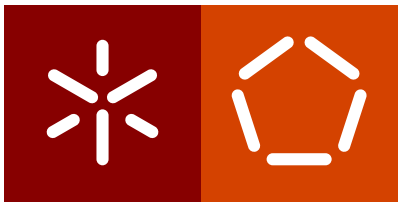

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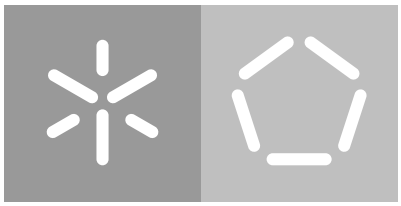
Márcia Annie Araújo Esteves

A Mobile Health Application to Assist Professionals

A Case Study in a Portuguese Nursing Home

July 2019



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Márcia Annie Araújo Esteves

A Mobile Health Application to Assist Professionals

A Case Study in a Portuguese Nursing Home

Master Dissertation
Master Degree in Biomedical Engineering

Dissertation oriented by
Professor José Manuel Ferreira Machado
and supervised by
Master Vasco António Pinheiro da Costa Abelha

July 2019

DECLARATION

Name: Márcia Annie Araújo Esteves

Dissertation Title: A Mobile Health Application to Assist Professionals: A Case Study in a Portuguese Nursing Home

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Mentor: Professor José Manuel Ferreira Machado

Supervisor: Master Vasco António Pinheiro da Costa Abelha

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Master Designation: Mestrado Integrado em Engenharia Biomédica

Master Branch: Informática Médica

Universidade do Minho, _____/_____/_____

Signature: _____

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After so many years of envisioning this moment, it is with great joy and emotion that I can say that an important chapter of my life has finally come to an end. The road to this moment has not always been easy for me, as I am sure it was not for many others, but after so many anxieties and years of hard work I am proud to say that I have successfully reached the end and excited to begin a new journey. However, before concluding this chapter, I would like to thank and express my deepest gratitude to all the people who made it possible in any way and helped me through all of it.

In the first place, I would like to express my sincere appreciation to both my mentor, Professor José Machado, and my supervisor, Master Vasco Abelha. I would like to thank them for their continuous availability, motivation, and support during this important chapter of my life and for always sharing their immense knowledge with me, which was fundamental for the development of this project.

On the other hand, I cannot end this chapter without expressing my deepest gratitude for the professionals working for the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital. During the development of the present dissertation, they have always been supportive and available to help me make this project possible. I could not have imagined having better support. Furthermore, I would like to express my deepest appreciation to all of the people of the Knowledge Engineering Research Lab for their support and help during the development of this project. More specifically, I would like to show my deepest gratitude to a special member of the Knowledge Engineering Research Lab, Marisa Esteves, who happens to be my sister, but was also some sort of an "unofficial" second supervisor during the development of my dissertation and helped me with her insight, knowledge, and assistance.

To all of my friends who have been part of this journey and stayed with me for the person that I am, I would like to thank them for their continuous support, for always believing in me, and for making this journey a fun and enjoyable ride. I will always carry with me the defeats, achievements, and magical moments that we shared together. Without them, this journey would not have been the same.

Most importantly, I have to address a few words to my family without whom I would not be writing these acknowledgments and concluding one of the most important chapters of my life. To my parents, I am deeply grateful for the opportunities they have provided to me and for teaching me so much in life. Without them, I would not know the true meaning of sacrifice, hard work, and integrity. Since a young age, they have taught me that life does

not always come easy but, despite the adversities I may encounter, I should always want more from life and work hard to achieve my goals. To my sister, I am most thankful for her continuous support, for always being there for me when I was lost, for believing in me when I didn't believe in myself, and for having my back when I didn't have mine. Without her support, knowledge, and insight, I don't believe this project would have been what it is today and for that, I will always be deeply grateful.

To all of you who made this journey possible, I am most thankful.

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.

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ABSTRACT

Over the past few years, the world has been witnessing a huge demographic change: the aging population has been growing at an alarming rate. This problem has been a matter of concern for many countries since it has been posing several challenges to healthcare systems worldwide. In Portugal, which is one of the countries with the largest aging population, this demographic change has led to several issues. In fact, in Portugal, the nursing homes have been getting a higher demand, and health professionals are overloaded with work. Furthermore, the fact that nursing homes still use paper to record information and to clinically manage their residents is another tremendous problem since this method is more prone to errors and time-consuming.

In this context, the present master's dissertation emerged and consisted in the design and development of a mobile application for the health professionals, i.e. the nurses and doctors, working in a Portuguese nursing home, more specifically in one of the nursing homes of *Santa Casa da Misericórdia de Vila Verde*. This mobile application was developed to help the health professionals to clinically manage the residents and to assist them at the point-of-care, namely to schedule, perform, and record their daily tasks and to have access and manipulate information.

Additionally, the present dissertation also included the definition of clinical and performance indicators to assist the decision-making process. It is important to mention that a mobile solution was chosen since a hand-held device, which can be used anywhere and any time, is able to give access and store all the needed information at the point-of-care.

Thereby, this project was developed in order for the nursing home to shift from the paper-based to the computer-based management of data as well as to introduce technological improvements in the facility, more specifically, Health Information and Communication Technology. Thus, by taking advantage of the benefits provided by these improvements, the mobile application could help the health professionals to provide better care, namely by reducing time-waste and errors, and, consequently, enhance elders' quality of life. Furthermore, the solution could relieve some of the workload of the health professionals and help them make more informed and evidence-based decisions and, hence, improve the decision-making process.

Keywords: Business Intelligence, Elders, Ethical Issues in Medicine, Health Information and Communication Technology, Health Professionals, Mobile Health, Nursing Home.

RESUMO

Ao longo dos últimos anos, o mundo tem vindo a testemunhar uma enorme mudança demográfica: o envelhecimento da população tem crescido a uma taxa alarmante. Este problema tem sido um motivo de preocupação para muitos países, uma vez que tem vindo a provocar inúmeros problemas para os sistemas de saúde através o mundo. Em Portugal, que corresponde a um dos países com maior população envelhecida, esta mudança demográfica tem originado vários problemas. De facto, em Portugal, os lares de idosos têm estado sobrelotados e os profissionais de saúde estão sobrecarregados com trabalho. Além disso, o facto dos lares de idosos ainda usarem papel para registar informação e efetuar a gestão dos utentes é um enorme problema, visto que este método é mais demorado e propenso a erros.

Neste contexto, a presente dissertação de mestrado surgiu e consistiu na projeção e no desenvolvimento de uma aplicação móvel para os profissionais de saúde, isto é, para os enfermeiros e os médicos, que trabalham num lar de idosos português, nomeadamente num dos lares da Santa Casa da Misericórdia de Vila Verde. Esta aplicação móvel foi desenvolvida de modo a ajudar os profissionais de saúde a efetuar a gestão dos utentes e auxiliá-los no local de prestação de cuidados, nomeadamente para agendar, realizar e registar as suas tarefas diárias e para ter acesso e manipular informação.

Adicionalmente, a presente dissertação também incluiu a definição de indicadores clínicos e de desempenho, de forma a auxiliar o processo de tomada de decisão. Importa mencionar que uma aplicação móvel foi escolhida visto que um dispositivo portátil, que pode ser usado a qualquer momento e em qualquer lugar, é capaz de dar acesso e armazenar toda a informação necessária no local de prestação de cuidados.

Assim sendo, este projeto foi desenvolvido de modo a permitir o lar de idosos a passar da gestão de dados em papel para a gestão de dados em computador, assim como para introduzir avanços tecnológicos no estabelecimento, mais especificamente, Tecnologia de Informação e Comunicação na Saúde. Assim, tomando vantagem dos benefícios proporcionados por estes avanços, a aplicação móvel poderia ajudar os profissionais de saúde a fornecer melhores cuidados de saúde, nomeadamente a reduzir a ocorrência de erros e desperdícios de tempo, e, consequentemente, melhorar a qualidade de vida dos idosos. Para além disso, a solução poderia ajudar a reduzir a carga de trabalho dos profissionais de saúde e ajudá-los a tomar decisões mais informadas e baseadas em evidências e, assim, melhorar o processo de tomada de decisão.

Palavras-Chave: Business Intelligence, Idosos, Lar de Idosos, Mobile Health, Problemas Éticos na Saúde, Profissionais de Saúde, Tecnologia de Informação e Comunicação na Saúde.

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ACRONYMS

API Application Programming Interface. 34, 35

BI Business Intelligence. xiii, 3, 8, 9, 11, 14, 17, 20–23, 25, 27, 31, 36, 37, 76, 81, 94, 96

CDSS Clinical Decision Support System. 3, 8, 11, 14–17, 24

DBMS Database Management System. 31, 32, 52
DM Data Mining. 23
DML Data Manipulation Language. 32
DSA Data Staging Area. 22
DSR Design Science Research. xiii, 8, 27–30, 44, 47
DSS Decision Support System. 16
DW Data Warehouse. 22, 23

EHR Electronic Health Record. 3, 13, 17, 21, 23, 49, 90, 94
EMR Electronic Medical Record. 3, 13
ETL Extract, Transform, and Load. xiii, 22, 23

GPU Graphic Processing Unit. 35

HICT Health Information and Communication Technology. 1–5, 8, 11–13, 15, 23–25, 27, 30, 37, 49, 51, 82, 83, 89–92, 94–96
HIS Health Information System. 3, 8, 11, 13–15, 19, 23, 24
HTTP Hypertext Transfer Protocol. 32, 33

ICT Information and Communication Technology. 2, 28, 30, 44
IS Information System. 13, 14, 16, 32
IT Information Technology. 13, 39–44

JS JavaScript. 9, 27, 31, 34, 52
JSON JavaScript Object Notation. 33
JSX JavaScript XML. 34
JWT JSON Web Token. 33

mHealth Mobile Health. xiii, 3–5, 8, 11, 13, 18–20, 23, 24, 30, 44, 47, 50, 52, 80, 92, 95

PDF Portable Document Format. 33, 60, 67, 70

PHP Hypertext Preprocessor. 9, 27, 28, 31, 33, 44, 52, 54
PoC Proof of Concept. 9, 27, 28, 30, 37, 44, 82, 83, 86

RDBMS Relational Database Management System. 31, 32
REST Representational State Transfer. 32, 33

SOAP Simple Object Access Protocol. 32, 33
SQL Structured Query Language. 9, 27, 31, 32, 52
SWOT Strengths, Weaknesses, Opportunities, and Threats. xiii, 9, 27, 28, 30, 31, 37–39, 44, 82–87

TAM Technological Acceptance Model. xiii, 9, 27, 28, 30, 31, 37, 40, 41, 44, 82–84
TAM2 Extended Technology Acceptance Model. xiii, 40–42
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TAV Theory of Reasoned Action. 40

UI User Interface. 34, 36
URI Uniform Resource Identifier. 33

WWW World Wide Web. 32

XML Extensible Markup Language. 32–34

1

INTRODUCTION

The present document has as main purpose to thoroughly describe the project of designing and developing a mobile application for the health professionals working in a Portuguese nursing home, more specifically in one of the *Santa Casa da Misericórdia de Vila Verde* nursing homes, which is managed by the *Misericórdia de Vila Verde* hospital, to help them clinically manage the residents and to assist them at the point-of-care, namely to schedule, record, and perform tasks and to have access, document, consult, and manipulate information. Additionally, this project aims to take advantage of the many benefits provided by Health Information and Communication Technology (HICT) to ultimately help health professionals to provide better care by reducing time-waste and errors. It must be mentioned that this project emerged as a master's dissertation of the Integrated Master in Biomedical Engineering of the University of Minho for the master branch of Medical Informatics.

Thus, this first chapter corresponds to an introductory chapter for the present dissertation and is divided into four distinct sections. Firstly, a brief contextualization of the project is made in Section 1.1 in order to have a better understanding of its scope. Then, in Section 1.2, the main motivation of the project is presented to assess its novelty and relevance nowadays. Moreover, in Section 1.3, the main objectives of the project are presented. In this context, the research questions associated with the present dissertation and that will be answered throughout this document are presented with the intention of identifying the main goals of the project. Finally, in the last section of this chapter (Section 1.4), the structure of the present document is thoroughly described.

1.1 SCOPE AND CONTEXTUALIZATION

Over the last few years, the world has been witnessing a huge demographic change: the population is aging at an alarming rate. In fact, by taking an in-depth look at the statistics regarding the aging population, they are concerning: comparatively to the growth of the whole population, it is estimated the elderly population is growing twice as fast [1]. This problem has been a matter of concert all over the world since it is posing several challenges to healthcare systems worldwide [1] [2] [3] [4]. Some of the main problems caused by this

demographic change are the increase of the costs of elderly care and of the number of elders in nursing homes [1] [3]. The harsh reality is that many countries are experiencing a growth in the proportion of older individuals and, consequently, an increase of the number of service requirements for them that, at the moment, they are not able to meet. Thus, due to the high demand for more and better medical services for the elderly, there is a need to evaluate the state of these services and assess if improvements are needed.

In Portugal, the increase in the proportion of elderly people has been a tremendous concern. In fact, Portugal is currently one of the countries with the largest aging population in the world [5] and this situation has been posing several challenges. One of the major challenges faced by the country is the increasing number of elders in nursing homes. Finding a place in a nursing home in Portugal has been a massive problem for several elders and their families due to the high demand and quick rate at which the vacancies are filling up [6] [7].

On the other hand, another concern faced by the country is the fact that health professionals working in nursing homes are overloaded with work, which can lead to the decrease of the quality of the nursing care delivered [8] [9]. This situation can be explained by the growth of the number of elders in nursing homes and by the lack of investment in these facilities. For these reasons, the number of elderly people is often to high compared to the number of health professionals.

Additionally, more than not, nursing homes use rudimentary methods, such as paper, to record information and clinically manage their residents, which can be time-consuming and more prone to errors [10] [11]. Naturally, by using handwritten charts and medical records, the risk of misplacing and losing information is a lot higher. On the other hand, health professionals working in nursing homes need to constantly return to the nursing stations in order to retrieve and record information, which can lead to more errors since information can be forgotten or written in the wrong place.

Therefore, there is currently a need to fill the lack of resources and access to technology in nursing homes in order to solve some of the problems faced by them and ultimately improve the nursing care delivered. In fact, nursing homes could greatly benefit from the introduction and implementation of technological advancements, such as HICT.

Over the years, Information and Communication Technology (ICT), which encompasses any form of electronic solution that allows to retrieve, store, manage, manipulate, and transmit digital information [12], has been transforming several industries, and the healthcare industry is not an exception [13] [14] [15]. In fact, the introduction of ICT in a healthcare setting, known as HICT, has dramatically transformed the medical practice and, due to its numerous benefits, it is certainly here to stay. In this context, HICT has proved to improve the quality and safety of the care delivered and its outcomes, e.g. by decreasing errors and taking full advantage of the stored information, to enhance the sharing and access

to information, e.g. by making a shift from paper-based to computer-based management of data, and to reduce time-waste, e.g. by accessing and recording the information at the point-of-care and making the information available anywhere and at any time [10] [12] [16].

However, despite the obvious advantages and positive effects provided by HICT, nursing homes have been lagging behind in their adoption, mainly due to the lack of investment and resources as well as to the lack of effort by these facilities to adapt to technological improvements [10] [11] [12] [17] [18]. Some specific forms of HICT that could enhance healthcare delivery in nursing homes and that have been experiencing a vast growth in recent years are Health Information Systems (HISs) and Mobile Health (mHealth).

HISs are complex systems designed and used to collect, store, manage, process, retrieve, and transfer healthcare digital data of the patients, also known as Electronic Health Records (EHRs) or Electronic Medical Records (EMRs), and digital data related to the institution [19] [20]. The goal of HISs is to improve the quality of the healthcare services not only for administrative purposes but also to enhance the care delivered to patients [20]. Consequently, these systems help reduce medical errors, enhance the safety of the patients, and allow health professionals to deliver care of high quality. This is possible since HISs give timely and accurate information and process data taking full advantage of them, providing information and knowledge to healthcare organizations [19] [21]. In this context, Clinical Decision Support Systems (CDSSs) can be highlighted and they are widely used to extract useful information and knowledge from healthcare data through the aid of emerging technologies, such as Business Intelligence (BI) tools [22] [23]. This knowledge can then be used to serve as a basis for a more accurate and efficient decision-making process.

On the other hand, mHealth, which refers to the use of mobile technology in a healthcare setting, has proved to positively improve healthcare delivery [24] [25] [26]. In fact, the use of mobile technology, namely of mobile devices and applications, in healthcare contexts, has been rapidly growing due to its numerous advantages. More specifically, by using a mobile device, health professionals can benefit of an easier, faster, and better information management since all data are gathered in a single device allowing them to have access and record information anywhere and at any time in the nursing home. These advantages are greatly beneficial for health professionals since they can reduce time-waste and errors [24] [27] [28].

Therefore, according to all that was mentioned above, this present dissertation emerged and consisted in the design and development of a mobile application for the health professionals working in a Portuguese nursing home, more specifically in one of the nursing homes of *Santa Casa da Misericórdia de Vila Verde*, to help them clinically manage the residents and to assist them at the point-of-care, namely to schedule, perform, and record their daily tasks and to have access, document, consult, and manipulate information. Therefore, the main purpose of this project was to introduce technological improvements in the nurs-

ing home and support health professionals through the help of a mHealth solution that would allow to relieve some of the work overload experienced by them, reduce time-waste and errors, and assist them in the decision-making process.

1.2 MOTIVATION

As mentioned in the previous section, a majority of the nursing homes still use rudimentary methods, such as paper, to clinically manage their residents, to schedule and perform tasks, and to record and process information. On the other hand, health professionals working in nursing homes are often overloaded with work due to the unsophisticated and simple methods used by them, which are time-consuming, and to the high number of elders in these facilities, which can be explained by the rapidly aging population.

Thus, all of the above leads to a higher error rate and to the decrease of the quality of the nursing care delivered. However, despite being greatly beneficial for healthcare environments and enhancing healthcare delivery, nursing homes are currently lagging behind when it comes to the use and implementation of technological improvements, such as HICT.

For these reasons, there is currently an urgent need to face these challenges and improve elders' quality of life and the care delivered in nursing homes. Portugal is not an exception to this harsh reality. In fact, at the moment, the country is facing several challenges due to the aging population and the overload of nursing homes.

Thus, with all of this in mind, the project described in this present dissertation emerged. The main motivation for the development of this project is to take advantage of the benefits provided by HICT in order to enhance healthcare delivery in nursing homes and face some of the problems encountered by the health professionals working in these facilities.

Therefore, the main purpose of the present project is to design and develop a mHealth solution for health professionals working in a Portuguese nursing home, more specifically in one of the *Santa Casa da Misericórdia de Vila Verde* nursing homes, to assist them at the point-of-care. Thus, it is intended to remove the paper-based management of data and introduce technological improvements in the facility by developing a mobile application that would allow the health professionals to schedule, perform, and record their daily tasks. Additionally, the mobile application would also allow these professionals to manage their residents by having access, documenting, consulting, and manipulating information of the residents at any time and anywhere in the nursing home. It is important to note that a mHealth solution was chosen since a single hand-held and portable device is able to give access and store all the needed information at the point-of-care.

Consequently, this mHealth solution proposes to help reduce time-waste since health professionals do not need to constantly return to the nursing stations to record and have access to information. On the other hand, it also intends to reduce the occurrence of er-

rors considering digital data are least likely to be forgotten or misplaced compared to the paper-based method. Finally, all of these advantages would ultimately lead to the improvement of elders' quality of life in the nursing home and of the nursing care delivered. Last but not least, it would also help relieve some of the work overload experienced by health professionals.

The novelty and relevance of the project lie in the fact that, nowadays, few nursing homes resort to HICT despite their well-known benefits and great potential, as mentioned previously. Moreover, the fact that there is currently a lack of literature and of an integrated body of knowledge on the use o HICT in nursing homes show that there is still much work that needs to be done in this area. Therefore, the present project intends to fill the lack of technological improvements in nursing homes and explore their benefits having as a case study one of the nursing homes of the *Santa Casa da Misericórdia de Vila Verde*.

1.3 OBJECTIVES

As indicated previously, the aim of the present manuscript is to design and develop a mHealth solution, more specifically a mobile application, for the health professionals working in a Portuguese nursing home in order to assist them at the point-of-care and to remove the paper-based management of residents, which is time-consuming and more prone to errors.

Thus, the main purpose of the project is to introduce technological improvements in a nursing home suffering from the consequences of the aging population and the usage of rudimentary methods with the aim of exploring the benefits provided by them and, ultimately, improve elders' quality of life and the nursing care delivered. Additionally, it is also intended to reduce some of the work overload experienced by the health professionals as the mobile application would allow them to schedule, record, and perform their tasks, to manage the residents, and to have access, document, consult, and manipulate information.

In this context, the development of the project described in the present dissertation was sustained by a set of research questions that gave rise to several objectives. The research questions identified are as follows:

- **Question 1:** What is the current state regarding the adoption of Health Information and Communication Technology of the *Santa Casa da Misericórdia de Vila Verde* nursing home?
  - **Question 1.1:** How is the current state regarding the adoption of Health Information and Communication Technology affecting the work carried out by the health professionals and the quality of the nursing care delivered to elders?

- **Question 2:** What are the current needs of the *Santa Casa da Misericórdia de Vila Verde* nursing home regarding the use of Health Information and Communication Technology?
  - **Question 2.1:** How could the use of Health Information and Communication Technology help overcome some of the challenges faced by the health professionals?
- **Question 3:** How to promote and successfully introduce Health Information and Communication Technology, namely a mobile application, in the *Santa Casa da Misericórdia de Vila Verde* nursing home in order to face and overcome the challenges faced by the institution?
  - **Question 3.1:** How could the implementation of a mobile application be beneficial for the nursing home?
  - **Question 3.2:** Which healthcare services or tasks performed by the health professionals of the nursing home in question could benefit from the use of Health Information and Communication Technology, namely of a mobile application?
  - **Question 3.3:** Which features should be integrated in a mobile application that has as main purpose to assist and help the health professionals of the nursing home in question?
  - **Question 3.4:** In order to develop these features, which are the relevant data that should be recorded in the database?
- **Question 4:** Which clinical and performance Business Intelligence indicators should be created when enough data are gathered in order to assist the decision-making process?
- **Question 5:** Which are the ethical issues that may arise from the implementation of Health Information and Communication Technology, namely a mobile application, in the *Santa Casa da Misericórdia de Vila Verde* nursing home?
  - **Question 5.1:** How could these ethical issues be safeguarded and guaranteed in order to ensure the quality, accuracy, and safety of the mobile application?
- **Question 6:** Which are the long-term implications and benefits of the mobile application developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home?
- **Question 7:** Which improvements should be applied and could be beneficial to the mobile application developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home?

In light of the research questions presented above, a set of objectives arose for the development of the project associated with this present dissertation. Therefore, the objectives defined are as follows:

- **Objective 1:** Analysis of the current state of the *Santa Casa da Misericórdia de Vila Verde* nursing home regarding the use of Health Information and Communication Technology;
- **Objective 2:** Identification of the challenges encountered by the health professionals of the *Santa Casa da Misericórdia de Vila Verde* nursing home and their current needs through focus groups, semi-structured interviews, and questionnaires;
- **Objective 3:** Identification of how these challenges could be solved through the use of Health Information and Communication Technology, namely mobile technology;
- **Objective 4:** Analysis of the state of the art regarding the current state of Health Information and Communication Technology, namely mobile technology, in nursing homes considering the identified needs and challenges;
- **Objective 5:** Identification of the needed requirements for the development of a mobile application in a healthcare setting;
- **Objective 6:** Understanding on how Health Information and Communication Technology, more specifically mobile technology, could benefit the *Santa Casa da Misericórdia de Vila Verde* nursing home and its health professionals;
- **Objective 7:** Selection of the research methodologies and developments tools to be used for the development of the mobile application, namely for the development of the database, the Web services, and the interfaces of the mobile application;
- **Objective 8:** Design of the mobile application, namely of the database, the Web services, and the interfaces and features of the mobile application;
- **Objective 9:** Development of the mobile application, namely of the database, the Web services, and the interfaces and features of the mobile application;
- **Objective 10:** Definition and identification of the clinical and performance indicators that should be created when enough data are gathered in order to enhance the decision-making process;
- **Objective 11:** Ensure that ethical issues are safeguarded and guaranteed during all phases of the development of the mobile application;
- **Objective 12:** Deployment and implementation of the database and Web services created in the server of the *Misericórdia de Vila Verde* hospital;

- **Objective 13:** Presentation and demonstration of the developed solution to the target audience in order to certify that the objectives are met and if changes need to be done;
- **Objective 14:** Critical analysis of the developed solution and the results achieved;
- **Objective 15:** Application of a proof of concept for the developed solution in order to assess its acceptance, potential, and feasibility;
- **Objective 16:** Analysis, identification, and proposition of improvements that could be applied to benefit the developed solution and ensure its successful use;
- **Objective 17:** Analysis and identification of the long-term benefits and implications of the developed mobile application.

1.4 DISSERTATION STRUCTURE

The present document is divided into six distinct chapters: Introduction, State of the Art, Research Methodologies and Development Tools, A Mobile Health Application to Assist Health Professionals: A Case Study in a Portuguese Nursing Home, Proof of Concept, and Conclusion and Future Work. Furthermore, the present dissertation also contains appendices. In this context, the content and themes approached in each chapter and appendix are as follows:

- **Chapter 1 – Introduction:** this introductory chapter aims to make a contextualization of the project described in the present dissertation, referring its general scope and all of its underlying themes and topics. The main motivations of the project are also approached in order to understand its novelty and relevance. Then, the research questions around which the project described in the present dissertation is centered are also presented as a way to identify its main objectives. Lastly, the structure of the present dissertation is thoroughly presented;
- **Chapter 2 – State of the Art:** this second chapter aims to explore the project's body of knowledge and its underlying scientific and theoretical themes and topics of relevance, using appropriate bibliographic references. Therefore, topics in the scope of Health Information and Communication Technology such as Health Information Systems (in particular, interoperability and Clinical Decision Support Systems), Mobile Health, Business Intelligence, and ethical issues in medicine are approached;
- **Chapter 3 – Research Methodologies and Development Tools:** the main purpose of this third chapter is to thoroughly explore and describe the research methodologies and development tools used throughout the course of the development of the project described in the present dissertation. Therefore, the Design Science Research (DSR)

methodology, which was the research methodology followed to ensure the success of the project, is approached in this chapter. Then, the Proof of Concept (PoC) methodology (in particular, the Technological Acceptance Model (TAM) and Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis) is also approached since it was used to evaluate the usefulness, potential, and feasibility of the developed solution. Finally, the development tools and technologies used to develop the solution are also approached in this chapter. Therefore, Structured Query Language (SQL), Hypertext Preprocessor (PHP), and JavaScript (JS) programming languages are explored since they were used to develop the database, the Web services, and the interfaces of the mobile application, respectively. Moreover, the MySQL database and the React Native framework are also explored in this chapter since they were used to develop the database and mobile application, respectively. Finally, Power BI is also approached in this chapter as it was the BI tool used to create examples of the clinical and performance indicators that could be created when enough data are gathered;

- **Chapter 4 – A Mobile Health Application to Assist Health Professionals: A Case Study in a Portuguese Nursing Home:** in this chapter, the solution developed is thoroughly described. For this purpose, the case study for which this solution was developed, namely one of the nursing homes of the *Santa Casa da Misericórdia de Vila Verde*, is presented in order to identify the problems and main challenges faced by the nursing home and, hence, pinpoint the motivation for the development of this project. Thereafter, the objectives for the realization of the solution are defined. The design and development of the solution are also described in detail in this chapter, namely the MySQL database created, the PHP Web services developed, and the architecture and features of the mobile application. Additionally, the clinical and performance indicators that could be created in the future in order to improve the decision-making process are identified. Finally, this chapter concludes with a brief discussion in which a general overview of the developed solution is presented;

- **Chapter 5 – Proof of Concept:** this fifth chapter presents the PoC applied to the developed solution and has the intention of identifying its usefulness and potential. In this context, the TAM was applied in order to identify the acceptability of the developed solution. Afterwards, based on the results obtained, a SWOT analysis was elaborated in order to assess the strengths, weaknesses, opportunities, and threats of the developed solution;

- **Chapter 6 – Conclusions and Future Work:** this final chapter aims to rigorously explore the main conclusions and contributions provided by the developed solution. Thereupon, the research questions presented in the first chapter of the present dissertation are answered in order to assess if the established objectives were successfully

met. Furthermore, a thorough analysis is made with the intention of identifying and proposing improvements that could be applied in the future to benefit the developed solution;

- **Appendix A – Questionnaire to Assess the Needs and Challenges Encountered in the Nursing Home:** in this appendix, the questionnaire performed with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital to assess the needs and challenges encountered in the nursing home is presented;
- **Appendix B – Questionnaire Based on the TAM3 to Assess the Acceptance of the Mobile Application:** in this appendix, the questionnaire performed with the health professionals to assess the acceptance of the mobile application is presented;
- **Appendix C – Publications:** in this appendix, the scientific publications elaborated during the development of the present dissertation are presented.

