydrographic of level 5 (Figs. 16.9 and 16.10).

Local water planning units are local participatory planning units that serve as a reference to form local watershed councils, having a representative for the user organizations of the productive sectors, a representative for the potable water board organization, a representative for the organization of existing irrigation boards in the planning unit, a representative for the provincial decentralized autonomous governments, a representative for the municipal decentralized autonomous governments, a representative for the parish governments, and a representative for the universities and polytechnic schools.

On the other hand, the Water Administration Boards in rural areas and communities are the spokespersons for the main needs of the sectors, and the municipal GADs should seek communication mechanisms and continuous organization with these groups. The perception of users about the water resource should be applied as a qualitative methodology in the evaluation of the management of the water resource [22].

Water management in Mexico also includes a comprehensive water resource management policy and a decentralized policy of environmental care by municipal

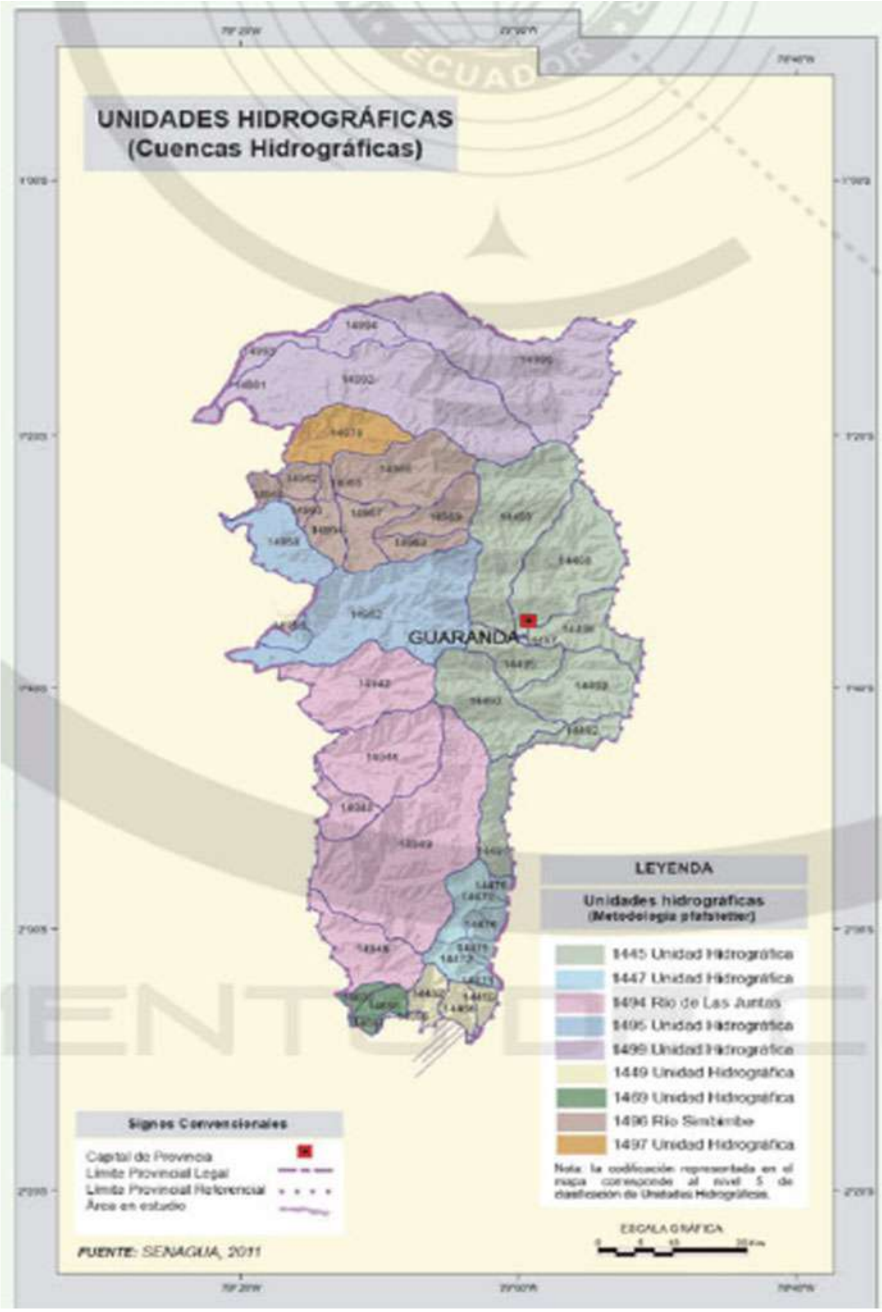


**Fig. 16.10** Thematic maps and indicators: hydrographic units in the province of Cañar. (Source: [21])

GADs, in addition to highlighting the importance of the participation of local actors such as protectors of this resource [22].

## 16.5 Conclusion

The situation of the rivers in the province of Bolívar and Cañar with respect to the environmental problems diagnosed in the PDOTs in the years 2010–2014 requires particular evaluations; a quantitative study of availability and quality requires meteorological and physicochemical data on its waters; however there is limited information due to the country's extensive water network.

The results of sanitation and solid waste treatment show better progress in the province of Cañar, which reflects the importance of the cantonal administration in the achievement of environmental objectives. The use of potable water in the province of Bolívar is a critical issue due to the lack of potable water coverage in rural areas. Savings programs in domestic use and irrigation techniques can represent savings in investment in drinking water and sanitation.

The environmental management in the municipal PDOTs is consistent with the problems diagnosed, and the protection of water recharge sources is essential to ensure the water resource. The pending environmental problems are solid waste management in the province of Bolívar, efficient use of agrochemicals, and treatment and reuse of sewage in the provinces of Cañar and Bolívar.

The implementation of communication mechanisms with local stakeholders is important for a real assessment of water resource management.

If the IoT is applied to the water sector, the advantages of new technologies can be combined with successful traditional knowledge. In this way, it will help in monitoring and obtaining information, improving quality, reducing pollution, and minimizing the release of hazardous materials using tools such as drones, control systems, big data, and sensors.

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# Chapter 17
# IoT-Based Smart Agriculture and Poultry Farms for Environmental Sustainability and Development

**Paola G. Vinueza-Naranjo, Hieda A. Nascimento-Silva, Rubén Rumipamba-Zambrano, Igor Ruiz-Gomes, David Rivas-Lalaleo, and Navinkumar J. Patil**

## 17.1 Introduction

The Internet of Things (IoT) is a major technological innovation in computing and communications that has been in a constant state of evolution. Ashton Kevin [1] has introduced the term IoT, defining it as a network of directional and interoperable objects with radio-frequency identification technology (RFID). However, until today there is no exact definition of IoT, as it is still under investigation. The fact is that IoT can be defined, in general, as a dynamic global network infrastructure, which specifically means that everyday objects (physical and virtual) can be

P. G. Vinueza-Naranjo (✉)
Universidad Nacional de Chimborazo, Facultad de Ingeniería, Carrera de Tecnologías de la Información, Riobamba, Ecuador
e-mail: paolag.vinueza@unach.edu.ec

H. A. Nascimento-Silva · I. Ruiz-Gomes
Universidade Federal do Pará, Castanhal, PA, Brazil
e-mail: hieda@ufpa.br; ruiz.igor@ufpa.br

R. Rumipamba-Zambrano
Universidad ECOTEC, Samborondón (Guayas), Ecuador

Corporación Nacional de Telecomunicaciones CNT E.P., Quito, Ecuador
e-mail: ruben@rumipamba.ec

D. Rivas-Lalaleo
Universidad de las Fuerzas Armadas ESPE, Departamento de Eléctrica y Electrónica, Sangolquí, Ecuador
e-mail: drrivas@espe.edu.ec

N. J. Patil
Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia (IIT-CBN), Arnesano (Lecce), Italy



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equipped with identification, detection, networking, processing capabilities, and auto-configuration, based on interoperable communication standards and protocols. These latter aspects enable the interaction between each other and with other network equipment and services over the Internet. In this context, the RFID and wireless sensor network (WSN) technologies have been played an important role for years in the industrial sector. All of these technological advances around IoT allow “things” or the so-called physical objects to see, think, speak, and work by themselves or in groups thus coordinating decision-making processes and sharing information. In other words, communication technologies, ubiquitous and omnipresent computing, protocols, embedded devices, sensor networks, and Internet applications have transformed various “things” of our world into “smart things.”

Currently, several areas have embraced IoT technology and automation. One of these is Industry 4.0, a transformation that involves several factors, such as sensors, machines, and IT systems that will be interconnected throughout the product value chain, eliminating communication barriers between departments, companies, and clients. At the Industry, we can mention several use cases of IoT, such as logistics control in the delivery and receipt of raw materials, collaborative robots (Cobots), autonomously guided vehicles (AGVs), control of the company’s assets, augmented reality for remote equipment maintenance, virtual reality for simulations, training, and maturity of the equipment maintenance process (reactive, preventive, based on current conditions and predictive). We can also mention the application of IoT in the health area. In such systems, e.g., the IoT devices can monitor vital signals of the patients ensuring not only more comfortable and friendly, but also less expensive health treatments. Moreover, the concept of *Smart X* has extended to the cities giving rise to the smart cities paradigm, which eases the interconnection between a wide range of complementary systems. The main idea is to create platforms for data sharing and integration to improve, in general, the well-being of society. For instance, some of the main aspects that have attracted the attention of the researchers are private data sharing, air quality, temperature, ultraviolet radiation, the waste of natural resources, among others.

Another relevant area for IoT application is agriculture and poultry farm since they play an important role in the economy. These research in this area are influenced by different aspects such as monitoring, control, cost, innovation, equipment, data storage, etc., as shown in Fig. 17.1. As a result, industries around the world have adopted IoT technology, to improve both agriculture and poultry farm sectors by making them smart, efficient, and productive, thus reducing manual tasks as well as optimizing time and economical resources. The stack of technologies in IoT includes sensors (for soil management to monitor pH level, humidity, temperature, etc.), actuators, navigation systems, drones, and cloud-based data services supporting innovative analysis that could significantly change these crucial sectors. Nowadays, IoT with drone technology has become very popular, especially in the agriculture, because it can be used to monitor several crop parameters aimed at verifying if plants are growing healthy, dying, or are being invaded by pest.

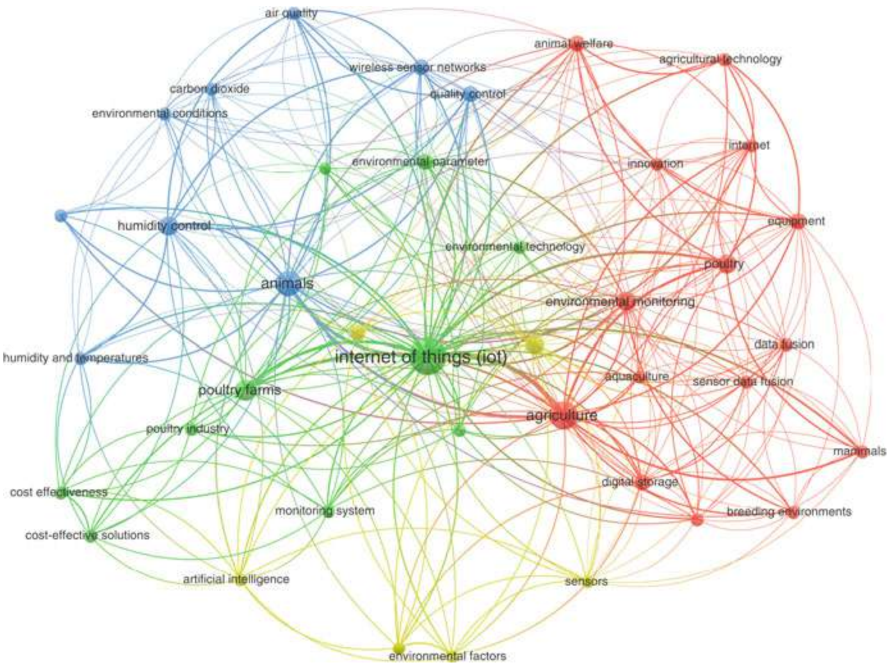



**Fig. 17.1** Relation of the investigation on IoT+agriculture+poultry farm

Those aspects, e.g., can be identified by analyzing the changes in their color. IoT has certainly brought revolutionary changes in agriculture and poultry farms by monitoring activities with accuracy and frequent updates, which is difficult to manage by means of traditional methods.

Thanks to the technological advancement, cost-effective and easily implementable sophisticated smart devices, such as drones, smartphones, and various IoT devices, agricultural and poultry workers can easily acquire data in real time and monitor the land in a continuous way (observe the growth of the crop) and animals to take appropriate decisions at the proper stage. These benefits avoid economic losses and save resources and time, i.e., IoT makes agriculture and poultry more efficient. New technologies such as fog and cloud computing could be applied, which would help to accelerate the evolution of smart agriculture by opening horizons for exchanging data in real time and making agriculture economically sustainable.

The rest of this chapter is organized as follows: Section 17.2 presents the related works on IoT. In Sect. 17.3, open issues and challenges on IoT are mentioned in detail. Section 17.4 addresses both IoT case studies with the corresponding results. Section 17.5 discusses the future research directions, and finally, some conclusions and recommendations are mentioned in Sect. 17.6.

## 17.2 Related Works

Various types of research involving IoT and agriculture data analysis have been developed in recent years where we could readily cite some of the classic examples of projects using IoT such as IoT and agriculture data analysis for smart farm [2], IoT in factories, hospital environments, agriculture, poultry farm, and smart cities, where contributions of IoT specifically focussed on the research related to agriculture and poultry farm are highlighted in Table 17.1. In agriculture, drones can provide an efficient and nimble way to constantly explore and monitor the growth of crops as well as to identify any problems and determine the right treatment plans. By utilizing high-resolution RGB cameras and professional multispectral sensors, drones can identify and quantify crop health issues right from the start, which could help reduce input costs and in turn increase yield. Figure 17.2 shows the implementation of IoT solutions in agriculture where drones, sensors, computer imaging, and cloud platform are used for crop monitoring, surveying the weather and soil conditions, and imaging, mapping, and surveying the farms for better and effective farm management.

Another important application of IoT refers to silviculture for wood production with eucalyptus. Silviculture is the science of cultivating forests and their possible products, based on knowledge of the life history and general characteristics of the trees and their geographical locations. The silvicultural system is a process that follows accepted silvicultural principles, during which forest products are cultivated, extracted, and renewed in a forest [9]. Thanks to the technological advances of last decades, precision agriculture based on the collection and analysis of geospatial data located in forests has been applied to forestry. Furthermore, the strong incorporation of technologies such as geographic information systems, remote sensing, and global positioning systems helps and allows increasingly precise interventions in the settlement of cultures [10–13].

The various works cited here present the concepts related to images, such as the study of RGB colors, the stages of image processing, and various areas of science that have used PADI in their applications. These works also highlight the importance of using the convolutional neural networks (CNNs), mathematical formulation, and the parameters of each layer of a CNN together with artificial intelligence techniques, especially machine learning, deep learning, and transfer learning [14, 15]. Furthermore, the relevance of image identification and classification is demonstrated in various case studies by applying state-of-the-art methodologies and strategies (c.f. Table 17.1).

Several researchers had proposed different smart poultry solutions, most of them based on monitoring temperature, humidity, air quality, etc. These types of air quality sensors are frequently inadequate for the acquisition of all essential parameters in an industrial poultry setting. Conversely, some applications in poultry farm area were developed using an intelligent monitoring system for environmental variables by deploying WSNs [16]. In a poultry, the crucial parameters that are important to be monitored are concentration of ammonia ($NH_3$), carbon dioxide

**Table 17.1** Research in agriculture and poultry farms

| References | Contribution |
|---|---|
| Balducci et al. [3] | The studies of this experimental work are focused on improving, through machine learning techniques, the productivity of an agricultural company. This work introduces easy-to-develop, cheap, and practical tasks that are useful to increase the productivity of an agricultural company, deepening the study of the smart farm model. |
| Batuto et al. [4] | This study addresses the Poultry Management System, an IoT system that automates the process of feeding water–feed to poultry. In this chapter, an application for Android was developed, the same one that helps to establish a schedule to feed the chickens. Water and food are constantly given to the coral birds, and there is a sensor that detects if the water or food has finished (empty container). Therefore, a notification system is implemented. At the same time, using renewable energy (i.e., solar energy to charge the battery supplying microcontrollers and motors), this study provides relevant results in the improvement of poultry companies to save costs, time and efforts. |
| Barbosa et al. [5] | They proposed a convolutional neural network (CNN) to take some different attributes to capture relevant spatial structures and combine to model yield response to nutrient and seed rate management. The authors made the experiments on corn fields to construct a suitable dataset to test and train the CNN model. The authors have evaluated four architectures combining input attributes at different stages in the network and compared to the most commonly used predictive models. |
| Forstmaier et al. [6] | In this research, the authors found negative effects of large-scale invasive behavior and plantations of eucalyptus trees. The authors have used medium-resolution multispectral satellite imagery to map eucalyptus trees with a focus on areas that are protected over habitats and birds. The authors use a method that allows the detection of small populations both incipient and mixed outside the plantations, using field studies and high-resolution images taken from satellites. These images were used to train neural networks. |
| Debauche et al. [7] | This work uses a WSN for scalable poultry monitoring. To predict and validate the environment parameters, the authors used the Gated Recurrent Unit, an artificial intelligence algorithm. |
| Majidi et al. [8] | The authors have proposed a system whose main system modules are the so-called Geolyzer and the Modular Rapid Implementation Internet. Geolyzer is the focus of the discussion, and the experiments and results of smart geospatial–temporal analysis based on big data are presented. Applications of smart remote sensing solutions, including satellite and UAV imagery, in disaster management, agriculture, and forestry are discussed. The presented solutions may offer to the local governments, and to several companies, a comprehensive view of the horticulture, grazing forest, and agriculture areas. |

($CO_2$), oxygen ($O_2$), and hydrogen sulfide ($H_2S$) in air. Besides, gases like nitrogen dioxide and methane are produced in the poultry farm environments; however, those parameters are rarely monitored [17–22]. In addition, system communication technologies like the Long-Range Technology (LoRa) together with cloud database are used to gather and store the information. In smart poultry, the data acquisition is

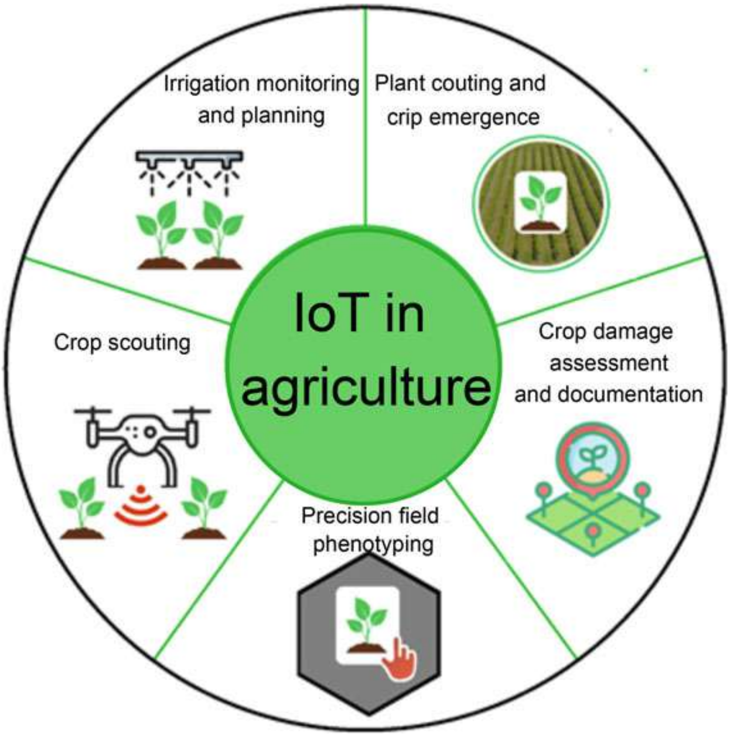



**Fig. 17.2** Main applications of IoT in agriculture

carried out specifically through a WSN activated at short-time intervals that generate a great quantity of data. As IoT and artificial intelligence open the space to real-time monitoring of poultry and other farm animals, it could potentially provide great amount and variety of data that could be used for analytics and automation [7].

One of the goals of the present is to make researchers even more aware of the importance of identifying and classifying images in order to benefit several areas such as agriculture, poultry farm, medicine, education, agrobusiness, robotics among others that will be exemplified in Sect. 17.5 on future research directions.

## 17.3 IoT Open Issues and Challenges

IoT in our daily life is the latest form of technology, and we have witnessed the great possibilities, potentials, and success that IoT has had, as well as how IoT applications in daily life have revolutionized our lifestyle. However, we still have to face problems and challenges of IoT that lead to new researches. The most important ones deal with standardization, integration, interoperability, system architecture, data storage, data processing, scalability, identification, security, privacy, power, and energy consumption, among others.

Key challenges such as IoT standardization, IoT platforms interoperability, interconnection, and integration are due to the existence of a wide range of IoT technologies, platforms, APIs, data formats, etc., which have been preventing the development of IoT applications at a large scale [23]. To address these issues, the research efforts are focusing on providing open standards to prevent the development of applications with a limited number of vendors. Nevertheless, there is a pending task related to the consolidation of different contributions consistently and coherently aiming at realizing IoT cross-platform applications and un-locking vendor dependency. The architecture supporting IoT has to be open to provide full integration, interoperability, and mobility without service disruption. Moreover, the architectures need to support heterogeneous components related to not only hardware but also software modules (APIs, virtualization, SDN/NFV, OS, etc.) [24]. In a nutshell, the massive heterogeneity problem requires a standardized architecture so that the solutions can interact regardless of the hardware and software used.

As for data storage and processing, the fact is that the data collected from the different sensors and other IoT devices is getting bigger and bigger due to our attempt to connect everything to the Internet and gather all the data provided by the smart systems. As a consequence, the management of all of this data is getting out of our hands since there is too much data that must be analyzed; thereby, the current computer systems have to be optimized to process this huge amount of data. To this end, the big data paradigm helps us to hand efficiently the five Vs characterizing these phenomena, namely, volume, variety, velocity, veracity, and value.

As a consequence of IoT massification, another issue is the way to identify and uniquely register billion of these devices during their entire lifecycle. In this context, the exhaustion of IPv4 addresses has brought to the fore the IPv6 protocol where the 128 bits solve the identification. However, the integration of IPv6 and its related protocols, e.g., service discovery protocols [25], is one of the great challenges in limited capable devices. In addition to attaining the initial deployment of one IoT system, to facilitate the inclusion of new devices and services without affecting the performance is a desirable feature of such systems. In other words, the system has to be scalable. To do this end, computing capabilities (memory, storing, processing, networking) have to be guaranteed for all devices to inter-operate between each of them in a mobility context. One solution to address this issue is to combine cloud computing and fog computing to process data close to the sensors while ensuring the processing of complex tasks at the cloud [26]. The challenge is mobility, i.e., the changes in the topology during the lifecycle in such a way that the applications are always available wherever they are located at the network, which is currently under investigation to realize innovative network architectures.

