University of Minho
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Doctoral Dissertation
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Doctoral Dissertation Supervised by
Professor José Manuel Ferreira Machado
and
Professor António Carlos da Silva Abelha

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It seems that the time has finally come: I concluded another milestone in my life, and I have to show my appreciation to all of those whom have made the conclusion of this research project possible in the most varied ways.

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I close these acknowledgements with a very heartfelt thanks to my family for the support they have always offered me throughout this long journey full of good and bad moments that is life. To my mother whom showed me the real meaning of the word sacrifice and what it is to give without ever expecting to receive something back in return. To my father that made me overcome many more obstacles than those that I should have because he has always demanded much more from me. And to my sister for supporting unconditionally the peculiar human being that sometimes I can be.

To all, thank you very much.

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

UM NOVO SISTEMA PARA AUXILIAR O AUTOCUIDADO DE IDOSOS E OS SEUS CUIDADORES INFORMAIS ATRAVÉS DE LARES

Nos últimos anos, dados estatísticos oficiais refletem o envelhecimento da população em todo o mundo. Esta situação acarreta vários desafios à nossa sociedade e temas como a independência e a mobilidade dos idosos se tornam cada vez mais uma situação crítica. Assim sendo, ser dependente num contexto domiciliar é uma situação que merece indubitavelmente mais atenção por parte de entidades de apoio social integradas na comunidade, tais como os lares, uma vez que desempenham um papel fundamental no apoio às famílias envolvidas.

Neste sentido, este estudo destina-se aos idosos dependentes no autocuidado, aos seus cuidadores informais e aos profissionais de saúde que trabalham em lares portugueses e emergiu de modo a apoiar o autocuidado de idosos e os seus cuidadores informais e fortalecer as estratégias de comunicação entre os diferentes elementos do público-alvo. Portanto, propõe-se o desenho e o desenvolvimento de um arquétipo de um novo sistema, cujos principais objetivos são de acompanhar, ensinar e partilhar informação entre os seus utilizadores, considerando uma validação médica segura e questões éticas, através de tecnologias emergentes da informação e comunicação na saúde. Este arquétipo é um reforço, isto é, uma forma de promover e completar o conhecimento e as habilidades para lidar com o bem-estar e a saúde dos idosos e dos seus cuidadores informais. Deste modo, devido às atuais elevadas taxas de ocupação dos lares e aos elevados custos associados, o objetivo é melhorar a qualidade do estilo de vida dos idosos nos seus espaços domésticos, já que eles preferem envelhecer em casa.

Finalmente, os resultados alcançados com esta dissertação de doutoramento são promissores. Algumas das vantagens mais significativas apontadas incluem a redução da distância entre os lares e a comunidade, combater o isolamento social e a solidão dos idosos e dos seus cuidadores informais, proporcionar segurança e proteção, facilitar a mobilidade, uma aprendizagem contínua ao longo da vida com aprovação médica e promover investigação científica na gerontecnologia. No entanto, a modernização e o desenvolvimento organizacional são indispensáveis nos lares antes da possibilidade de utilizar o sistema proposto com sucesso. De facto, a atual falta de enfermeiros que trabalham nestas instituições de saúde e a enorme sobrecarga de trabalho sobre os mesmos impedem o uso iminente do sistema. Por outro lado, a ainda potencial falta de aceitação e o medo de recorrer a novas tecnologias pelos idosos e os seus cuidadores informais também merecem ser destacados. Porém, após estes avanços essenciais, o seu sucesso de implementação é favorável nos próximos anos.

Palavras-chave: Autocuidado; Cuidadores Informais; Idosos; Lares; Tecnologias da Informação e Comunicação na Saúde.

A NOVEL SYSTEM TO ASSIST ELDERS' SELF-CARE AND THEIR INFORMAL CAREGIVERS THROUGH NURSING HOMES

In the last years, official statistics data show that the population is aging worldwide. This situation poses several challenges to our society and the topics of independence and mobility for the elderly become increasingly a critical situation. Thus, being dependent in a home context is a situation that deserves attention from social support entities that are integrated in the community, such as nursing homes, which play a central role in supporting the families involved.

In this sense, this study is aimed at seniors dependent in self-care, their informal caregivers, and health-care professionals working in Portuguese nursing homes, and emerged to assist elders' self-care and their informal caregivers and to strengthen the communication strategies between the different elements of the target audience. Therefore, the design and development of an archetype of a novel system is proposed, which main objectives are to accompany, teach, and share information between its users, taking into account safe medical validation and ethical issues, through emerging health information and communication technologies. This archetype is a reinforcement, that is, a way to promote and complete the knowledge and skills to deal with elders' well-being and health and their informal caregivers' welfare. Therefore, the goal is improving elders' lifestyle quality in their home environments due to the fact that they prefer to age in place, the current overcrowding of nursing homes, and the high costs associated with these health facilities.

Finally, the results achieved with this doctoral dissertation are promising. Some of the most significant advantages pointed out include to bridge the gap between nursing homes and the community, combating social isolation and loneliness of seniors and their informal caregivers, enabling safety and security, facilitating mobility, lifelong learning with medical approval, and promoting scientific research in gerontechnology. However, modernization and organizational development are indispensable in the nursing homes before the prospect of using successfully the proposed system. As a matter of fact, the current lack of nurses working in these health institutions and the tremendous work overload on them prevent the imminent use of the system. On the other hand, the still potential lack of acceptance and fear to resort to new technologies by older adults and their informal caregivers must also be highlighted. Nevertheless, after these essential advances, its implementation success is favourable in the coming years.

Keywords: Elders; Health Information and Communication Technology; Informal Caregivers; Nursing Homes; Self-care.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AIDA Agency for Integration, Diffusion and Archive of Medical Information. 99, 100, 116, 117, 136

AR Augmented Reality. xi, xiii–xv, 5–8, 20–24, 33–35, 43, 56, 92, 94, 118–127, 131, 133, 134, 136

BI Business Intelligence. xii, xiii, xv, 5–8, 16, 17, 23, 24, 37, 45, 53, 60, 61, 97–117, 130, 131, 133, 134, 136

CDSS Clinical Decision Support System. 23

CL Collaborative Learning. 5, 6, 8, 15, 16, 21, 23, 24, 83, 85, 88, 130, 133, 134

DM Data Mining. 17

DSA Data Staging Area. 18

DSR Design Science Research. xi, 6, 26, 28, 29, 43, 136

DW Data Warehouse. 17–20, 36, 98–100, 117, 136

EER Enhanced Entity–relationship. 100

EHR Electronic Health Record. 17

ETL Extract, Transform, and Load. 8, 17–19, 37, 43, 99, 100, 116, 117, 136

GPS Global Positioning System. 33

HICT Health Information and Communication Technology. 2, 3, 5, 6, 8–11, 13, 17, 21, 23, 24, 44, 45, 54, 55, 100, 116, 119, 133, 135, 136

HIS Health Information System. 22, 23, 45, 99

ICT Information and Communication Technology. 9, 10, 21, 22, 24, 26

IDE Integrated Development Environment. 26, 35, 43, 92, 118, 120, 122

IS Information System. 22, 23

IT Information Technology. 6, 9, 14, 24, 28, 29, 37, 39, 40, 42, 43, 115, 128, 129, 132, 135, 157, 160

JWT JSON Web Token. 30

mHealth Mobile Health. 5, 8, 12, 13, 23, 24, 133, 134

MVC Model-View-Controller. 29, 31

ORM Object-relational Mapping. 31, 46

PDF Portable Document Format. 72, 86, 126

PoC Proof of Concept. 5–7, 26, 27, 29, 37, 43, 95, 128, 132

RDBMS Relational Database Management System. 26, 29, 30, 36, 43, 45, 46, 52, 53, 99

REST Representational State Transfer. 57

RQ Research Question. 4, 5, 133

SDK Software Development Kit. xiii, xv, 26, 33–35, 43, 92, 118, 120–122

SEO Search Engine Optimization. 31

SLAM Simultaneous, Localization, and Mapping. 34

SMS Short Message Service. 95, 136

SQL Structured Query Language. 52, 53, 82, 90

SWOT Strengths, Weaknesses, Opportunities, and Threats. xi, 7, 26, 29, 37–39, 43, 128, 129, 132, 136

TAM Technology Acceptance Model. xi, 7, 26, 29, 37, 39, 40, 43

TAM2 Extended Technology Acceptance Model. xi, 40, 41

TAM3 Technology Acceptance Model 3. xi, xv, xvi, 40–43, 128, 129, 132, 136, 155, 158

UI User Interface. 31–33

URL Uniform Resource Locator. 31, 51, 86

VR Virtual Reality. 20

WHO World Health Organization. 12

1

INTRODUCTION

The research project described in this document arose within the scope of the realization of the doctoral dissertation titled "A Novel System to Assist Elders' Self-care and their Informal Caregivers through Nursing Homes" in the Doctoral Program in Biomedical Engineering at the University of Minho that ran between the academic year of 2016/2017 that started in February 2017 until the academic year of 2018/2019 that ended in June 2020.

This chapter intends to introduce the study conducted, which was undertaken at the Algoritmi Research Centre, a research unit of the School of Engineering at the University of Minho (Braga, Portugal), as well as in Portuguese nursing homes located in the north of the country.

Thus, to do so, this introductory chapter includes a scope and contextualization of the research project (Section 1.1), a description of the motivation behind it (Section 1.2), the list of objectives to be fulfilled with its realization (Section 1.3), and the presentation of the dissertation structure (Section 1.4), that is, the structure of this document.

1.1 Scope and Contextualization

In the last years, a noticeable demographic change has been felt worldwide: in many countries, official statistics data show that the population is aging [1, 2, 3, 4, 5], which leads to a tremendous increase of elderly care costs [5]. Indeed, people are increasingly living much longer than in the past [6].

This situation poses several challenges to our society, and the topics of independence and mobility for the elderly become increasingly a critical situation [7], raising the need of ensuring multidisciplinary nursing teams, but also solutions that promote the potential of each dependent's autonomy. Therefore, the goal is improving elders' lifestyle quality in their home environments since older adults prefer to age in place, and their informal caregivers' welfare [5, 8]. In the scientific community, this concept has been known as "ageing in place".

In fact, Portugal is not an exception to this current worldwide concern. At the moment, it is one of the countries with the largest aging population in the world [9] and, similarly to other countries, this situation has been negatively affecting several aspects of elderly care. One of the most challenging problems resulting from this situation is that nursing homes are overcrowded, which complicates and often even makes impossible the entry of seniors to nursing homes, being a issue for several families across the country [10, 11, 12, 13]. In 2018, the occupancy rate was at 92.6%, even though the costs associated

are high, which can lead various families into debt [12]. In fact, the number of individuals waiting to be admitted have been increasing, which also shows a lack of capacity to deal with the current demand [14].

Thus, the attempt to postpone as much as possible the departure of older adults to nursing homes is justified by creating the necessary and appropriate conditions in their home environments, given the predominant lack of vacancies for new patients in national nursing homes. On the other hand, it is also important to note that a large portion of elders do not even have the money necessary to support the costs associated with their entry into nursing homes due to the exorbitant values requested by these health institutions [12, 13].

Moreover, the elderly abuse and neglect care cases have been increasing in nursing homes, creating fear in the elderly and their informal caregivers, which is often one more reason for them to choose to be cared at home. In fact, in Portugal, several complaints have been submitted to the inspection services regarding these health facilities in the last years. The major irregularities identified are related to organizational problems, namely safety and operation conditions, legal situations, lack of proper documentation, poor care, nutrition assistance issues, health and hygiene assistance issues, and lack of care workers and professional staff [15].

To deal with those major challenges, the scientific community have suggested applying Health Information and Communication Technology (HICT) to provide solutions to current issues associated with an aging population [16], particularly for the remote monitoring of patients, which has been advocated as a concept that can radically transform and improve the delivery of healthcare [17, 18, 19, 20, 21]. Advantages linked with HICT include maintaining the elders' independence, reducing healthcare needs and costs, providing remote assistance, and promoting social interaction [8]. Thus, new technological solutions designed for elders can somewhat balance the gap between resources and the increasing demand of healthcare services that cannot be fulfilled. In fact, it is essential to reinforce the elderly and their informal caregivers with human and material resources to encourage the autonomy of seniors in their usual living environments [14, 22, 23].

The research and implementation of technology to assist older adults is defined as "gerontechnology", which is derived from the words "gerontology" and "technology". It covers domains such as health, communication, safety, mobility, and housing in order to prevent, delay, or compensate the aging process. Nonetheless, issues regarding safety, privacy, and autonomy are themes that are also worth exploring and should be considered. In fact, the fear of losing human contact is one of the main reasons behind the insecurity of older people regarding the use of new technologies [6, 24].

Thus, it is intended with this manuscript to describe the proposal of a research project aimed at seniors dependent in self-care, their informal caregivers, and health professionals working in Portuguese nursing homes, that is, the nursing, technical, and administrative staff, which emerged to ensure predominantly the care of older adults and to strengthen the communication strategies between the different elements of the target audience, namely elders dependent in self-care, their informal caregivers, and health professionals from nursing homes - the case studies. The novelty of this project lies in trying to fulfill the current lack of communication strategies to support the remote assistance by Portuguese nursing homes to the elderly and their caregivers using emerging technologies with medical approval. So, it will also facilitate the access

to care services by rural populations, which is essential for a country like Portugal since a huge percentage of older adults live in these remote areas, having reduced access to healthcare services.

Hence, the design and development of an archetype of a novel system to support elders' self-care and their informal caregivers is proposed, which main objectives are to accompany, teach, and share information between its users, taking into account safe medical validation, in other words, reliable information and ethical issues. The system will be a reinforcement to deal with seniors' well-being and health and informal caregivers' welfare by improving their lifestyle quality and promoting social interaction, through the aid of nursing homes. Nonetheless, it is important to note that it will act in a sense of supplementary, and never to completely replace necessary nursing services.

Therefore, I firmly believes that rooting technological innovation into elders' home care is an answer to support their self-care and informal caregivers' welfare, but also to prevent their dependence and, thus, support older adults' independence in a home context. This doctoral dissertation is a proof of such belief, which is also defended by countless researchers in the scientific community, and it will be defended throughout this document.

1.2 Motivation

As stated previously, it is intended with this research project to conduct a study aimed at designing and developing an archetype of a novel system to assist elders' self-care and their informal caregivers through nursing homes, which main objectives are to accompany, teach, and share information between all its users. In fact, the main motivation behind this doctoral dissertation is to strengthen the communication strategies between the different elements of the target audience, that is, older adults dependent in self-care, their caregivers, and care workers and professional staff from Portuguese nursing homes.

On the other hand, the novelty of this study lies in trying to fulfill current research gaps in gerontechnology, namely:

- The current non-existence of a bridge of communication between the elderly and informal caregivers and nursing homes, which are essential social support entities that are integrated in the community;
- Gerontechnology still mostly focuses on patients with single illnesses, such as diabetes, cancer, stroke, and dementia. The proposed solutions must be broad enough to cover most individuals of the older population;
- Lack of proper clinical validation of terms and practices in current systems. They must integrate clinical competencies to ensure patients' safety;
- The current usability issues of Health Information and Communication Technology in the elderly are still not properly addressed, resulting in initial prototypes that become obsolete;
- Boosting technological innovation in nursing homes since the successful use of HICT solutions in those healthcare facilities is still currently non-existent in Portugal.

Therefore, this new system to support the elderly and their informal caregivers with the assistance of health professionals from nursing homes was mainly motivated due to the following points:

- To bridge the gap between nursing homes and the community;
- Boosting technological innovation in nursing homes;
- Support for seniors and their informal caregivers;
- Combating social isolation and loneliness of elders and their informal caregivers;
- Promoting relevant new scientific research in gerontechnology;
- Enabling innovation in home support;
- Promoting intervention in community life;
- Leisure;
- Lifelong learning;
- Improvement of housing;
- Availability of safe health resources with medical approval;
- Psychological counseling;
- Enabling safety through medical validation from health professionals;
- Facilitate mobility;
- Well-being of all the parties involved.

Thus, rooting technological innovation into elders' home environments is an answer to support not only their self-care but also to prevent their dependence and, thus, enabling seniors' independence in their homes, and enhancing informal caregivers' welfare.

1.3 Objectives

The doctoral dissertation described in this document is focused on the design and development of a system to assist elders' self-care and their informal caregivers through the support of nursing homes using emerging technologies. Therefore, a novel approach is defined with the aid of these health institutions that play a fundamental role in supporting seniors and their families in their respective local community. As defended in the previous sections, it is intended to propose an archetype that responds to critical issues faced by the elderly and their informal caregivers but also current research gaps in the scientific community.

Accordingly, the main Research Question (RQ) that supports this doctoral dissertation is as follows:

"How can Health Information and Communication Technology efficaciously assist elders' self-care and their informal caregivers through the support of nursing homes?"

Thus, after an initial survey, the set of evolving technologies chosen to be studied and used in the design and development of the proposed archetype was reduced to the following ones:

- Web-based healthcare solutions;
- Mobile Health (mHealth);
- Telenursing;
- Collaborative Learning (CL);
- Business Intelligence (BI);
- Mobile Augmented Reality (AR).

All those technologies are included in the broad area of Health Information and Communication Technology, which is the main object of study of this research project, discussed in Chapter 2 of this manuscript. Nonetheless, it is important to note that the design and development process of the proposed archetype also takes into consideration several relevant ethical issues that are discussed in detail in Section 2.7 of the same chapter.

So, based on the principal RQ, this research project can be defined by the following main objectives to be fulfilled with its realization:

1) A literature review of the state of art within the scope of this doctoral dissertation;
2) Study of the case studies, that is, Portuguese nursing homes, to collect relevant data, and elders and their informal caregivers;
3) Definition of the best research strategies, methodologies, and technologies to conduct this study based on points 1) and 2);
4) Design of the architecture of the proposed system based on points 1) to 3);
5) Design of the data repository based on points 1) to 3);
6) Design of the Business Intelligence clinical and performance indicators based on points 1) to 3);
7) Design of the mobile Augmented Reality care services based on points 1) to 3);
8) Development of the system based on points 3) to 7);
9) Preliminary simulation, deployment, assessment, and implementation of developed solution;
10) Proof of Concept of the archetype;

11) Dissemination of the Information Technology artifact to the target audience and the scientific community.

Finally, this doctoral dissertation can be summarized by the scheme presented in Figure 1.

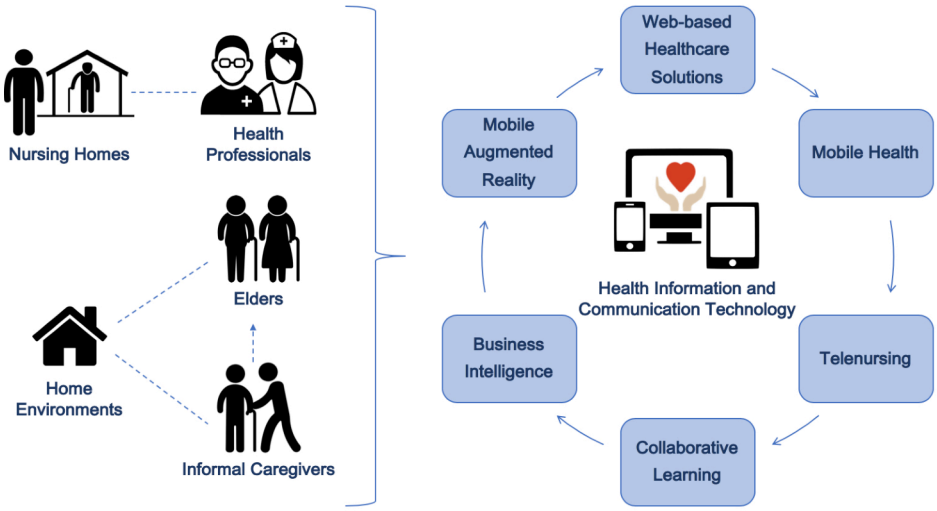


Figure 1: A general scheme of this doctoral dissertation.

1.4 Dissertation Structure

This manuscript is divided into nine different chapters, namely:

- Introduction: the first chapter of this manuscript aims to introduce the scope and contextualization of this research project, its motivation, a description of the principal objectives to be fulfilled with its realization, and the dissertation structure is presented;
- State of the Art: the theoretical and scientific concepts of major interest for this study are briefly described and discussed including Health Information and Communication Technology to support older adults, the use of Collaborative Learning to promote social interaction, the application of Business Intelligence in the healthcare industry, the innovative mobile Augmented Reality technology focusing on the ageing population, health information systems and interoperability in healthcare settings, as well as important information regarding ethical issues to take into account in the design, development, implementation, and use of healthcare solutions;
- Research Strategies and Development Tools: the overall strategy chosen to conduct this study is explained, including the set of principal methods and procedures that were followed, such as the Design Science Research (DSR) and Proof of Concept (PoC) methodologies. Information regarding data collection is also described. On the other hand, the selected technologies and their main advantages are also presented and discussed in detail;

- The Building of a Data Repository: in this chapter all the steps regarding the building of a new data repository are described, which involved the definition and creation of models, the generation of a relational database from such models and, thereafter, the loading of data into the repository with the validation of health professionals, enabling safe medical approval. Even though this data repository was built for the system presented in this manuscript, it could also be used for similar solutions;
- A New System to Assist Elders' Self-care and their Informal Caregivers: the new proposed system in this manuscript is presented and discussed in detail in this chapter. Thus, three main areas are approached, namely the MySQL database created and the Node.js Web services used to enable the sharing of data between the front-end and back-end, the React Web application, which is the main component of the system, and the React Native mobile application to complete the Web-based healthcare solution;
- Business Intelligence Clinical and Performance Indicators: the Business Intelligence clinical and performance indicators defined and created are highlighted, which present the potential to improve the quality of healthcare delivery, reduce the costs and waste associated, and provide relevant statistical data to the target audience, that is, seniors, their informal caregivers, and health professionals. Thus, all the steps from their definition to their analysis after their creation are thoroughly explained, and the processes inherent in their maintenance, that is, the periodic update of data over time;
- Mobile Augmented Reality Care Services: it seeks to present and explain the mobile Augmented Reality care services defined that should be provided to the target audience, namely elders and their informal caregivers, in order to enhance and facilitate their learning experiences. Such services were defined through a thorough data collection in order to define useful services for them;
- Proof of Concept: this chapter describes the PoC conducted for this research study through the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and the Technology Acceptance Model (TAM) methods. Therefore, the main goal of this chapter is to corroborate the feasibility and usefulness of the proposed solution by defending its potential;
- Conclusion and Future Work: it intends to summarize and present the main contributions that were achieved with the realization of this doctoral dissertation. Additionally, the next steps regarding possible future work are also addressed.

Nonetheless, this manuscript also includes three different appendix chapters:

- A questionnaire to assess current challenges, needs, and opportunities, which was used to define the proposed system;
- A questionnaire to study how the users come to accept and use the proposed system through the application of the TAM;
- A list of all the publications published during the course of this research project and all those that will be published in the near future, that is, that are awaiting publication.

2

STATE OF THE ART

This chapter introduces the state of art relevant to this doctoral dissertation. Thus, after a brief introduction (Section 2.1), the promise of Health Information and Communication Technology to support older adults (Section 2.2) is presented, which includes a discussion regarding Web-based healthcare solutions, Mobile Health, and telenursing in recent years. Next, the use of Collaborative Learning to promote social interaction is reviewed in Section 2.3. In Section 2.4, the rising use of Business Intelligence in the healthcare industry is addressed, which includes the Extract, Transform, and Load (ETL) process as well as the data warehousing technique widely used in BI solutions. Then, the use of mobile Augmented Reality focusing on the ageing population is discussed in detail in Section 2.5. On the other hand, health information systems and interoperability in healthcare settings are presented in Section 2.6. Finally, this chapter ends with a discussion regarding ethical issues in healthcare solutions (Section 2.7), which is followed with a short conclusion and discussion about this chapter in Section 2.8.

2.1 Introduction

An even brighter future approaches for the adoption of Health Information and Communication Technology. This technology presents the potential to enhance individuals' health, increase health knowledge and access to care, and improve the performance of the healthcare processes provided, namely in their efficiency, effectiveness, and in their significant reduction in cost, time, and medical error [17, 20, 21, 25, 26].

On the other hand, in recent years, an increase in the number of scientific papers published regarding the use of technologies to support the older population was observed. This situation demonstrates the current and significant interest of the scientific community in designing and developing proposals for the well-being of seniors in their home environments, in other words, "to age in place", but also their informal caregivers' welfare [16]. Nonetheless, there are relevant research gaps in gerontechnology that must be addressed and essential ethical issues that must be taken into account in the design and development process.

Therefore, in this chapter, it is intended to present the main theoretical concepts behind this doctoral dissertation, that is, the design and development of an archetype to assist elders' self-care and their informal caregivers. To do so, emerging technologies are discussed, such as Web-based healthcare solutions, Mobile Health, telenursing, Collaborative Learning, Business Intelligence, and mobile Augmented Reality, which includes delineating their advantages and disadvantages, as well as inevitable considerations that

must be considered. All these technologies were studied in order to evaluate the possibility of integrating them into the proposed Information Technology artifact. Thus, the initial hypotheses are later confirmed or denied throughout this document.

2.2 The Promise of Health Information and Communication Technology to Support Older Adults

In recent years, the adoption of Health Information and Communication Technology has been expanding dramatically [17, 25, 26]. Even though most current HICT solutions are immature, they are evolving quickly in healthcare, and a brighter future approaches [26].

HICT consists of the set of all activities and solutions provided by computational resources that allow the production, storage, transmission, access, and use of information in the healthcare industry, and enables people and organizations to interact in the digital world [21, 27, 28]. It is similar to Information Technology (IT), but emphases the role of unified communications, and focuses predominantly on the access to information through communication technologies, including the Internet, wireless networks, mobile devices, and computers, defining itself as Information and Communication Technology (ICT) [29].

It presents the potential to enhance individuals' health and increase health knowledge and access to care, as well as to improve the performance of the healthcare processes provided, namely in their efficiency and effectiveness, and in their significant reduction in cost, time, and medical errors [20, 21, 25]. HICT applications that support patient-centered communication are pointed out as being the most likely to result in improved patient experiences, patient-provider relationship, and vital communication, and in positive outcomes for patients, caregivers, and healthcare providers [25].

In the past few years, an increase in scientific publications regarding the use of technologies to support the aging population was observed, which demonstrates the current and relevant interest of the scientific community in developing proposals for the well-being of older adults in their home environments, but also their informal caregivers [16]. Nonetheless, gerontechnology has been mostly applied to reach individuals suffering from illnesses, such as diabetes, cancer, stroke, and dementia [30].

As stated previously, in this context, this doctoral dissertation emerged in a hope to ensure the care of elders dependent in self-care by promoting their independence in a home context, and, subsequently, support the remote assistance by nurses from Portuguese nursing homes to seniors and their informal caregivers by strengthening the communication strategies between the different elements of the target audience using novel technologies.

Nursing homes are public or private residential care that provide long-term personal or nursing care for people, such as older adults, who are unable to take care of themselves properly, as well as short-term rehabilitative stays. Therefore, as social support entities that are integrated in the community, they play a central role in supporting the families involved. However, the successful use of HICT solutions in those healthcare settings is currently non-existent in Portugal, and still immature in other developed countries, which is corroborated by the scarce literature on this subject. In fact, most nursing homes still use rudimentary methods, such as paper and handwritten boards and charts, to schedule and record

indispensable information of their residents, including confidential data, that is, personal and clinical information. This situation causes the tasks performed by health professionals in these facilities to be time-consuming and more prone to errors, and the risk of losing important data is higher. Additionally, oftentimes, there are not the necessary infrastructures and resources to implement those solutions in nursing homes, being far behind other types of health facilities, such as hospitals. Moreover, nursing homes are facing a critical labor shortage and most of their professionals have to work overtime and they are underpaid [31, 32]. Thus, technological innovation must be boosted in these health institutions.

Regarding older adults' acceptance of new HICT in their home environments, results could be considered surprising since they demonstrate a positive attitude towards technological solutions, but that acceptance seem to be associated with their current situation [8]. In other words, they are willing to accept and adopt technology if the benefits of using it are clear and also outweigh the cost of use [8]. Contrary to some common beliefs, elders are aware of the importance and benefits of modern technologies, showing a keen interest in learning and using advancing technologies and a good acceptance of multimedia applications such as videoconferencing and making online calls [33, 34].

Nonetheless, the obstacles linked with the effective implementation of HICT must also be addressed. Reported barriers include problems associated with use and access for older populations, which could be addressed by engaging the target audience in the design and development process of HICT solutions through focus groups, interviews, and questionnaires, and, subsequently, to assess their effectiveness and user-friendliness via usability testing in different settings [25, 29]. Findings from an iterative practice of qualitative research studies in the design and development process help to understand user requirements, attitudes, and acceptance [8]. Therefore, technology must be expressly targeted at fulfilling the needs of users.

On the other hand, in late adulthood, social isolation and loneliness issues are some of the most frequent and threatening for the independence and health of older adults [16]. Since the elderly feel easily socially excluded, many authors emphasize the importance of online social network sites, which can help to strengthen and intensify people's relationships by adding social networking capabilities [1, 2, 4, 24]. Communication technologies are important for promoting their independent living and social integration, overcoming social isolation and loneliness, and improving their health, quality of life, and safety [8, 16].

Finally, several studies show that the healthcare industry lags behind other economic sectors with regard to ICT adoption, despite a growing increase in its use, and that a great number of the proposed solutions were merely performed as pilot studies [17, 29]. Achieving the promise of HICT will require cautious efforts to ensure that it supports patient-centered communication and care processes, comprises a design and development process that is closely connected with the target audience, and integrates clinical competencies to ensure patients' safety [25, 29]. It is also believed that research to explore more thoroughly the impact of those solutions is needed [25, 29]. Moreover, they should combine the use of evolving technologies in their design and development to take full advantage of the resources available, as thoroughly discussed in the next sections and subsections of this chapter.

2.2.1 *Web-based Healthcare Solutions*

In recent years, a progressive shift from institutional to self-care and community care has been felt. In fact, most seniors prefer "to age in place". In this context, the elderly is increasingly depending on themselves and their caregivers, such as family members and friends, for support with their daily activities. Nonetheless, this situation causes oftentimes negative effects on elders and their informal caregivers, since they experience several restrictions in their social life, causing them a reduced quality of life due to social isolation. The poorer physical and mental health of caregivers when compared to non-caregivers must also be highlighted. Web-based solutions can serve as accessible platforms to support all the elements involved [30].

Thus, in these conditions, older adults and their caregivers generally resort to the Internet to find information to help with their problems and to seek peer support. In fact, it is reported that the elderly is the fastest growing group of users of the Internet in an attempt to avoid social exclusion but also to live with more autonomy [35]. Web-based applications can counteract their health and well-being declines, as well as depression and their burden, when solutions are optimally customized to their needs [30].

Relevant related work in this area includes, for instance, a Web-based videoconferencing system for rural palliative care to elders that live in their homes. This solution enables elderly patients to be provided with specialized palliative care support, which reduces the burden and expense of travel for all the individuals involved, namely patients, families, and providers, and increases providers' efficiency and productivity. However, the results of this research project enabled to conclude that technical issues can difficult its use. Additionally, the study suggests that the system is not the same as face-to-face interactions and that it should complement in-person visits to health facilities [36]. Another study worth highlighting is a website that provides elderly diabetes patients a tool to access information to assist them in making informed decisions regarding insulin initiation [35]. On the other hand, an another group of researchers designed and developed an application that enables seniors and their informal caregivers to record and manage the time of medication and medical consultations of sick individuals. Nonetheless, the biggest problem identified in this last study is the difficulty of interaction with the proposed solution [37].

In light of the above, one of the current major research gaps in gerontechnology is its focus on single illnesses, such as diabetes, cancer, stroke, and dementia, rather than being broad enough to cover the older population in its entirety. Thus, new solutions must reach more individuals of the community, considering the broad range of multiple chronic morbidities that are associated with aging. Therefore, the focus must be expanded in order to gain a better understanding of the broader gerontological context [30].

On the other hand, several studies indicate that the older population exhibits more usability problems that younger generations when it comes to the use of Health Information and Communication Technology, such as Web-based healthcare solutions. In fact, they find it more difficult to use novel technologies, showing a lower success rate when they use them, since their cognitive skills and capabilities decline considerably with age. They often encounter diverse barriers like frustration, anxiety, mistrust, and mental and physical limitations. Therefore, some considerations must be taken into account in the design and development process of these systems since it has been proved that by improving the usability of those

solutions, the efficiency of users also improves, regardless of their age [38]. However, there is few applications that are currently being designed and developed taking into account the accessibility of elderly users [39].

In spite of the above mentioned, those usability issues are mainly due to the design process of applications. Thus, researchers have been suggesting basic and necessary guidelines in order to enhance the usability, acceptability, and accessibility design of systems, particularly when they are aimed at the elderly since they have limitations linked to ageing, namely: [35, 38, 39, 40]

- Designing websites with a clear and organized hierarchy instead of non-structured websites. In fact, navigation greatly affect the user performance of seniors;
- Simplifying the graphical appearance, in other words, minimizing the information presented according to what is really needed;
- Increasing the size of buttons, icons, and the text to improve visibility and readability;
- Simplifying the graphical interface, that is, the interactions needed from users to perform a certain task;
- Colour contrast needs to be considered due to users with poor eyesight. Therefore, the colors of text and background must have a good contrast and minimize the screen brightness;
- Using simple and clear language;
- Building the pages with a consistent style.

Finally, despite the challenges posed by the advanced age and frailty of elders but also caregivers, if the current usability issues are properly addressed, the use of Web-based healthcare solutions could be feasible, acceptable, and effective in their homes [36]. Ultimately, it is intended to achieve faster development times and greater user satisfaction [35].

2.2.2 *Mobile Health*

According to World Health Organization (WHO), a critical healthcare workforce shortage crisis is affecting more than a quarter of the world's countries. As a solution, Mobile Health has been pointed out as a relatively easy and affordable solution to improve access to health services, self-management, and behaviour promotion, such as mental health, diet, and physical activity [41, 42]. In spite of its potential benefits, recent studies show that its adoption remains insignificant [41].

mHealth, which stands for the delivery of healthcare services, outcomes, and research through the use of mobile and wireless devices, is currently one of the fastest moving areas in medical informatics since evidences show that it can improve healthcare. In fact, it has been advocated for increased use in the developing world [26, 43]. On the other hand, mobile devices have been adopted globally and their adoption and use in healthcare are rapidly increasing. Indeed, the number of mobile phone users

is increasing throughout the world [41]. This situation enables mHealth to become progressively a trendy option in underserved areas, such as rural areas, in order to improve medical access in these areas and, consequently, to remove the current existing barriers to care [26].

The most common application of this technology is the use of mobile applications to educate users about preventive healthcare services. Nonetheless, it is also used for disease prevention, lifestyle changes, chronic disease management, disease surveillance, and treatment support. It can also help bridge gaps in care by allowing patients to communicate with their physicians without the need of meeting face-to-face [26, 42, 43].

However, although seniors correspond to a large group of users in mHealth, the adoption rate of mHealth applications by elderly users is relatively low when compared with their use of other more traditional health services or other user groups, such as younger user groups [44]. As a matter of fact, due to their physical and psychological characteristics, they usually spend more effort and time to familiarize themselves with Health Information and Communication Technology than younger users [44]. Factors such as technology anxiety, resistance to change, effort expectancy, and performance expectancy influence elders' behavioural intention to use this technology [41].

Nonetheless, mHealth has been pointed out as beneficial to the aging process and its adaptation should be thus further promoted [44]. In fact, since the adoption and acceptance of mHealth among elders is still significantly low, more research is needed to study their intention to adopt it [41].

A relatively recent mHealth research project is "iMHere", that is, "iMobile Health and Rehabilitation", which is a novel mHealth system to support self-care in management of complex and chronic conditions. In fact, most individuals with chronic conditions are vulnerable to secondary complications. Nonetheless, they can be prevented with adherence to self-care routines. Therefore, the main goal of this study was to develop and implement a system to support complex self-care tasks, monitoring of adherence, and secure a two-way communication between patients and clinicians [45]. On the other hand, "iCare" is a mHealth monitoring system for the elderly. It uses wireless body sensors and smartphones to monitor the well-being of elders and, consequently, offering them remote monitoring and personalized services based on their health condition. In case of an emergency, the mobile application automatically alerts individuals close to the senior [46]. Another scientific research worth highlighting is a diabetes monitoring application named "DeStress Assistant", which was supposedly developed to be suitable for older adults. However, after tests, the researchers concluded that it is too difficult to be used by the elderly. Nonetheless, their findings demonstrate that increased care must be taken in the development of mHealth applications for this target audience, that is, by trying to adapt the solutions to their needs, namely: [47]

- Involving elderly users in the design and development process;
- Taking into account the size, visibility, and comprehensibility of texts, buttons, and symbols in the applications;
- Colour contrast needs to be considered due to users with poor eyesight. Thus, the design process has to ensure that the text remains legible.

On the other hand, in healthcare settings, supplementing mobile applications with social media skills could help bring providers and patients closer together, and overcome social isolation and loneliness [8, 24, 26]. Therefore, there would be more peer-to-peer social support for patients and their caregivers. However, socialization for older adults through mobile devices has been poorly addressed [16]. The lack of proposals that integrate such capabilities highlights the current gaps worth exploring in this research area.

Therefore, the aging population's perspectives upon such technologies are primordial for the successful interaction and use of those solutions, which include factors such as their perceived usefulness and ease of use [43]. Thus, it is essential to understand the users' needs and to develop user-centered and user-friendly solutions [8]. The use of qualitative research methods such as questionnaires, focus groups, and interviews, and the iterative assessment of solutions through usability testing provide the means to better understand users' needs, perceptions, and willingness to use technology [8, 25].

2.2.3 *Telenursing*

Telenursing is a concept that can be defined as a growing technology that refers to the delivery of nursing services via remote telecommunications and Information Technology, whenever a large physical distance exists between patients and providers, in order to help achieve equitable community welfare. To do so, it focuses on using computers, internet, telemonitoring devices, and digital assessment tools, expanding the scope of nursing practice. Nonetheless, it still needs more awareness [48].

This novel technology helps to remove the barriers of geographical distance and to receive medical advice from health professionals no matter their distance to patients. Thus, it is used to provide nursing care using information and data that are obtained remotely. Its main advantage is the number of patients that can be effectively cared per nurse and, subsequently, nurses can nearly assist twice the number of patients when travel is not required. Therefore, it helps in filling the existing gap resulting from the scarcity of providers in health facilities. Telenursing is a fascinating model since it enables the decrease of unnecessary spending in a world where healthcare costs are continuously increasing [48, 49].

On the other hand, it can reduce the requirement for or the length of stays in health facilities such as hospitals or even nursing homes. Thus, in this context, elders who need frequent monitoring and assessment can be benefitted from this technology, especially those who do not have the necessary means in their homes or money to be admitted to nursing homes [50, 51, 52].

Therefore, telenursing can decrease healthcare costs and increase access to healthcare services with a more appropriate use of resources, bringing great advantages for both patients and their providers. Other advantages associated with this technology is the improvement of the quality of life, remote care services and monitoring, reducing human errors, easy access, flexible working hours, increasing response timings, and opportunity for skill development [48, 49]. However, it might also entail ethical dilemmas, less human contact, and cost of equipment, which must also be addressed [48, 52].

Indeed, it is relevant to refer that it affects the patient-provider relationship, both positively and negatively, but also unquestionably helps to overcome geographical barriers [50]. This technology can be more

convenient for patients, namely patients with limited access to providers, and allow nurses to reach many more patients by providing healthcare information to the population [50]. However, those interactions are often not as robust as face-to-face interactions, and some difficulties are often felt with nonverbal communication [26, 51]. Therefore, remote interactions should supplement face-to-face interactions and not replace them. It appears that we are forwarding up b-learning systems, which combine online and distance learning with mandatory face-to-face interactions, rather than e-learning systems where the interaction is merely done online without a real human contact. In fact, rather than being a substitute, telenursing should only complement the current existing healthcare services and, consequently, aids the implementation of telecommunication technologies in health facilities [48].

Finally, the acceptance of telenursing is still a current considerable challenge. As a matter of fact, the willingness of nurses to use this technology will only increase with time when they will have more experiences with these types of solutions. Thus, training is advised in order to facilitate its acceptance by nurses in their current healthcare pathways [48].

2.3 Collaborative Learning to Promote Social Interaction

The need in communities to think and start to work together on issues has been increasing. As a solution, Collaborative Learning is an instruction method that encompasses groups of learners working together towards a common goal such as solving a problem, completing a task or creating a product. In fact, it is a joint intellectual effort by different elements of a community through novel education approaches. They can work together in groups for mutually searching for understanding, meanings or solutions, promoting active work. Thus, learners are not only responsible for their own learning but also the learning of other members in the social support system [53, 54].

On the other hand, this educational approach involves five fundamental elements, namely positive interdependence, individual accountability, social skills, considerable interaction, and group processing [53]. Nonetheless, the following affordances must be fulfilled in order to allow the full success of the implementation and acceptance of telenursing, namely: [55]

- Flexibility of use;
- Timely feedback;
- Socialisation;
- Active participation;
- Self-evaluation;
- Cultural authenticity;
- Continuity of use;
- Personalisation;

- Peer coaching.

There are many benefits of learning in collaboration style, including supporting elders and their informal caregivers as well as promoting social interaction. Coupling CL with technology to support them can strengthen the connection between elders, their informal caregivers, and providers and, consequently, strongly enhance their learning experience [24]. Other considerable advantages include higher achievement, greater productivity, increased motivation, mutual encouragement between the different individuals of the community, engagement and enjoyment, and a significant reduction in anxiety, nervousness, and embarrassment. Nonetheless, negative aspects of this technology involve the possibility of distraction, safety concerns, and potential technical problems of the resources involved [54, 55].