2

STATE OF THE ART

In this second chapter, the body of knowledge of the project developed in the present dissertation is thoroughly described as well as its underlying scientific and theoretical themes and topics. Therefore, taking into account the topics that needed to be approached, this chapter is structured into six distinct sections.

At first, a brief introduction regarding the advantages and current state of Health Information and Communication Technology are presented in Section 2.1, focusing more specifically in its current state in nursing homes. Thereafter, in Section 2.2, Health Information Systems are introduced, including the concepts of interoperability (Section 2.2.1) and Clinical Decision Support Systems (Section 2.2.2). Then, in Section 2.3, Mobile Health is approached and its main advantages in healthcare settings are presented. Furthermore, Section 2.4 describes the concepts of Business Intelligence and clinical information. Additionally, in Section 2.5, ethical issues in medicine regarding the use of HICT in healthcare are presented. Finally, this chapter concludes with a brief conclusion in order to give a general overview of the topics and concepts described and approached throughout this chapter (Section 2.6).

2.1 INTRODUCTION

The healthcare industry has been facing several challenges: the expectations are higher and the pressure to deliver medical care of high quality is growing [14]. Consequently, healthcare organizations have been constrained to adopt better and advanced improvements in their facilities in order to meet the demands they are facing. In this context, Health Information and Communication Technology emerged and has been playing a vital and important role in healthcare settings all over the world.

In fact, over the last few years, HICT has been positively impacting the health industry all over the world, mainly due to its many advantages and its potential in healthcare settings to improve outcomes and the quality, safety, and efficiency of healthcare delivery [11] [16] [29] [30]. In fact, technologies encompassed in HICT have rapidly become a natural and indispensable part of healthcare settings. In simple words, HICT refers to any kind of tech-

nology that allows to retrieve, store, process, manipulate, and exchange digital information in a healthcare context [12] [29]. Therefore, HICT enables to manage healthcare data in a more efficient and secure way since it is performed across computerized systems.

The adoption and use of HICT have the potential to provide several advantages to healthcare environments and address some of the problems faced by them. For instance, some of the benefits pointed out to HICT are as follows [11] [12] [16] [17] [29]:

- Reduce healthcare costs;
- Enhance the quality, safety, and efficiency of healthcare delivery and its outcomes;
- Enhance the access, management, and sharing of information;
- Reduce time-waste by reducing the time spent on travels and on documenting and accessing information;
- Improve the productivity in healthcare systems;
- Reduce the occurrence of medical errors and adverse events;
- Support the decision-making process.

Nevertheless, despite the benefits associated with HICT and its positive effects in healthcare environments, several healthcare organizations and health professionals still remain hesitant regarding its use [16] [31]. In fact, nursing homes are one of the examples of healthcare organizations that are currently lagging behind regarding the introduction of technological improvements in their facilities [10] [11] [12] [17] [18].

One of the reasons that can be pointed out for the few technological improvements existing in nursing homes is the lack of effort by these facilities as well as by the professionals working in them to adapt to these advancements [11] [31]. On the other hand, the lack of investment in the necessary resources provided to nursing homes are also some of the reasons that can explain the disappointing state of HICT in these facilities [11]. Furthermore, at times, the systems developed are not user-friendly, do not use interoperable standards, are quite difficult to use, and are developed without meeting the needs of the health professionals leading, therefore, to a negative response by them and to the under-utilization of these systems [11] [32] [33].

Nonetheless, the benefits provided by Health Information and Communication Technology are indisputable and, therefore, a higher effort and investment should be done in this area. The success of HICT in healthcare organizations depends greatly on the quality of the systems and solutions that are being developed. Therefore, these solutions should be user-friendly and intuitive since health professionals cannot spend too much time learning how to use them, follow interoperable standards to allow the successful connection between the

different systems existing across the organization, and be user-centered taking into account the needs of the health professionals since they are the main users of these solutions [16] [33] [34].

In this context, some specific forms of Health Information and Communication Technology that have proven to improve healthcare delivery and that have been undergoing tremendous growth in recent years are Health Information Systems and Mobile Health. Therefore, in the next sections and subsections, these topics are thoroughly approached as well as their underlying themes.

2.2 HEALTH INFORMATION SYSTEMS

In simple terms, Health Information Systems are a specific kind of Information Systems (ISs) used to gather, store, manage, process, retrieve, and transfer data generated in healthcare organizations, being vital and essential for their performance [19] [35] [36] [37] [38]. Consequently, these systems are designed to manage all aspects of healthcare organizations, namely for administrative and financial purposes as well as to manage clinical aspects [21] [36].

Therefore, due to the existence of various lines of action in healthcare organizations, there is currently an extensive spectrum of Health Information Systems which can range from simple systems to relatively complex ones, such as [36] [37]:

- **Patient Information Systems:** these systems allow to gather and manage the electronic medical information of patients, known as Electronic Health Records or Electronic Medical Records;

- **Administrative Information Systems:** they are used to record and manage some of the business processes occurring in healthcare organizations, such as bill processing and the admission, discharge, and transfer of patients;

- **Clinical Information Systems:** these systems perform specific tasks and have particular purposes according to the clinical department in which they operate. Thus, they can be used for administrative or decision support, to monitor patients, to gather collections of data used for research, planning, or patient care, and to archive or analyze images, among others;

- **Telemedicine:** this kind of HIS is used to overcome distance barriers by providing healthcare services from a distance through the use of Information Technology (IT) and telecommunications;

- **Clinical Decision Support Systems:** these systems are used to assist the decision-making process by providing features such as alerts, reminders, predictions, and diagnoses to health professionals.

Therefore, HISs aim to improve the performance of healthcare organizations by allowing them to shift from the paper-based to the computer-based management of data, which is less time-consuming and more efficient since this method makes the information more legible and reduces the occurrence of errors [20] [39]. In addition to the fact that these systems are extremely useful to reduce the occurrence of medical errors and adverse events, HISs allow for clinical information to be more organized and complete and more rapidly and easily distributed and accessed across the organization, being, hence, essential to enhance the quality of healthcare delivery, to reduce costs, and to give access to timely information [19] [20] [21] [35] [39].

Furthermore, HISs are widely used to assist health professionals in the decision-making process since these systems help improve the management of data by enabling the extraction of knowledge that can then be used as a basis in the decision-making process [20] [40] [39]. Before the introduction of computer-based systems, all data generated in healthcare organizations were stored in papers, making the usage of these data in a meaningful way impossible. Thus, the migration from paper-based to computer-based systems turned possible the transformation of the vast amounts of clinical information collected daily into useful and new knowledge. Business Intelligence tools and Clinical Decision Support Systems are examples of technologies that enable the extraction of knowledge and new information from data.

However, despite the opportunities and positive effects Information Systems bring to healthcare organizations and their progressive implementation in these facilities, these systems have yet to attain their full potential and maturity in the healthcare industry [37] [39] [40] [41] [42] [43]. In fact, the adoption of ISs in healthcare has been lagging behind compared to other industries, mainly due to the costs and difficulties associated with the implementation and integration of such complex systems, to the reticence of health professionals to use these systems, and to the high requirements of the healthcare industry, more particularly in terms of data privacy and confidentiality [37] [39] [42].

Regardless, the benefits of Health Information Systems are unquestionable, being considered as essential and vital parts of healthcare organizations due to the opportunities and benefits provided by them. However, in order to ensure the successful and effective implementation of these systems, they should follow interoperable standards to allow their integration with other systems, be reliable and have a high performance, meet the requirements and needs of both the health professionals and the organization, take into account data privacy and security issues, and undergo continuous maintenance and evaluations in order to identify and perform improvements over time [44].

With all of the above mentioned, the following two subsections emerged. Therefore, Subsection 2.2.1 approaches the concept of interoperability, which is essential for the successful integration and communication between different systems. Afterwards, Subsection 2.2.2 discusses Clinical Decision Support Systems.

2.2.1 *Interoperability*

Healthcare organizations are currently producing high volumes of clinical data on a day-to-day basis and at a rapid rate. Naturally, these clinical data come from different sources and are, therefore, heterogeneous and stored into different Health Information Systems since healthcare organizations are composed of various stakeholders distributed across the institution, which perform different services and tasks [45] [46] [47] [48]. In fact, each of these stakeholders generates different types of data such as clinical notes, bills, laboratory tests, and patients' observations, treatments, and diagnosis, among others, leading to the fragmentation and storage of the clinical data all over the institution. On the other hand, the heterogeneity and diversity of the clinical information is due to the fact that this information may contain different terminologies, syntax, data types, file formats, and data formats.

However, although the clinical information generated in healthcare organizations is heterogeneous and is dispersed all over the institution, this information needs to interact together since health professionals constantly need to access and utilize this information. In fact, due to the nature of their professions, health professionals need to exchange information between each other daily, such as laboratory tests, diagnoses, medical reports, and clinical notes, for example, in order to treat patients. Therefore, the HISs existing across the organization need to safely connect together to allow the share of information in a secure, uniform, transparent, and effective way.

Therefore, in response to this need, interoperable standards were created in order to allow the communication and exchange of information between the different systems existing across organizations [45] [46] [47] [49]. In simple terms, the concept of interoperability refers to the ability of independent Health Information and Communication Technology systems, applications, and devices to communicate across an organization without any restrictions and in a transparent, secure, and reliable way in order to allow the exchange and use of information between the various stakeholders existing in the institution [47] [49] [50] [51] [52].

The goal of interoperability is to allow the sharing of information across an entire organization as seamlessly as possible in order to be accessed and used by health professionals anywhere and at any time. Furthermore, in order to achieve interoperability, the data shared should be correctly interpreted and understood across the different systems. Thus, a generic representation of the concept of interoperability is presented in Figure 1.

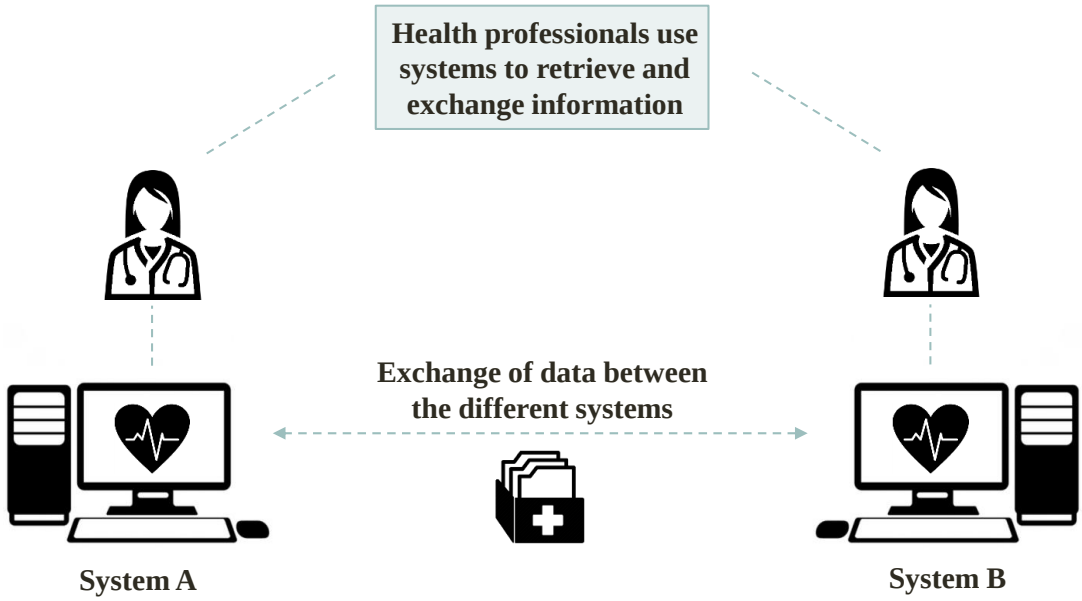

Figure 1.: Generic representation of the concept of interoperability. Adapted from [47].

Currently, the use of interoperable standards in healthcare settings is considered a necessary and fundamental requirement since, without them, the exchange of information across the entire environment would not be possible, compromising healthcare delivery [52]. In fact, several solutions have been created in order to achieve some degree of interoperability, such as data models, intelligent agents systems, and ontologies, among others [47] [50] [53]. However, interoperability has not yet attained its full potential in healthcare settings as it is a hard and complex task to achieve, namely due to the complexity and specificity of the clinical data and to ethical issues [47] [50].

2.2.2 *Clinical Decision Support Systems*

As noted in the previous subsection, nowadays, the healthcare industry generates daily massive amounts of data at a high rate. Thus, in order to justify the huge amounts of data that are being produced on a day-to-day basis, solutions and techniques must be developed so as to utilize these data in a meaningful and productive way, giving them economic value [54] [55] [56]. Without these solutions, the large amounts of clinical data generated would be meaningless and a burden to healthcare organizations since they require storage space, which entails high costs.

In this context, Clinical Decision Support Systems emerged as a solution and they enable the extraction of new and useful knowledge from healthcare data that can be used by health professionals to enhance healthcare delivery. In simple words, CDSSs are specific kinds of Decision Support Systems (DSSs), which are Information Systems able to support

and improve all stages of the decision-making process, introduced in healthcare contexts to assist health professionals [22] [23] [54] [55] [57] [58].

In recent years, the recognition of these computer-based systems as important and beneficial tools has been gradually increasing, mainly due to the rise of the costs and complexity associated with healthcare [22]. Furthermore, the development of these systems has been a priority and a necessity for healthcare environments as a result of the challenges associated with the management of information and knowledge, the need of a solution that could use the high amounts of Electronic Health Records in a meaningful way, and the intent to provide personalized healthcare services to patients [22] [23] [54] [59] [60].

It is important to note that CDSSs do not intend to replace health professionals and perform the clinical decision-making process by themselves. On the contrary, these systems offer relevant, useful, and evidence-based information, which is situation-specific and takes into account the clinical context, to the decision-makers in order for them to make based, informed, supported, and more accurate decisions [22] [58]. Thus, with this in mind, CDSSs aim to enhance the decision-making process by assisting health professionals and have as ultimate goal to improve outcomes and healthcare delivery and to reduce the occurrence of adverse events and costs [22] [58] [61].

There is currently several types of Clinical Decision Support Systems, such as [22] [58]:

- Systems that offer alerts, reminders, suggestions, and recommendations according to the situation and the patient. For this purpose, the health professionals must enter into the system information related to the patient. This information is then linked to knowledge existing in the system and, based on the correlations that are made, the system dispatch alerts, reminders, suggestions, or recommendations to the professionals;

- Systems that organize information into dashboards, reports, indicators, and graphical displays that can then be consulted by health professionals to assist the decision-making process by providing faster and based decisions. In this context, these systems resort to Business Intelligence tools in order to create these dashboards, reports, indicators, and graphical displays;

- Systems that, by taking into account the clinical context and the patient in question, retrieve and offer documents containing relevant information.

In light of what has been mentioned in this subsection, and since CDSSs encompass BI tools to achieve their goals, the section 2.4 approaches the concept of BI.

2.3 MOBILE HEALTH

During the past few years, the rapid expansion of mobile technology, which refers to any kind of technology that can be used "on-the-move", has been impacting several industries, and the healthcare industry is not an exception [24] [25] [62]. In fact, the ubiquitous presence of mobile devices, such as smartphones and tablets, and the rise in their adoption have led to the growth in the number of mobile applications. In this sense, there is currently a wide range of mobile applications that offer a variety of functions and, more recently, mobile health applications have been on the rise due to their potential to improve healthcare delivery [25] [62] [63].

In this context, the use of Mobile Health, more specifically of mobile devices and applications to support healthcare, the clinical practice, and healthcare providers [26] [64], has been transforming several aspects of the healthcare industry. In fact, mHealth has been proving to be quite promising and greatly beneficial for health professionals, namely to help them execute their daily tasks, to manage and monitor patients, to access and manage clinical data, and to enhance the decision-making process, among others [24] [27] [62]. On the other hand, mHealth has also been advantageous for healthcare consumers allowing them to strengthen their communication with healthcare organizations [63] [65].

Therefore, the use of mobile devices in healthcare settings has been rapidly growing and, consequently, the development of mobile applications for these devices, thus leading to the rapid integration of mobile devices in healthcare settings [24] [62] [65]. Furthermore, the adoption of mobile technology by health professionals can be explained by the need to have a better and easier communication and access to information at the point-of-care since a single device, which is portable, light, and small, can gather and give access to all the needed information anywhere and at any given moment [24] [27] [62] [65]. Moreover, regarding healthcare consumers, mobile technology is essential to remove the geographical barriers existing between them and healthcare organizations, allowing them to have access to care even in the comfort of their homes [63] [65].

The main benefits of mHealth are as follows [24] [27] [28] [63] [65]:

- Faster accessibility and better management of information since all data are gathered in a single source, which can be used anywhere and at the time of need, making access to information much more convenient. Therefore, mHealth leads to the improvement of the time it takes for health professionals to access and record information. Moreover, it reduces time-waste since health professionals can perform their tasks at the point-of-care and do not need to leave the patients and interrupt their workflow to go to another location;

- Help overcome some of the challenges introduced by the low number of computers available in healthcare environments. More than not, health professionals do not

have time to constantly go where the computers are located in order to check or record information. Therefore, these professionals cannot take full advantage of the Health Information Systems existing in their workplace. However, this situation can be solved through the use of mobile devices, which allow them to view, receive, and record information at the point-of-care;

- Faster and better decision-making process, since health professionals can have access to up-to-date information at the point-of-care where the decisions are being made, leading to more informed and based decisions. Therefore, this can promote a lower error rate, fewer adverse events, and better outcomes;
- Faster and improved communication since mHealth helps connect all the professionals distributed across the healthcare organization. This advantage is of particular interest since health professionals are highly dependent on their coworkers to perform their tasks, namely on their knowledge and expertise. Thus, a solution that helps health professionals to have direct and better communication with their coworkers could lead to faster and better healthcare delivery;
- Help healthcare organizations to strengthen their communication with healthcare consumers by providing information to them at any given moment through appointment reminders, test result notifications, diagnostics, and disease control, among others;
- Enhance the quality of healthcare delivery.

Figure 2 shows a generic representation of the concept of mHealth.

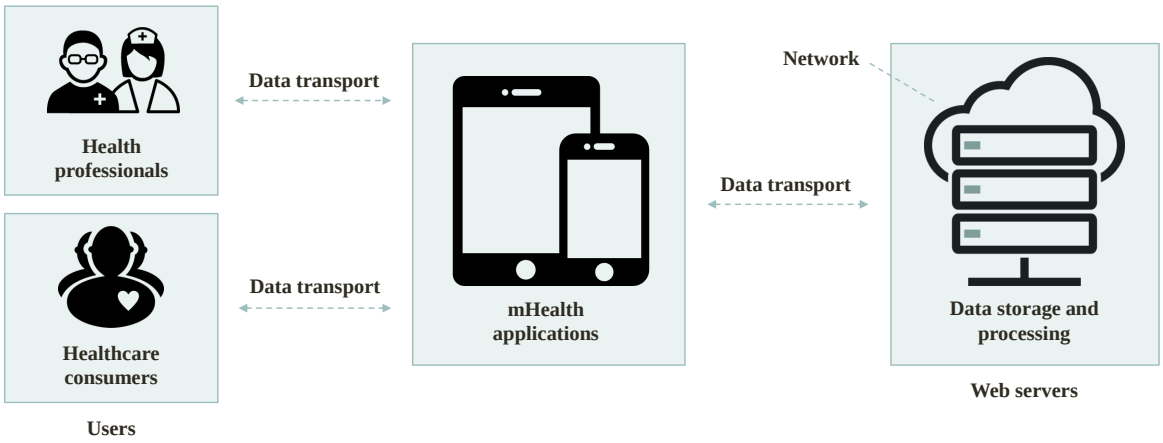

Figure 2.: Generic representation of the concept of Mobile Health. Adapted from [66].

However, despite the advantages provided by mHealth and the high number of mobile health applications currently available, a considerable amount of them are under-utilized or even abandoned [24] [27] [62] [64]. In some cases, mobile applications are developed

without truly understanding, assessing, and meeting the needs of their intended users, thus leading to applications of low quality and inaccurate and, therefore, to their underutilization [62] [64]. Therefore, a better evaluation of the needs of the users should be done before developing these applications.

On the other hand, some health professionals remain hesitant regarding the use of mobile technology in healthcare settings since mobile devices have small screens, which can difficult the entering and viewing of data [27]. However, it is important to note that the use of mobile applications in healthcare settings is not intended to replace or substitute desktop applications, which can be more powerful and less restrictive than mobile applications, but to complement them and, especially, to enhance outcomes at the point-of-care [24]. In fact, in situations where rapid information exchange is needed, where information should be entered at the point-of-care, and where health professionals are constantly on the move and have, therefore, less time to spend on computers, mobile technology is highly beneficial compared to desktop applications [27]. For instance, health professionals working in nursing homes could greatly benefit from mobile technology since they are constantly "on the go" and have little time to spend on computers, which are often located in nursing stations far away from the residents.

Nonetheless, the benefits of Mobile Health are undeniable and a higher investment should be done in this area since it can improve the quality of healthcare delivery and patients' quality of life.

2.4 Business Intelligence and Clinical Information

In simple terms, Business Intelligence corresponds to a set of methodologies, applications, processes, technologies, and analytical tools used to gather, store, manipulate, process, and analyze data in order to gain new knowledge and relevant information that can then be used by organizations to make informed and evidence-based decisions, thus improving the decision-making process [15] [67] [68] [69]. In the context of the healthcare industry, BI tools are greatly beneficial and essential since they enable the analysis of the clinical information that is constantly being generated in order to obtain new knowledge used as a basis and support in the decision-making process [67] [68] [69] [70].

Thus, BI emerged as a solution to make use of the huge amounts of data generated daily in organizations, offering analytical tools able to turn these data into meaningful, useful, and valuable information and knowledge to all the stakeholders distributed across the organization [69] [71] [72] [73]. Furthermore, regarding the healthcare industry, these tools allow to turn the medical practice more evidence-based and has as ultimate goal to enhance the quality of healthcare delivery by turning the decision-making process faster and more accurate.

In this context, some of the advantages provided by Business Intelligence tools in healthcare settings are as follows [67] [68] [74] [75]:

- Make use and understand the complex and huge amounts of clinical information gathered daily in order to gain knowledge and make faster, informed, evidence-based, and accurate decisions;
- Analyze and gain a deeper understanding of the overall performance of the healthcare organization and its stakeholders by comparing past and current data. Thus, by obtaining insight into the productivity of the organization, it is possible to plan and perform improvements if need be;
- Generate information that can highlight problem areas that should be targeted as well as opportunities and trends;
- Improve healthcare delivery and its outcomes by applying BI technology to EHR in order to gain valuable information and knowledge capable of offering real-time and evidence-based decisions;
- Reduce the occurrence of errors and adverse events;
- Give economic value to the huge amounts of clinical data generated daily;
- Reduce costs.

The architecture of the Business Intelligence process usually encompasses a variety of components that are closely related [68] [76] [77]. Thus, in Figure 3, a general architecture of the BI process is shown.

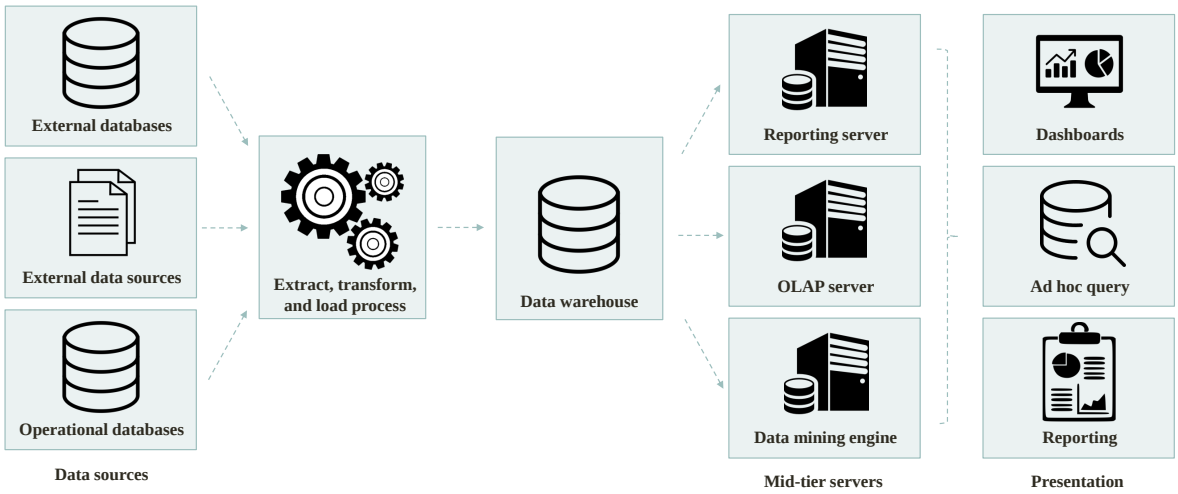

Figure 3.: General architecture of the Business Intelligence process. Adapted from [76].

Thus, based on the general architecture presented in Figure 3, the BI process starts with a set of data that usually come from different sources, such as external databases and operational databases, which are located in different areas and departments across the organization [76] [77]. Thereafter, the Extract, Transform, and Load (ETL) process has to be performed, comprising the following three steps [15] [76] [77] [78] [79] [80]:

1. **Extract:** the data are extracted from multiples sources and are integrated into the same area known as the Data Staging Area (DSA). The DSA corresponds to a temporary storage area between the data sources and the Data Warehouse (DW) in which data are stored in order to be processed, cleaned, and transformed;

2. **Transform:** in the DSA, the data go through various transformations. For instance, the more relevant columns are selected, errors are corrected, and the data are transformed into a unique form (e.g. through codes). Additionally, since the data are heterogeneous containing different syntax, formats, codes, representations, and terminologies, they have to be properly cleaned. Therefore, the main purpose of this step is to improve the quality of data before applying the BI tools by making it consistent, accurate, complete, and unambiguous since their performance and the results achieved depend greatly on the quality of data;

3. **Load:** finally, the transformed data located in the DSA are transported and loaded into a DW, which is a database separated from the other operational databases existing in the organization that aggregates data coming from different sources. However, before performing this step, the data warehousing process needs to be performed in order to build the appropriate DW.

Therefore, in order to have a clearer understanding of the ETL process, a general overview is given in Figure 4.