Power and energy consumption is another key challenge for IoT, not only regarding the supply but also regarding low-power sensors design. Obtaining sophisticated devices with improved computation capabilities at low cost and with low-energy consumption has remained a real issue. This problem is further accentuated because the protocol stack is not fully adapted for IoT devices. Although some initial standards (e.g., IEEE 802.15.4) have been focused on the physical and MAC layers, several features are still not suited for low-power multihop networks [27]. Another important aspect to save energy in this kind of network devices is the routing protocols [28] that are under continuous research to be increasingly optimized.

To finish this section, it is worth mentioning the security and privacy risks that wireless communications suffer. In the case of the IoT systems, these risks are further emphasized due to the openness and interoperability features of such systems [29]. That is, each device in the network should be able to check the privacy policies of all participant platforms for compatibility purposes. Some of the security aspects that the IoT systems have to fulfill are authentication, access control, data integrity, encryption, etc. Since these security aspects need to deal with computation-limited devices, their implementation needs to be highly energy efficient. Moreover, despite implementing some security features (e.g., encryption), some vulnerability issues are still inevitable (e.g., a man-in-the-middle attack) due to the nature of the transmission media. Hence, to deploy security and privacy mechanisms at all protocol stack layers is a key factor to achieve robust and scalable IoT systems.

## 17.4 Case Studies

IoT is emerging as one of the most prominent technologies across the globe driven by technology advancement, as discussed in the previous sections of this chapter. The current section presents two projects related to smart agriculture and poultry farming developed and carried out in Latin American countries, namely, Ecuador and Brazil.

### *17.4.1 Poultry Farming Applications*

Our global population is increasing and forecasting to reach 10 billion by 2050, which will represent a population increase of more than 25% from 2020 [30]. The Agriculture Organization of the United Nations and Food mentions that this increment will cause a higher demand for the consumption and production of food, particularly, those rich in protein, to feed the growing population [31]. One of the most appreciated products is poultry meat as it has a high level of nutrients and proteins, while low levels of fat and cholesterol [32]. Furthermore, eggs are poultry-derived products, which are basic food in the human diet. Specifically in Ecuador, the local market has greatly grown in the last four years to satisfy the demands, and according to the Latin American Institute of Chicken (LIC) [33], the commercialization of a variety of chicken *Broiler* has been observed.

Poultry farms of the Cotopaxi province in Ecuador are notable examples of this industry, with the capacity of roughly 10,000 birds per house. In view of that, animal welfare has become an important concern today, as well as the factors that have an important impact on animal productivity. Therefore, measuring and constant monitoring of environmental parameters such as temperature, humidity, and ammonia levels are crucial since these variables have a direct impact on the proper growth, development, and welfare of poultry [34]. One of the crucial factors that prevent the proper development of poultry are harmful gases such as ammonia ($NH_3$), which are the most prevalent odorous gases in poultry houses with relatively high concentrations. Ammonia is a colorless, water-soluble alkaline gas produced by the decomposition of animal waste in high concentrations due to the bad litter management in poultry farms. Besides litter management, the production and concentration level of ammonia depend on multiple other factors such as humidity, pH, and temperature. Ammonia can cause environmental problems such as acidification, which, in its turn, may harm sensitive vegetation, disrupt biodiversity, degrade water quality, and may directly influence farm employees' health, poultry, and livestock.

Therefore, it is necessary to look for solutions that allow monitoring environmental factors such as temperature, humidity, light, and ammonia gas in a reliable, practical, and economic way. In this regard, the use of IoT technology is a promising solution by providing automation of poultry farms through wireless sensor and mobile networks in order to control and monitor environmental parameters. In this sense, this case study introduces an intelligent monitoring system assembled from the network of sensors (star-type) for mini-monitoring and tracking variables in the agricultural farm, whereas Long-Range Technology (LoRa) is utilized for system communication. The information is collected and analyzed in a cloud database and processed and visualized through historical trends to create reports, alarms, and decisions that create an affordable interpretation and easy solution. Figure 17.3 shows the proposed scheme for monitoring environmental parameters such as temperature, humidity, and ammonia levels. The parts involved in the proposed scheme are described as follows.

#### 17.4.1.1 Network Topology

LoRa protocol uses star topology. In this case, two star topologies are employed. The first star topology is formed by the sensor nodes together with the gateway, and the second star topology is formed by the gateway and network server. This intelligent design avoids interchanging information traffic, eases the addition of new nodes easily, and enables resilience, i.e., the network continues working normally even if any of the nodes fails. The five different systems highlighted in Fig. 17.3 are briefly discussed:

1. **Data acquisition system:** The data acquisition system consists of different sensors for monitoring different environmental parameters in a poultry farm. As shown in Table 17.2, the sensors $MQ$ 135 [35] and $DHT$ 22 [36] are used for obtaining the levels of gas concentration ($CO_2$ and $NH_3$), temperature, and humidity. The sensor $MQ$ 135 is used for obtaining the concentration of $CO_2$

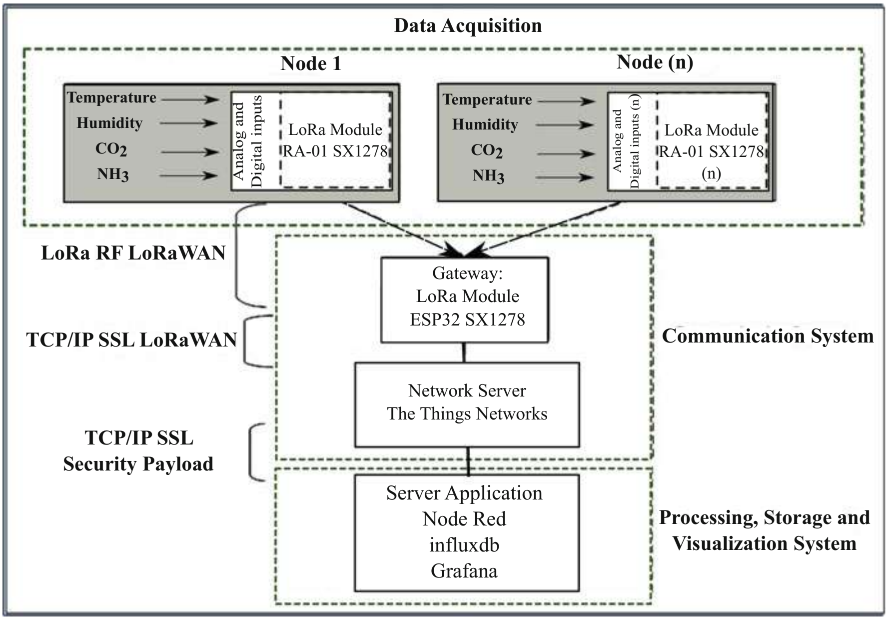



**Fig. 17.3** **Network diagram** consisting of five different systems where (1) **data acquisition system** is composed of sensor nodes, (2) **communication system** consists of LoRa wireless communication working with the Things Network Server, (3) **storage system** stores Influx database in the cloud, (4) **processing system** performs data filtration to reduce error and classifiers used for machine learning, and (5) **visualization system** handles human interaction via human–machine interface

and $NH_3$. Specifically, for $CO_2$ monitoring, the sensor provides the accuracy and resolution of 2 ppm and 0.1 ppm, while for $NH_3$ the accuracy and resolution are 1.5 ppm and 0.1 ppm, respectively. The sensor $DHT$ 22 is used for obtaining temperature and humidity with accuracy and resolution of 0.5 °C and 0.1 °C for temperature and $\pm 2\%$ $RH$ and $\pm 0.1\%$ $RH$ for humidity.

2. **Communication system:** This system consists of a long-range (LoRa) communication module for IoT networks, with a frequency of 433 MHz, power up to 600 dmips, and a high sensitivity $-148$ dBm, suitable for working under the standards suggested by the Ministry of Agriculture in Ecuador (MAGAP) for building poultry farms [37].
3. **Storage system:** The storage system is used for obtaining information of the communication system. This information is taken by the gateway node through flow editor established in the browser, in which nodes are added or removed, to write and consult the database.
4. **Processing system:** Processing system uses real-time filtering techniques where offline tasks like statistical processing and machine learning are performed on the data acquired from humidity, temperature, and gas sensors.

**Table 17.2** Parameters of the biovariables for the growth of the chickens *Broiler* from week 1 to week 7

| Variables | Levels | Weeks |
|---|---|---|
| Temperature | 32 and 34 °C | 1–2 |
| | 26 and 30 °C | 3–4 |
| | 18 and 24 °C | 5–7 |
| Humidity | 51 and 69% | 1–7 |
| $CO_2$ | <5000 ppm. | 1–2 |
| | <4000 ppm. | 3–4 |
| | <3000 ppm. | 5–7 |
| $NH_3$ | <55 ppm. | 1–2 |
| | <40 ppm. | 3–4 |
| | <10 ppm. | 5–7 |

- Commonly used digital filters consist of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters for signal processing, which are applied in real time. FIR filters requiring no feedback loops and designed to have a linear phase and greater stability than IIR filters are used here.
- Statistical processing is performed to gather parameters such as mean, correlation, and Pearson's correlation, whose patterns are used for the machine learning process.
- Machine learning is performed by using Fisher's linear discriminant (FLD) consisting of artificial elements or computer systems with the ability to learn from examples [38].

5. **Visualization system:** Visualization system is used to visualize temporal and real-time data. In this case, a web-based human–machine interface is designed inside the chicken coop. By using Grafana [39], it is possible to visualize time series data in web environments. To this end, such a tool is connected to the database in order to present indicators, historical and alarm reports of temperature, humidity, and gases. The web interface can be seen in Fig. 17.4.

#### 17.4.1.2 Implemented Experimental Design

#### 17.4.1.3 Obtained Results

The proposed scheme is installed on a farm with 160 m length, 3 m width, 12 m height, and a maximum capacity of up to 18,000 broilers with a distance of 300 m between the chicken coop and the control center. The evaluated parameters are the following.

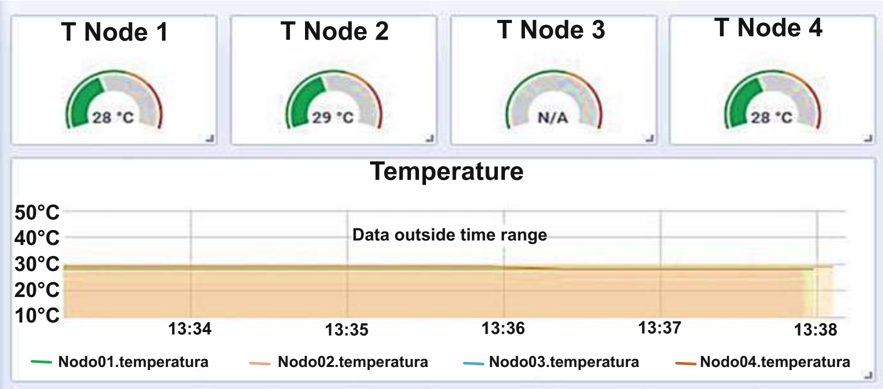



**Fig. 17.4** Human graphic interface—remote and local machine. The top console shows the instantaneous temperature of the nodes, and the bottom console displays the temperature history of the last hour

#### 17.4.1.4 Communication

For the experimentation environment, the chicken coop area covered is 160 m × 12 m. For this experiment, the internal and external communications are evaluated as listed below:

- **Inside coverage**: To locate the optimal points for sensor placement inside the chicken coop, it is found the coverage generated by the gateway node with a power of up to 600 dmips and 433 MHz installed in the center of the chicken coop at a height of 2.5 m. The signal strength is measured by using the Field Fox portable spectrum analyzer model N9912a from the Agilent factory with a difference of 2 m. In Fig. 17.5a, we can see the distribution of the sensor node's radiation power, where it is determined that the maximum power received by the sensor nodes placed at a height of 30 m above the ground occurs in a perpendicular gateway area. Figure 17.5b shows the exponential decrease in received power as the sensor nodes move away.
- **Outdoor coverage**. The distance between the chicken coop and the monitoring center is 300 m. To guarantee communication between these two points, the quality of propagation is measured with respect to the measurement range, for which the repeater node was installed (the signal power is measured by the same equipment as in the previous section). The modified gateway node was installed, which has a coverage of 400 m. By moving away from the repeater node, 20 samples every 50 m were taken. Within this measurement, two important parameters were taken into account: Receive Signal Strength Indicator (RRSI) or signal strength reaching the receiver in dBm and the signal-to-noise ratio (SNR) of the power radiated by the transmitter and the gain of the received antenna.

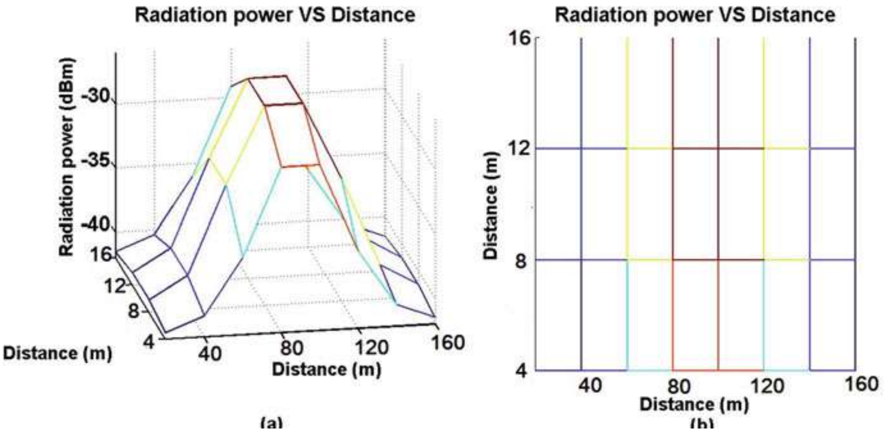



**Fig. 17.5** Plot representing the variation of radiation power to distance: (**a**) 3D view, (**b**) 2D view, with 35 dBm (blue, light blue) and 20 dBm (yellow, brown, light brown) power output

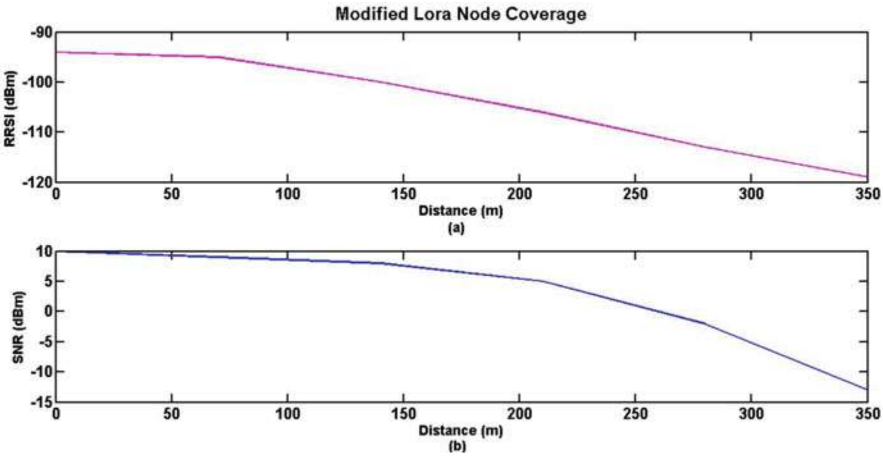



**Fig. 17.6** (**a**) RRSI values, (**b**) SNR values

This experiment is shown in Fig. 17.6, with a line of sight at the test site, and a significant signal is obtained in terms of the number of received packets up to 350 m, SNR, and RSSI. In this case, as there is no acceptable power intensity, it produces signals with more noise and data loss.

#### 17.4.1.5 Sampling Frequency

Considering that the measured variables are slow, the sampling rate that best fits the measured variables was set to 30 sg, 40 sg, 50 sg, and 60 sg. For this experiment,

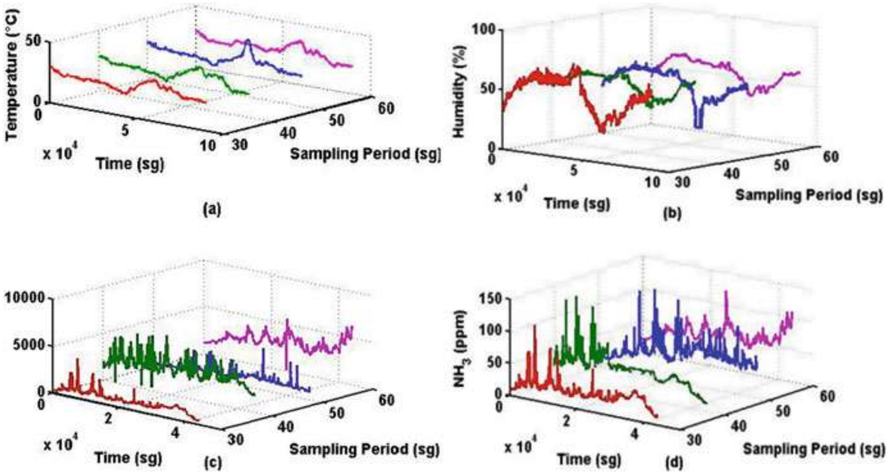



**Fig. 17.7** Panels representing (**a**) temperature, (**b**) humidity, (**c**) $CO_2$, and (**d**) $NH_3$ with different sampling periods where the frequency of acquired samples is represented by the following color codes: 30 sg (red), 40 sg (green), 50 sg (blue), 60 sg (purple)

the knots are placed together in the center of the chicken coop at a height of 30 cm above the ground. Each node measures temperature, humidity, $CO_2$, and $NH_3$. In Fig. 17.7, a three-dimensional graph is shown, where the **x**-*axis*, **y**-*axis*, and **z**-*axis* represent time, measured, and sampling periods, respectively. Panels *a* to *d* represent air temperature, humidity, $CO_2$ content, and $NH_3$ content in the environment, respectively. The color code is used to represent sample frequency where colors red, green, blue, and purple represent samples every 30 sg, 40 sg, 50 sg, and 60 sg, respectively. It can be observed that the trend of the measurements, namely, temperature, humidity, and gases, is similar for the different number of samples. Aiming to train the intelligent system, the shortest sampling period is chosen, since it defines in a better way the transition trends of the variables, leaving aside the energy efficiency for this occasion.

#### 17.4.1.6 Data Processing

To generate the database of this experiment, the position of the sensor nodes is changed following the scheme of Fig. 17.8. The selected sampling period is 30 s, where the sensors are contrasted with standard laboratory equipment resulting in an error of 1% in $CO_2$ measurements and 2% in $NH_3$ measurements. The procedure is performed under the ISO/IEC 17025–2005 standard [40].

It is necessary to analyze the data that has been acquired over the period of 7 weeks that is the breeding period of the *Broiler* chicken. Figure 17.9 shows the signals measured by the four nodes in a period of 2 days where the presence of noise in each of the nodes could be seen.

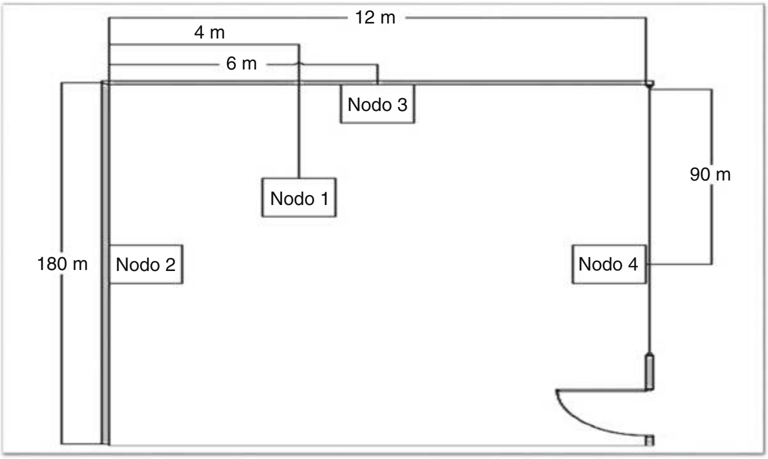



**Fig. 17.8** Positions of the nodes inside the test chicken coop

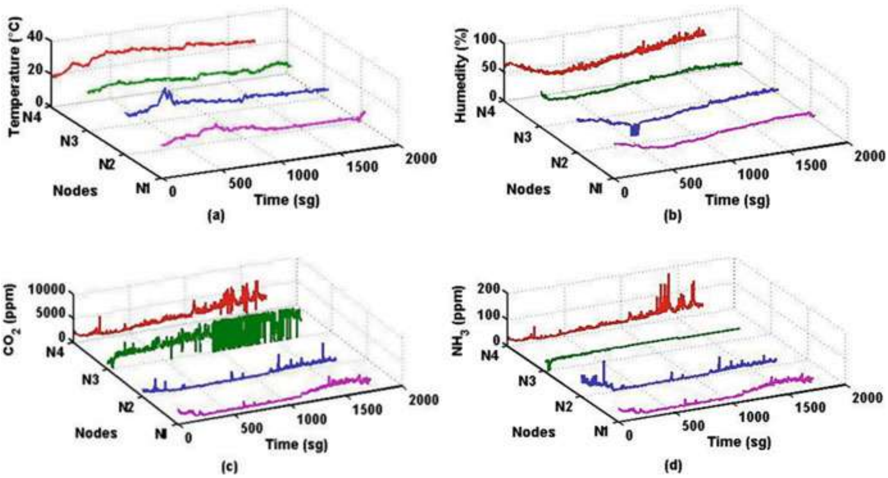



**Fig. 17.9** Signals acquired with the frequency of one sample every 30 sg. Panels representing (**a**) temperature, (**b**) humidity, (**c**) $CO_2$, and (**d**) $NH_3$, where color codes for nodes are as follows: node1 (purple), node2 (blue), node3 (green), node4 (red)

To eliminate the noise, IR filter and FIR experimentations are carried out based on order 1, 2, 3, 4, 5 and 2, 4, 8, 16, 24, 32, respectively. FIR filter of order 24 provides the best results with improved stability and elimination of noise. Moreover, FIR filter presents a sharper signal without affecting the rising and falling edges as well as without generating offset and truncating minimum and maximum values as shown in Fig. 17.10.

To verify the same nature of the signals, two variables of the same nature are related by utilizing the concept of correlation where the criterion of the Bland–

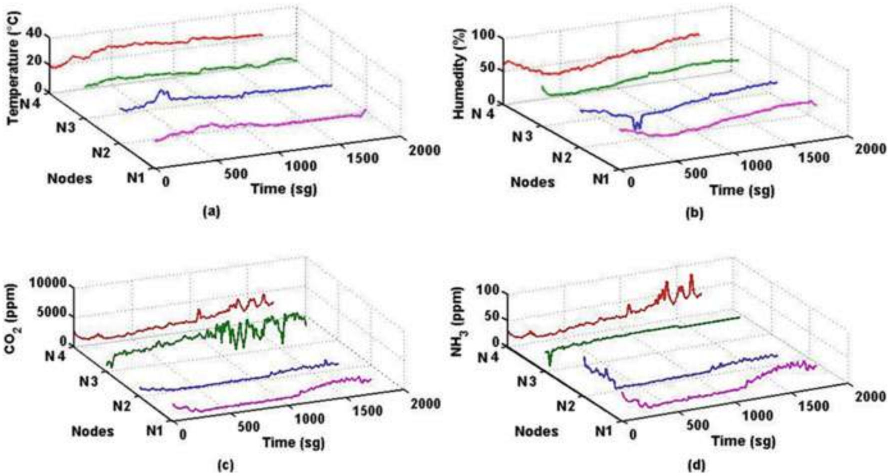



**Fig. 17.10** Signals acquired through the FIR filter of order 24, with the frequency of one sample per 30 sg. Panels representing (**a**) temperature, (**b**) humidity, (**c**) $CO_2$, and (**d**) $NH_3$ where color codes for nodes are as follows: node1 (purple), node2 (blue), node3 (green), node4 (red)

Altman analysis is applied. As an example, Fig. 17.11 shows the relationship between node1 and node2. Four different panels are used to analyze temperature, humidity, $CO_2$ content, and $NH_3$ content, respectively. The results obtained from the soft element analysis are extracted from Table 17.3. Temperature correlation values of certain nodes (i.e., correlation of node1 with node2) present better stability characteristics in the signal, while the correlation values of the other nodes have a threshold lower than 0.7 due to the distance between them.