On the other hand, social media has always been pointed out as a great channel through which knowledge can be transmitted between different individuals of the same community. In fact, it can be used to promote CL and social interaction, promoting learning in groups. Recent studies reported the positive influence of social media on the learning process, which can even improve the performance of learners and encourage CL. Additionally, the amount of research on the application of CL in mobile technologies has increased. Indeed, the connection between Web-based and mobile solutions and CL activities is increasingly tighter. In spite of that, those applications must be carefully designed according to the target audience to guide users to experience a more effective and pleasant learning process and, subsequently, enabling the acceptance of those solutions [56, 57].

In this context, elders and their informal caregivers can greatly benefit from CL. Indeed, this technology can even be combined with the use of online social environments to enable the communication with their peers to solve problems or even organize social events in a collaborative way, which include health professionals that can provide fundamental clinical validation. Therefore, it also allows combating the loneliness and social isolation that this group of individuals so often feel through social interaction [56].

Finally, learning through Collaborative Learning demands an active work by community members, including responsibility, persistence, and sensitivity, but the outcome is promising. In fact, the result is a community of learners in which everyone is welcome to join and the personal growth and participation of each individual are encouraged in a more caring, supportive, and committed relationships. Then, it results in a greater psychological health, social competence, and self-esteem [54].

2.4 The Rising Use of Business Intelligence in the Healthcare Industry

The concept of Business Intelligence refers to the process of collecting, transforming, organizing, analysing, and distributing data from various internal and external sources of information to improve the decision-making process [27]. It corresponds to a set of theories, methodologies, processes, structures, and decision support technologies that allows grouping data in order to make a more informed decision [58].

In this way, based on past experiences, BI transforms a large amount of raw data into useful information for an even more strategic decision-making process. It transforms information into knowledge and presents the ability to put the right information, in the right hands, at the right time [58].

BI systems correspond to the component of the architecture of an information system within an organization that supports the decision-making process by analysing data from a business [27]. Their greatest advantage is the standardization of information that is dispersed by several sources of information, and, subsequently, to access it through queries for multidimensional data analysis. In this way, using BI, it is guaranteed that everyone works with the same reality, facilitating the decision-making process. Its standardization also allows a faster access to information as well as greater reliability in data, thus generating significant gains in work efficiency, and a considerable reduction of time-waste [28, 58, 59].

Solutions that resort to BI include the application of several processes including the ETL process that handles the extraction, clean-up, normalization, and loading of data from data sources; the construction of data warehouses for structuring data in order to facilitate their analysis, in other words, data warehousing; and, finally, the visualization, analysis, and interpretation of the information represented by data [28, 58].

In Figure 2, the general framework of the BI process is demonstrated, which includes three different steps, namely: [27, 58, 60, 61, 62]

- Data Collection from internal and external data sources;
- Data Storage of those data through the construction of a Data Warehouse (DW) via the ETL process;
- Data Use that encompasses potential outcomes such as reporting, OLAP, and Data Mining (DM).

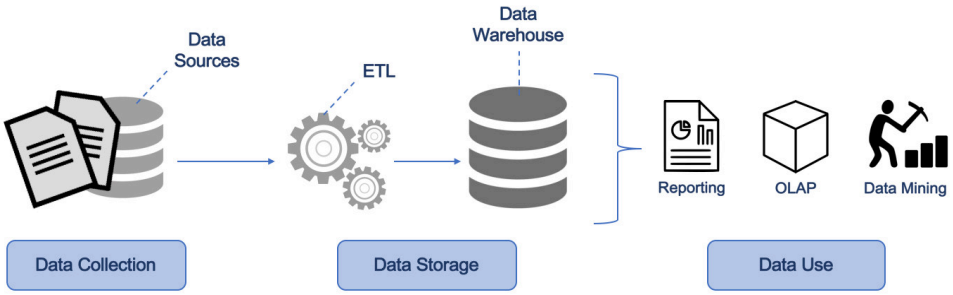


Figure 2: A general framework of the business intelligence process.

Over the past few years, BI has been increasingly a major interest to HICT professionals due largely to its great potential, which includes its applicability in the Electronic Health Record (EHR) [58]. BI solutions are now used globally to obtain useful real-time knowledge with the aim of improving the decision-making process in the most diverse scientific areas [63, 64, 65].

In the healthcare industry, more and more large amounts of structured and unstructured data have been generated, mostly due to increasingly demanding requirements to be fulfilled by healthcare settings. Those large datasets, also known as "big data", present the ability to improve the quality of healthcare delivery and reduce costs and time-waste by being able to support a wide range of functionalities, including BI [58, 59, 66]. Therefore, better maintenance and management of those clinical records are required in order to be more easily queried and analysed [27, 59, 67, 68, 69].

However, despite the evolution of BI into a promising field in healthcare, it does not have reached its full potential in health institutions, and several challenges must be overcome regarding essentially availability,

continuity, ease of use, and quality assurance [59, 70, 71]. Therefore, the health data that is expected to grow dramatically in the years ahead must be acquired, analysed, visualized, and consumed befittingly.

2.4.1 *Extract, Transform, and Load Process*

Extract, Transform, and Load is a set of processes that involves extracting data from internal and external data sources that can come in various formats, transforming them to fit business needs and, ultimately, loading them into a target data structure such a data mart or a DW [72, 73, 74, 75], being typically associated with data warehousing, which is thoroughly described in the next subsection (Subsection 2.4.2). This process is divided into three consecutive phases – "Extract", "Transform", and "Load" of data.

The ETL process is schematized in Figure 3, which includes its three consecutive phases.

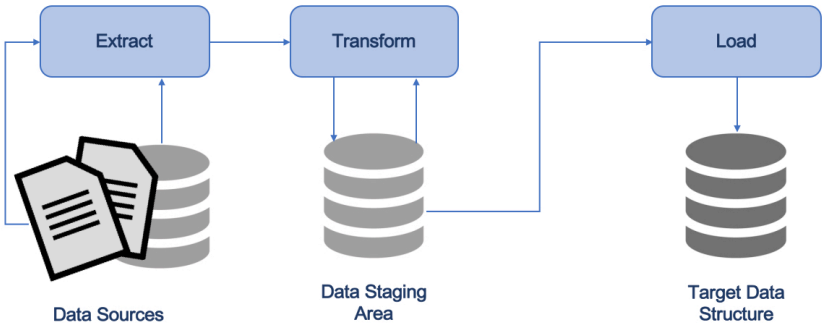


Figure 3: A general framework of the extract, transform, load process.

The three database functions are described as follows: [72, 73, 74, 75]

- Extract: corresponds to the process of reading data from specified internal and external data sources and extracting a desired subset of data. The data are then propagated to the Data Staging Area (DSA) where they are transformed and cleaned (transform step) before loaded to a repository (load step);
- Transform: transforms the extracted/acquired data by storing them into the proper format or structure for the purposes of querying and analysis, that is, cleaning them up and formatting them uniformly. Nonetheless, some data does not require any transformation at all;
- Load: loads the transformed data into the target multidimensional structure, for example, data mart or DW.

Thus, ETL is a key set of processes used to bring all the data together in a standard homogeneous environment, that is, by reshaping the relevant data from the data sources into useful information to be stored in the target data structure.

In conclusion, the ETL process is one of the most complex, critical, and time consuming step in building a DW because it involves processing large volumes of data, taking about 60-80% of the time in the construction of a DW system [74].

2.4.2 *Data Warehousing*

A Data Warehouse corresponds to a repository composed of all the data that an organization collects, which supports the decision-making process [76]. Warehoused data must be stored in a manner that is secure, reliable, and easy to retrieve and manage. Therefore, information must be stored in an optimized data structure for such tasks [77].

On the other hand, data warehousing emphasizes the collection of data from diverse heterogeneous sources through the Extract, Transform, and Load process, which corresponds to the construction of DWs and/or data marts, to usefully access and analyse data [78, 79]. The information extracted is processed, formatted, and consolidated into a unique target data structure to facilitate essentially the analysis of data [78, 79].

Due to the high cost of data warehousing, a DW is often divided into smaller parts, namely data marts [77]. Generally, a data mart is a subset of the DW that it is usually oriented to a specific department or line of business, in other words, it is basically a small slice of the DW. Data marts typically contain data required for specific departments or business processes. Thus, it serves the same role as a DW, which applies to an entire organization, but it is intentionally limited in scope [77].

A general framework of the data warehousing process is portrayed in Figure 4.

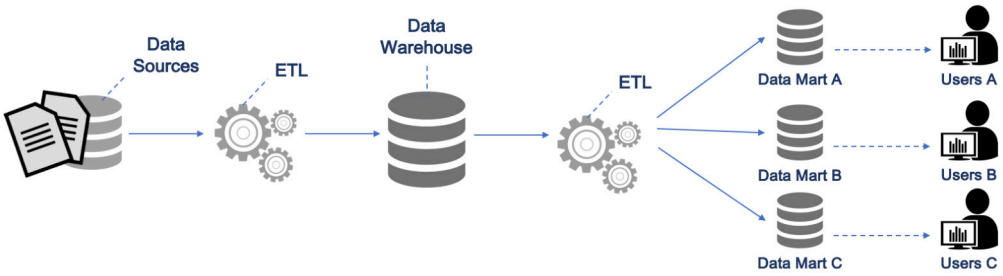


Figure 4: A general framework of the data warehousing process.

On the other hand, DWs present their information organized according to the dimensional model chosen, existing different types. Nonetheless, the most common are the "star schema" and "snowflake schema" for modelling a DW [80, 81].

In the star schema, the "dimension tables" are directly connected to one central table named "fact table". The connections between the fact table and dimension tables are made between the primary keys of the dimension tables and the foreign keys of the fact table. Summing up, the dimension tables contain the description of the facts measured and saved in the fact table [80, 81].

Regarding the snowflake schema, due to normalization questions aimed at reducing the space occupied by dimension tables, some dimensions are not directly connected to the fact table but they are rather connected to other dimension tables. Thus, dimension tables are also connected to the fact table. However, the connection might not be done directly but rather by auxiliary dimension tables that normalize the main dimension [80, 81].

Therefore, the snowflake schema reduces the space required to store the data but increases the complexity of the model by having more tables than a DW built and supported by the star schema. As the complexity of the model increases and, consequently, the number of connections between the tables, data access through queries is slower in the case of the snowflake schema. Thus, it is easier and faster to extract information from data organized based on the star schema than on the snowflake schema, and, additionally, it is more advantageous to use it by providing faster and simpler data access. The use of the snowflake schema in the construction of a DW is only justified when its use compensates for the loss of speed and ease of data access when compared to the space occupied by data [80, 81].

Finally, it is relevant to refer the existence of another type of dimensional model, namely the "fact constellation schema" also known as "galaxy schema". This schema, unlike the star and snowflake schemas, is a collection of multiple fact tables that share dimension tables between them. It is a very widely used type of schema that is more complex than both types of schema previously referred but, on the other hand, it is also considered a very flexible schema for implementation. Nonetheless, its use is required for more sophisticated solutions even though this type of schema can be harder to maintain and support [80, 81].

2.5 Mobile Augmented Reality Focusing on the Ageing Population

Developments in computing technology have led to the creation of novel technologies, such as Augmented Reality. AR can be defined as the integration of digital information with the user's environment, that is, an enhanced version of the existing reality in order to make it more meaningful through the ability to interact with it [82, 83, 84]. Unlike Virtual Reality (VR), which creates a simulated environment through digital recreation, AR delivers virtual elements as an overlay to the real world [83]. In other words, it is an emerging technology that consists on the superimposition of images or animations over an image captured by the digital camera of a device [34].

The ubiquity of mobile devices has raised awareness and usage of AR, and its popularity is growing incessantly [85]. It is integrated into applications and the result can be viewed through mobile devices, such as smartphones and tablets [82]. Generally, using a mobile device, users scan a target image with the camera through an AR+ application. When the application recognizes the target image, it overlays pre-programmed virtual objects on top of the target image on the mobile device display, enabling the user's interaction with the outcome in the real world [85]. A general summary of this process is outlined in Figure 5.

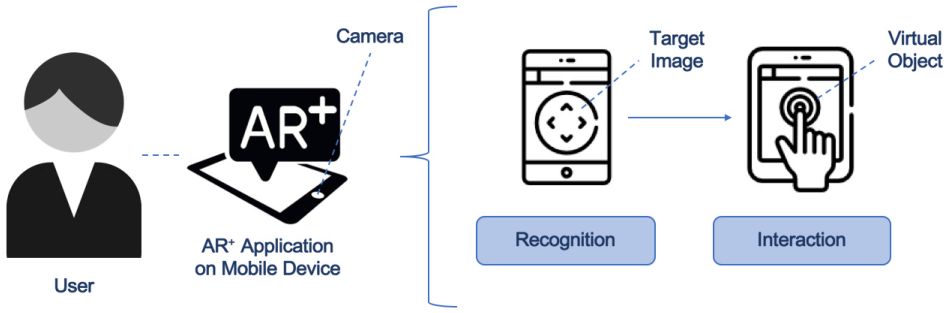


Figure 5: A general overview of the use of an Augmented Reality application on a mobile device, such as smartphones and tablets, by a user.

In developed countries, evidence shows a growth of elderly mobile users, and thus the possible trends of using AR solutions to support them [33, 86], but it is crucial serving users in terms of usability [87]. Contrary to some common beliefs, seniors are aware of the importance and significant benefits to be gained of modern technologies, showing a keen interest in learning and using advancing technologies [33, 34]. In fact, elders show a good acceptance of solutions that complement their daily activities. Those applications have the potential to promote social interaction, but also stimulate the cognitive skills and capabilities in the older population, thus improving their autonomy and quality of life. Moreover, several studies mention how important it is for this age group to stay in contact with other people, such as friends and family members, which can prevent social isolation [34].

Related work includes, for instance, a mobile AR application that reminds, motivates, guides, and tracks hydration in seniors with dementia, which is associated with numerous negative health outcomes that can often result in a burden for caregivers. Thus, it is a reminder system designed to increase hydration in older adults [88]. Additionally, another study involved the design and development of a mobile application to help elders diagnosed in the early stages of Alzheimer's disease to identify objects and people through AR features. It also enables caregivers to track the location of their patients through the solution [89]. It is also worth highlighting a research project entitled "Smart Assist" that proposed an AR application for drug compliance for seniors and people with special needs, providing a solution that enables them to easily and flexibly manage their medication [90].

Nonetheless, although the adaptation of Information and Communication Technology has been pointed out as necessary for the elderly, the proposed solutions must be customized and scaled according to the target audience so they will indeed use and accept the technology. In fact, in spite of the recognition of the relevance and usefulness of those applications, they often feel discouraged or intimidated by modern technologies when they are not adapted to their needs and capabilities [34]. Additionally, tests on large-scale setups are needed to achieve an in-depth analysis [90].

On the other hand, the use of mobile technology is here to stay [91, 92, 93]. Even though AR is still in its early stages of application within healthcare education, due to the incessant progress of mobile devices, it is growing rapidly since its integration into mobile devices makes contact with Health Information and Communication Technology and digital facilities a more pleasant and natural experience [34, 86, 94]. Moreover, the use of AR in education to create Collaborative Learning experiences has also been

progressively increasing [85]. However, frequently, choosing the correct device for each patient can still be considered a difficult mission [87].

Nevertheless, there is currently a lack of solutions using Augmented Reality for addressing older population's requirements and experience, despite its enormous potential for promoting learning in healthcare, that is, its advantages when used in educational settings [7, 86, 94, 95]. Most of those potentially related studies assessed report initial prototypes, they do not integrate clinical competencies to ensure patients' safety, and their contribution and impact are merely analysed [94, 95]. In fact, numerous studies have indicated that AR can enhance the learning performance of learners in educational settings. However, the most reported challenge is that it can be rather difficult for the target audience to use, mostly in location-based AR applications. On the other hand, different studies reached conflicting conclusions regarding if AR decreases cognitive load or causes an overload [95].

Finally, although there is an increasing expectation that integrating AR in mobile solutions will make the contact of users with ICT and facilities a more pleasant and intuitive experience, more progress is needed to enhance its positive prospect. Advances in visualization and portable technology are essential to reach the promised potential of AR, that is, improving the experience of most individuals of society, regardless of their age. Therefore, a more prominent technological evolution is required in mobile devices, more efficient image recognition algorithms, and smart glasses that are smaller, more portable and comfortable, and cheaper that can be used instead of mobile devices to offer optimized AR features. In fact, mobiles devices, such as smartphones and tablets, require constant interaction and manipulation, which can make them unsuitable depending on the type of content delivery intended, as well as the target audience at hand. Although these technical limitations must be amended, the expected technological developments should improve the utility of AR in the near future [34, 95].

2.6 Health Information Systems and Interoperability in Healthcare Settings

A Health Information System (HIS), which corresponds to a subcategory of an Information System (IS), is implemented to manage administrative, financial, and clinical activities and processes in healthcare settings [96].

Therefore, HISs are complex computer systems designed to facilitate the management of administrative, financial, and clinical information of a health institution, which includes clinical records. They make it possible to reduce costs and time-waste, improve the quality of healthcare delivery, and encourage evidence-based decision making [97, 98, 99, 100].

In recent years, the implementation of HISs is progressively increasing in the healthcare industry. However, there is still a small number of health institutions that have reached a level of implementation and sufficient maturity to allow the complete communication and sharing of structured information among all health professionals within their units [97, 99, 101, 102, 103].

The main barriers highlighted are the heterogeneity of the activities, tasks, and health professionals involved, the diversity of the structure of organizations, and the complexity and difficulties in the adoption and management of changes in healthcare settings [96, 97, 103].

Nevertheless, the implementation of HISs is increasingly considered a mandatory requirement in health institutions by medical decision makers, since it offers many benefits to those healthcare settings by serving as a repository of health information in the storage and management of clinical data [97]. Their implementation allows the automation of clinical data maintenance and management activities and, therefore, improving information storage and retrieval, reducing waiting and response times, and increasing the efficiency and effectiveness of the professionals involved in those activities [100, 101, 102].

Nowadays, with the continuous growth of clinical information registered in HISs, one of the major concerns in medical informatics is to ensure interoperability between different ISs in healthcare settings [104, 105]. Thus, interoperability is increasingly considered a requirement for HISs rather than an option to implement adequate communication, sharing, and cooperation between systems [106].

The concept of interoperability can be defined as the ability of a system to communicate and share information with another system that arises to overcome the heterogeneity and distribution of several different sources of information [104, 106]. In the healthcare industry, the main goal of interoperability is to connect applications and data so that they can be shared across the entire organization and, subsequently, disseminated by health professionals [104, 106].

Thus, in this context, comes the need to implement dynamic platforms, for example, multi-agent systems, that allow the access and sharing of information between different ISs, in order to connect them, standardize distributed Clinical Decision Support Systems and, therefore, reduce the delays normally generated in the information sharing process [107].

2.7 Ethical Issues in Healthcare Solutions

As mentioned throughout this chapter, Health Information and Communication Technology, Web-based healthcare solutions, Mobile Health, telenursing, Collaborative Learning, Business Intelligence, and mobile Augmented Reality, among other technologies, provide several advantages for the healthcare industry, namely enhancing elders' and their informal caregivers' quality of life. However, despite the benefits that these technologies can offer, some ethical issues may arise from their use in healthcare solutions, which must be discussed.

Therefore, one of the main problems for many individuals is the fear that the confidentiality, privacy, and protection of personal data are compromised [108, 109]. This situation can become problematic mainly due to the the laws currently in force and the measures implemented to safeguard the privacy and protection of data. On the other hand, issues related to privacy are also considered as critical for older adults themselves. However, they are ready to comprise their wishes if the use of technology is beneficial compared to the disadvantages associated [6].

It is also relevant to note that some individuals may be hesitant to use emerging technologies in healthcare settings mainly due to the fear that they could replace health professionals and services, causing the removal and, consequently, the absence of face-to-face and direct contact of patients with health professionals [108, 110]. So, the fear of losing human contact and social interaction is referred by a lot of elders since genuine contact with another individual could never be entirely replaced by technology [6]. Moreover,

this situation can also cause harm to patients if they and their situation are not properly evaluated, the care services provided are inaccurate and inappropriate, and if the senior and/or their informal caregivers cannot properly provide the necessary care. Visits by human beings close to the patients, including family members, friends, and health professionals, are essential for them to feel as if they belong to the community [6]. Thus, technology cannot replace these genuine interactions but only enhance and complement them.

Another issue pointed is the fact that many health solutions based on these new technologies are currently being made and used without having a thorough knowledge of their accuracy and associated risks [109]. Thus, some health professionals are still cautious about them, since they can lead to errors that can impact the patients' quality of life negatively. Therefore, medical validation is necessary in order to provide safe information to users.

Nonetheless, although using innovative technology can bring freedom and independence to the elderly as well as decrease feelings of loneliness, giving them a possibility to live longer in their home environments, concern and fear is pointed out as another ethical issue. Older adults and informal caregivers can be concerned about their ability to use new HICT solutions, in other words, there is the possibility of difficulties in understanding such applications [6]. Thus, the solutions designed and developed must be user-friendly in order to facilitate their learning process and, consequently, ensure their positive usability.

Finally, these points suggest that several considerations must be taken into consideration when implementing HICT solutions. Therefore, this doctoral dissertation has taken into consideration these ethical issues and appropriate measures are being followed and implemented in an attempt to counteract them.

2.8 Conclusion

In this chapter, a survey of the potential technologies to use in the development of the proposed solution was performed. Therefore, some technologies were studied in order to evaluate the possibility of using each in the development of the system, namely Web-based healthcare solutions, Mobile Health, telenursing, Collaborative Learning, Business Intelligence, and mobile Augmented Reality.

The study conducted enabled to conclude that the healthcare industry lags behind other economic sectors with regard to Information and Communication Technology adoption, despite a growing increase in its use, and that a great number of the proposed solutions were merely performed as pilot studies. Its success depends on the support of patient-centered communication and care processes, a design and development process that is closely connected with the target audience, and it must integrate clinical competencies to ensure patients' safety.

In this context, Information Technology artifacts aimed at the elderly and their informal caregivers must be user-friendly in order to facilitate their learning process and, consequently, ensure their positive usability, since they often feel discouraged or intimidated by modern technologies when they are not adapted to their needs and capabilities. Thus, the proposed solutions must be customized and scaled according to the target audience so they will indeed use and accept the technology. Researchers have been suggesting

basic and necessary guidelines in order to enhance the usability, acceptability, and accessibility design of systems, particularly when they are aimed at the elderly since they have limitations linked to ageing.

Additionally, it was concluded that the use of qualitative research methods such as questionnaires, focus groups, and interviews, and the iterative assessment of solutions through usability testing provide the means to better understand users' needs, perceptions, and willingness to use technology.

Finally, fundamental ethical issues must be taken into account, such as if the confidentiality, privacy, and protection of personal data are compromised, the fear of losing human contact and social interaction by using novel technologies, using solutions that were developed without having a thorough knowledge of their accuracy and associated risks, and the overall concern and fear of using technology by the intended target audience.

3

RESEARCH STRATEGIES AND DEVELOPMENT TOOLS

This chapter intends to highlight the main research strategies selected to conduct this study and the development tools used for its development. To do so, this chapter starts with a short introduction (Section 3.1), which is followed by a description regarding the Design Science Research methodology (Section 3.2). Next, the selected technologies and their main advantages are described in detail in Section 3.3, namely MySQL Relational Database Management System (RDBMS) (Subsection 3.3.1), Node.js JavaScript runtime environment (Subsection 3.3.2), React JavaScript library (Subsection 3.3.3), React Native JavaScript framework (Subsection 3.3.4), Vuforia Augmented Reality SDK (Subsection 3.3.5), and Unity3D Game Engine and Integrated Development Environment (IDE) (Subsection 3.3.6). On the other hand, the Kimball Lifecycle methodology is addressed in Section 3.4, which is followed by the Proof of Concept methodology in Section 3.5 that includes two subsections, namely Strengths, Weaknesses, Opportunities, and Threats analysis (Subsection 3.5.1) and Technology Acceptance Model (Subsection 3.5.2). Finally, this chapter ends with a short conclusion in Section 3.6.

3.1 Introduction

The choice of the most adequate research strategies to follow and the development tools to use in the design and development process of a solution is an inevitable step in any Information and Communication Technology research project. In fact, it is an essential subsequent phase after the initial definition of the problem identification and motivation. A consistent methodological approach enables to structure and organize research methods since it determines the skeleton of decision-making and problem solving.

Therefore, this doctoral dissertation is sustained by a set of principal methods and procedures in order to have standards to follow along with an organized path. After identifying and analysing the options available, the choices made were considered the most efficient way to attain the objectives projected, that is, the design and development of a novel system to support elders' self-care and their informal caregivers using emerging technologies. The aim is to propose an archetype for the problem at hand taking into account current research gaps in gerontechnology that must be inevitably addressed.

First, the main research methodology that is being followed is Design Science Research since is it suitable for rigorous ICT research projects as is the study that is described in this document.

Moreover, it is predominantly being conducted through a pragmatic perspective – the philosophy of pragmatism – where the focus is on practical applied research, combining different perspectives to help interpret the data. This philosophy defends that a researcher can adopt both objective and subjective points of view. Thus, observable phenomena and/or subjective meanings can provide satisfactory knowledge. The diversity in the data collection techniques chosen for this study reflects such choice.

Based on the case study research method, ethnography, and a cross-sectional study, an up-close and detailed examination of several subjects of study (the cases), as well as their related contextual conditions, at specific points in time, was conducted. Thereby, the objective is to examine multiple nursing homes to gather a diverse set of information in order to design and develop a universal archetype suitable for a maximum number of similar healthcare settings. Five different nursing homes that are integrated in a Portuguese social entity were studied.

Regarding the target audience, the elderly, their caregivers, and care workers and professional staff working in the nursing homes were studied through a cross-sectional study. No specific age range was aimed since it is not pertinent for this research project. Non-probability and subjective sampling techniques were applied because the size of the samples is ambiguous. The techniques used include purposive, own-selection, and convenience samplings.

On the other hand, case studies can encompass both types of research methods – qualitative and quantitative. This study is based on mixed methods research, that is, different research methods are used separately or combined to collect and analyse data. Therefore, different types of quantitative and qualitative research methods are used to collect and analyse quantitative and qualitative data. Nonetheless, this project is mostly sustained by qualitative data.

Data collection includes predominantly primary data via participant observation, focus groups, semi-structured interviews, and self-administered or interviewer-administrated questionnaires, that is, surveys. Furthermore, secondary data supported by a literature review that principally cover material from primary (theses and conference proceedings) and secondary (journals and books) sources were also collected through archival research. Thus, this collection of information involves nursing homes and their related contextual conditions, the elements of the target audience, and scientific manuscripts from research databases and search engines.

Thereafter, through grounded theory, the generation of new theories and models was possible based on the quantitative and qualitative data gathered and analysed, mainly of an archetype. Therefore, it is supported by an inductive approach since the development of those theories and models could only appear after gathering and analysing the data, which are later related with the literature. However, this scientific project also followed a deductive approach since it is very difficult to conduct a solid and reliable study, which depends strongly on the case studies, merely relying on an inductive approach. The risk associated with the inductive approach is high. Thus, the realization of this doctoral dissertation is based on a literature review of the state of the art. Therefore, departing from existing theories, hypotheses are developed and, consequently, a research strategy is designed to test those hypotheses based on a deductive approach.

Additionally, evaluation methods performed include usability testing of the system through an iterative process by different user types and, through a cross-sectional study, a Proof of Concept to corroborate

its feasibility and usefulness, that is, to evaluate the impact of the archetype. Unfortunately, since there was not enough time to conduct this study over a long period of time by being a doctoral dissertation, a longitudinal study was not viable.

Lastly, it is also fundamental to refer that ethical issues are safeguarded through sensitivity, confidentiality, and anonymity guarantees to all the participating organizations and individual participants.

Finally, in this chapter, each research strategy and development tool chosen is presented and discussed. The reasons behind their selection are explained in the next sections.

3.2 Design Science Research Methodology

In the area of Information Technology, the main objective of using the Design Science Research methodology is the construction and evaluation of objects, also known as "artifacts", which allows professionals to process organizational information and take action when facing a specific problem [111, 112].

Thus, the research methodology that drove the realization of this doctoral dissertation is the DSR methodology. It is a rigorous method of scientific research used to develop successful artifacts [113]. It focuses on the IT artifact with a high priority on its relevance in its application domain. Thus, in the context of solving business problems in the real world, it is critical to try to improve the relevance and usefulness of the artifact [114, 115]. The designed artifact must correspond to a viable technology solution for solving important and relevant business problems, and its usefulness, quality, and effectiveness must be rigorously demonstrated through well-executed assessment methods. In addition, research should provide clear and verifiable contributions, and also be based on the application of rigorous methods in its construction and evaluation process [114, 115].

Figure 6 outlines the DSR methodology, that is, its different interconnected steps that summarize the steps to be followed through DSR in the construction of scientific IT artifacts, namely "Problem Identification & Motivation", "Definition of the Solution's Objectives", "Design & Development", "Demonstration", "Evaluation", and "Communication". These are the phases that were adopted for the realization of this doctoral dissertation.

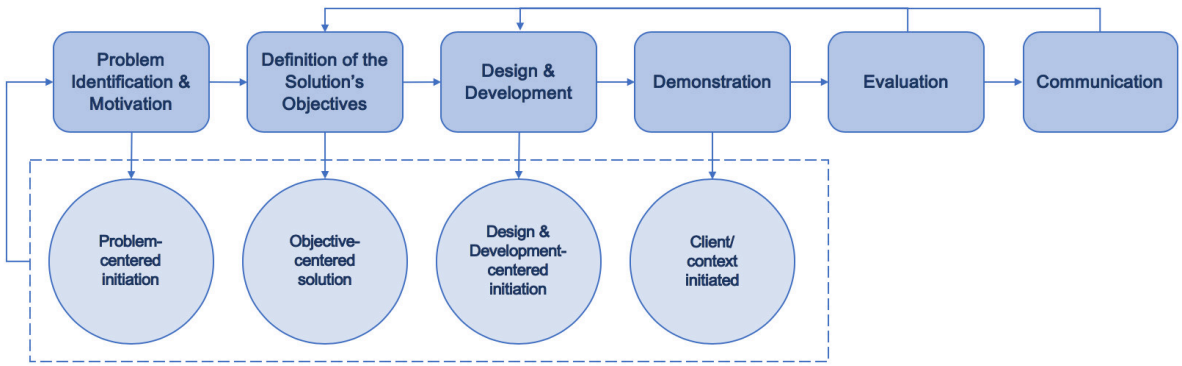


Figure 6: Schematic representation of the steps encompassed in the Design Science Research methodology (adapted from [113]).

In short, in the first steps, the problem and motivation are defined, as well as the objectives of the solution found. Then, the artifact is designed and developed, which addresses an important unresolved business problem that should be relevant to its solution. Its development must follow a rigorous scientific process based on the knowledge and theory already explored. Finally, the solution must be efficiently demonstrated, evaluated, communicated, and propagated to the target audience [111, 116].

Thus, the research project described in this document follow the DSR methodology because each IT solution found for each problem meets the current needs of elders dependent in self-care and their informal caregivers, that is, a new system to support them with the aid of health professionals from Portuguese nursing homes, in accordance with the challenges currently faced by them, which were investigated in theory and in the field. On the other hand, it also intends to respond to current relevant issues in the scientific community regarding the design and development of innovative solutions for the elderly and their informal caregivers that use emerging technologies.

In this way, this doctoral dissertation provides and describes appropriate and well-founded solutions to the target audience, which were supported by methods and technologies already explored and appropriate to solve the problem in question. On the other hand, it also encourages new knowledge, both for the organization and at scientific level. Thus, the realization of this research project also included the dissemination of the IT artifacts to the target audience, as well as the writing of scientific papers (Appendix C).

Finally, it is important to note that the system designed and developed has been properly assessed through a Strengths, Weaknesses, Opportunities, and Threats assessment. A usability study of the proposed solution was also carried out by preparing a questionnaire for the target audience based on the Technology Acceptance Model. Thus, it is noteworthy to refer that the Proof of Concept methodology was carried out in order to prove the feasibility, usefulness, and usability of the system, which included conducting a SWOT analysis and a usability study through TAM, succinctly described in Chapter 8 of this manuscript.

3.3 Selected Technologies and their Main Advantages

This section presents a brief description of each technology chosen to develop the proposed system, as well as their main advantages, which justify the choice made concerning their use.

3.3.1 *MySQL Relational Database Management System*

Every Web application must be supported by a good relational model and Relational Database Management System, the so-called "back-end" or the model component of the Model-View-Controller (MVC) view.

MySQL is a free-to-use open source RDBMS maintained by Oracle Corporation since 2010 and currently the world's most popular RDBMS on the Internet [117, 118]. There are a few features that make this RDBMS a perfect match for this research project. The website "DevOps.com" [119], which has the largest collection of original content related to DevOps on the Web, indicates that data security, on-demand scalability, a high

performance due to the storage-engine framework, and flexibility of the free open source are some of the features that most contribute to the success of MySQL.

In the context of this doctoral dissertation, the free open source and high-performance aspects of MySQL and past successful experiences with this RDBMS in other research projects influenced a lot its choice. On the other hand, when dealing with healthcare data, data security is an important subject that must always be considered and guaranteed. Thus, without doubt, the MySQL RDBMS revealed to be a good alternative and was, therefore, chosen for the development of the Web and mobile applications.

3.3.2 *Node.js JavaScript Runtime Environment*

In order to build the Web services of both the Web and mobile applications and allow the sharing of data between the front-end, that is, the Web and mobile applications, and the database, Node.js was chosen. Briefly, Node.js is an open source JavaScript runtime environment that enables the execution of JavaScript code in contexts other than in the browser [120].

According to the websites "DevOps.com" [121] and "ThinkMobiles.com" [122], Node.js is an excellent option for the development of applications, mainly because of its high performance since it uses the Google V8 engine to compile JavaScript code and non-blocking asynchronous behaviour, thus leading to faster execution of the code. Moreover, Node.js can easily be learned and is highly extensible [123, 124].

Therefore, the mentioned benefits combined with the fact that React and React Native were chosen to develop both applications, are the main reasons Node.js was chosen to build the Web services since it allows the front-end and back-end code to be both written in the same programming language, that is, JavaScript, making the development of the applications a lot easier and faster.

On the other hand, the main Node.js packages used to develop the Web services are as follows:

- bcrypt: this library enables to hash passwords;
- body-parser: this is a Node.js body parsing middleware. It enables parsing incoming request bodies in a middleware before the handlers and, consequently, it is available under a property, that is, req.body;
- concurrently: this package permits to run multiple commands concurrently. In this case, it is used to run the front-end and back-end simultaneously;
- dotenv: it loads environment variables from a .env file into process.env. In this case, the database configuration, that is, confidential data;
- express: it is a minimal and flexible Node.js application framework that provides an interesting set of features to develop the applications, enabling an easy and fast development. The features provided by this module include a robust routing focused on high performance;
- jsonwebtoken: this module enables the implementation of JSON Web Token (JWT);

- moment: it is a lightweight JavaScript date library for parsing, validating, manipulating, and formatting dates;
- morgan: it is a HTTP request logger middleware for Node.js;
- mysql2: it is a fast MySQL driver with focus on performance;
- sequelize: it is a promise-based Node.js Object-relational Mapping (ORM) that has compatibility with a vast set of different types of databases, including MySQL, which is described in more detail in Chapter 4.

3.3.3 *React JavaScript Library*

React is a JavaScript library for the development of interfaces maintained by Facebook in collaboration with Instagram [125]. Created in 2013, the main feature of this library is the possibility of creating large Web applications that can change over time without reloading the whole page. In the Model-View-Controller pattern, React corresponds to the view (V) being, therefore, responsible for processing an User Interface (UI) [126, 127, 128].

The renowned blog "PTC – PRO-TeK Consulting" points out that the advantages of using React to develop a Web application are: [129]

- Efficiency – enormous flexibility and amazing gain in performance;
- Makes writing code in JavaScript easier by using a special syntax called JSX, which allows mixing HTML with JavaScript;
- Has "out-of-the-box" developer tools;
- Awesome for Search Engine Optimization (SEO);
- Easy to test.

The combination of the advantages mentioned above with the fact that the UI code is readable and maintainable [129] made choosing this library for the development of the Web application an easy choice.

The main modules used in the development of the Web application are the following:

- antd: this package is an enterprise-class UI design language and React UI library with a set of high-quality React components;
- axios: it is a promise-based HTTP client for the browser and Node.js;
- react-color: this module offers a vast set of color pickers;
- react-player: it is a React component for playing a Uniform Resource Locator (URL), which is used in the Support Resources module for displaying videos;

- react-router-dom: DOM bindings for React Router, which is a declarative routing for React;
- recharts: it is a redefined chart library built with React and D3 that helps writing charts in React applications easily;
- redux: this library is a predictable state container used for Javascript applications, which is mostly used in applications where reasonable amounts of data are changing over time. It enables the definition of a single source of truth, avoiding approaches that keep everything in a top-level React component's state;
- react-redux: performant and flexible React bindings for Redux;
- redux-thunk: thunk middleware for Redux that allows writing action creators that return a function instead of an action, handling the dispatching itself;
- redux-persist: this module persists and rehydrates a Redux store.

3.3.4 *React Native JavaScript Framework*

React Native is a JavaScript framework that allows the building of native mobile applications using the same design as React [130]. In 2015, the developers of React, that is, Facebook, announced the development of a new framework called React Native, which allows React to render natively on mobile platforms, such as iOS and Android [131, 132, 133].

Once again, the blog "PTC – PRO-TeK Consulting" mentions the main benefits of using React Native to build native mobile applications [134, 135]. These advantages combined with the ones that are presented in the Facebook GitHub website for React Native are as follows: [130]

- The possibility of using the same code to deploy on both Android and iOS, thus saving time while developing the application;
- It has a "live-reload" feature that allows reloading the application instantly after changes are made instead of recompiling it and, thus, saving time;
- It is UI-oriented and the UI is highly responsive;
- It has an intuitive interface, such as React, which makes the development of mobile applications a lot easier;
- It is compatible with third-party plugins;
- It has high performance in mobile environments.

The mentioned advantages, combined with the fact that React was already chosen to develop the Web application, made choosing this framework to build the mobile application the obvious choice since there

is no need to learn other programming languages, such as Swift or Java, as JavaScript is used for both React and React Native as well as Node.js, which is used to develop the Web services.

Regarding the main packages used to develop the mobile application, they are as follows:

- formik: it is a small library that simplifies the building of forms in React, namely by getting values in and out of form state, validation and error messages, and handling form submission;
- native-base: it is an essential cross-platform UI components for React Native that enables using any native third-party libraries out of the box;
- react-native-elements: this module is also a cross-platform React Native UI toolkit, which is used to complement the native-base package;
- react-native-color-picker: it is a React Native implementation of a color picker;
- react-native-image-picker: this module allows developers to use native UI to select media from the device library or directly from the camera;
- react-native-navigation: it is a simple native navigation library;
- react-native-vector-icons: it is an easy library to extend, style, and integrate, which provides thousands of icons perfect for buttons, logos, and navigation and tab bars;
- react-native-video: this package enables playing videos inside React Native applications;
- yup: it is a JavaScript object schema validator and object parser that simplifies the validation of data, including forms.

Additionally, other modules such as axios, redux, react-redux, and redux-thunk were used in the development of the mobile solution. They are presented and explained in Subsection 3.3.3 since they were also used to develop the Web application.

3.3.5 *Vuforia Augmented Reality SDK*

There are two types of Augmented Reality applications: the marker-based supported by image recognition and the location-based that uses the Global Positioning System (GPS), accelerometers, and digital compasses to establish the location and create AR objects. The first scenario is simpler since it uses the camera of the device to detect a certain pattern or marker (for example, QR codes or images) and, afterwards, it overlays the digital information.

The first step in the development of an AR application is the choice of the Software Development Kit. According to the website "UpWork", several criteria must be considered, namely: [136]

1) Type of licence;
2) Supported platforms;

3) Smart glasses support;

4) Unity support;

5) Cloud recognition;

6) 3D recognition;

7) Geolocation;

8) Simultaneous, Localization, and Mapping (SLAM).

A list of popular AR SDKs can be assembled from the Web pages [136, 137], which are compared in Table 1, where "1" stands for type of licence, "2" for supported platforms, "3" for smart glasses support, "4" for Unity support, "5" for cloud recognition, "6" for 3D recognition, "7" for geolocation, "8" for SLAM, "F" for free, "FOS" for free and open source, "C" for commercial, "A" for Android, "W" for Windows, "UWP" for Universal Windows Platform, and "L" for Linux.

Table 1: Comparison between the most popular Augmented Reality SDKs where "1" stands for type of licence, "2" for supported platforms, "3" for smart glasses support, "4" for Unity support, "5" for cloud recognition, "6" for 3D recognition, "7" for geolocation, "8" for SLAM, "F" for free, "FOS" for free and open source, "C" for commercial, "A" for Android, "W" for Windows, "UWP" for Universal Windows Platform, and "L" for Linux [136, 137]

	Vuforia	**Wikitude**	**EasyAR**	**Kudan**	**ARToolKit**	**Maxst**	**ARKit**	**XZIMG**
1	F, C	C	F, C	F, C	FOS	F, C	F	F, C
2	A, iOS, UWP	A, iOS	A, iOS, UWP, macOS	A, iOS	A, iOS, L, W, macOS	A, iOS, W, macOS	iOS	A, iOS, W
3	Yes	Yes	No	No	Yes	Yes	Yes	No
4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	No	No	No	Yes	No
6	Yes	Yes	Yes	Yes	No	Yes	Yes	No
7	Yes	Yes	No	No	Yes	No	Yes	No
8	No	Yes	Yes	Yes	No	Yes	Yes	No

From the analysis of Table 1, SDKs with only commercial releases are no good for the development of this research project, so Wikitude is out. Another important point is the potential future adaptation of the AR application to smart glasses, which, therefore, eliminates the SDKs EasyAR, Kudan, and XZMIG. On the other hand, in the first stage, the solution is being designed for Android devices – the world's most popular mobile operating system, which leaves ARKit behind. Between the Vuforia and Maxst SDKs, only

the first one uses geolocation, which is an even more important aspect than SLAM since it is essential for location-based applications. Another important factor is the capability of Vuforia to store the markers on the cloud, unlike ARToolKit. Additionally, since the release of Unity 2017.2, Unity3D integrates the Vuforia engine, making it even easier to create AR solutions. Therefore, the best choice is the Vuforia SDK.