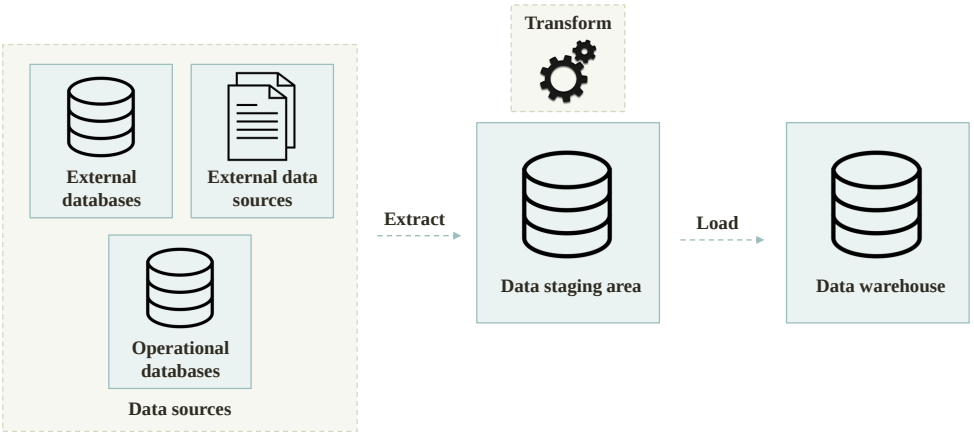

Figure 4.: General overview of the Extract, Transform, and Load process. Adapted from [78].

Finally, after performing the ETL process, the data loaded into the DW have to be analyzed and interpreted in order to obtain new knowledge that was previously unknown to the organization. Therefore, for this purpose, a variety of analytical tools and applications can be used, such as Data Mining (DM) tools or applications capable of providing charts, reports, spreadsheets, and dashboards, among others [76] [77].

It is important to note that before applying the BI tools, the DW can also be complemented by mid-tier servers, which provide different and specialized functionalities depending on the BI scenario intended [76]. On the other hand, since the data sources change over time, the ETL process must follow these changes, and the DW has to be designed in a way that allows its update over time [79].

In light of what has been mentioned throughout this section, it is clear that Business Intelligence is greatly beneficial to many industries, and the healthcare industry is not an exception. In fact, BI has been impacting several industries over time due to its ability to improve the decision-making process and to provide useful knowledge capable of improving diverse aspects and areas of an organization [72] [73] [81]. Thus, through BI, it is possible to give economic value and meaning to data that were previously considered a burden. Opportunities, trends, problematic areas, and issues previously unknown to an organization can also be highlighted through BI.

2.5 Ethical Issues in Medicine

Without any doubt, the use of Health Information and Communication Technology, more specifically of Health Information Systems and Mobile Health, and of Business Intelligence in the healthcare industry has been greatly beneficial and advantageous for healthcare organizations since these technologies have the potential to enhance the quality of the care delivered, among other advantages, as mentioned throughout this chapter. However, despite the many benefits and opportunities offered by these technologies, challenges and issues may arise from the implementation and use of solutions based on them. In this context, one of the main challenges associated with the introduction of any form of technological improvements in healthcare settings are ethical issues.

As mentioned previously, nowadays, healthcare organizations produce daily vast amounts of Electronic Health Records and other types of data related to both the patients and the organization. However, since these data are stored in HISs, patients are fearful that their confidentiality and privacy are compromised and not guaranteed, since, compared to the traditional paper-based management of data, technological advancements made access to data and the break of privacy easier [64] [82] [83]. Additionally, the EHRs of the patients can be consulted by various health professionals across the organization, which can be

problematic for patients who do not want their sensitive information shared and viewed by other professionals [82] [84].

Thus, in this sense, privacy issues and patient confidentiality should always be taken into account and safeguarded while developing technological solutions. In fact, if the privacy and confidentiality of the users are not protected and ensured, some of them may not want to use HICT solutions [84]. Furthermore, legal issues may arise if sensitive information of the users is disclosed without their consent and if their privacy is lost. Therefore, it is important to define data access policies in order to only give information access to authorized users [83] [84]. Moreover, if needed, the data can also be encrypted when stored and accessed by users who have the decryption keys [84]. Nonetheless, implementing security protections remains a difficult task to perform, but it should always be taken into account and viewed as a priority when developing HICT solutions [83].

On the other hand, regarding the introduction of mHealth solutions in healthcare settings, some health professionals still remain hesitant regarding their use despite the many advantages and benefits provided by them. One of the main causes of this situation is the fact that many mHealth applications are currently being used without having a complete understanding of their effectiveness, accuracy, quality, and associated risks, which can, in extreme cases, impair healthcare delivery [24] [64].

Therefore, during the design, development, and implementation of mHealth solutions, a set of best-practice standards should be thoughtfully followed in order to ensure their quality, accuracy, and safety [24] [64] [85]. Moreover, after their development, these applications should be subjected to a proper and rigorous set of validation and evaluation methods as a way to guarantee their quality, accuracy, correct use, safety, and importance in a healthcare setting [24] [64] [85].

2.6 Conclusion

Over the last few years, the healthcare industry has been facing several challenges: the expectations and the pressure to deliver medical care of high quality are constantly growing. In this sense, healthcare organizations have been urged to implement technological improvements in their facilities in order to improve healthcare delivery and their services' performance. Thus, over the years, Health Information and Communication Technology has been introduced into the medical practice so as to meet the demands faced by them.

As mentioned throughout this chapter, HICT as well as some of its specific forms, such as Health Information Systems, Clinical Decision Support Systems, and Mobile Health, have been positively impacting the healthcare industry all over the world due to their potential to improve outcomes, the decision-making process, and the quality, safety, and efficiency of healthcare delivery. Moreover, these technologies help reduce the occurrence of medical

errors, adverse events, time-waste, and healthcare costs. On the other hand, Business Intelligence tools have been proving to be an indispensable part of healthcare environments since they allow to make the medical practice more evidence-based and the decision-making process faster and more accurate.

However, despite the many benefits and advantages provided by HICT solutions, their successful use and implementation in healthcare contexts depend on diverse factors. For instance, privacy and confidentiality issues should be safeguarded and a set of best-practice and interoperable standards should be followed. On the other hand, these solutions should be reliable and have a high performance, meet the requirements and needs of users, and undergo continuous maintenance and evaluations.

That being said, Chapter 3 thoroughly approaches the research methodologies and development tools used throughout the development of this research project.

3

RESEARCH METHODOLOGIES AND DEVELOPMENT TOOLS

In this third chapter, the research methodologies and development tools used for the development of the solution described in this manuscript are meticulously described. Therefore, in order to approach all the necessary topics, this chapter is divided into five distinct sections.

At first, Section 3.1 introduces the present chapter. Then, Section 3.2 approaches the Design Science Research strategy, which is the main research strategy that was followed during the course of this project. Furthermore, Section 3.3 describes the database, framework, programming languages, and BI tool used to design and develop the solution described in this dissertation. In this sense, SQL, PHP, and JS programming languages, which were used to develop the database, the Web services, and the interfaces of the mobile application, respectively, are explored in this section as well as the MySQL database and the React Native framework. Additionally, in the same section, Power BI is also approached as it was the BI tool used to create examples of the clinical and performance indicators that could be created when enough data are gathered. On the other hand, Section 3.4 approaches the Proof of Concept methodology, in particular, the Technological Acceptance Model and Strengths, Weaknesses, Opportunities, and Threats analysis since they were used to evaluate the usefulness, potential, and feasibility of the developed solution. Finally, the chapter concludes with Section 3.5, which contains a brief conclusion that gives a general overview of the topics approached in this chapter.

3.1 INTRODUCTION

Unquestionably, before the development of any solution encompassed in the HICT area, thorough and meticulous research has to be executed to select the appropriate development tools, methodologies, and research strategies to be used for the development of the solution in question. Therefore, a careful analysis of the available tools, methodologies, and strategies has to be done taking into account their advantages and any kind of limitations that might exist.

In this context, after performing extensive research, the research strategy followed during the course of this dissertation was the Design Science Research strategy since it is considered suitable for ICT projects, which is the case of the present study, and it was considered the most effective to meet the established objectives and adequate according to the scope of the project. Furthermore, meticulous research was executed to select the most fitting development tools to develop all the components of the solution: the database, the Web services, and the interfaces of the mobile application. Therefore, the MySQL database, PHP, and the React Native framework were chosen to create the database, the Web services, and the interfaces of the mobile application, respectively. On the other hand, Power BI was used to create examples of the clinical and performance indicators that could be created when enough data are gathered in order to improve the decision-making process. Finally, a Proof of Concept, in particular, a Technological Acceptance Model and a Strengths, Weaknesses, Opportunities, and Threats analysis were performed to evaluate the usefulness, potential, and feasibility of the developed solution.

Therefore, in the following sections and subsections, the development tools, methodologies, and strategies mentioned above as well as the reasons behind their selection are thoroughly described.

3.2 DESIGN SCIENCE RESEARCH METHODOLOGY

The main purpose of the Design Science Research methodology is to create and evaluate objects known as artifacts, or more specifically, solutions, developed in order to solve and address organizational problems [86] [87] [88]. In other words, the Design Science Research methodology corresponds to a rigorous science research method that encompasses a set of techniques, principles, and procedures that must be followed in order to design and develop successful solutions capable of solving problems faced by an organization [87].

Therefore, the DSR methodology does not only intend to build an innovative solution capable of solving an organizational problem but also to evaluate the artifact in order to ascertain its utility and efficacy to face the problem in question [86] [87] [89]. Additionally, the success of the DSR methodology depends greatly on the rigor of the methods used to build and evaluate the artifact, and the research is not complete without communicating the results achieved to the appropriate audience [86] [87] [89]. It is also important to note that the development of the artifact involves a search process that enables to obtain knowledge essential for the successful development of the artifact [86] [87] [89].

In light of the points mentioned above, the DSR methodology can be divided into the following six distinct steps [87] [90]:

1. **Problem identification and motivation**: in this step, the research problems are identified to justify and motivate the development of the solution. Thus, it is intended to

carefully identify the importance of the solution according to the problems that need to be solved;

2. **Definition of the solution's objectives**: according to the research problems, this step intends to identify and present the objectives of the solution;

3. **Design and development of the solution**: in this step, the solution is designed, more specifically, its features and architecture are defined, and then developed in order to meet the established objectives;

4. **Demonstration**: the developed solution is demonstrated through experimentation and simulations in order to assess if the solution is capable of solving the research problems;

5. **Evaluation**: in this step, the solution is evaluated to compare the results achieved in the demonstration step with the objectives established in the second step. Thus, it is intended to evaluate if the developed solution is capable of supporting the research problems and if the objectives are met. It is important to note that according to the observations obtained in this step, researchers can return to the third step in order to perform improvements and changes;

6. **Communication**: finally, in the last step, it is intended to communicate the problem and the developed solution to an audience. The main purpose of this step is to disseminate the importance of the problem and the novelty of the solution.

In order to have a better understanding of the DSR methodology, a schematic representation is presented in Figure 5.

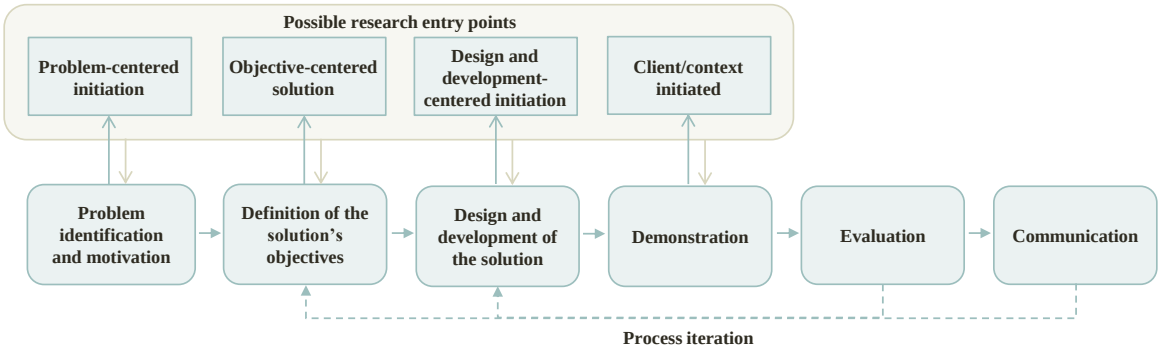

Figure 5.: Schematic representation of the steps composing the Design Science Research methodology. Adapted from [87].

It is important to note that although the DSR methodology has a sequential order, researchers can initiate the methodology at almost any given step according to the type of

approach used, moving forward from this step [87]. In fact, if the research is due to the observation of an organizational problem that needs to be solved (problem-centered initiation), then the methodology starts with the first step. On the contrary, if the research results from a need that can be addressed by the development of a solution (objective-centered solution), then the methodology starts with the second step. The methodology starts with the third step if it is intended to apply an already existing artifact to a new problem at hand (design and development-centered initiation). In other words, a solution that was created in response to another research or problem can be used as a start point and a solution for a new problem. Finally, the methodology can start with the fourth step if the research results from the observation of another solution (client/context initiated). In this case, the artifact built is a by-product of another research.

In order to have well-defined steps and an organized path to follow, the project described in this manuscript was sustained by a set of methods with the intention of ensuring its success. Therefore, the research methodology used is the DSR since it is suitable for ICT research projects, which is the case with the present dissertation. Additionally, this methodology was used since the solution developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home meets the needs of the health professionals working in the nursing home and is able to solve the problems faced by them. In fact, by introducing a HICT solution into the nursing home, more specifically, a mHealth solution that allow health professionals to have access, manipulate, and insert information and to schedule, perform, and record their tasks at the point-of-care, it is possible to substitute the paper-based management of information, support the decision-making process, reduce time-waste and the occurrence of errors and adverse events, and, consequently, lessen the work overload experienced by health professionals and improve the nursing care delivered.

Therefore, since the DSR methodology was used for the development of the research project described in this dissertation, the problems and challenges faced by the health professionals working in the nursing home had to be identified in order to motivate the development of the solution. Thus, focus groups, semi-structured interviews, and questionnaires were made with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital to gather valuable information capable of identifying and understanding the main challenges encountered by them. In this sense, in Appendix A, the questionnaire used to assess the needs and challenges encountered in the nursing home are presented. Additionally, observation of the case study was also performed since it allowed to have a better understanding of the conditions of the nursing home

Consequently, the objectives of the solution were defined according to the problems identified and, afterwards, the features and architecture of the solution were designed and developed. Once the solution was developed, it had to be demonstrated and evaluated through the execution of a Proof of Concept, which included a SWOT analysis and a Tech-

nological Acceptance Model, in order to assess its usefulness, feasibility, and potential and if improvements and changes needed to be done. In this sense, Chapter 5 approaches the SWOT analysis performed based on the results of the TAM applied. Moreover, Appendix B presents the questionnaire used to assess the acceptance of the mobile solution. Additionally, the present study also involved the communication of the problem and the solution to an audience, namely through the presentation of the solution to the health professionals and the writing of scientific papers, which are included in Appendix C.

3.3 Database, Framework, Programming Languages, and Business Intelligence Tool

In this section, the programming languages, database, framework, and BI tools used to develop the mobile application for the *Santa Casa da Misericórdia de Vila Verde* nursing home are described as well as the reasons behind their selection. In this context, the next subsections approach the following themes: React Native, which is a JavaScript framework used to create native mobile applications; MySQL and SQL, which were used to create the database and manipulate data; PHP, which was the programming language used to create the Web services; and Power BI, which was used to create examples of the clinical and performance indicators that could be created in the future to improve the decision-making process when enough data are gathered.

3.3.1 *MySQL Database and SQL*

In simple words, a database is an organized and structured repository of data designed to respond to the needs of an organization [91] [92]. On the other hand, a Database Management System (DBMS) is a software with which users interact in order to define, create, manipulate, manage, and access databases [91]. More specifically, a DBMS allows users to define, modify, and create a database and to insert, update, delete, and retrieve data from the database. In addition, a DBMS offers controlled access to the database, namely a security system that blocks unauthorized users when they try to access the database, an integrity system that allows to maintain the consistency of the data, a concurrency control system that allows shared access of data, a recovery control system that resets the database to its previous state in case of a failure, and a catalog accessed by the users to consult the descriptions of the data stored in the database [91].

Thus, in this context, MySQL is a Relational Database Management System (RDBMS) meaning that it is a DBMS that uses the relational model as its database model [70] [91] [92]. Databases based on the relational model usually have several tables, which consist of rows (records) and columns (attributes), in which data are stored. Moreover, these tables

are logically related, i.e. linked, to each other through relations existing between them [92] [93]. For instance, a relation exists between two tables if they have a column or several columns in common. Thus, this type of database model enables to combine data from several tables that can be accessed through a Data Manipulation Language (DML).

MySQL uses the Structured Query Language as its query language, i.e. as its DML, in order to access and manipulate the data stored in the databases [91]. Therefore, SQL is used to access and manage structured data stored in relational databases and enables to create queries capable of inserting, deleting, updating, and retrieving data [93]. On the other hand, SQL is also used to define, create, and modify database schemas and to create stored procedures and triggers [93]. A stored procedure is a piece of code written in SQL that can be invoked to perform a specific action. On the other hand, a trigger is a piece of code written in SQL that is automatically invoked when a certain event occurs, e.g. when a specific table is updated.

For the development of this research project, MySQL was chosen to define and create the database since it is a relational DBMS, open-source, and a fast, secure, reliable, and easy to use RDBMS [70] [92]. Additionally, the server in which the database had to be deployed and implemented, which belongs to the *Misericórdia de Vila Verde* hospital that manages the nursing home, was already configured for this type of database, thus making MySQL the most appropriate choice.

3.3.2 *PHP Web services*

In simple words, a Web service is defined as a software application that enables various systems to communicate and interact with each other over a network through messages conveyed by Internet protocols [94] [95] [96]. One of the most commonly used Internet protocol is Hypertext Transfer Protocol (HTTP), which is a request-response protocol that enables data transfer between Information Systems through the World Wide Web (WWW). Simply put, a client sends a HTTP request message to a server and, after receiving it, the server sends a HTTP response message back to the client with the data requested or with completion status information.

In this context, there are currently two types of Web services that are widely used: SOAP-based Web services and RESTful Web services [96]. SOAP-based Web services use Simple Object Access Protocol (SOAP), which is an XML-based messaging protocol, to access Web services and resort to existing transport protocols, such as HTTP, among many others, to convey the request and response messages [96] [97]. Thus, SOAP-based Web services use Extensible Markup Language (XML) to exchange data between ISs.

On the other hand, RESTful Web services are based on the Representational State Transfer (REST) architecture, which is a client-server based architecture, and depends on the

HTTP protocol to convey the messages [96] [98]. Thus, instead of being a protocol, the REST architecture offers a set of principles on how data should be transferred over a network. RESTful Web services are identified by Uniform Resource Identifiers (URIs), which enable the interaction and exchange of messages with the Web services over a network [96]. Moreover, by taking advantage of the specific features of HTTP, RESTful Web services are able to GET, PUT, DELETE, and POST data [96] [98].

In this sense, in order to allow the communication and interaction between the mobile application developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home and the MySQL database created, RESTful Web services were created using PHP (version 7.2.13). Thus, the Web services were created in order to enable the mobile application (client) to send requests to the database (via queries) and to send back to the application responses in the JavaScript Object Notation (JSON) format. The Web services created enable to select data from the database as well as update and insert data. Consequently, in order to allow the communication between the mobile application and the Web services, an Apache server was used, which is a HTTP server capable of receiving and sending HTTP messages.

The choice of RESTful Web services over SOAP-based Web services was due to the fact that the former are much more flexible since any kind of message format can be used, such as JSON and XML [99] [100]. However, SOAP messages rely exclusively on XML and must have a specific structure. On the other hand, RESTful Web services have higher performances for mobile devices since SOAP messages have a higher payload compared to the REST messaging framework, thus consuming less bandwidth [99] [100] [101]. In fact, a lot of resources are used to encode and decode XML-based SOAP messages [100]. Moreover, RESTful Web services are much simpler to develop than SOAP-based Web services and support stateless operations [99].

Regarding the use of PHP to develop the Web services, this choice was due to the fact that it is an open-source, fast, and easy to use language. On the other hand, the server in which the Web services had to be implemented was already configured for this programming language since other applications were developed for the *Misericórdia de Vila Verde* hospital using PHP. Thus, taking into account the reasons mentioned above and to avoid maintenance and integration issues in the future, PHP revealed to be the most appropriate choice.

Finally, it is important to note that during the development of the Web services some libraries had to be used, such as:

- **JWT**: enables to create access tokens, i.e. JSON Web Tokens (JWTs), that allow to securely transfer data between parties as a JSON object;

- **TCPDF**: allows to generate Portable Document Format (PDF) documents in PHP.

3.3.3 *React Native Framework and JavaScript*

The interfaces of the mobile application developed for the health professional working in the *Santa Casa da Misericórdia de Vila Verde* nursing home were created using React Native (version 0.55.4), which is a JavaScript framework developed by Facebook for building native mobile applications, i.e. applications built for specific mobile platforms [102] [103] [104].

React Native was released in 2015 and is based on React, which is a JavaScript library used to build User Interfaces (UIs) and targets the Web. However, React Native targets mobile platforms and enables developers to simultaneously develop and maintain one application that can be deployed to both iOS and Android [102] [103]. Thus, developers do not need to develop distinct applications in order to target these two platforms. It is important to note that although the mobile application built in the present dissertation was developed only for Android devices, choosing a cross-platform framework was still essential to allow its quick and easy development for iOS devices in the future.

React Native applications are written in JavaScript XML (JSX), which is a hybrid language between JavaScript and XML. However, since JavaScript is not the native language for both iOS and Android platforms, React Native needs to invoke the native rendering Application Programming Interfaces (APIs) in Java and Objective-C for Android and iOS, respectively, through a JavaScript bridge during the compilation process [102] [103] [104]. This bridge allows applications to be rendered with real mobile UI components and not webviews, which is one of the main advantages of React Native since webviews worsen the performance of mobile applications [102] [103] [104]. Thus, Figure 6 shows a visual representation of the architecture of React Native.

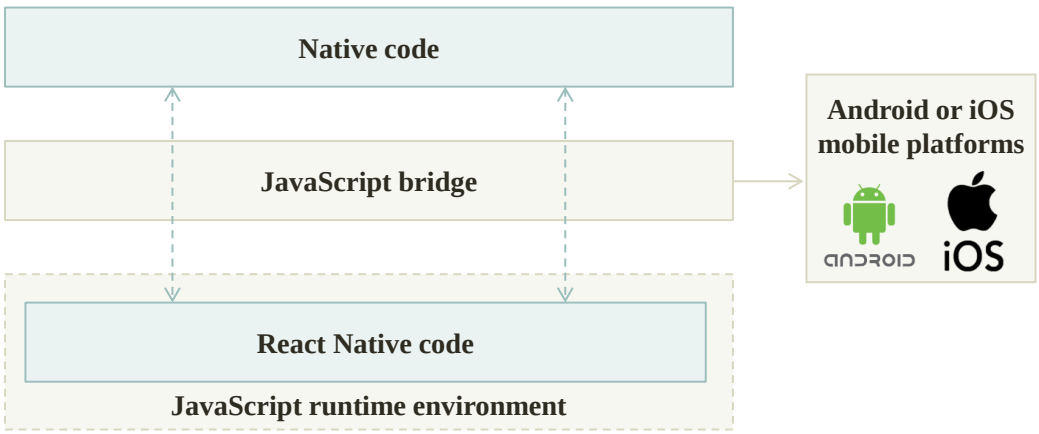

Figure 6.: React Native architecture. Adapted from [103].

Additionally, as mentioned previously, another advantage of React Native is the fact that it enables developers to use the same code to develop applications that can be used in

both iOS and Android platforms, i.e. to build cross-platform mobile applications. In the past, developing applications for mobile devices was quite time-consuming since developers needed knowledge in different programming languages and development environments depending on the mobile platform targeted (for instance, Java for Android and Objective-C or Swift for iOS) [103].

Mobile web applications, which are applications designed for mobile devices but accessed through web browsers, are a solution to this problem but, in terms of their performance, they tend to be worse than native applications, which are faster and more flexible [26] [103] [104]. Moreover, with mobile web applications developers still need to have knowledge in native code for more advanced features [103]. In fact, since mobile web applications are accessed through browsers and not through mobile platforms, they cannot use platform specific features. Thus, to do so, developers need to develop hybrid applications by integrating native code into their mobile web application, thus leading to a mobile application that runs on the device and not on web browsers but is built using web techniques able to call native APIs [26] [103] [104]. However, hybrid applications usually have a lower performance than native applications since they use webviews [103] [104].

Therefore, in recent years, React Native has been proving to have a lot of potential as a cross-platform framework enabling developers to build cross-platforms native applications while having a high performance. In fact, React Native is currently used in various well-known applications, such as Facebook, Instagram, Skype, and Uber.

On the other hand, React Native offers several other advantages, such as [105]:

- It is an open-source and free platform, making the development of mobile applications a lot easier since all documentation is available for free and it is community-driven;
- Existence of a huge variety of third-party plugins and libraries to help and facilitate mobile development;
- Existence of a hot reload feature allowing developers to see updates without recompiling their application and updating its state;
- Existence of a live reload feature allowing developers to instantly reload their application without recompiling it;
- Straightforward and easy to use since it has a modular and intuitive architecture;
- Has a great performance in mobile devices since it makes use of the Graphic Processing Unit (GPU).

Therefore, all of the reasons mentioned above made React Native the most indicated choice to develop the interfaces of the mobile application. Furthermore, at the time of

the development of this research project other applications were being developed for the *Misericórdia de Vila Verde* hospital using React and React Native. Thus, React Native revealed to be the obvious choice to avoid maintenance and integration issues in the future.

Finally, it is important to note that during the development of the interfaces of the mobile application, various cross-platform libraries had to be used, such as:

- **Redux:** used to manage the application's state in an efficient and consistent way;
- **React Native Navigation from Wix:** manages the navigation between the various screens existing in the mobile application;
- **Formik:** allows to create complex and organized forms by providing validation and error messages, handling form submission, and changing values in the state;
- **Yup:** used for object schema validation, i.e. to validate the values inserted into a form before its submission;
- **React Native Elements:** UI toolkit used to build React Native mobile applications;
- **React Native Vector Icons:** provides customizable icons for React Native;
- **Native Base:** UI component library used to build React Native mobile applications;
- **React Native Image Picker:** allows to use native UI in order to select media directly from the camera as well as from the device library;
- **RN Fetch Blob:** makes file access and data transfer much easier and efficient.

3.3.4 *Power BI as a Business Intelligence Tool*

One of the objectives of this study was to identify and define clinical and performance indicators to be implemented in the future when enough data are gathered in order to make the decision-making process more evidence-based and accurate. Thus, to this end, Power BI was used in order to create examples of the clinical and performance indicators defined.

In simple words, Power BI is a business analytics platform released in 2013 by Microsoft Corporation and provides Business Intelligence tools to the users able to collect, analyze, visualize, and share data [106]. Thus, by aggregating data from various data sources, such as Excel, MySQL databases, and CSV files, among others, Power BI is capable of creating charts, reports, and graphs to obtain visuals and a better insight on the data [106].

On the other hand, Power BI is available in a desktop application, which is only executable on Windows, and in a cloud service [106]. Whereas the desktop application is used

to model data and create reports, graphs, and charts, the cloud service is used to share and visualize them as well as create them. Therefore, when users need to perform data modelling, the desktop application is the best choice. However, to share dashboards, users need to use the cloud service.