Regarding the humidity variable, it is argued that the correlation values are stable except between node2 and node3 as well as between node3 and node4 since it has a threshold lower than 0.7.

The $CO_2$ has correlation values between node1 and node2 as well as between node 1 and node4, while the other nodes have correlation values lower than the threshold of 0.7. Finally, $NH_3$ has a low correlation since this particular variable is prone to be easily affected by external disturbances such as air currents.

Upon filtering signals, the events in low, medium, and high ranges of the measured variables are selected according to the growth phases of the bird indicated in Table 17.3. Under these parameters, the intelligent algorithm is trained by means of the conditions of Fisher's linear discriminant. The database used corresponds to the data acquired by node1 and node2. Out of the three ranges composed of 147 sampled days with the sampling period of 30 sg, 80% of the sampling period is randomly selected for training the intelligent algorithm, while 20% is selected for testing.

Table 17.4 indicates the values of the area under the curve (AUC) for each of the variables in the different stages of growth. In the first stage, it is observed that the certainty values of both humidity and temperature measurements exceed the

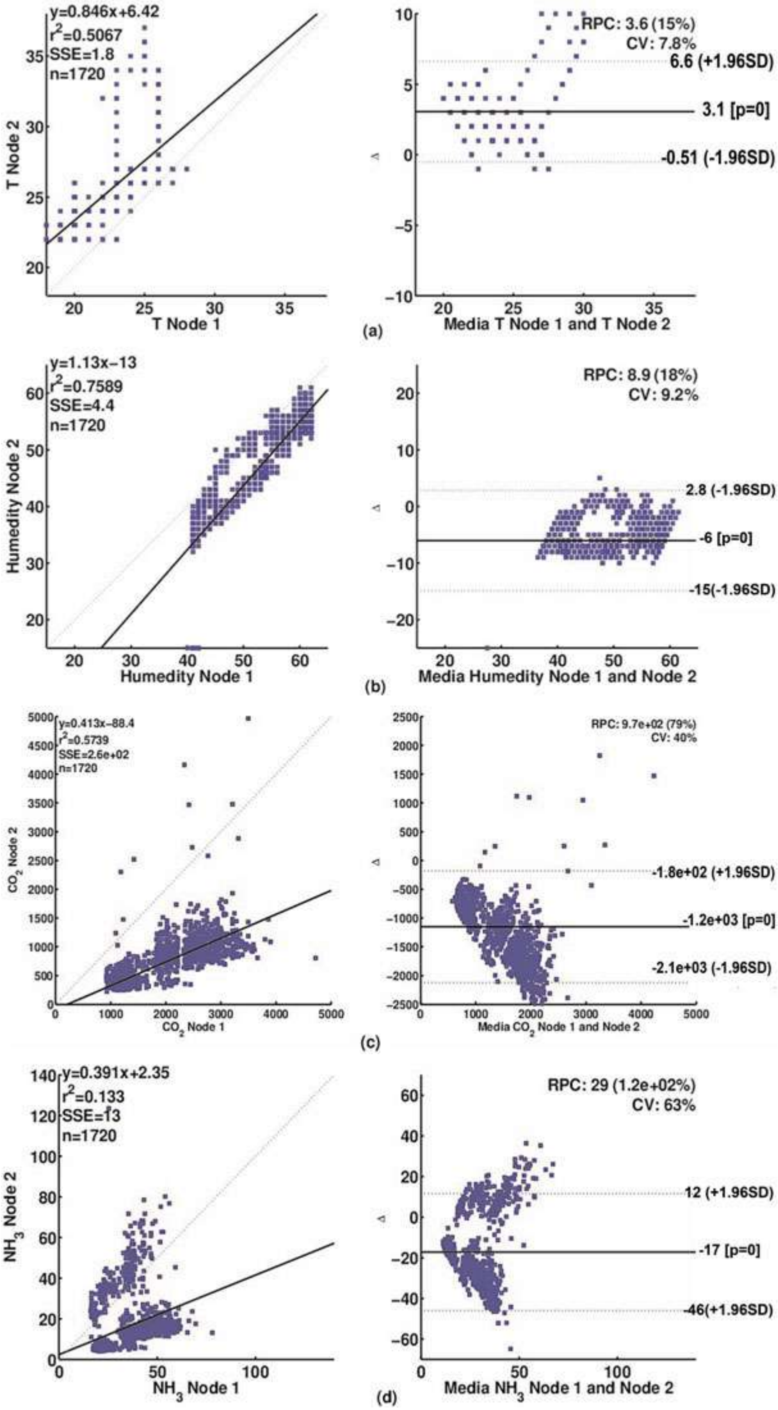



**Fig. 17.11** Bland–Altman analysis for poultry biovariables

**Table 17.3** Correlation values

| Variables | N1–N2 | N1–N3 | N1–N4 | N2–N3 | N2–N4 | N3–N4 |
|---|---|---|---|---|---|---|
| Temperature | 0.70 | 0.57 | 0.45 | 0.52 | 0.22 | 0.08 |
| Humidity | 0.86 | 0.78 | 0.92 | 0.58 | 0.85 | 0.58 |
| $CO_2$ gas | 0.76 | 0.12 | 0.73 | 0.12 | 0.56 | 0.18 |
| $NH_3$ gas | 0.35 | 0.31 | 0.69 | 0.57 | 0.12 | 0.12 |

**Table 17.4** Fisher's discriminant method

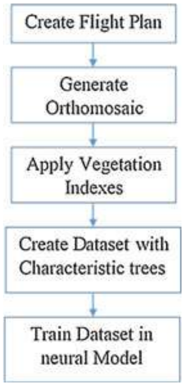
| | Variables | Low values | Normal values | High values |
|---|---|---|---|---|
| Phase 1 weeks | Temperature | 0.68 | 0.66 | 0.82 |
| | Humidity | 0.72 | 0.70 | 0.75 |
| | $CO_2$ | 0.55 | 0.57 | 0.61 |
| | $NH_3$ | 0.57 | 0.59 | 0.72 |
| Phase 2 weeks | Temperature | 0.77 | 0.77 | 0.88 |
| | Humidity | 0.82 | 0.80 | 0.85 |
| | $CO_2$ | 0.52 | 0.60 | 0.71 |
| | $NH_3$ | 0.52 | 0.63 | 0.75 |
| Phase 3 weeks | Temperature | 0.87 | 0.88 | 0.92 |
| | Humidity | 0.91 | 0.89 | 0.94 |
| | $CO_2$ | 0.49 | 0.63 | 0.81 |
| | $NH_3$ | 0.44 | 0.67 | 0.78 |

threshold of 0.7, while the variables of $CO_2$ and $NH_3$ are close to 0.5. For stage two, both humidity and temperature exceed 0.75 certainties, while $CO_2$ and $NH_3$ are close to 0.55. In contrast, the certainties in stage three exceed 0.85 and 0.6 for the same parameters, respectively. By analyzing these results, it can be noted that both temperature and humidity parameters exhibit similar characteristics in all stages. In addition, it can be seen that some environmental conditions, namely, solar radiation, rain, and frost, influence both temperature and humidity. On the other hand, the $CO_2$ and $NH_3$ variables become much more unstable in their behavior due to their volatile nature. The fact is that these variables register different values without following a consistent pattern, as a consequence of the influence of air currents and the accumulation of feces. As a result, the system fulfills with accurate alarm indication for both low and high humidity and temperature, but for high concentrations of $CO_2$ and $NH_3$ in the air the certainty has to be improved at the moment.

### *17.4.2 Tree Growth Analysis, Oil Palm Plantation, Using Deep Learning Techniques from a Case Study*

The unmanned aerial vehicles (UAVs) [41] are highly practical, and they have become differential among agricultural producers, by helping to define strate-

**Fig. 17.12** Project development stages




gies aimed at improving the efficiency of their plantations and generating more competitiveness [42–44]. As a case study, the combination of using drones with specific techniques for digital image processing and artificial intelligence [45] allows reducing production losses by identifying defects in planting and other abnormal conditions.

Based on this principle, the main goal of this research was to capture aerial images of regions with plantations using drones and to use digital image processing algorithms and convolutional neural networks, in order to identify possible abnormalities in the growth of trees related to the culture of the oil palm in the state of Pará. The project was divided into five stages mentioned in Fig. 17.12, including planning and development. In Brazil, ANAC (National Civil Aviation Agency) has established standards for UAV flight since 2017, which include, for example, different maximum flight heights for different UAV weights [46]. The flight plan is an important step for the execution of the project because any errors in the flight configuration can compromise the quality of the orthomosaic. At the end of 2018, EMBRAPA (a Brazilian agricultural products company) launched a booklet that helps pilots on how to plan a flight for mapping purposes.

#### 17.4.2.1 Methodology

The images were obtained by the company WDK Drone, using a DJI UAV. The model used was the Mavic Pro drone, a small multi-engine, which can be applied, in some cases, to aerial mapping. The drone has an autonomy of 27 min, a range of up to 7 km, and an onboard camera with a $1/2.3''$ CMOS-sensor. Through the 12MP camera, an orthomosaic of quality useful for the project was generated. Figure 17.13a is an example of the orthomosaic obtained from the images captured during the flight. The map was generated using the Agisoft PhotoScan software. The mapped area has 18 ha located in the municipality of Santo Antônio do Tauá (PA). For the map, a standard camera with an RGB sensor was used.

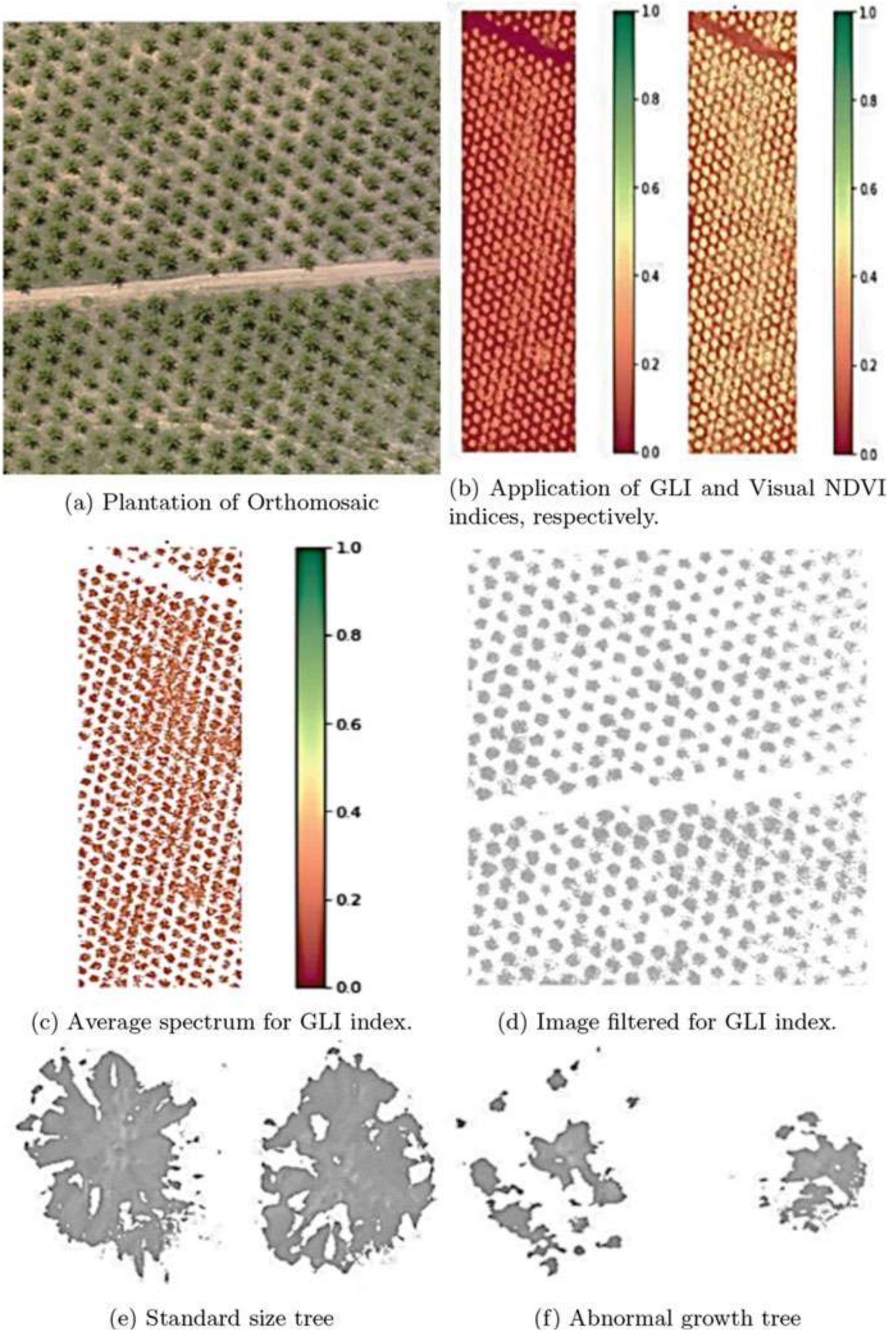



**Fig. 17.13** Stages of tree image processing. (**a**) Plantation of orthomosaic. (**b**) Application of GLI and Visual NDVI, respectively. (**c**) Average spectrum for GLI. (**d**) Image filtered for GLI. (**e**) Standard size tree. (**f**) Abnormal growth tree

Aiming to plan a quality flight for mapping purposes, the project followed the necessary parameters for a flight using the DJI Mavic pro UAV, established by the EMBRAPA company. The flight height was 120 m, considering the maximum height allowed for flights of unmanned aircraft. To define the parameters, the DroneDeploy flight planner software was used. In accordance with the data presented by the software, the cruise had an approximate time of 18 min and only one battery was needed.

The algorithm was implemented using the Python language. Initially, the image in the TIFF format was separated into RGB bands. To work with geospatial data, the raster library was used. The map was cropped into smaller sizes so that the information could be read separately. After the separation of the bands, it would be necessary to apply vegetation indexes to make the vegetation differentiation possible. The drone's camera is limited to the RGB type, so some indexes could not be used. The most popular ones, like NDVI (Normalized Difference Vegetation Index) [47], use the infrared frequency band to generate statistics. There are less popular indexes, in which it is possible to use only the three bands, such as the NDVI visual and the GLI (Green Leaf Index) [48]. The calculations to generate the indexes are

$$\text{Visual NDVI} = \frac{(\mathcal{G} - \mathcal{R})}{(\mathcal{G} + \mathcal{R})}, \tag{17.1}$$

$$\text{GLI} = \frac{(2 \times \mathcal{G} - \mathcal{R})}{(2 \times \mathcal{G} + \mathcal{R})}. \tag{17.2}$$

$\mathcal{G}$ and $\mathcal{R}$ are green and red, respectively, in Eqs. (17.1) and (17.2). Both Visual NDVI and GLI use the green color, from a tree considered healthy, to calculate the index and can also be used as a chlorophyll indicator. The results vary between 0 and 1. Figure 17.13b illustrates the application of the GLI and Visual NDVI on the map, respectively.

For better understanding, false colors are applied to the map to differentiate the elements by coloring. The GLI has a greater contrast between soil and local vegetation, which facilitates filtering for study. It is generally possible to limit the index close to zero in two classes: Positive results tend to select the green leaves of living materials, while negative results tend to be non-living material or soil. However, due to the changes in lighting and environmental conditions, this limit is not always directly at zero. After all calculations, the filtering of what is vegetation to the soil is carried out. As shown in Fig. 17.13c, the vegetation could be separated from the soil, making only the trees visible.

Once the vegetation is already filtered out of the soil, the creation of the dataset was planned, separating trees that have the same size. The images were cut to equal sizes and separated into two sets: standard growth and abnormal growth. Figure 17.13d shows part of the map with the applied GLI and filtered soil vegetation. The image is represented without using false positives.

It is observed through the map that some trees are represented only by small spots, which reveals a drop in their leaf area and may indicate some failure in the development of the plant. Figure 17.13e shows enlarged images of the map, composed of trees with visually similar structures, and in Fig. 17.13f are observed enlarged images with abnormal growth trees, represented by few spots, indicating a low green area index. It comprises the standard growth set of 80 images of trees with similar sizes. For the abnormal growth set, 35 images were selected with some anomaly or differentiation in growth. For each classification, 80% of the images were separated for training, and 20% for validation. In order to increase the possibilities for each training set, due to the small amount of data, changes were made to the images through Python, where each image was rotated, had its dimension changed, and the shear zone increased by 20%, also for the zoom, allowing, through these changes, that the algorithm could read these images as if they were new training data.

In this research, a convolutional neural network with seven hidden layers was developed. The classifier starts the sequential model, and then the layers are added. The first layer determining the data entry indicates the size of the images to be inserted and their method of activation. The images inserted in the network were scaled to 64 × 64 and had 32 neurons as output. In this algorithm, the number of epochs or the number of iterations chosen was 25. For each epoch, there are updates for backpropagation calculations. These calculations reduce the loss value and improve the accuracy of the algorithm. For each epoch of neural network training, the images were resized to increase the number of data in the set. At the beginning of the training, the precision value was around 60–70%. As the number of epochs increased, this value reached a 95% range and, as a result, the loss value decreased, making the network more accurate.

#### 17.4.2.2 Results

The algorithm showed satisfactory results, reaching loss values of less than 10% at the end of the 25 epochs training and hits of around 95%. When increasing the number of epochs to 30, the precision value approached 100%. However, this value became worrying, since the occurrence of overfitting can happen at perfect rates, which is not the objective of this chapter. The choice of very high values for periods, such as 75, makes the algorithm unable to correct some differentiation of trees.

It is necessary to carry out further research so that the model can be used in large-scale projects. The model can indicate which trees have differentiated growth; however, it is not possible to determine the cause of this event. Several factors must be considered based on the local culture, such as soil, climate, pests, etc. To improve the algorithm, studies have been suggested for: optimization of orthophoto; adjustments to the algorithm, such as the number of epochs; tests using other models; improving the database; image processing; and leaf overlap.

The number of epochs is a key parameter to improve the convolutional neural network results; however, this number must be tested so that there are no overfitting problems. During the tests, very high values were tested for the epochs, between 75 and 100. During the tests with values above 75, accuracy values very close to 100% were noted; however, the algorithm was not able to correct some differentiations of trees. Several processes can be improved, from photo capture to post-processing, increasing the quality, decreasing the computational cost, and improving the accuracy of the algorithm.

## 17.5 Future Research Direction

Big data environment is capable of storing and processing the large data volume generated by IoT systems in a few seconds, whether on-premise or on-cloud. This data processing can involve several steps, such as data transformation, report generation, data analysis, and software development support.

Nevertheless, a strong infrastructure is needed to process all of this data and generate value, e.g., by using artificial intelligence (AI) algorithms. Moreover, advanced deep learning algorithms can generate insights for the large data volumes fed by multiple IoT platforms.

Computing and AI advances have been made possible to dedicate resources for data processing each time at lower cost. This data processing is crucial for the calculations of metrics that impact business and people's lives. In this way, IoT data is seen as the fuel for new funding aimed at improving the quality of human life.

As future work, prediction and analysis methods presented in this chapter still need to be improved. Other tests can be done using the main machine learning tools shown in Table 17.5. These tools would allow processing satellite images, as Landsat-8 and Sentinel-2 by using the conjunction of ANN and wavelet decomposition, namely, Wavelets Artificial Neural Networks (WANN) in order to conduct experiments aimed at exploring the performance of the new models in different categories for large areas.

Regarding WANN, the wavelet decomposition is useful to separate detailed components and an input time series into approximations. In this sense, it is possible for future research to use the decomposed time series as inputs for ANNs to predict agriculture data. For example, by using satellite image it is possible to test which combinations provide useful information for classification in agriculture, employing time series analysis and multi-temporal database to train neural networks.

Another future research line can be the development of a Convolutional Artificial Neural Network Architecture Embedded in Raspberry Pi analyzing the main points related to the identification and classification of images. The identification of characteristics in images has been widely used in agriculture as it enables the use of the digital camera, a wide access sensor with valuable information for a large set of automated tasks.

On the other hand, it is necessary to deep in concepts related to images, such as the study of colors, the stages of image processing, in addition to the various areas

**Table 17.5** Main machine learning (ML) tools

| ML tools | Characteristics |
|---|---|
| Google Colab [49] | It is a cloud tool that allows you to create and execute code in the Python language. With Google Colab, we can run programs directly from your browser, simply and quickly. This tool offers an environment very similar to that of open-source software Jupyter Notebook, with the convenience of not needing configurations—since it works entirely online. For this reason, the codes created on both are called notebooks and are structured as a set of cells. |
| Orange [50] | Orange Data Mining is an open-source tool that allows you to create the entire workflow for a date project mining, with no code required. Ideal for those who want to practice machine learning but do not intend to learn to code or for beginners who want to apply some concepts, as well as for experts in the subject. Orange Data Mining has a drag and drop interface. Similar to some tools like SPSS Modeler and Azure ML from IBM and Microsoft, respectively. |
| Weka [51] | Is a software platform for machine learning and data mining written in Java. Weka is a free software distributed under the GNU-GPL license. It contains tools for data preparation, classification, regression, grouping, mining of association, and visualization rules. |
| Teachable machine [52] | It is a tool that allows users to train a machine learning model in the browser, uses a technique called transfer learning (transfer of learning), which in general is the idea that models already exist made by someone based on a large amount of data, a model that is called MobileNEt and the data used to train this one, are called ImageNet, being able to save this model, and use it in your own project. |

of science using this technology. Many modern applications rely on AI methods. AI techniques are highlighted, especially machine learning, deep learning, and transfer learning, combined with convolutional neural networks (CNN). However, large amounts of data can overcome the computational power available in IoT environments, which makes the process of designing them a challenging task.

The most common processing conduits use several high-computational cost functions, which require combining high-computational capacity with energy efficiency. For this reason, a possible strategy to overcome these limitations and provide enough computational power, combined with low-energy consumption, is to incorporate image-based classification solutions in embedded systems, by using AI and CNN, which yields higher speed, performance, quality in the obtained results, as well as fast processing and time commitment.

Another aspect to concentrate on research effort is how to manage a variety of data with different formats generated continuously by several sensors (e.g., temperature, presence, magnetic, pressure, humidity, position, etc.). Besides, the large amount of data tends to grow without limit and very fast. As the formats are different, it is important to be aware when processing this information. In line with the IoT data properties, this data is non-synchronized due to the limitations of communication technologies. Moreover, IoT data contains little information because each data comprises a limited view of the environment in which the sensors are inserted.