As stated previously, Vuforia is an AR SDK for mobile devices that enables the development of AR applications. In short, it uses computer vision techniques to recognize and track planar images such as ImageTargets and VuMarks, and 3D objects, in real time [138, 139, 140]. Therefore, it supports a myriad of 2D and 3D target types.

VuMarks is the next generation bar code, delivering AR experiences on any object and allowing freedom for a customized design. When compared with the standard ImageTargets, both have the same basis and are recognized and tracked by the Vuforia SDK. Nonetheless, the advantages of VuMarks are: [141, 142]

- Capability of presenting millions of unique instances of a VuMark;
- Capability of encoding a variety of data formats;
- Possibility of differentiating among identical looking products based on their instance ID.

Some of their use cases comprehend the identification of parts and equipment, as well as precisely register service and operations instructions to the areas and surfaces they pertain to [141, 142]. By the objectives of this study, the VuMark solution is ideal and easy to implement.

3.3.6 *Unity3D Game Engine and IDE*

According to Pietro Polsinelli, Unity3D is a cross-platform game engine with a built-in Integrated Development Environment developed by Unity Technologies [143]. It supports the development of applications for Web plugins, desktop platforms, consoles, and mobile devices.

Introduced in 2005 by Unity Technologies, Unity3D allows a workflow based on the separation of concerns [144, 145]. Therefore, developers, game designers, graphical designers, modellers, and audio guys can all develop their work individually with Unity.

Since the beginning of game development, Unity3D positioned itself as the best game engine and IDE for Augmented Reality development. When comparing Unity with other popular game engines like Unreal Engine 4, it is possible to recognize that the former is a better choice for novice developers, since it offers a broad set of components and IDE extensions available via the Asset Store. Additionally, Unity has a good relationship with Android development and the Vuforia SDK [144, 145, 146]. Although it is more limited in terms of graphics capabilities, Unity has more documentation of quality available, and it is programmer and designer-friendly in counterpoint with Unreal Engine 4, which is only designer-friendly [147]. Thereby, the choice of Unity3D for the development of an AR application was clear.

3.4 Kimball Lifecycle Methodology

All phases of the Kimball Lifecycle methodology, originally referred to as the "Business Dimensional Lifecycle", are presented in Figure 7 and properly described below [80, 81].

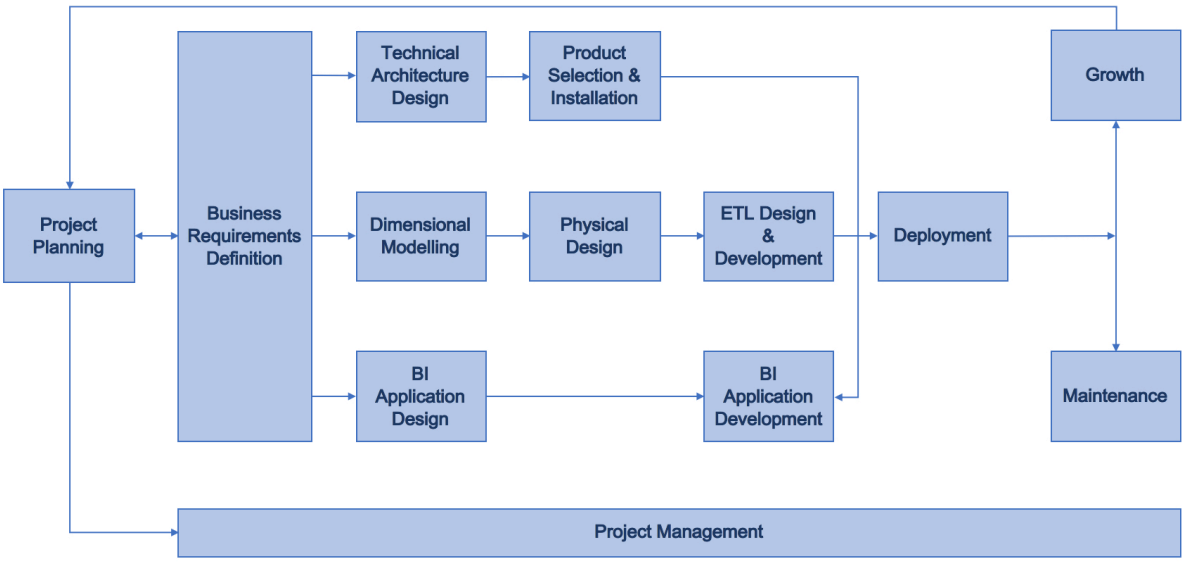


Figure 7: Schematic representation of the Kimball Lifecycle methodology (adapted from [80, 81]).

The lifecycle begins with the *Project Planning* task, which includes identifying project tasks, constituting a critical activity for the following project steps. This step is intrinsically linked to the *Project Management* task that ensures the monitoring of all phases of the Kimball lifecycle and their implementation. In the *Business Requirements Definition* step, the technical considerations that are indispensable for the next steps are defined.

The first set of activities corresponds to the technological path of the methodology, that is, the *Technology Track*, and it focuses on integrating technologies into the data warehousing process, including the *Technical Architecture Design* and *Product Selection and Installation* steps. According to Dr. Kimball, the first task corresponds to one of the most important in the Data Warehouse construction project, which defines a structure and overview of the product architecture, including the specification of the technical environment, as well as the necessary components for the DW construction. In the *Product Selection and Installation* step, research and study tasks are followed in order to select the most suitable products for the construction of the DW.

Then, it is followed by the *Data Track*, where the data collected in the *Business Requirements Definition* task are aggregated to construct a dimensional model. Thus, this second set of activities begins with the *Dimensional Modelling* of information, resulting in a dimensional model consisting of dimension tables linked to fact tables that have been aggregated to form a dimensional model. The database modelling approach followed is the fact constellation schema, where multiple fact tables share dimensional tables. While fact tables store business values, the dimension tables define the facts. The next step, *Physical Design*, focuses on defining the structures, including choosing the Relational Database

Management System. The *ETL Design & Development* step includes the development of data extraction, transformation, and loading processes, as described in Subsection 2.4.1 of Chapter 2.

The third set of activities corresponds to the *Business Intelligence Application Track*, which includes the *BI Application Design* and *BI Application Development* steps. Priority areas are identified and tasks for their configuration and construction are carried out.

These three sets of parallel tasks culminate into the *Deployment* task, which is supported by the *Maintenance* and *Growth* activities, that restart the Kimball cyclic process, redefining new business requirements. Thus, continuous support, training, and monitoring of users, as well as maintenance of the infrastructure are performed.

Hence, briefly, the application of the Kimball Lifecycle methodology to this research project included defining the requirements of the Information Technology artifact, choosing the appropriate research strategies and development tools for the case study in question, the design and development of dimensional modelling, Extract, Transform, and Load process, and Business Intelligence module, as well as ensuring maintenance and growth of the IT solution.

3.5 Proof of Concept Methodology

The Proof of Concept methodology is a practical model that can prove or validate the established concept or theory for real-world application through analysis or even technical papers. Thus, it goes through verifying if a certain solution is successful and viable and, on the other hand, if it is susceptible to be usefully exploited [148]. It is also known as proof of principle.

Therefore, conducting a PoC is often pointed to as one of the most important steps in the process of designing, developing, implementing, and proposing a prototype of a particular solution in the Information Technology area, mainly by establishing whether a particular IT solution meets its purpose, in other words, meets the defined requirements and objectives for which it was initially designed. On the other hand, it also allows the identification of potential flaws or errors in the developed IT solution, that is, potential gaps that might interfere with its success [149].

In short, a PoC demonstrates in practice the concepts, methodologies, and technologies involved in the elaboration of a given project and, thus, validates the proposed solution by proving its viability and usefulness for its intended purpose, in other words, by defending its potential by demonstrating its feasibility.

In this doctoral dissertation project, the defense of the feasibility and usefulness of the proposed system went through the application of the PoC research methodology, in which a Strengths, Weaknesses, Opportunities, and Threats analysis and the Technology Acceptance Model were applied. The PoC of this research project and all the steps involved in its realization are described thoroughly in Chapter 8 of this manuscript.

Next, the SWOT analysis and the TAM are meticulously explained in subsections 3.5.1 and 3.5.2, respectively.

3.5.1 *SWOT Analysis*

Strengths, Weaknesses, Opportunities, and Threats analysis is an easy tool used to structure strategic planning, promoting an analysis of the strengths and weaknesses of an organization (internal factors), as well as the opportunities and threats to which it is exposed (external factors). Therefore, this tool promotes an analysis of internal and external factors in order to compile everything into a SWOT matrix and, thus, facilitate the visualization of the characteristics of a given solution.

This technology is divided into two distinct environments, namely the internal and external environments. The internal environment refers to the organization itself (internal factors) and relies on its strengths and weaknesses. The second environment, the external environment, refers to external factors outside the control of the organization. Opportunities and threats are forward-looking predictions that are directly or indirectly linked to external factors [150, 151].

Thus, in the context of applying the SWOT analysis to this research project, each of its characteristics can be summarized as follows: [150, 152]

- Strengths: can be defined as the advantages that a certain solution has over its potential competitors;
- Weaknesses: correspond to the weaknesses that somehow interfere or undermine a particular solution;
- Opportunities: they are the external factors that positively influence a given solution;
- Threats: they are the external factors that negatively influence a particular solution.

In this way, the SWOT analysis can maximize the opportunities of the environment through the strengths of a given solution while minimizing the threats and weaknesses it presents. It should be used by any organization that wants to become competitive in the market where it operates [151].

Figure 8 shows the SWOT analysis and its previously described characteristics, namely internal factors (from its organization) and external factors (from its environment).

Figure 8: Schematic representation of the Strengths, Weaknesses, Opportunities, and Threats analysis (adapted from [150]).

3.5.2 *Technology Acceptance Model*

"What causes people to accept or reject Information Technology?" This question generated the need from researchers to create models or theories to identify factors that could justify the acceptance or rejection of technology. Therefore, it was intended to try to explain users' behaviour towards technology [153, 154].

Introduced by Fred Davis in the 1980s, the Technology Acceptance Model is one of the most widely used theories in the field of technology acceptance, which is mainly used to understand the users' position towards potential acceptance or rejection of a certain technology, particularly in the area of IT. The target audience includes individuals, groups, and even entire organizations. Nowadays, TAM is considered a leading model in explaining and predicting system use, being cited in most of the scientific papers that involve studying the users' acceptance of technology. It has quickly become a well-established, robust, and powerful model to predict user acceptance [154, 155, 156, 157].

It was originated in the psychological theory of reasoned action and theory of planned behaviour, being considered a user-centric, data-driven, and evidence-based approach, as well as a quite effective model to predict the acceptance and use of IT [153, 154].

Among the many variables that may influence system use, the original version of this conceptual model defended that two variables are especially important, namely *perceived ease of use* and *perceived usefulness*, in a complex relationship between system characteristics, that is, external variables, and potential system usage. It defends that a user's intent to use a technology (acceptance of technology) and its actual use (usage behaviour) is predicated by his perceptions of the technology's ease of use and usefulness (benefit from using the technology). Nonetheless, Fred Davis' initial version of his theory

also included a third factor, namely *attitude toward using*. He considered that the attitude of a user towards the IT solution was a major variable whether the user will actually use or reject the system, which is influenced by two major beliefs, which are *perceived ease of use* and *perceived usefulness* [153, 154].

In this context, Davis defined these two concepts as follows: [153, 154]

- Perceived ease of use - "the degree to which a person believes that using a particular system would be free from effort";
- Perceived usefulness - "the degree to which a person believes that using a particular system would enhance his or her job performance".

Thus, a IT solution high in *perceived ease of use* is more likely to be accepted by users. On the other hand, an application perceived as useful (*perceived usefulness*) is a system that the users believe has a positive user-performance relationship, enabling its consequent easier acceptance. The TAM is illustrated in Figure 9.

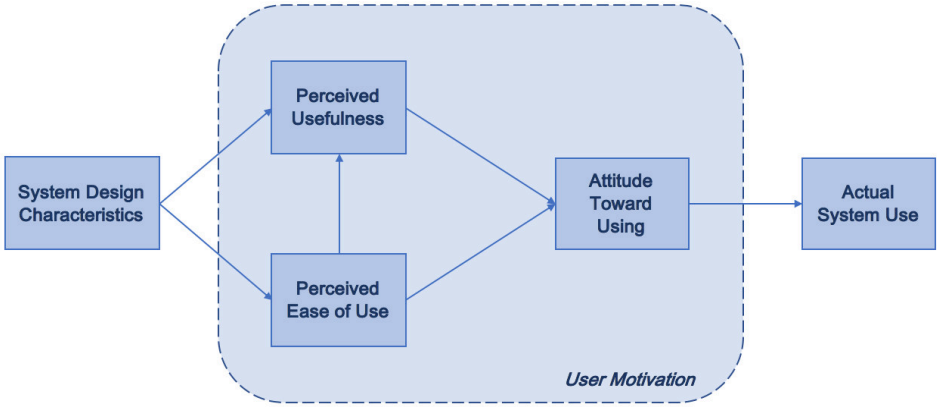


Figure 9: Schematic representation of the Technology Acceptance Model (adapted from [158]).

Nonetheless, over the years, TAM has been continuously revised and expanded, one of its major upgrades being the Extended Technology Acceptance Model (TAM2), which was followed by Technology Acceptance Model 3 (TAM3). Theses extensions involved the addition of factors and variables, which where incorporated into the original model in order to explain the predictors of TAM core elements [154].

Viswanath Venkatesh and Fred Davis proposed an extended model named TAM2 due to their impressive findings regarding the obvious influence of the *perceived usefulness* on the *intention to use*. Therefore, this new version of the theory intended mainly to identify the variables that influence the *perceived usefulness*. The variables added are *subjective norm*, *image*, *job relevance*, *output quality*, *result demonstrability*, *experience*, and *voluntariness*. On the other hand, the *attitude toward using* was removed since they concluded that it did not fully mediate the *perceived usefulness* and *perceived ease of use* as initially concluded with the TAM [154, 155, 158]. The TAM2 is represented in Figure 10.

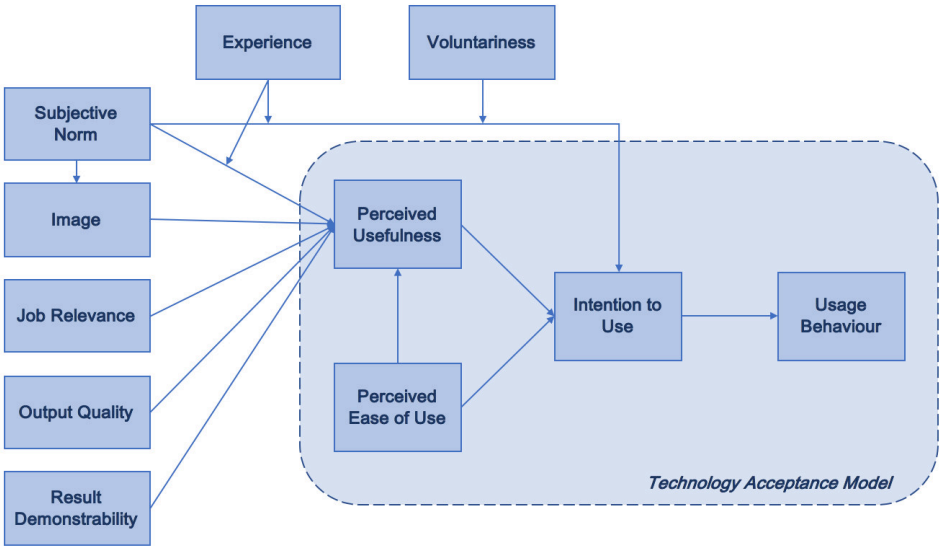


Figure 10: Schematic representation of the Extended Technology Acceptance Model (adapted from [155]).

Viswanath Venkatesh and Hillol Bala combined the TAM2 and Venkatesh's model of the determinants of *perceived ease of use* [159] in order to propose an integrated model of technology acceptance, that is, TAM3. This new version of the original conceptual model takes into account other determinants of *perceived usefulness* and *perceived ease of use*, namely the individual differences, system characteristics, social influence, and facilitating conditions. Furthermore, it is suggested that the determinants of *perceived usefulness* do not influence *perceived ease of use* and vice-versa [158, 160]. The TAM3 is demonstrated in Figure 11.

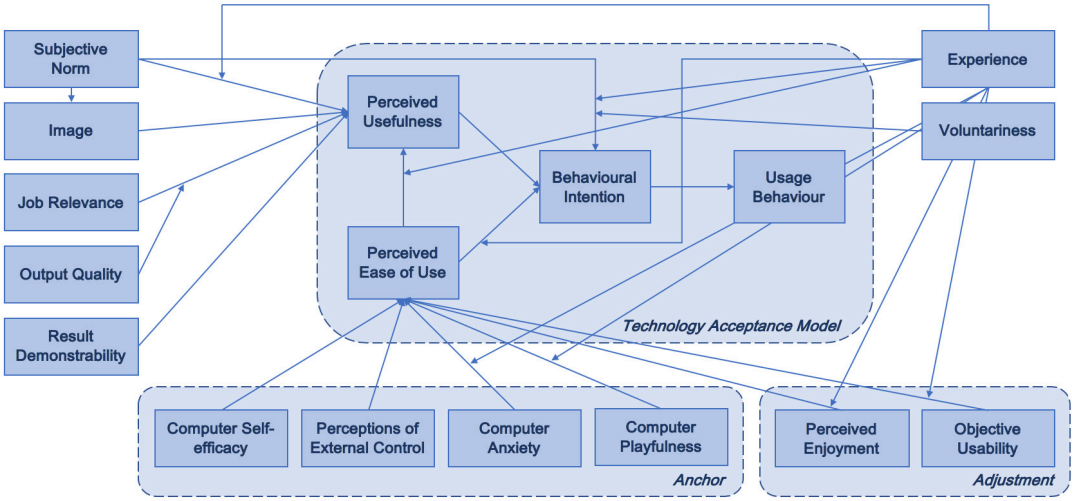


Figure 11: Schematic representation of the Technology Acceptance Model 3 (adapted from [160]).

The constructs included in the TAM3 are presented in Table 2, which includes a brief description for each construct [159, 160].

Table 2: Brief description of each construct of the Technology Acceptance Model 3

Construct	**Definition**
Perceived ease of use	The extent to which the user considers that the system is effortless to use.
Subjective norm	The degree to which the user believes that he should or should not use the IT solution based on social pressure, that is, the opinion of people close to him.
Image	The extent to which the user thinks that the use of the IT solution will improve his social status.
Job relevance	The degree to which the user considers that the system is adequate and relevant to his job.
Output quality	The extent to which the user believes that the IT artifact enables him to perform well his job.
Result demonstrability	The degree to which the user considers that the results obtained from the system are demonstrable and observable.
Computer self-efficacy	The extent to which the user believes that he is able to use a computer in order to execute the tasks related to his job.
Perceptions of external control	The degree to which the user thinks that adequate organizational and technical resources are available to assist the use of the IT solution.
Computer anxiety	The degree of fear and apprehension associated with the use of a computer by the user.
Computer playfulness	The tendency of the user to interact spontaneously with a computer.
Perceived enjoyment	The degree to which the user considers that he is enjoying using the system.
Objective usability	This construct enables the comparison between different systems based on the level of effort needed to execute tasks by users.
Experience	Highlights possible previous experiences and contact with other IT solutions by users.
Voluntariness	The degree to which the user believes that he is using the system due to his own choice.

Construct	Definition
Perceived usefulness	The expectation that the user has that the IT artifact can improve his job performance.
Behavioural intention	The extent to which the user has the intention to execute a certain behaviour.
Use behaviour	The degree to which the user will steadily and regularly use the system over time.

Finally, the TAM3 was applied in order to study the acceptance of the proposed system through the preparation of questionnaires for both groups of the target audience, namely health professionals (nursing and technical and administrative staff) and elders and their informal caregivers. More information is given in Section 8.3 of Chapter 8 in this document.

3.6 Conclusion

This chapter highlighted the main research methodology followed to conduct this study, that is, Design Science Research, as well as all the most adequate research strategies and technologies used in each of the phases of this doctoral dissertation, including the Proof of Concept methodology applied in order to prove the feasibility and usefulness of the proposed artifact. The application of the PoC included the Strengths, Weaknesses, Opportunities, and Threats analysis, which is an easy tool used to promote an analysis of the strengths and weaknesses of an organization and the opportunities and threats to which it is exposed, and the Technology Acceptance Model, which is mainly used to understand the users' position towards potential acceptance or rejection of a certain technology, particularly in the area of Information Technology.

Regarding the development process of the archetype, the React JavaScript library was used for the Web application and the React Native JavaScript framework for the mobile application. Both are supported by Node.js JavaScript runtime environment for the creation of the RESTful Web services that enable the retrieve of resources stored in the database, but also their update and deletion, or even the creation of new resources. The database is MySQL, that is, a Relational Database Management System.

On the other hand, the Extract, Transform, and Load process, data warehousing, and the implementation of the BI solution were based on the Kimball Lifecycle methodology.

Additionally, Unity3D game engine and Integrated Development Environment and Vuforia Augmented Reality Software Development Kit were chosen to develop the mobile AR features of the system based on the analysis conducted.

Finally, from the next chapter, that is, Chapter 4, the results achieved with this research project are presented and thoroughly discussed.

4

THE BUILDING OF A DATA REPOSITORY

This chapter intends to explain in detail all the steps involved in the building of a data repository for the proposed system, and the main results obtained and conclusion drawn from them. To do so, it starts with a brief introduction in Section 4.1, which is followed by the problem identification and motivation in Section 4.2. Then, the objectives of the solution are described in Section 4.3 and the design and development process is presented in Section 4.4 that includes the presentation of the results obtained. This chapter ends with a detailed discussion (Section 4.5), which is followed by a brief conclusion (Section 4.6).

4.1 Introduction

The aim of this study was to build a data repository for the proposed system. However, the goal was also to make it broad enough to be reused in other similar solutions, that is, Health Information and Communication Technology applications focused on the care of the elderly, which include potential future solutions for the nursing homes.

To do so, data collection methods were applied to identify the different relevant knowledge areas in the nursing homes studied. Nevertheless, the validation of the information collected by health professionals was essential to enable the use of safe medical terms by the users of the system.

In short, this data repository will allow the definition of an organized data structure, the standardization of information, and, consequently, to facilitate the communication process between all the parties involved since there is consistency in the use of terms. On the other hand, there is a further ease of generating new knowledge from stored data since the information is normalized.

In this chapter, the database design and development process and the main results achieved will be presented and discussed.

4.2 Problem Identification and Motivation

At the beginning, focus groups, semi-structured interviews, and questionnaires were performed with health professionals working directly or indirectly in the nursing homes in order to obtain valuable information regarding the storage of information in their facilities, as well as the potential current use of informatics applications. The health professionals questioned included nursing staff, healthcare assistants, doctors,

and technical and administrative staff for a total of about fifteen professionals. On the other hand, the case studies were also subjected to the observation method in order to have a better understanding of their conditions.

After studying the nursing homes used as case studies, it was concluded that the information regarding all the different areas of knowledge involved in the care of the elderly was not properly stored in any form of repository, that is, there is not an Health Information System implemented or even a proper paper registration. On the other hand, no Health Information and Communication Technology or any other form of technological progress are currently used in the nursing homes. Nonetheless, handwritten charts and boards are used by some health professionals, which is a method more error-prone, confusing, and less organized since there is not a consistency in the use of terms between all individuals involved. This situation became problematic and, thus, created the need for further research.

Hence, a thorough study of the case studies and, then, data collection was necessary in order to build a data repository for the proposed system, as well as other similar solutions involving the same type of knowledge, that is, taking care of the elderly. In this way, it was mandatory to define a data model and, consequently, to build a data repository by loading the database with real data obtained from the data collection conducted. Nevertheless, a data analysis was necessary in order to sort information of interest before loading the database with information.

Thus, this solution allows the definition of an organized data structure, the standardization of information, and, consequently, it facilitates the communication process between all the parties involved since it creates consistency in the use of terms. On the other hand, there is a further ease of generating new knowledge from stored data, for example, through the Business Intelligence technology, which will be explained in detail in Chapter 6. This process is easier since the information stored is normalized, which reduces data redundancy and improves data integrity, enabling an easier knowledge extraction process.

4.3 Definition of the Solution's Objectives

Based on the problem presented in the previous section, the main objectives to be fulfilled with this solution are as follows:

1) Data collection regarding existing knowledge areas in the nursing homes through focus groups, semi-structured interviews, questionnaires (Appendix A), and observation;

2) Sorting the information collected in Point 1) in order to keep only relevant data;

3) Definition of other information of interest that must be stored in the database not included in Point 2);

4) Definition of all the sequelize models and their associations (Sequelize is explained in Subsection 3.3.2 of Chapter 3);

5) Choice of the Relational Database Management System to store the information;

6) Creation of the database;

7) Loading of the database with real data through the information collected in points 1) to 3);

8) Validation of data by health professionals, enabling the use of safe medical terms.

In the next section, each steps involved in the design and development process are described in detail, including the results achieved.

4.4 Design and Development

As already described in Subsection 3.3.2 of Chapter 3, Node.js was used to develop the server-side applications, that is, the RESTful Web services that enable the sharing of data between the front-end and the database. Applications designed with this JavaScript platform can include many libraries to support server-side functionalities. The JavaScript library Sequelize is one of them.

In short, Sequelize is a promise-based Object-relational Mapping that permits the conversion of data between incompatible systems using an object-oriented programming language. It supports Postgres, MySQL, MariaDB, SQLite, and Microsoft SQL Server databases. Its main advantage is that it provides powerful database synchronization mechanisms that can create databases structure by specifying the models structure, the associations between the models defined (the possible association types in Sequelize are "BelongsTo", "HasOne", "HasMany", and "BelongsToMany"), and the database configuration. Thus, the Relational Database Management System can easily be changed from MySQL to another if needed. This is possible since database entries are mapped to objects and vice-versa.

Therefore, the definition of the relational database structure was performed in the RESTful Web services using the JavaScript programming language, which included the models structure (mainly the columns and respective datatype for each one), the associations between the models depending on the association type, that is, one-to-one, one-to-many or many-to-many associations, and the database configuration. Then, through the synchronization mechanisms made available by Sequelize, the database is created according to the information specified.

To exemplify the defined and created MySQL database, Table 3 presents twenty-five of the implemented tables and a brief description for each one. However, the database is large containing about seventy-five different tables, making it impossible to present and describe each. It would also most likely become repetitive. On the other hand, the description of the system in Chapter 5 will clarify even more all areas of knowledge involved in the system and, consequently, the tables intrinsic to their maintenance and management.

Table 3: The name and description of twenty-five of the seventy-five tables implemented in the MySQL database

Table Name	Description
alerts	This table contains information regarding the alerts created through the system. The data saved include a unique identifier for each alert, description, area, user type and ID of who added the alert (if not automatically generated), user type and ID of who the alert was sent to, date and time when it was sent, status if the alert was sent (”1” for yes and ”0” for no), status if the alert was seen (”1” for yes and ”0” for no), and date and time if the alert was seen, among others.
allergies	It lists the allergies available in the system, including their unique identifier, description, and status (”1” for active or ”0” for inactive).
caregivers	It contains data regarding the caregivers registered in the system, namely their unique identifier, complete name, ID of gender, photo, identity card number, date of birth, address, zip code, phone number, mobile number, e-mail, password (encrypted), observations, date and time when they were registered in the system, and status (”1” for active and ”0” for inactive).
caregivers_notes	It saves information regarding the notes added by caregivers in the system. The columns include a unique identifier for each note, ID of the caregiver who added the note, title, description, color, date and time of creation, date and time of last update, and status (”1” for active and ”0” for inactive).
drugs	It lists the drugs available, which includes a unique identifier for each drug, name, active ingredient, dosage form, dosage, if it is a generic drug or not, commercial status, and status (”1” for active and ”0” for inactive).

Table Name	Description
external_services_appointments	This table contains data regarding the appointments (external services) scheduled for seniors, that is, a unique identifier, ID of patient, user type and ID of who added the external service, speciality, accompany's status ("1" for yes and "0" for no), where, observations of scheduling, date and time of scheduling, expected start date and time of realization, and expected end date and time of realization. If it was realized, date and time of realization and observations are recorded; if it was not realized, date and time of non-realization, motive, and observations; and if it was deleted, date and time of deletion.
health_professionals	It contains data regarding the health professionals registered in the system, namely their unique identifier, unique identifier in their respective nursing home(s), complete name, ID of gender, photo, identity card number, date of birth, address, zip code, phone number, mobile number, e-mail, password (encrypted), observations, date and time when they were registered in the system, and status ("1" for active and "0" for inactive).
individual_cares_medications_assistance	This table contains data regarding medication assistance (individual cares) scheduled for elders, that is, a unique identifier, ID of patient, user type and ID of who added the individual care, drug, quantity, unity, type of support, where, observations of scheduling, date and time of scheduling, and expected date and time of drug administration. If it was realized, date and time of realization and observations are recorded; if it was not realized, date and time of non-realization, motive, and observations; and if it was deleted, date and time of deletion.
medical_diseases_conditions	It lists the medical diseases and conditions in the system through a unique identifier, description, and status ("1" for active and "0" for inactive).

Table Name	Description
objectives	This table contains information regarding the list of objectives predefined for patients, namely a unique identifier, description, objectives' area, and status ("1" for active and "0" for inactive).
objectives_areas	It lists the different objectives' areas, which includes a unique identifier and description.
objectives_indicators	It contains information concerning the indicators associated with each objective. To do so, each line saves the unique identifier of the indicator, the respective objective to which it belongs, description, and status ("1" for active and "0" for inactive).
patients	This table presents data regarding all patients registered in the system, namely their unique identifier, complete name, nickname, ID of gender, photo, identity card number, date of birth, ID of blood type, address, zip code, phone number, mobile number, e-mail, password (encrypted), health professional supervising him, observations, date and time when they were registered in the system, and status ("1" for active and "0" for inactive).
patients_allergies	It enables the association between patients and allergies. The columns are the ID of the patient, ID of the allergy, date and time of association, date and time of last update, and status ("1" for active and "0" for inactive).
patients_caregivers	This table permits the association between patients and caregivers. The columns are the ID of the patient, ID of the caregiver, date and time of association, and status ("1" for active and "0" for inactive).

Table Name	Description
patients_collaborative_boards	It enables the management of the collaborative board of each patient. Thus, the information registered includes a unique identifier for each comment in the collaborative board, ID of the patient, date and time of creation of the comment, user type and ID of who created the comment, description, date and time of last update, and status (”1” for active and ”0” for inactive). If it was archived, the date and time is recorded; and if it was deleted, the date and time of deletion.
patients_current_medications	It lists the current medications for each patient. The data include a unique identifier for each current medication, ID of patient, ID of drug, quantity, unity, periods of the day (binary number), days of the week (binary number), start date, end date, observations, date and time of association, date and time of last update, and status (”1” for active and ”0” for inactive).
patients_emergency_medications	It lists the emergency medications for each patient. The data include a unique identifier for each emergency medication, ID of patient, ID of drug, type of situation, quantity, unity, observations, date and time of association, date and time of last update, and status (”1” for active and ”0” for inactive).
patients_medical_diseases_conditions	This table enables the association between patients and medical diseases and conditions. The columns are the ID of patient, ID of medical disease and condition, date and time of association, date and time of last update, and status (”1” for active and ”0” for inactive).

Table Name	Description
patients_objectives	It contains information regarding the objectives associated with each patient. To do so, the data include the ID of the patient, ID of objective, date and time of association, user type and ID of user who planned the objective, observations of planning, deadline (date), date and time of last update, and status ("1" for completed and "0" for not completed). If it was archived, date and time and observations are recorded; and if it was deleted, date and time of deletion.
patients_objectives_indicators	This table enables the management of the indicators of each objective associated with patients. Thus, it contains information regarding the ID of the patient, ID of the objective, date and time of association, ID of the indicator, date and time of last update, and status ("1" for completed and "0" for not completed).
patients_prohibited_medications	It lists the prohibited medications for each patient. The data include a unique identifier for each prohibited medication, ID of patient, ID of drug, observations, date and time of association, date and time of last update, and status ("1" for active and "0" for inactive).
repository_videos	It enables the management of the videos uploaded to the repository. The columns include a unique identifier for each video, title, description, URL of video, language, added date and time, ID of the user who added the video, date and time of last update, ID of the user who last updated the video, and status ("1" for active and "0" for inactive).
specialities	This is a listing of specialities through their unique identifier, description, and status ("1" for active and "0" for inactive).
types_support	This table lists all the existing types of support in the system, which is described by a unique identifier, description, and status ("1" for active and "0" for inactive).

It is relevant to note that, in the future, only by changing the database configuration, the database can be easily and quickly cloned in the same or even in a different RDBMS. On the other hand, it is also important to refer that some database management and maintenance processes are performed using triggers, procedures, and functions implemented in the database in Structured Query Language. This last point will be discussed in further detail in Chapter 5 where the system designed and developed is described.

Finally, after the implementation of the database, it was loaded with real data collected through diverse data collection methods. Thus, tables that correspond to listings were loaded in advance, such as "allergies", "medical_diseases_conditions", and "specialities". However, they can be updated over time using the system, which will be explained in Chapter 5. On the other hand, a validation of data was performed by health professionals, enabling the use of safe medical terms.

4.5 Discussion

The main advantages verified in the building of the data repository for the proposed system are as follows:

- Easier and faster access to information;
- Search capability since it enables fast queries to the database, which can answer questions of interest quickly;
- Flexibility, in other words, new information can be easily added, updated or deleted at any time;
- Maintains data integrity, that is, data are accurate and consistent, since constraints are used to store data;
- Less manual inputting is done in the front-end, leaving less room for error, since information is often inputted automatically through the selection of predefined options, which involves the definition of constraints;
- Data are more accurate and reliable since they were previously validated by health professionals. Therefore, safe medical terms are used;
- Enables an easy knowledge extraction process from "big data";
- Minimizes data redundancy;
- Eases application development since it allows data sharing for other solutions centered in the care of the elderly;
- Maintains data consistency since data redundancy is greatly reduced;
- Provides data security through the storage of information in a secure Relational Database Management System. On the other hand, only individuals having enough privileges are granted access to critical data store in the database;

- Automatic backup and restore through the RDBMS. Thus, information will always be preserved since data loss is a very big problem for many organizations;
- Standards are enforced, including data format and terminology;
- Chances of data loss are minimum since there is a lot of security constraints made on the database.

Additionally, it is important to note that the front-end of the system, which will be described in detail in Chapter 5, is optimized in order to use the listings already defined in the database, for example, "blood_types", "nursing_services", and "personal_cares". Thus, few are the fields in which it is possible to enter free text other than, for instance, observations fields. These restrictions defined in the front-end combined with the database implemented engender the advantages presented above.

4.6 Conclusion and Future Work

Finally, several advantages can be attributed to the building of a data repository focused on the care of the elderly. In fact, as discussed throughout this chapter, an easier and faster access to information is provided, it potentiates data integrity, consistency and security, data are more accurate and reliable since they were previously validated by health professionals, it minimizes data redundancy and loss, and standards are enforced, including data format and terminology.

Additionally, it enables an easy knowledge extraction process since the information is normalized, that is, through the Business Intelligence technology, which permits the creation of clinical and performance BI indicators to provide valuable insights and a smart-driven decision-making process for users.

Regarding future work, it will involve the update of the data model if information that is not currently represented must be recorded in the database. To do so, Sequelize can be used to define the new models structure and the associations between them depending on the association type. If needed, triggers, procedures, and functions in Structured Query Language can also be added over time to the database in order to perform some database management and maintenance processes required.

5

A NEW SYSTEM TO ASSIST ELDERS' SELF-CARE AND THEIR INFORMAL CAREGIVERS

In this chapter, a new system to assist elders' self-care and their informal caregivers is proposed and described in detail. Thus, this chapter starts with a brief introduction in Section 5.1, which is followed by the problem identification and motivation in Section 5.2. Then, the solution's objectives are explicitly defined in Section 5.3. The "Design and Development" section (Section 5.4) is divided into three different subsections, namely MySQL database and Node.js Web services (Subsection 5.4.1), React Web application (Subsection 5.4.2), and React Native mobile application (Subsection 5.4.3). The chapter ends with a detailed discussion in Section 5.5 and a short conclusion in Section 5.6.

5.1 Introduction

Nowadays, there is regularly the attempt to postpone as much as possible the departure of the elderly to nursing homes by creating the necessary and appropriate conditions in their home environments. As a matter of fact, this is largely due to the current predominant lack of vacancies for new patients in nursing homes. On the other hand, a large portion of older adults and their families do not even have the necessary means to support the costs associated with their admission in these health institutions. It is noteworthy that the elderly also prefer to age in place.

In this context, as already stated throughout this document, the novelty of this study lies in trying to fulfill the current lack of Health Information and Communication Technology to support the remote assistance by Portuguese nursing homes to seniors and their informal caregivers using emerging technologies. In fact, no studies linking the design and development of health informatics applications for the target audience in question and the support of nursing homes were found. Therefore, a new system to assist elders' self-care and their informal caregivers is proposed based on an innovative approach through nursing homes.

On the other hand, it is also intended to facilitate the access to care services with medical validation by rural populations as they are often displaced from health centers and hospitals. Additionally, rooting technological innovation into seniors' home environments is an answer to support not only their self-care but also to prevent their dependence and, thus, enabling older adults' independence in their homes. Furthermore, it is envisaged to combat social isolation and loneliness.

Finally, the proposed solution will be a reinforcement to deal with seniors' well-being and health and informal caregivers' welfare by improving their lifestyle quality and promoting social interaction.

In the next sections of this chapter, the overall architecture of the system and its main interfaces and functionalities are described and discussed in detail.

5.2 Problem Identification and Motivation

The study presented in this chapter corresponds to the central focus of this doctoral dissertation. The research project emerged in an attempt to respond to current and relevant research gaps in gerontechnology. In short, it is expected to enable the remote assistance by care workers and professional staff working in the nursing homes, principally nurses, to seniors and their informal caregivers. Therefore, this thesis is mainly motivated by the attempt to bridge the gap between nursing homes and the community since the contact between both parties is currently non-existent, which could be highly beneficial to rural populations.

Thus, the aim of the proposed system is to assist elders' self-care and their informal caregivers through the support of nursing homes. It is constituted by two different components, namely a Web application and a mobile application. It is also important to refer that usability issues are being taken into account in the design process given the target audience at hand, which includes individuals of older age groups. Additionally, it integrates clinical competencies to ensure patients' safety since there is currently a lack of proper clinical validation of terms and practices in existing systems.

On the other hand, gerontechnology still mostly focuses on patients with single illnesses, such as diabetes, cancer, stroke, and dementia. Thus, the system is being designed to be broad enough to cover most individuals of the older population.

Nonetheless, this thesis also potentiates boosting technological innovation in nursing homes since the successful use of Health Information and Communication Technology solutions in those healthcare facilities is still currently missing in Portugal.

5.3 Definition of the Solution's Objectives

The main objectives to be fulfilled with this solution are the following:

1) Data collection through focus groups, semi-structured interviews, questionnaires (Appendix A), and observation with health professionals working directly or indirectly in the nursing homes, seniors and their informal caregivers, and Health Information and Communication Technology professionals;

2) Definition of the overall system architecture based on the information collected in Point 1);

3) Definition of the modules of the system and the functionalities in each based on the data collected in Point 1);

4) Choice of the technologies for the development of the solution according to points 1) to 3);

5) Development of the solution with the technologies chosen in Point 4);

6) Simulation, deployment, and assessment of the developed solution by users of different user types;

7) Preliminary implementation of the developed solution in a server.

5.4 Design and Development

The different elements of the target audience of the new system that is proposed include elders dependent in self-care, their informal caregivers, and health professionals from Portuguese nursing homes, namely nurses and administrators. Therefore, the system has four different user types, that is, user roles:

- User type 1: elders;
- User type 2: informal caregivers;
- User type 3: nurses;
- User type 4: administrators.

It is also important to note that this system takes into consideration the following points:

- Older adults can be partially or totally dependent on their informal caregivers;
- Informal caregivers may have one or more seniors in their charge;
- Each elder has a nurse associated with him whom is his remote supervisor in the nursing homes;
- Nursing staff can only use the system when they are not taking care of their own patients in the nursing homes;
- Administrators are responsible for the management of the system, including its users and resources;
- The system must be user-friendly in order to facilitate its use and adoption by the target audience. As the age groups include seniors, redoubled attention is being paid to usability issues to ensure continued use of the system.

On the other hand, the system encompasses two main distinct components – a Web application and a mobile application. All user types have access to the Web application, but only elders and their informal caregivers (user types 1 and 2) will use the mobile application. In short, through the Web application, it is possible to proceed to the complete management of the system for all user types, but each has access to different system features. Regarding the mobile application, its main objectives is to be able to have a quick access to relevant information that is already included in the Web solution, to receive push notifications, as well as to provide new features through Augmented Reality that cannot be included in the Web application. Moreover, each user type has a different role and associated permissions assigned.

These different roles and permissions will be discussed in more detail for each component in subsections "React Web Application" and "React Native Mobile Application", namely subsections 5.4.2 and 5.4.3.

Therefore, the next three subsections describe in detail the MySQL database used to store data and the Node.js Web services that allow the sharing of data between the database and the system, the React Web-based healthcare solution, and the React Native mobile application, in subsections 5.4.1, 5.4.2, and 5.4.3, respectively.

5.4.1 *MySQL Database and Node.js Web Services*

As stated in Chapter 4, the database system was defined and implemented using the JavaScript library Sequelize in the Node.js Web services, which enables the definition of models and the associations between them and, consequently, the creation of a database through the database configuration delineated. Sequelize is one of the various libraries that are used in the RESTful Web services in order to enable the sharing of data between the front-end, that is, the Web and mobile applications, and the database. The most important libraries used are described in Subsection 3.3.2 of Chapter 3. Therefore, the Web services allow the communication between two different softwares.