Thus, in this dissertation, the Power BI desktop application was used in order to create visual examples of the clinical and performance indicators defined. The choice of using this BI platform was due to the fact that it is a free, easy to use, and intuitive tool that enables to quickly create charts and graphs without too much effort and to visualize them in a simple and explicit way.

3.4 Proof of Concept Methodology

Without a doubt, one of the most important steps during the design, development, and implementation of any solution encompassed in the HICT area is to verify its feasibility and potential to the target audience. On the other hand, it is also essential to ensure if the developed solution fulfills its purposes, more specifically, if the objectives and requirements established during the design of the solution, i.e. before its development, are successfully met so as to assess future improvements that could be performed. Thus, in this context, a Proof of Concept is often performed and aims to carry out a thorough evaluation of the solution in order to demonstrate and verify its usefulness and potential and if it was successfully developed according to the objectives initially proposed [107].

Therefore, a Proof of Concept enables to demonstrate in practice the concepts, methodology, and technologies encompassed in the development of a solution. Additionally, it allows to validate the developed solution towards the target audience and ensures that the solution provides all of the requirements initially proposed. On the other hand, besides being able to assess the usefulness, potential, and benefits of a solution, a Proof of Concept is also capable of identifying potential issues and threats associated with the solution.

Thus, the demonstration of the potential and feasibility of the mobile application developed for the health professionals of the *Santa Casa da Misericórdia de Vila Verde* nursing home was performed through the execution of a SWOT analysis to identify the strengths, weaknesses, opportunities, and threats of the developed solution. Thus, to this end, a Technological Acceptance Model was applied in order to access how the target audience accepts and receives the solution.

In this context, Chapter 5 thoroughly presents the SWOT analysis performed based on the results of the Technological Acceptance Model applied. Furthermore, in the next subsections, a general overview of the concepts of SWOT analysis and TAM is given.

3.4.1 *SWOT Analysis*

The SWOT analysis is a relatively simple strategy tool, which exists since the 1960s, widely used by industries, organizations, and companies to help them analyze and assess the strengths, weaknesses, opportunities, and threats faced by them or related to a specific project or solution [108] [109]. This strategy tool was developed based on the idea that the performance of a given business or solution with respect to their objectives depends on how the business or solution interact with both the internal and external environment [109].

Thus, with a SWOT analysis, it is intended to identify the internal and external factors that affect in a favourable and unfavourable way the objectives established for a given business or solution. Therefore, favourable factors are characterized by being helpful and able to contribute positively to achieve the established objectives. On the contrary, unfavourable factors are characterized by impacting negatively the achievement of the established objectives, being thus harmful and undesirable factors. In this context, internal and external factors can be distinguished in the following way [110] [111]:

- **Internal factors:** these are factors that can be controlled by an organization since they are obtained in its own environment. Strengths and weaknesses are favourable and unfavourable internal factors, respectively;
- **External factors:** these are factors that cannot be or at least not completely controlled by an organization since they are obtained in its competitive environment. Opportunities and threats are favourable and unfavourable external factors, respectively.

On the other hand, strengths, weaknesses, opportunities, and threats can be described in the following way [110] [112]:

- **Strengths:** correspond to favourable and positive factors of the internal environment that give additional value to the object of analysis when compared to other objects;
- **Weaknesses:** correspond to unfavourable and negative factors of the internal environment that are disadvantageous to the object of analysis when compared to other objects;
- **Opportunities:** correspond to favourable and positive factors of the external environment that yield advantages and benefits for the object of analysis;
- **Threats:** correspond to unfavourable and negative factors of the external environment that can trouble the object of analysis.

In light of the above mentioned, the SWOT analysis is often represented in the form of a 2x2 matrix similar to the one represented in Figure 7.

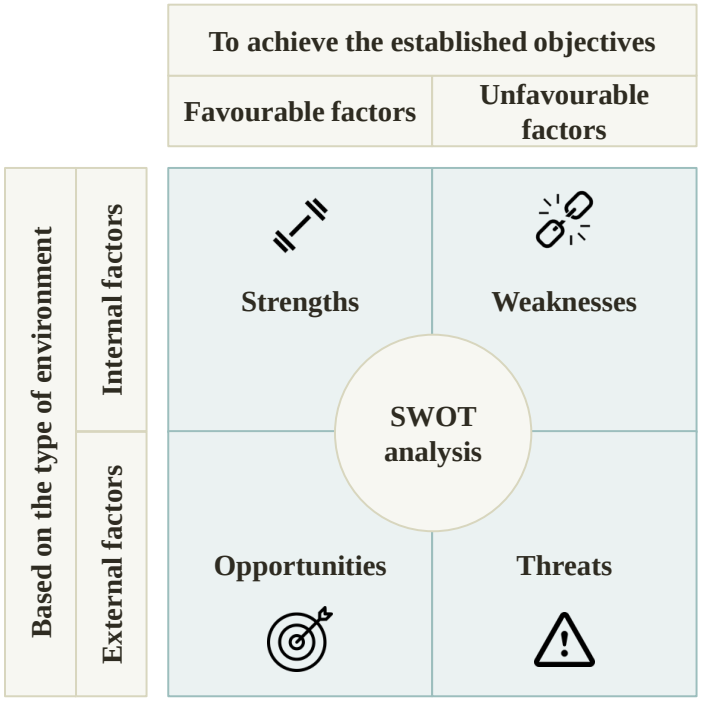

Figure 7.: Matrix of the Strengths, Weaknesses, Opportunities, and Threats analysis. Adapted from [111].

It is important to note that by identifying the favourable and unfavourable factors of a business or solution taking into account the internal and external environment, it is intended to obtain information that could help the decision-making process and to identify future improvements that could be performed [108] [111]. In fact, the true potential of the SWOT analysis is not to blindly list the strengths, weaknesses, opportunities, and threats of a given business or project, but rather to analyze the implications of the information obtained in order to improve the object of analysis [111]. Thus, it is intended to analyze how each strength could be used, how to stop the weaknesses, how to exploit the opportunities, and how to defend against all the threats.

3.4.2 *Technological Acceptance Model*

Over the years, several industries have been investing in Information Technology due to the pressure they are facing to reduce costs and improve the quality of their services, among other reasons [113]. In this sense, nowadays, IT is considered an essential and mandatory tool in various industries worldwide. However, despite the investments in the adoption of IT, the implementation of such technology in organizations has been getting mixed results [113]. More specifically, various projects are cancelled or are completed without meeting the requirements established and others are not completed on time or go over the budget

specified. Thus, for all of these reasons, over the years, researchers have been trying to identify the factors behind the successful integration and use of IT in organizations. In this context, the Technological Acceptance Model was proposed in the 1980s by Davis [114] and Davis et al. [115] and, since then, this model revealed to be quite effective to predict the acceptance and use of IT [113].

In simple words, the Technological Acceptance Model corresponds to a tool capable of predicting the acceptance of an IT solution by users in an organization as well as the likelihood of this technology being adopted by them [113] [116] [117]. Thus, it intends to identify the reasons why users may accept or reject IT. This model was proposed based on the Theory of Reasoned Action (TAV), which is a theory capable of predicting the attitude and behaviour of people in specific contexts, and considers that the acceptance and use of technology are affected by the internal beliefs, attitudes, and intentions of users and that their satisfaction towards IT results from the combination of the feelings and attitudes regarding a set of factors linked to the adoption of the technology [113] [116] [117].

Therefore, the attitudes and acceptance of users towards a IT solution influence and affect its successful implementation and use in an organization. In other words, if users are not acceptable of a certain IT solution and do not intend to use it, then it will not bring benefits and positive impacts to the organization [118]. Thus, analyzing the acceptance of users towards a new IT solution is quite essential since the more accepting they are, the more willing they are to make changes and spend their time and effort to use the solution [118]. Organizations can then use the factors that affect the opinion of users towards the acceptance of a new IT solution and manipulate these factors to promote its successful use.

The original TAM takes into account five distinct factors in order to predict the acceptance and use of technology, namely the perceived ease of use, the perceived usefulness, the attitude towards use, the behavioural intention to use, and the actual system use [113] [116] [118]. The perceived usefulness corresponds to the prospect a user has that a certain IT solution can improve his job performance [114] [115] [118]. On the other hand, the perceived ease of use is the degree to which a user believes that a certain IT solution is effortless [114] [115] [118]. Therefore, the perceived usefulness and the perceived ease of use of a certain IT solution are two of the most important factors that influence the attitude of users towards the acceptance and behavioural intention of using the solution, thus leading to its actual use [119].

Despite being quite an effective and reliable model to predict users' acceptance and use of IT, the TAM has been revised over the years suffering several modifications [113]. In this context, an extension of the TAM was proposed in 2000 by Venkatesh and Davis [120], known as the Extended Technology Acceptance Model (TAM2), and resulted from the identification of the determinants of the perceived usefulness. The TAM2 emerged from the need of having more detailed factors and variables capable of predicting users' acceptance

and use of IT [119] [121]. Thus, in this sense, the TAM2 was proposed considering that both social influence processes (subjective norm, voluntarism, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use) influence users' acceptance [119] [120]. However, this model does not include the attitude towards use since it was proved that it is not a good variable to predict the behavioural intention to use and the actual system use [116] [119]. Therefore, the evolution of the TAM to the TAM2 allowed to create a stronger model without changing its core ideology [116].

In this context, Figures 8 and 9 show a representation of the original TAM and TAM2, respectively.

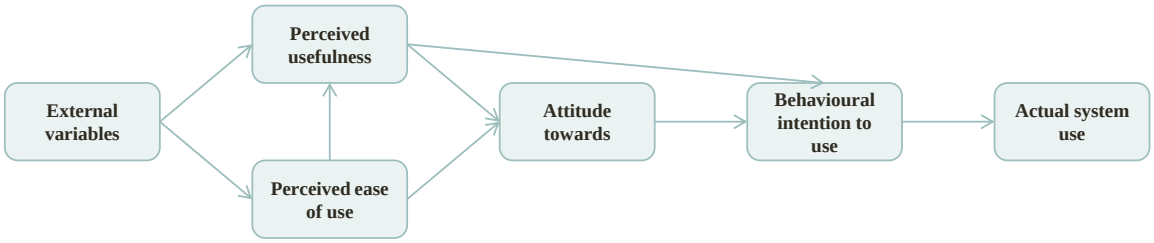

Figure 8.: Original Technological Acceptance Model. Adapted from [115].

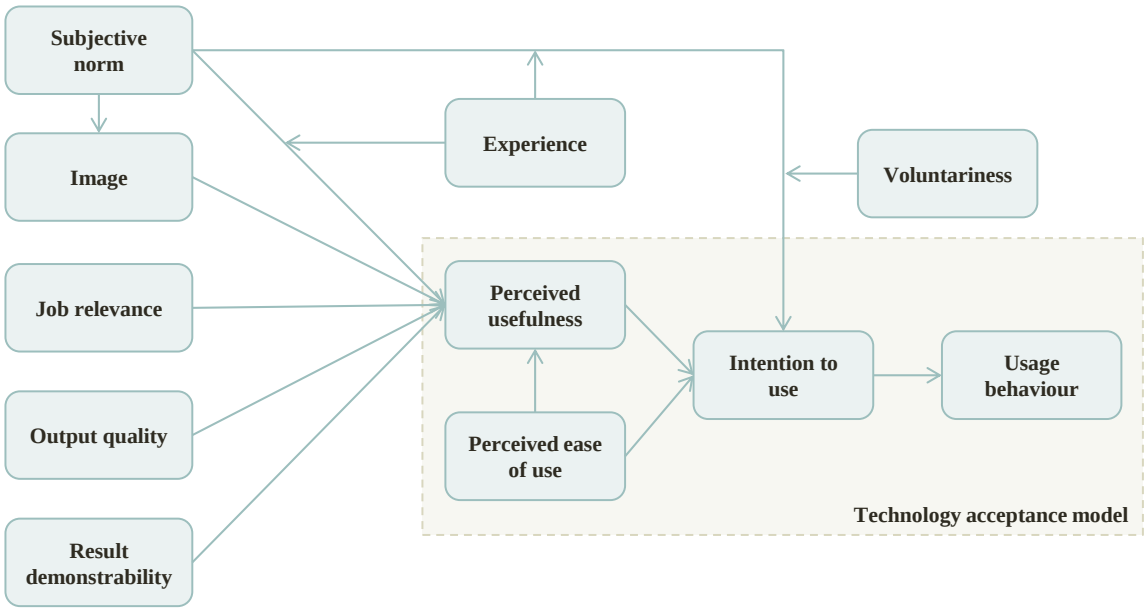

Figure 9.: Original Extended Technology Acceptance Model. Adapted from [120].

Finally, more recently, in 2008, Venkatesh and Bala [122] proposed a new extension of the TAM, known as the Technology Acceptance Model 3 (TAM3). This model was obtained

by combining the TAM2 with the model of the determinants of the perceived ease of use proposed by Venkatesh [123]. The determinants of the perceived ease of use (namely, computer self-efficacy, perception of the external control, computer anxiety, computer playfulness, perceived enjoyment, and objective usability) were obtained since Venkatesh believed that users form prior perceptions of the perceived ease of use of a IT solution based on their general opinions regarding computer use [122] [123]. Thus, according to this perspective, the TAM3 emerged being a more complete model of the determinants of users' acceptance and use of IT, since it combined the determinants that affect both the perceived usefulness and the perceived ease of use [122].

In order to have a better understanding of the TAM3, Figure 10 shows its representation and a summary of the constructs included in the model is presented in Table 1 [122] [123].

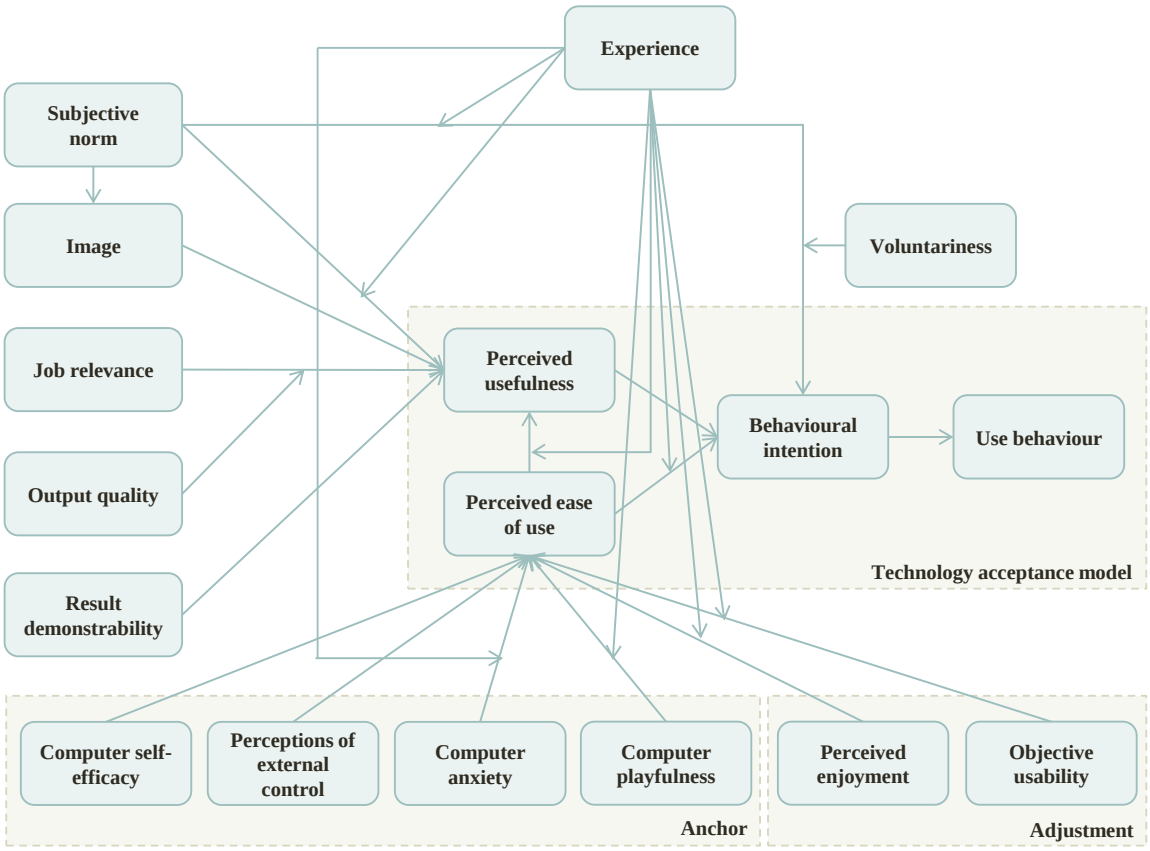

Figure 10.: Original Technology Acceptance Model 3. Adapted from [122].

Table 1.: Summary of the constructs of the Technology Acceptance Model 3

Construct	Definition
Perceived ease of use	The degree to which a user assumes that a certain IT solution is effortless.

Construct	Definition
Subjective norm	The extent to which a user considers that the majority of the people close and important to him think he should or should not use a certain IT solution.
Image	The extent to which a user considers that the use of a certain IT solution will improve his social status.
Job relevance	The degree to which a user believes that a certain IT solution is appropriate and relevant to his job.
Output quality	The degree to which a user feels that a certain IT solution is capable of performing his job well.
Result demonstrability	The extent to which a user feels that the results of a certain IT solution are demonstrable and observable.
Computer self-efficacy	The degree to which a user feels that he can use a computer to execute a specific task related to his job.
Perceptions of external control	The degree to which a user believes that organizational and technical resources are available to assist the use of a certain IT solution.
Computer anxiety	The degree of fear and apprehension of a user when the possibility of using a computer is presented.
Computer playfulness	The tendency that a user has to interact spontaneously with a computer.
Perceived enjoyment	The degree to which a user enjoys using a specific IT solution, excluding performance consequences that may result from the use of the solution.

Construct	Definition
Objective usability	Enables to compare different IT solutions based on the level of effort needed to execute specific tasks.
Experience	Previous experience and contact with a certain IT solution that a user may have had.
Voluntariness	The extent to which a user considers that the use of a certain IT solution is a choice resulting of his own free will.
Perceived usefulness	The prospect a user has that a certain IT solution can improve his job performance.
Behavioural intention	The degree to which a user has the intention and plans to perform a certain behaviour or action.
Use behaviour	The degree to which a user will consistently use and interact with a certain IT solution.

In light of the above mentioned, the TAM3 was used to assess the acceptance of the health professionals working in the *Santa Casa da Misericórdia de Vila Verde* nursing home regarding the use of the mobile application developed for this research project.

3.5 CONCLUSION

Throughout this chapter, the research methodologies and development tools used for this study were meticulously described. In this sense, the Design Science Research methodology was presented since it was the methodology followed throughout the present dissertation as it is suitable for ICT projects and to create and evaluate solutions developed to address organizational problems.

Additionally, MySQL was chosen to define and create the database, PHP was used to develop the RESTful Web services, and React Native was selected to develop the interfaces of the mobile application. Finally, the Proof of Concept methodology was also approached, more specifically, the SWOT analysis and the TAM since they were used to assess the strengths, weaknesses, opportunities, and threats of the application and the acceptance of the health professionals regarding its use, respectively.

Therefore, in the next chapter (Chapter 4), all of the phases executed to develop the mHealth application for the health professionals of the *Santa Casa da Misericórdia de Vila*

Verde nursing home are thoroughly presented. More specifically, the case study used is described so as to identify the challenges encountered by the health professionals and the nursing home and, thus, motivate this study. Moreover, the objectives of the developed solution are presented as well as the results achieved in the design and development processes.

4

A MOBILE APPLICATION TO ASSIST HEALTH PROFESSIONALS IN A PORTUGUESE NURSING HOME

As mentioned previously, the Design Science Research methodology was followed to conduct this research project. In this sense, this chapter thoroughly approaches and describes all of the steps executed to develop the Mobile Health application for the health professionals of the *Santa Casa da Misericórdia de Vila Verde* nursing home. Thus, taking into account the steps that were executed, this chapter is divided into six distinct sections.

At first, Section 4.1 introduces the present chapter. Then, in Section 4.2, the project described in this dissertation is contextualized and motivated through a brief identification of the needs and challenges encountered by the health professionals working in the nursing home and, in Section 4.3, the main objectives of the project are identified. Afterwards, in Section 4.4, the results achieved are thoroughly presented and described. In this context, the MySQL database and Web services created are discussed. Moreover, the architecture and the features of the mobile application are also approached in this section. Additionally, in Section 4.5, the clinical and performance indicators that could be created in the future to enhance the decision-making process are defined. Finally, this chapter concludes with a brief discussion of the results achieved as well as with a conclusion in order to have a general overview of the content approached throughout this chapter.

4.1 INTRODUCTION

Over the last few years, the world has been witnessing a huge demographic change: the aging population is growing at an alarming rate [1]. Moreover, this problem has been a matter of concern for many countries since it is posing several challenges in healthcare systems worldwide, namely the increase of the costs of the elderly care and of the number of elders in nursing homes [1] [2] [3].

Portugal is not an exception to this situation. In fact, Portugal is currently experiencing several challenges due to the growth in the proportion of older individuals. In this context, one of the major challenges faced by the country is the increasing number of elders in nurs-

ing homes and, consequently, the high demand and the quick rate at which the vacancies of these establishments are filling up [6] [7].

Additionally, although nursing homes are, for the most part, full and overloaded, there is currently a lack of investment in these facilities. In this sense, the number of elderly people is often too high compared to the number of health professionals, whereby the latter are often overloaded with work, which can lead to the decrease of the quality of the nursing care delivered [8] [9]. On the other hand, nursing homes often use rudimentary methods, such as paper, to manipulate information and clinically manage their residents, which is time-consuming and prone to errors [10] [11].

In light of the above mentioned, there is currently a need to improve the nursing care delivered and, consequently, fill the lack of resources and access to technology in nursing homes so as to overcome some of the challenges encountered by these facilities. Thus, in this context, this study emerged and consisted in designing and developing a mobile application for the health professionals working in a Portuguese nursing home, more specifically in one of the nursing homes of the *Santa Casa da Misericórdia de Vila Verde*, which is managed by the *Misericórdia de Vila Verde* hospital, to help them manage the residents and to assist them at the point-of-care, namely to schedule, perform, and record their job-related tasks and to have access, document, consult, and manipulate information.

Therefore, the project described in this document aimed to introduce technological improvements in the nursing home in order to assist health professionals, namely at the point-of-care, and to relieve some of the work overload experienced by them, reduce time-waste and errors, and assist them in the decision-making process.

In the next sections, this research project is motivated and contextualized and its objectives are presented. Furthermore, the design and development of the mobile application are thoroughly described.

4.2 problem identification and motivation

As referred in previous sections, a vast majority of the nursing homes still use handwritten charts and medical records to clinically manage their residents and to record and document information. Naturally, the use of these rudimentary and unsophisticated methods is a tremendous problem for these facilities since they are time-consuming. Moreover, with these methods, health professionals are more prone to misplace or lose information and to commit errors when compared with the computer-based management of data.

Additionally, since all the information is gathered in papers, health professionals spend a lot of time travelling to and from nursing stations to retrieve and record information, resulting in a higher risk of forgetting or writing information in the wrong place. On the other hand, health professionals working in nursing homes are, more than not, overloaded

with work due to the high number of elders in these facilities, leading to the decrease of the nursing care delivered.

With all of the above mentioned, there is currently an urgent need to face the challenges faced by nursing homes and improve elders' quality of life and the care delivered. Therefore, the project conducted in this manuscript emerged and resulted as a way to solve and overcome some of the problems mentioned above.

As already stated, this study consisted in designing and developing a mobile application for health professionals working in a Portuguese nursing home in order to assist them at the point-of-care, e.g. to schedule, perform, and record tasks and to have access, record, consult, and manipulate information, and to help them clinically manage the residents. In this sense, one of the nursing homes of the *Santa Casa da Misericórdia de Vila Verde* was used as a case study. It is important to mention that the *Santa Casa da Misericórdia de Vila Verde* is composed of several nursing homes, which are all managed by the *Misericórdia de Vila Verde* hospital. However, in the present dissertation, only the nursing home located more closely to the hospital was used as a case study.

Thus, in order to have a better understanding of the relevance and motivation of this project, it is essential to identify the main issues and challenges faced by the health professionals and the nursing home for which this study was developed. Therefore, focus groups, semi-structured interviews, and questionnaires were performed with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital to obtain valuable information that could enlighten the main challenges faced by the nursing home. In Appendix A, the questionnaire distributed to the professionals working for both the nursing home and the hospital in order to assess the needs and challenges encountered in the nursing home is presented. On the other hand, the case study was also subjected to observation so as to have a better understanding of the conditions of the nursing home.

In this context, the following set of challenges and issues were identified:

- Health Information and Communication Technology or any other form of technological progress are not used in the nursing home. Although there is one computer in the nursing station, it is not used to record clinical information of the residents or even to schedule tasks. In addition to this fact, since there are not Electronic Health Records or any other form of digital information, health professionals have to use handwritten charts and medical records. Therefore, all the information is stored in papers, which makes the management of information a lot more time-consuming, especially at the point-the-care, as the professionals have to consistently go back to the nursing station in order to have access to information. This situation can also lead to a higher risk of losing, misplacing, forgetting, and documenting information in the wrong place;

- The job-related tasks of the health professionals are scheduled and documented in handwritten charts or boards. This situation is particularly problematic since it is more prone to errors, confusing, and less organized;
- The nursing home does not have access to a wireless internet connection. The health professionals can only have access to an internet connection in the nursing station where the computer is located. This situation is especially challenging since it complicates the implementation of any kind of mHealth solution;
- The number of health professionals compared to the high number of elderly people is low. Consequently, at times, the health professionals are overloaded with work. Thus, this situation combined with the paper-based management of data can lead to more errors and decrease the nursing care delivered and its quality;
- Failed attempt to implement a Web application. The Web application aimed to shift from the paper-based to the computer-based management of data, allowing the health professionals to schedule tasks, document them, and record clinical information. However, the application was abandoned as it was time-consuming and not user-friendly: the health professionals constantly had to go back to the nursing station, where the computer is located, to use the application, and the application was too confusing and required a lot of time to schedule tasks and document information.

In addition to the above mentioned, the present project was also motivated by the fact that the health professionals manifested their wish to have a mobile application that would allow them to be anywhere in the nursing home and still have access to information and schedule and document their daily tasks. Therefore, there was a need to design and develop a solution, more specifically, a mobile application, that could assist the health professionals at the point-of-care by allowing them to have access, document, consult, and manipulate information anywhere in the nursing home and, subsequently, enhance the care delivered and elders' quality of life, reduce the occurrence of errors and time-waste, and ease some of the workload experienced by them.

4.3 definition of the solution's objectives

As mentioned throughout this document, the main purpose of this research project was to design and develop a mobile application for the health professionals, more specifically, for the doctors and nurses working in one of the *Santa Casa da Misericórdia de Vila Verde* nursing homes in order to assist them at the point-of-care, namely to schedule, perform, and record tasks and to have access, manipulate, consult, and record information.

Thus, with this application, it was intended to shift from the paper-based to the computer-based management of data and to introduce technological improvements into the nursing

home, namely HICT. Consequently, by taking advantage of the benefits provided by HICT, it was envisioned to reduce the occurrence of errors and time-waste, enhance the decision-making process, reduce some of the work overload experienced by the health professionals, and, ultimately, improve the nursing care delivered and elders' quality of life.