In summary, the characteristics of the IoT data are essential to be analyzed and used for future analysis. Moreover, it generates insights by applying artificial intelligence algorithms in order to obtain higher accuracy in the results.

## 17.6 Conclusion and Recommendations

IoT was applied in agriculture to analyze the growth of trees, oil palm plantation, as well as poultry farming applications to measure the levels of humidity, temperature, and harmful gases. Regarding agriculture, the obtained results disclose that it is possible to use computer vision and deep learning technologies in IoT, so that plantation problems can be detected in early stages. Moreover, this case study reveals satisfactory results using vegetation indices to be treated with image processing. Otherwise, if images were treated in their standard form, many variables should be considered, such as luminance, saturation, exposure, spectral range, etc. Specifically for oil palm plantations, the results demonstrated that possible anomalies in oil palm plantations were avoided by applying color analysis, which is translated in cost optimization for oil palm agriculture through the detection and identification of plant by diseases using deep learning.

This chapter has demonstrated high confidence results in deep learning applications to provide useful analysis for oil palm plantations and represents an initial step toward the development of new technologies that can further facilitate the rural producer work. Regarding poultry farming, an important solution was proposed to monitor environmental parameters, such as temperature, humidity, and ammonia levels, as key factors to improve the production of poultry farming sector, e.g., by preventing early poultry deaths. By combining WSNs intercommunicated through LoRa technology and ML-based algorithms, the system was able to monitor biovariables with less than 2% error against to the pattern equipment. In addition, the system was able to indicate predictive alarms regarding low and high levels of humidity and temperature, but the alarms for $CO_2$ and $NH_3$ increasing had low certainty and need to be improved in a future work by developing multivariable classifier.

The proposed methods for monitoring environmental parameters are specific for poultry farm, although these methods can also be used in monitoring variables from other industries. Indeed, the techniques applied in the present study can aid in evaluating important environmental variables, which, in turn, facilitate the identification of possible anthropogenic impacts. This benefit is relevant in environmental management and policy decision-making processes aimed at mitigating those negative impacts and restoring the environment. In this context, it is important to recall that the end and main goal of the technology (IoT, in this case) is to improve quality and sustainability of various sectors, thus providing more efficiency, optimizing costs, contributing to the global economy, facilitating the implementation of public policies related to environmental processes, and mainly improving the quality of the human life.

Finally, it is worthy to mention that the application of new techniques in training, pre-processing, and analysis to obtain even better results could be carried out in a future work.

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# Chapter 18
# Conceptualization of a Dialectic Between an Internet of Things System and Cultural Heritage

**Ana Melro, Lídia Oliveira, and Ana Carla Amaro**

## 18.1 Introduction

The development of technological software and hardware has been such that the possibilities for communication, interaction, and transmission are numerous. These possibilities include the Internet of Things (IoT), that is, a set of tools that allows interaction between people and objects, helping them to recognize commands and respond to those commands. The definition of this system is so vast that it can be carried out as follows "a service that can cover different types of demand based on the use of some of its faculties" [1]. Or, more specifically, as the authors Gokhale, Bhat, and Bhat refer "Physical and virtual things in an IoT have their own identities and attributes and are capable of using intelligent interfaces and being integrated as an information network. In easy terms IoT can be treated as a set of connected devices that are uniquely identifiable" [2].

In the specific context of this paper, the application of the IoT system is made to promote cultural heritage. In this field there are numerous experiments already carried out [3–5]. What is presented is the result of the ethnographic research carried out between 2018 and 2019, geographically located in the place of the Amiais, Sever do Vouga, interior of Portugal. This research resulted in the survey of Amiais' cultural heritage, through techniques such as formal and informal interviews, participant observation, and documentary research.

The paper reflects how knowledge about a territory and the people who visit it, who reside there and who operate in it, can become something appealing to others but also something that promotes its and their development and the recognition of its and their potential. Thus, coupled with the way the IoT allows to encourage and

A. Melro (✉) · L. Oliveira · A. C. Amaro
DigiMedia, University of Aveiro, Campus Universitário de Santiago, Aveiro, Portugal
e-mail: anamelro@ua.pt; lidia@ua.pt; aamaro@ua.pt



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improve contact with the local cultural heritage, there is also the capacity that this relationship has to make territories smart.

According to Garcia-Ayllon and Miralles [6], the concept of smart territories has expanded that of smart cities. According to the authors, there is a qualitative leap, which includes geographic information systems that verify the current situation, make diagnoses, and propose scenarios of corrective measures for existing problems. It is, therefore, a leap in territorial governance strategies, which are not only directed to the city. The concept of smart cities "is based on implementing sustainability and efficiency criteria in the development and planning of cities" [6]. However, one cannot consider smart territories as perfectly managed places, since, as McGuire [7] also enlighten, all the smart territory management can lead to citizens that develop less their capabilities.

The article is organized considering the importance of the referred concepts (IoT, cultural heritage, and smart territories) for its understanding and of the LOCUS project and also considering the importance of those concepts for the project. LOCUS is being implemented in Amiais, as an action-research project, with a strong component of a technological co-created IoT system. The project aims to understand how playful interactions with intelligent and social objects can be designed to support intergenerational involvement in the creation and exploration of cultural and learning content on rural territories.

Furthermore, it intends to point out how it can contribute to the development of smart territories, following the relational exercise of (1) promoting the increase in knowledge of cultural heritage (through the involvement of different generations in the construction of a list of material and immaterial cultural heritage) and (2) facilitating its access, through the co-creation of an IoT system, and how it will be possible to contribute that its demand and preservation become appealing (namely, with tourism) and, consequently, for the territory sustainability [8].

The paper is organized into three main sections: in the first, a brief description of the LOCUS project will be made, but specifically considering the relevance of cultural heritage and the IoT system. Thus, a brief description of the objectives of the project and the tasks involving those two dimensions will be made.

In the second section, attention will be paid to the theoretical development of the central concepts for the paper: Internet of Things, cultural heritage, and smart territories. This way it is possible to present the project's methodology that allowed the identification and collection of Amiais' cultural heritage main elements. Still in the third section, relevance will be given to the development of some IoT scenarios, which will make cultural heritage appealing.

The paper aims to (1) relate the concepts of cultural heritage, IoT, and smart territories and highlight the importance of this relationship, (2) present the LOCUS and its relevance for the knowledge and awareness of local cultural heritage and for the smart territories development, and (3) present some scenarios using IoT that are under development and that include elements of Amiais' heritage.

## 18.2 LOCUS' Project Description Considering the Importance of Cultural Heritage and IoT

LOCUS project is being developed in Amiais, a village located in the parish of Couto de Esteves, municipality of Sever do Vouga. It is a technology-based project that, having as a starting point the Amiais' cultural heritage ethnographic research, aims to develop an IoT system.

The construction of this system goes through several phases: (1) the recognition of cultural heritage; (2) co-design sessions to reflect on the IoT system, which includes the inhabitants' participation (which allows the promotion of intergenerationality), tourists, and local stakeholders; (3) development of the system itself, with operational tests with inhabitants, tourists, and stakeholders; and (4) implementation of the IoT system in place (Amiais).

The first step, then, was to bring the project team closer to the Amiais' population and the territory. This approach was accomplished through ethnographic research. What was intended was to make the members of the team as familiar as possible to the Amiais' inhabitants, as these would be the main vehicles of information about the local cultural heritage. Additionally, for this survey of cultural heritage to be robust, several visits, different interactions, and even participation in traditional activities were important to occur. For this, too, it was relevant for inhabitants to see the team members as someone close and familiar, someone they remembered to invite to those moments.

Thus, the goal of the first task was to make the survey as extensive and as close to the truth as possible, as close to what was done in the past. And, for that, it was necessary to repeat requests for information, repeat conversations, talk to different people, and systematize the collected information.

Then, co-design sessions were organized with two essential purposes: once again, to confirm, standardize, and systematize information about cultural heritage, collected in informal and formal moments (conversations and interviews). The second purpose was related to the need to collect feedback on idealized scenarios that combined the relationship between cultural heritage and the IoT system. As spaces for co-creation, it was essential that the sessions be coated with interaction, questioning, but also with proposals that came from Amiais' inhabitants, tourists, and stakeholders.

The third phase suffered some setback. With the pandemic scenario, it was necessary to interrupt the co-design sessions, which made it impossible to jointly create the IoT system. Thus, in the two sessions held, it was possible to systematize the information regarding the cultural heritage survey carried out (first session) and to identify the most relevant Amiais' places and monuments (second session).

For the following sessions, which didn't take place (and the generated instability won't allow the team to predict when it will be possible to do so), some prototypes were being planned and implemented. The team continues to develop these prototypes in order to take them to the field and test them with the inhabitants whenever it is possible.

Thus, while the IoT system is strengthened and the scenarios for its implementation are being diversified, the fourth phase awaits the possibility of becoming effective in the territory. For now, as mentioned, several scenarios are being created and tested, using Amiais' cultural heritage and the interaction between people and objects, with the introduction of sensors.

When it is possible to resume co-design sessions, the objective will be to continue to ask for the inhabitants, visitors, and stakeholders' collaboration to define strategies and include more relevant scenarios and possibilities of interaction with the system and with objects or with the intangible heritage, as well as collect information concerning the cultural heritage that they consider will be more relevant to cover as well.

Some projects that had an approach contemplating the use of IoT systems or even other technologies that enable the recognition and cultural heritage preservation are the following: the one developed by Garau [9] proposes a study using co-design to promote the use of augmented reality as a way to promote cultural tourism. Chianese, Piccialli, and Valente [10] developed a new concept of intelligent environment, with technology, namely, the use of an IoT system, serving as an intermediary between visitors and the enjoyment of space. Geographically located in the protection of cultural heritage, World Heritage by UNESCO, Sassi di Matera (Italy), Gribaudo, Iacono, and Levis [11] monitored the multitudes of tourists who visit that place every day and the consequent wear and tear of monuments. To protect museological artifacts, the project carried out by Konev et al. [12] implemented an IoT system that parameterizes and regulates microclimate parameters. The last study proposes the preservation of historical monuments, namely, churches using an IoT system [13].

## 18.3 Internet of Things, Cultural Heritage, and Smart Territories

Smart visit experiences have been referred to as the process through which information and communication technologies (ICT), combined with and enhancing cultural heritage, promote an interaction between people and the territory that is different from the usual one, because it is more enriched in terms of involvement and with the possibility of greater knowledge acquisition about its history and the heritage that compose it [14].

In this paper it is particularly important to focus attention on IoT systems and the way in which their characteristics enhance access to cultural heritage but also preserve it. In a way, and in general, ICT, namely, IoT, makes cultural heritage even more appealing (or intends to make it appealing), not only in order to encourage its search/visit but also to make it recognized. And cultural heritage itself also plays an active role in making IoT systems appealing and interesting in that particular context. It is, therefore, a dynamic and dialectical process between one dimension and the other of the interaction with visitors and those interested in cultural heritage.

The potential of making cultural heritage appealing is demonstrated in the study by Chianese and Piccialli [15]. The authors designed a smart museum (what they call a smart indoor cultural space), using an innovative model of sensors and services. In this way, the authors consider that this may attract more visitors and increase their enjoyment and fun in their cultural experience. But here, too, there are concerns about preserving cultural heritage.

Complementary to preservation is access to cultural heritage. The starting point is that the conservation, preservation, and, consequently, the sustainability of cultural heritage are ways of providing access and knowledge of this cultural heritage. In this way, perhaps a circle effect will be generated, since, based on knowledge, they will tend to contribute to its preservation and, from the moment it happens, as mentioned, it allows access to the knowledge of its existence and its history. Piccialli and Chianese [16] proposed a platform that promotes an interaction between visitors and objects of cultural heritage, transforming a static cultural space into an intelligent environment. Thus, and similar to the study mentioned previously, an incorporation of ICT in objects, the use of IoT architectures and the use of sensors and other interaction systems, will promote the enjoyment of cultural learning in a fun and dynamic way, even if the context is static [15].

The use of the word in the referred studies "smart" is verified. It is not only done because the focus of the projects is the use of technology systems architecture but above all because this use will contribute to the territories and cultural heritage sustainability [17–19]. Thus, the places become smart territories, that is, when protocols of sustainability and efficiency for the development and planning of cities make the leap to the regional scale [6].

IoT is defined as "a dynamic global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network" [20]. Relevant expressions are removed from the previous definition, such as the identity of virtual objects, their physical attributes and also virtual personalities or intelligent interfaces, and integration in the information network, to describe the importance they have to give life and intelligence to heritage and, consequently, to territories.

Also stating, as some authors do, that cultural heritage sites contribute to economic growth [13], it will be relevant to associate the three concepts (or expressions) in the same equation. Thus, the Internet of Things promotes and even helps in the cultural heritage preservation, conservation, and sustainability. The maintenance of cultural heritage will lead to the development of smart territories, insofar as the smart economy is one of the parameters but also because the cultural heritage is related to the other dimensions considered in the definition of what is a smart territory, namely, people, governance, smart living, mobility, and environment [8, 21, 22].

Thus, the three buzzwords have been associated: IoT, cultural heritage, and smart territories, in a logic of shared gains, where some contribute to the development and recognition of others (cultural heritage) and these become key pieces for the recognition of the importance of others (IoT and smart territories).

## 18.4 Methodology

The LOCUS Project is being developed in Amiais. It is a village which belongs to the municipality of Sever do Vouga, Couto de Esteves Parish, located in Portugal center region (Fig. 18.1). Amiais is characterized as rural, since its main economic activity is agriculture and its inhabitants still dedicate themselves to the cultivation of specific products, such as grapes, blueberries, and corn.

Historically, it is a village linked to other villages, Ribeiradio and Vilarinho, because of their closeness, which provided their inhabitants to share the religious parties' organization, their children to share the way to school (at Couto de Esteves), and the sell and buy of local products at Ribeiradio.

The project has a strong dimension of ethnographic research, and that was the beginning of its development. Thus, initially, some formal interviews and informal conversations were carried out with the aim of characterizing the resident population and collecting information about the general traits of cultural heritage: relevance to the place, most relevant places and stories, and main stakeholders, among other aspects.

Amiais is a place with 15 permanent inhabitants, only 3 of whom are under 10 years old. It is, therefore, a very demographically aged population, predominantly rural, of the interior of Portugal. The following table shows the distribution

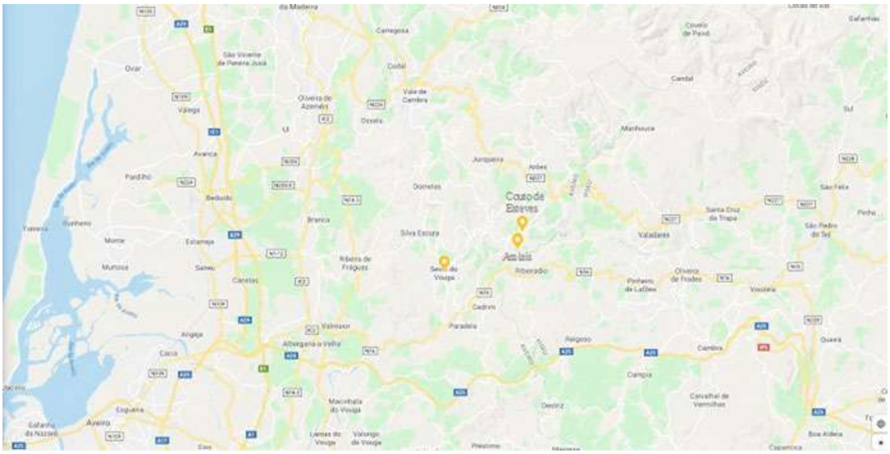

**Fig. 18.1** Amiais' location. (Source: Google Maps)

**Table 18.1** Amiais' inhabitant characterization

| Gender | Age | Residence type | Connection to Amiais |
|---|---|---|---|
| Male | 87 | Permanent | Marriage |
| Female | 85 | Permanent | Place of birth |
| Male | 80 | Permanent | Place of birth |
| Female | 78 | Permanent | Marriage |
| Male | 65 | Permanent | Place of birth |
| Female | 69 | Permanent | Place of birth |
| Female | 40 | Permanent | Marriage |
| Female | 42 | Permanent | Place of birth |
| Male | 42 | Permanent | Place of birth |
| Female | 40 | Permanent | Place of birth |
| Female | 3 | Permanent | Place of birth |
| Female | 8 | Permanent | Place of birth |
| Female | 62 | Permanent | Marriage |
| Female | 66 | Permanent | Place of birth |
| Female | 7 | Permanent | Place of birth |
| Male | 42 | Holiday house | Place of birth |
| Female | 20 | Holiday house | Place of birth |
| Male | 40 | Holiday house | Place of birth |
| Male | 52 | Holiday house | Place of birth |
| Female | 50 | Holiday house | Marriage |
| Male | 72 | Holiday house | Met in tourism |
| Female | 49 | Holiday house | Place of birth |
| Male | 50 | Holiday house | Marriage |
| Male | 18 | Holiday house | Parents are naturals |
| Male | 20 | Holiday house | Parents are naturals |
| Male | 50 | Weekend house | Place of birth |
| Female | 51 | Weekend house | Marriage |
| Male | 72 | Weekend house | Place of birth |
| Female | 73 | Weekend house | Place of birth |
| Male | 40 | Weekend house | Met in tourism |
| Male | 70 | Weekend house | Place of birth |
| Male | 50 | Weekend house | Parents are naturals |
| Female | 50 | Weekend house | Marriage |
| Male | 50 | Weekend house | Parents are naturals |
| Female | 50 | Weekend house | Marriage |

of Amiais inhabitants, both permanent and those who chose to (re)build houses for seasonal use. In total there are 35 inhabitants (Table 18.1).

After this population characterization, visits to the site focused on characterizing the spaces, the local heritage. Thus, in the following two subsections, the visits made and their purpose are presented, followed by a list of the main results of the cultural heritage traits.

### 18.4.1 Amiais' Cultural Heritage Survey

In the LOCUS project, there are several activities and tasks that have a direct implication on the residents and local leaders' participation in the project, whether it is a more or less active intervention. Ethnographic research was the first task that included the participation of the target audience and, the visits made are listed in Table 18.2.

Shortly after the project started, two visits to the field were made by the researchers, with the aim of getting to know it, as well as getting to know the people and making the team known. During these visits it was also possible to conduct interviews with local leaders, namely, the Mayor of Sever do Vouga, the President of the Parish Council of Couto de Esteves, the President of the League of Friends and Naturals of Couto de Esteves, and the President of the Cultural and Social Association of Couto de Esteves. These interviews were of great importance because it was possible to understand how the territory was organized, the entities' investment in the different villages, as well as the availability to host the project, which came to be perceived to be high.

Participant observation was constant, throughout all visits. Understand how certain practices are relevant to the population, the rituals that are present, the way they coexist and come together. Especially activities 3, 6, 7, and 8 contributed to the perception of the importance of religion (activities 3 and 6), for example, times when the whole family gets together, but also for the perception of the way the meetings are always moments when, even without knowing what it is about, people

**Table 18.2** Visits and events of ethnographic research

| Nr. | Date | Visit or event goal |
|---|---|---|
| 1 | 2019.09.25 | Recognition of Amiais territory. Informal presentation to residents |
| 2 | 2019.03.26 | Recognition of Amiais territory. Informal presentation to residents. Interviews with local leaders, in Couto de Esteves |
| 3 | 2019.04.27–28 | Participation in São Francisco de Assis and Nossa Senhora do Amparo festivities, in Sever do Vouga and in Amiais. Participant observation |
| 4 | 2019.05.24 | Recognition of Amiais territory. Informal presentation to residents. Interviews with local leaders, in Couto de Esteves |
| 5 | 2019.06.25 | First LOCUS Seminar, in Aveiro |
| 6 | 2019.07.13–14 | Participation in the Feast of the Lord, in Couto de Esteves. Mills photography exhibition and flowered balconies contest. Participant observation |
| 7 | 2019.08.10 | Moonlight serenade, in Amiais. Gathering with residents and local leaders |
| 8 | 2019.09.28 | Traditional corn leaf, in Amiais. Gathering with residents and local leaders |
| 9 | 2019.11.23 | "Magusto" festivity, in Amiais. First co-design session |
| 10 | 2019.12.07 | Second co-design session |
| 11 | 2020.06.29 | Second LOCUS Seminar, online |

get ready and show up, even if it is only to see what is going on (activities 7 and 8). The serenade was also a moment of gathering of the emigrants who were in the village at the time of the summer.

Activities 5 and 11, although they did not correspond to a field visit, were relevant because they included the participation of local leaders in the event as speakers. They were very relevant moments for the growth of the sense of closeness between the team and the leaders and of appreciation of their work and presence in events that belong to the project itself.

Thus, task 5 of LOCUS project (ethnographic research) aimed to bring the research team closer to the resident population and local leaders, to demonstrate the relevance that their participation had (and continues to have) for the project development and success, and to contribute to the understanding of what LOCUS is and what its objectives are, so that people feel familiar and want to collaborate and learn about the ways of doing and belonging to the Amiais' population.

Task 6 (data analysis, interpretation, discussion, and consolidation) is closely linked to task 5 due to its implicit need, that is, task 6 does not exist without the previous one, in the sense that, if there were no data to analyze, it would not be possible to carry out this task (and even some of the following). It was the collected data analysis that, often, resorted to the inhabitants themselves, for example, in order to understand some recreational activities that were mentioned when surveying the cultural heritage in informal conversations.

Activities 9 and 10 already belong to the scope of task 8. The co-design sessions, as the name implies, involve the inhabitants, visitors, and local leaders' active participation, whether through the suggestion of recreational, work, and family activities, among others relevant from the point of view of the local cultural heritage, or, at a later stage, through the incorporation of the IoT system in the territory and the handling of the mobile application with AR and the suggestion of functionalities' changes, inclusions, and/or eliminations. It is an objective that the application and all the information systems and technologies that will be available are built with the continuous collaboration of those people.

So far, two co-design sessions have been held that included the inhabitants' participation. The survey of the cultural heritage activities that was done in informal conversations and interviews was completed in the first session; the information and characterization gaps that still existed were filled. In the second session, a recognition of the territory was made, with the help of Google Maps, from which it was possible to identify the homes of each person and the places of interest in terms of carrying out the activities, for example, the community threshing floor, where corn was stripped in the past or where children got together to play and adults to sing songs. The first session will feed the mobile application in terms of content. The second session will feed the application in terms of geographic identification. In both sessions it was also possible to extract some information from real objects and physical spaces to be used and incorporated in the IoT system.

In terms of the impact that LOCUS has generated so far on people, there are several evidences that allow us to conclude that effects have already been produced as a result of the presence of the project and researchers in the territory. On the one hand, being aware that there is an interest in the local cultural heritage and talking about it makes them go back to the past, revisiting memories, something that, in psychological and sociological terms, has high impacts. Revisiting the past means remembering happy moments but also some sad ones in which the population in question lived moments of hunger, mistreatment, and hard work when they were still children [23].

On the other hand, the sociability of the Amiais' people has changed. For example, invitations to participate in activities organized by local associations have been frequent, precisely because they know that it is important for LOCUS to be present. In addition, in co-design sessions there are always between 10 and 14 people, which is quite significant considering that the population has 15 permanent inhabitants. In addition to these aspects, there has been a lot of care on the part of the local associations in carrying out traditional activities specifically in the Amiais, because they know of the interest of this for the project, for example, the realization of the moonlight serenade or the traditional corn leaf that every year occurs in a different village.