Since the RESTful Web services are based on the Representational State Transfer technology, which is an architectural style and approach to communications, it uses four different types of HTTP requests in order to manipulate the data stored in the database through the system, namely:

- GET: to retrieve resources;
- POST: to create a resource;
- PUT: to change the state of or update a resource;
- DELETE: to remove a resource.

5.4.2 *React Web Application*

As previously referred, the Web application is the main component of the new system to assist seniors' self-care and their informal caregivers. This component of the system is completed with a mobile application that will be explained later in this document. The Web application was developed with React JavaScript library in JSX (a syntax extension to JavaScript), and it is supported by the MySQL relational database management system as the back-end database. The sharing of data between the Web application and database is performed through a Node.js RESTful API. It is also relevant to note that the solution can be used in two different types of devices by being responsive, namely computers and mobile devices, that is, tablets and smartphones.

A schematic representation of the Web solution is illustrated in Figure 12.

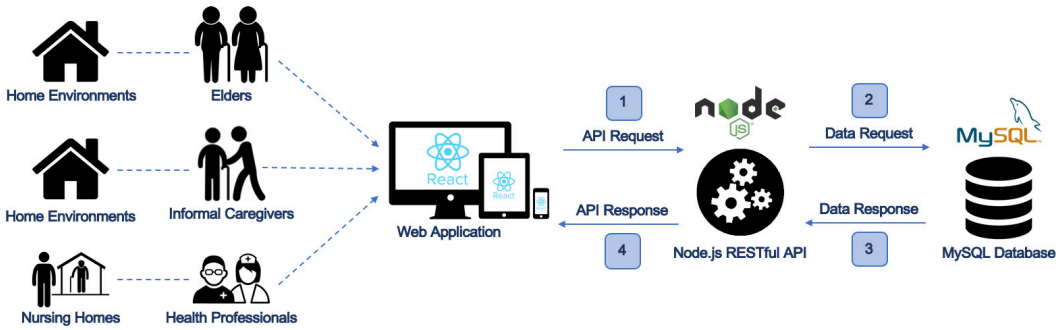


Figure 12: Schematic representation of the React Web application.

The Web application is constituted by different modules. Each user type (user role) has different permissions assigned, in other words, each module can only be accessed by specific user types and, according to the user, each module offers a group of tasks to be performed. Thus, in Table 4, the permissions assigned to each user type, namely elders, informal caregivers, nurses, and administrators, by module in the Web solution are presented in detail. It is important to note the meaning of the following acronyms in the table:

- "R" means that the user has read permissions, that is, he can view all the information in the module;
- "W" signifies the user has write permissions, that is, he can directly modify data stored in the database (insert or update) through the module;
- "E" corresponds to execute permissions, that is, the user can execute a particular action but modifying the data stored in the database is not its principal aim (for example, logging out of the solution or launching an external application);
- "NA" stands for "Not Available", in other words, the user does not have access to the module.

If the module is divided into different areas, the denomination of the area is preceded by a hyphen in the name of the module in Table 4.

Table 4: The permissions assigned (R: read permissions, W: write permissions, E: execute permissions, and NA: module not available) to each user type (elders, informal caregivers, nurses, and administrators) by module (list in leftmost column) in the Web application

	Elders	**Informal Caregivers**	**Nurses**	**Administrators**
Homepage	R	R	R	R
User Data	RW	RW	RW	RW
Patients Data	NA	RW	R	NA
Individual Cares - Scheduling	RW	RW	NA	NA
Individual Cares - Registration	RW	RW	NA	NA

	Elders	Informal Caregivers	Nurses	Administrators
Individual Cares - History	R	R	NA	NA
External Services - Scheduling	RW	RW	NA	NA
External Services - Registration	RW	RW	NA	NA
External Services - History	R	R	NA	NA
Tasks - Scheduling	NA	NA	RW	RW
Tasks - Registration	NA	NA	RW	RW
Tasks - History	NA	NA	R	R
User Management	NA	NA	NA	RW
Resource Management	NA	NA	NA	RW
Patients Objectives	RW	RW	R	NA
Collaborative Board	RW	RW	RW	NA
User Notes	RW	RW	RW	RW
BI Indicators - User	R	R	R	R
BI Indicators - Patients	NA	R	R	R
BI Indicators - Informal Caregivers	R	NA	R	R
BI Indicators - Nurses	NA	NA	NA	R
BI Indicators - General	NA	NA	R	R
Forum	RW	RW	RW	RW
Support Resources - Textual Guides	R	R	RW	RW

	Elders	Informal Caregivers	Nurses	Administrators
Support Resources - Videos	R	R	RW	RW
Skype	E	E	E	E
Alerts	RW	RW	RW	RW
Profile	RW	RW	RW	RW
Logout	E	E	E	E

It is important to refer that in order to exemplify the functionalities that were defined and developed for this Web-based healthcare solution, a few print screens will be presented to complete the written explanation provided for each module. Nonetheless, due to confidentiality issues, and since this is an on going project still open for future research, some information will not be fully provided. It is also interesting to note that the figures of the system presented are all in Portuguese since this research project was conducted for Portuguese elderly population and nursing homes. On the other hand, the data presented in the application are fictitious since the system is not yet being used by real users.

Next, the eighteen modules included in the Web application will be discussed in detail, namely Homepage, User Data, Patients Data, Individual Cares, External Services, Tasks, User Management, Resource Management, Patients Objectives, Collaborative Board, User Notes, BI Indicators, Forum, Support Resources, Skype, Alerts, Profile, and Logout.

Homepage Module:

The first module of the Web application is the Homepage module. Depending on the user type, the information presented to users is different. This module is divided as follows according to the user type:

- Elders (user type 1):
  i) Active Alerts: if there are active alerts for the user, a warning is displayed with the total number of alerts;
  ii) Dashboard: a dashboard with three different Business Intelligence indicators is displayed to seniors, namely the total number of pending individual cares, realized individual cares, and unrealized individual cares;
  iii) Next Individual Cares: the next individual cares to be realized are presented in a table, that is, the individual cares that must be realized today, which also include overdue individual cares. The imminent individual cares are presented in yellow (today) and the overdue ones in red. The information presented includes the type of individual care, the description of the care itself, the date and time of realization, the type of support, and optional observations;

iv) Next External Services: the next ten external services to be attended by the elder are presented in a table, which includes data regarding the type of external service, the description of the service itself, where it is, the date and time of realization, the accompany's status ("Yes" or "No"), who planned the service, and optional observations. The overdue external services are highlighted in red and the imminent ones in yellow, that is, the external services that must be attended in less or equal to twenty four hours from today.

- Informal caregivers (user type 2):

  i) Active Alerts: as for seniors, if there are active alerts, a warning is displayed with the total number of alerts to informal caregivers;

  ii) Dashboard: as for elders, a dashboard with three BI indicators is presented to caregivers, namely the total number of pending individual cares, realized individual cares, and unrealized individual cares for all his patients;

  iii) Next Individual Cares: a table with the next individual cares to be realized by a given informal caregiver is also presented to them. It is similar to the one presented to older adults. Nonetheless, the individual cares displayed concern all the patients that the informal caregiver is taken care of, so the name of the patient is also presented for each individual care;

  iv) Next External Services: a table with the next external services are also made available to this user type. However, the name of the patient that must attend the external service is also shown since this component presents the next ten external services of all the informal caregiver's patients.

- Nurses (user type 3) and Administrators (user type 4):

  i) Active Alerts: a component with the total number of alerts is presented to users if the user has active alerts;

  ii) Dashboard: a dashboard with three different BI indicators is displayed, namely the total number of pending tasks, realized tasks, and unrealized tasks;

  iii) Next Tasks: the next ten tasks to be realized by nurses and technical and administrative staff are presented in a table, which includes data regarding the description of the task, the start date and time, the end date and time, and optional observations. The overdue tasks are highlighted in red and the imminent ones in yellow, that is, the tasks that must be realized in less or equal to twenty four hours from today.

As an example, Figure 13 demonstrates the homepage of an informal caregiver, where the different components can be observed, namely his active alerts, the dashboard with BI indicators, the next individual cares to be realized by him (today), and the next external services to be attended by his patients.

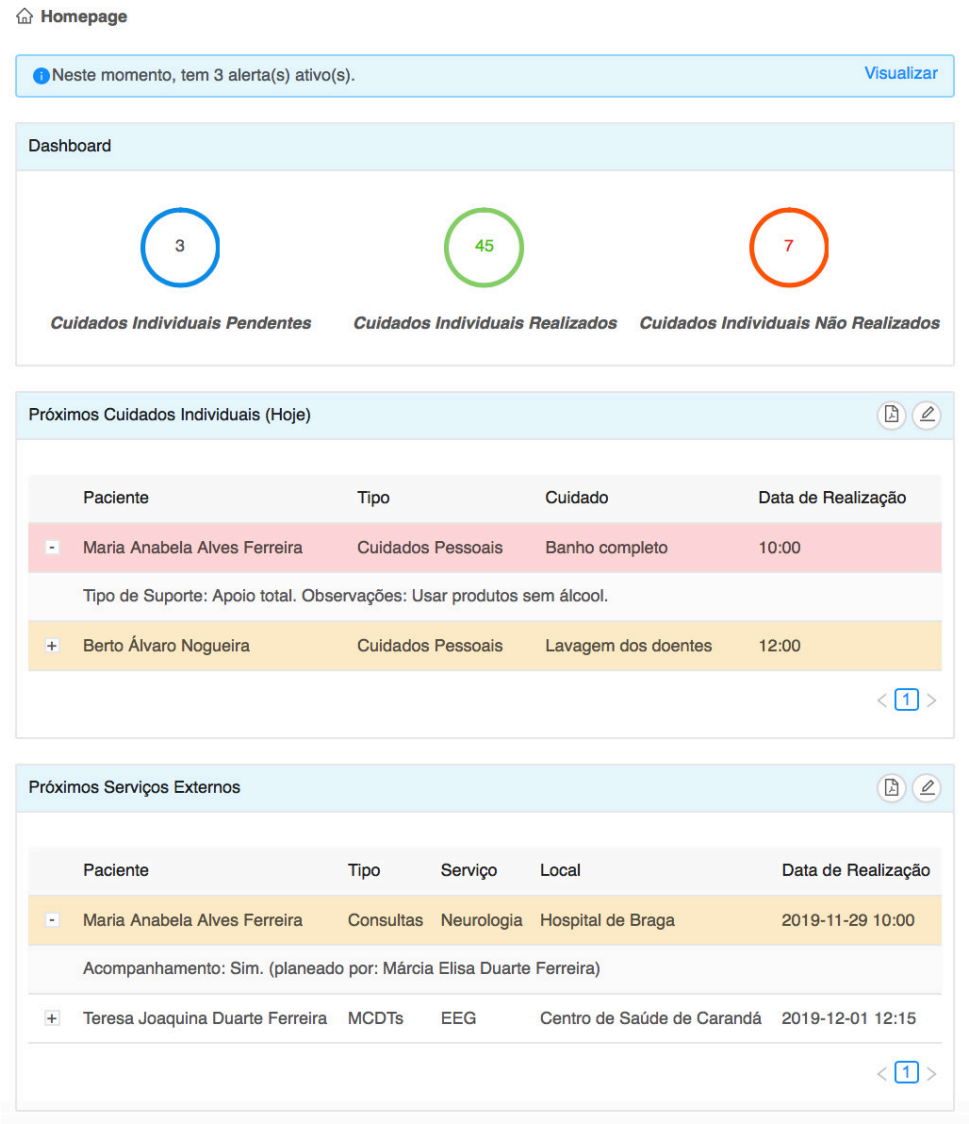


Figure 13: Homepage module in the React Web application for an informal caregiver (with fictitious data).

User Data Module:

The User Data module enables users to visualize their relevant information registered into the system. Nonetheless, depending on the user type, the components and data displayed to users are different. Next, the components shown for each user type are presented, which also include the data presented in each component.

- Elders (user type 1):
    i) General Information: this component presents general information associated with seniors, namely their unique identifier, name, gender, date of birth, citizen card number, nickname, blood group, address, zip code, locality, phone number, mobile number, e-mail, registration date in the system, and a profile picture. A few fields can be edited as well as the password;

ii) Informal Caregivers and Responsible Nurse: all the informal caregivers of the patient and his responsible nurse in the nursing homes are presented in a list. Data regarding their unique identifier, name, gender, date of birth (and age), phone number, mobile number, e-mail, and observations are available to users;

iii) Medical Diseases and Conditions: a list is displayed with all the medical diseases and conditions of the senior. It also enables adding and deleting medical diseases and conditions associated with him;

iv) Allergies: this component lists all the allergies associated with the elder and it permits new additions or deletions;

v) Observations: optional observations can be added and updated.

- Informal caregivers (user type 2), Nurses (user type 3), and Administrators (user type 4):

  i) General Information: the information presented includes their unique identifier, name, gender, date of birth, citizen card number, address, zip code, locality, phone number, mobile number, e-mail, registration date in the system, and a profile picture. Nonetheless, for nurses and administrators, other unique identifiers are also registered regarding their respective job. On the other hand, some values of the fields can be updated as well as passwords;

  ii) Medical Diseases and Conditions: as for seniors, all the medical diseases and conditions associated with those user types are listed. New items can be added and old ones deleted;

  iii) Observations: this component enables users to add observations to their data and to proceed to updates.

Patients Data Module:

This module enables informal caregivers to visualize and edit the information of their patients and the nursing staff to only visualize the data of the elders they are responsible for. This module is identical to the User Data module for elders presented above. Nonetheless, a list with all the seniors associated with the user is presented to them in order to choose from the list the intended elder. By default, the first element of the list is chosen. It is also relevant to refer that even though informal caregivers can update data, they cannot edit the password of their patients.

As an example, in figures 14 and 15, the Patients Data module for a particular informal caregiver is presented. The five different components can be visualized: General Information and Informal Caregivers and Responsible Nurse in Figure 14; and Medical Diseases and Conditions, Allergies, and Observations in Figure 15, according to the item chosen in the list of patients.

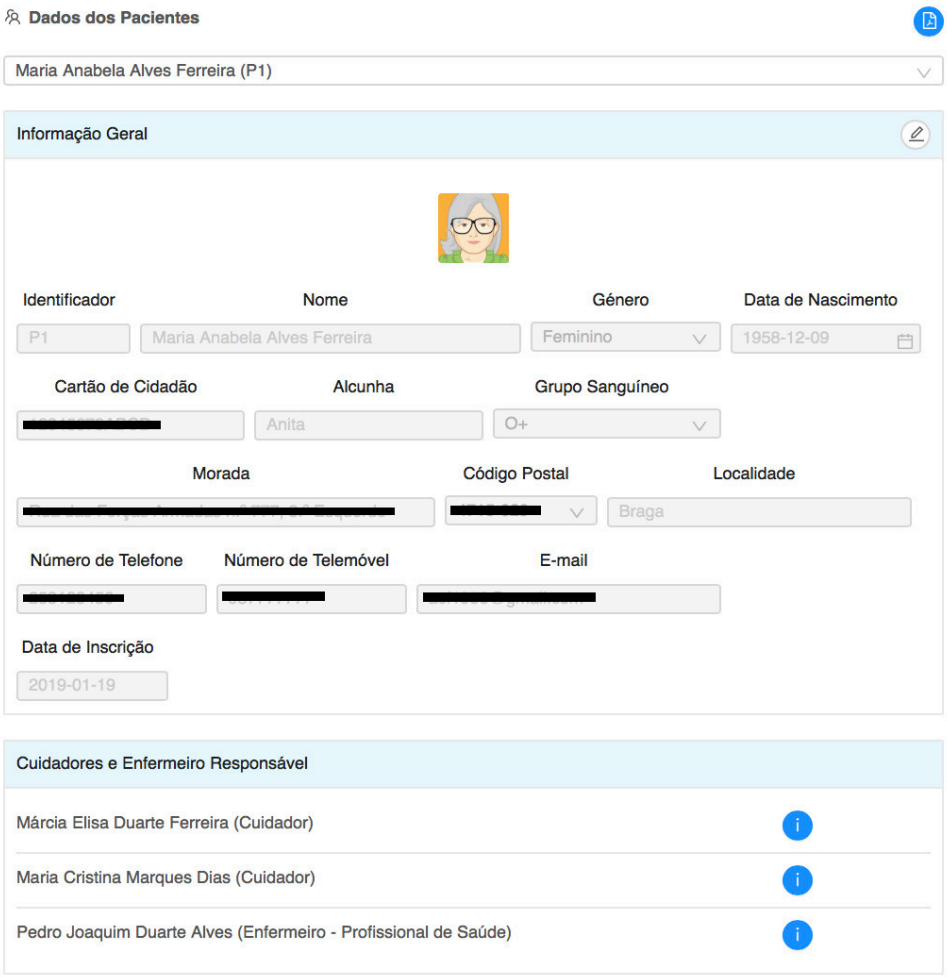


Figure 14: Patients Data module (General Information and Informal Caregivers and Responsible Nurse components) in the React Web application for an elder of a particular informal caregiver (with fictitious data).

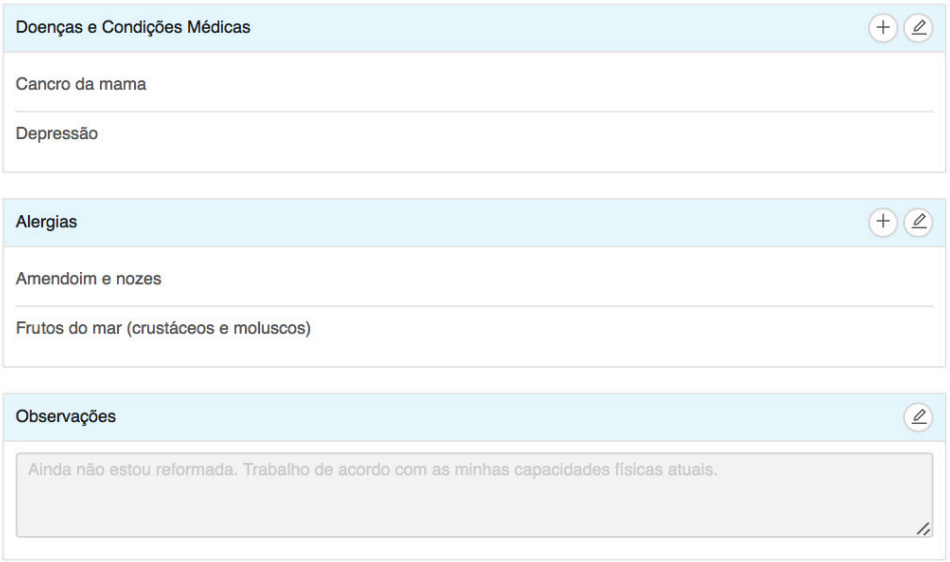


Figure 15: Patients Data module (Medical Diseases and Conditions, Allergies, and Observations components) in the React Web application for an elder of a particular informal caregiver (with fictitious data).

Individual Cares Module:

The Individual Cares module is one of the most important modules of the system since it enables the scheduling, registration, and history of individual cares. On the other hand, through the use of its functionalities, the elderly and their informal caregivers are able to receive specific alerts in order to prevent forgetfulness. Thus, this module enables older adults to schedule their own individual cares and informal caregivers to plan tasks for their patients.

Its definition was possible after several semi-structured interviews and focus groups with health professionals from the nursing homes used as case studies. Thus, the nursing homes were studied in order to identify which areas should be included in this module. The data collection also involved participant observation in order to determine the different types of individual cares performed in nursing homes. Thereafter, a screening was done so that only individual cares that can be performed by elders and their informal caregivers in their home environments were included.

So, first, it is important to refer that the Individual Cares module is divided into three different areas, namely:

1) Scheduling: it enables to proceed to the scheduling of individual cares. Depending on the type of individual care chosen, the fields to fill up might vary. Through this area, the user can plan an individual care with punctual, daily, weekly or monthly frequency. Therefore, an efficient algorithm was developed and implemented in order to quickly generate dates according to the chosen periodicity and data inserted. Nonetheless, the scheduling of meals with the Alimentation submodule and drug administration through the Medication Assistance submodule differ from the other submodules and do not use the scheduling modal with punctual, daily, weekly or monthly frequency (more information is given in the description of each submodule). It is also relevant to refer that older adults can plan their own individual cares (planned by them and practised on themselves) and informal caregivers can plan and practice individual cares on one of more elders (patients) since a list of patients associated with them is provided to the user;

2) Registration: this area lists the individual cares that must be executed by the user, that is, tasks that were already scheduled by him. The sorting of data is made through the start date and time by ascending order to present first the nearest tasks. Additionally, the information presented includes patient's data, description of the individual care to perform, start date and time, end date and time, the type of support needed from informal caregivers, and optional observations. On the other hand, each task can be recorded as realized, not realized or can even be eliminated if it was added by error. An individual care registered as realized includes the possibility of adding optional observations. Furthermore, a task not realized must be obligatorily accompanied by the motive selected through a list with options and optional observations. Finally, it is relevant to refer that overdue tasks are marked in red and the tasks of the day in yellow in order to highlight the need for their imminent and necessary execution;

3) History: information regarding tasks that were already recorded can be consulted in this area. The data presented include patient's information, the individual care description, date and time of the record, status (realized or not realized), and observations. If the task was not realized, the motive is also displayed.

Regarding the scheduling of individual cares, four different frequencies are available: punctual, daily, weekly, and monthly. Nonetheless, some restrictions were implemented in order to avoid that the user plan too many tasks at once as well as the overload of the system. Therefore, daily tasks can only be planned in a maximum validity period of one month, weekly tasks for six months, and monthly tasks for one year.

The scheduling modal is represented in Figure 16. The daily frequency is used as an example.

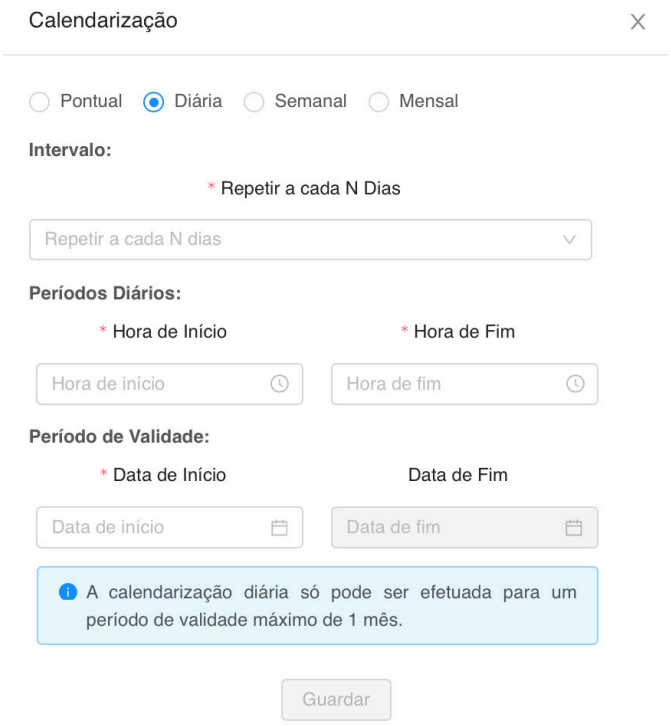


Figure 16: Scheduling modal in the React Web application.

As can be observed in Figure 16, in the scheduling modal for the daily frequency, the fields that have to be filled are the interval (repeat every N days), daily periods (start time and end time), and validity period (start date and end date).

Then, each of these areas are divided into eight different submodules, which are:

A) Alimentation;

B) Personal Care, which is divided into Hygiene Care and Cosmetics Care;

C) Medication Assistance;

D) Positioning;

E) Faeces and Urine;

F) Nursing Interventions;

G) Instrumental Activities;

H) Other Services.

As examples, the Registration and History areas for the Personal Care submodule, which were previously explained, are represented in Figure 17 and Figure 18, respectively. Both areas are very similar for each submodule.

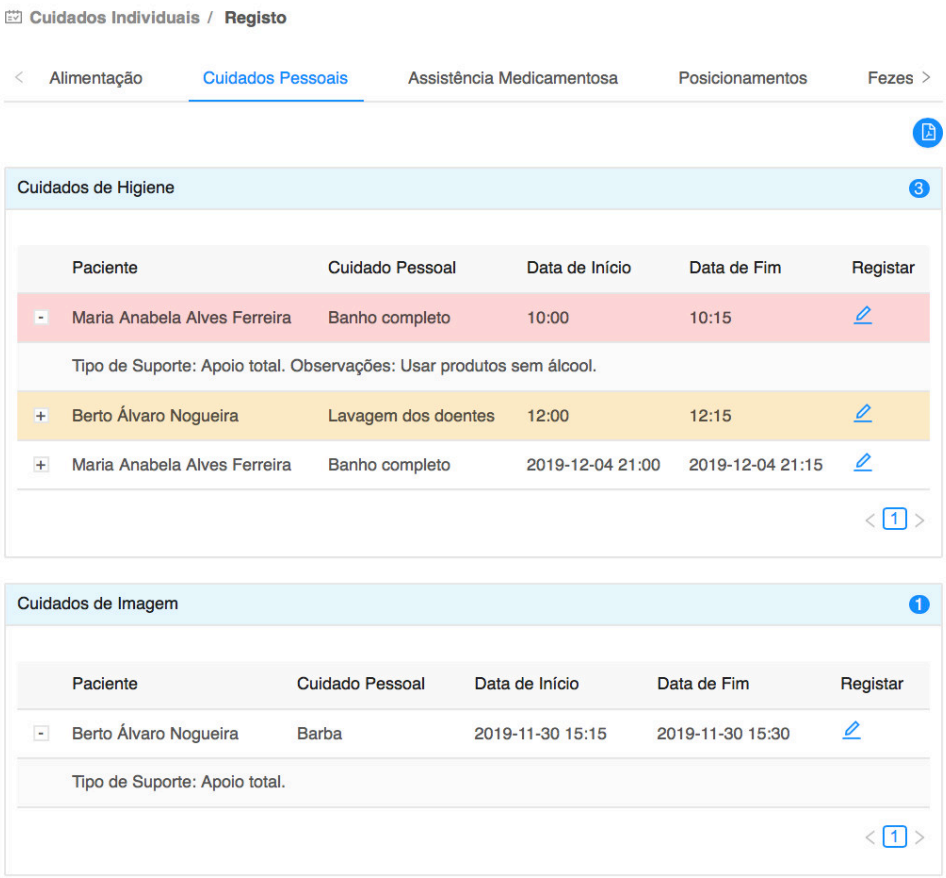


Figure 17: Personal Care submodule (Registration area) in the Individual Cares module in the React Web application for an informal caregiver (with fictitious data).

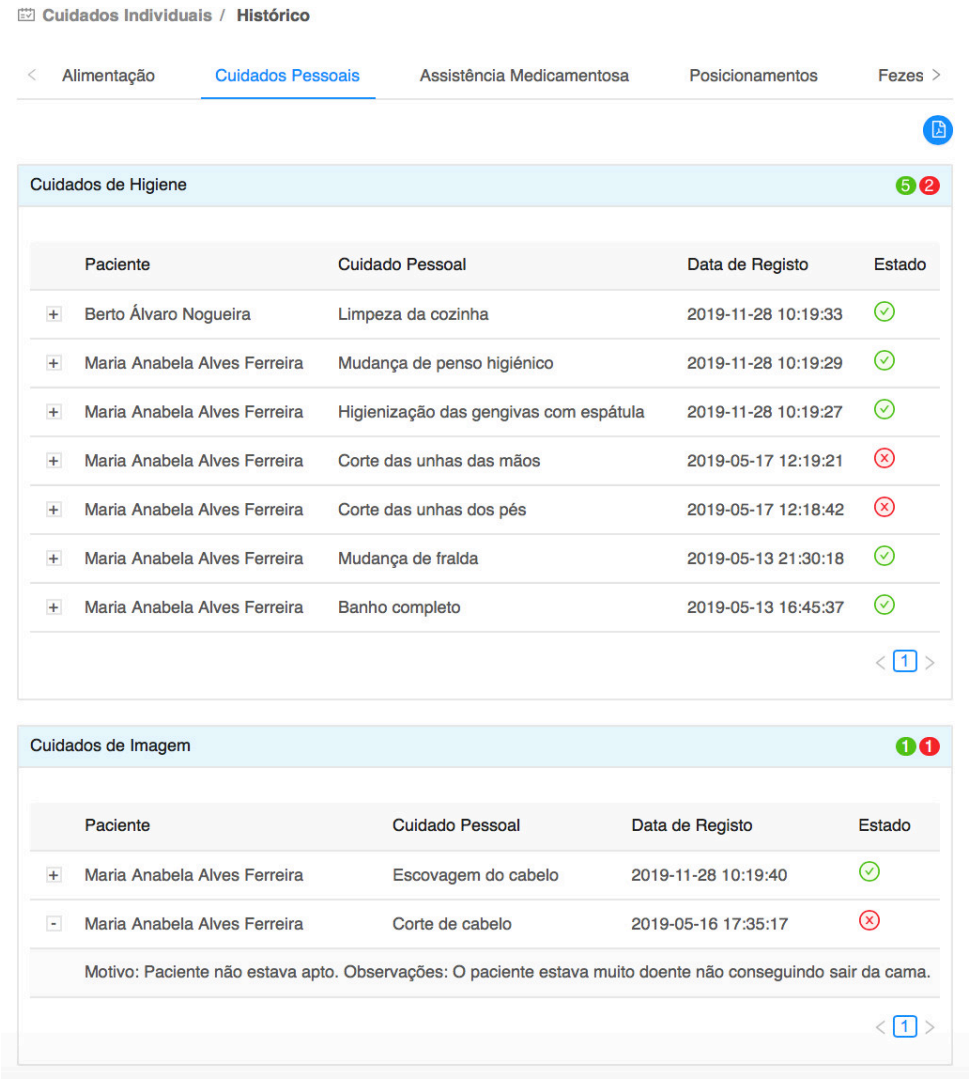


Figure 18: Personal Care submodule (History area) in the Individual Cares module in the React Web application for an informal caregiver (with fictitious data).

Next, each submodule will be discussed in detail in this subsection. Nonetheless, a greater importance will be allocated to the Scheduling area in the description since the biggest differences between the different submodules are in this area and not in the Registration and History areas.

A) Alimentation Submodule:

The first submodule of the Individual Cares module is the Alimentation submodule. The main goal of this submodule is to provide elderly people and their informal caregivers an helpful tool to plan weekly meals and to record important information regarding patients' eating habits. Thus, it enables the users to define a healthy weekly meal plan according to the patient's diet type.

The following information can be permanently recorded through options in dynamic lists:

- If there is a need for support with an object during the meal, if so which one(s);
- Type of food administration;

- Food size;
- Food texture;
- Diet type(s), for example, ”vegetarian”, ”salt-free”, ”gluten-free”, and ”lactose-free” diets, among others;
- Type of support by an informal caregiver, that is, ”full support”, ”partial support”, ”without help” or ”not applicable”;
- Some observations regarding dietary restrictions and food-related risks.

Nonetheless, these data can be edited in the future if necessary. The biggest advantage of the recording of the above information is, hereafter, its consultation by other informal caregivers or even other individuals who are in charge of punctually feeding the patient.

On the other hand, to plan with the Alimentation submodule, the user has to choose from a predefined list the meal that he wants to plan and then choose which day(s) of the week the meal will be taken by the patient (Monday to Sunday), the period(s) of the day (breakfast, lunch, afternoon snack, dinner, and supper), and the period of time (start date and end date) with a maximum validity of one month to minimize excessive planning.

It is important to note that depending on the patient’s diet type, a specific list of meals is made available to the user to choose from. Therefore, this avoids the wrong choice of meals that are not within the patient’s diet type.

B) Personal Care Submodule:

The submodule Personal Care is divided into two different components, namely Hygiene Care and Cosmetics Care. Through this submodule it is possible for older adults and their informal caregivers to schedule diverse personal cares and, thus, enable later the creation of alerts to prevent their forgetfulness.

To plan a hygiene care, the user must fill in the following information:

- Type of hygiene care;
- Hygiene care;
- Type of support by an informal caregiver, that is, ”full support”, ”partial support”, ”without help” or ”not applicable”;
- Observations.

It is important to note that the hygiene care can only be selected after the selection of the type of hygiene care since it is a dynamic list. For example, if the type of hygiene care ”personal hygiene” is selected, the options available for hygiene care would be ”full bath”, ”partial bath”, and ”skin moisturizing”, among others. A different type of hygiene care would have different options.

On the other hand, to plan a cosmetics care, the user must fill in the following information:

- Cosmetics care;
- Type of support by an informal caregiver, that is, "full support", "partial support", "without help" or "not applicable";
- Observations.

Unlike hygiene care, cosmetics care does not have a type associated since there are less options available. Some examples are "shaving", "haircut", and "waxing".

After filling up these fields, the user is able to proceed to the scheduling of the personal care in question with punctual, daily, weekly or monthly frequency.

The Scheduling area of the Personal Care submodule is demonstrated in Figure 19.

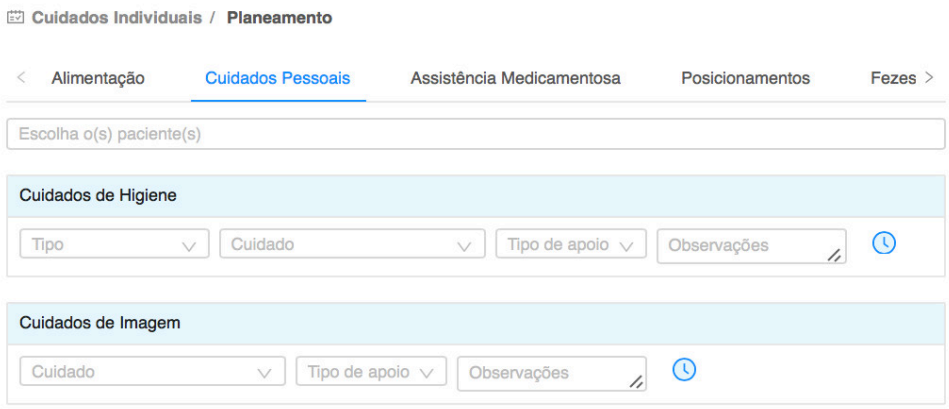


Figure 19: Personal Care submodule (Scheduling area) in the Individual Cares module in the React Web application for an informal caregiver.

C) Medication Assistance Submodule:

This submodule offers to the target audience a tool to manage several tasks related to drug administration. The Medication Assistance submodule is divided into three different components, namely:

1) Current Medications;
2) Emergency Medications;
3) Prohibited Medications.

The Current Medications component enables users to add, edit, and delete the current medications of the patient since it includes his usual medications and temporary medications. To add a medication, the user must select it in a list, which is generated through the drug repository provided by a Portuguese hospital stored in the database. The following information must be also provided by the user:

- Quantity;

- Unity (”pills”, ”grams”, ”milliliters” or ”drops”);
- Period(s) of the day (”breakfast”, ”lunch”, ”afternoon snack”, ”dinner”, and ”supper”);
- Day(s) of the week (Monday to Sunday);
- Start date;
- End date (leaved empty if it is an usual medication);
- Optional observations.

Thereafter, if desired, it is possible to plan the administration of a specific medication according to the period of time chosen and, consequently, the user will receive specific alerts to notify the need for such drug administration. Nonetheless, in order to prevent an excessive scheduling, some restrictions are made, that is, an user cannot schedule drug administration for a usual medication for a period of time longer than one month. Nonetheless, a temporary medication can be planned for the entire period of time that it must be administered (start date to end date). On the other hand, it is also important to refer that if a certain medication is already planned, the validity period of the scheduling is presented to the user and it is also impossible to plan a new administration of the same drug within that period of time. During the scheduling process, data regarding the type of support and optional observations are requested to the user.

By clicking on a medication from the list of current medications, the Medication Sheet is displayed. Such form provides to user information concerning the drug administration of such medication for each day of the week. To do so, the user has to choose the day of the week from a list (the current day of the week is selected by default) and, thereafter, data regarding its period of validity, optional observations, and the quantity and unity of drug administration for each period of the day is presented. An example of a Medication Sheet for a drug of a particular elder is presented in Figure 20.

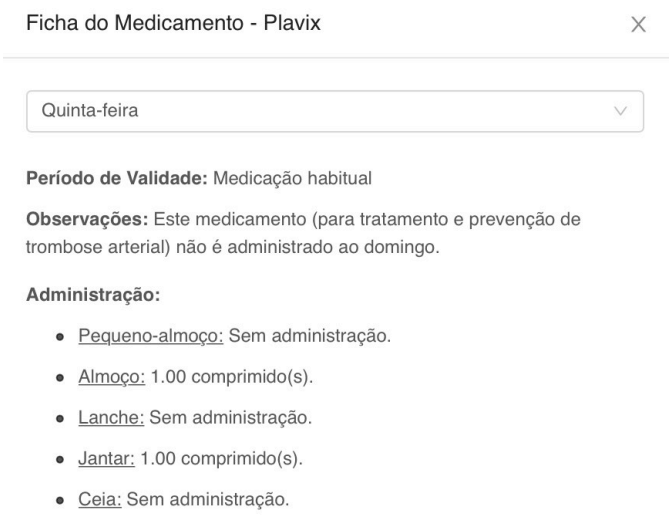


Figure 20: Medication Assistance submodule (Medication Sheet) in the Individual Cares module in the React Web application for a drug of a particular elder (with fictitious data).

Through the Emergency Medications component the users can add, edit, and delete the drugs that must be administered to the patient in emergency situations. Data regarding the type of situation that requires such administration, quantity, unity (pills, grams, milliliters or drops), and optional observations must be provided by the user.

The Prohibited Medications component is used to add, edit, and delete the patient's prohibited medications. This component is very important since it allows individuals to know which medications cannot be administered to the patient. Optional observations can also be added by the user.

Finally, all this information can be saved through the creation of a Portable Document Format (PDF). The document can be printed out and then fixed or even sent to be consulted by informal caregivers, family members, and health professionals, among others. Thus, through this functionality, it is possible to generate a Patient Medication Record with all the information regarding his current, emergency, and prohibited medications. Some individuals can even use such document in order to prepare the patients' weekly pill organizer (7-day pill box), which is widely used by the elderly.

The Scheduling area for the Medication Assistance submodule is showed in Figure 21. The Current Medications, Emergency Medications, and Prohibited Medications components can be viewed for a specific elder chosen by an informal caregiver.

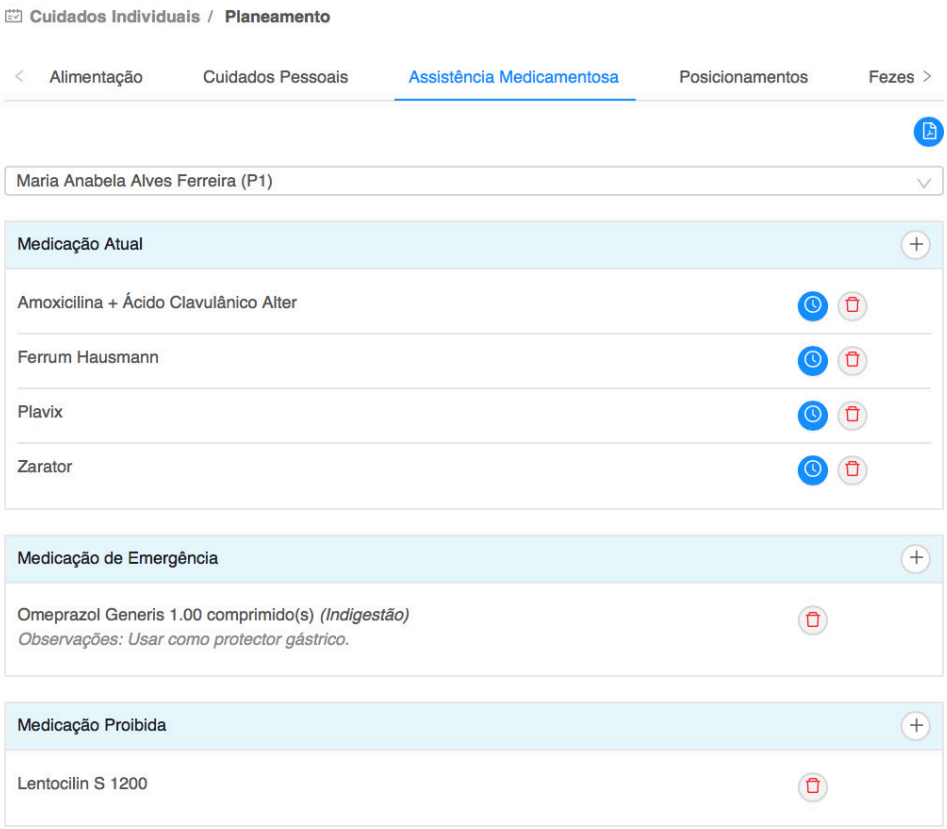


Figure 21: Medication Assistance submodule (Scheduling area) in the Individual Cares module in the React Web application for an elder of a particular informal caregiver (with fictitious data).

D) Positioning Submodule:

The Positioning submodule enables elders and their informal caregivers to schedule the reposition of patients' in bed. Turning patients over in bed is of utmost importance since it helps keep blood flowing. Therefore, this helps the skin to stay healthy and prevents bedsores, which is caused due to pressure by lying in bed in one position. Additionally, such reposition is a good opportunity to check for redness and sores on the patient. So, the scheduling modal enables users to plan such reposition according to the patient's needs in order to prevent forgetfulness.

Thus, in order to schedule through the Positioning submodule, the user must fill up a few fields, namely:

- The type of reposition, that is, "left lateral decubitus", "right lateral decubitus", "supine position", "prone position", and "raise";
- Type of support by an informal caregiver, that is, "full support", "partial support", "without help" or "not applicable";
- Optional observations.

Finally, an area to record the risks associated with the patient's reposition is available as optional observations.

E) Faeces and Urine Submodule:

This submodule is used to control older adults' faeces and urine. Information such as consistency, color, and frequency are excellent indicators regarding elders actual health status. Such data can provide evident clues to the current state of their health.