Thus, after motivating and contextualizing this research project, the following objectives were established for the realization of the proposed solution:

- Realization of focus groups, semi-structured interviews, and questionnaires with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital in order to obtain useful information for the design and development of the mobile application, namely about the relevant data that should be stored into the database, the tasks and services performed by the health professionals that would benefit from emerging technologies, the features that should be integrated into the mobile application, and the clinical and performance indicators that could be created;
- Realization of focus groups, semi-structured interviews, meetings, and questionnaires with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital to identify the technical requirements that should be considered while designing and developing the mobile application, namely the ethical issues inherent from the development of such solution;
- Selection of the most appropriate development tools for the development of the database, the Web services, and the interfaces of the mobile application;
- Design of the mobile application, namely of the database, the Web services, and the interfaces of the mobile application;
- Development of the mobile application, namely of the database, the Web services, and the interfaces of the mobile application, ensuring that it is user-friendly and intuitive;
- Deployment and implementation of the database and the Web services in the server of the *Misericórdia de Vila Verde* hospital;
- Demonstration of the developed solution to the target audience to ensure that the objectives were archived and to identify future improvements.

4.4 Design and Development

First, it is important to refer that, at this point in time, the mobile application is fully developed, and the Web services and the database are deployed in the server of the *Misericórdia de Vila Verde* hospital. However, despite the previous mentioned, the solution is still being

evaluated and tested by the health professionals. Moreover, the mobile application is not being used since the necessary needs, such as mobile devices and a reliable wireless internet connection, have not yet been provided to the nursing home. Nevertheless, until the required needs are available to the nursing home, it is envisioned to continue improving the solution through the continuous opinions and knowledge provided by the professionals.

Regarding its realization, the mobile application was designed and developed using the development tools and programming languages presented in Chapter 3. Briefly, the interfaces of the mobile application were developed using React Native, which is a JavaScript framework that enables to build native mobile applications. It is important to state that, although React Native allows to use the same code to deploy to both iOS and Android devices, the mobile application was only deployed for Android since these type of devices are more affordable and common and are, therefore, more likely to be provided by the nursing home when the application will be used in the future. However, if needed and after small modifications, the application can be quickly and easily deployed to iOS devices. On the other hand, the MySQL relational DBMS was also used to define and create the database. In this sense, SQL was the language used to manipulate and access the data stored in the database. Furthermore, in order to enable the communication and transfer of data between the mobile application and the database, RESTful Web services were created using PHP.

Therefore, the proposed solution is divided into three distinct elements, having each one of them different purposes and structures. In this sense, each one of these elements is thoroughly described and presented in the following subsections.

4.4.1 *MySQL Database and PHP Web services*

As mentioned previously, the *Santa Casa da Misericórdia de Vila Verde* nursing home used as a case study uses handwritten medical records and resorts to unsophisticated methods, such as paper, to store information. In this sense, the nursing home did not have any database implemented prior to the development of this project. Therefore, before designing the interfaces of the mHealth application, a database had to be defined in order to allow the application to have access and store data.

Thus, for this purpose, a MySQL relational database was defined and created taking into account the data that needed to be stored. Then, the database was deployed and implemented in the server of the *Misericórdia de Vila Verde* hospital. However, it must be mentioned that the database still remains to be populated with real data, namely information related to the residents and health professionals.

The database created was designed to allow the storage of:

- Data related to the users of the mobile application, namely the nurses and doctors working for the nursing home. Thus, personal information of the health professionals

(namely, their full name, email, profile picture, telephone and mobile phone numbers, date of birth, institution identification number, and gender, among others) is stored as well as their login credentials;

- Personal data related to the residents (namely, their full name, institution process number, bed and bedroom numbers, admission date, date of birth, profile picture, telephone and mobile phone numbers, and national health service number, among others);

- Personal data related to the informal caregivers and personal contacts of the residents (namely, their full name, telephone and mobile phone numbers, relationship with the resident, and observations, among others);

- Clinical notes written by the doctors. In this context, the content of the note, the institution identification number of the professional who wrote the note, the resident's institution process number, and the date and time of the creation of the note are stored;

- Nursing notes written by the nurses. In a similar way to the clinical notes of the doctors, the content of the note, the institution identification number of the professional who created the note, the resident's institution process number, and the date and time of the creation of the note are stored;

- Clinical information related to the residents, namely their general evaluation (e.g. alcohol and tobacco consumption), usual medication, clinical history (e.g. existence of diabetes, diseases, allergies, and past surgeries and fractures), physical assessment (e.g. weight, height, blood pressure, heart rate, skin integrity, turgidity, and colour, vision, and hearing), nutritional and eating patterns (e.g. type of diet, dentition, and use of a nasogastric tube), bowel and bladder elimination patterns (e.g. use of adult diapers or of a urinary catheter), physical activity patterns (e.g. strength of the limbs), sleeping patterns (e.g. insomnia problems and number of hours of sleep during the day and night), and general assessment made by the health professionals (e.g. emotional state or autonomy level);

- Data related to the wounds of the residents, namely the type of wound, pictures of the wound, and its location, treatments, and start and finish dates. The evolution of the wounds is also documented through photos and observations provided by the health professionals. Additionally, the various treatments used throughout the evolution of the wound are stored;

- Periodic evaluations recorded by the health professionals (namely, blood pressure, weight, heart rate, and axillary temperature). In this context, the date and time of the

evaluation, the institution identification number of the professional who made the evaluation, and the resident's institution process number are stored;

- Periodic evaluations of the capillary blood glucose of residents with diabetes. Again, the date and time of the evaluation, the institution identification number of the professional who made the evaluation, and the resident's institution process number are stored;
- The history of the medical and inpatient reports of the residents. In this case, the date, the type, and a brief description of the report are stored, among other information;
- The nursing interventions scheduled by the health professionals through the identification of the type of nursing intervention, the scheduled and realization dates of the intervention, the resident's institution process number, the institution identification numbers of the professionals who scheduled and performed the nursing intervention, and the state of the intervention, i.e. if the intervention was performed or not;
- Data related to the nursing home, namely the name of the institution and the bedroom and bed numbers existing in the nursing home;
- Technical data, namely the types and sizes of urinary catheters and nasogastric tubes available and types of wounds, injectable medications, nursing interventions, wounds location, and medical and inpatient reports, among others.

Thus, in order to store the information mentioned above, a relational MySQL database composed by forty-nine tables was designed and created. Afterwards, RESTful Web services written in PHP with SQL queries were developed in order to allow the sharing of data between the frontend (the mobile application) and the backend (the database). In this sense, numerous Web services were created in order to allow users to manipulate data from the database, namely to insert, update, and select data. Finally, similarly to the database, the Web services were deployed in the server of the *Misericórdia de Vila Verde* hospital.

4.4.2 *React Native Mobile Application*

First and foremost, it is important to note that all data contained in the figures shown in this subsection are fictitious and any similarity with actual persons is purely coincidental.

After designing and developing the database and the Web services, the interfaces and the features of the mobile application had to be designed and developed. For this purpose, React Native was chosen as stated previously. Considering the above mentioned, Figure 11 is presented in order to have a better understanding of the architecture and different interactions existing between the various elements of the mobile application.

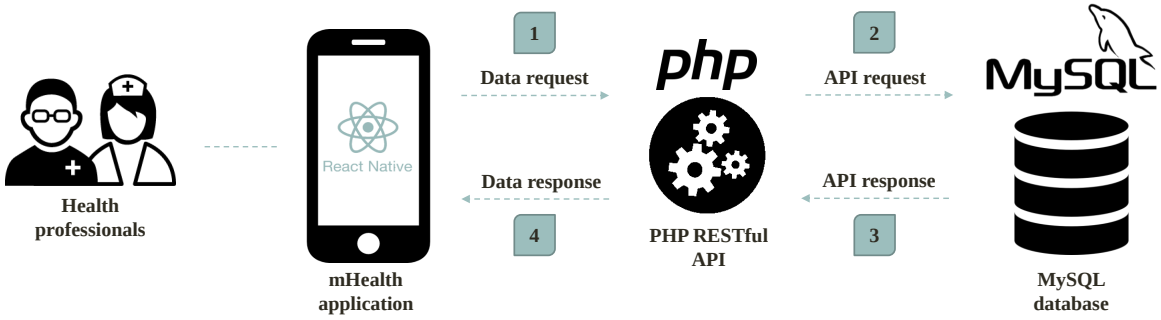

Figure 11.: Schematic representation of the architecture of the mobile application.

At first, when the user, i.e. the health professional, launches the mobile application, he needs to sign up for an account if he does not have one. In this context, the user is asked to provide his login credentials, i.e. his password and institution identification number, and his personal data, i.e. his full name and gender. Additionally, the user is requested to specify if he is a nurse or a doctor since these two types of health professionals have access to different features once signed in into the application. Finally, the user is also asked to specify in which *Santa Casa da Misericórdia de Vila Verde* nursing homes he works. This information is asked since, in the future, it is envisioned to extend the mobile application to the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes and, naturally, only the residents living in the nursing homes in which a user works should be featured in the mobile application.

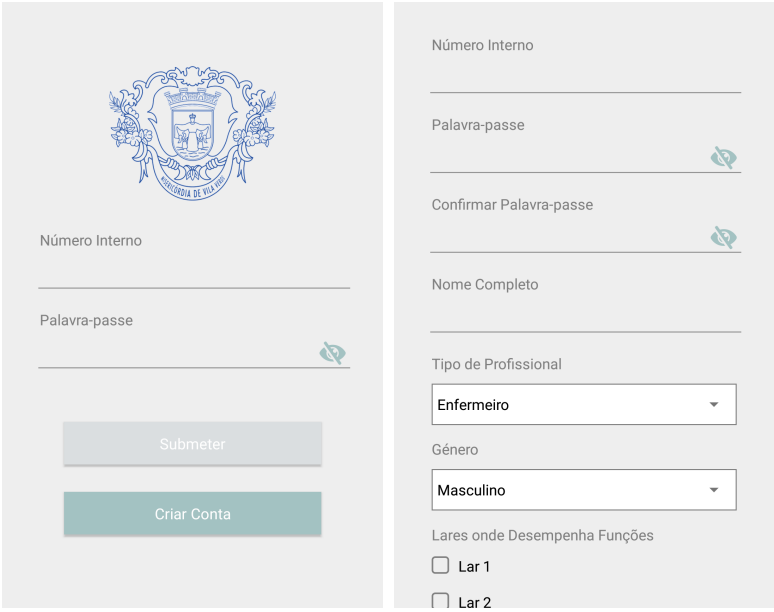

Figure 12.: Sign in (left) and sign up (right) screens of the mobile application.

Then, once the user has provided his login credentials and his personal data, the data are stored into the database. Alternatively, if the user already has an account, he can directly sign in into the mobile application with his login credentials, i.e. his institution identification number and password. Finally, if his login credentials match with the ones stored in the database, the user is successfully signed in into the application, having access to several features. Thus, in the following sections, the various features implemented in the mobile application are presented and described in detail. Figure 12 presented above shows the sign in and sign up screens of the mobile application.

Homepage and Bottom Navigation

The homepage corresponds to the first screen accessed by the user right after he has successfully signed in into the mobile application. Then, in the homepage, the user has access to a bottom navigation from which he can navigate to different screens through bottom tabs. According to the type of health professional, the homepage varies as well as the bottom tabs available to the user.

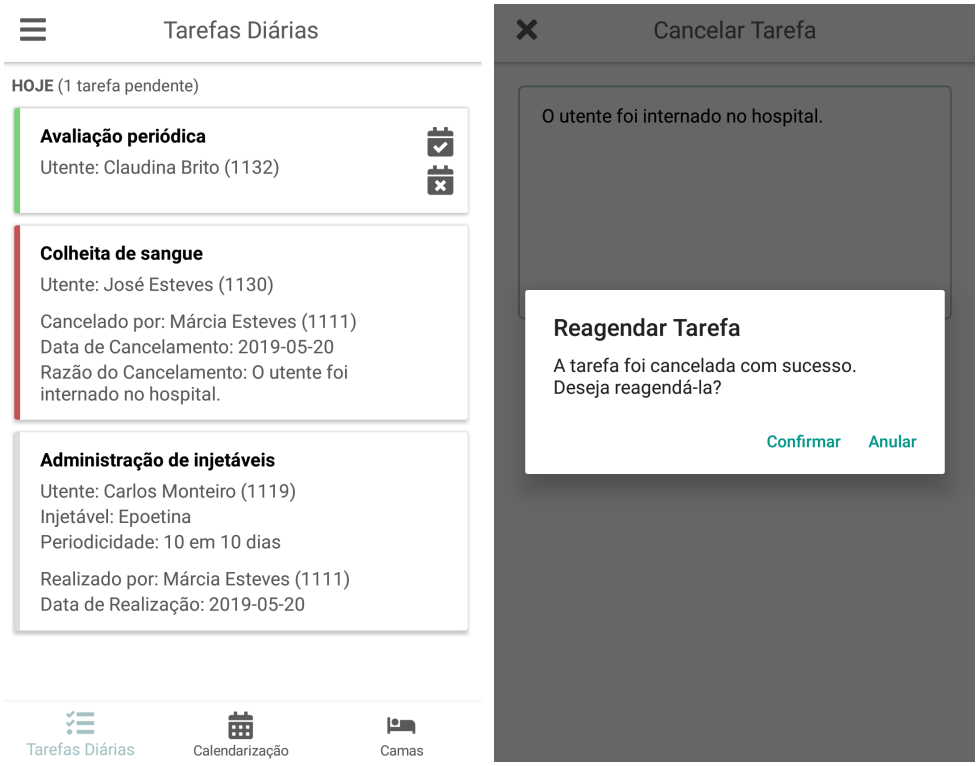

Figure 13.: Screens of the *Tarefas Diárias* bottom tab and when the user is asked to reschedule a nursing intervention after cancelling it - figure obtained when signed in as a nurse.

Thus, if the user is a nurse, he is directed to the *Tarefas Diárias* tab. In this tab, the user can consult the nursing interventions/tasks that are planned for the day. The user is also able to confirm the execution of a nursing intervention or cancel a task. However, for the

latter case, the user has to specify the motive of the cancellation and, afterwards, if he wishes to do so, the user is able to reschedule the nursing intervention, being redirected to the *Planeamento de Intervenções de Enfermagem* module. Furthermore, besides consulting the tasks that are planned for the day, the user is also able to consult the tasks that were executed and cancelled. Figure 13 presented above shows the screen of the *Tarefas Diárias* bottom tab in which the user is able to consult the pending tasks (green), the cancelled tasks (red), and the finished tasks (grey). Additionally, in this figure, the screen presented to the user when he is asked to reschedule a nursing intervention after cancelling it is shown.

Additionally, besides the *Tarefas Diárias* tab, the user can also navigate to other screens through the following bottom tabs:

- ***Calendarização***: This tab is similar to *Tarefas Diárias*. However, the user is able to consult the pending tasks, the cancelled tasks, and the finished tasks scheduled in the future, i.e. after the current date. Additionally, he can also cancel or confirm the execution of a task. If the user cancels a task, he is able to reschedule it if he wishes to do so;

- ***Camas***: In this tab, the user has access to the list of *Santa Casa da Misericórdia de Vila Verde* nursing homes in which he works. Then, by clicking on one of the nursing homes, the list of the bedrooms existing in the nursing home is provided to him. Finally, by choosing one of the bedrooms, the user has access to the following information: the number of beds available and the name of the residents living in the bedroom. For each resident, the bed number is specified as well as the number of pending tasks associated with the resident for the day.

It is important to mention that when a nursing intervention is scheduled any nurse can cancel or execute it. This decision was made since, usually, the nursing interventions are planned in advance on a certain day of the week by the nurse present that day. Moreover, the shifts between the nurses rotate quite frequently. Thus, when a nursing intervention is planned, it is not associated with any health professional in particular and can be performed by any nurse available in the nursing home.

On the contrary, if the user is a doctor, he is directed to the screen of the *Camas* bottom tab once he signs in into the application. However, this type of user has only access to this bottom tab since the scheduled nursing interventions, which can only be performed by nurses, are not relevant to doctors. Therefore, this information is not presented to them, whereby it was decided to remove the *Calendarização* and *Tarefas Diárias* bottom tabs. This decision was made through interviews performed with the health professionals in which it was concluded that the doctors do not schedule any specific task when present in the nursing home. In fact, when present, they usually only need to have access to the clinical information of the residents and to write clinical notes.

Finally, from any of the available bottom tabs, the user can access the menu by pressing on the button located on the upper left corner of any of the screens. This menu can be accessed regardless of the user type and grants access to the rest of the features implemented in the mobile application.

Figure 14 presented hereafter shows the screens of the *Calendarização* and *Camas* bottom tabs. Regarding the latter, the screen shown corresponds to the one obtained after the user has selected the nursing home and bedroom he wants to consult.

Figure 14.: Screens of the *Calendarização* (left) and *Camas* (right) bottom tabs - figures obtained when signed in as a nurse.

Menu

As mentioned previously, the menu, which grants access to the rest of the features implemented in the mobile application, can be accessed through any of the screens of the bottom tabs. Moreover, similarly to the homepage and bottom navigation, the menu varies according to the type of health professional. Thus, by pressing on the button located on the upper left corner of any of the bottom tabs screens, the user has access to the menu shown in Figure 15 and, consequently, to the modules described hereafter.

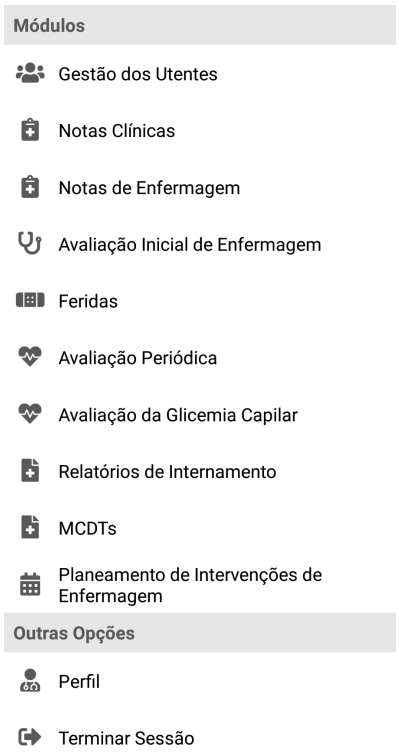

Figure 15.: Menu of the mobile application - figure obtained when signed in as a nurse.

- ***Gestão dos Utentes***: if the user is a nurse, he is able to manage the residents living in the nursing home by pressing on this option. He can also view and edit their personal data as well as add new residents or disable a given resident if needed. Additionally, the user can view and edit the informal caregivers and personal contacts of each resident as well as add and remove contacts. However, if the user is a doctor, he is only able to view the personal data of the residents and the informal caregivers of each resident. Thus, doctors cannot insert new residents and informal caregivers, disable them, and edit their personal data;

- ***Notas Clínicas***: if the user is a doctor, he is able to create new clinical notes and consult the clinical notes' history of each resident. However, nurses are only able to view the clinical notes' history of each resident since clinical notes can only be written by doctors;

- ***Notas de Enfermagem***: if the user is a nurse, he is able to create new nursing notes and consult the nursing notes' history of each resident. However, doctors are only able to consult the nursing notes' history of each resident since nursing notes can only be written by nurses;

- ***Avaliação Inical de Enfermagem***: if the user is a nurse, he can manage, i.e. edit and view, the clinical information of the residents. However, doctors can only view the clinical information of the residents;

- ***Feridas***: if the user is a nurse, he can manage the wounds of the residents and consult the wounds' history of each resident. More specifically, the user can insert new wounds for each resident as well as consult and record their evolution through photos and observations. Additionally, it is also possible to consult the history of the treatments used throughout the evolution of a wound and modify the current treatment if needed. Moreover, the user can also download a PDF file of the evolution of a given wound. However, doctors can only consult the wounds' history of each resident, the evolution of each wound and of the treatments used, and download the PDF file of the evolution of the wound;

- ***Avaliação Periódica***: this module is available to both users and allows them to add new periodic evaluations and consult the periodic evaluations' history of each resident;

- ***Avaliação da Glicemia Capilar***: this module is available to both users, enabling them to add new periodic evaluations of the capillary blood glucose for residents with diabetes. It is also possible to consult the history of the periodic evaluations of the capillary blood glucose of each resident with diabetes;

- ***Relatórios de Internamento***: this module is available to both users and allows them to add new inpatient reports and consult the inpatient reports' history of each resident;

- ***MCDTs***: this module is available to both users, allowing them to add new medical reports and consult the medical reports' history of each resident;

- ***Planeamento de Intervenções de Enfermagem***: this module is only available for nurses, enabling them to schedule nursing interventions for each resident;

- ***Perfil***: this module is available to both users, allowing them to have access and edit their personal data;

- ***Terminar Sessão***: this module is available to both users and allows them to sign out of their accounts.

Gestão dos Utentes Module

As mentioned previously, the *Gestão dos Utentes* module has as main purpose to allow the management of the residents living in the nursing home as well as consult and edit their personal data and informal caregivers. However, depending on the user type, features may or may not be available. It is important to mention that the choice of the available features for each user type resulted from interviews performed with the health professionals. Thus, it was concluded that the doctors do not need to be able to manipulate, more specifically, to update, remove, and insert data since the nurses are usually in charge of these tasks. In this sense, this module can be divided into the following submodules:

- ***Informação Geral do Utente***: after selecting a resident, both user types can consult the personal data of the resident, such as his full name, bed and bedroom numbers, profile picture, and telephone and mobile phone numbers, among others. Moreover, if the user is a nurse, he is also able to edit the personal data of the resident;

- ***Contactos do Utente***: after selecting a resident, both user types can consult the personal data of the informal caregivers and personal contacts of the resident, such as their full name, telephone and mobile phone numbers, relationship with the resident, and observations. Moreover, if the user is a nurse, he is also able to edit the personal data of the informal caregivers and personal contacts of the residents and add and remove contacts;

- ***Desativar Utente***: this submodule is only available to nurses, allowing them to disable/remove a resident if needed (e.g. when a resident leaves the nursing home or passes away);

- ***Adicionar Novo Utente***: this submodule is only available to nurses, enabling them to add a new resident by providing his personal data, namely his full name, bed and bedroom numbers, national health service number, and telephone and mobile phone numbers, among others.

In Figure 16, the screens of the *Gestão dos Utentes* module and the *Informação Geral do Utente*, *Contactos do Utente*, and *Adicionar Novo Utente* submodules are presented.

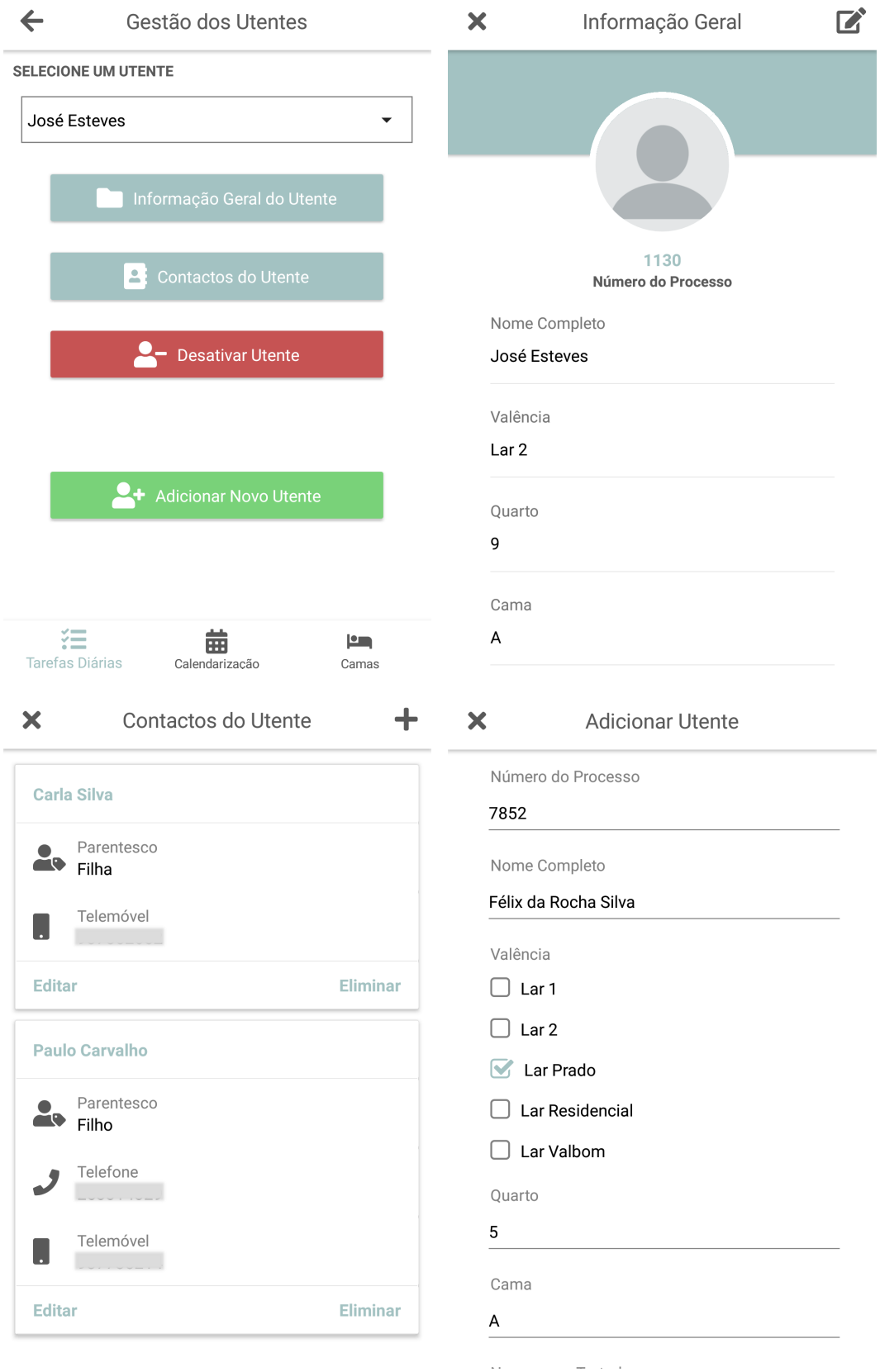

Figure 16.: Screens of the *Gestão dos Utentes* module (upper left corner) and the *Informação Geral do Utente* (upper right corner), *Contactos do Utente* (lower left corner), and *Adicionar Novo Utente* (lower right corner) submodules - figures obtained when signed in as a nurse.

Notas Clínicas Module

The *Notas Clínicas* module was implemented in the mobile application in order to allow users to create clinical notes. Additionally, users can also consult the clinical notes' history for each resident. Similarly to the previous module, features may or may not be available depending on the type of health professional. In this case, the doctors are the only health professionals authorized to write clinical notes. Thus, in this sense, this module can be divided into the following submodules:

- ***Consultar o Histórico***: this submodule can be access by both user types, allowing them to consult the clinical notes' history of a given resident;

- ***Adicionar uma Nota***: this submodule is only available for doctors, enabling them to create a new clinical note for a given resident.

In Figure 17, the screens of the *Notas Clínicas* module and the *Adicionar uma Nota* submodule are presented.