For the inhabitants, it is considered that the LOCUS team is already so familiar that there is already an evident ease in telling stories and sharing daily experiences. But the introduction of concepts such as technology, IoT, augmented reality, mobile, digital applications, etc. is already beginning, which is expected to generate some disruption in habits from now on. What happens now is the rare use of smartphones, tablets, computers, or chat applications. But co-design sessions are foreseen that imply training in the use of these tools, which will certainly generate an impact on people, mainly because these are tools that are not part of their current daily life.

In terms of territory, sensors will also be installed at a more advanced stage of the project in various monuments or places relevant to cultural heritage, which will impact the territory and its demand. And it is expected that they will promote interest in investing in network infrastructure, something that, at the moment, seems to be a difficulty that the project has to overcome.

However, it is important to note that the inclusion of this technological component should always take into account the respect for the territory and how the entire infrastructure of IoT and sensors will help to share experiences and the sustainability of the place cultural heritage.

### *18.4.2 Amiais' Cultural Heritage Results*

With the conduct of the Amiais ethnographic research, with the main purpose of collecting information about their cultural heritage, it was possible, from an early age, to identify central areas in which the interviewees referred to cultural elements, namely, playfulness, crafts, family traditions, and the other affective connections, for example, with neighbors and religion.

#### 18.4.2.1 Cultural Heritage and Playfulness

Not infrequently, games and play are associated with very complete and complex forms of learning and with ways to enhance interaction, whether between individuals belonging to the same age group or between ones from different generations. In the specific context of application of this research project (Amiais), this fact is no different. There were several recreational activities associated with one of the biggest agricultural assets of that place, corn, namely, finding the king corn during defoliation (a corn ear with a reddish color, different from the majority), which allowed the happy person embrace the woman/man he/she wanted (who, invariably, was the person they liked best). Of course, this was an activity, mostly, allowed to men, who, a few days before the defoliation, went to the nearest villages to try to find the red corn and strategically placed it in the defoliated wheel so that they could easily find and embrace the girl.

A game more associated with girls was the scarf. Arranging themselves in a circle, sitting and facing each other, girls and boys play, one of them standing up, by walking outside the circle and around it, with a handkerchief in hand, humming. When wanted, the person dropped the handkerchief on the back of one of the players who would have to take care of it and notify all the other players. At that time, he started to have the scarf in his hand and started the same process.

The nail was already a game associated with men/boys. Each player had a nail, which he had to shoot into a hole in the ground, made specifically for this purpose before the start of the game. Whoever managed to strike the nail in such a way as to keep it upright would win. The girls had the same game, but with a button; whoever hit the button in the hole, won.

A game played indifferently by boys and girls was the spin: a circular object made of wood, around which a string was wrapped, one end being in the player's hand. The goal was to throw the spin toward the ground and keep it spinning as long as possible.

The patella was another game most liked by girls as well. A circuit was drawn on the ground, with several squares, through which each player had to circulate until reaching the last, throwing a stone (the patella) at each of the squares and jumping between each one with only one leg. The winner was whoever managed to pass through all the squares without dropping the stone outside the squares and whoever managed to pass through all the squares without stepping on the lines.

Among the various elements common to all these games is, for example, the clear distinction between games for boys and girls, and it was not appreciated that the two mix together, especially at younger ages. The separation of the sexes was something very present, not only in the game but also in domestic and agricultural tasks, with men taking on the heavier jobs and women taking on more homework or lighter tasks at agricultural work.

Another relevant element was music. Almost all games or playful meetings in free time had music associated with them, with several of the interviewees even mentioning that, on Sunday afternoons, they would gather at the community threshing floor with musical instruments and someone who would sing and thus spend their afternoons. But this is also an element present in the work moments, for example, during the defoliation there was always musical accompaniment. Finally, it is worth mentioning the importance of music during the religious festivals of the village's religious saints, with various musical groups livening up the afternoons and evenings of those days.

Playfulness is a relevant element for people, who have been referring to us, always in a lively tone, the moments they had to play over the years and the different games according to their age. This dimension of game is very relevant to LOCUS project, since this will be the dimension that will have the greatest relevance in the technological implementation that we intend to make. Thus, it was necessary to understand the roots of the games, as well as their detailed characterization, so that they can integrate the application as faithfully as possible and can be known by everyone who uses it.

#### 18.4.2.2 Labor Dimension

The dimension of work is subdivided, in his analysis, into two dimensions: when the reference is made to adults, it will be the working time in the strict sense; when the reference is to children, the reference is not only to the hours they are helping in domestic and agricultural tasks but, and above all, to school time.

As it was already possible to see work as an economic activity, in Amiais it is very related to agriculture and animal production, since the reference is, to a rural context, located in the interior of Portugal, characterized, precisely, by these two elements: rurality and interiority. Thus, not only families but also the whole community was organized according to agricultural products and animals.

In fact, this labor dimension focused on agriculture led to many relationships being established with neighboring locations, for example, Ribeiradio, Vilarinho, and even Couto de Esteves. To Ribeiradio people often went to trade products from the harvests; with Vilarinho the families shared the community threshing floor where maize was worked; and Couto de Esteves was the market par excellence, where the fruits of the harvest were also sold, for example, milk, since there was a cooperative in Couto de Esteves.

Thus, there are several associated activities, as well as several products: the production of American wine; the cultivation and treatment of various cereals and herbs such as corn, rye, and flax; and the gorse harvesting for the ovens. There were also those who produced milk and who cut trees for wood, which, as previously mentioned, were later sold in neighboring locations.

Never having been separated from this agricultural production, the instruments used have undergone some changes and adaptations over the years or have served as inspiration for some products, such as the *argau* spirit drink. In addition, the productions have seen new qualities bloom, like the cultivation of blueberries nowadays.

Despite this variety, corn has always stood out, being represented a little throughout the parish, with the *canastros* (places where the corn was stored to dry after being picked) spread in several places, and being recently intervened toward requalification. These *canastros* symbolized (and symbolize) not only the importance of corn but also the sharing existing in the places, since many of them were (and still are today) owned by several families who shared their use.

Mines were also mentioned in the interviews, which were used mainly by men.

#### 18.4.2.3 Emotional Connections/Families

A very relevant and mentioned dimension in the interviews was related to affective relationships, of family members, family formation, and friendship. Thus, if, in the past, there were many trips to neighboring locations in order to find a girlfriend (because they were also mostly men who moved), with the passage of time and the development of land routes, distances were shortening. For this reason, several families of people interviewed said that the spouse was from the neighboring place or village.

This aspect also outlined the cultural heritage of Amiais, since it is, precisely, this family constitution that allows the continuity of generations and that, in the current days, has enabled the younger generations to look for more remote places, such as Aveiro, or even other countries, and end up settling there, leading to that village more and more desertified, something that still has implications in the transmission of knowledge about local cultural heritage.

Currently, the religious festivals in honor of São Francisco de Assis and Nossa Senhora do Amparo, which take place in Amiais, still a joint organization with Vilarinho, are the privileged moments of gathering for family and friends. The same happens during Easter, Christmas, or even the religious festivals in Couto de Esteves.

#### 18.4.2.4 Religion Dimension

This dimension, as was already possible to understand along the dimensions previously analyzed, is perhaps one of the most relevant for Amiais inhabitants. It was the religion that contributed to people getting and having a party. It is, even today, the religion that promotes the meetings of people who have not seen each other for some years. It is also the religion that helps families to participate together.

Additionally, religion is felt in every corner of Amiais [24]. The relevance for the joining of several couples, today families, was already analyzed in the previous subsection, as well as the way in which two neighboring villages (Amiais and Vilarinho) share the organization of a religious festival.

The aforementioned party in honor of São Francisco de Assis and Nossa Senhora do Amparo, saints of Amiais and Vilarinho, respectively, is still a moment of great importance for the inhabitants of both places, although it has changed its contours a little over the years.

In the past, it was possible to know that the party had even started in Ribeiradio, with the saints being transported by boat to Amiais and continuing the procession from the Amiais margin. In addition, the party lasted for 2 days, with musical groupings at two points in Amiais, quite different from what happens today, where the procession only happens on one of the days (Saturday or Sunday).

Couto de Esteves hosts the most important festival in the parish, the Feast of the Lord or *Santíssimo*, which, in the past, was attended by all the inhabitants of the villages, including Amiais. In fact, being a butler at the party was very important, and a lot of money was spent to organize the best party possible. This is, therefore, a larger party, lasting 3 days, with several events taking place at the same time and several people involved in the organization.

But one of the most relevant monuments in religious terms is the *Alminhas*, very mentioned by all Amiais' inhabitants and even by stakeholders. They are small stones, strategically placed in places where people passed by on foot and took the opportunity to pray, while resting from long walks (especially when the path between villages was made only on foot). The stones had inscribed small works and were painted, with religious figures.

### *18.4.3 Appealing Cultural Heritage: IoT and Smart Territories*

From the survey of Amiais' cultural heritage, some scenarios for the IoT system application were designed. The specific objective of this design was to make the cultural heritage appealing, to contribute to its recognition and, consequently, to its preservation and sustainability. In this way, the territory will also become smart, as previously concluded [6].

Thus, starting from some of the cultural heritage elements identified previously, the scenarios were divided by the possibilities of individual interaction with the objects/places. This interaction is done using a smartphone, a bracelet, and sensors placed on both devices and objects.

The following table shows the definition of these scenarios. These are divided into providing information or the possibility for the user to play a game. The following scenarios were designed to create prototypes to be used in co-design sessions, namely, to demonstrate people what is possible to do with technology (Table 18.3).

## 18.5 Conclusion

The potential that IoT brings to what is of great relevance, such as the preservation of cultural heritage, is enormous. Taking into account the consideration of the 1972 General Convention of UNESCO "Considering that it is essential for this purpose to adopt new provisions in the form of a convention establishing an effective system

**Table 18.3** List of developed scenarios for Amiais' cultural heritage

| Cultural heritage | Device | Information | Game |
|---|---|---|---|
| Corn leaf | With smartphone (without bracelet) | When advancing the smartphone to one of the granaries, the textual information contained in the "brief description of the activity" appears | When advancing the smartphone to one of the sensors, the user may have to pretend to be taking the leaves from the corn in interaction with the smartphone (the corn appears on the screen and the user will have to remove the leaves) |
| | With smartphone and bracelet | When reading the RFID tag, textual information about the granaries is automatically displayed | When advancing the bracelet to one of the sensors, the user may have to pretend to be taking the leaves from the corn<br>When moving the arm, the user will hear a sound<br>When advancing the bracelet to one of the sensors, the user may have to pretend to be taking the leaves from the corn in interaction with the smartphone (the corn appears on the screen and the user will have to remove the leaves)<br>At the end, a little toy appears and congratulates the user for the success |
| Scarf game | With smartphone (without bracelet) | Next to the clock square, there may be a sensor that allows the user to approach the smartphone and see the description of the activity | – |
| | With smartphone and bracelet | When reading the RFID tag, textual information about the game automatically appears | When advancing the bracelet to one of the sensors, the user may have to pretend to be running in a circle with the scarf<br>The bracelet makes a sound for the user to stop<br>When advancing the bracelet to one of the sensors, the user may have to pretend to be walking in a circle with the scarf, and he/she clicks on the smartphone to indicate that he/she dropped the scarf behind one of the players<br>A falling scarf appears on the screen |

(continued)

**Table 18.3** (continued)

| Cultural heritage | Device | Information | Game |
|---|---|---|---|
| Procession of São Francisco de Assis and Nossa Senhora do Amparo | With smartphone (without bracelet) | Next to the chapel and/or off the cross square, there may be a sensor that allows the user to approach the smartphone and see the description of the festival | The user, when making the procession path, is invited to point the smartphone at other monuments/places that she/he will find or wherever she/he goes. At each location, take a photo that is included in the slideshow of images that already exist |
| | With smartphone and bracelet | When reading the different RFID tags along the way or just in the chapel, textual information about the festival automatically appears | The user, when making the procession path, may be invited to point the smartphone at other monuments/places that she/he will find or wherever she/he goes. The user can use the bracelet for this purpose<br>Each location identified with the bracelet gives her/him a point<br>The user can also select to answer a question:<br>"For the year to be good, spend Christmas on the street and Easter . . .<br>(a) in family<br>(b) in the guard<br>(c) at home." |
| *Alminhas* | With smartphone (without bracelet) | Next to each Soul Monument (*Alminha*), the user brings the smartphone closer to the RFID tag, which gives her/him textual information about it | The user, when making the Soul Monument (*Alminhas)* route, is invited to point the smartphone. At each location, take a photo that is included in the slideshow of images that already exist |
| | With smartphone and bracelet | Next to each Soul Monument (*Alminha*), the user brings the bracelet closer to the sensor, which displays in the smartphone her/him textual information about the monument | If there is an outlined route of the Soul Monument (*Alminhas*), the user can identify the *Alminhas* where she/he goes. Each *Alminha* emits a sound<br>The user, when making the *Alminhas* route, is invited to point the smartphone. Each location identified with the bracelet/smartphone gives her/him a point<br>At the end, a little toy appears and congratulates the user for success |

of collective protection of the cultural and natural heritage of outstanding universal value, organized on a permanent basis and in accordance with modern scientific methods,[1]" it is understood that scientific methods can mean technological ones, which allow the protection of heritage.

Identified cultural heritage in the formal interviews and in the inhabitants' conversations in Amiais and later confirmed and with its knowledge stabilized in the co-design sessions allowed to understand the importance (even emotional) that it has for the study participants. They are identity elements of a population.

The LOCUS project aims to reinforce this importance and contribute to the recognition of its existence. Not only in a static way but using an IoT system that allows the preservation and sustainability of the cultural heritage elements to be prolonged over time but at the same time, so that, if necessary, add new elements over time.

The project is still under development, and scenarios are currently being built using an IoT system and sensors. However, it suffered some setback, since the co-design sessions had to be suspended.

The goal is that, in the end, the participatory construction of the IoT system will have the greatest impact for Amiais' inhabitants, visitors, and stakeholders, promoting its tourist and economic but also social impact. In this way, the IoT-cultural heritage-smart territories trilogy will be brought together, in a logic of reciprocal contribution between what are smart systems, smart territories, and smart culture.

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# Part V
# Security and Privacy

# Chapter 19
# Participative Sensing Challenges

**Teresa Guarda, Maria Fernanda Augusto, Isabel Lopes, and Luis Mazon**

## 19.1 Introduction

With the technological advances of the last decades, its impact on the environmental level is increasingly notorious, which causes sources of contamination that affect health and personal performance. Technology changes our daily habits every day, giving the feeling that technological advances will solve many of our problems, without thinking about the possible prejudicial impacts of that.

Due to the constant technological innovation and its decentralized diffusion, these are essential for environmental sustainability, despite the existing anti-technical and reductionist attitudes.

T. Guarda (✉)
Universidad Estatal Península de Santa Elena, La Libertad, Ecuador

CIST – Centro de Investigación en Sistemas y Telecomunicaciones, La Libertad, Ecuador

Algoritmi Centre, Minho University, Guimarães, Portugal

M. F. Augusto · L. Mazon
Universidad Estatal Península de Santa Elena, La Libertad, Ecuador

CIST – Centro de Investigación en Sistemas y Telecomunicaciones, La Libertad, Ecuador

I. Lopes
Algoritmi Centre, Minho University, Guimarães, Portugal
e-mail: isalopes@ipb.pt

Polytechnic Institute of Bragança, Bragança, Portugal

UNIAG - Applied Management Research Unit, Bragança, Portugal



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Environmentalism, among other contemporary sectors, must capture the innovation of large corporations and government agencies and disseminate it to all social groups, creating conditions for the establishment of plural and efficient environments. Technological innovation may be the solution; the logic of risk and precaution cannot prevent constant experimentation and the search for technological efficiency, as long as they are combined with the imperatives of democracy and sustainability.

Despite the fact that technology is increasingly present in our daily lives, it is even used to manage large urban centers. In this sense, the concept of smart cities has become popular, which can be defined as systems of individuals that interact and use energy, services, materials, and financing in order to promote quality of life.

The interactions that occur between citizens and the technology used in cities are considered intelligent because they are strategically used in the advances in infrastructure and services from information and communication technologies, which is made possible through urban management planning, which purpose is increasing the efficiency of local operations, in order to meet the needs of the city.

In this sense, the massive use of mobile devices, together with the growing worldwide adoption of social media sites by its users, allowing them to be connected, and share data, anytime and anywhere, leads us to the concept of participative sensing. In this context users act as voluntarily sensors, capturing and providing data of their day-to-day life. The huge volume of social data available can be used to support the decision-making processes of different entities.

This chapter aims to discuss the research challenges, opportunities, and concerns in the field of participative sensing, using participative sensing networks that provide the data, which have a very comprehensive scale and can be easier to obtain than other sources, as they rely on the collaboration of users in data collection, presenting an overview of different applications, like the case of healthcare in the context of urban environment that allow a more sustainable environmental management.

## 19.2 Remote Sensing

Remote sensing (RS) can be defined in a simple way as the technique of obtaining data about an object without touching it. In this sense, the definition will include satellites, airplanes, and weather radars, because they all capture information from a specific target, without any contact between them [1].

In more detail, we can define remote sensing as the set of techniques and technological procedures that aim at the representation and collection of data from the Earth's surface without the need for direct contact [2]. Therefore, all information is obtained through sensors and instruments in general. Such process is linked to the treatment, storage, and analysis of such data in order to better understand the phenomena that appear on the surface [3].

The use of this type of technique is of fundamental importance in the current context of societies, as it is capable of revealing many geographical and even historical data concerning urban, social, and natural spaces.

In the past, remote sensing was performed based on data from cameras, dependent on the existence of photographic films [4]. Around the middle of the twentieth century, with the advent of artificial satellites, sensor technology was developed, which did not depend on photographic films and could have a greater number of spectral bands [5].

While the technology of cameras can be called panchromatic, the technology of sensors corresponds to multispectral [6]. In the mid-1980s, an evolution of multispectral technology emerged, enabling imagers that could obtain images in hundreds of narrow bands, the so-called hyperspectral sensors [7].

Currently, technological advances already allow us to foresee the next advance in the area of sensors, which will be called ultra-spectral and will be able to collect data in thousands of spectral bands.

## 19.3 Urban Sensing

The sensing architecture in smart cities is divided into seven areas: smart surveillance, smart electricity and water distribution, smart buildings, smart healthcare, smart services, smart transportation, and smart infrastructures (see Fig. 19.1) [8].

Smart surveillance is comprised of monitoring and security technologies, mainly through camera systems. Smart surveillance applications can assist in the detection of violent actions and also in the identification of the people involved. The sensing in this area allows to contribute in the aid of the monitoring and security with the objective of assisting in supposed investigations that involve violent actions [9]. Therefore, sensing in smart cities in this area is extremely important.

Advanced sensing applications for smart electricity and water distribution allow for more accurate measurement and prediction compared to traditional techniques.

In smart buildings, sensing techniques are developed to help reduce resource consumption. Sensing plays a fundamental role in this task, and for that it is necessary to accurately assess current consumption.

In the case of smart healthcare, all technologies that assist management in hospitals or clinics are considered. Sensing in the smart healthcare area uses technologies that assist in hospital management through remote monitoring, in order to detect problems that can compromise the health of a patient in real time, through sensors interconnected in different parts of the body. In this area, we highlight the wireless body area networks, which consist of interconnected sensors located in different parts of the body. These sensor networks allow remote monitoring of the patient's vital signs, as well as the storage and transmission of information in real time [10].


**Fig. 19.1** Sensing in smart city

Technologies are used in smart services. The sensing in this area can be applied to several services, for example, it can be applied in the detection of fires, since any signal emitted by the sensor can activate the devices, thus allowing rescue teams to be present to fight fires and enabling improvements in the service provided.

In smart transportation, technologies for monitoring and managing vehicle traffic in the smart transport area are addressed. Applications such as GPS navigation systems allow drivers to choose more efficient routes to get around the city, thereby reducing travel time to destination and traffic in major cities [11].

In the smart infrastructure area, technologies for sensing are used in public infrastructures such as buildings, bridges, and roads, thus allowing, based on the data collected, a more efficient maintenance and use of resources.

## 19.4 Participative Sensing

The sensing carried out through mobile devices causes costs to obtain data from large areas to be mitigated, as it would be much more costly to manually deploy a large number of sensors to cover them. Systems that use data from this type of sensing are called participative sensing.

Users are the central element of a participative sensing network (PSN), sensing their daily environment. In this context, people participate as social sensors, voluntarily providing data about a certain aspect of a location that implicitly captures their daily life experiences, with the help of sensing devices, such as sensors incorporated in smartphones accelerometer, barometer, gyroscope, GPS, pedometer, iris and fingerprint reader, magnetometer, light sensor, proximity sensor, heart rate sensor.

The urban population has been growing in recent years. The increase in population density in large urban centers and the aging of the population brought the need to allocate resources, such as health, energy, transport, security, and economy, in a more efficient way.

Cities are crucial to a region's socioeconomic development. The term smart city refers to the use of information and communication technologies for this purpose. Thus, through the participatory sensing paradigm, which combines information and communication technologies and smartphone users, it is possible to understand characteristics of the dynamics of a city and the urgencies of the citizens who live in it.

Participatory sensing in smart cities allows participants to send event records about the city, through a smartphone application. These events can be related to health, safety, infrastructure, and city mobility, among others.

### *19.4.1 Smart City Participative Sensing*

The participation of the population is important for smart city solutions. Some of the services need users to monitor the urban environment, the case of the participative sensing services [12]. These services can be exchanging photos and comments with other users or with the responsible entities. Participatory sensing collects data from the environment and makes it possible to obtain relevant information from society, analyzing the data collected with appropriate techniques.

Participative sensing is a distributed process of collecting personal data and covering different aspects of the city [13]. For this, participation of activated people is necessary to voluntarily share the detected data and contextual information; in other words the user manually determines how, when, what, and where to sample. Thus, through participative sensing, it is possible to monitor aspects of the city, and also the collective behavior in real time, of people connected to the Internet. Participative sensing is also known as urban sensing.

Another concept that can be related to participative sensing is that of collective intelligence, starting from the principle that nobody knows everything, but everyone knows something.

The functionality of the systems that use it derives from the decomposition of a problem by specialists and the integration of solutions provided by ordinary people. The diversity of people and independence between them can cause results for several problems to be found more optimally than by an expert.

In participative sensing, several people collect data that will be used by researchers or companies that will carry out the desired analyses.

To better characterize the data collected through participative sensing, it is necessary to know who (the data has an associated user), what (the sensed values), when (date and time of the data collected), and where (spatial coordinate of the location). The data can be structured or not. Structured data has a value that already presents relevant information, while unstructured data has a set of values that generate information. This information can be shared voluntarily or not, by sending it to one or more servers, thus making it accessible to other users. Information shared by the same user can be used by others in whole or in part [8].

### *19.4.2 Participative Sensing Systems*

Systems that use data from this form of sensing are called participative sensing systems (PSS). The data in a PSS is not restricted to that obtained by devices, but derivatives of human sensors are also included, like sight, taste, hearing, touch, and smell. PSS with these characteristics can be termed as ubiquitous crowdsourcing sources in which data is obtained by various users, manually or automatically, from any location, with the aim, for example, of being used to offer services to citizens [14]. That integration of technology into people's habits refers to the ubiquitous computing.