Thus, through the Scheduling area in the Faeces and Urine submodule, users can set reminders and, consequently, receive alerts regarding the need of recording specific information about faeces and urine. Therefore, in order to perform the control of faeces and urine, the user can fill in information regarding optional important observations. Then, it is possible to proceed to the scheduling of such task with the desired periodicity. Nonetheless, it must be indicated if it is intended to plan for the registration of faeces, urine or both types of bodily wastes elimination.

In the Registration area, after the scheduling of the individual care, the user must fill in essential information. If the individual care is registered as realized, the data that must be completed include optional observations and more importantly the aspect of faeces and/or urine. Thus, according to if it was scheduled to record faeces, urine or both, a field must be filled up for each regarding the aspect of such bodily wastes through a dynamic list with predefined options. Intestinal elimination (faeces) includes options such as "liquid stools" and bladder elimination (urine) "brown urine". The option chosen is a good indicator regarding the elder's current health status.

F) Nursing Interventions Submodule:

The Nursing Interventions submodule is a pertinent submodule since it enables users, that is, older adults and informal caregivers, to schedule nursing interventions. Nonetheless, the nursing intervention

scheduled must be performed by the user who planned the task and not health professionals such as nurses and healthcare assistants. Nursing interventions practiced by health professionals must be planned through the External Services module, which will be described later in this document.

In order to schedule a nursing intervention, the user must fill in the following fields:

- Type of nursing intervention, for example, "nasogastric intubation", "vital signs monitoring", and "colostomy";
- Nursing intervention;
- Type of support by an informal caregiver, that is, "full support", "partial support", "without help" or "not applicable";
- Observations.

It is interesting to note that the "nursing intervention" field is a dynamic list, that is, depending on the value chosen in "type of nursing intervention", a different list of values is available in "nursing intervention". For example, if the user chooses the value "monitor vital signs" as the type of nursing intervention, the values "monitor pain", "monitor respiratory rate", "monitor temperature", "monitor heart rate", and "monitor blood pressure" are available to choose from as the nursing intervention.

The Scheduling area for the Nursing Interventions submodule is presented in Figure 22 for a given informal caregiver.

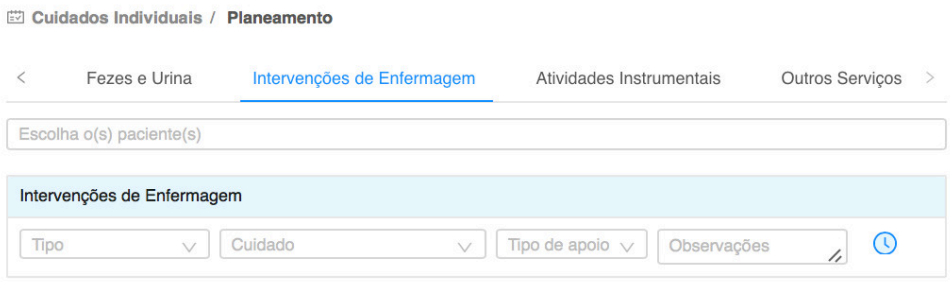


Figure 22: Nursing Interventions submodule (Scheduling area) in the Individual Cares module in the React Web application for an informal caregiver.

G) Instrumental Activities Submodule:

Instrumental activities of daily living include activities that support daily living activities at home or in the community, in other words, they are not necessary for the fundamental functioning of elders, but they can let them live independently in a community. They can be considered more complex tasks of unassisted living and being able to do them can add to an older adult's quality of life tremendously. Examples of instrumental activities include:

- Cleaning and maintaining the house;

- Financial management;
- Preparing meals;
- Taking care of pets;
- Communication management, for example, using the telephone or an other form of communication;
- Moving within the community;
- Shopping for groceries and necessities.

Therefore, in order to be able to schedule an instrumental activity through the system, the user must fill in three different fields, namely:

- Instrumental activity from a list (description);
- Type of support by an informal caregiver, that is, ”full support”, ”partial support”, ”without help” or ”not applicable”;
- Observations.

H) Other Services Submodule:

The Other Services submodule enables users to schedule individual cares that are not included in the Alimentation, Personal Care, Medication Assistance, Positioning, Faeces and Urine, Nursing Interventions, and Instrumental Activities submodules.

To do so, users must complete information regarding:

- Description of the service, which is a free text field;
- Type of support by an informal caregiver, that is, ”full support”, ”partial support”, ”without help” or ”not applicable”;
- Observations.

External Services Module:

The External Services module enables elders and their informal caregivers to schedule, register, and visualize external services that were already realized or not realized. It is of utmost importance since it allows an efficient sharing of information between users, that is, the informal caregivers of a specific senior can know in time the external services that their patients have to attend and if he needs to be accompanied and, if necessary, by whom.

This module is divided into three different areas, namely:

1) Scheduling: it permits users to schedule external services. Seniors can schedule their own external services that they have to attend and informal caregivers for one of more elders at the same time since a list with all their patients is made available to them. To do so, the user has to fill in four different fields, namely the description of the external service that depends on the submodule chosen, accompany's status (if the patient needs to be accompanied, that is, "Yes" or "No"), where it is, and optional observations. Then, the user can plan the external service with punctual, daily, weekly or monthly frequency through the scheduling modal, which was already described in the Individual Cares module;

2) Registration: this area lists all the external services that an older adult has to attend and, in the case of an informal caregiver, those that have to be attended by his patients. The listing is made by ascending order where older items are listed before newer items. The information presented includes patient's data, description of the external service to attend, where it is, date and time of realization, accompany's status ("Yes" or "No"), optional observations, and by whom it was planned. On the other hand, each external service can be registered as realized with mandatory observations, not realized with a required motive and optional observations, and eliminated if it was added by mistake. It is also interesting to note that the overdue external services are highlighted in red and the imminent ones in yellow, that is, the external services that must be attended in less or equal to twenty four hours from today;

3) History: it presents in a table all the external services registered for a specific elder or the set of patients of an informal caregiver. The data shown include patient's data, the description of the external service, where it was, date and time of registration, observations, by whom it was recorded, and status (realized or not realized). If the external service was not realized, the motive is also displayed.

Then, each of these areas are divided into five different submodules, which are:

A) Appointments;

B) Medical Examinations;

C) Nursing Interventions;

D) Rehabilitation Services;

E) Other Services.

The five submodules are quite similar. The only difference is in the description of the external service since a different list is made available for each submodule. The possible description for appointments is a list of specialities, medical examinations a list of different types of medical examinations, and so on.

As an example, Figure 23 demonstrates the History area for the Appointments submodule.

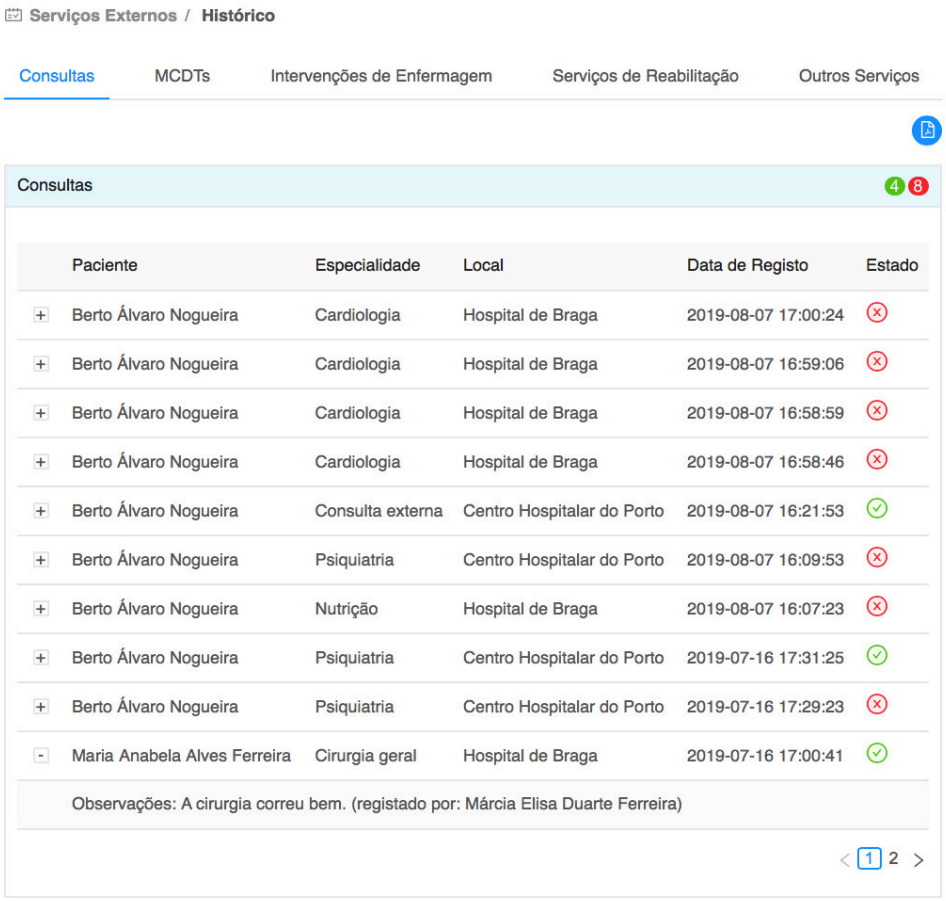


Figure 23: Appointments submodule (History area) in the External Services module in the React Web application for an informal caregiver (with fictitious data).

Tasks Module:

The Tasks module is available to all health professionals, that is, nursing and technical and administrative staff. This module enables them to schedule tasks related to the system, register such tasks, and then consult the history of the tasks recorded. As they have other tasks within the nursing home(s) where they are working, this module allows them to remain engaged in the system through a task management module and to receive timely alerts.

Similarly to other modules, it is divided into three different areas:

1) Scheduling: this area enables users to plan their tasks. To do so, they have to fill in two fields, namely the description of the task itself and optional observations. Then, it is possible to schedule the task described with punctual, daily, weekly or monthly frequency through the scheduling modal, which was already described in the Individual Cares module;

2) Registration: this area is used by users to proceed to the registration of the tasks planned. All the tasks scheduled are listed in a table with their description, start date and time, end date and time, and optional observations. Each task can be recorded as realized with optional observations, not

realized with a mandatory motive and optional observations, and eliminated if the task was added by error. On the other hand, the overdue tasks are highlighted in red and the imminent ones in yellow, that is, the tasks that must be realized in less or equal to twenty four hours from today;

3) History: a table presents the listing of all tasks recorded through the Registration area. The information displayed includes the description of the task, its date of registration, observations, and status (realized or not realized). For tasks that were not realized, the motive is also visible.

Figure 24 shows an example of the Registration area for the Tasks module.

Figure 24: Tasks module (Registration area) in the React Web application.

User Management Module:

The User Management module is only made available to technical and administrative staff, that is, administrators. It enables them to add, edit, and delete users from the system, including elders, their informal caregivers, and care workers and professional staff working in the nursing homes.

Therefore, through this module, new members can be added to the community at the time of their registration. Nonetheless, their personal information can also be updated by administrators using this module, including their associations with other user types, that is, seniors and their informal caregivers and the nurse who is supervising them. Additionally, users can be removed from the system.

Resource Management Module:

The Resource Management module lets administrators manage the system's resources, that is, the various listings of items used through the system. To do so, the user has to choose from a list the type of resource that he wants to visualize. Nonetheless, the first type of resource from the list is chosen by default. Then, this module enables users to add, edit, and delete items from the list displayed in a table that includes information regarding the unique identifier of each item and its description.

Eighteen different types of resources are available to the technical and administrative staff to manage, namely:

- Allergies;
- Alimentation;

- Medication Assistance;
- Instrumental Activities;
- ZIP Codes;
- Personal Care;
- Medical Diseases and Conditions;
- Specialities;
- Faeces and Urine;
- Genders;
- Blood Groups;
- Nursing Interventions;
- Medical Examinations;
- Motives (non-realization);
- Objectives;
- Positioning;
- Rehabilitation Services;
- Types of Support.

It is relevant to note that for each type of resource an initial data collection was conducted and, thereafter, the models were loaded with the information. Nonetheless, if necessary, the initial listing defined for each type of resource can be updated through the Resource Management module over the years.

As an example, Figure 25 displays the Allergies resource in the Resource Management module.

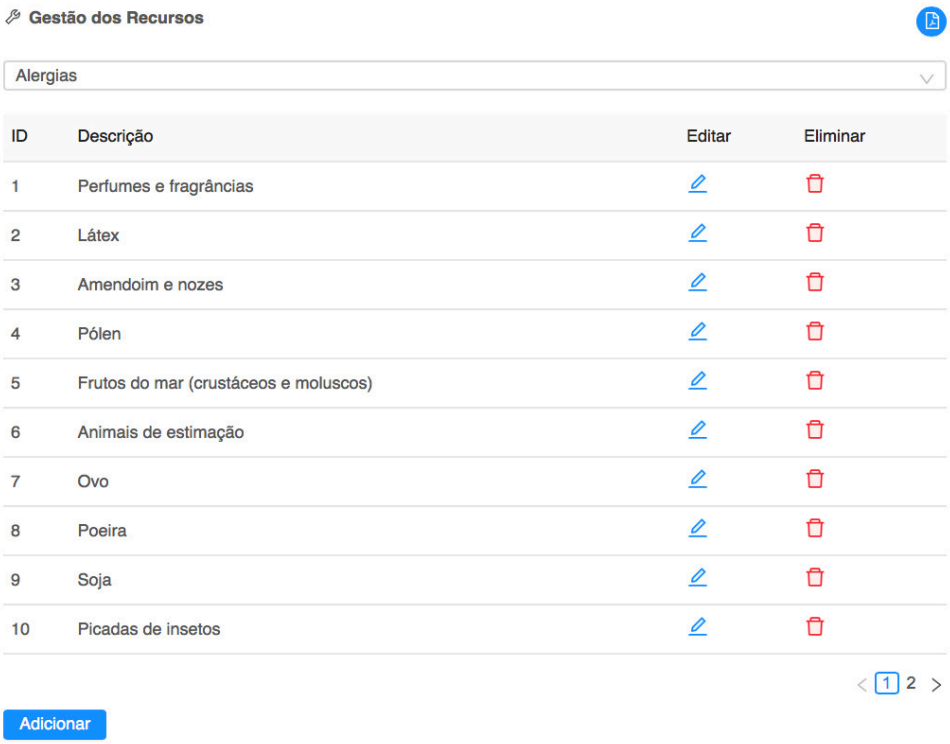


Figure 25: Resource Management module in the React Web application.

Patients Objectives Module:

The Patients Objectives module enables seniors and their informal caregivers to define objectives for themselves or their patients, respectively. Nurses can only visualize the objectives of the elders that they are supervising.

This module is an interesting addition to the system since it encourages the evolution of the elderly in four different areas, namely human expression, physical, mental, and sociocultural. Each area is then divided into different objectives, which are in turn divided into predefined indicators that must be completed. Thus, through the Patients Objectives module, the welfare of the elderly is strengthened and duly accompanied by informal caregivers and nurses.

In Table 5, the list of objectives per objectives' area is presented.

Table 5: List of objectives per objectives' area

Objectives' Area	List of Objectives
Human Expression	• Develop interpersonal communication skills; • Develop group interaction; • Communicate needs; • Express emotions.
Physical	• Promote sensory abilities; • Develop physical activity; • Maintain favourable health status; • Autonomously perform basic essential activities.
Mental	• Develop temporal orientation; • Develop spatial orientation; • Develop reasoning and calculation skills; • Develop memory.
Sociocultural	• Bring the patient closer to the family; • Involve the patient in the community; • Make choices.

As previously mentioned, each objective is divided into different predefined indicators that must be completed. As an example, the objective "Express emotions" of the objectives' area "Human Expression" is divided into five different indicators, namely "Express anger", "Express sadness", "Express happiness",

"Express fear", and "Express anxiety". The goal is the senior to complete the list of indicators of the objective chosen by the set deadline.

On the other hand, the module is divided into three different components, namely:

i) Add Objective: this component enables users to add objectives. To do so, four different fields must be fill in, namely the objectives' area, objective, deadline (date), and optional observations;

ii) Pending Objectives: the pending objectives are listed in a table, which includes data regarding the description of the objective, list of indicators and the status for each (completed or not completed), deadline, and optional observations. The objectives can be registered in this component through three different options, namely edit, archive, and delete. The option "edit" permits users to update data regarding the status of each indicator, deadline, and optional observations. Objectives can be archived through the "archive" option, where optional observations can be added. On the other hand, an objective can be deleted with the "delete" option;

iii) Archived Objectives: in this component, information regarding the archived objectives can be visualized, namely the description of the objective, list of indicators and the status of each, date and time when the objective was archived, optional observations, and status (realized or not realized).

It is interesting to note that the automatic management of this module is performed with triggers, procedures, and functions implemented in the database in Structured Query Language.

In Figure 26, an example of the interface of the Patients Objectives module is represented for a particular informal caregiver (user type 2).

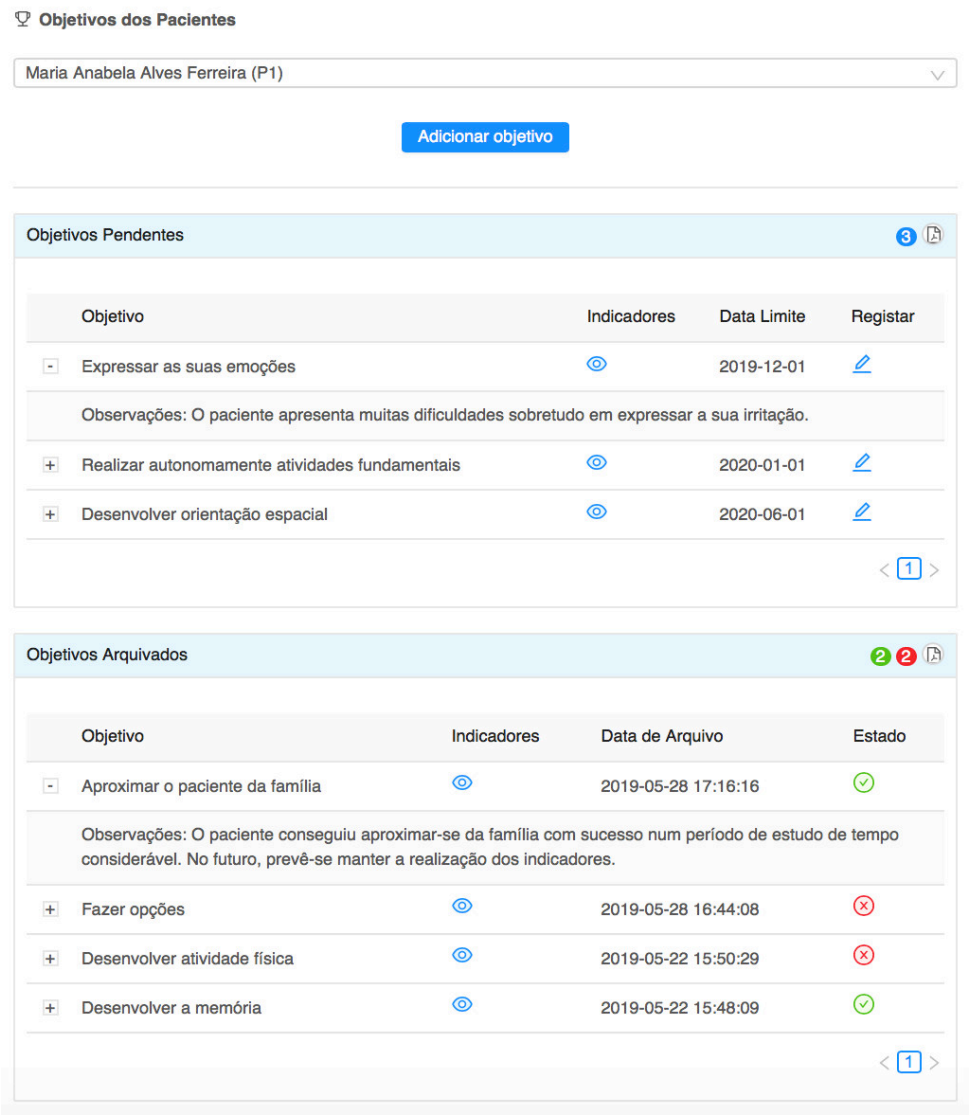


Figure 26: Patients Objectives module in the React Web application for an informal caregiver (with fictitious data).

Collaborative Board Module:

The Collaborative Board module lets elders, informal caregivers, and nurses share between them relevant comments. Through this module it is possible, for example, to share recommendations and advice between all the elements involved, create customized reminders and alerts, send requests including suggestions or even simply post important information. Thus, it strengthens the Collaborative Learning features embedded in the system but also combats social isolation. On the other hand, it is a patient-oriented board so informal caregivers and nurses must choose a patient from the list that is displayed in order to visualized his board. Nonetheless, the first item of the list is chosen by default.

The module is divided into two different components, namely:

i) Add Comment: this component enables users to add new comments. To do so, two fields must be filled in, namely the description of the comment and its degree of priority (”Low” or ”High”);

ii) Comments: it lists all the comments in the collaborative board by descending order, that is, the newer items are listed before the oldest ones. The name and unique identifier of the user who posted the comment, date and time when it was posted, description of the comment, and an alert icon if the comment is of high priority are data presented to users. This component also enables users to edit (description of the comment and its degree of priority), archive or delete their own comments.

As an example, in Figure 27, the Collaborative Board module for a specific elder of an informal caregiver is presented.

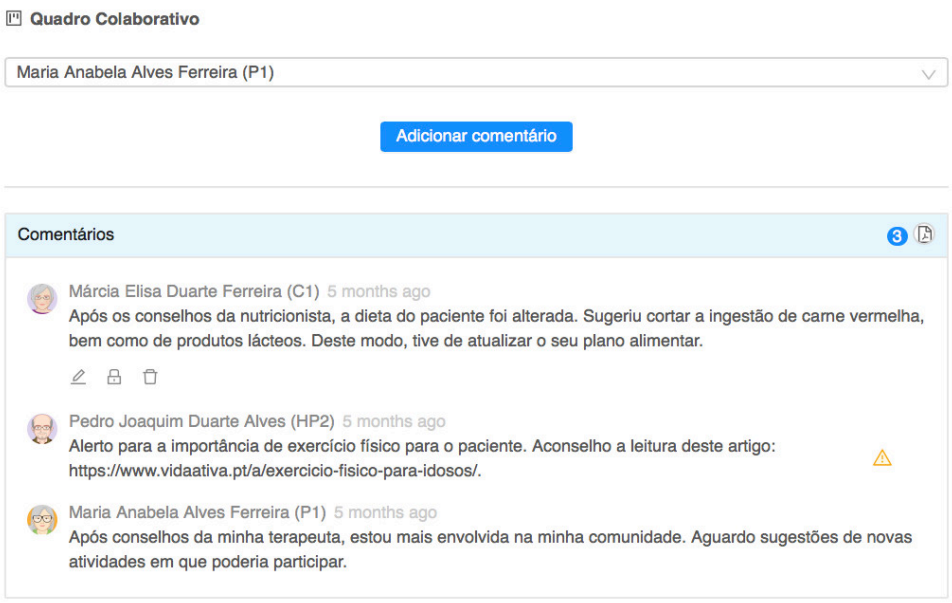


Figure 27: Collaborative Board module in the React Web application for an elder of a specific informal caregiver (with fictitious data).

User Notes Module:

The User Notes module enables all user types, that is, seniors, informal caregivers, nurses, and administrators to add new notes and visualize their own list of notes already added. This is a useful module since it permits users to save information of interest that can be consulted later on by them. On the other hand, all system-related notes are also centered on the same solution.

This module is divided into two different components, namely:

i) Add Note: this component enables users to add new notes. To do so, three fields must be filled in, that is, title, description, and color of note that is chosen from the color picker;

ii) Notes: it lists all the notes by descending order, in other words, the newer items are listed before the oldest ones. The title, description, and date and time of last update for each note are presented to users in the color chosen from the color picker when the note was added. This component also enables users to edit (title, description, and color), archive or delete their own notes.

In Figure 28, an example of the User Notes module is represented for a specific user.

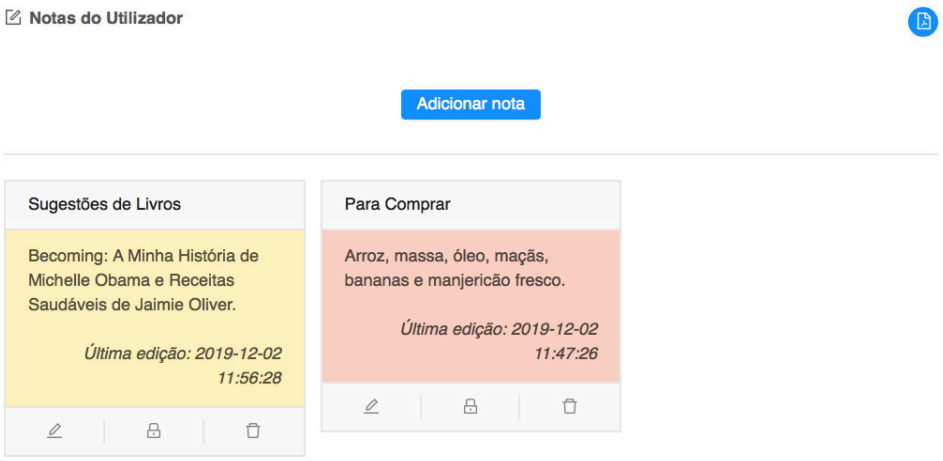


Figure 28: User Notes module in the React Web application for a specific user (with fictitious data).

BI Indicators Module:

The BI Indicators module and its five different submodules are described and explained in detail in Chapter 6 of this manuscript, that is, in the "Business Intelligence Clinical and Performance Indicators" chapter.

Forum Module:

The Forum module can be used by all user types, that is, elders, informal caregivers, nursing staff, and administrators, to communicate with other members in the community. Thus, through this module, they can hold conversations in the form of posted messages in the encouraged online discussion.

With the help of this module, it is intended to strengthen knowledge sharing and mutual help among the different members of the community (collaboration), thus presenting Collaborative Learning features. It is planned to also improve social interaction especially for seniors and their informal caregivers since social isolation and loneliness are issues already mentioned in the State of the Art chapter (Chapter 2) that this system aims to counteract. In fact, it can affect not only the physical but also mental health of older adults and their informal caregivers. Additionally, other advantages of the implementation of this module include building trust, sharing experiences, clarifying assumptions, visitor retention, improving communication, and better engagement, among others.

On the other hand, the forum is hierarchical in structure. It will be divided into different categories and each category can have different subforums that will be defined by the administrators of the system (both the categories and, consequently, their subforums). Then, each subforum may have several topics that can be created by all user types. Each topic is a new discussion started that can be replied by all users registered in the system.

Support Resources Module:

The Support Resources module lets authorized users add new support resources to the repository and all user types to consult the items added to it. It is a fundamental module integrated into the system since it offers to users, mainly seniors and their informal caregivers, safe support resources that they can consult since medical validation and approval are made by health professionals who add new resources to the repository. Therefore, through this module, the health and safety of the elderly are greatly improved and prioritized by trying to reduce the use of unapproved or even wrong medical resources by them and their caregivers.

Nonetheless, this module is divided into two different areas since two different types of support resources were differentiated, namely:

1) Textual Guides: enables nurses and administrators to add textual guides and all user types to visualize the items added to the repository;

2) Videos: this area is used by nurses and administrators to add videos and all user types can then visualize the items added to the repository.

On the other hand, each area is divided into two components, that is:

i) Add Item: this component enables nurses and administrators to add textual guides or videos to the repository, depending on the area chosen (Textual Guides or Videos). To do so, they must fill in four different fields, namely title, description, file (upload) in PDF for textual guides or URL for videos, and language ("PT" (Portuguese) or "EN" (English));

ii) Repository of Items: this component lists by descending order the items added to the repository (textual guides or videos). The information presented includes the title, description, date and time of last update, and an option to visualize the item, that is, the textual guides in a PDF viewer and videos in a video player. Nonetheless, nurses and administrators also have the options to edit (title, description, uploaded file or URL, and language), archive, and delete items from the repository.

As an example, the Videos area for the Support Resources module is represented in Figure 29 for a specific administrator.

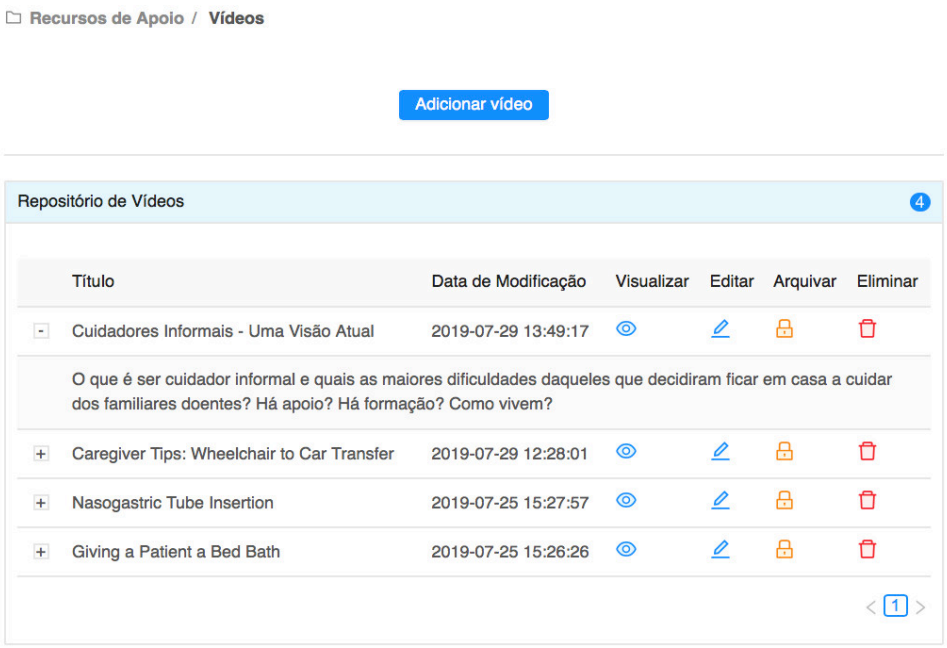


Figure 29: Support Resources module (Videos area) in the React Web application for a specific administrator (with fictitious data).

Skype Module:

The Skype module is a very useful module for all user types of the system, that is, elders, their informal caregivers, nurses, and administrators. Through the Web application, it is possible to launch an external application that is one of the most popular applications in the world, namely Skype, which is an application used by millions of people to mainly chat and call every day. To do so, the users do not need to have the application installed in their computer or mobiles devices such as tablets and smartphones. There is a version of Skype for the Web, which can be used to communicate in Skype using the browser (available via `https://web.skype.com/`). Such online version of Skype is launched through the system, which avoids downloading and installing the program to a computer or mobile device. Nonetheless, if the user wants to, he can launch Skype directly from its device if the application is installed.

Skype was chosen among other solutions due to its great set of interesting functions and features, namely: [161]

- Audio and HD Video Calling - free one to one or group calls that only need access to the Internet and a webcam;
- Screen Sharing - it is possible to easily share anything on screen during a call with integrated screen sharing, including group screen sharing;
- Call Recording and Live Subtitles - enables users to record Skype calls' key moments and use live subtitles to read the words that are spoken;

- Call Phones - seniors, informal caregivers, family members, friends, health professionals, and colleagues can be effortlessly reached when they are not online with affordable international calling rates to mobiles and landlines;
- Sending Files - it is possible to share photos, videos, and other files by simply dragging and dropping them into the conversation window;
- Contacts - to stay constantly in touch, various functions are provided in Skype for managing contacts. The contacts added are stored in the server of the program and can be reached on any device with the user's credentials;
- Privacy - sensitive conversations are kept private with industry standard end to end encryption;
- Among others.

Thus, it is expected that this module will be used by users in order to execute mostly the following tasks:

- Communication between elders, informal caregivers, family members, friends, health professionals, and colleagues through audio, video calling or even call phones;
- Health professionals (nursing staff) can show step-by-step guides to older adults and their informal caregivers on an one-to-one basis or in a group setting through video calling;
- Seniors and their informal caregivers can record important explanations from nurses and listen to them again later;
- The sharing of files, for example, photos of wounds to be analysed, between elders, informal caregivers, and nursing staff;
- The building of a permanent repository of contacts associated with the user, including the contacts available in the proposed system in this doctoral dissertation (seniors, their informal caregivers, and nurses).

The integration of such capabilities is absolutely necessary since it strengthens the communication between the different elements of the target audience and improves older adults' well-being and health and their informal caregivers' welfare by promoting CL, mutual support, and social interaction.

Alerts Module:

The Alerts module is an essential module in the system since it enables all user types to receive in time notifications of interest. So, it is intended to maintain not only the members of the community informed but also to reduce the number of tasks not performed due to forgetfulness. Additionally, through this module, users can be alerted of unusual situations that need to be checked and then possibly corrected.

It is divided into three different components, namely:

i) Add Alert: enables administrators to add customized general alerts that all user types will receive. To do so, he must fill in two fields, that is, the area and description of the alert;

ii) General Alerts: lists all general alerts of the system by ascending order, which includes the description and date and time of creation of the alert. Each general alert remains active during a validity period of one week;

iii) Specific Alerts: this component lets users visualize their own specific alerts by ascending order, which includes information regarding the description and date and time when the alert was sent. When alerts are flagged as seen by the user, they are removed automatically from the component.

About 22 different alerts are currently defined in the system, namely:

- Individual cares to be realized by seniors or their informal caregivers one hour before the scheduled date and time;
- External services to be attended by seniors 24 hours before the scheduled date and time;
- Tasks to be realized by health professionals one hour before the scheduled date and time;
- If the total number of individual cares not realized by elders or their informal caregivers reaches the value of 3;
- If the total number of individual cares not realized by elders or their informal caregivers reaches the value of 10;
- If the total number of individual cares not realized by elders or their informal caregivers reaches the value of 25;
- If the total number of external services not attended by a senior reaches the value of 1;
- If the total number of external services not attended by a senior reaches the value of 5;
- If the total number of external services not attended by a senior reaches the value of 10;
- If the total number of tasks not realized by health professionals reaches the value of 3;
- If the total number of tasks not realized by health professionals reaches the value of 10;
- If the total number of tasks not realized by health professionals reaches the value of 25;
- When a new patient is associated to a health professional;
- If the nurse that supervises a patient is changed;
- If a new support resource is added to the repository (textual guide or video) in the Support Resources module;

- If a new comment is added in the Collaborative Board module;
- If an objective is added or archived in the Patients Objectives module;
- If a new medical disease or condition is added to a patient;
- If a new allergy is added to a patient;
- If an informal caregiver is added or removed from a patient;
- If a new medical disease or condition is added to an informal caregiver;
- Customized general alerts created by administrators, for example, a new functionality was added to the system or system maintenance period.

It is relevant to note that this module is managed automatically through triggers, procedures, and functions implemented in the database in Structured Query Language. Each alert is sent to the group of individuals concerned.

An example of the Alerts module is presented in Figure 30 for a specific informal caregiver.

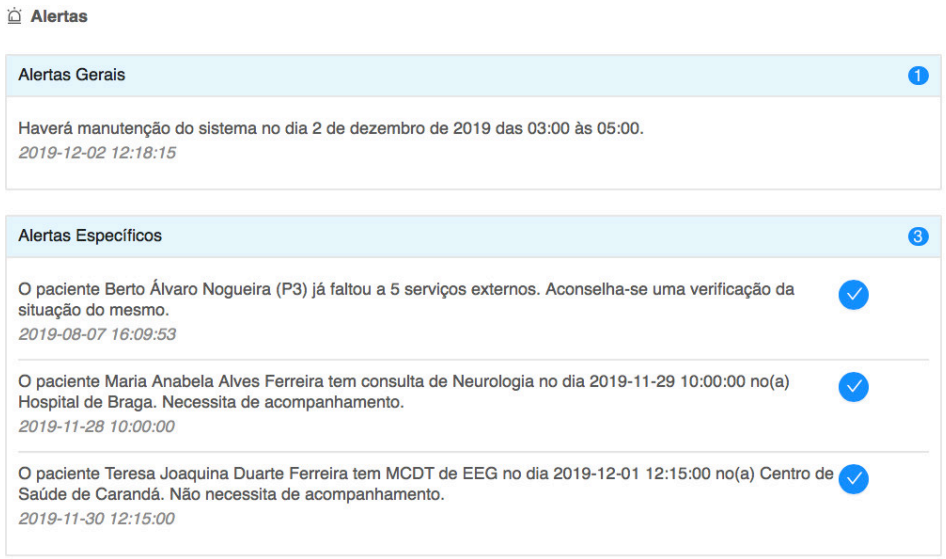


Figure 30: Alerts module in the React Web application for a specific informal caregiver (with fictitious data).

Profile Module:

The Profile module is a public profile that can be accessed by all the members of the community. Each user has his own profile that includes the following information:

- Complete name;
- User type;

- Unique identifier;
- Profile picture;
- Gender;
- Date of birth and age;
- Interests (description);
- About me (description);
- E-mail;
- Date of registration and number of days since registration;
- Date of last activity and number of days since last activity.

On the other hand, the interests, about me, and color of the profile can be edited directly from the Profile module by each user. Personal data such as the complete name, profile picture, gender, date of birth, and e-mail must be edited in the User Data module already described in this subsection.

Nonetheless, the date of birth (and age) and e-mail are optional fields since it is possible for users to edit their settings and hide data that they consider confidential from their public profile.

Figure 31 shows as an example the Profile module for a specific user.

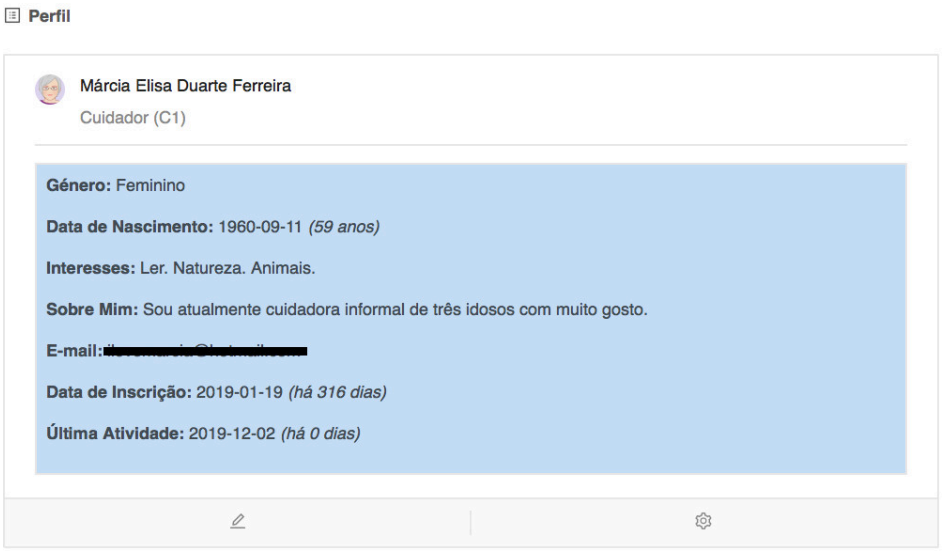


Figure 31: Profile module in the React Web application for a specific user (with fictitious data).

Logout Module:

The Logout module enables users to logout from the application through an option made available at the top right corner of the Web solution.

5.4.3 *React Native Mobile Application*

The mobile application is being developed with the React Native JavaScript framework, and the Unity3D game engine and Integrated Development Environment and Vuforia Augmented Reality Software Development Kit in the programming language C# for the integration of Augmented Reality features. In a first stage, the solution is being designed for Android devices since Android is currently the world's most popular mobile operating system. However, the React Native framework permits writing a mobile application for both iOS and Android from the same codebase. On the other hand, Unity enables the creation and export of ".apk" files, which is the package file format used by the Android operating system for the installation of mobile applications. Nonetheless, Unity solutions can be deployed to other platforms such as iOS and UWP. The sharing of data between the mobile application and MySQL database is performed through a Node.js RESTful API.

The main aim of the mobile application is to provide services enhanced with AR capabilities that cannot be included in the Web application and, on the other hand, to offer some of the most important modules of the Web solution but with an increased attention in the responsive mobile design. Thus, it is also intended to improve the user-friendliness of the system by upgrading the presentation of a few interfaces. Additionally, the users will be able to receive push notifications through the mobile solution and, thus, receiving timely notifications. However, this component of the system is only made available to elders and their informal caregivers since it is their interaction with the system that it is intended to improve.

A schematic representation of the mobile solution is exemplified in Figure 32.

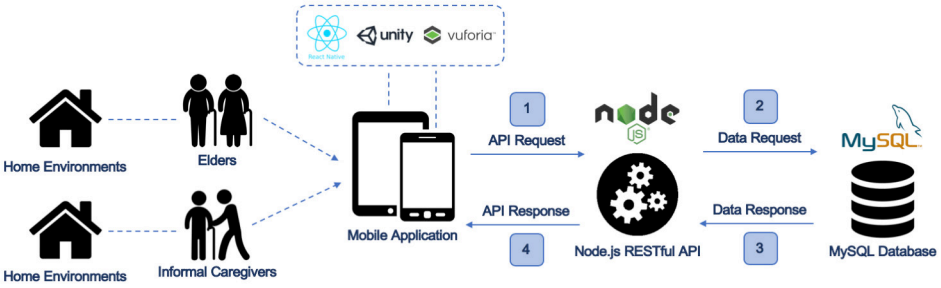


Figure 32: Schematic representation of the React Native mobile application.

The modules of the Web application included in the mobile solution are as follows:

- Homepage;
- Patients Data;
- Individual Cares (Scheduling, Registration, and History areas);
- External Services (Scheduling, Registration, and History areas);
- Collaborative Board;
- User Notes;

- Support Resources (Textual Guides and Videos areas);
- Skype;
- Alerts;
- Logout.

The sidebar menu of the mobile application is presented in Figure 33.