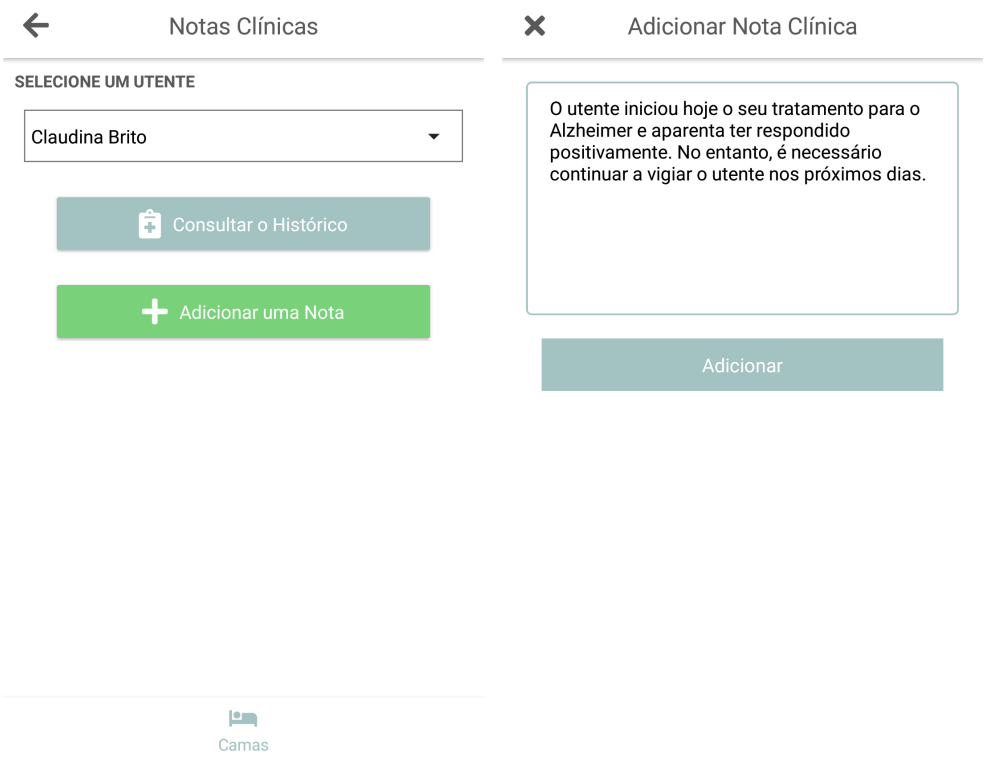

Figure 17.: Screens of the *Notas Clínicas* module (left) and the *Adicionar uma Nota* submodule (right) - figures obtained when signed in as a doctor.

Notas de Enfermagem Module

The *Notas de Enfermagem* module was developed in order to allow nurses to create nursing notes when necessary as they are the only health professionals authorized to write nursing notes. On the other hand, users can also consult the nursing notes' history for each resident. In this sense, this module can be divided into the following submodules:

- ***Consultar o Histórico***: this submodule can be access by both user types, allowing them to consult the nursing notes' history of a given resident;
- ***Adicionar uma Nota***: this submodule can only be accessed by nurses, enabling them to create a new nursing note for a given resident.

Figure 18 presents the screens of the *Notas de Enfermagem* module and the *Consultar o Histório* submodule.

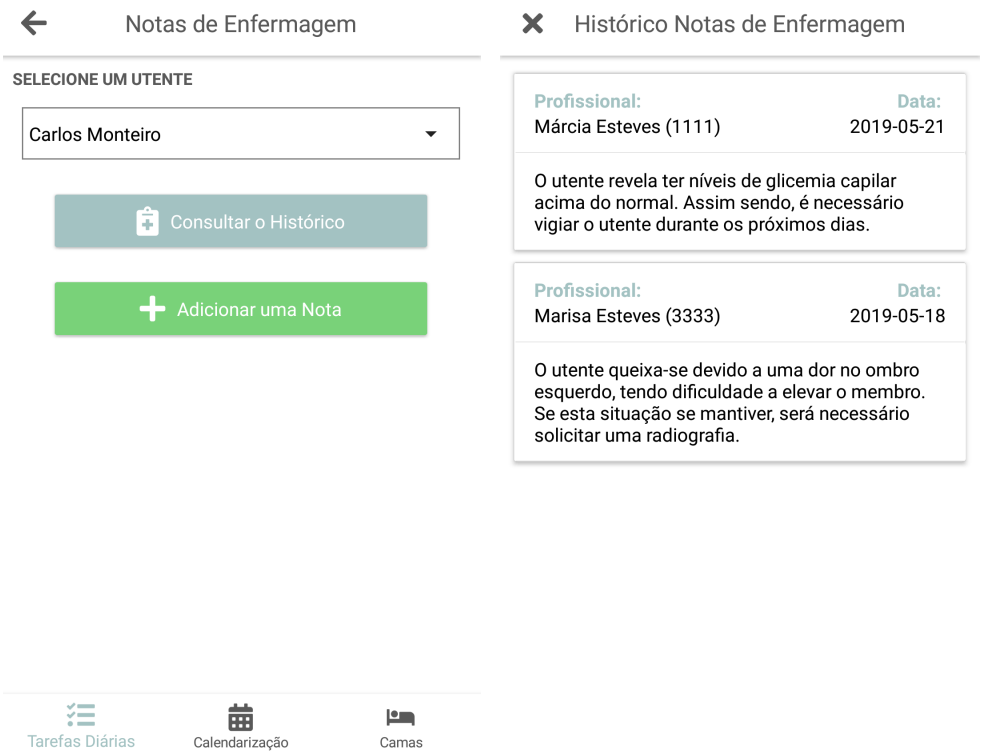

Figure 18.: Screens of the *Notas de Enfermagem* module (left) and the *Consultar o Histórico* submodule (right) - figures obtained when signed in as a nurse.

Avaliação Inicial de Enfermagem Module

The *Avaliação Inicial de Enfermagem* module was developed in the mobile application in order to allow both user types to have access to the clinical information of the residents. On the other hand, if the user is a nurse, the clinical information of the residents can also be

edited since they are usually in charge of this task. Thus, in light of the above mentioned, this module can be divided into the following submodules according to the different types of clinical information available:

- ***Avaliação Geral:*** in this submodule, users can consult the general evaluation of each resident, namely regarding the alcohol and tobacco consumption, professional situation, and education level, among others. This information can also be edited if the user is a nurse;

- ***Antecedentes Clínicos:*** in this submodule, users can have access to the clinical history of each resident, namely regarding the existence of diabetes, diseases, allergies, and past surgeries and fractures, among others. Once again, if the user is a nurse, he is also able to edit this information;

- ***Medicação Habitual:*** by accessing this submodule, users can consult the usual medication of each resident. Additionally, it is also possible to add and remove new medication if the user is a nurse;

- ***Avaliação Física:*** in this submodule, users can consult the physical assessment of each resident, such as the weight, height, blood pressure, heart rate, vision, hearing, and skin integrity, turgidity, and colour, among others. Furthermore, nurses have also the possibility to edit this information;

- ***Padrão de Nutrição:*** this submodule is accessed by the users when they wish to consult the nutritional and eating patterns of a given resident, namely regarding the diet type, dentition, and use of a nasogastric tube, among others. If this submodule is accessed by a nurse, he can also edit this information;

- ***Padrão de Eliminação:*** this submodule allows users to consult the bowel and bladder elimination patterns of each resident, namely regarding the use of adult diapers or of a urinary catheter and the urinary and intestinal habits, among others. Additionally, nurses have the option to edit this information;

- ***Padrão de Atividade:*** in this submodule, users can consult the physical activity patterns of each resident, such as the strength, superficial sensibility, and joint amplitudes of the limbs, among others. This information can also be edited by nurses;

- ***Padrão de Sono:*** in this submodule, users can have access to the sleeping patterns of each resident, namely regarding the insomnia problems and number of hours of sleep during the day and night, among others. This information can also be edited by nurses;

- ***Avaliação do Enfermeiro:*** in this submodule, users can consult the general assessment made by a nurse of each resident, namely regarding the emotional state and autonomy level, among others. If this submodule is accessed by a nurse, the user has the possibility to edit this information.

In Figure 19, the screens of the *Avaliação Inicial de Enfermagem* module and the *Medicação Habitual* and *Padrão de Sono* submodules are presented.

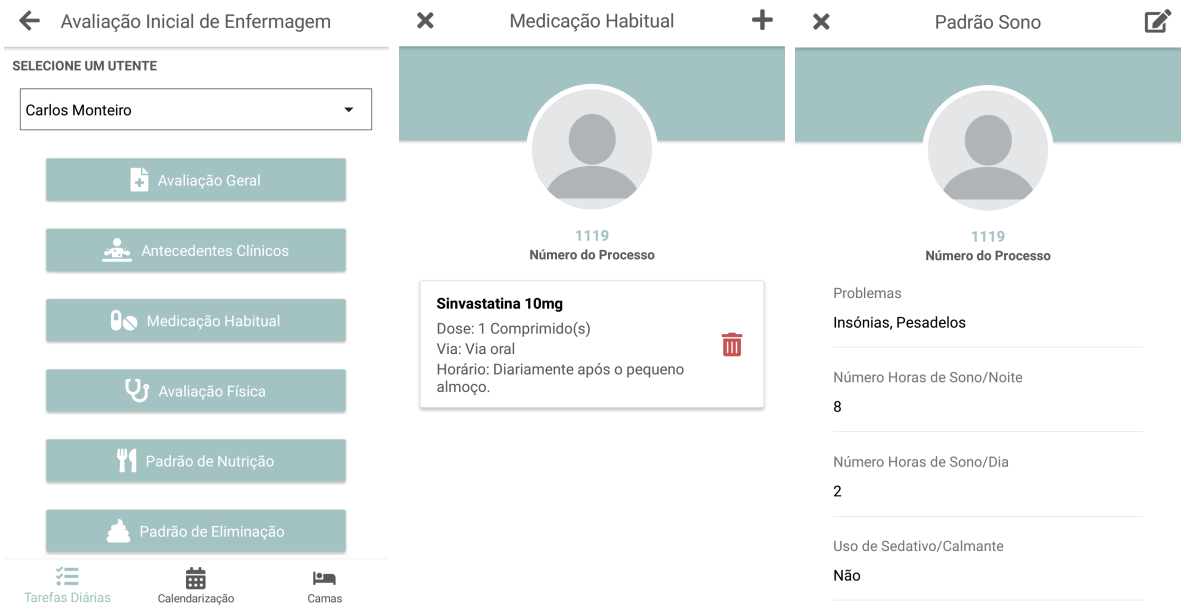

Figure 19.: Screens of the *Avaliação Inicial de Enfermagem* module (left) and the *Medicação Habitual* (center) and *Padrão de Sono* (right) submodules - figures obtained when signed in as a nurse.

Feridas Module

The *Feridas* module is certainly one of the most important modules developed in the mobile application since the vast majority of the nursing interventions performed daily by nurses is related to wound care. Therefore, in this module, several features were developed in order to allow users, more specifically, nurses to manage the wounds of the residents and document their evolution over time. Regarding the doctors, they can only consult the information present in this module since the nurses are the ones responsible for wound care. In this sense, this module was divided into the following submodules:

- ***Histórico de Feridas:*** in this submodule, both user types can consult the wounds' history of each resident. Therefore, wounds that are currently being cured and wounds that were already cured are presented in this submodule. Additionally, after accessing this submodule, users have access to the following features for each wound:

  - ***Consultar Registo de Evolução:*** this feature is available for both user types, allowing them to consult the evolution of the wound. In this context, general information about the wound is provided, namely the wound type and its location. Moreover, if the wound is still being cured, the current treatment that is being used and its periodicity are provided. The various evolutions documented by the nurses (through photos and observations) over time are also presented in chronological order;
  - ***Consultar Histórico de Tratamentos:*** this feature is also available for both user types, enabling them to consult the history of the treatments used over time. Furthermore, this feature can be accessed regardless of the state of the wound, i.e. if it still being cured or not;
  - ***Registar Evolução:*** this feature can only be accessed by nurses since they are responsible for wound care. Thus, with this feature, nurses are able to document the evolution of a wound by providing a photo of the wound and observations. Naturally, this feature is only available for wounds that are still being treated;
  - ***Alterar Tratamento:*** for the same reasons mentioned above, this feature can only be accessed by nurses, allowing them to change the current treatment of the wound. Thus, to this end, the new treatment must be provided as well as its periodicity. As might be expected, this feature is only available for wounds that are still being cured;
  - ***Terminar Tratamento:*** similarly to the last two features, this one is only available for nurses, enabling them to end the treatment of the wound when the health professional deems that the wound is already cured and no further treatment is needed. To this end, the user is asked to provide a photo of the wound. Naturally, this feature is only available for wounds that are still being treated;
  - ***Descarregar Evolução da Ferida:*** this feature is available to both user types regardless of the state of the wound. Thus, by accessing this feature, the users are able to download a PDF file of the evolution of the wound, which includes the same information that is provided in the *Consultar Registo de Evolução* submodule, in his mobile device. The users can then use this file for various purposes. For instance, they may want to send via email the file to a external doctor in order to have a second opinion about the treatment of the wound.

- ***Registar Nova Ferida:*** this submodule is only available to nurses, allowing them to insert new wounds for each resident. In this context, the health professionals are required to provide the wound type, the location of the wound, the treatment to be used and its periodicity, and a photo of the wound.

In Figure 20, the screens of the *Feridas* module and the *Histórico de Feridas* and *Registar Nova Ferida* submodules are presented.

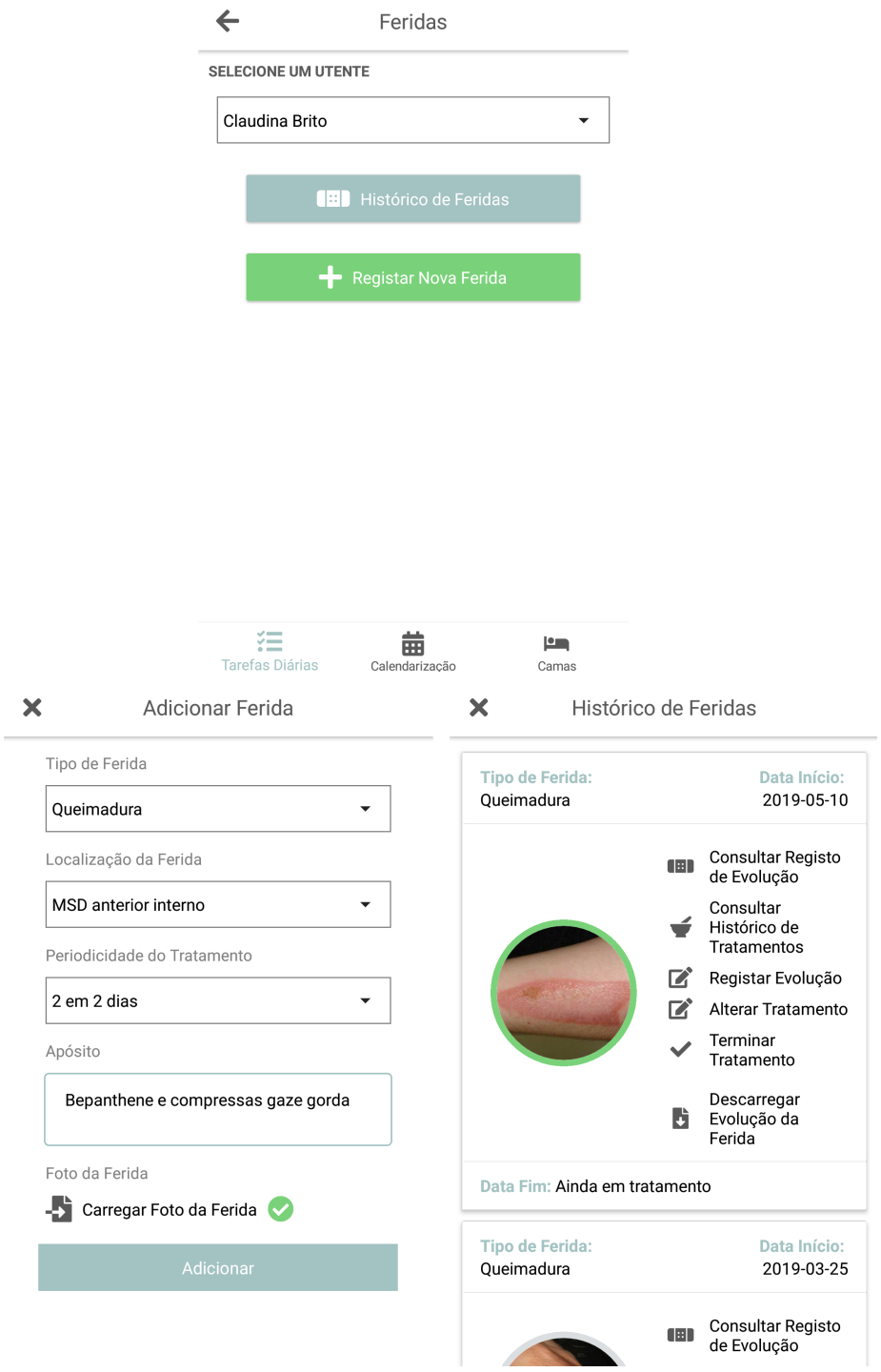

Figure 20.: Screens of the *Feridas* module (top) and the *Registar Nova Ferida* (lower left corner) and *Histórico de Feridas* (lower right corner) submodules - figures obtained when signed in as a nurse.

Additionally, in Figures 21, the screen of the *Consultar Registo de Evolução* feature is shown. Then, in Figure 22, the screens of the *Alterar Tratamento* and the *Consultar Histórico de Tratamentos* features are presented.

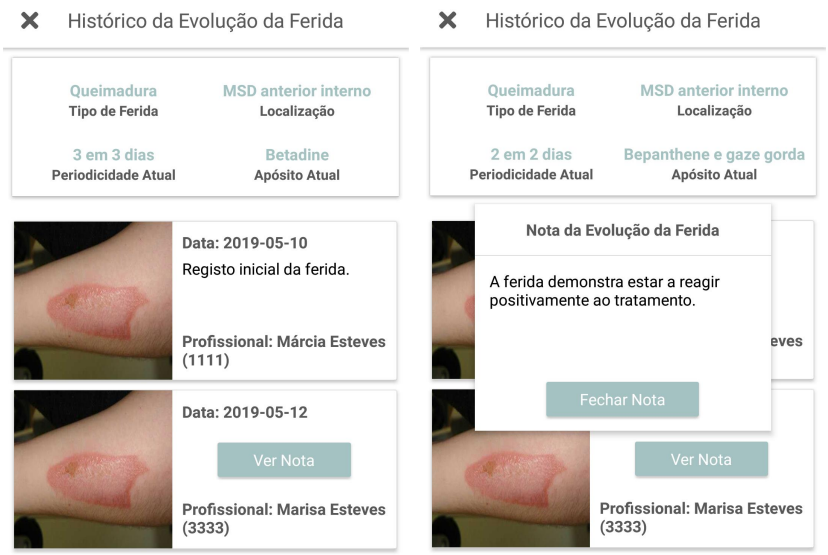

Figure 21.: Screens of the *Consultar Registo de Evolução* feature (left) and the result obtained when the user presses on the *Ver Nota* button (right) - figures obtained when signed in as a nurse .

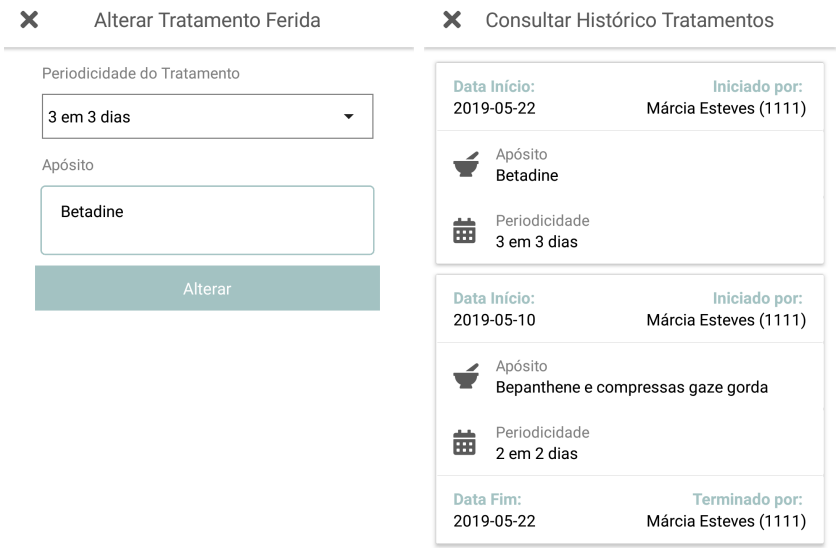

Figure 22.: Screens of the *Alterar Tratamento* (left) and the *Consultar Histórico de Tratamentos* features (right) - figures obtained when signed in as a nurse.

Finally, in Figure 23, the screen of the *Registar Evolução* feature and the PDF downloaded by the *Descarregar Evolução da Ferida* feature are shown.

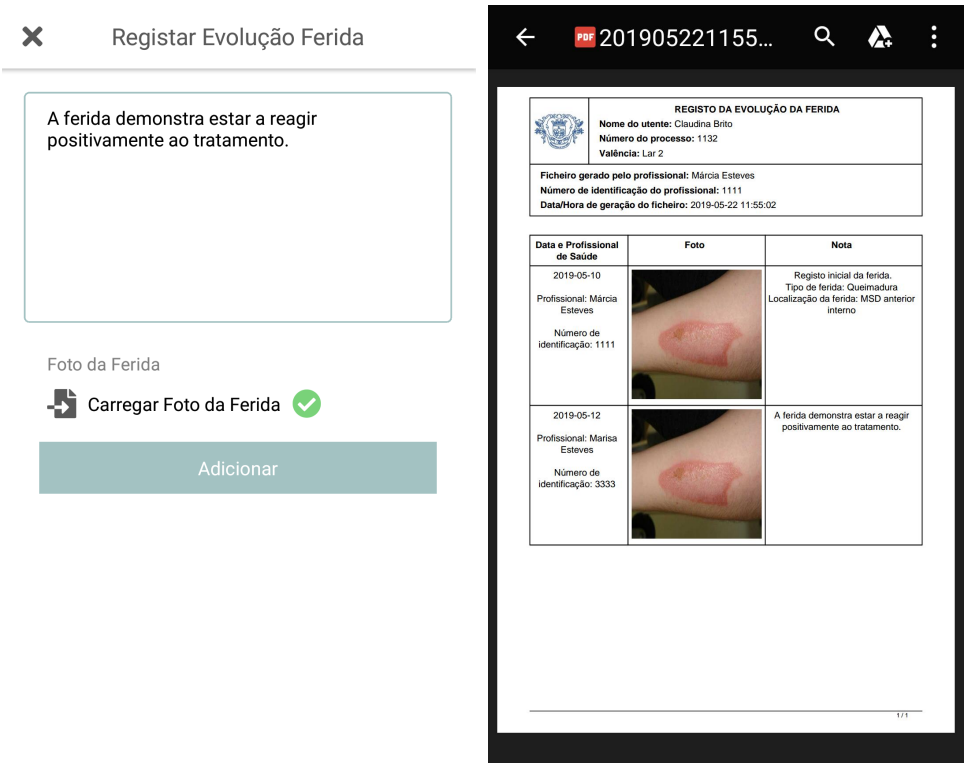

Figure 23.: Screens of the *Registar Evolução* feature (left) and the file downloaded by the *Descarregar Evolução da Ferida* feature (right) - figures obtained when signed in as a nurse.

Avaliação Periódica Module

The *Avaliação Periódica* module has as main purpose to allow the creation of periodic evaluations by health professionals as well as consult the history of the periodic evaluations for each resident. In this case, the features available are independent of the user type since both of them can add and consult periodic evaluations. Thus, in this sense, this module can be divided into the following submodules:

- ***Consultar o Histórico:*** this submodule is available for both user types, allowing them to consult the periodic evaluations' history of a given resident;
- ***Adicionar Avaliação Periódica:*** this submodule can also be accessed by both user types, enabling them to add a new periodic evaluation for a given resident. To this end, the user is asked to provide the blood pressure, weight, heart rate, and axillary temperature, among others, of the resident.

In Figure 24, the screens of the *Avaliação Periódica* module and the *Consultar o Histórico* and *Adicionar Avaliação Periódica* submodules are presented.

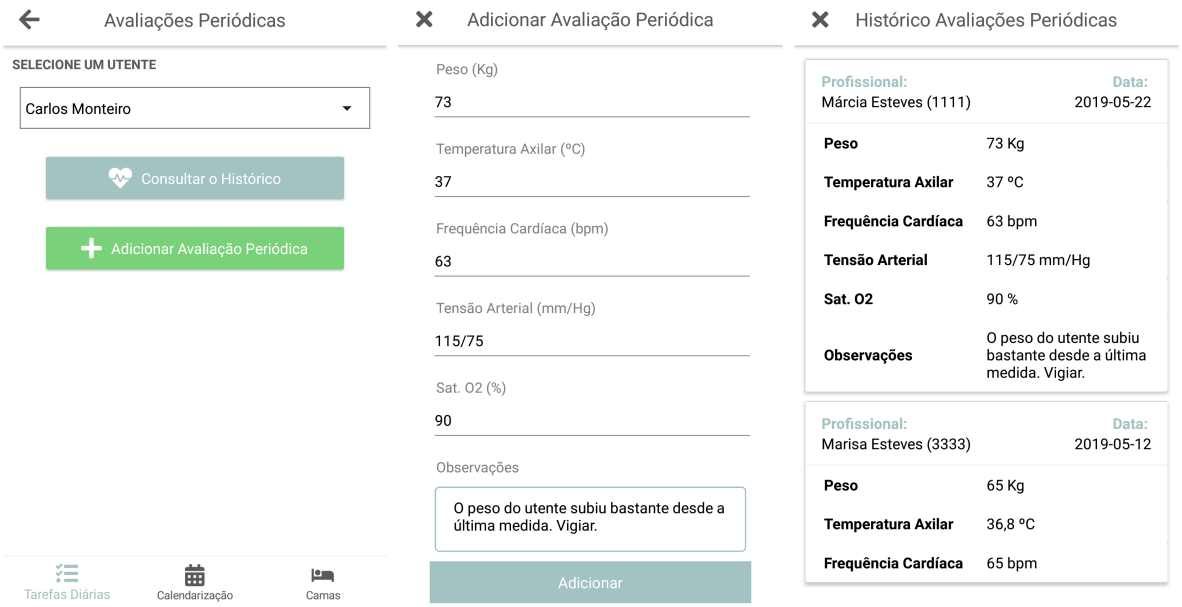

Figure 24.: Screens of the *Avaliação Periódica* module (left) and the *Adicionar Avaliação Periódica* (center) and *Consultar o Histórico* (right) submodules - figures obtained when signed in as a nurse.

Avaliação da Glicemia Capilar Module

The *Avaliação da Glicemia Capilar* module was developed in order to allow health professionals to create new periodic evaluations of the capillary blood glucose as well as consult the history of the periodic evaluations of the capillary blood glucose for each resident. Once again, the features available in this module are independent of the user type as both of them can add and consult periodic evaluations of the capillary blood glucose. In this sense, the following submodules were developed:

- ***Consultar o Histórico:*** this submodule can be accessed by both user types, allowing them to consult the history of periodic evaluations of the capillary blood glucose of a given resident;

- ***Adicionar Avaliação:*** this submodule is also available for both user types, allowing them to add a new periodic evaluation of the capillary blood glucose for a given resident. To this end, the user is asked to provide the value of the blood sugar of the resident.

Figure 25 shows the screens of the *Avaliação da Glicemia Capilar* module and the *Consultar o Histórico* and *Adicionar Avaliação* submodules.