Another concept related to PSS is that of collective intelligence, based on the fact that nobody knows everything, but everyone knows something [15]. The functionality of the systems that use it derives from the decomposition of a problem by specialists and the integration of solutions provided by ordinary people.

The diversity of people and independence between them can allow results for different problems to be found more optimally than by an expert. This is how PSS works: several people collect data that will be used by researchers or companies that will carry out the desired analyses.

The PSS can be analyzed together in a model called layers, where each PSS is a layer, that is, each represents a system with its activities of collection, processing, and distribution of data. Since mobile devices can contain multiple PSS, a node can be in several layers simultaneously. When the layers are unified, they form a work plan that can bring useful information to users.

Although they are already part of people's daily lives, assisting them in several aspects, the PSS present several challenges. The PSS are dependent on the people who carry their devices for data to be provided; it is necessary promote the incentive to participation, to establish policies that aim to keep collaboration at a minimum, acceptable level in order to maintain the functionality of the system [3].

Ensuring quality is another challenge. In addition to the amount of data, it is necessary that they represent the veracity of the monitored items, in order that the participants are obtaining realistic data. Maintaining data quality, that is, when they conflict with reality, is also a concern in participatory sensing. If inconsistent values are transmitted, the reliability of the system is affected.

Users' private information must be preserved; only sensed data should be available to participants [4]. The participant's privacy information must be prevented from leaking.

### *19.4.3 Participative Sensing Networks*

Participative sensing networks offer unprecedented opportunities for accessing large-scale sensing data. This large amount of data facilitates obtaining information that is not readily available with the same practically global scope and can be used to improve the decision-making processes of different entities, from the people level to the groups, organizations, services, and even applications [16].

The central element of a participative sensing network are the users capable of sensing the city using their smart devices and collaborating as sensors as social sensors in a voluntarily way, collecting and providing data about a certain aspect of a location, which captures daily life experiences. This data can be obtained with the help of sensors incorporated in smartphones or other smart devices, such as the case of GPS, accelerometer, gyroscope, and microphone, among others.

Sensing by mobile devices allows sensing data to be collected through the sensors of smartphones and other mobile devices. More and more of these devices are becoming the main computing device in people's lives, and this further increases their potential for sensing applications.

Sensing applications can be classified into three categories: personal sensing, group sensing, and community sensing. Personal sensing applications are designed for a single individual and are focused on data collection and analysis. Personal sensing applications generate data for the sole and exclusive benefit of the user who collected it and are not shared with any other user. Group sensing applications are designed for a group of individuals to share sensing data freely or with privacy protection in order to achieve a common goal. In the case of community sensing, they use applications, which represent large-scale data collection, analysis, and sharing for the common good of a community. This type of application implies the cooperation of people who do not necessarily have a trusting relationship with each other and consequently requires a higher degree of privacy protection as well as a low level of commitment from users.

## 19.5 Healthcare Participative Sensing

Participative sensing helps people to optimize their health. In 2019, 38.2 million children under the age of 5 years were overweight or obese [17]. Analyzing the worldwide distribution by age, 38.9% of adults are overweight, in the adolescents 17.3%, and in children 26.5% (preschool age 5.9% and school age 20.6%).

There are several factors contributing to this condition, such as poor-quality sleep, stress, inadequate nutrition, and lack of physical activity, among others (Fig. 19.2).

Mobile health (mHealth) is a subdivision of eHealth and refers to tools and practices performed on mobile, wireless devices that emerged not only to facilitate the patient's life, helping to monitor treatments and patients' vital signs and medication consumption, but also to optimize healthcare services.

The spread of the mobile Internet has contributed to new possibilities for transmitting information, transforming the patient-health professional relationship and allowing the exchange of diagnostic parameters remotely and in real time.

The possibility of obtaining information on clinical data in a reliable way, available at any time and place, and designing customized therapeutic interventions has changed the ways in which some health services are offered [21]. Mobile health opens new perspectives for the collection of environmental, biological, behavioral, and emotional data, including patient monitoring and therapeutic interventions.

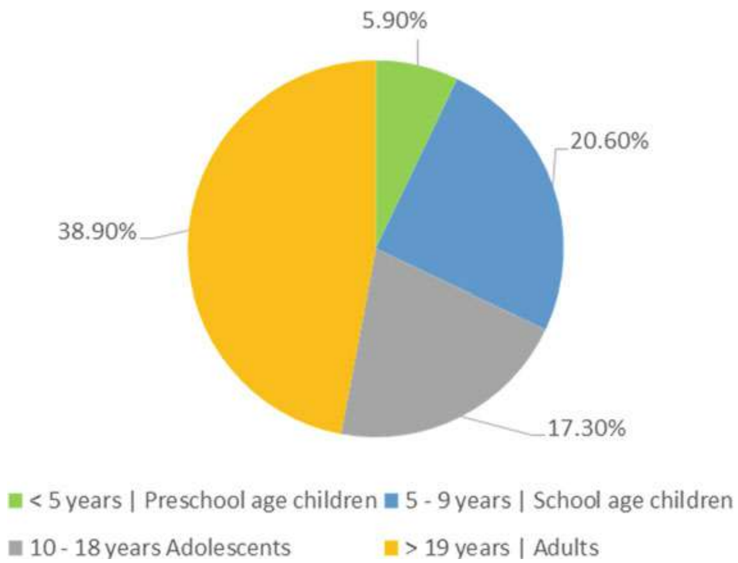


**Fig. 19.2** Year 2019 people with overweight worldwide. (Adapted from [18])

mHealth creates conditions for the continuous assessment of health parameters, sets up a new scenario to encourage healthy behaviors, and assists self-management of chronic conditions, among other aspects of application.

Monitoring patients' behavior and analyzing health conditions can help in the development of services for recommending physical activities and remote diagnosis [19]. Monitoring service at distance, such monitoring variables as blood pressure, heart rate and blood sugar levels, acting if the sensors report readings of limits close to the abnormal limits [20].

The fast explosion of personal eHealth, premising self-management and data collection of health conditions, is changing the way to deliver and collect healthcare information.

Organizations have already identified and started working on projects to address issues related to security, scalability, data collection, and interoperability [21].

Although the mobile devices make our lives easier and allow a constant connection to the world around us, they carry some security risks. Computer threats to mobile devices, especially smartphones, have become very common, and attack strategies are increasingly effective. More and more vulnerabilities have emerged, taken advantage of by malware installation schemes, which not only corrupt devices but also result in data and money losses.

Fraud can take many forms, and some types of fraud are perpetrated through mobile devices. Fraud involves social engineering, services, and spam, which leads the victim to reveal confidential information, both personal data and the services they consume, without realizing that they have compromised their own security.

It is important to highlight that, whatever the security solution adopted, regardless of the devices used, people remain the most vulnerable element, due to behaviors and psychological traits that can make them susceptible to social engineering attacks. The path to invasion can be in very common situations, such as the desire to be useful, the search for new friends, and persuasion.

Social engineering, in the context of information technology, refers to techniques for manipulating people in order to overcome security barriers. They are ways of obtaining information in which the target rarely realizes this type of action. Among the most used forms, we have phishing, SMiShing, QRishing, and vishing [23].

Phishing is the most used technique in social engineering; the objective is to steal private information: user authentication data, bank details, sensitive information, and social network data, among others. This technique can also be used to install malicious software on the target equipment. For this, the attacker pretends to be a trusted person or entity and tries to persuade the victim. The attack uses emails and messages via social networks as its main vehicle, requesting some urgent action, so when continuing the process, the victim is directed to a phishing site, which looks familiar, or downloads an attachment with malicious content [23, 24].

In 2020, the country with the most users attacked by phishing was Mongolia with 15.54%, followed by Israel with 15.24, France with 12.54%, and the last place in the top 10 which is Ecuador with 9.52% (Fig. 19.3). Analyzing by continent, the majority of attacks occurred on the Asian continent, with Africa being the least

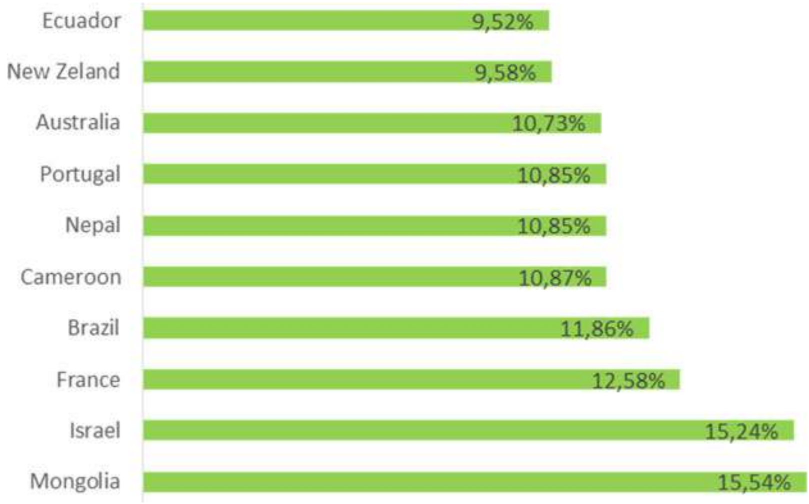


**Fig. 19.3** 2020 countries most targeted by phishing ([25])

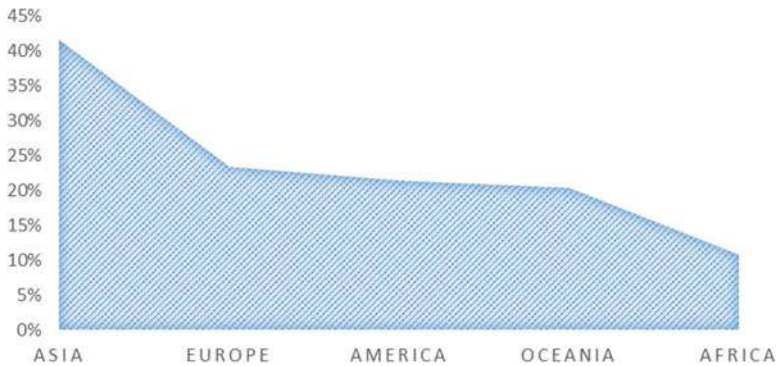


**Fig. 19.4** 2020 phishing impact of phishing attacks

affected the continent. The difference between the other continents is not relevant (Fig. 19.4).

In the case of SMiShing, this approach is carried out by sending SMS messages or other messaging applications for smartphones, usually containing a link that directs the victim to a form, requesting some answers that may vary, such as updating a registration and redemption of premiums, among others. This technique has as main objective the collection of personal information such as credit card data, bank access passwords, access credentials to social networks, and e-mail events.

QRishing is another approach through QR codes that are very present in our daily lives; through a reader we can access a wide range of information and services. The problem being that the maliciously modified QR code appears in public places where legitimate codes normally exist. When the QR code is scanned, you are redirected to a fake website that puts the user's safety at risk.

Vishing is defined as the practice of obtaining information or trying to influence actions over the phone. The purpose of this method is to obtain valuable data that can contribute to the direct commitment of an organization or individual, exploring people's willingness to help. During a vishing attack, the attacker impersonates someone who can build a bond of trust with the victim, such as a customer service or support employee [23, 25].

Social engineering is a field of study of greater relevance in that all people and organizations have data, information, and knowledge that should not or cannot be shared and that, in a totally digital world, specific care is increasingly needed to keep data private.

Privacy is another problem, since most mobile applications have access to huge amount of data and store it in the cloud.

The use of healthcare participative sensing for delivery of healthcare to citizens raises new challenges at security and privacy levels.

There are still a lot of confusion about the legal status of the data collected from mobile devices, and it's not clear the level of authority that agencies have over the smart devices of citizens and organizations.

The European Union has established laws and guarantees of personal privacy that affect data collected or transmitted to devices based in Europe, which has created some stir, since the laws must affect transactional negotiations with non-European countries [22].

In the case of the United States, the Federal Trade Commission is providing information and supply to the users with doubts and questions about mobile data practices.

## 19.6 Conclusion

The ubiquity of modern technologies allows for constant monitoring of the daily activities of citizens, making communication technologies the bridge between the real world and the virtual world, by promoting digital interactions and transactions.

Sensing applications for smart healthcare area use technologies that assist in hospital management through remote monitoring, in order to detect problems that can compromise the health of a patient in real time, through sensors interconnected in different parts of the body. Then the sensor networks allow remote monitoring of the patient's vital signs, as well as the storage and transmission of information in real time.

Data, and the exchange of sensitive information between people, between objects and between people and objects in wireless medical sensor networks make data security a priority issue. Communications must be protected, guaranteeing authentication, access control, confidentiality, integrity, availability, and irreversibility.

Although the wireless sensor network devices facilitate the control and monitoring of functions and devices, inevitably they can also cause the vulnerability of devices and network [23]. These devices handle highly personal health data, some of which have life support functions; security attacks on connected health devices can put the patient at risk for life.

The privacy and security of health information is a particularly delicate matter; it is essential to keep people's data safe. Constant innovation in this area is critical for eHealth systems to remain relevant. Data security and the adoption of secure privacy measures will evolve along with intelligent healthcare systems.

The new perspectives for the provision of health services and the popularization of these mobile devices can contribute to the reduction of health expenditures, minimization of medical errors, prevention of unnecessary hospitalizations, and expansion of the possibilities for interaction between patients and health professionals.

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# Chapter 20
# Novel Heuristic Scheme to Enforce Safety and Confidentiality Using Feature-Based Encryption in Multi-cloud Environment (MCE)

**N. Thillaiarasu, S. Chenthur Pandian, and Naveenbalaji Gowthaman**

## 20.1 Introduction

Cloud computing is commonly described as the calculations performed in the cloud which consist of a set of network permitted services. Cloud computing has several features such as the expansion of cloud, quality of service (QoS) assurance, and mostly customizable and low-cost evaluation platforms. Simply, cloud computing is referred to as the aggregation of many technologies, a platform that offers hosting and storage as a service over the Internet.

The main objective of cloud computing is to provide expandable and cheap on-demand computation service structures with improved levels of service without sacrificing the standards [36]. Proving these features to the end-users might introduce a wide range of issues to the cloud computing system. Hence, this work intends to address these possible threats prevailing within the cloud computing environment and to provide an optimal solution for the same.

N. Thillaiarasu
School of Computing and Information Technology, Reva University, Bengaluru, Karnataka, India

S. C. Pandian
SNS College of Technology, Coimbatore, India

N. Gowthaman (✉)
University of KwaZulu-Natal, Durban, South Africa



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## 20.2 Background

The main aim of this work is to provide security, secrecy, and also confidentiality to the users of the cloud services with a reduced time of operation and lower estimation cost. Cloud computing plays a major role in organizing the data of the end-user with added features such as increased security and advanced confidentiality. In the olden days, third-party auditor is used to providing safety in cloud-based online services [1]. This technique also provides the end-user with the secrecy of data storage. An unauthorized user cannot access data from the cloud storage. After cloud computing came into existence, it has some difficulty in implementing security on a larger scale. Hence, users needed a multi-cloud architecture, so that they can access their data from anywhere using the Internet [25]. This also provides the end-user with integrity in accessing the information from the servers.

The main focus of the scheme of secure public verification is to make the cloud immune to vulnerable attacks. After several stages of verification, the user data is encrypted and stored in the data server to ensure additional security [18]. After a couple of years, cryptography came into existence in the cloud computing regime. The intention is to wrap the general safety and confidentiality risks for the subcontracted information and related fresh methods and schemes with their proposed varieties related to safety, confidentiality, features, and behavior [29]. The target of BYOD schemes is to offer a basis for designing the concept of safeguarding privacy using BYOD and entails the crucial technical and firm-related disputes faced by BYOD firms [37].

In the design of semantically stranded information segmentation, it is probable to mechanically identify the segments of information that might create threats related to confidentiality and segment them in the local environments [11]. Therefore the segmentation scheme minimizes the missing information and offers the safety of information stored in the cloud. The segmentation schemes also provide advanced confidentiality to vulnerable attacks over the cloud by unauthorized access. Even if the cloud gets attacked, the unauthorized person will not get the full information by attacking a certain node of the cloud [12]. The intention of secured cloud computing transactions is initially based on aggregating official frameworks and virtualization to demonstrate safeguarding privacy during the process of relocation. This is done by resource distribution in the cloud to the end-user [10]. All the diversified cloud servers are subjected to multiparty estimation of data. The safety of cloud services can be increased by using safe multiparty estimation on online-based services. The user information always uses multiparty estimation techniques to allow data encryption and some likelihood services. These types of services often lack to maintain the secret of the users' data.

Online-based services are always known to the third party which in turn the user lacks secrecy to maintain a particular data. The first objective of this work is to assess the prerequisites of general privacy issues in a framework that focuses on providing priorities in preserving the confidential data of the users [18]. This framework mainly involves the storage of data in the cloud repositories. The technological advancement of this domain may create a situation for the end-users to lose the influence of their data over to the repositories [6]. Hence, the aim is to be modified in such a way that it fulfills the long-term needs of cloud user and their requirements. And, also it should provide valuable data stored within the system with limitless features.

## 20.3 The Goal of the Novel Scheme

The end-users always submit their valuable data to the cloud after accepting all the terms and conditions of the cloud provider. Roughly 10% of the cloud users are indeed aware of the real situation that their confidential data are vulnerable. Though there are several advantages in implementing cloud counting, there also exist serious issues in terms of privacy. The advantages of cloud computing are cost cut-downs, expansion, and accessibility from anywhere [36]. Privacy issues occur due to missing control over the stored information and administration of outsourced data. Hence many users avoid storage of their private data in the cloud environment.

The design of the diversified confidentiality data safeguarding technique is implemented using the pre-planned encoding of outsourced information. The data encoding provides advanced safety but lacks to cut down cost feature of the cloud; this, in turn, affects the effectiveness of the services rendered and restrictions in some features through encoding the data [10]. Since effectiveness and features are significant merits of cloud computing, particularly in cloud-based services, it is essential to design a novel confidentiality safeguarding scheme. This scheme is dependent on dividing the information, and also it is based on the scattered storage provided by the progressively standard schemes of multi-clouds. Precisely, the main objective of this work is to design a semantic-based information segmentation that is capable of identifying information chunks that might create a malfunction in the cloud [9]. The segmentation divides the information from the restricted rules so that every segment does not face any possible threats.

Each error-free information segment is stored into individual positions of a multi-cloud, so no peripheral objects can gain access to the comprehensive private information. It is to be noted that the fractional information is stored in vibrant cloud environments [7]. The outsourced uniqueness in data is effectively aided by distributing the requests to several cloud positions.

## 20.4 The Extent of the Feature-Based (FB) Scheme

Many cloud frameworks are set off, and their safety, confidentiality, and probabilities are discussed. Feature-based encryption is offered to the information of the cloud users. It is mandatory to focus on the cloud malfunctions which prevent the loss of information. These schemes offer elevated confidentiality and a twofold safety mechanism to the users. This novel scheme is intended to address the issues related to safety and confidentiality in cloud computing, and it is evident the designed scheme offers better performance as compared to the prevailing conventional schemes.

### 20.4.1 Foreword of the FB Scheme

Presently, the utilization of cloud-based services faces diverse disputes related to safety such as the intrusion of confidential information or exploitation of information by unauthorized personnel. There are various studies carried out for addressing these issues. As a result, the multi-cloud framework serves as an optimal solution. Based on the multi-cloud framework, it is possible to split the information into diverse varieties and stockpile them into diverse clouds [3]. In case if any service provider of the cloud or any unauthorized user desires to gain access to the information, they cannot gain access to the entire information since a diverse variety of information is stockpiled into diverse clouds. The usage of cryptography-based schemes recovers the information and collects the information onto the cloud [13].

The intention is to minimize the threats prevailing in information and the applications in the public cloud which synchronously makes use of diverse clouds. Diverse schemes utilizing these patterns are designed for experimentation [15, 38]. They fluctuate in separation and scattering models, cryptographic schemes, and flooded schemes along with the safety levels. The designed multi-cloud frameworks permit the classification of the prevailing methods and to estimate them based on safety [4, 5]. The evaluation of diverse schemes in terms of authorized features and observance inferences is offered. The goal is to split the information into diverse varieties and store them into diverse clouds to acquire safety. For achieving much more information safety to the information of cloud users, encryption and decryption are performed using advanced cryptographic schemes.

### 20.4.2 Development of Confidentiality Scheme

Presently, the employment of cloud-based services faces diverse disputes such as the intrusion of confidential information or the exploitation of information by an unauthorized individual. Diverse analysis actions are attempted to address these issues. Based on these actions, multi-cloud frameworks serve as a solution. The multi-cloud framework splits the information into diverse varieties and stockpiled it into two diverse cloud systems [5, 23]. The service provider of the cloud or an unauthorized user desires to attain the information, but he could not gain the entire information because diverse varieties of information are hoarded onto diverse cloud systems. The cryptographic schemes are used for recovering the information and hoard the information on to the cloud. In conventional schemes, there are no possible solutions for faults within the cloud system, and there are diverse likelihoods for data losses due to faults within the cloud system [14, 32].

Cloud computing generates a huge number of safety-related problems and disputes. These problems range from the necessary beliefs – from the provider of the cloud system on the cloud interface for exploiting the cloud service-based assaults on other systems [35, 37]. The chief issue with the cloud computing model is that it holds safe outsourcing of susceptible as well as business significant information and processes. With the cloud-based services, the users must be conscious of all the information hoarded into the cloud, and the service provider must leave behind its control and safety. Moreover based on the setup of information processing to the cloud, the service provider of the cloud system acquires the fullest control on these processes [26, 34].

Therefore a tough association among the provider of cloud and cloud end-user is believed as a common requirement in cloud computing services. The initiative to minimize the threats in information and application in public clouds is the immediate procedure of diverse clouds [2, 28]. Diverse approaches utilizing these models are designed presently. They fluctuate in the contributing and allocation model along with the schemes, cryptographic techniques, and the besieged condition as well as safety levels. It is an expansion and encloses an analysis of diverse safety and multi-cloud implementation schemes.

## 20.5 Problems Concerning Cloud Safety

Cloud computing offers a huge sort of safety-related disputes and problems. The threats in cloud computing remain a great dispute in the cloud framework because they introduce safety-related issues into the system. The problems range from the necessary faiths by the provider of the cloud computing and assaults on the cloud systems because the intruder might exploit the cloud services intended for the users. The major issues are that the cloud computing pattern completely holds safe outsourcing of susceptible as well as vital information and processes. For employing cloud-based services, the user must be conscious of the information that all the data stored by the provider of the cloud depart their control and defense. For organizing data operation applications, the service provider of the cloud gains the fullest control over these processes [19, 22].

A tough accurate association exists between the provider of the cloud and the users of the cloud, and it is deemed as a common precondition in cloud computing. Based on the assaults in cloud computing, the cloud computing model holds an unspoken danger within a negotiated cloud system [24]. In case an intruder is capable of educating the cloud system by itself, all the information and processes of all the users working on that cloud system might focus on the malevolent acts in a mass manner.