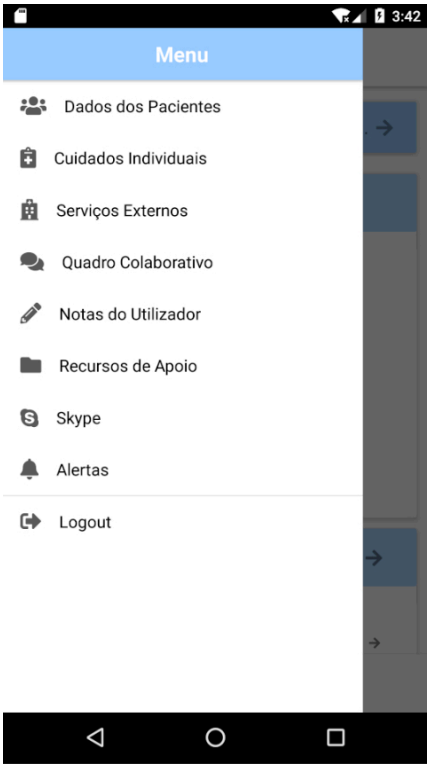


Figure 33: Sidebar Menu in the React Native mobile application.

On the other hand, as an example, one of the application interfaces is represented in Figure 34, namely the Homepage module.

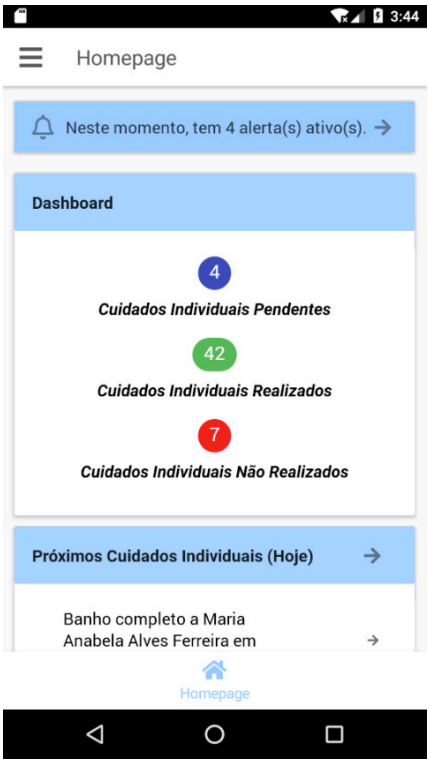


Figure 34: Homepage module in the React Native mobile application (with fictitious data).

It is important to refer that the mobile application is currently in its development process. On the other hand, the tests performed regarding the integration of mobile Augmented Reality care services are presented and discussed in Chapter 7. Additionally, it is essential to state that all the modules of the mobile application were covered in the previous section, that is, in Section 5.4.2, since they are the same as the Web application.

5.5 Discussion

The proposed system will assist elders' self-care and their informal caregivers through two main distinct components – a Web application and a mobile application. Nonetheless, an innovative approach is suggested through nursing homes, enabling the remote assistance by health professionals working in nursing homes, mainly nursing staff, to seniors and their informal caregivers, including those living in rural populations. Therefore, the main aim of this system is to bridge the gap between these health institutions and the target audience by giving them an adequate support and, consequently, enabling the well-being of all the parties involved.

On the other hand, it is also intended to combat social isolation and loneliness of the target audience through the promotion of intervention in community life, leisure, psychological counseling, and facilitating mobility. Additionally, it is expected to promote lifelong learning of older adults and their informal caregivers and enabling safety through the medical validation from health professionals of the health resources made available to users. Furthermore, this system will also enable innovation in home support and improvement of housing.

Finally, it is relevant to note that it is intended through this study to promote relevant scientific research in gerontechnology, including further studies in the areas concerned. Nevertheless, current pertinent research gaps are also being addressed.

This system is discussed in more detail in the Proof of Concept chapter of this document, namely Chapter 8.

5.6 Conclusion and Future Work

As discussed throughout this chapter, the proposed system will have significant advantages for elders and their informal caregivers. In fact, the solution will enable the target audience to being supported by essential support entities that are integrated in the community, namely nursing homes.

A few of the main advantages identified that are associated with the system are to bridge the current gap between nursing homes and the community, combating social isolation and loneliness of seniors and their caregivers, promoting relevant scientific research and respond to current research gaps in gerontechnology, lifelong learning, enabling safety through the use of medically approved terms and practices, and the well-being and welfare of all the parties involved.

Future work regarding the React Web application may include managing the patient's associated drug stock in the Medication Assistance submodule (Individual Cares module), in other words, integrate a stock control into the solution. Thus, if any medication in stock is below a preset threshold, alerts would be sent to the patient himself and his informal caregivers in order to alarm them of the need to do a restock of such medication. Therefore, the aim would be to avoid drug administration failure due to a lack of quantity available.

On the other hand, it is also intended to send Short Message Service (SMS) to users concerned about alerts classified as critical in the Alerts module, namely:

- External services to be attended by seniors 24 hours before the scheduled date and time;
- If the total number of individual cares not realized by elders or their informal caregivers reaches the value of 25;
- If the total number of external services not attended by a senior reaches the value of 10;
- If the total number of tasks not realized by health professionals reaches the value of 25;
- When a new patient is associated to a health professional;
- If the nurse that supervises a patient is changed.

Additionally, another potential improvement could be to provide to seniors and their informal caregivers the possibility to request physical support services available in the nursing homes, that is, integrating into the system features that would enable to place new orders and manage them online. Therefore,

older adults and their caregivers could receive remote but also physical support from care workers and professional staff working in the nursing homes.

Finally, it is expected to finalize the overall development of some pending functionalities of the proposed system, particularly its mobile component, that is, the React Native mobile application.

6

BUSINESS INTELLIGENCE CLINICAL AND PERFORMANCE INDICATORS

This chapter intends to present the main results and conclusions drawn from the design and development of Business Intelligence clinical and performance indicators for the proposed system. To do so, it is introduced with a short introduction in Section 6.1, the problem identification and motivation in Section 6.2, and the definition of the solution's objectives in Section 6.3. These sections are followed by Section 6.4 that sheds light on the design and development process of these BI indicators. Finally, a detailed discussion is presented in Section 6.5, which is followed by a short conclusion in Section 6.6.

6.1 Introduction

The aim of this study was to evaluate the hypothesis of using Business Intelligence to extract valuable knowledge, that is, information from the data stored in the database. Thus, it involved a thorough data collection with adequate research methods in order to define which BI indicators should be created and the access permissions assigned to each.

This technology has been proven vital to proceed to the data analysis of business information. Indeed, BI enables to have a firm grip on what "big data" can tell by properly analyzing it, in other words, getting structured and analyzable insights from relevant information in order to make timely and reliable decisions. In fact, it is intended to obtain valuable insights but also trigger smart-driven actions.

The advantages of BI include a better decision-making process since the decisions are fact-based and not "guesswork" or assumptions, improved data quality, user satisfaction, user efficiency, and a competitive edge in an ever-increasingly competitive market. Thus, its ultimate goal is to give the right information to the right individuals at the right time to enable the right decisions.

Regarding this study, the main objectives to be achieved are to spot trends and react quicker to potential risky situations that require greater attention and to understand how the users are interacting with the system. Nonetheless, following the well-known Kimball Lifecycle methodology, the application of BI involves a specific set of steps ranging from the initial project planning to the final growth and maintenance of the solution. Each step and the main results achieved are described and discussed in the following sections of this chapter.

6.2 Problem Identification and Motivation

As stated in the literature, it is vital to have a firm grip on what a big amount of data, also known as "big data", can tell by properly analyzing it. To do so, the concept of Business Intelligence, which comprises strategies and technologies, is applied in order to proceed to the data analysis of business information.

Nonetheless, such information is stored in a target structure that is optimized for data analysis through BI, in other words, a Data Warehouse. Another great advantage of creating a DW is also due to security issues since the users that have access to the database system are not the same as the ones that have access to the DW. In fact, confidential data such as users' passwords, phone and mobile numbers, and photos are stored in the database system but not in the DW.

Therefore, the main motivation behind this solution is to convert the data stored in the database system into structured and analyzable insights that can inform strategic decision-making across the community, which includes seniors, their informal caregivers, and nursing and technical and administrative staff. Having up-to-date BI clinical and performance indicators can lead to better decisions by users but also ultimately contribute to a better performance by all.

Additionally, it is expected to spot trends and react quicker to potential risky situations that require greater attention. Thus, users could be alerted in time of situations that need more support through the BI dashboards integrated into the system. On the other hand, it is also planned to rapidly check if certain resources are being applied appropriately.

It is also intended to understand how the users are interacting with the system and, consequently, reach them better through the conclusions drawn after data analysis. Fundamentally, it is expected to improve users' engagement with the system, their experience, and the support provided. The business growth targets can also be adequately followed in order to verify if the predefined goals are met, that is, having a clearer idea of how the system is running.

In Section 6.4, all the BI clinical and performance indicators defined and created are presented and, consequently, properly discussed. This section clarifies the main conclusions that can be drawn from the information extracted.

6.3 Definition of the Solution's Objectives

Based on the Kimball Lifecycle methodology described in Section 3.4 of Chapter 3, the main objectives to be fulfilled with this solution were defined as follows:

1) Data collection through focus groups, semi-structured interviews, questionnaires (Appendix A), and observation with health professionals working directly or indirectly in the nursing homes;

2) Analysis of the database system implemented, which was discussed in Chapter 4;

3) Definition of the questions to be answered through Business Intelligence based on the study conducted in points 1) and 2), that is, business requirements definition;

4) Definition of the BI clinical and performance indicators based on the conclusions drawn from Point 3), that is, BI application design;

5) Technical architecture design and product selection and installation;

6) Physical design, which included choosing the Relational Database Management System to store the Data Warehouse. In this case, MySQL in order to maintain the same RDBMS used for the database system;

7) Definition and implementation of the DW schema, in other words, dimensional modelling;

8) Design and development of the Extract, Transform, and Load process;

9) Integration into the system of the BI indicators created with React and D3 Recharts library, in other words, the deployment of the solution;

10) Design and development of the processes associated with the growth and maintenance of the solution.

The design and development process regarding the BI solution implemented is described in the next section, that is, in Section 6.4.

6.4 Design and Development

First, the most important questions were where and how the data should be store in the Data Warehouse, deciding what is important, that is, which Business Intelligence clinical and performance indicators should be designed and implemented from the database system, and, finally, who should have access to which information, in other words, defining the set of indicators made available for each user type.

In this context, Agency for Integration, Diffusion and Archive of Medical Information (AIDA) emerges, which is a platform based on the use of proactive agents that ensures interoperability between different Health Information Systems and other entities such as complementary systems. It was designed and developed by members of the research group to which I belong and it is currently being used in various health institutions in Portugal [104, 105, 106, 107, 162, 163].

AIDA is a complex system consisting of simple and specialized subsystems, defined as intelligent agents, which are responsible for tasks such as communication between heterogeneous systems, sending and receiving information, for example, clinical reports, medical images, and prescriptions, as well as managing and archiving data [104].

Thus, directly from AIDA, it is possible to integrate, diffuse, and archive large datasets from different sources, for example, services, departments, hospital units, computers, and medical devices [104]. AIDA provides an easy access and sharing of recorded information, including for the Extract, Transform, and Load process, enabling the construction of DWs. Consequently, it also facilitates medical research through

the application of Health Information and Communication Technology to optimize the services provided at a particular health institution.

Therefore, initially, the BI clinical and performance indicators were defined based on data collection and the database system analysis. Then, the DW schema was defined, in other words, dimensional modelling, based on the fact constellation schema (galaxy schema) as an Enhanced Entity–relationship (EER) diagram in MySQL, which is constituted by several fact tables that share dimension tables between them, as discussed in Subsection 2.4.2 of Chapter 2. However, the database system is not yet loaded with real data since the system is still in its early stages of testing, making it impossible to load the DW from the database system. Nonetheless, in the future, it is expected to use AIDA to load the DW using data from the database already implemented, that is, for the ETL process. Regarding the growth and maintenance of the solution, AIDA allows the automatic periodic update of the DW according to the settings configured for its agents. It is intended to update the DW daily. Thus, AIDA agents will run every day at night where the utilization of the system is reduced.

Hence, in order to create the BI indicators and integrate them into the Web application, it was necessary to force the storage of dummy data. The D3 Recharts library from React was used for their creation.

As stated in Chapter 5, the React Web application includes a Business Intelligence module, which enables the visualization of relevant BI clinical and performance indicators. In short, this module is divided into five different submodules and each submodule can be accessed by a different set of user types, namely:

1) BI Indicators - User: each user has access to specific BI clinical and performance indicators associated with him. To do so, depending on his user type, a different set of indicators are presented in the submodule interface;

2) BI Indicators - Patients: it can be accessed by every user type except elders. Through this submodule, a set of indicators associated with each senior is shown after his selection in a list that is displayed. However, informal caregivers can only visualize indicators associated with their own patients, nurses can consult data of the elders that they are supervising, and technical and administrative staff can have access to every seniors in the collaborative community;

3) BI Indicators - Informal Caregivers: in this submodule, specific indicators regarding each informal caregiver are presented. All user types have access to this submodule except informal caregivers themselves. Nonetheless, patients can only have access to indicators associated with their own informal caregivers, nurses to the informal caregivers taking care of their patients, and administrators can select any informal caregiver registered in the system from the list;

4) BI Indicators - Nurses: dashboard with indicators concerning each nurse using the system accessible only by administrators. After the selection of a nurse from the list, the indicators associated with him are displayed;

5) BI Indicators - General: general indicators regarding the overall system and all its users that can be accessed by nursing staff and administrators, that is, health professionals. This submodule includes reliable and analyzable statistics generated from all the data collected through the system.

Next, each submodule in the Business Intelligence module are described, namely the BI clinical and performance indicators included in each and, consequently, they are discussed thoroughly regarding their relevance and the conclusions that can be drawn from them.

Nonetheless, once again, it is important to note that dummy data were used since the database is not yet loaded with real data. In fact, in a real-life context, only after a considerable period of time of using the system, the BI indicators will be created and, consequently, integrated into it after thorough testing and validation processes.

1) BI Indicators - User:

First, it is important to refer that depending on the user type, the indicators presented in this submodule vary, that is, patients, informal caregivers, nurses, and administrators have access to a different set of Business Intelligence clinical and performance indicators.

On the other hand, the indicators presented to patients are the same that can be visualized in the BI Indicators - Patients submodule, informal caregivers in the BI Indicators - Informal Caregivers submodule, and nurses in the BI Indicators - Nurses submodule, which are all described and discussed later in this document.

Nonetheless, regarding technical and administrative staff, each have access to the information presented in Table 6.

Table 6: Business Intelligence clinical and performance indicators available in the system regarding each administrator

Title	**Type of Visualization**
Percentage between tasks realized and unrealized	Pie chart
Total number of tasks unrealized per reason	Column chart
Number of weekly hits to the system over the last year	Line chart
Total number of hits per module	Treemap
Total number of tasks realized related to user management	Single number
Total number of tasks realized related to resource management	Single number
Total number of support resources added	Single number
Total number of posts in the forum	Single number
Total number of alerts received	Single number
Total number of alerts generated	Single number

In Figure 35, the percentage between tasks realized and unrealized for a given administrator is presented. As can be viewed, it is possible to obtain information concerning the portion between tasks realized and unrealized but also the exact number of tasks for each. Thus, this BI indicator enables mainly the identification of administrators who are not performing enough tasks and, consequently, taking appropriate decisions according to the situation at hand. So, it can function as a warning to the need of analyzing the case in question.

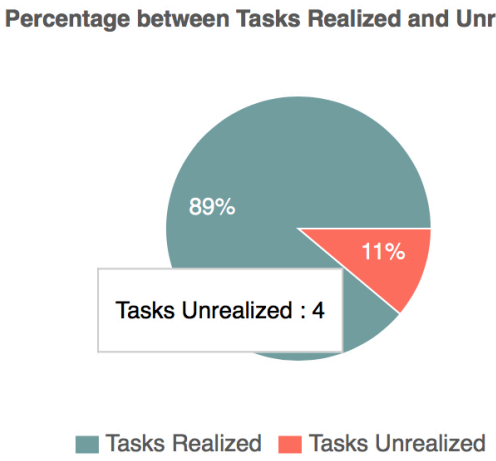


Figure 35: Business Intelligence indicator regarding the percentage between tasks realized and unrealized for a given administrator (created with fictitious data).

On the other hand, Figure 36 represents the number of weekly hits to the system over the last year for a given administrator. This BI indicator makes it possible to study the evolution of the use of the system by the user in recent months. Therefore, it enables, for example, to detect whether the user has not used the system during a certain period of time and then ascertain the situation.

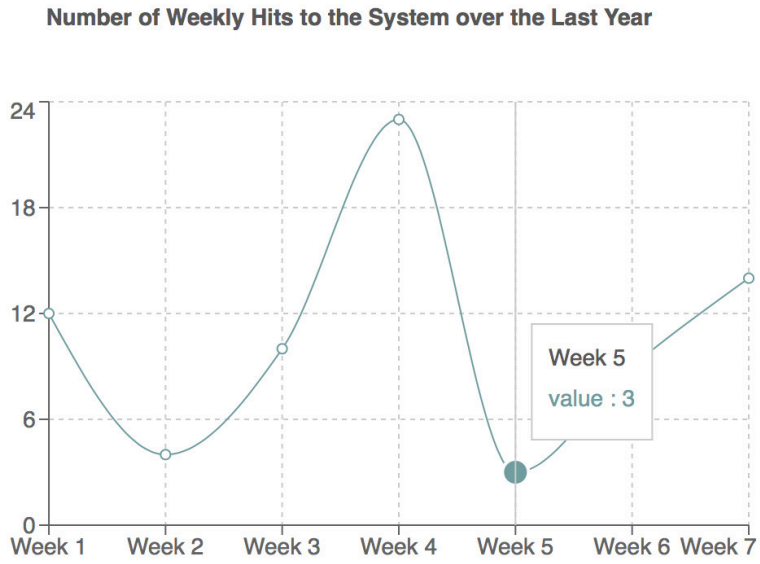


Figure 36: Business Intelligence indicator regarding the number of weekly hits to the system over the last year for a given administrator (created with fictitious data).

Finally, in Figure 37, it can be visualized the total number of hits per module for a given administrator in a treemap. So, through this BI indicator, it is possible to distinguish the modules that the user uses more and those he uses less.

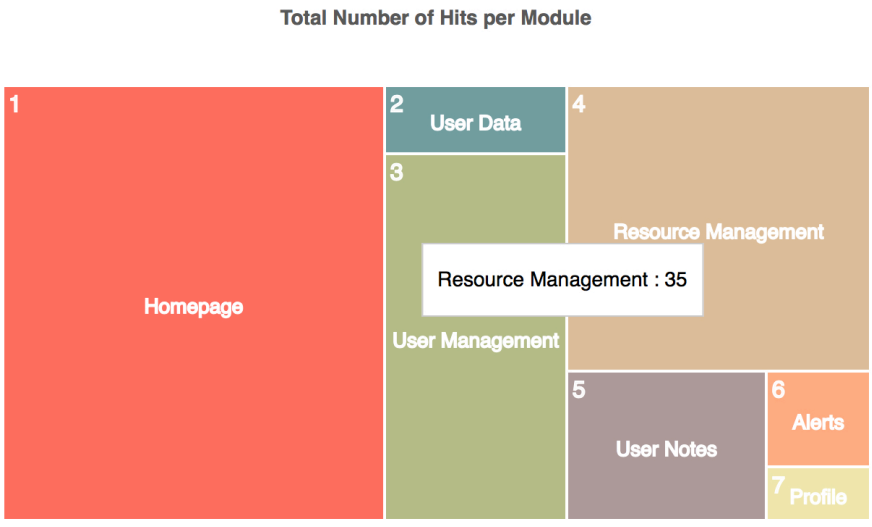


Figure 37: Business Intelligence indicator regarding the total number of hits per module for a given administrator (created with fictitious data).

2) BI Indicators - Patients:

This submodule is made available to informal caregivers, nurses, and administrators. As previously stated, a list of patients is displayed to each user, which is constituted by all the elders associated with

the user in question. After selecting an individual from the list, a dashboard with Business Intelligence indicators is presented to the user. Nonetheless, the first element of the list is chosen by default.

In this submodule, the BI indicators that can be visualized by users regarding the patient chosen are presented in Table 7.

Table 7: Business Intelligence clinical and performance indicators available in the system regarding each patient

Title	**Type of Visualization**
Total number of allergies	Single number
Total number of medical diseases and conditions	Single number
Total number of informal caregivers	Single number
Percentage between individual cares realized and unrealized	Pie chart
Total number of individual cares unrealized per reason	Column chart
Total number of individual cares realized per type	Table
Total number of individual cares realized and unrealized per informal caregiver	Stacked column chart
Total number of individual cares realized per informal caregiver and type	Treemap
Total number of individual cares unrealized per informal caregiver and reason	Treemap
Percentage of individual cares per type of support	Pie chart
Percentage between external services realized and unrealized	Pie chart
Total number of external services unrealized per reason	Column chart
Total number of external services realized per type	Table
Total number of external services planned per informal caregiver and type	Treemap
Percentage of external services per accompany's status	Pie chart
Number of weekly hits to the system over the last year	Line chart
Total number of hits per module	Treemap
Total number of objectives realized, unrealized, and pending	Pie chart
Total number of objectives added per informal caregiver	Column chart
Total number of comments in the collaborative board	Single number
Total number of comments in the collaborative board per informal caregiver	Column chart

Title	Type of Visualization
Total number of posts in the forum	Single number
Total number of support resources visualized	Single number
Total number of alerts received	Single number

Figure 38 presents the total number of individual cares realized and unrealized per informal caregiver for a given patient in a stacked column chart. Thus, for each elder, it can be visualized the distribution between individual cares realized and unrealized for all the informal caregivers responsible for taking care of him and, consequently, identifying the possibility of a bad distribution of tasks between them since some may be overloaded with work in comparison with others. On the other hand, this BI indicator also enables the identification of informal caregivers who have a low rate of accomplishment of their tasks, which is a situation that undoubtedly deserves attention and a thorough analysis of the causes for such outcome.

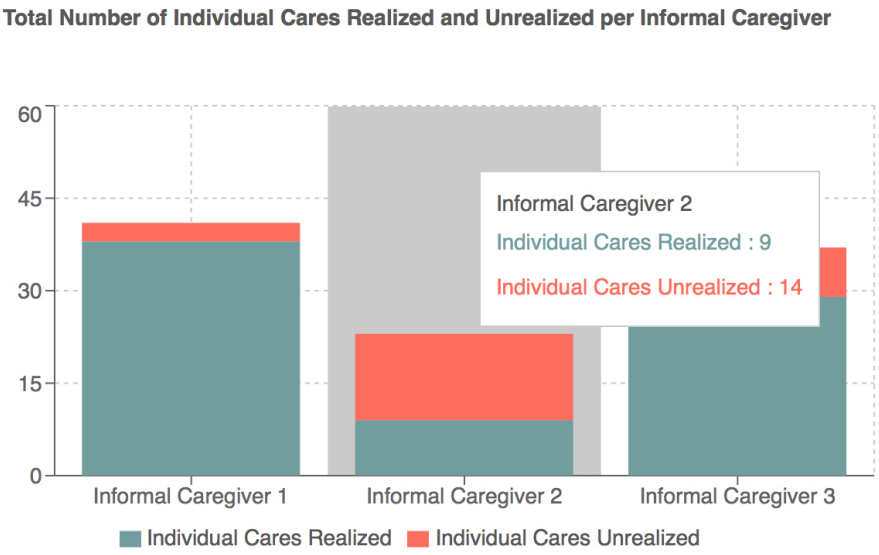


Figure 38: Business Intelligence indicator regarding the total number of individual cares realized and unrealized per informal caregiver for a given patient (created with fictitious data).

In Figure 39, the total number of individual cares unrealized per informal caregiver and reason for a given patient is demonstrated. This treemap provides a way to quickly identify the informal caregivers that do not realize a large number of tasks, namely "Informal Caregiver 2" in the example presented. On the other hand, each total number of individual cares unrealized per informal caregiver is divided per reason. Therefore, it is possible to study if the low performance of an informal caregiver in question is justified or not according to the reason given for not accomplishing a task.

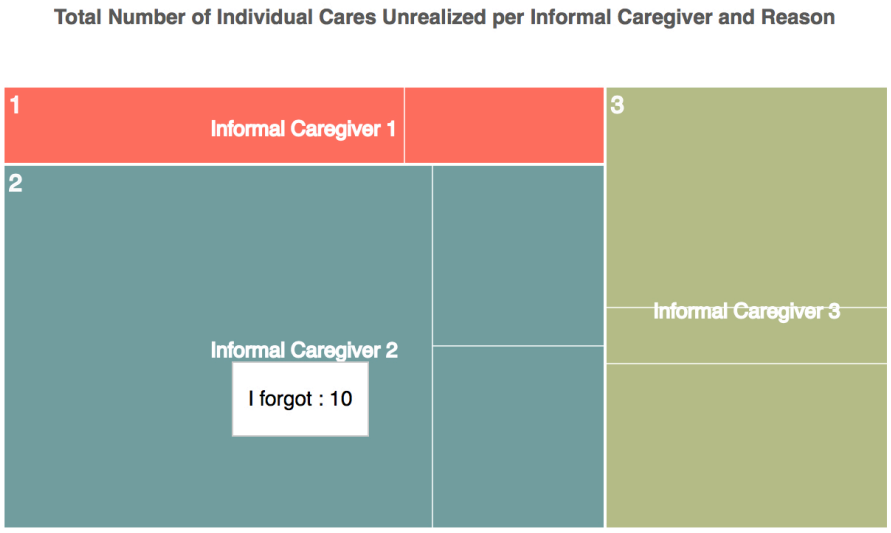


Figure 39: Business Intelligence indicator regarding the total number of individual cares unrealized per informal caregiver and reason for a given patient (created with fictitious data).

Finally, Figure 40 presents the percentage of individual cares per type of support for a given patient. Thus, it enables to verify the level of dependency of an elder by analyzing the difference between the percentages of "Full Support", "Partial Support", and "Without Help". Older adults with a higher percentage of individual cares realized with full support need to be more supported in comparison with elders with a higher percentage of individual cares realized without help. A greater attention has to be given to them and more resources are necessary.

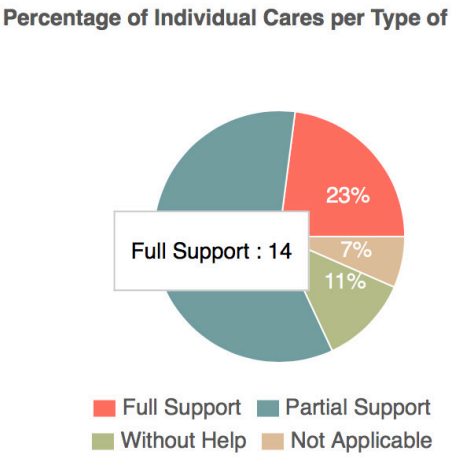


Figure 40: Business Intelligence indicator regarding the percentage of individual cares per type of support for a given patient (created with fictitious data).

3) BI Indicators - Informal Caregivers:

The BI Indicators - Informal Caregivers submodule can be accessed by three different user types, namely patients, nurses, and administrators. A dashboard with Business Intelligence indicators is built according to the informal caregiver chosen from the list that is displayed. By default, the first element of the list is chosen.

The submodule includes the BI indicators according to the informal caregiver chosen presented in Table 8.

Table 8: Business Intelligence clinical and performance indicators available in the system regarding each informal caregiver

Title	**Type of Visualization**
Total number of medical diseases and conditions	Single number
Total number of patients supervising	Single number
Percentage between individual cares realized and unrealized	Pie chart
Total number of individual cares unrealized per reason	Column chart
Total number of individual cares realized and unrealized per patient	Stacked column chart
Total number of individual cares realized per type and patient	Treemap
Percentage of individual cares per type of support	Pie chart
Total number of external services planned per patient and type	Treemap
Number of weekly hits to the system over the last year	Line chart
Total number of hits per module	Treemap
Total number of objectives added per patient	Column chart
Total number of comments in the collaborative board per patient	Column chart
Total number of posts in the forum	Single number
Total number of support resources visualized	Single number
Total number of alerts received	Single number

Figure 41 represents the total number of individual cares realized per type and patient for a given informal caregiver. Through this BI indicator it is possible to identify the types of individual cares that a certain informal caregiver performs the most, namely "Full Bath" in the example presented. Thereby, it enables to determine where a higher workload is being deposited by each informal caregiver and forecast where more support and resources are needed. It is relevant to note that each type is divided into the different elders according to the number of individual cares realized on each one of them for the type of individual care in question.

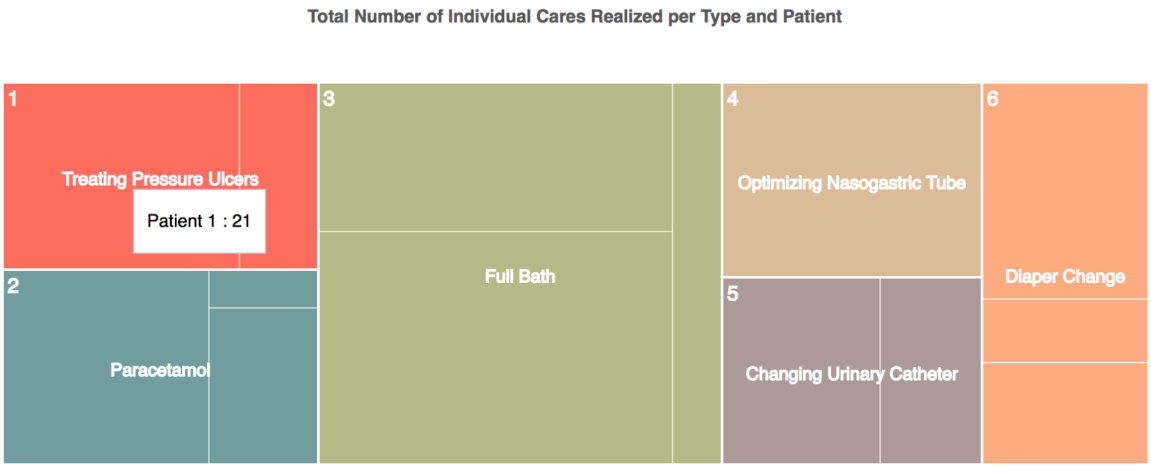


Figure 41: Business Intelligence indicator regarding the total number of individual cares realized per type and patient for a given informal caregiver (created with fictitious data).

On the other hand, in Figure 42, the total number of external services planned per patient and type for a given informal caregiver is shown. Thus, information regarding the external services requested per patient can be visualized quickly since for each elder the total number of external services planned per type can as well be selected. Therefore, this BI indicator also enables the identification of the older adults that need more support from informal caregivers, namely "Patient 2" in the example presented, including his potential needing to be accompanied by an individual in each external service planned.

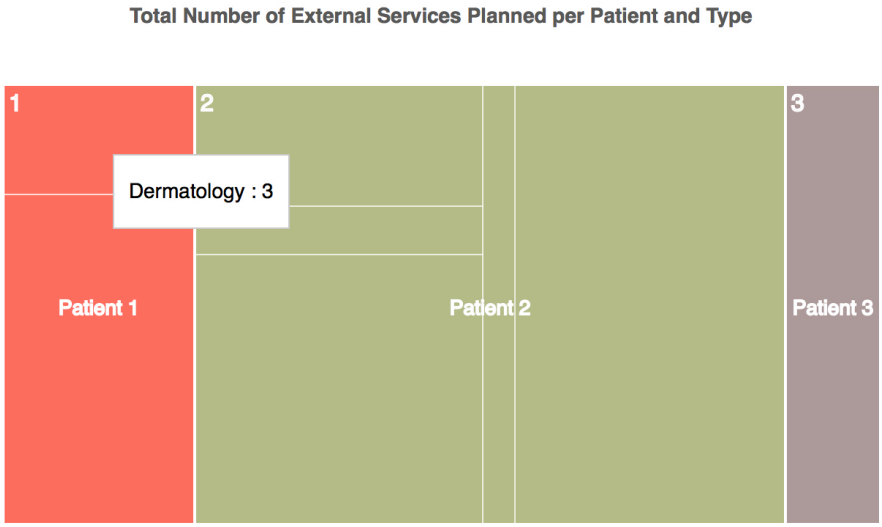


Figure 42: Business Intelligence indicator regarding the total number of external services planned per patient and type for a given informal caregiver (created with fictitious data).

Last, Figure 43 demonstrates the total number of objectives added per patient for a given informal caregiver. Thereby, it enables the analysis of the distribution of objectives per patient and, consequently, inciting setting objectives for seniors who have few objectives assigned or even none. On the other hand,

this BI indicator also indicates the elders that need more monitoring regarding objectives' fulfillment if more objectives are attributed to them.

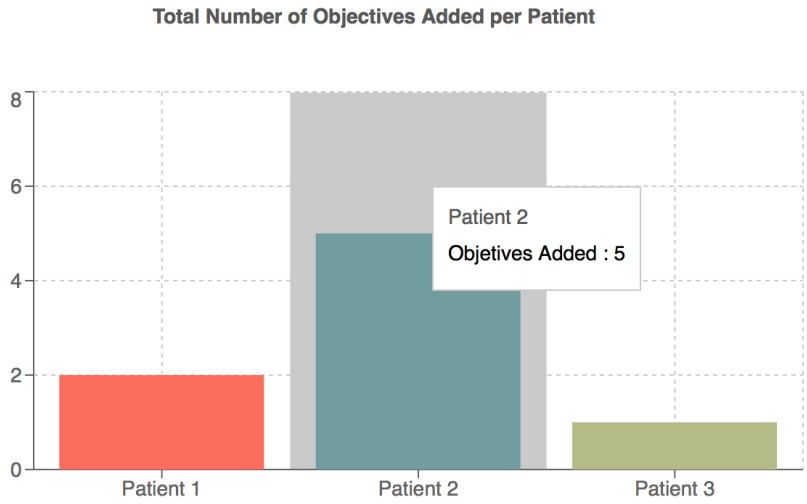


Figure 43: Business Intelligence indicator regarding the total number of objectives added per patient for a given informal caregiver (created with fictitious data).

4) BI Indicators - Nurses:

This submodule is only made available for technical and administrative staff. Users have to select a nurse from the list in order to visualize the dashboard with the Business Intelligence indicators. Nonetheless, as for the other submodules, the first element of the list is chosen by default.

All the BI indicators currently made available in this submodule regarding the nurse chosen are presented in Table 9.

Table 9: Business Intelligence clinical and performance indicators available in the system regarding each nurse

Title	**Type of Visualization**
Total number of patients supervising	Single number
Percentage between tasks realized and unrealized	Pie chart
Total number of tasks unrealized per reason	Column chart
Number of weekly hits to the system over the last year	Line chart
Total number of hits per module	Treemap
Total number of comments in the collaborative board per patient	Column chart
Total number of support resources added	Single number
Total number of posts in the forum	Single number

Title	Type of Visualization
Total number of alerts received	Single number

In Figure 44, the total number of tasks unrealized per reason for a given nurse can be visualized. Thereby, this BI indicator enables the identification of nurses that have a high number of tasks unrealized, which deserves greater attention from the system's administrators. On the other hand, it also permits to conclude if such numbers are justified since the number of tasks unrealized can be distributed per justified (for example, "I was not well") and/or unjustified reasons (for example, "I forgot"). So, a thorough analysis is required according to each outcome and adequate actions must be taken accordingly.

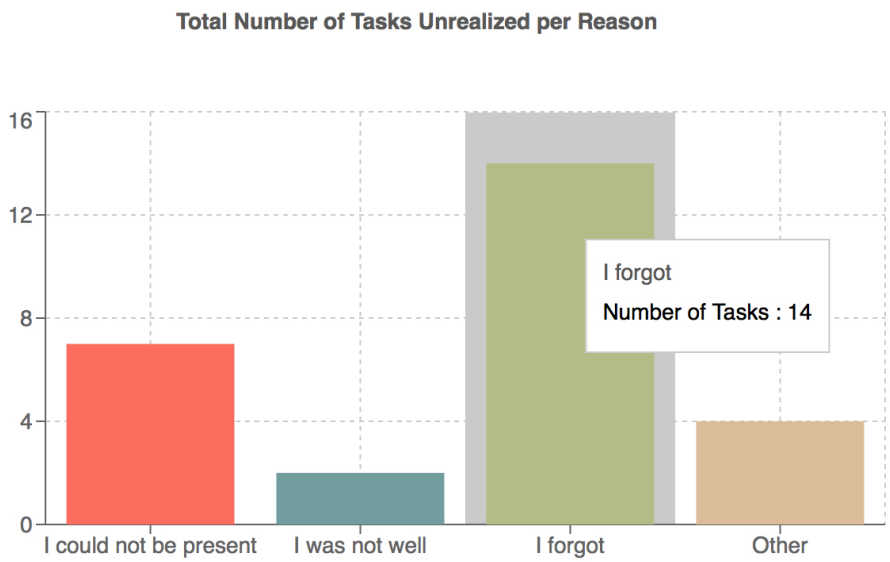


Figure 44: Business Intelligence indicator regarding the total number of tasks unrealized per reason for a given nurse (created with fictitious data).

Then, Figure 45 presents the total number of comments in the collaborative board (a module of the system presented in Section 5.4.2 of Chapter 5) per patient for a given nurse. It enables the analysis of the distribution of effort applied by each nurse to each elder and, consequently, try to match the support provided to each older adult. Thereby, this BI indicator can alert nurses if too little or too much effort is allocated to each senior in the collaborative board.

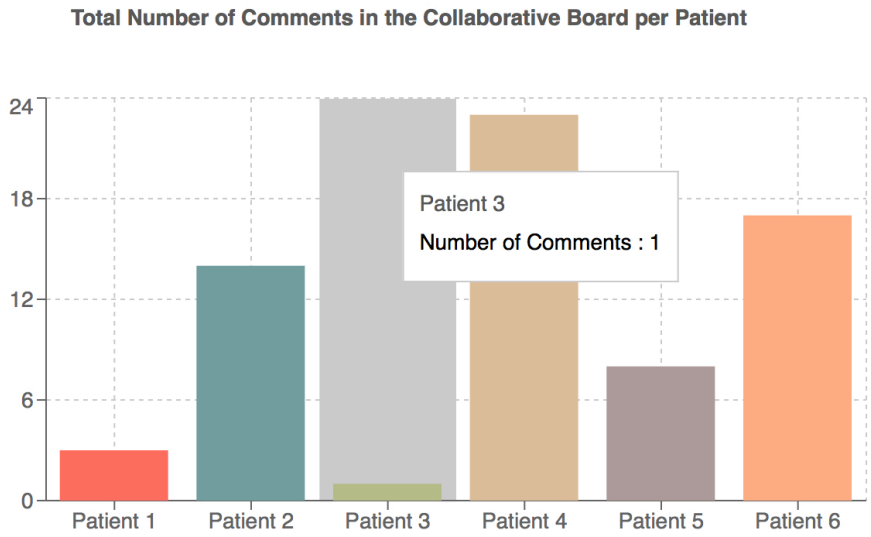


Figure 45: Business Intelligence indicator regarding the total number of comments in the collaborative board per patient for a given nurse (created with fictitious data).

Lastly, Figure 46 presents the total number of support resources added for a given nurse. This BI indicator is a single number that can provide interesting insights regarding the participation of each nurse in the construction of the support resource repository of textual guides and videos for seniors and their informal caregivers. Thereby, nurses that participate a lot can be rewarded and those who do not help so much can be alerted of not contributing enough for the community.

Figure 46: Business Intelligence indicator regarding the total number of support resources added for a given nurse (created with fictitious data).

5) BI Indicators - General:

The BI Indicators - General submodule is accessible by two different user types, namely nursing and technical and administrative staff, that is, health professionals working in the nursing homes.

The BI indicators presented in this submodule are presented in Table 10.

Table 10: General Business Intelligence clinical and performance indicators available in the system

Title	Type of Visualization
Total number of users per user type	Column chart
Average number of allergies per patient	Single number
Average number of medical diseases and conditions per patient	Single number
Average number of patients per informal caregiver	Single number
Average number of patients per nurse	Single number
Total number of patients per allergy	Table
Total number of patients per medical disease and condition	Table
Percentage of patients per gender	Pie chart
Total number of patients per locality	Map
Total number of patients per informal caregiver	Table
Total number of patients per nurse	Table
Number of weekly hits to the system over the last year	Line chart
Percentage of hits to the system per user type	Pie chart
Total number of hits per module and user type	Treemap
Percentage between individual cares realized and unrealized	Pie chart
Total number of individual cares realized per type	Table
Percentage of individual cares realized per type of support	Pie chart
Percentage of individual cares unrealized per reason	Pie chart
Percentage between external services realized and unrealized	Pie chart
Total number of external services realized per type	Table
Percentage of external services realized per accompany's status	Pie chart
Percentage of external services unrealized per reason	Pie chart
Total number of tasks realized and unrealized per nurse	Stacked column chart
Total number of tasks realized and unrealized per administrator	Stacked column chart
Percentage of objectives realized, unrealized, and pending	Pie chart

Title	Type of Visualization
Percentage of comments in the collaborative board per user type	Pie chart
Percentage of notes per user type	Pie chart
Total number of posts in the forum per user type	Column chart
Total number of support resources added	Single number
Total number of visualizations per support resource	Table
Total number of alerts sent	Single number

First, Figure 47 shows the percentage of external services realized per accompany's status. This simple yet relevant BI indicator permits to conclude if there is a larger portion of seniors that need to be accompanied to external services ("Yes"), such as medical examinations, than those that do not need such support ("No"). Thereby, this is one of the indicators that can provide a great overview of the target audience and its current needs, namely elders.