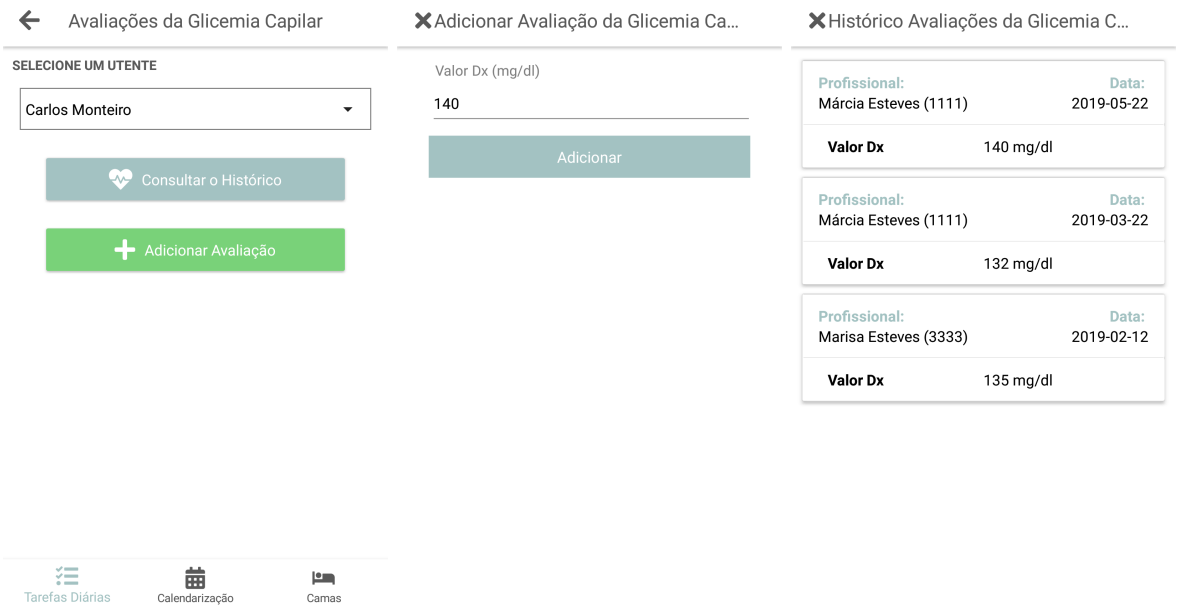

Figure 25.: Screens of the *Avaliação da Glicemia Capilar* module (left) and the *Adicionar Avaliação* (center) and *Consultar o Histórico* (right) submodules - figures obtained when signed in as a nurse.

Relatórios de Internamento Module

The *Relatórios de Internamento* module was developed in order to allow health professionals to insert the inpatient reports of each resident by providing relevant information that is able to identify the report. Therefore, the health professionals can then have access to the history of the inpatient reports for each resident at any point in time without having to go through the huge amount of files gather in folders. In this sense, the following submodules were developed:

- ***Consultar o Histórico:*** this submodule can be accessed by both user types, allowing them to consult the history of inpatient reports of each resident;

- ***Adicionar Relatório:*** this submodule is also available for both user types, enabling them to add a new inpatient report for a given resident. Thus, to this end, the user is asked to provide the type of inpatient report, the name of the institution and service of the report, the episode number, and date of the report, among others.

In Figure 26, the screens of the *Relatórios de Internamento* module and the *Adicionar Relatório* and *Consultar o Histórico* submodules are presented.

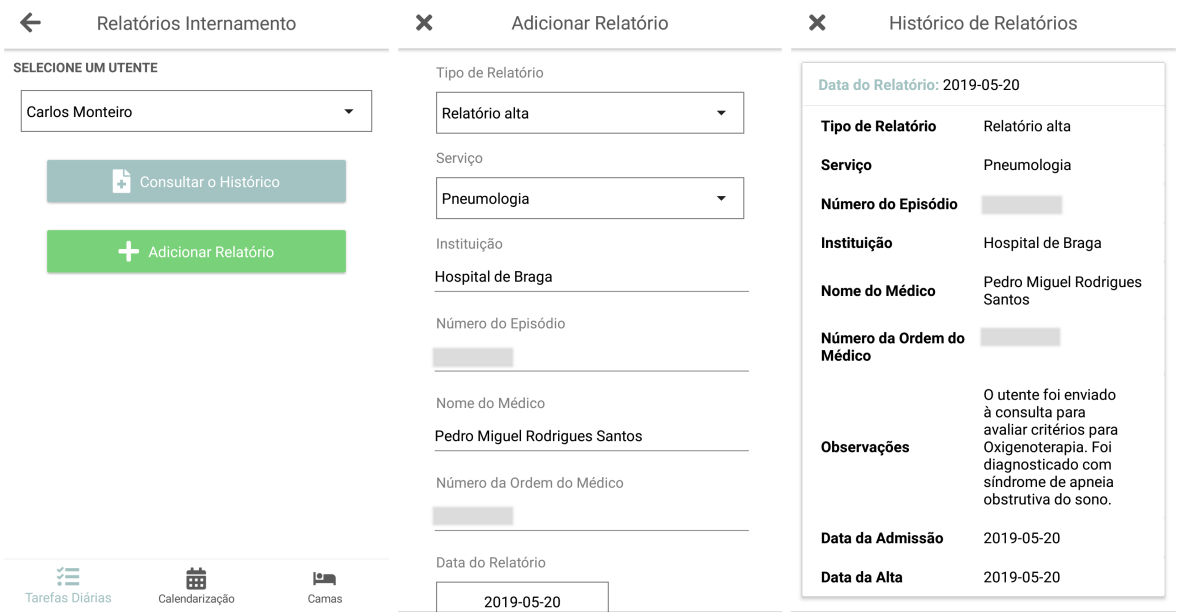

Figure 26.: Screens of the *Relatórios de Internamento* module (left) and the *Adicionar Relatório* (center) and *Consultar o Histórico* (right) submodules - figures obtained when signed in as a nurse.

MCDTs Module

Similarly to the module approached above, the *MCDTs* module enables the health professionals to insert the medical reports of each resident by providing relevant information capable of identifying the report. Thus, the health professionals can consult the history of the medical reports of each resident anywhere and at any time without having to return to the nursing station to go through the files gathered in folders. To this end, the following submodules were implemented:

- ***Consultar o Histórico:*** this submodule is available for both user types, enabling them to consult the history of medical reports of each resident;

- ***Adicionar MCDT:*** this submodule can also be accessed by both user types, allowing them to add a new medical report for a given resident. In order to add a new report, the user has to provide the type of medical test, the name of the institution of the report, the episode number, and date of the report, among others.

Figure 27 presents the screens of the *MCDTs* module and the *Adicionar MCDT* and *Consultar o Histórico* submodules.

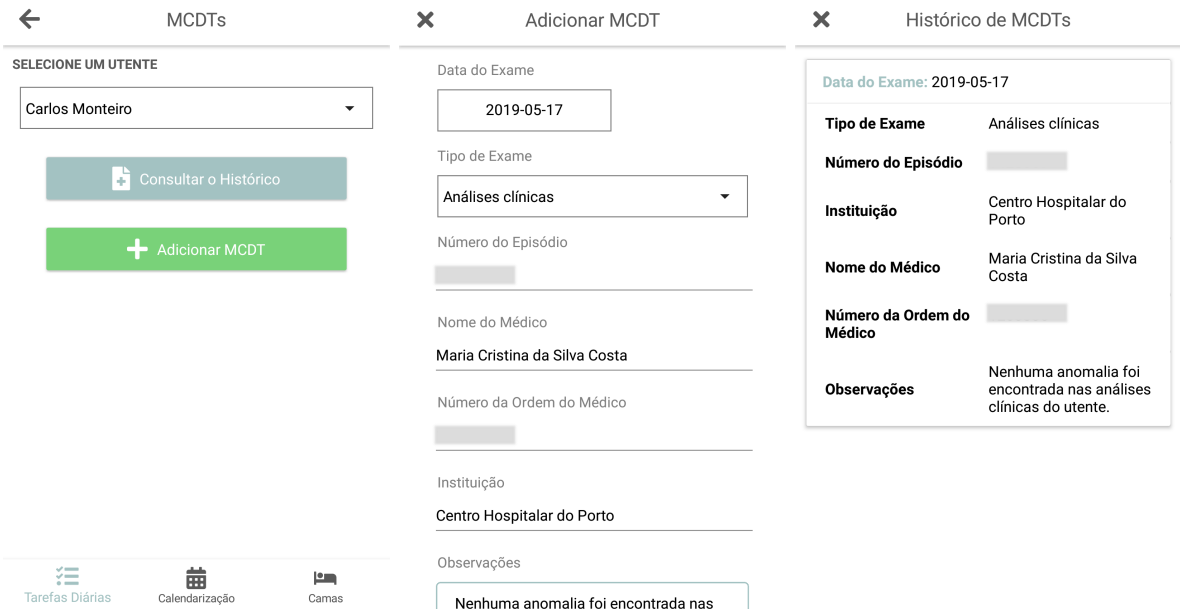

Figure 27.: Screens of the *MCDTs* module (left) and the *Adicionar MCDT* (center) and *Consultar o Histórico* (right) submodules - figures obtained when signed in as a nurse.

Planeamento de Intervenções de Enfermagem Module

The *Planeamento de Intervenções de Enfermagem* module was implemented in the mobile application to allow the health professionals, namely, the nurses to schedule nursing interventions for each resident of the nursing home. Once scheduled, the nursing intervention can be performed or cancelled by any nurse. However, as mentioned previously, this module is not available to doctors since they do not perform nursing interventions. In fact, through interviews performed with the health professionals, it was concluded that the access to the clinical information of the residents and the creation of clinical notes are more relevant to them as they do not tend to schedule any specific task when present in the nursing home.

On the other hand, in order to schedule a nursing intervention, the user is required to select the resident to whom the intervention will be performed as well as the type of nursing intervention and the scheduled date. The user may also be obliged to provide other information depending on the type of nursing intervention. For instance, if a nurse wishes to schedule the insertion of a nasogastric tube, the size and type of the nasogastric tube must be specified. Alternatively, if a nurse wants to schedule wound care for a given resident, the wound to be cured, among the ones that are currently being treated, has to be selected.

In Figure 28, the screens of the *Planeamento de Intervenções de Enfermagem* module when a nurse tries to schedule wound care and the insertion of a nasogastric tube are presented.

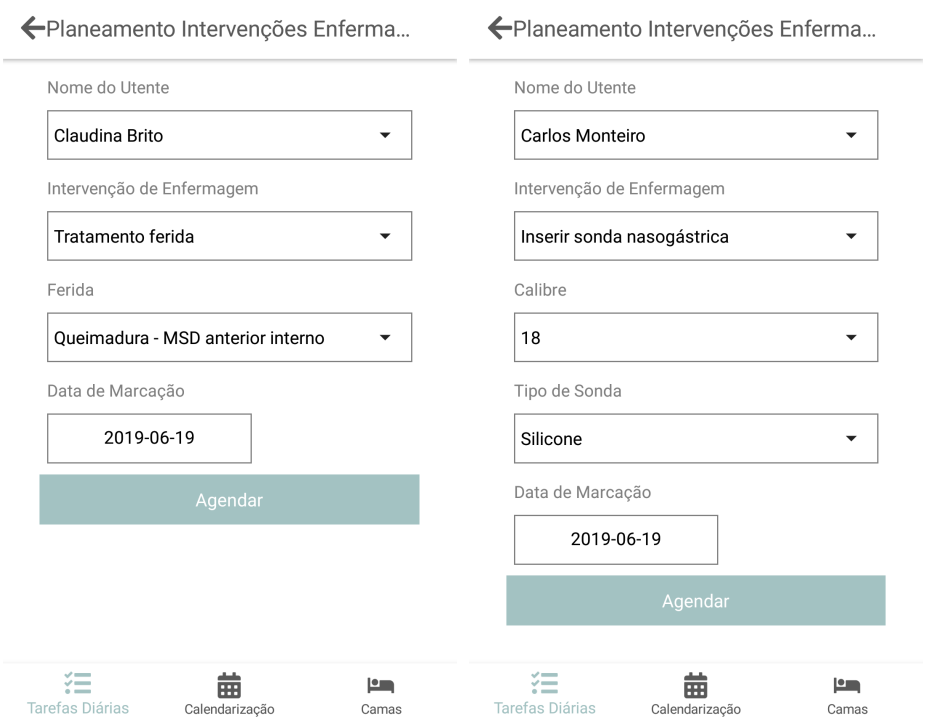

Figure 28.: Screens of the *Planeamento de Intervenções de Enfermagem* module when a user tries to schedule wound care (left) and the insertion of a nasogastric tube (right) - figures obtained when signed in as a nurse.

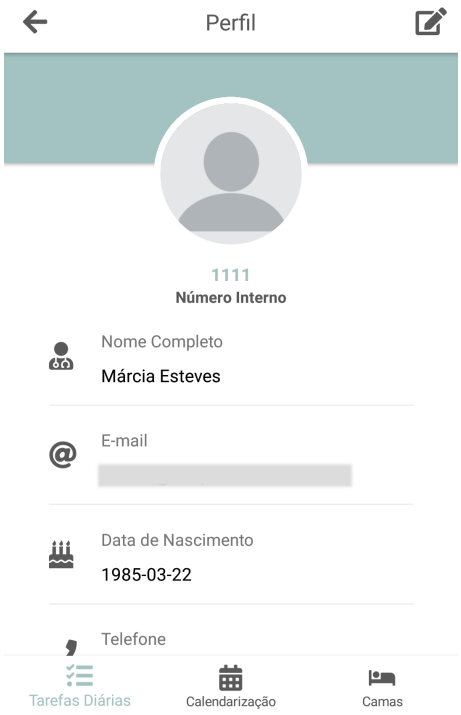

Figure 29.: Screen of the *Perfil* module - figure obtained when signed in as a nurse.

Perfil Module

The *Perfil* module corresponds to the profile of the user. Thus, in this module, both user types are able to consult and modify their personal data, such as their full name, email address, date of birth, telephone and mobile phone numbers, medical education number, gender, type of health professional (nurse or doctor), and the names of the *Santa Casa da Misericórdia de Vila Verde* nursing homes in which he works. Figure 29 presented above shows the screen of the *Perfil Module*.

4.5 Clinical and Performance Business Intelligence Indicators

As mentioned in Chapter 2, BI tools are greatly beneficial and essential in healthcare settings to analyze the clinical information gathered daily and to obtain previously unknown and meaningful knowledge used as a basis in the decision-making process. In fact, by providing valuable and useful information, BI tools lead to a more accurate and evidence-based medical practice, enhancing the decision-making process.

Thus, in this sense, in order to analyze and gain a deeper understanding of the overall performance of the nursing home and its health professionals as well as to improve the nursing care delivered and its outcomes, clinical and performance indicators were defined. However, at the moment, these indicators have not yet been created since the database does not have data. Moreover, in order to create meaningful and valuable indicators, data should be gathered over a relatively long period of time, which is not the case at the moment. Furthermore, it is envisioned to implement the clinical and performance indicators in a Web application and not in the mobile application discussed in this document to have a better visualization and control over the indicators.

Therefore, in the future, when enough data are gathered, it is envisioned to create the clinical and performance indicators presented hereafter. It is important to mention that the figures associated with each indicator were created using Power BI, which allowed to create examples for each indicator with fictitious data as previously stated.

Percentage of Nursing Interventions Realized per Nurse

First and foremost, it is envisioned to create a pie chart indicator of the percentage of nursing interventions realized per nurse over a time horizon, for instance, per month and year. Thus, with this performance indicator, it would be possible to identify if the nursing interventions are performed proportionately between the nurses working in the nursing home. Additionally, this indicator would be capable of highlighting if a certain health professional has a higher workload compared to others. Consequently, with the information

obtained through this indicator, improvements and measures could be realized to have a better distribution of the nursing interventions between the nurses.

In Figure 30, an example of the indicator described above is shown.

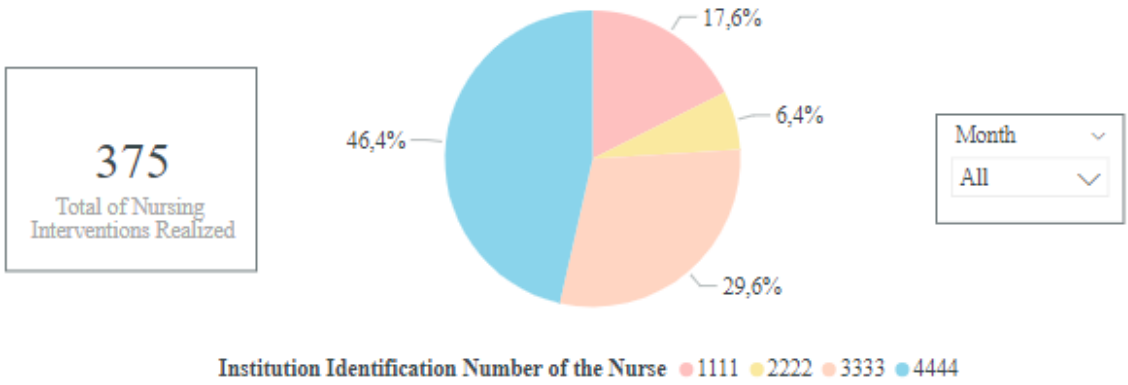

Figure 30.: Indicator of the percentage of nursing interventions realized per nurse (created with fictitious data).

Total of Realized and Unrealized Nursing Interventions per Month

On the other hand, it is also envisioned to create a stacked column chart indicator of the total of realized and unrealized nursing interventions per month similar to the one presented in Figure 31.

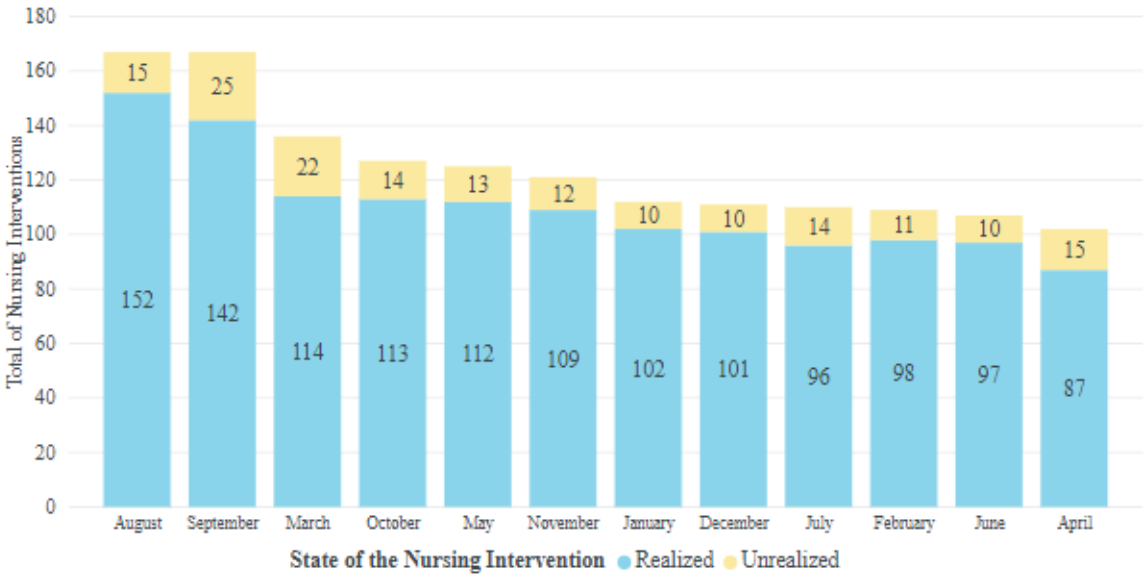

Figure 31.: Indicator of the total of realized and unrealized nursing interventions per month (created with fictitious data).

It is important to refer that a nursing intervention is realized when a nurse has confirmed its execution in the *Tarefas Diárias* or *Calendariazação* screens. However, a nursing intervention is considered unrealized when it was neither realized nor cancelled.

Therefore, this indicator would help identify abnormalities in the number of unrealized nursing interventions as well as the months in which more tasks are performed or unrealized. Consequently, regarding the former, if too many nursing interventions are unrealized, it may suggest that the nurses are not performing their job as well as they should. For instance, it may shed a light on the fact that the nurses are overloaded with work, not having enough time to perform all of their tasks. On the other hand, regarding the latter, if some specific months are busier than others, more nurses could be present for each shift in order for the nursing interventions to be realized as scheduled.

Variation of the Capillary Blood Glucose of a given Resident over Time

In order to analyze more rapidly and visually the variation of the capillary blood glucose of a given resident over time, it was decided to create a line chart indicator similar to the one shown in Figure 32.

Thus, with this clinical indicator, the health professionals would be able to have a better visualization of variation of the capillary blood glucose and, thus, detect more rapidly abnormalities and act on them. Additionally, this indicator could also be extended to other types of evaluations, namely to analyze the variation of the weight, blood pressure, heart rate, oxygen saturation, and axillary temperature of a given resident over time.

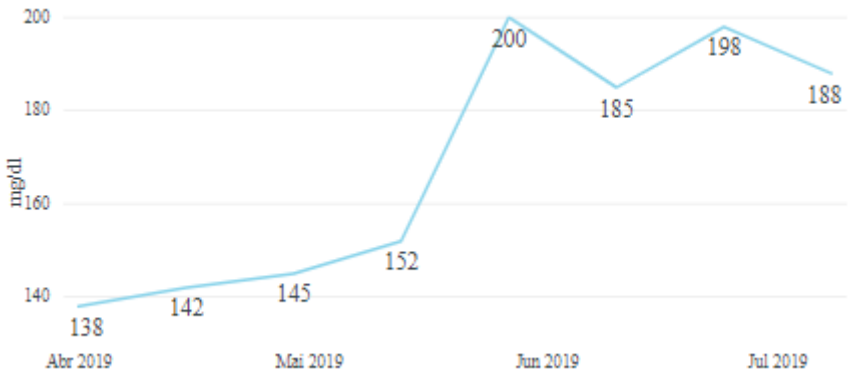

Figure 32.: Indicator of the variation of the capillary blood glucose of a given resident over time (created with fictitious data).

Percentage of Wounds per Resident

In addition to the indicators mentioned previously, it was also decided to create a bar chart indicator of the percentage of wounds per resident over a time horizon, for instance, per month or year. Consequently, with this clinical indicator, the health professionals would be able to identify the residents with an abnormal amount of wounds and, thus, supervise them more closely so as to avoid and reduce the occurrence of wounds for these residents.

In Figure 33, an example of the clinical indicator described above is presented.

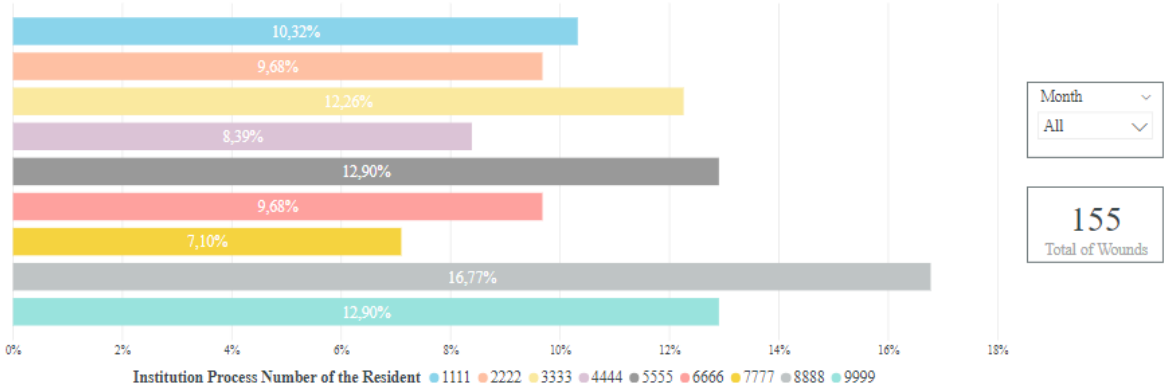

Figure 33.: Indicator of the percentage of wounds per resident (created with fictitious data).

Percentage of Wounds per Wound Type

On the other hand, it was also envisioned to create a donut chart indicator of the percentage of wounds per wound type over a time horizon, for instance, per month or year. In Figure 34, an example of this indicator is shown.

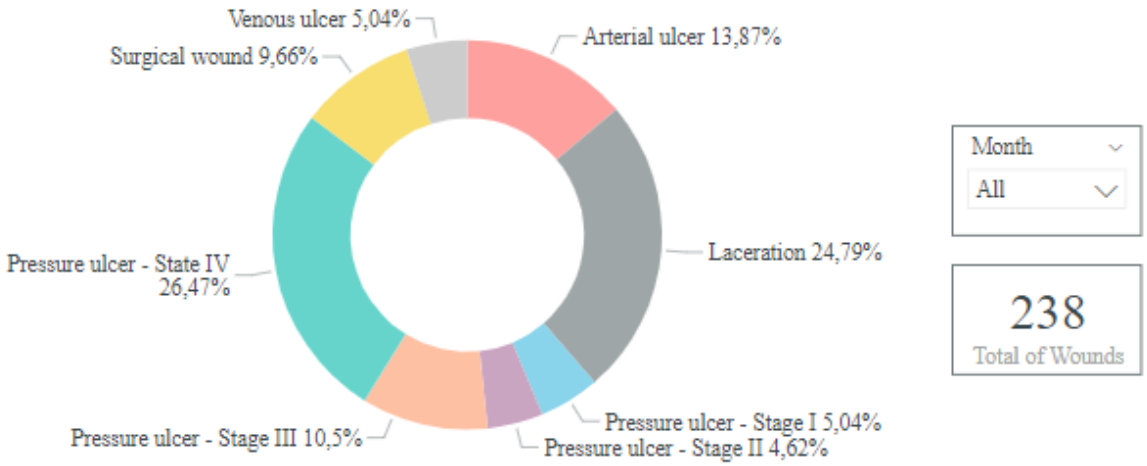

Figure 34.: Indicator of the percentage of wounds per wound type (created with fictitious data).

Thus, through this clinical indicator, the health professionals would be able to identify if certain wound types occur more frequently than others. Consequently, according to the results obtained, further research and improvements could be realized so as to identify and reduce wound-causing factors.

Percentage of Nursing Interventions Realized Annually per Type of Nursing Intervention

Finally, it was decided to create a bar chart indicator of the percentage of nursing interventions realized annually per type of nursing intervention. Therefore, through this indicator, the health professionals would be able to identify and be aware of the nursing interventions that are not realized with the expected frequency. Hence, with this knowledge, the health professionals could perform these nursing interventions more frequently.

In Figure 35, an example of the indicator discussed above is shown.

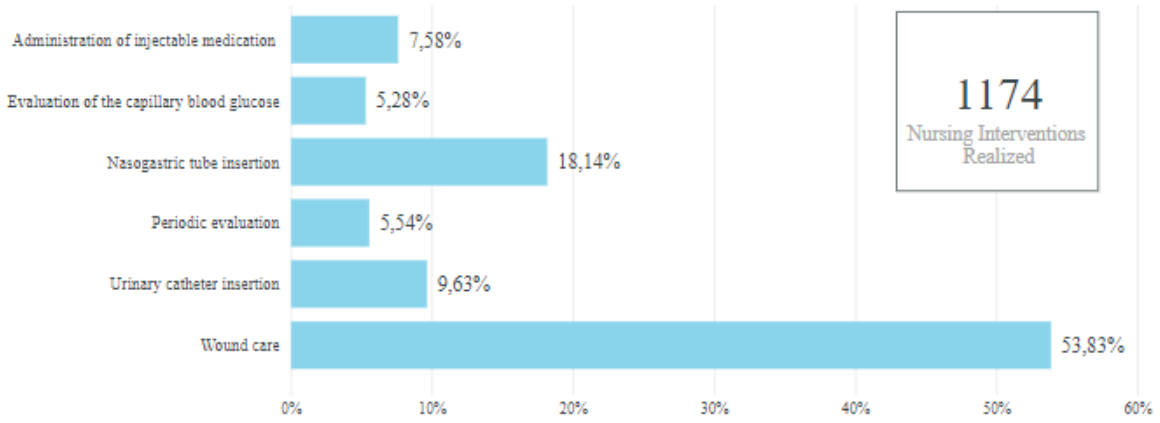

Figure 35.: Indicator of the percentage of nursing interventions realized annually per type of nursing intervention (created with fictitious data).