Therefore the cloud computing scheme needs an in-depth review of the type of safety obligation concerned by the misuse events. Normally the hosting of the single cloud provider and processing all its information allow instant intrusion in terms of accessibility, truthfulness, and privacy of the information, and the processes are despoiled along with added malevolent accomplishment acts that might be carried out in terms of uniqueness of the cloud users. These cloud safety problems and disputes activate diverse analysis actions, thus resulting in diverse design schemes with the intention of diverse cloud-related safety risks. Based on these safety problems, the cloud model emerges with a fresh collection of exclusive aspects that discloses a pathway to the new safety methods, schemes, and frameworks.

### *20.5.1 Multi-cloud Framework*

The fundamental intention is to employ multiple different clouds to disappear or to trounce the threats of managing malevolent information and disturbances in operation. By incorporating diverse different clouds, a belief supposition could be pre-assumed as non-mutual providers of cloud services [21, 25]. With the help of a multi-cloud framework, it is possible to improve the safety and confidentiality against outside intruders to recover or harm the hoarded information of the application of a specific cloud user. Diverse safety-related schemes and techniques are implemented for addressing these problems in cloud computing. Over multi-cloud, the cryptographic scheme like encryption and decryption along with key administration is employed. Repository separation is another crucial safety method employed in multi-clouds. The below stated are the key components of the multi-cloud framework [11, 20].

### *20.5.2 Duplication of Applications*

The application duplications permit acquiring diverse outcomes from one process carried out in different clouds and evaluated against them with their hypothesis. This permits the users to gain confirmation on the confidentiality of the outcomes. Rather than implementing a specific application on one particular cloud, a similar process is implemented by different clouds. By comparing the acquired outcomes, the users of the cloud gain confirmation regarding the confidentiality of the outcomes [27]. Here, the necessary belief toward the provider of the cloud service is minimized vividly. Rather than believing in one service provider completely, the user of the clouds requires depending on the supposition which the cloud services do not team up nastily against.

### *20.5.3 Separation of Application System into Layers*

The separation of the application system into layers permits splitting the reason from the information. This offers supplementary safety against the information outflows due to the application logic. The framework initiated addresses the threats of the unneeded information outflows. The multi-cloud framework improves and imposes schemes to overcome the faults in the application logic that does not influence the user information [33].

### *20.5.4 Separation of Application into Pieces*

The separation of the application into pieces permits the allocation of applications to different clouds. It holds two advantages. Initially, no providers of the cloud discover the overall application. Subsequently, no cloud provider discovers the entire estimated outcomes of the application [20, 30]. Thus it directs to information and application discretion. None of the concerned providers of the cloud gains access to the entire multi-cloud framework to improve the safety regarding information privacy.

## 20.6 Novel Feature-Based Encryption

Based on the evaluation of the diverse works of different scholars on the assaults of cloud systems, the cloud computing model holds inherent risks in operating in a negotiated cloud system. In case an intruder is capable of accessing all the information and all the operation, the users working on the cloud system might become susceptible to malevolent acts in a mass way. Therefore the cloud computing model needs a full-fledged review on the safety-related necessities. More commonly for a single provider of cloud hosting and processing, all the information of the users must be safe from safety risks in terms of availability, confidentiality, and discretion of information, and the operation might become disobeyed, and added malevolent acts might be carried out in terms of the uniqueness of the cloud users [30, 31].

The cloud safety problems and disputes activate diverse estimation, thus offering diverse designs addressing diverse cloud-related safety risks. The safety challenges of the cloud model emerge with a fresh collection of independent aspects which reveals a pathway for fresh safety-related aspects, methods, and frameworks. The intention is to design confidentiality and safety for the users of the cloud with minimal calculation and reduced time [30, 34, 35]. Based on the usage of a multi-cloud framework, two-layered encryption and decryption are designed which offer twofold safety for the information of cloud users. The conventional scheme does not provide a solution for the crash in the cloud system, and there are likelihoods for equalizing data loss due to faults in the cloud system. It must be addressed for overcoming the data losses.

### *20.6.1 Method of Structuring the Cloud Environment*

The intention (as shown in Fig. 20.1) is to minimize the threats to information and the applications over a public cloud due to the concurrent utilization of diverse clouds. Diverse schemes making use of these methods are designed which are different in terms of separation and allocation models, schemes, cryptography-based techniques, and besieged conditions without compromising the levels of safety. The design scheme focused on the diverse schemes designed by diverse scholars in terms of safety by the multi-cloud implementation schemes. This designed multi-cloud framework permits the classification of prevailing techniques and to estimate the lawful features and fulfillment [14, 28, 34].

The design of confidentiality and safety to the cloud users with minimal processing costs and reduced time offers better performance. The utilization of the multi-cloud framework with twofold encryption and decryption methods offers extended levels of safety to the users of the cloud. Feature-based encryption is employed to offer safety to the information of cloud users. In the conventional scheme, there are no possible addressing schemes prevailing, and there are likelihoods to avoid loss of information [12]. This scheme offers elevated confidentiality and twofold safety to the users. The features of the schemes are entailed as below.

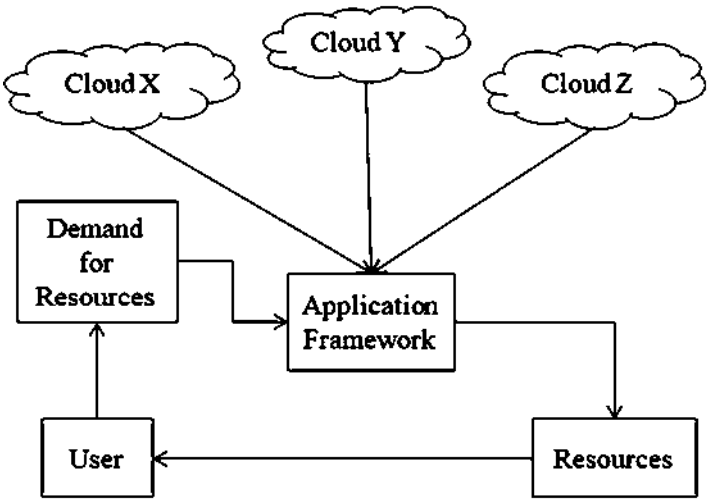


**Fig. 20.1** Mechanism of the feature-based cloud environment

### *20.6.2 Cloud Scheme*

Elevated progress in the cloud with intricate schemes are considered based on the communication routines namely the Byzantine concurrence standard. In this standard, it has been considered that the presence of "Cn" cloud service providers where "m" work together spitefully against the users of the cloud where "Cn" is higher than "m." Here each "Cn" cloud carries out the execution of the process by the user of the cloud. The service providers of the cloud execute a scattered algorithm that addressed the common byzantine concurrency issues [10]. Based on which it is assured that all the non-vulnerable service providers of the cloud know the accurate outcomes of the estimation.

Therefore the conclusion is that the outcomes are transmitted to the users of the cloud through safe transmission. Therefore the user of the cloud could decide about the precise outcomes during the existence of "m" vulnerable clouds.

#### 20.6.2.1 Feasibility

Rather than holding cloud X and Y to carry out similar appeals, another feasible scheme contains having one service provider observe the implementation of another service provider of the cloud. For consideration cloud X might proclaim in-between outcomes of its execution to an observation process implementing at cloud Y. In this manner, cloud Y could confirm that cloud X makes development and joins with the estimation planned by the user of the cloud. Additionally, along with this scheme, the cloud Y might execute the scheme verifier services which attempt the implementation routes chosen by cloud X on Y permitting for rapid identification of abnormalities.

### *20.6.3 Information Separation by Cryptography*

The most fundamental cryptography scheme stockpiled the information safely in encrypted form. The cryptography key can stay with the knowledge of the users to escalate the usage in processing cloud information or to facilitate diverse user systems which is profited to have the key obtainable online during necessities [1, 16]. The scheme transmits the key substance and encrypted information into diverse clouds. An identical scheme is chosen based on diverse solutions for safe cloud hosting.

The remaining scheme of cryptography-based cloud storage is a possible manner for encrypting key or the value in the cloud while preserving the capabilities to effortlessly gain access to the information. It entails obtainable encryption as the key part to accomplish the requirement. The obtainable encryption permits the investigation of the encrypted information in case an approved token for the keyword is offered. The key is hoarded in a reliance confidential cloud, while the information remains in non-belief public cloud.

#### 20.6.3.1 Repository System

To safeguard the data prevailing inside the repositories, it is necessary to differentiate safety objectives in terms of privacy of information present within the repository and secrecy of the associations between them. The information separation needs a condition identical to other schemes with a minimum of one belief contributor [9, 21]. Therefore, mostly only the associations will be safeguarded, and these could be accomplished based on belief and interested service providers. In perpendicular separation, the information is scattered to the providers of the cloud in a way that no single provider establishes a secure association by themselves.

For instance, insurance documentation can be separated into two segments. A sole provider only studies to non-decisive information associations. Hence these preliminary applications are unimportant and separate. Initially, fresh associations can be offered by executing transitive assimilation of the prevailing, and subsequently, diverse associations could be finished employing exterior information. In the above case, the provider moreover discovers the associations strictly do not hold any information regarding the type of insurance [7, 16]. Hence, the individual with insurance knowledge could obtain information from the records.

Moreover, fresh associations could also be consequent by an aggregating diverse collection of information. For example, the usage of association with the aggregated insurance results in the retrieval of the individual's insurance record. In low levels, database separation is needed and is called parallel separation.

Lastly, the repository separation could also be aggregated with the help of encryption employing a key administration scheme along with encrypting database columns. The aggregation of encryption and separation safeguards secret columns and permits inquiring the repository entry using simple text columns [2, 22].

## 20.7 Examination of FB Scheme

The designed scheme is tested based on the implementation of security and confidentiality over the cloud system. The estimation is performed on a machine with a dual CPU running at the rate of 1.46 GHz and the encrypted set of files over the viable public cloud services such as simple cloud storage. The analysis is accomplished in terms of creation time, directory storage space, time of locating, and safety assessment.

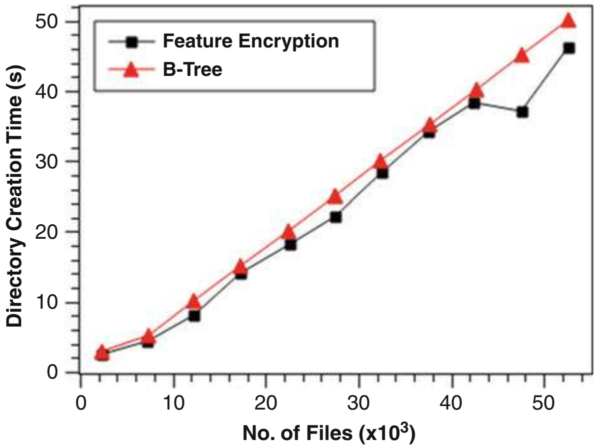


**Fig. 20.2** Time for creation of directory under the cloud environment based on feature extraction

### *20.7.1 Time of Creation*

Figure 20.2 depicts the difficulty involved in time for creating the directory which is directly proportional to the number of information files. The creation of an index is accomplished before the subcontracting of information into the cloud; this process could be overlooked. During the creation of the directory, the encoding of the files is a supplementary process. The conventional B-Tree scheme requires 13.03 seconds to create the directory for 10000 files, while the designed scheme requires only 12.98 seconds to accomplish a similar process on the identical set of information files. Likewise for 20000 files, the B-Tree needs 30.21 seconds, and the designed scheme needs only 28.51 seconds. The evaluated schemes increase sequentially with the increasing count of files, and it is evident that the time of the creation for the designed scheme is more effective than the B-Tree [17].

### *20.7.2 Directory Storage Space*

The directory files employ a minimal volume of storage space evaluated against the conventional scheme. Information security is crucial instead of the storage space of the directory. Figure 20.3a depicts the capacity of the directory hierarchies for both schemes. The expenses for storing 10000 files in B-Tree scheme are 8 MB, while the designed scheme expenses are 6.44 MB. The B-Tree scheme for 20000 file expenses 15.33 MB, whereas the designed scheme needs 12.45 MB for the directory files. An elaborate analysis reveals that the designed scheme needs only minimal space for storing the directory terms as evaluated against the B-Tree schemes [17].

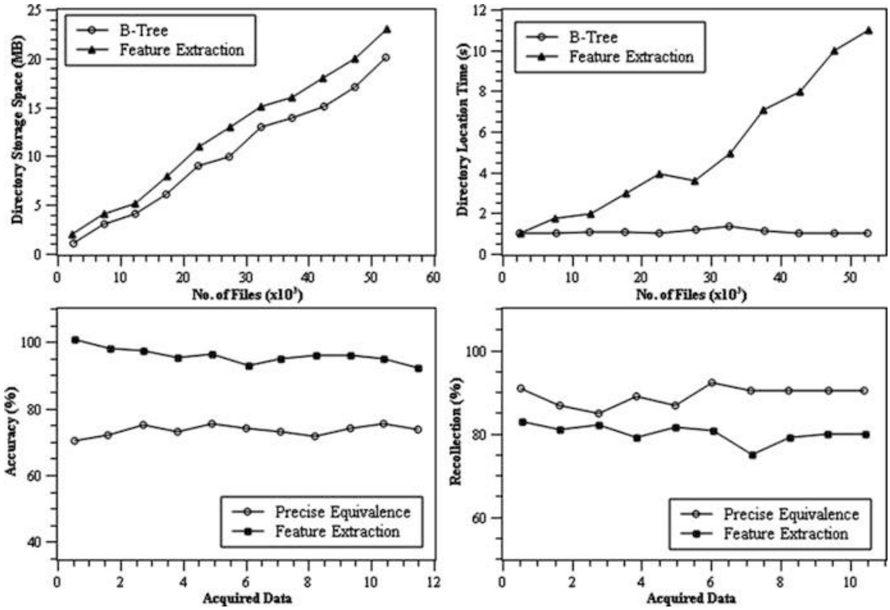


**Fig. 20.3** (**a**) Directory storage space for both the schemes proposed and [17] (**b**) time for locating the designed scheme is effective as evaluated against the B-Tree [17] (**c**) accuracy and (**d**) recollection differences among the precise equality and term equality

### *20.7.3 Time for Locating a Data*

Here the performance of the designed location scheme is assessed with the escalation in the number of files. The location process is started by the cloud servers which are performed and evaluated by estimating the rank of the terms and their location outcomes based on the scores. Figure 20.3b depicts the time of locating both the schemes, and the time for locating the designed scheme is effective as evaluated against the B-Tree as the designed scheme stockpiled the terms based on segmenting the directory trees.

### *20.7.4 Accuracy*

In the designed scheme, the terms are not precisely linked, while some false-positive terms are searched to complicate the opponents. The accuracy and recall are employed to calculate the precision of the locating outcome which is entailed as

$$\text{Accuracy} = f'/f$$

$$\text{Recollection} = f'/f''$$

Here $f$ symbolizes the terms revived from the cloud server, and $f$' symbolizes the count of positive topmost $f$ responses based on the $f$ revived terms along with $f$" representing the reply from $f$ revived terms. From Fig. 20.3c, d, it is clear that the performance parameters of accuracy and recollection differences among the precise equality and term equality [12]. The precise equivalence locates precise equivalence of terms, and there are no recollections of the precise equivalence since they do not accomplish negative location outcomes. The precise equivalence accuracy is minimized for the precise equivalence since they do not accomplish negative location outcomes [4, 5, 21].

## 20.8 Rundown of Conventional Cloud Schemes

With the aid of safe multiparty estimation, diverse individuals could estimate processes based on their input values without disclosing any data regarding their personnel input during the estimation. Here multiparty estimation is implemented among diverse clouds. By using safe multiparty estimation, a better safety could be offered for the user's information for online-based services prevailing and employed nowadays but also has the perspective to perform fresh likelihood services which do not subsist currently due to the secrecy of user's prerequisites and lack of faithful third parties [8, 18]. The efficiency of the distribution process is demonstrated based on the equalization of exposure extents based on diverse positions employed.

Based on the heuristics method, the normalized average remains maximum, and it is closer to 98.77% which represents that the exposure budget provided by every position in terms of fixed values is frequently made use of. The outcomes are logical for all the documents irrespective of the confidentiality prerequisites inferring the private information like illness or recognition of information like the name of the individuals [11]. It is regarded that the heuristic-based segmentation policies briskly attempt to store the words which provide terminated data due to their synchronization which does not crucially escalate the levels of exposure of the segments, while the split balancing words with least shared data are stored independently.

## 20.9 Conclusion

The expenses for storing 10000 files in B-Tree scheme are 8 MB, while the designed scheme expenses are 6.44 MB for 20000 file expenses. The proposed technique offers a reduction of 0.3% and 5.62% system time for creating a directory for 10k and 20k files, respectively, when compared to the conventional B-Tree technique. All encoding services rendered by servers to provide privacy of data are a difficult process that affects the effectiveness of the cloud and its services. Local sides for storage and location/recovery process (inappropriate for cloud suppliers) which provide restricted services for the subcontracted features and appends problems like local managing of keys, the requirement to organize individually designed software components in the cloud to aid precisely subcontracted features.

Besides, this method provides the user with privacy features along with a background framework in comparison with other frameworks available in the market. Semantic labeling of data is available at the clouds which are mainly serviced by algebraic and advanced abstract level algorithms. This kind of algorithms makes user prerequisites for labeling without accessing the entire data of the user to provide privacy at all levels of processing and also protects a unified implementation of prevailing semantics on qualitative information safety.

Based on the studies carried out, the other conventional safety methods fail to estimate the threats on the safety of information when compared to the proposed idea of semantics. It discharges the users from the liability of physically recognizing the delicate chunks of information as required based on the analysis and provides natural services for unplanned text-based information that could be barely organized by most of the prevailing confidentiality safeguarded solutions.

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# Chapter 21
# From the Traditional Police Model to Intelligence-Led Policing Model: Comparative Study

**Ana Rosa Pires Pereira, David Pascoal Rosado, and Helga Santa Comba Lopes**

## 21.1 Introduction

Over the years, there has been a phenomenon of globalization, which generates an increase in the flow of people, goods, and capital between states, leading to greater entry into its borders. This phenomenon not only contributes to the development and well-being of the population but also makes the frontiers permeable to new threats. To combat crime, the criminal police bodies have been adapting their performance in view of the diversity of criminal modus operandi. Therefore, it is essential to carry out a periodic analysis of the policing model in force.

The choice of the theme arose from the construction that this context has for the National Republican Guard, emphasizing policing, combating crime, and safeguarding the well-being of citizens. In addition to what has been explained, the theme becomes relevant since it evidences, by nature, several limitations but also opportunities, namely, using dissemination policing models.

This work of applied application, as general objective, analyzes if the application of an information-oriented policing model, intelligence-led policing, would be

A. R. P. Pereira (✉)
Academia Militar, Amadora, Portugal

D. P. Rosado
Academia Militar, Amadora, Portugal

Universidade Europeia, Lisbon, Portugal
e-mail: david.rosado@academiamilitar.pt

H. S. C. Lopes
Academia Militar, Amadora, Portugal

Instituto Politécnico da Lusofonia, Lisbon, Portugal
e-mail: helga.lopes@academiamilitar.pt

 
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beneficial for the institution. That said, throughout the investigation, a precise approach to two models has been made, namely, the traditional policing model and the intelligence-based policing model, an approach that initially refers to its genesis and characteristics, and finally, prepares a survey of the advantages and disadvantages of using each model under study.

## 21.2 Theoretical Background

If this work is a comparative study between two policing models, it is important to determine the latter concept. The development of society, technologies, and globalization caused the FSS's way of acting to undergo changes to achieve the involvement and demand of society.

A policing model can be defined as "a conceived strategy that aims to achieve the objectives, obeying the ideas of the decision makers. In the case of a Policing Model, the strategy must be correctly adapted to the internal reality of the modern state" [5:22]. The policing models allow observation of "theoretical and political bases inherent in the option for certain police management models and tactics, helping to identify the ideological lines inherent to certain police intervention philosophies and tactics" [6]. Whatever the policing model used, it is intended that it adapts its policing to the reality of the internal security of your state, "with the aim of addressing and defining the guidelines regarding the powers of the police organization, regarding prevention and criminal repression" [5:21].

There are several models, namely, traditional policing, community policing, problem-oriented policing, and intelligence-oriented policing, which is the same to that of information-oriented policing. In this work, two types of policing are analyzed, the traditional policing model and the information-oriented policing model [6].

### *21.2.1 Traditional Policing Model*

The traditional policing model is also called professional police model and classic or professional-bureaucratic policing model. It had its origin in the United States [22]. This strategy, adopted by the American police, aimed to combat corruption between the police and political power. This model can be characterized using law as the main means of resolution [6]. It is a process which all operational means are used, to respond to successful incidents, and police actions are essentially reactive to provide a quick response to various occurrences [22]. Following the same perspective, "Professional Model must be random and reactive, so the police only acted when practicing the illicit. This policing is seen as repressive, so prevention is neglected" [7:28].

When patrols were not at the exchange to answer incoming calls, they were patrolling tours, which were randomly determined, without considering the nature and spatial distribution of the crime. Based on the calls received at the central, the reaction was to mobilize the patrol that had the car closest to the place where the incident would have occurred [6]. This model "strategies have been based on the assumption that criminal activity and disorder could be prevented if the police were a visible presence on the streets and immediately arrested people who broke the law" [30:23].

#### 21.2.1.1 Advantages and Disadvantages

This is a policing model that aims to give a brief response to the incidents that have occurred; the fact that it is carried out randomly has not proven to be effective: "random motorized patrolling and rapid response may not effectively eradicate crime or even lead to greater detention of criminals" [30:24].

On the other hand, the capacity to prevent crimes through this model was reduced. Its "reactive form causes an immediate cut in the continuity of the criminal action, however it does not allow to make perspectives of combat measures, because as long as the causes that motivated the crime are unknown, we can hardly prevent it" [18:58].

### *21.2.2 Intelligence-Led Policing*

Intelligence-led policing (ILP) model has origins in England [23]. This model emerged in the early 1990s, due to the increase in crime recorded in the late 1980s and early 1990s. Fuentes defines this model as a philosophy that begins with information collected at all that posteriorly analyzed to assist the leadership in making the best possible choices. This information will help the commander define strategies to fight crime, as well as to manage the means at his disposal [9, 26].

Information-oriented policing "privileges the analysis of the patterns of crimes or incivilities and the patterns of action of criminals or delinquents, focusing on the identification of potential offenders, their correlations, modus operandis and time of operation" [17:145]. This model uses "techniques such as crime-mapping, data-mining, of CCTV systems, which facilitates acquisition of data for the production of information" [8:32].

To explain functioning of this policing model, Ratcliffe created a model which establishes a relationship between information, police decision-makers, and the environment, called "model 3-i." This model was developed; the "4-i model" is added with the intention component to explain the functions and the relationship between the main actors of the ILP [24–26] (Fig. 21.1).