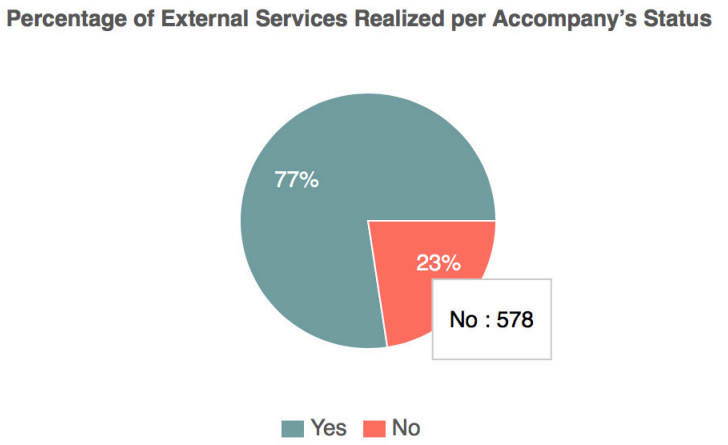


Figure 47: Business Intelligence indicator regarding the percentage of external services realized per accompany's status (created with fictitious data).

In Figure 48, the total number of tasks realized and unrealized is presented per nurse. This BI indicator provides the possibility of analyzing the distribution of work between the different nurses in the system. Thereby, a better distribution could be done among nurses if a disproportionate distribution is identified. On the other hand, it also enables the visualization of the portion of tasks realized and unrealized per nurse. Thus, nurses that have a huge number of tasks unrealized can be detected and, consequently, appropriate assessment and measures must be followed.

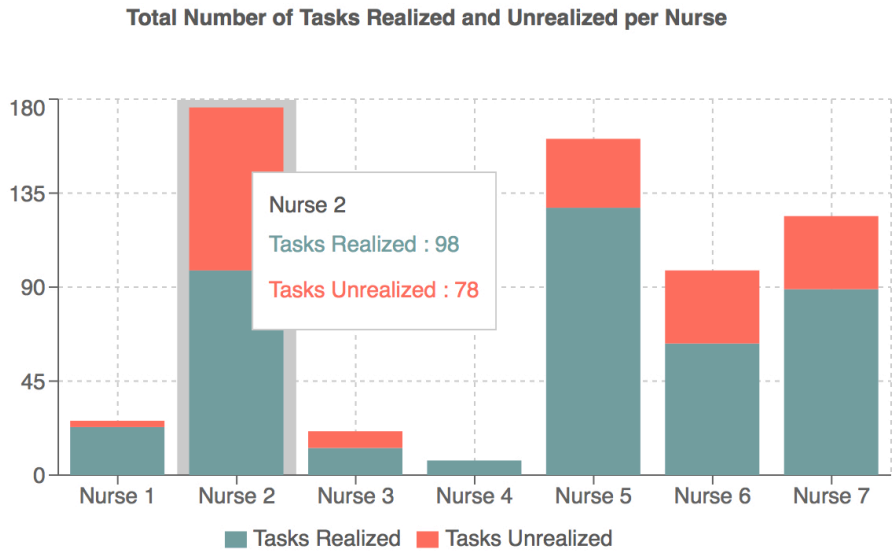


Figure 48: Business Intelligence indicator regarding the total number of tasks realized and unrealized per nurse (created with fictitious data).

At last, Figure 49 represents in a column chart the total number of posts in the forum per user type, that is, elders, informal caregivers, nurses, and administrators. Thereby, it enables the identification of the most and least active user types in the forum.

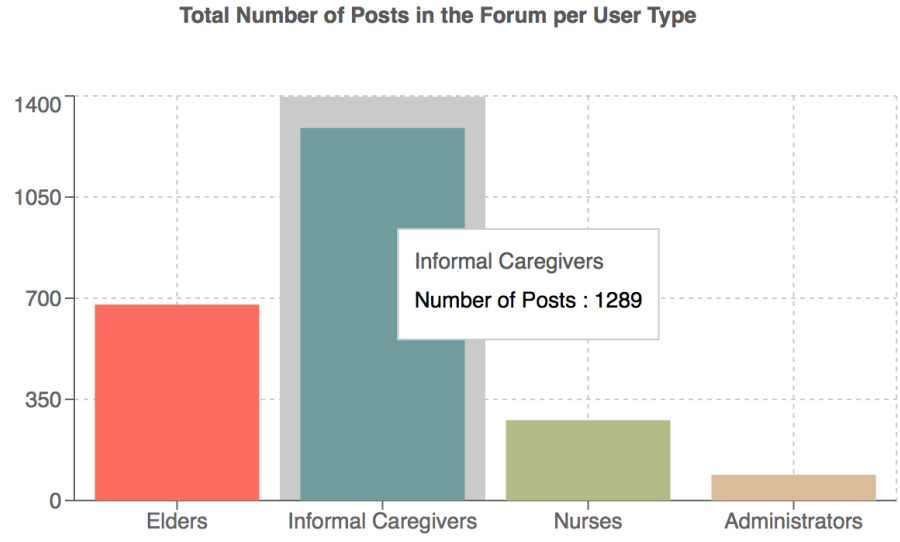


Figure 49: Business Intelligence indicator regarding the total number of posts in the forum per user type (created with fictitious data).

The results achieved and presented in this section are discussed in detail in the next section, that is, Section 6.5.

6.5 Discussion

As previously mentioned, the system was already prepared to present Business Intelligence clinical and performance indicators at the right time, that is, when huge amounts of data to process will be stored in the database system since it enables better benefits regarding logistics or even productivity when trends are studied over time. Thus, many indicators presented in Section 6.4 depend on data collection during a significant period of time, that is, months or even years in some cases, in order to draw truthful conclusions. So, the BI technology is vital since it allows individuals to gain targeted insights into the past, present, and future in order to make more informed decisions.

Therefore, the aim is to collect complex data and, consequently, condensing such information into richly visualized and intuitive reports. Thus, BI collects and processes data to get actionable information from it. The BI indicators designed and developed from collected data focus on specific areas but also give an overall view of the current system status.

By being a growing industry, there is a wide range of reasons why organizations should use BI solutions or at least integrate BI components into their Information Technology solutions. Nonetheless, the common goal amongst those organizations is that BI is able to turn data into not only valuable insights but also action. It should help individuals understand the environment under study and, consequently, act on that knowledge. To do so, the right information is given to the right individuals at the right time to enable the right decisions.

Although the design and development of BI solutions can be considered a complex process, even described as costly and time-consuming, when implemented, its correct use can provide significant advantages. In fact, many organizations have been slow to do so mainly due to a lack of knowledge regarding its design and development process and associated benefits, even more so in the healthcare industry, as discussed in the State of the Art chapter of this manuscript (Chapter 2).

The main benefits identified regarding the design and development of a BI module into the proposed system can be highlighted as follows:

- Getting structured and analyzable insights from relevant information in order to make timely and reliable decisions;
- Faster and more accurate analysis, reporting, and planning of the data stored in the database system through rich visualization capabilities, leading to time-saving;
- Enables users to see detailed and current important information on diverse areas depending on their user type;
- Better the decision-making process through the extraction of valuable knowledge, in other words, better decisions are made since they are fact-based and not "guesswork" or assumptions. So, users' decisions are considered smartly data-driven;
- Improved data quality;

- Improved user satisfaction;
- Improved user efficiency;
- Enhances awareness;
- Reduces costs by analyzing the distribution of resources;
- Eliminates waste and losses in areas that could go unnoticed without the application of BI;
- Identifies situations of inefficiency and, consequently, suggestions can be outlined to alleviate these problem areas;
- It can help identify new opportunities;
- Boosts performance management significantly since users can easily get moment-to-moment updates and, consequently, deal with problems immediately;
- Tracks goals fulfillment. This information can be then used to gauge overall productivity;
- Improves resources management;
- Competitive edge in an ever-increasingly competitive market.

This powerful combination of advantages offers to the proposed system an innovative edge that can make all the difference in the modern age. It also enables the extraction of new knowledge with scientific value.

6.6 Conclusion and Future Work

Finally, over the past few years, Business Intelligence has been increasingly a major interest to Health Information and Communication Technology professionals largely due to its great potential, that is, to help decision-makers to make more informed and better decisions through the extraction of knowledge from "big data". Its main aim is to provide beneficial insights to the individuals concerned that can be then turned into actions.

The results achieved with this study are promising. In fact, the BI clinical and performance indicators defined and created will facilitate the decision-making process of the target audience, that is, the elderly, informal caregivers, and care workers and professional staff working in the nursing homes. It will enable them to spot trends and react quicker to potential risky situations that require greater attention but also to understand better how the users are interacting with the system for administrators.

As future work, after a considerable period of time when enough data will be saved in the database, tests will be performed with the Agency for Integration, Diffusion and Archive of Medical Information in order to evaluate the Extract, Transform, and Load process and, subsequently, the growth and maintenance

processes to maintain the Data Warehouse updated with up-to-date data. Then, the BI indicators will be validated, which will be followed by the final implementation into the system of the indicators approved.

In a distant second phase, the following BI clinical indicators regarding nursing interventions, namely individual cares and external services, could also be integrated into the system:

- Variation of the weight of a given senior over time;
- Variation of the height of a given elder over time;
- Variation of the body mass index (BMI) of a given older adult over time;
- Variation of the capillary blood glucose of a given senior over time;
- Variation of the blood pressure of a given elder over time;
- Variation of the heart rate of a given older adult over time;
- Variation of the respiratory rate of a given senior over time;
- Variation of the temperature of a given elder over time.

The type of visualization would be a line chart for each indicator.

Nonetheless, to create the indicators presented above, modifications in the system are required, including the database. To do so, a new attribute that would be optional must be added to each model of nursing interventions in the back-end, namely individual cares and external services. On the other hand, in the Registration submodule in the Individual Cares and External Services modules for nursing interventions, a new conditional field must be added to the front-end in order to enable users to register the value in question depending on the type of nursing intervention selected (for example, "Weight", "BMI" or "Capillary blood glucose"). So, if the type of nursing intervention selected by the user requires the registration of a value, a new field will be shown to the user in the front-end to proceed to such registration and, consequently, enabling the future possible creation of other BI indicators. Then, the DW schema must be updated and the settings of the intelligent agents of AIDA in order to load the new target structure properly through the ETL process.

7

MOBILE AUGMENTED REALITY CARE SERVICES

In this chapter, the mobile Augmented Reality care services defined for the proposed system are presented and discussed. Thus, it starts with a brief introduction (Section 7.1), which is followed by the problem identification and motivation (Section 7.2), and the definition of the solution's objectives (Section 7.3). In Section 7.4, all the steps involved in the design and development process are explained in detail. This chapter is concluded with an enlightening discussion (Section 7.5), which is followed by a short conclusion (Section 7.6).

7.1 Introduction

The aim of this proposed solution was to test the hypothesis of using a novel technology, namely mobile Augmented Reality, in order to enhance the learning experience of the elderly and their informal caregivers. Their lack of appropriate knowledge and suitable support motivated this specific study.

After a thorough data collection with the target audience, namely seniors, their caregivers, and care workers and professional staff working in the nursing homes, a set of individual cares were defined, that is, potential mobile AR care services were identified to be integrated into the system. Then, the ultimate goal would be to integrate an Augmented Reality module into the React Native mobile application with each service defined. The module could be launch directly from one of the components of the system.

Nevertheless, a demonstration was designed and developed using Unity3D game engine and Integrated Development Environment and Vuforia as the Augmented Reality Software Development Kit before the design and development of the individual cares. The demonstration is constituted by all the basic elements that can be part of a mobile AR care service. In fact, it was intended to test and evaluate the demonstration in order to ascertain the feasibility of the proposed solution. Thus, the final implementation of the Augmented Reality module depended on the results achieved with the demonstration.

Next, each phase of this study is explained in detail, which also includes the main results obtained, as well as the main conclusions drawn.

7.2 Problem Identification and Motivation

The literature review and data collection conducted through specific research strategies, including focus groups, semi-structured interviews, questionnaires, and observation with the target audience, enabled the possibility of identifying the main current needs of seniors and their informal caregivers. Nonetheless, it also made it possible to identify how such gaps could be fixed by applying different emerging technologies from the broad area of Health Information and Communication Technology.

Two of the most referred gaps were the lack of knowledge and support currently available for elders and their informal caregivers. On the other hand, it was also indicated that, oftentimes, self-teaching, in other words, autodidacticism, can provide a bad teaching experience since it is often executed without the validation of qualified health professionals, such as nurses. In order to respond to these issues, this system was designed and developed to provide to the elderly and their caregivers a large set of resources to assist and educate them regarding correct practices through safe medical approval to execute specific individual cares.

As a matter of fact, to enhance their learning experience, the Augmented Reality technology has been pointed out by the scientific community since it helps getting enlightening virtual experiences that can be then implemented in a real-life context. One of its main advantage is the unique, immersive, and tangible user experience that can be offered. In fact, AR enables individualized learning, motivation by making instructions more visual and appealing for learners, and fostering the learning process by developing learners' creativity and curiosity.

Therefore, this solution intends to complement the system with an Augmented Reality module in the React Native mobile application in order to enhance users' experiences concerning self-learning by defining mobile AR care services.

7.3 Definition of the Solution's Objectives

According to the problem identification and motivation discussed in the previous section (Section 7.2), the objectives defined for this solution are the following:

1) Study and data collection regarding the individual cares that should be enhanced with Augmented Reality through focus groups, semi-structured interviews, questionnaires (Appendix A), and observation with the target audience, namely the elderly, their informal caregivers, and health professionals working in the nursing homes, such as nursing staff;

2) Definition of the individual cares to be supported with AR;

3) Technical architecture design and product selection and installation;

4) Physical design;

5) Design and development of a mobile AR service as a demonstration. This demonstration is constituted by all the basic elements that can be part of a mobile AR care service, which is explained in greater detail in Section 7.4;

6) Integration into the system of the demonstration created in Point 5);

7) Testing and evaluation of the demonstration;

8) Depending on the results achieved and the main conclusions drawn in Point 7), proceed to the system implementation or non-implementation of the individual cares defined in Point 2).

In Section 7.4, all the steps involved in the design and development process are explained, which includes a description regarding each mobile AR care service defined through data collection.

7.4 Design and Development

In a first step, a survey was conducted with the target audience in order to determine which individual cares should be enhanced with the Augmented Reality technology. The aim was to identify a set of important individual cares that needs more support from the system to assist seniors and their informal caregivers through the use of an emerging technology. To do so, the main research strategies used were focus groups, semi-structured interviews, questionnaires, and observation. In total, eight different individual cares can be highlighted from data collection. Table 11 presents the individual cares defined.

Table 11: Mobile Augmented Reality care services defined to be integrated into the system

	Description
1	Transferring the patient from his bed to a wheelchair and vice versa
2	Transferring the patient from his wheelchair to a car and vice versa
3	Giving a patient a partial or complete bath in bed
4	Maintaining a nasogastric tube
5	Repositioning a patient in bed to prevent pressure ulcers
6	Home wound care
7	Feeding a bedridden and/or a device-dependent patient (for example, through a feeding tube)
8	Maintaining a urinary catheter

As discussed in Chapter 3, the technologies chosen to develop the mobile AR services are Unity3D game engine and Integrated Development Environment (version 2019.1.14f1) and Vuforia as the AR Software Development Kit. Through Vuforia, it is possible to create a license key, that is, a development key, that

can then be used in the application by copying the license key provided into the Unity3D solution - "License Manager" module in Vuforia. Then, Vuforia also enables the creation of databases with targets - "Target Manager" module in Vuforia. Each target has its own features in order to be recognized by the AR camera. The quality of each target is represented with a rating that goes from 0 to 5 stars, in other words, how much it is "augmentable". In fact, the augmentable rating defines how well a target can be detected and tracked by the AR camera using the Vuforia SDK. Additionally, the database created with the targets can be downloaded through the Target Manager module and then imported in Unity3D to be used in the development of the solution.

In Figure 50, the target used in the demonstration is represented, that is, a QR code. In Subfigure 50a, the QR code without features is presented and, on the other hand, in Subfigure 50b, the same target with features is shown, which are highlighted in yellow. The target used had a perfect augmentable rating of 5 stars, thus, being easy to detect by the AR camera.

(a) Target without features.

(b) Target with features.

Figure 50: The target of a QR code, with and without features, used in the demonstration of the mobile Augmented Reality solution.

Additionally, a research was conducted in order to identify all the different elements that could be part of a mobile AR care service. Thus, in short, a service is a sequence made of one or more basic elements. Afterwards, a demonstration was designed and developed with every element identified in order to test the feasibility of the solution. If a positive result was obtained, the objective would be then to design and develop each defined individual care presented in Table 11.

The demonstration is a simple sequence made of all the following six basic elements:

- Text box;
- 2D object, for example, an arrow;
- 3D object, for example, a three-dimensional representation of a medical instrument;
- An image;
- An audio, that is, mp3 file;
- A video with or without sound, that is, mp4 file.

In Figure 51, an example of a scene in Unity3D, using Vuforia as the AR SDK, is presented. In this specific example, after the detection of the target, that is, a QR code, by the AR camera, the 3D object, namely a three-dimensional representation of syringes, is shown to the user.

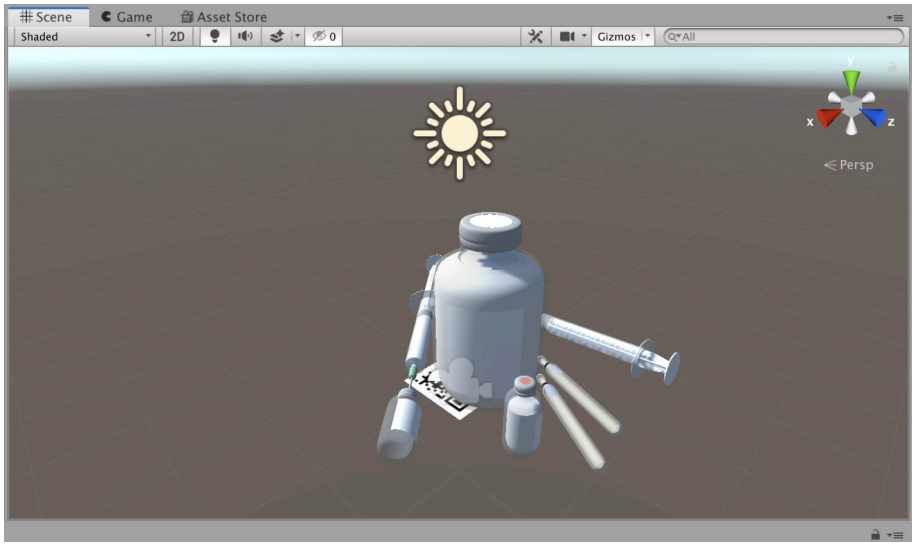
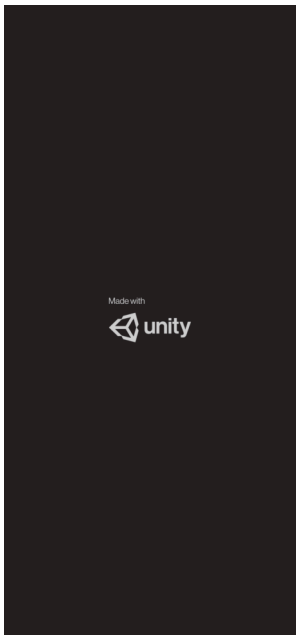
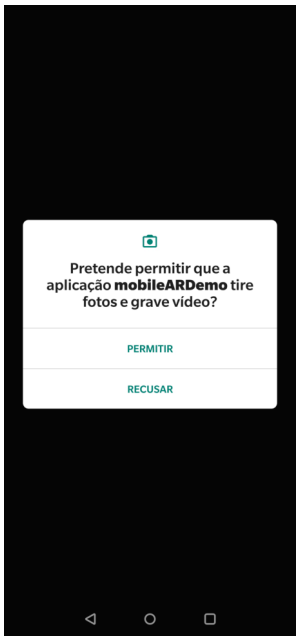


Figure 51: An example of a scene in Unity3D, using Vuforia as the Augmented Reality Software Development Kit.

After the development of the demonstration using Unity3D as the game engine and IDE, it was integrated into the mobile application, in other words, its deployment was carried out. Therefore, this component of the system enables the launch of the Augmented Reality module. In Figure 52, the demonstration of the Unity3D/Vuforia solution is presented in an Android smartphone, namely the launch of the solution in Subfigure 52a and the permissions required by the smartphone for the AR camera in Subfigure 52b.



(a) Launch of the solution.



(b) Permissions required by the Augmented Reality camera in the solution.

Figure 52: Demonstration of the Unity3D/Vuforia solution in an Android smartphone.

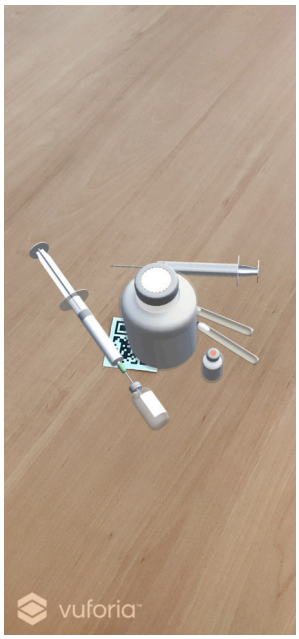
On the other hand, in Figure 53, two different snapshots of the demonstration are presented as examples, namely the three-dimensional representation of an arrow in subfigures 53a and 53b. In Figure 54, the three-dimensional representation of medical instruments, that is, syringes, are shown in subfigures 54a and 54b. Additionally, in Figure 55, a 3D object of a wheelchair is also presented in two different perspectives, namely in subfigures 55a and 55b. They correspond to three of the elements of the sequence that were tested after the development of the demonstration. Nonetheless, as previously mentioned, each basic element was incorporated into the tested solution, namely text boxes, 2D objects, 3D objects, images, audios, and videos.

(a) The first perspective of a three-dimensional representation of an arrow.

(b) The second perspective of a three-dimensional representation of an arrow.

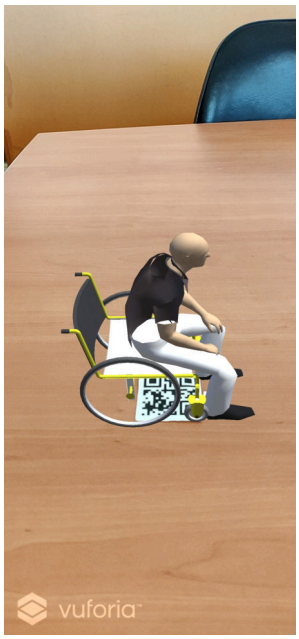
Figure 53: Presentation of an arrow in two different perspectives after the detection of the target by the Augmented Reality camera of the Android smartphone in the Unity3D/Vuforia demonstration.

(a) The first perspective of a three-dimensional representation of medical instruments, namely syringes.

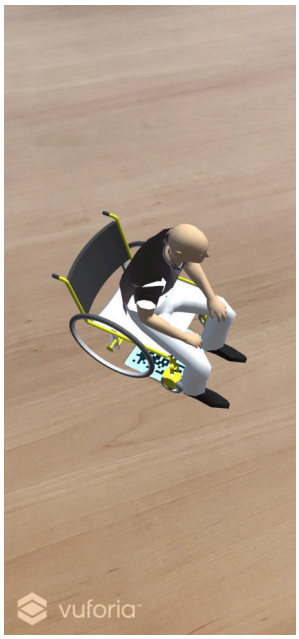


(b) The second perspective of a three-dimensional representation of medical instruments, namely syringes.

Figure 54: Presentation of syringes in two different perspectives after the detection of the target by the Augmented Reality camera of the Android smartphone in the Unity3D/Vuforia demonstration.



(a) The first perspective of a three-dimensional representation of a wheelchair.



(b) The second perspective of a three-dimensional representation of a wheelchair.

Figure 55: Presentation of a wheelchair in two different perspectives after the detection of the target by the Augmented Reality camera of the Android smartphone in the Unity3D/Vuforia demonstration.

After the design and development of each mobile AR service, the ultimate goal would be to proceed to their deployment, that is, to integrate them into the React Native mobile application, such as the demon-

stration previously described. Thus, it would be possible to launch the services directly from one of the components of the system, in this case, the mobile application.

Finally, the results obtained regarding the testing and evaluation of the demonstration designed and developed are discussed in detail in the next section, that is, in Section 7.5.

7.5 Discussion

The testing and evaluation of the demonstration designed and developed enabled to draw relevant conclusions regarding this proposed solution. In fact, the system implementation of each mobile Augmented Reality care service depended on the main results achieved and conclusions drawn from the demonstration presented in Section 7.4 of this chapter.

Although the results can be considered somewhat positive and promising, it was concluded that a mobile AR module to assist seniors and their informal caregivers regarding specific individual cares was not the ideal solution for the problem at hand, that is, a solution to prevent autodidacticism, which can lead to a bad teaching experience without the validation of health professionals. Thus, it was intended to support elders and their caregivers by improving and enhancing their learning experience, using an emerging technology.

Therefore, the main points identified that justify the non-integration of the AR module into the system are as follows:

- Users can have poor experiences on lower spec mobile devices, such as smartphones and tablets, that can negatively affect their learning experience. Taking into account the target audience, that is, elders and their informal caregivers, it can most likely happen that they do not possess high-value mobile devices. Making AR responsive is the only approach to truly make it ubiquitous;

- The marker-based image recognition is limiting, forcing the disposition of targets on objects. Moreover, in some cases, it is not even conceivable to do so, such as on human beings. Thus, new technological advances are needed so that an efficient learning process without physical targets is feasible;

- The handling of a mobile device to proceed to the execution of most individual cares defined in Table 11 is not even imaginable, being rather difficult for the target audience to do it while performing the tasks. In fact, frequently, choosing the correct device for each patient can still be considered a difficult mission. Therefore, other types of devices should be used such as AR glasses, that is, smart glasses. The smart glasses currently commercially available include Microsoft HoloLens 2 [164], which incorporates a Skype add-in that enables the drawing of holograms, adding them to video calls and then interacting with them [165], Vuzix Blade Smart Glasses [166], and Google Glass Enterprise Edition [167]. Nonetheless, AR glasses are a work in progress. In order to be conceivable, the smart glasses currently available in the market should be smaller, more portable and comfortable, and cheaper, taking into account the target audience of the projected solution. However, nowadays, they are still mostly aimed at business and enterprise-level users;

- The possibility of causing physical harm to users. In fact, there is a significant possibility of harming themselves and their surroundings due to nature of the solution, in other words, a mobile AR application that requires the handling of a mobile device. The lack of attention can also endanger even more older adults and their caregivers since AR can increase distractions and make walking more perilous.

In spite of the above mentioned, a new module has been designed and developed to respond to the non-integration of the Augmented Reality module into the system, namely the Support Resources module that includes the Textual Guides and Videos areas, which is explained in greater detail in Subsection 5.4.2 of Section 5.4 in Chapter 5. In short, this module enables health professionals, namely nurses and technical and administrative staff, to add new resources that can then be consulted by elders and their caregivers. It offers them safe support resources with medical validation and approval made by health professionals. To facilitate the learning process according to the users' liking, the resources are available in two different formats, namely textual guides (PDF files) and videos (mp4 files).

Finally, more progress is needed to achieve the prospect of Augmented Reality. As discussed, advances in visualization and portable technology are essential to reach the promised potential of this novel technology, that is, improving the learning experience of all seniors and their informal caregivers in the community, regardless of their age. In fact, mobile devices require constant interaction and manipulation, which make them unsuitable in this scenario, in other words, to promote efficiently their learning.

7.6 Conclusion and Future Work

As stated throughout this chapter, the study conducted enabled to refute the hypothesis initially formulated, that is, that the emerging mobile Augmented Reality technology could be used to design and develop individual cares to enhance successfully the learning experience of the elderly and their informal caregivers.

Nonetheless, it was concluded that a prominent technological evolution is required in order to enable the feasibility of the integration of an Augmented Reality module into the system. In fact, more efficient image recognition algorithms are needed since the current marker-based image recognition is limiting and smart glasses that are smaller, more portable and comfortable, and cheaper that can be used instead of mobile devices to offer optimal experiences to users, that is, unique AR features. As a matter of fact, mobile devices such as smartphones and tablets are not the correct device for the problem at hand. Users can have poor experiences on lower spec mobile devices, the handling of a mobile device to proceed to the execution of most individual cares defined is not even possible, and there is the possibility of causing physical harm to users mainly due to a potential lack of attention. However, choosing the correct device for each user is still frequently considered a difficult mission.

Thus, the expected technological developments should improve the utility of AR in the near future and, consequently, allow to make the proposed solution viable. In a distant future, after the amendment of the technical limitations addressed, the goal would be to design and develop a demonstration for smart glasses since the use of a mobile device has been proven to not be the correct device for the problem at

hand. If its implementation is successful, each individual care would be designed and developed to be used with AR smart glasses.

Nevertheless, to respond to the non-integration of the Augmented Reality module, a new module has been designed and developed to respond to its non-integration into the system, namely the Support Resources module, as described in Chapter 5.

8

PROOF OF CONCEPT

The aim of this chapter is to prove the feasibility of the proposed system, in other words, that the archetype defined has practical potential. To do so, after a short introduction (Section 8.1), the Strengths, Weaknesses, Opportunities, and Threats analysis is presented and discussed in Section 8.2. This chapter ends with a brief conclusion (Section 8.3).

8.1 Introduction

In the area of Information Technology, any type of research project must be subjected to tests and evaluations before being made available to its end users, first proceeding to its installation, testing, and evaluation in a non-production environment. Therefore, it is crucial to follow a series of guidelines in order to evaluate the proposed solution, namely regarding the achievement or not of the requirements and objectives predefined.

Thus, a Proof of Concept was carried out in order to prove the feasibility and usefulness of the proposed artifact, that is, if it can be exploited in a useful way. This research methodology is described in Section 3.5 of Chapter 3 of this manuscript.

In this research project, this process was performed by conducting a Strengths, Weaknesses, Opportunities, and Threats analysis of the archetype mostly based on the Technology Acceptance Model 3. Nonetheless, data collection also included participant observation, focus groups, semi-structured interviews, and self-administered and interviewer-administrated questionnaires.

Nevertheless, in the future, it is intended to conduct a more accurate and detailed study after the final implementation of the system and its use during a considerable period of time in order to be able to draw more accurate conclusions.

In the next section, the PoC carried out within the scope of this doctoral dissertation is described in detail.

8.2 Swot Analysis

The aim of this section is to present and discuss the Strengths, Weaknesses, Opportunities, and Threats analysis conducted in order to study the internal and external environments of the organization, in this

case, elders' home environments and the nursing homes, by identifying and analyzing the strengths and weaknesses of the proposed solution, as well as the opportunities and threats to which it is exposed. Therefore, it is intended to identify factors that influence the functioning of the system, providing useful data in the strategic planning process.

As explained in Section 3.5 of Chapter 3, the SWOT analysis is divided into two different parts, namely:

- Internal environment: the strengths and weaknesses are determined, which enables the standardization of processes and elimination of inefficiencies;
- External environment: the threats and opportunities are identified, which supports the management in strategic decision-making.

To outline the SWOT analysis, a questionnaire was defined based on the Technology Acceptance Model 3 on a 7-point Likert scale in order to enable the study of the acceptance of the proposed Information Technology artifact, where:

- 1: *strongly disagree*;
- 2: *moderately disagree*;
- 3: *somewhat disagree*;
- 4: *neutral* (neither disagree nor agree);
- 5: *somewhat agree*;
- 6: *moderately agree*;
- 7: *strongly agree*.

The questionnaire is presented in Appendix B, which was divided into two different questionnaires according to the two groups defined, namely: 1) health professionals, which include nurses and administrators (Appendix B.1); and 2) elders and their informal caregivers (Appendix B.2). Nonetheless, it is important to note that it will be answered by a larger sample size of the target audience in the future. Therefore, it was distributed to a small sample to enable the definition of the points of the SWOT analysis, that is, a qualitative evaluation, but it is intended to increase the total number of individuals in order to permit a more thorough quantitative evaluation. However, to do so, the design and development of the system must be completely completed and, then, it must be used by the target audience during a considerable period of time to allow a proper evaluation.

Furthermore, the definition of the SWOT analysis also included data collection through predominantly participant observation, focus groups, semi-structured interviews, and self-administered and interviewer-administrated questionnaires.

Thus, regarding the strengths, the following points were identified:

- To bridge the gap between nursing homes and the community;

- The proposed artifact is broad enough to cover most individuals of the older population;
- Provides a new security and safety to the elderly and their informal caregivers through telenursing services;
- Combats social isolation and loneliness of seniors and their informal caregivers through social interaction;
- Offers safe health resources to older adults and their informal caregivers with medical approval from health professionals;
- Improves elders' health and well-being and informal caregivers' welfare by supporting them adequately;
- Promotes intervention in community life;
- Incites personal growth and the evolution of the welfare and health of the elderly;
- Encourages unremitting learning through emerging technologies, including Collaborative Learning. CL highly promotes group learning;
- Improves housing;
- Timely sharing and centralization of information between all the elements of the target audience, namely seniors, informal caregivers, and health professionals;
- Enables the extraction of new knowledge from a vast amount of data through Business Intelligence, which improves the decision-making process;
- Enables the scheduling of diverse types of tasks in a more organized and less confusing way;
- Permits to reduce human errors, time-waste, and forgetfulness;
- High usability since it is an intuitive and user-friendly system. Current usability issues were taken into account since the target audience includes older age groups;
- High scalability by being relatively easy to expand the features of the proposed solution;
- High adaptability to different case studies, in other words, to expand the community and the covered area to more nursing homes, since it was designed to allow its fast and easy expansion;
- In such a competitive market, the system is a tremendous asset for the nursing homes due to the technological innovation driven;
- Boosts technological innovation in the nursing homes;
- Promotes relevant scientific research and responds to current research gaps in gerontechnology.

On the other hand, its weaknesses were also recognized:

- Requires an Internet connection in the homes of seniors and their informal caregivers and in the nursing homes, which is not currently available in all these health facilities;
- Data must be collected during a relatively long period of time before the BI clinical and performance indicators can be implemented.

Concerning the opportunities, which correspond to the external factors that could positively influence the proposed solution, the next topics can be outlined:

- Modernization and organizational development in the nursing homes;
- Hiring more health professionals in these health facilities, especially nursing staff, in order to reduce the workload on each one;
- The implementation of the necessary infrastructures in the nursing homes in order to, subsequently, allow the use of novel innovative solutions;
- More information stored in the database, which could permit the extraction of new knowledge through BI;
- The launch of more portable, comfortable, and cheaper AR smart glasses to enable the design and development of a new suitable Augmented Reality module;
- The implementation of membership fees for elders and their informal caregivers to join the system. In this way, it would be cost-effective for the nursing homes, that is, profitable, and thus justify the resources spent by them, namely health professionals' time and money;
- The introduction and implementation of the system in more case studies, that is, nursing homes.

Finally, it is possible to highlight the following threats associated with the system:

- Elders and informal caregivers that do not have the necessary devices to use the system, namely computers and mobile devices such as smartphones or tablets;
- The still potential lack of acceptance and fear to resort to new technologies by a few individuals of the target audience, that is, seniors, informal caregivers, and health professionals (mostly nurses);
- The current lack of health professionals working in the nursing homes and, consequently, the tremendous work overload on these few nurses;
- The current lack of modernization in these health facilities, that is, adequate infrastructures, and, subsequently, the non-utilization of novel innovative technologies in their establishments;
- Potential problems can arise regarding the network connectivity, that is, Internet connection, for example, if it is unreliable and then fails;

- New similar solutions may arise due to the novelty of the proposed system, namely competitors, since it approaches current and relevant issues.

8.3 Conclusion

In this chapter, the Proof of Concept carried out was presented and defended within the scope of this doctoral dissertation project, namely of an archetype to assist elders' self-care and their informal caregivers with a novel approach through nursing homes.

In this context, a Strengths, Weaknesses, Opportunities, and Threats analysis was applied to the proposed artifact mostly based on the Technology Acceptance Model 3. To do so, a questionnaire aimed at the different elements of the target audience was prepared, which was divided into two different questionnaires as there are two different groups in the target audience, namely health professionals working in the nursing homes (nursing and technical and administrative staff) and elders and their informal caregivers.

In a first phase, the questionnaire was answered by a small sample of the target audience. Nonetheless, in the future, it is intended to distribute it to a larger sample after the final implementation of the proposed system and its use during a considerable period of time. Thus, even more exact conclusions could be drawn after a new analysis. On the other hand, a quantitative analysis could be performed to complete the qualitative analysis already conducted.

Therefore, in this chapter, the feasibility, utility, and usability of the Information Technology artifact have been proven. In short, it bridges the current existing gap between nursing homes and the community, it is broad enough to cover most individuals of the older population, the security, safety, and welfare of the elderly and their informal caregivers are enhanced, it combats social isolation and loneliness through social interaction, medically approved health resources are made available, and it responds to current research gaps in gerontechnology.

However, modernization and organizational development are crucial in the nursing homes, which include the implementation of the necessary infrastructures in their establishments and hiring more health professionals in order to reduce the current workload on each one. The still potential lack of acceptance and fear to resort to new technologies by a few individuals of the target audience must also be addressed.

Finally, in the next chapter, that is, the "Conclusion and Future Work" chapter, this doctoral dissertation is thoroughly discussed, which includes its main contributions and insights regarding potential future work.

9

CONCLUSION AND FUTURE WORK

This manuscript ends with a detailed "Conclusion and Future Work" chapter. Thus, in a first section, the main contributions achieved with the realization of this doctoral dissertation are debated (Section 9.1), which includes answering the principal Research Question defined in Section 1.3 of Chapter 1. Then, insights regarding potential relevant future work for this research project are presented (Section 9.2).

9.1 Main Contributions

This doctoral dissertation in the Doctoral Program in Biomedical Engineering was conducted in order to be able to respond to the following main Research Question:

"How can Health Information and Communication Technology efficaciously assist elders' self-care and their informal caregivers through the support of nursing homes?"

To do so, after an initial survey, a set of evolving technologies was chosen in order to be studied and used in the design and development of the proposed archetype, that is, a system to support seniors' self-care and their caregivers. Nonetheless, a novel approach that involves the support of social entities that are integrated in the community was followed, namely Portuguese nursing homes located in the north of the country. The technologies studied that correspond to the initial hypotheses weighted are the following:

- Web-based healthcare solutions;
- Mobile Health;
- Telenursing;
- Collaborative Learning;
- Business Intelligence;
- Mobile Augmented Reality.

Therefore, throughout this research project, each hypothesis was tested in order to conclude whether the technology in question really is a right solution to the problem at hand.

Summing up, it was concluded that the novel system that is being designed and developed could effectively support elders' self-care and their informal caregivers through the aid of nursing homes, but it can also enable the elderly to live more independently in their home environments since they prefer "to age in place". To do so, it was divided into two different components, namely a React Web application - Web-based healthcare solution - and a mobile React Native mobile application - Mobile Health. On the other hand, it can also be a reinforcement to deal with seniors' well-being and health and informal caregivers' welfare by improving their lifestyle quality, enhancing users' experience using emerging technologies, promoting social interaction to combat social isolation and loneliness, providing security and safety, and inciting personal growth of all parties involved. Nonetheless, as stated throughout this manuscript, it is predominantly intended to help bridge the gap between nursing homes, that is, the case studies, and the community, taking into account safe medical validation and ethical issues. Thus, the goal is to minimize the large existing physical distance between the elderly and their caregivers and providers, in this case, nurses working in the nursing homes, in order to help achieve equitable community welfare - telenursing.

Additionally, through Collaborative Learning, unremitting learning is encouraged by highly promoting group learning among all elements of the target audience, namely older adults and their informal caregivers and care workers and professional staff working in the nursing homes. Thus, learners are not only responsible for their own learning but also the learning of other members in the social support system. Other considerable advantages include higher achievement, greater productivity, increased motivation, mutual encouragement between the different individuals of the community, engagement and enjoyment, and a significant reduction in anxiety, nervousness, and embarrassment.

On the other hand, the Business Intelligence technology enables the extraction of new knowledge from a vast amount of data, that is, "big data", which improves the decision-making process. In fact, the right information is given to the right individuals at the right time to enable the right decisions. As a consequence, better decisions are made since they are evidence-based and not made based on intuition or simple assumptions. For instance, this technology enables to highlight trends and, thus, answer quicker to alarming situations that require greater attention, but also to assess how users are interacting with the system.

However, the hypothesis initially formulated regarding the possibility of applying mobile Augmented Reality was refuted since mobile devices require constant interaction and manipulation, which make them unsuitable in the scenario at hand, in other words, to promote efficiently the learning of seniors and their caregivers. The launch of more portable, comfortable, and cheaper AR smart glasses is inevitable to enable the design and development of a new suitable Augmented Reality module to be integrated into the system.

Nevertheless, the work carried out also aimed to promote further scientific research and respond to current and pertinent research gaps in gerontechnology, namely:

- The current non-existence of a bridge of communication between the elderly and their informal caregivers and nursing homes, which the proposed solution solves by creating a connection between professionals working in the nursing homes and the seniors and caregivers through adequate features in the system;

- Gerontechnology still mostly focuses on patients with single illnesses. Consequently, the proposed archetype is broad enough to cover most individuals of the older population and not only elders with a particular disease or medical condition;
- The lack of proper clinical validation of terms and practices in current systems, which endangers patients' safety. Thus, this research project was carried out in collaboration with health professionals, principally nursing staff working in nursing homes, in order to integrate properly validated clinical terms and practices;
- The current usability issues of HICT in the elderly are still not properly addressed. Therefore, basic and necessary guidelines suggested by researchers of the scientific community were followed in order to enhance the usability, acceptability, and accessibility of the system;
- It is essential to boost technological innovation in nursing homes since the successful use of HICT solutions in those healthcare facilities is still currently non-existent in Portugal. In this context, this doctoral dissertation can incite essential modernization and organizational development in these health institutions that are inevitable to the successful implementation of new technological solutions.

However, in fact, modernization and organizational development in the nursing homes are crucial in order to allow the future successful implementation of the proposed Information Technology artifact in the case studies. It includes hiring more health professionals in these health facilities, especially nurses, in order to reduce the workload on each one and the implementation of the necessary infrastructures in the nursing homes in order to, subsequently, allow the use of novel innovative solutions in their establishments. Additionally, the implementation of membership fees for elders and their informal caregivers to join the system could also be fundamental for the future success of the system. In this way, it would be cost-effective for the nursing homes, in other words, profitable, and thus justify the resources spent by them, namely health professionals' time and the associated costs. On the other hand, in the temporal and geographical contexts in question, there is still elders and informal caregivers that do not have the necessary devices to use the system, namely computers and mobile devices such as smartphones or tablets, and the potential lack of acceptance and fear to resort to new technologies by a few individuals belonging to the target audience.