Initially, the decision-maker's intention is transmitted to analysts, since the analysts interpret the criminal environment and, through the analysis result, influence

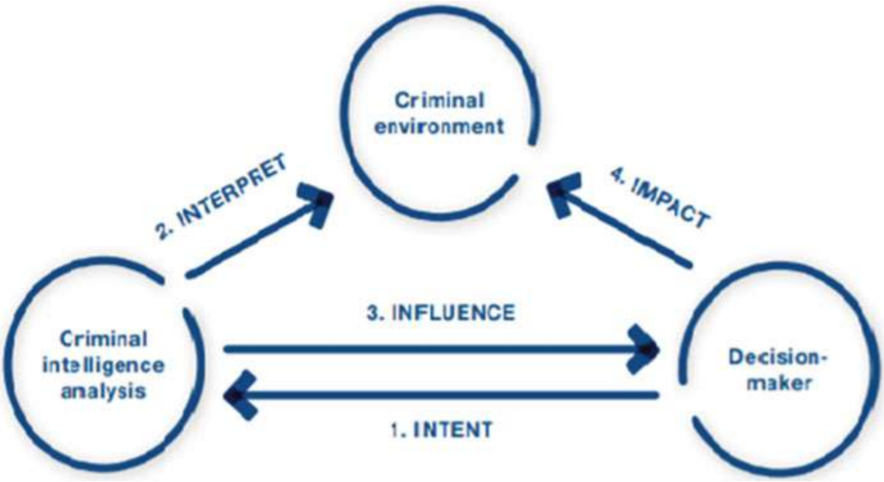


**Fig. 21.1** The 4-i model: intent, interpret, influence, and impact

the decision-maker, and this through their agency will cause an impact on the criminal environment [23].

#### 21.2.2.1 Advantages and Disadvantages

The information-oriented policing model uses several resources in its application; however it allows assistance in decision-making. This model was previously characterized, and it was possible to identify benefits and implications related to this policing strategy.

The benefits of applying this policing model are as follows: its adaptability to transnational threats allows for informed decision-making, providing interoperability and cooperation between units, states, and organizations and providing information sharing and acquisition of information about risks and threats, and it presents an evidence-based prioritization of tasks and resource allocation. In the same line of thought, the use of POI allows "to balance the increasingly scarce resources and means where they are most needed and better fulfilling the objectives and missions outlined" [20:247]. Strengths of this model are as follows: the fact of allowing to balance resources, focusing on more dangerous and recurrent crimes; direct some routine activities to other structures; through support structures, influence and support decision making; the use of best command and control practices; save costs; better knowledge of the population; as well as the highest success rate in reducing, preventing, and eradicating crime [19].

In another OSCE document, it is mentioned that the production of information may have implications for human rights, "the collection of data and information, but also its processing, analysis and dissemination, which are all integral elements of the

ILP, can have serious implications for the protection of human rights, in particular, but not only, for the right to privacy" [23:26].

This model helps to reduce, prevent, and eradicate crimes and damage [27]. The use of techniques such as crime mapping allows the decision-maker to identify criminal outbreaks, to identify more sensitive areas allowing him to direct policing. It is argued that "police intelligence favors the prediction of dangers and the removal of socially alarming incivilities and facilitates the management of incidents on the public road" [2:25].

According to Ratcliffe "the difficulty with current information-driven policing models is that, with the exception of the model implemented in the United Kingdom, few are documented" [25:2]. It is also a model that requires investment at a technological level and "despite the popularity of the concept among police commanders, what is seen is a clear discontinuity between intentions and practice" [6:191].

### *21.2.3 Policing in the Republican National Guard*

The guard has been adjusting its policing according to changes and requirements that have been observed in society. From the Royal Police Guard of the 1980s, the Republican National Guard employed reactive behavior at the crime stage. From that decade, the guard seeks to abandon its purely reactive behavior in the face of the population's problems and carries out its adaptation centered on proximity to citizens, through the model of proximity policing [15]. The action strategy has been adopting increasingly preventive patterns and for crime prevention to be carried out; it is necessary to have an approach to the community. Proximity policing is carried out in accordance with the guard's activity plan, through development of thematic operations, supported by several special programs, who approaching to people is one of the strategic guidelines aiming to strengthen citizens' confidence, promoting community, and proximity patrolling [13, 16].

Although Republican National Guard is present with well-connected policing, the ILP model is not indifferent. In 2019, plan where the main strategy for each one is identified with reference to the institution's strategy for 2020, the information-driven model is demonstrated [14].

The Republican National Guard at its different levels has responsible professionals to analyze information for decision-making. Assisting institution's activity has information systems as integrated police operational information system (SIIOP) and the SIRESP geographic information system (SIG-SIRESP). SIIOP is a tool used by the Republican National Guard, where all crimes occurred in guard's action zone are registered, allowing mapping crime, access to recorded data, as well as a better perception of occurrences. SIG-SIRESP is a geographic-based system used for allowing monitoring patrols' location by georeferencing radio terminals [21]. Both systems allow situational comprehension as "Geographic Information Systems are, therefore, fundamental in security information such as the National Republican Guard, as they are a decision support system" [1:37].

Plus, among others, Republican National Guard also has an information center (CI), implemented in the information department, aiming to assist in decision-making, the CI is generally responsible for monitoring and analyzing data, news, and information, producing information at the operational and tactical level to assist decision-making [12].

In artificial intelligence area, Republican National Guard has been developing partnerships, such as the modeling and prediction of road accidents project (MOPREVIS) in the Setúbal District, developed by University of Évora and Setúbal Republican National Guard Head-Command, developing an artificial intelligence platform to locate most predictable road accidents' locations [10].

In this context, considering the importance of a decision-making process based on information that has been subjected to an analysis process, it is intended to investigate whether the ILP is implemented in the Republican National Guard, since in Portugal this policing model is not formally documented. However, the analysis carried out on two dissimilar policing models allows the identification of advantages in the use of each model, which are relevant in determining the policing model to be used and for the decision-making of a commander.

## 21.3 Materials and Methods

### *21.3.1 Research Question and Instruments*

The methodology is defined as "the sequence of procedures that describe how the research will be carried out, it will answer how it is possible to achieve the objectives generated" [11:21].

The research problem is indicated by the main question: Is the intelligence-led policing model applicable in the National Republican Guard?

From the main question to lead the research, four derived questions were created:

- Q1: What is the policing model currently implemented by the Republican National Guard?
- Q2: Which are essential requirements for implementing the intelligence-led policing model?
- Q3: Which are advantages and limitations of the intelligence-led policing model compared to the conventional policing method developed by the Republican National Guard?
- Q4: Which requirements are necessary for the implementation of intelligence-led policing in the Republican National Guard?

In order to be able to give more concise responses to the different derived questions, interviews were conducted to collect data.

### 21.3.2 Participants and Data Analysis (Dimensions and Variables)

In order to gather more rich and substantiated information, semi-structured interviews were carried out "combining closed and open questions. In this type of interview, the interviewee is free to position himself favorable or not on the topic, without being attached to the question asked" [4:29]. The questions asked during the interviews were chosen with the purpose to contribute in the answer to the drifting questions and the starting question.

As for the procedure used in the preparation of the interviews, they were based on the script structured on 13 questions, which is defined as "an instrument for collecting information in the form of text, which serves as the basis for the interview proper" [29:31].

As for the mode, interviews were conducted essentially in a non-face-to-face manner; only two were subject to travel to the intended entity. Through a prior consent of the interviewees, all the interviews carried out were recorded, in order to facilitate their subsequent analysis and transcription.

The knowledge by Republican National Guard officers, based on studies on the theme of intelligence and intelligence-led policing, policing models, as well as the current or already performed role in the operations department, information department, and the criminal investigation department, displays the determined criteria for the selection of the 15 interviewees.

During an investigation there are three types of reasoning that can be used: deductive, inductive, and hypothetical-deductive reasoning, the same being related to the investigation methods [28]. In this research work, the deductive method was used: "the deductive method, which is based on a logic that starts from one or more theoretical options in order to explain a particular phenomenon" [28:118].

In this research, the deductive method is used, and the analysis performed is qualitative. About the interviews, their treatment was carried out through a content analysis, that is, the analysis of the responses that each interviewee gave to the 13 questions that were asked was performed. Subsequently, the main ideas were transcribed, and a vertical and horizontal reading was carried out. By reading them, segments of content were identified in the interviewees' volunteer's registration units, statements that can be compared, enabling the connection between the various responses. After this initial analysis, tables were created, since they constitute an effective means of exposing the results obtained [3]. These tables show which registration units are present in each answer and how many times they appear in each question, enumeration units [29] (Table 21.1).

**Table 21.1** Alphanumeric coding of interviews

| Question | Categories | Items | Registration units (UR) |
|---|---|---|---|
| 1 | Characterization of policing | Application of various models | A1.1. |
| | | Applies only one policing model | A1.2. |
| | | Reaction-based policing | A1.3. |
| | | Prevention-based policing | A1.4. |
| 2 | Policing suitability | Adequate | A2.1. |
| | | Partially adequate | A2.2. |
| | | Inappropriate | A2.3. |
| 3 | Application of ILP in the institution | Doesn't apply in the institution | A3.1. |
| | | Partially applied in the institution | A3.2. |
| | | It's applied throughout the institution | A3.3. |
| 4 | Decision-making support | Technological means | A4.1. |
| | | Specialized human resources | A4.2. |
| | | Knowledge of the criminal environment | A4.3. |
| | | Information culture | A4.4. |
| 5 | ILP application requirements | Organizational commitment | A5.1. |
| | | Formation | A5.2. |
| | | Specialized human resources | A5.3. |
| | | Time for the implementation of the model | A5.4. |
| | | Technological investment | A5.5. |
| | | Information structure | A5.6. |
| 6 and 7 | Comparison between the models under analysis | ILP provides resource management | A6–7.1. |
| | | The traditional model provides resource management | A6–7.2. |
| | | Complementarity between models | A6–7.3. |
| | | ILP provides forecast of events | A6–7.4. |
| | | The traditional model provides forecast of events | A6–7.5. |
| | | ILP provides speed in police action | A6–7.6. |

(continued)

**Table 21.1** (continued)

| Question | Categories | Items | Registration units (UR) |
|---|---|---|---|
| | | The traditional model provides speed in police action | A6–7.7. |
| | | ILP provides sustained decision-making | A6–7.8. |
| | | Traditional model provides sustained decision-making | A6–7.9. |
| | | ILP implementation is complex | A6–7.10. |
| | | Traditional model implementation is complex | A6–7.11. |
| | | ILP application requires large financial investment | A6–7.12. |
| | | Traditional model application requires large financial investment | A6–7.13. |
| 8 | Information and criminal investigation sections | Can determine hotspots | A8.1. |
| | | Can't determine hotspots | A8.2. |
| 9 | Contribution of information systems | Resource control | A9.1. |
| | | Data recording and storage | A9.2. |
| | | Source of criminal analysis | A9.3. |
| 10 | Acquisition of products | Can acquire products (intelligence) | A10.1. |
| | | Cannot acquire products (intelligence) | A10.2. |
| | | Make no conclusions | A10.3. |
| 11 | Police activity | It is directed toward the ILP | A11.1. |
| | | It is partially directed toward the ILP | A11.2. |
| | | It is not directed toward the ILP | A11.3. |
| 12 | Future guidelines | Reply positively | A12.1. |
| | | Reply negatively | A12.2. |
| | | Make no conclusions | A12.3. |
| 13 | Resources necessary for the sustained implementation of the ILP in the institution | Organizational commitment | A13.1. |
| | | Formation | A13.2. |
| | | Specialized human resources | A13.3. |
| | | Time to implement the model | A13.4. |
| | | Technological investment | A13.5. |
| | | Information structure | A13.6. |

## 21.4 Results

In order to be able to answer the derived questions and the main question of the investigation, interviews were conducted. In these interviews a guide of 13 questions was used, in order to understand the policing used by the Republican National Guard, the necessary requirements for the application of the ILP, and the advantages and disadvantages in the use of the two models under analysis and finally understanding in what phase of using the ILP the Republican National Guard is in.

### *21.4.1 Data Demonstration*

#### 21.4.1.1 The Policing Model Implemented by the Republican National Guard (Tables 21.2, 21.3, and 21.4)

**Table 21.2** Total statistics for question 1

| Registration units | *Enumeration units* | % |
|---|---|---|
| Application of various models (A1.1.) | 13 | 87 |
| Reaction-based policing (A1.3.) | 10 | 67 |
| Prevention-based policing (A1.4.) | 10 | 67 |

**Table 21.3** Total statistics for question 2

| Registration units | *Enumeration units* | % |
|---|---|---|
| Adequate (A2.1.) | 4 | 27 |
| Partially adequate (A2.2.) | 9 | 60 |
| Inappropriate (A2.3.) | 2 | 13 |

**Table 21.4** Total statistics for question 3

| *Registration units* | *Enumeration units* | % |
|---|---|---|
| Doesn't apply in the institution (A3.1.) | 2 | 13 |
| Partially applied in the institution (A3.2.) | 7 | 47 |
| It's applied throughout the institution (A3.3.) | 6 | 40 |

#### 21.4.1.2 Requirements for the Implementation of Intelligence-Led Policing (Tables 21.5 and 21.6)

**Table 21.5** Total statistics for question 4

| Registration units | *Enumeration units* | % |
|---|---|---|
| Technological means (A4.1.) | 13 | 87 |
| Specialized human resources (A4.2.) | 7 | 47 |
| Knowledge of the criminal environment (A4.3.) | 3 | 20 |
| Information culture (A4.4.) | 8 | 53 |

**Table 21.6** Total statistics for question 5

| Registration units | *Enumeration units* | % |
|---|---|---|
| Organizational commitment (A5.1.) | 3 | 20 |
| Formation (A5.2.) | 9 | 60 |
| Specialized human resources (A5.3.) | 5 | 33 |
| Time for the implementation of the model (A5.4.) | 2 | 13 |
| Technological investment (A5.5.) | 12 | 80 |
| Information structure (A5.6.) | 4 | 27 |

#### 21.4.1.3 Comparison of the Models Under Analysis (Table 21.7)

**Table 21.7** Total statistics for questions 6 and 7

| Registration units | *Enumeration units* | % |
|---|---|---|
| ILP provides resource management (A6–7.1.) | 10 | 67 |
| The traditional model provides resource management (A6–7.2.) | 0 | 0 |
| Complementarity between models (A6–7.3.) | 4 | 27 |
| ILP provides forecast of events (A6–7.4.) | 7 | 47 |
| The traditional model provides forecast of events (A6–7.5.) | 0 | 0 |
| ILP provides speed in police action (A6–7.6.) | 0 | 0 |
| The traditional model provides speed in police action (A6–7.7.) | 3 | 20 |
| ILP provides sustained decision-making (A6–7.8.) | 7 | 47 |
| Traditional model provides sustained decision-making (A6–7.9.) | 0 | 0 |
| ILP implementation is complex (A6–7.10.) | 8 | 53 |
| Traditional model implementation is complex (A6–7.11.) | 0 | 0 |
| ILP application requires large financial investment (A6–7.12.) | 5 | 33 |
| Traditional model application requires large financial investment (A6–7.13.) | 0 | 0 |

#### 21.4.1.4 Requirements for the Implementation of Intelligence-Led Policing in the Republican National Guard (Tables 21.8, 21.9, 21.10, 21.11, 21.12, and 21.13)

**Table 21.8** Total statistics for question 8

| Registration units | *Enumeration units* | % |
|---|---|---|
| Can determine hotspots (A8.1.) | 15 | 100 |
| Can't determine hotspots (A8.2.) | 0 | 0 |

**Table 21.9** Total statistics for question 9

| *Registration units* | *Enumeration units* | % |
|---|---|---|
| Resource control (A9.1.) | 4 | 27 |
| Data recording and storage (A9.2.) | 12 | 80 |
| Source of criminal analysis (A9.3.) | 12 | 80 |

**Table 21.10** Total statistics for question 10

| Registration units | *Enumeration units* | % |
|---|---|---|
| Can acquire products (intelligence) (A10.1.) | 14 | 93 |
| Cannot acquire products (intelligence) (A10.2.) | 0 | 0 |
| Make no conclusions (A10.3.) | 1 | 7 |

**Table 21.11** Total statistics for question 11

| Registration units | *Enumeration units* | % |
|---|---|---|
| It is directed toward the ILP (A11.1.) | 5 | 33 |
| It is partially directed toward the ILP (A11.2.) | 9 | 60 |
| It is not directed toward the ILP (A11.3.) | 1 | 7 |

**Table 21.12** Total statistics for question 12

| Registration units | *Enumeration units* | % |
|---|---|---|
| Reply positively (A12.1.) | 10 | 67 |
| Reply negatively (A12.2.) | 2 | 13 |
| Make no conclusions (A12.3.) | 3 | 20 |

**Table 21.13** Total statistics for question 13

| Registration units | *Enumeration units* | % |
|---|---|---|
| Organizational commitment (A13.1.) | 7 | 47 |
| Formation (A13.2.) | 9 | 60 |
| Specialized human resources (A13.3.) | 6 | 40 |
| Time to implement the model (A13.4.) | 1 | 7 |
| Technological investment (A13.5.) | 10 | 67 |
| Information structure (A13.6.) | 5 | 33 |

### *21.4.2 Descriptive Analysis*

After interviews, first task was validating answers given by the 15 interviewees; a careful and consecutive reading was carried out, based on methodology mentioned by Sarmento. In this way, the content analysis ends with the elaboration of a conclusion "evidencing results above 50% and emphasizing results greater than or equal to 80%" [29:66].

So, to currently adopt policing, 87% (Q1) agree with the application of several policing models in guard. However, reaction-based application of policing model does not differ from the application of policing based on prevention (both has 67%) (Q1). This conclusion considers the complementarity that exists between the models.

As for the adequacy of policing, 60% (Q2) of sample conclude it appears to be partially adequate, since there is an evolutionary way. Regarding tools to support decision-making, with 87% (Q4) of incidence, technological means were considered and with 53% (Q4) a culture of information, as essential requirements for sustained decision-making. Still on requirements, but as an ILP application in an organization, 80% (Q5) mentioned technological investment and 60% (Q5) points in training necessity for organization's elements.

Comparing advantages and disadvantages about both methods, 67% (Q6 e Q7) referred ILP provides means management, and 53% (Q6 e Q7) points complexity of model. On analysis nucleus, 93% (Q10) mentions ability to acquire products, and all the interviewees affirms that criminal investigation and information sections can determine hotspots (Q8). The recording and storage of data, from an analysis source perspective, makes information systems influencing in the application of the information-based model, which refers to 80% (Q9) of the sample.

In police activity perspective, 60% (Q11) shows a partial direction to ILP model, and 67% (Q12) mentions that the 20/25 strategy is also directed toward the same effect.

At last, as ILP implementation is a necessary resource on institution, 67% (Q13) refers technological investment needs and 60% (Q13) training needs, as a present and important requirement for the application of this model.

## 21.5 Discussion

The data obtained in the interviews carried out with entities that have knowledge on the subject allow the acquisition of answers to the investigation.

As 87% of the interviewed agreed, there is the application of several models of policing by Republican National Guard. However, the documents approved at the strategic level assume the implementation of a model of community and proximity policing based on thematic operations, supported by several special programs. Based on high number of special programs that have been implemented, the Republican National Guard presents a policing model based on a proximity policy. However, unexpected occurrences have necessity for a reactive approach by the security force, which consequently makes the traditional model still employed making a single policing model not enough.

According to 80% of respondents' answers, technological investment is evidenced as a requirement for the implementation of the ILP, as well as training in this theme, defended by 60% of the sample. Regarding the comparison of the two models, it is concluded that conventional policing has limitation on saving resources, compared to the ILP. However, it requires smaller monetary spending on technology and presents itself as an easy-to-implement model. In contrast, the use of information-oriented policing allows for sustained decision-making and thus resource management and crime prevention. However, it requires higher spending on technology compared to traditional policing, as well as being at the level of implementation more complex than the other model.

Finally, regarding the necessary requirements for the ILP in the institution, the need for technological investment is concluded. Throughout the interviews, the need for SIIOP interoperability was mentioned, the existence of software at the rear that interconnects all SIIOPs, establishing the correlations of the data entered, allowing the purchase of products. Therefore, data screening is relevant in the application of this model, in a perspective of "qualitative information vs quantitative information" making training as necessary for the practice of an information culture.

## 21.6 Conclusions and Recommendations

In this last phase, it is intended to answer the derived questions and, consequently, the main question, based on the knowledge acquired during the investigation. In this sense, the objectives of the work are confirmed, limitations are listed, and recommendations and proposals for future investigations are made.

Answering the first question derived (Q1), given the high number of special programs that have been implemented, the National Republican Guard presents a policing model based on a proximity policy. However, unexpected occurrences call for a reactive approach by the security force, which consequently makes the traditional model still employed. So it appears that there is no application of a single policing model.

Regarding the second derived question (Q2), the essential requirements demonstrated were a technological implementation that allows the sharing of information between diversify institutions and organizations; a structure composed of analysts at different levels of the organization, responsible for producing information; and a culture of present information that promotes the production of timely information that influences decision-making.

In response to the third question (Q3), according to the joint analysis carried out on these questions, with 67% agreement by the interviewees, it is determined that the ILP model when compared to the traditional model about the management of means/resources, is advantageous in the application of this information-oriented policing model, being logically presented as a limitation in the application of traditional policing.

In terms of implementation, this proved to be a disadvantage to the ILP model, when it is compared to the traditional model, an ideology defended by 53% of the sample. This complexity implementation is reported in the OSCE document, which states that the production of information may conflict with human rights. Adopting the previous logical reason, the complexity of implementing the ILP is shown to be an advantage of reactive policing, where such complexity is not expressed. These were the most significant characteristics, but over the theoretical framework, more characteristics are revealed, which express benefits and limitations present with the isolated applicability of these models.

So answering this question succinctly, it is concluded that policing based on reaction as is traditional policing has difficulty of managing resources, a disadvantage when compared to the ILP. However, it requires less monetary spending on technology and presents itself as an easy-to-implement model. In contrast, the use of information-oriented policing allows for sustained decision-making and thus resource management and crime prevention. However, it requires higher spending on technology compared to traditional policing, as well as presenting a more complex level of implementation than the other model.

As for the last derived question (Q4), in agreement with 67% of the interviewees, the need for technological investment in the institution was concluded. Throughout the interviews, the need for SIIOP interoperability was mentioned, the existence of software at the rear that interconnects all SIIOPs, establishing the correlations of the data entered, allowing the purchase of products. Referred by 60% of respondents, there is a need in the GNR for specific training about information. The distinction between what may be relevant data or non-relevant data, on the part of the military, before their introduction in the information systems applied by GNR, becomes relevant in the application of this model, as it is not enough that there is information; these must be timely. In this sense, training in this area is advocated, as necessary for the practice of an information culture. Along this investigation, there was mentioned the use of some tasks where the information-oriented model is used by the institution. It was verified application of ILP ideology on isolated cases, even a minimal scale. There has been an effort to use ILP methodologies, as a complement to proximity policing. It is verified the accomplishment of analysis at statistical level, as well as the georeferencing; however artificial intelligence is not developed to automatic data treatment under Portuguese reality.

After responding to the DQs, it is important to respond to the main question: "Is the intelligence-led policing model applicable in the National Republican Guard?". So, about main question, policing method used in Republican National Guard is guided by information but not carried out through guidelines and higher directives that ensure that it is provided in the same way all over the organization. It is not presented as an automatic or sustained process yet, and its implementation should be the object of reflection at the strategic level, taking into account to all requirements.

One of the biggest limitations of this study was the fact that it was carried out during the pandemic period experienced worldwide and also the lack of books in Portuguese about the subject.

The recommendations made are oriented toward the development of future research; in this context it would be interesting conducting a study at the national level, of strategic locations, where the installation of CCTV systems could promote the safety of the population.

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**D**

**M**



**N**

**W**



**X**



**Z**