9.2 Future Work

As potential future work, it is expected to continue the design and development of the proposed Information Technology artifact, which will include tasks associated with the database that supports the system, the React Web application and the React Native mobile application, as well as the Web services (back-end) that enable the sharing of data between the system (front-end) and the database.

In fact, overall, it is expected to finalize the development process of some pending functionalities of the proposed system, particularly its mobile component, that is, the React Native mobile application.

Regarding the Web-based healthcare solution, it may include adding a feature to manage the patients' associated drug stock in the Medication Assistance submodule (Individual Cares module), in other words, to integrate a stock control into the solution. It is also intended to send Short Message Service to users concerned about alerts classified as critical in the Alerts module. Another potential improvement could be to provide to the elderly and their informal caregivers the possibility to request physical support services available in the nursing homes. In this way, seniors and their caregivers could receive remote but also physical support from care workers and professional staff working in those health facilities.

On the other hand, regarding the Business Intelligence technology, after a considerable period of time when enough data is stored in the database, tests will be performed with the Agency for Integration, Diffusion and Archive of Medical Information in order to evaluate the Extract, Transform, and Load process and, subsequently, the growth and maintenance processes to maintain the Data Warehouse updated with up-to-date data. Then, the clinical and performance BI indicators will be validated, which will be followed by the final implementation into the system of the indicators approved. Additionally, more indicators could be added if new information is recorded in the database.

Additionally, more progress is needed to achieve the prospect of Augmented Reality. As discussed throughout this manuscript, advances in visualization and portable technology are essential to reach the promised potential of this novel technology, that is, improving the learning experience of older adults and their informal caregivers in the community, regardless of their age. In a distant future, after the amendment of the technical limitations addressed, the ultimate goal would be to design and develop a solution for AR smart glasses since the use of a mobile device has been proven to not be the correct device for the problem at hand.

Regarding the defense of the feasibility and usefulness of the proposed system, a questionnaire was defined based on the Technology Acceptance Model 3 on a 7-point Likert scale in order to, thereafter, outline a Strengths, Weaknesses, Opportunities, and Threats analysis. Nonetheless, it is important to note that it will be answered by a larger sample size of the target audience in the future. Therefore, initially, it was distributed to a small sample to enable the definition of the points of the SWOT analysis, that is, a qualitative evaluation, but it is intended to increase the total number of individuals in order to permit a more thorough quantitative evaluation. However, to do so, the design and development of the system must be fully completed and, then, it must be used by the target audience during a considerable period of time to allow a proper evaluation.

On the other hand, in the future, costs should be associated with the proposed solution in order to be profitable for the nursing homes according to the resources expended by them, that is, materials and professionals, and associated costs. Thus, the implementation of membership fees for elders and their caregivers to join the system could be fundamental for the success of the system. As discussed in the previous section, inevitable modernization and organizational development are also necessary in their establishments.

Nevertheless, it is important to note that the next phases of this research project must continue to follow rigorously the steps of the Design Science Research methodology since it is intended to construct and evaluate a useful and rigorous Health Information and Communication Technology artifact to assist the

elderly and their informal caregivers with the helpful support of social support entities that are integrated in the community, that is, nursing homes.

Finally, the results achieved with this doctoral dissertation are promising. However, the considerations mentioned throughout this manuscript must be properly addressed in order to permit the effective implementation of the proposed archetype in the nursing homes. Consequently, it will enable its future successful use by all individuals of the target audience and its full potential could be truly reached in the coming years.

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A

QUESTIONNAIRE TO ASSESS CURRENT CHALLENGES, NEEDS, AND OPPORTUNITIES

In this appendix chapter, the questionnaire used to assess current challenges, needs, and opportunities is presented. Nonetheless, it is essential to refer that this chapter is divided into two different sections since this questionnaire was answered by two different groups of people, namely 1) health professionals (mostly nurses) and health information and communication technology professionals that work closely with nursing homes and 2) elders and their informal caregivers. Thus, the first group responded to the questionnaire presented in Appendix A.1 (Table 12) and the second group to the questionnaire in Appendix A.2 (Table 13).

a.1 Health Professionals and Health Information and Communication Technology Professionals

Table 12: Questionnaire to assess current challenges, needs, and opportunities answered by health professionals and health information and communication technology professionals

	Questions
1	What are the most significant reasons attributed to the current lack of health information and communication technologies to successfully support seniors' self-care and their informal caregivers?
2	What are the negative effects associated with the lack of health information and communication technologies to support elders' self-care and their informal caregivers?
3	How could health information and communication technologies mitigate the negative effects mentioned in the previous question?
4	What are the main reasons for the current absence of the use of emerging technologies for older adults' self-care and their informal caregivers with the aid of remote assistance through nursing homes?

	Questions
5	How is workflow management in nursing homes, that is, the internal and external interactions between health professionals and their patients?
6	What is the current situation regarding the collection and organization of data in nursing homes?
7	What is the current situation regarding the adoption of health information and communication technologies in nursing homes?
8	What are the current apparent needs regarding the implementation of health information and communication technology solutions in nursing homes?
9	What are the current limitations associated with nursing homes regarding the implementation and adoption of new technologies?
10	What are the biggest difficulties faced by the elderly and their informal caregivers and, consequently, their greatest needs?
11	How the use of emerging technologies can help older adults and their informal caregivers with the aid of remote assistance through nursing homes?
12	What relevant data should be recorded in databases for informatics solutions focused on the care of the elderly?
13	What are the clinical and performance business intelligence indicators that should be integrated in this type of solutions? Justify the relevance of each indicator.
14	What activities would benefit from the mobile augmented reality technology to support seniors and their informal caregivers? Justify each activity.
15	What features should be integrated into a system to support elders' self-care and their informal caregivers? Justify each feature.
16	What would be the potential willingness and acceptance of users of health information and communication technology solutions to support older adults' self-care and their informal caregivers? Justify.
17	Would you be willing to use emerging technologies to assist elders' self-care and their informal caregivers? Justify.
18	What are the ethical issues that may arise in the process of designing, developing, implementing, and using the proposed solution?

a.2 Elders and their Informal Caregivers

Table 13: Questionnaire to assess current challenges, needs, and opportunities answered by elders and their informal caregivers

	Questions
1	What are the biggest difficulties faced by the elderly and their informal caregivers and, consequently, their greatest needs?
2	What features should be integrated into a system to support elders' self-care and their informal caregivers? Justify each feature.
3	What would be the potential willingness and acceptance of users of health information and communication technology solutions to support older adults' self-care and their informal caregivers? Justify.
4	Would you be willing to use emerging technologies to assist elders' self-care and their informal caregivers? Justify.

B

QUESTIONNAIRE TO ASSESS THE ACCEPTANCE OF THE SYSTEM

This appendix chapter presents the Technology Acceptance Model 3 questionnaire prepared to be answered by a larger sample size of the target audience in the future regarding the acceptance of the proposed solution. Nonetheless, as for the questionnaire to assess current challenges, needs, and opportunities (Appendix A), it was divided into two different questionnaires since the questions posed depend on the group to which the user belongs. So, this appendix chapter is divided into two different sections according to the two groups defined, namely: 1) health professionals, which include nurses and administrators (Appendix B.1); and 2) elders and their informal caregivers (Appendix B.2). This division is based on the four different user types of the system where the user types that perform functions that can be considered similar in the system were grouped.

On the other hand, it is also relevant to note that all items of the questionnaires are measured on a 7-point Likert scale, where 1: *strongly disagree*, 2: *moderately disagree*, 3: *somewhat disagree*, 4: *neutral* (neither disagree nor agree), 5: *somewhat agree*, 6: *moderately agree*, and 7: *strongly agree*.

b.1 Health Professionals (Nurses and Administrators)

Table 14: Questionnaire to assess the acceptance of the system based on the Technology Acceptance Model 3 on a 7-point Likert scale answered by health professionals (nurses and administrators)

Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Perceived Ease of Use							
I consider the system to be easy to use.							
Interacting with the system does not require a lot of effort, that is, it is effortless.							
My interaction with the system is clear and understandable.							
I can easily manage my resources with the system.							
I can easily manage the elders that I supervise with the system. (*)							

Question	1	2	3	4	5	6	7
I am able to effortlessly have access to information with the system.							
I am able to effortlessly record data with the system.							
I am able to easily manage my tasks with the system.							
The information displayed in the system is well-organized, adequate and easily understandable, that is, it is user-friendly.							
The solution is visually appealing.							
Subjective Norm							
The health professionals of the nursing homes think that we should use the system.							
In general, the nursing homes have supported the use of the system.							
Image							
Health professionals in the nursing homes who use the system are better seen than those who do not.							
Having the system is a tremendous asset for the nursing homes in such a competitive market.							
In general, I consider that the use of the system benefits the prestige of the nursing homes in comparison with those who not not.							
Job Relevance							
Using the system is important and relevant to perform my job-related tasks.							
Output Quality							
I estimate that the overall results that I can achieve through the system are excellent, that is, of high quality.							
Result Demonstrability							
It is apparent to me the benefits of using the system.							
It is easy for me to explain to others the results that can be achieved through the system.							
Computer Self-efficacy							
I am able to use the system even if there is no one around to tell me what to do as I go.							

Question	1	2	3	4	5	6	7
I would only be able to use the system if someone showed me how to do it first.							
Perceptions of External Control							
The nursing homes provide the resources necessary to use the system.							
I believe that I have the knowledge necessary to use the system.							
It is easy to me to use the system given the resources and knowledge required.							
Computer Anxiety							
I have fear and apprehension about using a computer.							
I consider that I feel at ease and comfortable using a computer.							
Computer Playfulness							
I consider that my interaction with a computer is spontaneous and playful.							
Perceived Enjoyment							
I consider using the system to be enjoyable and pleasant.							
Experience							
I have experience with solutions similar with the proposed system.							
I have experience with other types of Information Technology solutions.							
Voluntariness							
My use of the system is voluntary.							
It is not required to use the system in the nursing homes.							
Although the system might be helpful, using it is certainly not mandatory in my job.							
Perceived Usefulness							
Using the system can improve my performance and effectiveness in my job-related tasks.							
Using the system can increase my productivity in my job-related tasks.							
I find the system to be useful and a strong asset to manage elders and their informal caregivers.							
Behavioural Intention							

Question	1	2	3	4	5	6	7
I intend to use the system.							
Use Behaviour							
I intend to use the system regularly and consistently.							

(*) Questions only made available to nurses.

b.2 Elders and their Informal Caregivers

Table 15: Questionnaire to assess the acceptance of the system based on the Technology Acceptance Model 3 on a 7-point Likert scale answered by elders and their informal caregivers

Question	1	2	3	4	5	6	7
Perceived Ease of Use							
I consider the system to be easy to use.							
Interacting with the system does not require a lot of effort, that is, it is effortless.							
My interaction with the system is clear and understandable.							
I can easily manage my resources with the system.							
I can easily manage the elders that I take care of with the system. (*)							
I am able to effortlessly have access to information with the system.							
I am able to effortlessly record data with the system.							
I am able to easily manage my tasks with the system.							
The information displayed in the system is well-organized, adequate and easily understandable, that is, it is user-friendly.							
The solution is visually appealing.							
Subjective Norm							
My family members and friends think that I should use the system.							
In general, my peers have supported the use of the system.							
Image							
I believe that individuals who use the system are better seen than those who do not.							

Question	1	2	3	4	5	6	7
In today's society, having the system is a tremendous asset for my peers and I.							
In general, I consider that the use of the system benefits the prestige of my peers and I in comparison with those who not not.							
Job Relevance							
Using the system is important and relevant to perform my care-related tasks.							
The use of the system is essential to manage the seniors that I take care of. (*)							
Output Quality							
I estimate that the overall results that I can achieve through the system are excellent, that is, of high quality.							
Result Demonstrability							
It is apparent to me the benefits of using the system.							
It is easy for me to explain to others the results that can be achieved through the system.							
Computer Self-efficacy							
I am able to use the system even if there is no one around to tell me what to do as I go.							
I would only be able to use the system if someone showed me how to do it first.							
Perceptions of External Control							
The nursing homes provide the resources necessary to use the system.							
I have the resources necessary to use the system.							
I believe that I have the knowledge necessary to use the system.							
It is easy to me to use the system given the resources and knowledge required.							
Computer Anxiety							
I have fear and apprehension about using a computer.							
I consider that I feel at ease and comfortable using a computer.							

Question	1	2	3	4	5	6	7
I have fear and apprehension about using a mobile device, such as smartphones and tablets.							
I consider that I feel at ease and comfortable using a mobile device, such as smartphones and tablets.							
Computer Playfulness							
I consider that my interaction with a computer is spontaneous and playful.							
I consider that my interaction with a mobile device, such as smartphones and tablets, is spontaneous and playful.							
Perceived Enjoyment							
I consider using the system to be enjoyable and pleasant.							
Experience							
I have experience with solutions similar with the proposed system.							
I have experience with other types of Information Technology solutions.							
Voluntariness							
My use of the system is voluntary.							
Although the system might be helpful, using it is certainly not mandatory in my care-related tasks.							
Perceived Usefulness							
Using the system can improve my performance and effectiveness in my care-related tasks.							
Using the system can increase my productivity in my care-related tasks.							
I find the system to be useful and a strong asset to manage the elders that I take care of. (*)							
Behavioural Intention							
I intend to use the system.							
Use Behaviour							
I intend to use the system regularly and consistently.							

(*) Questions only made available to informal caregivers.

C

PUBLICATIONS

In this appendix chapter, the main scientific papers published during the course of this doctoral dissertation are presented as well as manuscripts that were already submitted but await publication. Each paper is presented in a different section of this chapter with detailed information.

c.1 The Development of a Business Intelligence Web Application to Support the Decision-making Process Regarding Absenteeism in the Workplace

AUTHORS: Sara Oliveira, Marisa Esteves, Rui Cernadas, António Abelha, and José Machado

TITLE: The Development of a Business Intelligence Web Application to Support the Decision-Making Process Regarding Absenteeism in the Workplace

CONFERENCE PROCEEDINGS: Information Technology and Systems (ICITS'2020). Advances in Intelligent Systems and Computing (AISC), Vol. 1137, pp. 104-113. Springer, Cham.

YEAR OF PUBLICATION: 2020

ABSTRACT: Nowadays, one of the biggest concerns of industries all over the world is situations regarding absenteeism, since it has a great impact on the productivity and economy of companies, as well as on the health of their employees. The major causes of absenteeism appear to be work accidents and sickness leaves, which lead to the attempt by companies of understanding how the workload is related to the health of their collaborators and, consequently, to absenteeism. Thus, this paper proposes the design and development of a Web Application based on Business Intelligence indicators in order to help the health and human resources professionals of a Portuguese company analyse the relation between absenteeism and the health and lifestyle of employees, with the intention of concluding whether the work executed on the company is harming workers' health. Furthermore, it is intended to discover the principal motives for the numerous and more frequent absences in this company, so that it is possible to decrease the absenteeism rate and, hence, improve the decision-making process. This platform will also provide higher quality healthcare and the possibility to find patterns in the absence of collaborators, as well as reduce time-waste and errors.

KEYWORDS: Information and Communication Technology; Business Intelligence; Decision-making Process; Absenteeism; Web Application; Health and Human Resources Professionals.

STATE OF PUBLICATION: Published

c.2 A New System to Assist Elders' Self-care and their Informal Caregivers

AUTHORS: Marisa Esteves, Márcia Esteves, and António Abelha

TITLE: A New System to Assist Elders' Self-care and their Informal Caregivers

JOURNAL: International Journal of Reliable and Quality E-Healthcare (IJRQEH), Special Issue "Emerging Trends, Issues, and Challenges in Healthcare Solutions", Vol. 9(1), pp. 50-65. IGI Global.

YEAR OF PUBLICATION: 2020

ABSTRACT: The ageing of the population increases the number of elders dependent in self-care. Thus, being dependent in a home context is a fact that deserves attention from social support entities integrated into the community, such as nursing homes, which play a central role in supporting the families involved. In this sense, this study is aimed at seniors dependent in self-care, their informal caregivers, and health professionals from Portuguese nursing homes and emerged to assist elders' self-care and their informal caregivers and to strengthen the communication strategies between the different elements of the target audience. Therefore, the design and development of an archetype of a new system is proposed, which main objectives are to accompany, teach, and share information between its users, taking into account safe medical validation and ethical issues, through emerging health ICT technologies. This archetype is a reinforcement, that is, a way to promote and complete the knowledge and skills to deal with elders' well-being and health, as well as their informal caregivers' welfare.

KEYWORDS: Health ICT; Telenursing; Web-based Healthcare Solutions; mHealth; Collaborative Learning; Augmented Reality; Business Intelligence; Nursing Homes; Elders; Caregivers; Self-care; Ethical Issues.

STATE OF PUBLICATION: Published

c.3 A Proof of Concept of a Mobile Health Application to Support Professionals in a Portuguese Nursing Home

AUTHORS: Márcia Esteves, Marisa Esteves, António Abelha, and José Machado

TITLE: A Proof of Concept of a Mobile Health Application to Support Professionals in a Portuguese Nursing Home

JOURNAL: Sensors, Vol. 19(18), pp. 3951. MDPI.

YEAR OF PUBLICATION: 2019

ABSTRACT: Over the past few years, the rapidly aging population has been posing several challenges to healthcare systems worldwide. Consequently, in Portugal, nursing homes have been getting a higher demand, and health professionals working in these facilities are overloaded with work. Moreover, the lack of health information and communication technology (HICT) and the use of unsophisticated methods, such as paper, in nursing homes to clinically manage residents lead to more errors and are time-consuming. Thus, this article proposes a proof of concept of a mobile health (mHealth) application developed for the health professionals working in a Portuguese nursing home to support them at the point-of-care, namely to manage and have access to information and to help them schedule, perform, and digitally record their tasks. Additionally, clinical and performance business intelligence (BI) indicators to assist the decision-making process are also defined. Thereby, this solution aims to introduce technological improvements into the facility to improve healthcare delivery and, by taking advantage of the benefits provided by these improvements, lessen some of the workload experienced by health professionals, reduce time-waste and errors, and, ultimately, enhance elders' quality of life and improve the quality of the services provided.

KEYWORDS: Business Intelligence; Elders; Health Information and Communication Technology; Health Professionals; Mobile Health; Nursing Homes; Smart Health.

STATE OF PUBLICATION: Published

c.4 A Mobile Health Application to Assist Health Professionals: A Case Study in a Portuguese Nursing Home

AUTHORS: Márcia Esteves, Marisa Esteves, António Abelha, and José Machado

TITLE: A Mobile Health Application to Assist Health Professionals: A Case Study in a Portuguese Nursing Home

CONFERENCE PROCEEDINGS: 5th International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AWE'19), Vol. 1, pp. 338-345.

YEAR OF PUBLICATION: 2019

ABSTRACT: The rapidly aging population has been a matter of concern over years since this problematic has been posing several challenges to healthcare systems worldwide. In Portugal, which is one of the countries with the largest aging population, nursing homes have been getting a higher demand, and health professionals are overloaded with work. Furthermore, the fact that few nursing homes use health information and communication technology (ICT) resorting to paper to record information and clinically manage their residents is a tremendous problem, since this method is more

prone to errors and time-consuming. Thus, this paper proposes the design and development of a mobile application for health professionals working in a Portuguese nursing home with the intention of assisting them at the point-of-care, by recording and providing all the necessary information, and helping them to schedule, perform, and digitally record their tasks. This solution will help health professionals to provide better care, by reducing time-waste and errors, and, consequently, to improve elders' quality of life. A mobile solution was chosen since a hand-held device, which can be used anywhere and anytime, is able to give access and store all the needed information at the point-of-care.

KEYWORDS: Health Information and Communication Technology; Mobile Health; Health Professionals; Elders; Nursing Home; Ethical Issues in Medicine.

STATE OF PUBLICATION: Published

c.5 Application of Data Mining for the Prediction of Prophylactic Measures in Patients at Risk of Deep Vein Thrombosis

AUTHORS: Manuela Cruz, Marisa Esteves, Hugo Peixoto, António Abelha, and José Machado

TITLE: Application of Data Mining for the Prediction of Prophylactic Measures in Patients at Risk of Deep Vein Thrombosis

CONFERENCE PROCEEDINGS: New Knowledge in Information Systems and Technologies (WorldCIST'19). Advances in Intelligent Systems and Computing (AISC), Vol. 932, pp. 557-567. Springer, Cham.

YEAR OF PUBLICATION: 2019

ABSTRACT: In the last decades, with the increase in the amount of data stored in the healthcare industry, it is also extended the possibility of obtaining important information to support the decision-making process of health professionals. This article has as evidence to apply Data Mining (DM) techniques to health databases of patients with medical Deep Vein Thrombosis (DVT) risk, with the objective of classifying, based on different attributes obtained in medical discharge reports, the main prophylactic measures taken. Therefore, to achieve this goal, the free software Weka was used aiming to facilitate the process of DM, along with the algorithms chosen. In view of this, it was concluded that the service to which each patient is associated is the most relevant factor for prophylactic measures followed by the age range to which the patient belongs. This study also deduces that it can be possible to obtain classifiers capable of predicting the best prophylactic measures with a qualitative level similar as one of a health professional and, thereafter, it can be possible to obtain the classification.

KEYWORDS: Deep Vein Thrombosis; Prophylactic Measures; Data Mining; Classification; Prediction; Weka.

STATE OF PUBLICATION: Published

c.6 The Development of a Pervasive Web Application to Alert Patients Based on Business Intelligence Clinical Indicators: A Case Study in a Health Institution

AUTHORS: Marisa Esteves, António Abelha, and José Machado

TITLE: The Development of a Pervasive Web Application to Alert Patients based on Business Intelligence Clinical Indicators: A Case Study in a Health Institution

JOURNAL: Wireless Networks, pp. 1-7. Springer, US.

YEAR OF PUBLICATION: 2019

ABSTRACT: This paper proposes the development of a pervasive Web application based on business intelligence clinical indicators created with the data stored into the health information systems of a Portuguese health institution in the last 3 years i.e. between the beginning of 2015 and the end of 2017. With this computational tool, it is principally intended to reduce the number of appointments, surgeries, and medical examinations that were not carried out in the hospital most likely due to forgetfulness since most patients who attend this health institution are elderly people and memory loss is very common with increasing age. Therefore, patients and/or their caregivers and family members are alerted via SMS in advance and appropriately by health professionals through the Web application. This alternative is cheaper, faster, and more customizable than sending those SMS using a smartphone. Advantages liked with the use of this solution also include decreasing losses concerning time, human resources, and money.

KEYWORDS: Health Information and Communication Technology; Web Application; Business Intelligence; Data Warehousing; Health Institution; Elderly People; Caregivers.

STATE OF PUBLICATION: Published

c.7 A Data Mining Approach to Classify Serum Creatinine Values in Patients Undergoing Continuous Ambulatory Peritoneal Dialysis

AUTHORS: Cláudia Brito, Marisa Esteves, Hugo Peixoto, António Abelha, and José Machado

TITLE: A Data Mining Approach to Classify Serum Creatinine Values in Patients Undergoing Continuous Ambulatory Peritoneal Dialysis

JOURNAL: Wireless Networks, pp. 1-9. Springer, US.

YEAR OF PUBLICATION: 2019

ABSTRACT: Continuous ambulatory peritoneal dialysis (CAPD) is a treatment used by patients in the end-stage of chronic kidney diseases. Those patients need to be monitored using blood tests and those

tests can present some patterns or correlations. It could be meaningful to apply data mining (DM) to the data collected from those tests. To discover patterns from meaningless data, it becomes crucial to use DM techniques. DM is an emerging field that is currently being used in machine learning to train machines to later aid health professionals in their decision-making process. The classification process can found patterns useful to understand the patients' health development and to medically act according to such results. Thus, this study focuses on testing a set of DM algorithms that may help in classifying the values of serum creatinine in patients undergoing CAPD procedures. Therefore, it is intended to classify the values of serum creatinine according to assigned quartiles. The better results obtained were highly satisfactory, reaching accuracy rate values of approximately 95%, and low relative absolute error values.

KEYWORDS: Data Mining; Knowledge Extraction; Chronic Kidney Diseases; Continuous Ambulatory Peritoneal Dialysis; Serum Creatinine; Clinical Decision Cupport Systems; Weka; Classification Algorithms.

STATE OF PUBLICATION: Published

c.8 Waiting Time Screening in Healthcare

AUTHORS: José Neves, Henrique Vicente, Marisa Esteves, Filipa Ferraz, António Abelha, José Machado, Joana Machado, and João Neves

TITLE: Waiting Time Screening in Healthcare

CONFERENCE PROCEEDINGS: Big Data Technologies and Applications (BDTA'17). Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (LNICST), Vol. 748, pp. 124-131. Springer, Cham.

YEAR OF PUBLICATION: 2018

ABSTRACT: In Medical Imaging (MI), various technologies can be used to monitor the human body for diagnosing, monitoring or treating disease. Each type of technology provides different information about the body area that is being investigated or treated for a possible illness, injury or effectiveness of a medical treatment. Routine screening has identified malfunction detection in many otherwise asymptomatic patient images such as computed tomography or magnetic resonance. Studies have shown that, compared to patients whose disease was symptomatic (i.e., self-recognizing), screen-detected diseases may have more favourable clinicopathological features, leading to better prognosis and better outcome. This paper aims to assess the issue of health care wait screening. It deviates from a decision support system that evaluates the waiting times in diagnostic MI based on operational data from various information systems. Last but not least, one's assumptions may have an important impact in determining the usefulness of routine laboratory testing at admission.

KEYWORDS: Waiting Time Screening; Logic Programming; Case-based Reasoning.

STATE OF PUBLICATION: Published

c.9 Mobile Collaborative Augmented Reality and Business Intelligence: A System to Support Elderly People's Self-care

AUTHORS: Marisa Esteves, Filipe Miranda, José Machado, and António Abelha

TITLE: Mobile Collaborative Augmented Reality and Business Intelligence: A System to Support Elderly People's Self-care

CONFERENCE PROCEEDINGS: Trends and Advances in Information Systems and Technologies (WorldCIST'18). Advances in Intelligent Systems and Computing (AISC), Vol. 747, pp. 195-204. Springer, Cham.

YEAR OF PUBLICATION: 2018

ABSTRACT: The ageing of the population increases the number of elderly people dependent in self-care. Thus, being dependent in a home context is a fact that deserves attention from social support entities integrated into the community, such as nursing homes. In this sense, this study is aimed at elderly dependent people in self-care, their caregivers, and members of nursing teams, and emerged to ensure predominantly the continuity of care of patients from Portuguese nursing homes and to strengthen the communication strategies between the different elements of the target audience. Therefore, at this stage of the project, the design of a preliminary archetype of a mobile collaborative augmented reality and business intelligence system is proposed, which main objectives are to accompany, teach, and share information between its users. It will be a reinforcement, that is, a way to promote and complete the knowledge and skills to deal with patients' health.

KEYWORDS: Health Information and Communication Technology; Telenursing; Mobile Health; Collaborative Learning; Augmented Reality; Business Intelligence; Data Warehousing; Nursing Homes; Elderly People; Self-care.

STATE OF PUBLICATION: Published

c.10 Improving the Codification of Hospital Discharges with an ICD-9-CM Single-page Application and its Transition to ICD-10-CM/PCS

AUTHORS: Cecília Coimbra, Marisa Esteves, Filipe Miranda, Filipe Portela, Manuel Filipe Santos, José Machado, and António Abelha.

TITLE: Improving the Codification of Hospital Discharges with an ICD-9-CM Single-page Application and its Transition to ICD-10-CM/PCS

JOURNAL: International Journal on Advances in Life Sciences, Vol. 10 (1, 2), pp. 23-30. IARIA.

YEAR OF PUBLICATION: 2018

ABSTRACT: In recent years, in Centro Hospitalar do Porto (CHP), there has been felt an increasing need for a computerized clinical coding tool to aid in the codification of the episodes of hospital discharges from patients admitted to its healthcare units. The process was slow and performed manually by the coding professionals, so there was neither the centralization nor the unification of the information and processes associated with the clinical coding of a hospital discharge. Hereupon, in the context of this study, the aim of the present work was to design and develop a clinical coding tool for ICD-9-CM to support the clinical practice in healthcare units. It additionally included its subsequent transition to the newer ICD-10-CM/PCS coding version. In short, the codification of hospital discharge processes enables the grouping of episodes into diagnosis-related groups (DRGs). The main motivation for the implementation of this classification system is that it provides a financial and patient classification system to contain the costs and waste associated with healthcare services. Thereby, a single-page application (SPA) for ICD-9-CM was designed in order to help health professionals of CHP in their daily work, namely the clinical coding of the episodes of hospital discharges, and it was subsequently updated to the ICD-10-CM/PCS coding version that predominantly improved specificity in describing clinical situations. The main advantages and contributions of the development and use of this Web application are the centralization of information and tasks associated with the coding of hospital discharges, the increase of productivity, and the reduction of wastes of time. Consequently, the ambition is sought to mainly improve the quantity and the quality of work performed by coding professionals at CHP.

KEYWORDS: ICD-9-CM; ICD-10-CM/PCS; Hospital Discharge; Diagnosis-related Group; Single-page Application; Proof of Concept.

STATE OF PUBLICATION: Published

c.11 A Deep-big Data Approach to Health Care in the AI Age

AUTHORS: José Neves, Henrique Vicente, Marisa Esteves, Filipa Ferraz, António Abelha, José Machado, Joana Machado, João Neves, Jorge Ribeiro, and Lúzia Sampaio.

TITLE: A Deep-big Data Approach to Health Care in the AI Age

JOURNAL: Mobile Networks and Applications, pp. 1-6. Springer, US.

YEAR OF PUBLICATION: 2018

ABSTRACT: The intersection of these two trends is what we call *The Issue* and it is helping businesses in every industry to become more efficient and productive. One's aim is to have an insight into

the development and maintenance of comprehensive and integrated health information systems that enable sound policy and effective health system management in order to improve health and health care. Undeniably, different sorts of technologies have been developed, each with their own advantages and disadvantages, which will be sorted out by attending at the impact that Artificial Intelligence and Decision Support Systems have to everyone in the healthcare sector engaged to quality-of-care, i.e., making sure that doctors, nurses, and staff have the training and tools they need to do their jobs.

KEYWORDS: Artificial Intelligence; Decision Support Systems; Medical Imaging; Deep Learning; Logic Programming; Knowledge Representation and Reasoning; Artificial Neural Networks; Big Data.

STATE OF PUBLICATION: Published

c.12 Pervasive Business Intelligence Platform to Support the Decision-making Process in Waiting Lists

AUTHORS: Marisa Esteves, Filipe Miranda, and António Abelha

TITLE: Pervasive Business Intelligence Platform to Support the Decision-making Process in Waiting Lists

BOOK: Next-Generation Mobile and Pervasive Healthcare Solutions, pp. 186-202. IGI Global.

YEAR OF PUBLICATION: 2018

ABSTRACT: In recent years, the increase of average waiting times in waiting lists is an issue that has been felt in health institutions. Thus, the implementation of new administrative measures to improve the management of these organizations may be required. Hereupon, the aim of this present work is to support the decision-making process in appointments and surgeries waiting lists in a hospital located in the north of Portugal, through a pervasive Business Intelligence platform that can be accessed anywhere and anytime by any device connected within the hospital's private network. By representing information that facilitates the analysis of information and knowledge extraction, the Web tool allows the identification in real-time of average waiting times outside the outlined patterns. Thereby, the developed platform permits their identification, enabling their further understanding in order to take the necessary measures. Thus, the main purpose is to enable the reduction of average waiting times through the analysis of information in order to, subsequently, ensure the satisfaction of patients.

STATE OF PUBLICATION: Published

c.13 Improving Diagnosis-related Groups with a Computerized Clinical Coding Tool for ICD-9-CM Codification

AUTHORS: Cecília Coimbra, Marisa Esteves, Filipe Miranda, Filipe Portela, Manuel Filipe Santos, José Machado, and António Abelha

TITLE: Improving Diagnosis-related Groups with a Computerized Clinical Coding Tool for ICD-9-CM Codification

CONFERENCE PROCEEDINGS: The Ninth International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED'2017), pp. 33-36. IARIA.

YEAR OF PUBLICATION: 2017

ABSTRACT: In recent years, in Centro Hospitalar do Porto (CHP), a major Portuguese hospital at the North of the country, there has been felt an increasing need for a computerized clinical coding tool to aid in the codification of the episodes of hospital discharges from patients admitted to its healthcare units. The process was slow and performed manually by the coding professionals, not having a centralization and unification of the information and processes associated with the clinical coding of a hospital discharge. Hereupon, in the context of this study, the aim of the present work was to design and develop a clinical coding tool for International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) to support the clinical practice in healthcare units. The coding of hospital discharge processes enables the grouping of episodes into diagnosis-related groups (DRGs) that correspond to clinically coherent and similar groups that are expected to use the same level of hospital resources. The main motivation for the implementation of this classification system is that it provides a financial and patient classification system, trying to contain the costs and waste associated with healthcare services. Thereby, a single-page application (SPA) for ICD-9-CM was designed in order to help health professionals of CHP in their daily work, namely the clinical coding of the episodes of hospital discharges. The main advantages and contributions of the development and use of this Web application are the centralization of information and tasks associated with the coding of hospital discharges, the increase of productivity, and the reduction of wastes of time. Consequently, the ambition is sought to mainly improve the quantity and the quality of work performed by coding professionals.

KEYWORDS: ICD-9-CM; Diagnosis-related Groups; Hospital Discharges; Single-page Application; Proof of Concept.

STATE OF PUBLICATION: Published

c.14 Understanding Stroke in Dialysis and Chronic Kidney Disease

AUTHORS: Mariana Rodrigues, Hugo Peixoto, Marisa Esteves, José Machado, and António Abelha

TITLE: Understanding Stroke in Dialysis and Chronic Kidney Disease

CONFERENCE PROCEEDINGS: EUSPN 2017/ICTH-2017 (Affiliated Workshops). Procedia Computer Science, Vol. 113, pp. 591-596. Elsevier.

YEAR OF PUBLICATION: 2017

ABSTRACT: Patients with severe kidney failure need to be carefully monitored. One of the many treatments is called Continuous Ambulatory Peritoneal Dialysis (CAPD). This kind of treatment intends to maintain the blood tests as normal as possible. Data Mining and Machine Learning can take a simple and meaningless blood's test data set and build it into a Decision Support System. Through this article, Machine Learning algorithms will be explored with different Data Mining models in order to extract knowledge and classify a patient with a stroke risk or not, according to his/her blood analysis.

KEYWORDS: Data Mining; Classification; Dialysis; Stroke Risk; Chronic Kidney Disease.

STATE OF PUBLICATION: Published

c.15 An Agent-based RFID Monitoring System for Healthcare

AUTHORS: Fernando Marins, Luciana Cardoso, Marisa Esteves, José Machado, and António Abelha

TITLE: An Agent-based RFID Monitoring System for Healthcare

CONFERENCE PROCEEDINGS: Recent Advances in Information Systems and Technologies (WorldCIST'2017). Advances in Intelligent Systems and Computing (AISC), Vol. 571, pp. 407-416. Springer, International Publishing.

YEAR OF PUBLICATION: 2017

ABSTRACT: In the last years, with the progressive expansion of Healthcare Information Systems (HISs), the healthcare platforms for interoperability and monitoring systems have become increasingly more vital sources of clinical information. In this context, in Centro Hospitalar do Porto (CHP), the INTCare system was developed with the purpose to create new useful knowledge for decision support in real-time. It is an unquestionable potential area to develop effective systems for the prediction of clinical events, including Decision Support Systems (DSSs), for organ failure and death in Intensive Care. The INTCare uses multiple data sources that are collected at the bedside. However, this system fails on the recognition of the patient absence in bed. Thereby, this problem led to the development of the Patient Localization and Management System (PaLMS), i.e., a RFID localization and monitoring system. Thus, this paper describes the PaLMS Intelligent Multi-agent System for the integration of PaLMS into the hospital platform for Interoperability, Diffusion and Archive – Agency for Integration, Diffusion and Archive of Medical Information (AIDA) platform. On the other hand,

a failure prevention system that actuates in the PaLMS agents, improving their availability, is also presented and thoroughly discussed.

KEYWORDS: Ambient Intelligence; Monitoring Systems; Prevention Systems; Intensive Care Unit; Multi-agent Systems; RFID.

STATE OF PUBLICATION: Published

c.16 A Benchmarking Analysis of Open-source Business Intelligence Tools in Healthcare Environments

AUTHORS: Andreia Brandão, Eliana Pereira, Marisa Esteves, Filipe Portela, Manuel Filipe Santos, António Abelha, and José Machado

TITLE: A Benchmarking Analysis of Open-source Business Intelligence Tools in Healthcare Environments

JOURNAL: Information, Vol. 7(4), pp. 57. MDPI.

YEAR OF PUBLICATION: 2016

ABSTRACT: In recent years, a wide range of Business Intelligence (BI) technologies have been applied to different areas in order to support the decision-making process. BI enables the extraction of knowledge from the data stored. The healthcare industry is no exception, and so BI applications have been under investigation across multiple units of different institutions. Thus, in this article, we intend to analyze some open-source/free BI tools on the market and their applicability in the clinical sphere, taking into consideration the general characteristics of the clinical environment. For this purpose, six BI tools were selected, analyzed, and tested in a practical environment. Then, a comparison metric and a ranking were defined for the tested applications in order to choose the one that best applies to the extraction of useful knowledge and clinical data in a healthcare environment. Finally, a pervasive BI platform was developed using a real case in order to prove the tool viability.

KEYWORDS: Business Intelligence; Open-source; Healthcare; Benchmarking.

STATE OF PUBLICATION: Published

c.17 A Case Based Methodology for Problem Solving Aiming at Knee Osteoarthritis Detection

AUTHORS: Marisa Esteves, Henrique Vicente, José Machado, Victor Alves, and José Neves

TITLE: A Case Based Methodology for Problem Solving Aiming at Knee Osteoarthritis Detection

CONFERENCE PROCEEDINGS: Recent Advances on Soft Computing and Data Mining (SCDM'2016). Advances in Intelligent Systems and Computing (AISC), Vol. 549, pp. 274-284. Springer, Cham.

YEAR OF PUBLICATION: 2016

ABSTRACT: Knee osteoarthritis is the most common type of arthritis and a major cause of impaired mobility and disability for the ageing populations. Therefore, due to the increasing prevalence of the malady, it is expected that clinical and scientific practices had to be set in order to detect the problem in its early stages. Thus, this work will be focused on the improvement of methodologies for problem solving aiming at the development of Artificial Intelligence based decision support system to detect knee osteoarthritis. The framework is built on top of a Logic Programming approach to Knowledge Representation and Reasoning, complemented with a Case Based approach to computing that caters for the handling of incomplete, unknown, or even self-contradictory information.

KEYWORDS: Knee Osteoarthritis; Knee X-ray Image Feature Extraction; Knowledge Representation and Reasoning; Logic Programming; Case-based Reasoning.

STATE OF PUBLICATION: Published

c.18 Monitoring Time Consumption in Complementary Diagnostic and Therapeutic Procedure Requests

AUTHORS: Ana Alpuim, Marisa Esteves, Sónia Pereira, and Manuel Filipe Santos

TITLE: Monitoring Time Consumption in Complementary Diagnostic and Therapeutic Procedure Requests

BOOK: Applying Business Intelligence to Clinical and Healthcare Organizations, pp. 208-240. IGI Global.

YEAR OF PUBLICATION: 2016

ABSTRACT: Over the years, information technologies and computer applications have been widespread amongst all fields, including healthcare. The main goal of these organizations is focused on providing quality health services to their patients, ensuring the provision of quality services. Therefore, decisions have to be made quickly and effectively. Thus, the increased use of information technologies in healthcare has been helping the decision-making process, improving the quality of their services. For an example, the insertion of Business Intelligence (BI) tools in healthcare environments has been recently used to improve healthcare delivery. It is based on the analysis of data in order to provide useful information. BI tools assist managers and health professionals through decision-making, since they allow the manipulation and analysis of data in order to extract knowledge. This work aims to study and analyze the time that physicians take to prescribe medical exams in Centro Hospitalar do Porto (CHP), though BI tools. The main concern is to identify the physicians who take more time than average to prescribe complementary means of diagnosis and treatment, making it possible to identify and understand the reason why it occurs. To discover these outliners, a BI platform was developed using the Pentaho Community. This platform presents means to represent information through tables and graphs that facilitate the analysis of information and the

knowledge extraction. This information will be useful to represent knowledge concerning not only the prescription system (auditing it) but also its users. The platform evaluates the time prescription, by specialty and physician, which can afterwards be applied in the decision-making process. This platform enables the identification of measures to unravel the time differences that some physicians exhibit, in order to, subsequently, improve the whole process of electronic medical prescription.

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c.19 Waiting Time Screening in Diagnostic Medical Imaging – A Case-based View

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ABSTRACT: Due to the high standards expected from diagnostic medical imaging, the analysis of information regarding waiting lists via different information systems is of utmost importance. Such analysis, on the one hand, may improve the diagnostic quality and, on the other hand, may lead to the reduction of waiting times, with the concomitant increase of the quality of services and the reduction of the inherent financial costs. Hence, the purpose of this study is to assess the waiting time in the delivery of diagnostic medical imaging services, like computed tomography and magnetic resonance imaging. Thereby, this work is focused on the development of a decision support system to assess waiting times in diagnostic medical imaging with recourse to operational data of selected attributes extracted from distinct information systems. The computational framework is built on top of a Logic Programming Case-based Reasoning approach to Knowledge Representation and Reasoning that caters for the handling of incomplete, unknown, or even self-contradictory information.

KEYWORDS: Waiting Time; Diagnostic Medical Imaging; Knowledge Representation and Reasoning; Logic Programming; Case-based Reasoning; Similarity Analysis.

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