4.6 DISCUSSION

To summarize, the research project described in this section consisted in the design and development of a mHealth application for the health professionals of one of the nursing homes of the *Santa Casa da Misericórdia de Vila Verde* in order to help them clinically manage the residents and to assist them at the point-of-care, more specifically, to schedule, perform, and record their daily tasks and to have access and manipulate information. Thus, this solution aimed to introduce technological improvements in the nursing home and support the health professionals in their daily tasks.

In this sense, a user-friendly mobile application was designed and developed, allowing to attain the following benefits:

- Shift from the paper-based to the computer-based management of data and, thus, reduce the amount of paper produced daily with hand-written charts;
- Reduce time-waste and, thus, an increase in productivity since the health professionals can have access and manipulate information at the point-of-care, not having to constantly return to the nursing station;
- Reduce the occurrence of errors since the solution decreases the risk of losing, misplacing, or forgetting information compared to the paper-based management of data;
- Ease some of the work overload experienced by the health professionals;
- Improve the nursing care delivered and elders' quality of life as fewer errors are made and the health professionals have more time to perform their tasks;
- Timely sharing and centralization of the clinical information of the residents;
- Simplify the access and manipulation of information;
- Optimize the various processes occurring in the nursing home;
- Less confusing and more organized scheduling of nursing interventions;
- Improve and assist the health professionals in the decision-making process since they can have access to information at the point-of-care;
- Highlight problem areas and opportunities through BI clinical and performance indicators and, thus, improve the decision-making process as the health professionals can make informed and evidence-based decisions.

Therefore, in the future, when the necessary needs are provided to the nursing home, such as a wireless internet connection and mobile devices, it is intended to introduce this mobile application in the facility in order to be used by the health professionals. Furthermore, due to its high adaptability, the solution could easily be implemented in the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes in the future. On the other hand, one of the main advantages of the mobile application is its high usability since it has a user-friendly design with well-defined paths and organized information. Additionally, the solution is easy to maintain and new features can easily be added due to its high scalability.

Finally, it must be mentioned that during all stages of the design and development of the project described in the present dissertation, ethical issues were taken into account and safeguarded to guarantee that confidentiality issues do not arise and the quality, accuracy, and safety of the solution. In this sense, the health professionals were constantly consulted throughout the design and development of the solution in order to develop an accurate mobile application with high quality.

4.7 CONCLUSION

It is common knowledge that the aging population has been a matter of concert for several countries all over the world due to the challenges this situation has been posing for healthcare systems. In fact, taking an in-depth look at the current state of Portugal, the rapidly aging population has been causing major challenges, namely the overload of nursing homes. In addition, due to the lack of investment in these facilities, the number of elderly people is often too high compared to the number of health professionals and, more than not, unsophisticated methods, which are usually time-consuming and prone to errors, are used.

Consequently, the research project described in this manuscript emerged and aimed to overcome some of the challenges faced by nursing homes in response to the aging population. In this sense, by using a Portuguese nursing home as a case study, a mobile application was designed and developed in order to introduce technological improvements, namely Health Information and Communication Technology in the nursing home and, thus, take advantage of their benefits. Therefore, the solution aims to shift from the paper-based to the computer-based management of data and, hence, reduce the occurrence of errors and time-waste caused by the use of unsophisticated methods.

Additionally, by using a mobile device, which can be used anywhere and at any time in the nursing home, the health professionals are able to have access to timely information as well as manipulate data directly at the point-of-care. Accordingly, by minimizing error and time-waste and by allowing the health professionals to have access and manipulate information in a faster and more organized way, it is possible to relieve some of the workload of the health professionals and improve elders' quality of life and the nursing care delivered.

However, although the mobile application is fully developed, it is not currently being used by the nursing home since a wireless internet connection and mobile devices have not yet been provided to the facility. Thus, as future work, it is envisioned to make the necessary resources available to the nursing home as well as populate the database with data of the residents and health professionals. Additionally, if the use of the mobile application reveals to be successful, the solution could be implemented in the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes. The design and development of a Web application that includes some of the features of the mobile application, e.g. features related to the management of the residents, as well as clinical and performance indicators are also planned in the foreseeable future.

That being said, in the next chapter (Chapter 5), the Proof of Concept performed is presented. In this context, based on the results obtained through the TAM, the SWOT analysis performed to evaluate the strengths, weaknesses, opportunities, and threats of the developed solution is meticulously approached.

5

PROOF OF CONCEPT

In the previous chapter, the mobile application designed and developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home is described in detail. Therefore, in this chapter, the Proof of Concept applied to the developed solution is presented with the intention of identifying its usefulness, feasibility, and potential. In this sense, the SWOT analysis and TAM performed to assess the strengths, weaknesses, opportunities, and threats and to identify the acceptability of the developed solution, respectively, are presented. Thus, in order to approach all of the needed topics, the present chapter is divided into three distinct sections.

At first, Section 5.1 introduces the present chapter. Then, in Section 5.2, the SWOT analysis performed to analyze and assess the strengths, weaknesses, opportunities, and threats of the developed solution is presented. Thus, to this end, the TAM applied to analyze the acceptance of the solution is discussed since its results were used as a basis in the SWOT analysis. Finally, the chapter concludes with a brief conclusion, which gives a general overview of the content described in this chapter.

5.1 INTRODUCTION

Unquestionably, after the development of any solution encompassed in the HICT area, a meticulous and rigorous set of evaluations has to be performed in order to assess the usefulness, feasibility, potential, and acceptability of the solution towards the target audience before its implementation in the production environment. In fact, initially, the solution must be implemented, tested, and evaluated in a non-production environment to verify if the established objectives have been fulfilled and if future improvements should be performed.

Thus, in this sense, a Proof of Concept was elaborated in order to validate the usability, feasibility, and usefulness of the developed solution towards the target audience and to ensure that the solution provides all of the requirements initially proposed. Therefore, in the section presented hereafter, the SWOT analysis elaborated to identify the strengths, weaknesses, opportunities, and threats related to the solution is presented. Therefore, to

this end, the Technological Acceptance Model applied to assess the acceptability of the target audience, i.e. how the target audience accepts and receives the mobile application, is discussed since its results were used as a basis in the SWOT analysis.

5.2 SWOT ANALYSIS

As mentioned in Chapter 3, the SWOT analysis enables to identify the internal and external factors that affect in a favourable and unfavourable way the objectives established for a given solution so as to assess its usefulness, potential, and usability. Therefore, through various tests and evaluations, the SWOT analysis allows to identify the strengths, weaknesses, opportunities, and threats related to a solution.

Therefore, the developed solution was presented to the target audience to be evaluated and to obtained valuable information about its acceptance, usefulness, and potential. In this sense, a survey questionnaire, which is presented in Appendix B, was conducted with the health professionals in order to assess the acceptance of the mobile application. This questionnaire was elaborated based on the TAM3 and is, thus, divided into various sections according to the constructs used, which were discussed in Chapter 3. However, it is important to mention that only the relevant constructs were used in this survey since some of them were not pertinent to evaluate the mobile application. Furthermore, the Likert scale, which is a five-level scale, was used by the health professionals to answer each question. Accordingly, the health professionals answered each question with one of the following items:

- **Level 1 -** Strongly disagree;
- **Level 2 -** Disagree;
- **Level 3 -** Neutral;
- **Level 4 -** Agree;
- **Level 5 -** Strongly agree.

Subsequently, based on the results obtained through the conduction of the survey questionnaire mentioned above, a SWOT analysis was performed. Furthermore, this analysis was also based on personal opinion as well as valuable information obtained through semi-structured interviews and focus groups realized with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital.

It must be mentioned that, the survey questionnaire was conducted with few health professionals, namely the nurses working for the nursing home used as a case study. Thus, not enough results were obtained in order to be presented. However, the results obtained

were used as a basis for the SWOT analysis and, in the future, it is intended to evaluate the mobile application with the health professionals of the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes and, thus, have a more complete evaluation of the solution.

In light of the above mentioned, the SWOT analysis performed to evaluate the mobile application is presented hereafter. Thus, regarding the internal factors, the following strengths were identified:

- Decrease of time-waste and, consequently, an increase in productivity since the health professionals can have access and record information at the point-of-care. Hence, they do not need to constantly return to the nursing station to do so;
- Decrease of the occurrence of errors since the solution reduces the risk of misplacing, losing, or forgetting information;
- Enhancement of the nursing care delivered and elders' quality of life due to the decrease of errors and time-waste;
- Easier access and manipulation of information;
- Timely sharing and centralization of information;
- Optimization of the various processes occurring in the nursing home;
- Answer to the needs of the health professionals;
- Scheduling of tasks less confusing and more organized compared to hand-written boards;
- Reduction of the amount of paper generated daily with hand-written charts due to the shift from the paper-based to the computer-based management of data;
- Evidence-based and more accurate decision-making process since the health professionals can have access to information at the point-of-care;
- High usability since the mobile application has a simple, user-friendly, and intuitive design with well-defined paths and organized information;
- High adaptability since the solution was designed to allow its easy implementation in the rest of *Santa Casa da Misericórdia de Vila Verde* nursing homes;
- High scalability since new features can easily be added and the mobile application can easily be maintained.

On the other hand, the following weaknesses can be pointed out:

- Need of a wireless internet connection, which is not currently available in the nursing home;
- Need of mobile devices, namely mobile phones and tablets, in order to use the solution;
- Need to populate the database with real data, namely information of the residents and health professionals, which will require time resources;
- Need to train the health professionals before using the solution;
- Need to wait a relatively long period of time before creating the clinical and performance indicators.

Afterwards, regarding the external factors, the opportunities of the developed solution are as follows:

- Introduction and implementation of the mobile application in other nursing homes;
- Enhancement of other processes due to the technological improvement of the nursing home;
- Creation of clinical and performance indicators due to the elimination of the paper-based management of data and the storage of information in a database.

Finally, the following threats can be highlighted:

- Issues may emerge if a reliable wireless internet connectivity is not available;
- New systems and competition may arise due to the novelty of the solution that approaches recent problems.

5.3 CONCLUSION

In this chapter, the Proof of Concept elaborated to evaluate the usability, feasibility, and usefulness of the mobile application designed and developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home was meticulous presented. In this sense, a survey questionnaire based on the TAM3 was applied in order to assess the acceptance of the solution towards the target audience. Subsequently, a SWOT analysis was performed using as a basis the results obtained through the survey questionnaire as well as valuable information obtained through semi-structured interviews. However, in the future, in order to have a more complete evaluation of the solution, it is envisioned to conduct the questionnaire with more

health professionals, namely with the health professionals working for the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes.

Hereupon, through the SWOT analysis performed, the usability, feasibility, acceptance, and potential of the research project described in this manuscript were proven. Briefly, through the analysis elaborated, the mobile application revealed to have met the requirements initially proposed. Additionally, the solution presents high adaptability and, thus, could easily be implemented in the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes. On the other hand, the mobile application has high usability due to its simple, intuitive, and user-friendly design and presents high scalability in the sense that it can easily be maintained and new features can easily be added. However, despite the previously mentioned, some aspects still remain to be solved, namely the necessary resources, i.e. a wireless internet connection and mobile devices, have not yet been provided to the nursing home.

6

CONCLUSIONS AND FUTURE WORK

Throughout this document, the project of designing and developing a mobile application for the health professionals of a Portuguese nursing home, namely one of the *Santa Casa da Misericórdia de Vila Verde* nursing homes, was described and presented in meticulous detail. Therefore, to conclude the present manuscript, a brief conclusion is presented in order to approach the main contributions achieved with the developed solution as well as improvements that could be applied in the future to improve the mobile application. In this sense, the present chapter is structured into two distinct sections.

At first, in Section 6.1, the main contributions and conclusions achieved through the development of the mobile application are presented. Finally, in Section 6.2, suggestions for future work and improvements that could be applied to enhance the mobile application are presented. Thereby, to this end, the research questions that were defined in Chapter 1, more specifically, in Section 1.3, are directly answered in the sections hereafter in order to highlight the main conclusions reached with this research project as well as future prospects.

6.1 MAIN CONTRIBUTIONS

As mentioned in previous chapters, the present master's dissertation aimed to introduce Health Information and Communication Technology in a Portuguese nursing home suffering from the consequences of the aging population and the usage of rudimentary methods and, subsequently, take advantage of the benefits provided by HICT in order to improve elders' quality of life and the nursing care delivered. Therefore, considering the issues and challenges faced by the *Santa Casa da Misericórdia de Vila Verde* nursing home used as a case study, a mobile application was designed and developed for the health professionals working in the facility in order to help them manage the residents and assist them at the point-of-care.

In this context, a set of research questions were identified in Chapter 1 in order to sustain this research project. Although these research questions have already been answered

directly or indirectly throughout this manuscript, concise answers are presented in order to respond to each question and, consequently, identify the main conclusions and contributions of this project.

Question 1: What is the current state regarding the adoption of Health Information and Communication Technology of the *Santa Casa da Misericórdia de Vila Verde* nursing home?

The answer to this first research question was obtained through focus groups, semi-structured interviews, and questionnaires conducted with the professionals working for both the *Santa Casa da Misericórdia de Vila Verde* nursing home and hospital. Additionally, observation of the case study was also performed in order to have a better understanding of the conditions of the nursing home. Thereby, it was concluded that the current state regarding the adoption of Health Information and Communication Technology or even of any other form of technological progress is reduced and practically non-existent.

Moreover, although there is one computer in the nursing station, it is not used to document clinical information of the residents or even to schedule tasks. Therefore, there are not EHR or any other form of digital information, whereby all the information is stored in papers, and the health professionals have to use hand-written charts to record clinical information of the residents and to schedule tasks.

Furthermore, in the past, there was a failed attempt to implement a Web application, which aimed to shift from the paper-based to the computer-based management of data allowing the health professionals to schedule tasks, document them, and record clinical information. However, this application was rapidly abandoned as it was time-consuming (the health professionals constantly had to go back to the nursing station, where the computer is located, to use the application) and not user-friendly (a lot of time was required to schedule tasks and document information).

Question 1.1: How is the current state regarding the adoption of Health Information and Communication Technology affecting the work carried out by the health professionals and the quality of the nursing care delivered to elders?

The current state regarding the adoption of Health Information and Communication Technology in the nursing home used as a case study is affecting negatively the work carried out by the health professionals and the quality of the nursing care delivered to elders. In fact, since all the information is stored in papers, the management of information is a lot more time-consuming, especially at the point-the-care, as the professionals have to frequently return to the nursing station to have access to information. In addition to

this fact, it can lead to a higher occurrence of errors since the risk of losing, misplacing, forgetting, and documenting information in the wrong place is higher.

Moreover, regarding the scheduling of nursing interventions, the use of hand-written charts and boards is particularly problematic since it is more prone to errors, confusing, and less organized. Finally, all of the above mentioned combined with the fact that the number of health professionals is low compared to the number of elderly people leads to the work overload of health professionals and, consequently, to the decrease of the nursing care delivered.

Question 2: What are the current needs of the *Santa Casa da Misericórdia de Vila Verde* nursing home regarding the use of Health Information and Communication Technology?

In light of the answers provided to the two previous questions and through the focus groups, semi-structured interviews, and questionnaires conducted, it was obvious that the nursing home needed to introduce Health Information and Communication Technology and take advantage of its benefits. In fact, the health professionals manifested their wish to have a mobile application that would allow them to be anywhere in the nursing home and being able to manipulate information and schedule their daily tasks instead of recording information in papers and frequently return to the nursing station.

Question 2.1: How could the use of Health Information and Communication Technology help overcome some of the challenges faced by the health professionals?

The use of Health Information and Communication Technology, namely of a mobile application, would help health professionals to have access and manipulate information at the point-of-care without having to return to the nursing station to do so. Consequently, it would help reduce time-waste and ease the access and manipulation of information. Additionally, a mobile solution would help reduce the occurrence of errors compared to the paper-based management of data as it decreases the risk of misplacing, losing, or forgetting information. In fact, by manipulating information directly at the point-of-care, the health professionals would be able to record information in the moment and, thus, avoid lapses. Regarding the scheduling of nursing interventions, the solution would help turn this process less confusing and more organized compared to hand-written boards. Therefore, all of the benefits mentioned above would ultimately lead to the enhancement of the nursing care delivered and elders' quality of life, to the optimization of the processes occurring in the nursing home, and to the decrease of the work overload experienced by health professionals.

Question 3: How to promote and successfully introduce Health Information and Communication Technology, namely a mobile application, in the *Santa Casa da Misericórdia de Vila Verde* nursing home in order to face and overcome the challenges faced by the institution?

Mobile Health solutions are frequently underutilized or even abandoned since they are developed without truly understanding and meeting the needs of their intended users, hence leading to low quality and inaccurate applications. In this context, the key to successfully introduce Health Information and Communication Technology, namely a mobile application, in the *Santa Casa da Misericórdia de Vila Verde* nursing home resided in the inclusion of the health professionals during all the phases of the design and development of the solution. In fact, through frequent focus groups, semi-structured interviews, and questionnaires conducted with the health professionals, it was possible to obtain valuable and crucial knowledge about their needs and opinion on the features and information that should be included in the solution. Therefore, with this knowledge, it was possible to design and develop a mobile application that actually meets the needs of the health professionals and, hence, that would be used by them in order to face and overcome the challenges faced by the facility.

In addition to the above mentioned, the solution needs to have a user-friendly, intuitive, and simple design in order to be used by the health professionals. In fact, mobile applications that are not easy to use and user-friendly are more likely to be abandoned, as it was the case with the Web application previously implemented in the nursing home.

Question 3.1: How could the implementation of a mobile application be beneficial for the nursing home?

A mobile application similar to the one developed for this dissertation would decrease time-waste and ease the access and manipulation of information as it would help the health professionals to have access and manipulate information at the point-of-care without having to constantly return to the nursing station to do so. Additionally, the solution would help reduce the occurrence of errors since the health professionals are less likely to misplace, lose, or forget information if they are able to manipulate it at the point-of-care. Furthermore, regarding the scheduling of nursing interventions, the solution would help turn this process less confusing and more organized.

Considering the above mentioned, the mobile application would ultimately enable to improve elders' quality of life and the nursing care delivered as well as reduce some of the work overload experienced by the health professionals. Therefore, in the long-term, the solution would greatly benefit the nursing home as it would improve the overall performance

of the facility as well as of the health professionals and optimize some of the processes occurring in the facility.

Question 3.2: Which healthcare services or tasks performed by the health professionals of the nursing home in question could benefit from the use of Health Information and Communication Technology, namely of a mobile application?

The paper-based management of data is one of the main challenges faced by the nursing home due to the many disadvantages inherent to this unsophisticated method, which is confusing and less organized. In fact, through focus groups, semi-structured interviews, and questionnaires, the health professionals revealed the need for an application that would allow them to have access and manipulate information in a more organized, easier, and faster way, namely to schedule nursing interventions, to record and view evaluations of the residents, and to have access and manipulate their clinical information. Additionally, since the vast majority of the nursing interventions performed daily by nurses is related to wound care, the health professionals manifested their wish to have a specific module for this task in order to be able to rapidly and easily record the evolution of the wounds and their treatments.

Question 3.3: Which features should be integrated in a mobile application that has as main purpose to assist and help the health professionals of the nursing home in question?

In order to assist and help the health professionals of the *Santa Casa da Misericórdia de Vila Verde* nursing home, the mobile application encompasses all the nursing procedures performed by the health professionals. Therefore, the solution allows the professionals to have access and manipulate personal information as well as clinical information of the residents. Furthermore, the mobile application enables the health professionals to write clinical and nursing notes and evaluations of the residents as well as consult their history. Additionally, the health professionals are able to schedule nursing interventions as well as confirm their execution or cancel them. Finally, one of the most important features included in the mobile application is related to wound care in which they are able to rapidly and easily record and consult the evolution of the wounds and their treatments.

Question 3.4: In order to develop these features, which are the relevant data that should be recorded in the database?

Taking into account the features that were implemented in the mobile application, the database created allows the storage of data related to the users of the mobile application

as well as personal data and clinical information related to the residents. In this context, personal data related to the informal caregivers and personal contacts of the residents can also be stored. Additionally, the database enables to store the clinical and nursing notes written by the health professionals as well as the evaluations of the residents. Data related to the nursing home, the wounds and the medical and inpatient reports of the residents, and the nursing interventions scheduled are also stored in the database. Finally, it is also important to enable the storage of technical data, such as the types and sizes of urinary catheters and nasogastric tubes available, among others.

Question 4: Which clinical and performance Business Intelligence indicators should be created when enough data are gathered in order to assist the decision-making process?

In order to improve the decision-making process, it is important to define clinical and performance BI indicators that enable to highlight opportunities as well as problem areas existing in the nursing home. Therefore, in the future, when enough data are gathered, it is envisioned to create at least the following indicators:

- Percentage of nursing interventions realized per nurse;
- Total of realized and unrealized nursing interventions per month;
- Variation of the capillary blood glucose of a given resident over time;
- Percentage of wounds per resident;
- Percentage of wounds per wound type;
- Percentage of nursing interventions realized annually per type of nursing intervention.

Question 5: Which are the ethical issues that may arise from the implementation of Health Information and Communication Technology, namely a mobile application, in the *Santa Casa da Misericórdia de Vila Verde* nursing home?

One of the main ethical issues associated with the implementation of Health Information and Communication Technology are privacy and confidentiality issues. In fact, due to the vast amounts of EHR and other types of data produced daily in healthcare organizations, patients are fearful that their confidentiality and privacy are compromised and not guaranteed, since, compared to the traditional paper-based management of data, technological advancements made access to data and the break of privacy easier. In this sense, legal issues may arise if sensitive information of the users is disclosed without their consent. On the

other hand, regarding the introduction of mHealth solutions in healthcare settings, ethical issues may arise if they are being used without having a complete understanding of their effectiveness, accuracy, quality, and associated risks, which can harm healthcare delivery.

Question 5.1: How could these ethical issues be safeguarded and guaranteed in order to ensure the quality, accuracy, and safety of the mobile application?

The implementation of measures to avoid ethical issues remains a difficult task to perform, but it should always be considered a priority when developing HICT solutions. Thus, regarding confidentiality and privacy issues, it is important to define data access policies in order to give information access only to authorized users, which was the case with this solution. Furthermore, every time data are manipulated, i.e. inserted, deleted, and updated, the institution identification number of the health professionals responsible is recorded in the database. On the other hand, the mobile application was validated and evaluated with the health professionals to guarantee its quality, accuracy, correct use, safety, and importance in the nursing home.

Question 6: Which are the long-term implications and benefits of the mobile application developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home?

In the long-term, the mobile application would allow easier and faster access and manipulation of the information by the health professionals compared to the paper-based management of data since, after some time, a paper-based process is composed by several pages. Additionally, it would help reduce time-waste and errors and, hence, improve elders' quality of life and the nursing care delivered as well as reduce some of the work overload experienced by health professionals. Furthermore, it would help improve the overall performance of the nursing home and health professionals as well as optimize some of the processes occurring in the facility.

6.2 Prospect for Future Work

The research project developed aimed to introduce Health Information and Communication Technology in a Portuguese nursing home suffering from the consequences of the aging population and the usage of rudimentary methods in order to help the health professionals to clinically manage the residents and to assist them at the point-of-care. Subsequently, by taking advantage of the benefits provided by HICT, the present master's dissertation aimed to improve elders' quality of life and the nursing care delivered as well as reduce some of the work overload experienced by health professionals.

In the previous section, the main contributions and conclusions achieved were highlighted through the answers provided to each research question. However, the last research question was left unanswered and is, therefore, approached hereafter in order to identify future improvements to be applied to enhance the mobile application.

Question 7: Which improvements should be applied and could be beneficial to the mobile application developed for the *Santa Casa da Misericórdia de Vila Verde* nursing home?

First and foremost, one of the most important steps before improving the mobile application, is to provide the necessary resources to the nursing home since, without them, the health professionals would not be able to use the solution. Thus, it is intended to provide mobile devices, such as tablets and mobile phones, and a reliable wireless internet connection in order for the mobile application to be used. Afterwards, it is intended to populate the database defined and developed with the appropriate data, namely data related to the health professionals and residents. It is important to mention that the database already contains technical data (e.g. the sizes and types of urinary catheters and nasogastric tubes available and types of wounds, among others) since this information was gathered through the help of the health professionals.

On the other hand, it is envisioned to design and develop a Web application that could assist the mobile application and, hence, integrate some of its features. In this sense, the Web application would integrate most of the features of the mobile application allowing the health professionals to manage the residents from a computer if they prefer to do so. Additionally, it is intended to integrate into the Web application a module to manage the users of the applications. Furthermore, it is also envisioned to integrate a Business Intelligence module in which the clinical and performance indicators referred in Section 4.5 would be included. However, this module would only be available when enough data are gathered since, otherwise, the knowledge acquired would not be meaningful and valuable.

Finally, in the long-term, it is planned to introduce the mobile and Web applications to the rest of the *Santa Casa da Misericórdia de Vila Verde* nursing homes. Therefore, considering the above mentioned, it is envisioned to encourage the continuous maintenance, growth, and expansion of HICT solutions in nursing homes.

Therefore, in light of what has been mentioned throughout this manuscript, it is possible to conclude that all of the objectives identified in Section 1.3 have been successfully achieved.

BIBLIOGRAPHY

[1] Rana Mostaghel. Innovation and technology for the elderly: Systematic literature review. *Journal of Business Research*, 69(11):4896–4900, 2016.

[2] Mu-Hsing Kuo, Shu-Lin Wang, and Wei-Tu Chen. Using information and mobile technology improved elderly home care services. *Health Policy and Technology*, 5(2):131–142, 2016.

[3] Daniel Howdon and Nigel Rice. Health care expenditures, age, proximity to death and morbidity: implications for an ageing population. *Journal of Health Economics*, 57:60–74, 2018.

[4] Ricardo Costa, Paulo Novais, José Machado, Carlos Alberto, and José Neves. Inter-organization cooperation for care of the elderly. In *Integration and Innovation Orient to E-Society Volume 2*, pages 200–208. Springer, 2007.

[5] United Nations. World population prospects: The 2015 revision, key findings and advance tables. Technical report, Department of Economic and Social Affairs, Population Division, 2015.

[6] Ana Cristina Pereira. Os centros de dia atraem cada vez menos idosos, mas os lares estão cheios. https://www.publico.pt/2018/12/15/sociedade/noticia/centros-dia-atraem-menos-lares-estao-cheios-1854827#gs.lswiFrPB, 2018. Accessed: 2019-04-05.

[7] RTP. Segurança social encerrou 109 lares ilegais em 2018. https://www.rtp.pt/noticias/pais/seguranca-social-encerrou-109-lares-ilegais-em-2018_v1125675, 2019. Accessed: 2019-04-05.

[8] Romana Borja-Santos. Falta de profissionais de saúde nos lares coloca idosos em risco. https://www.publico.pt/2015/10/29/sociedade/noticia/quase-20-dos-idosos-em-lares-cairam-pelo-menos-uma-vez-em-meio-ano-1712731#gs.hJfTaLa5, 2015. Accessed: 2019-04-05.

[9] DN/Lusa. Portugueses em risco devido à falta de enfermeiros que estão exaustos. https://www.dn.pt/portugal/interior/portugueses-em-risco-devido-a-falta-de-enfermeiros-que-estao-exaustos---bastonaria-9075853.html, 2018. Accessed: 2019-04-05.

[10] Gregory L Alexander and Douglas S Wakefield. Information technology sophistication in nursing homes. *Journal of the American Medical Directors Association*, 10(6):398–407, 2009.

[11] W Broughton, H Lashlee, C Marcum, and GM Wilson. Health information technology: a new world of nursing homes. *Journal of Gerontology and Geriatric Research*, 2, 2013.

[12] Geneviève Rouleau, Marie-Pierre Gagnon, and José Côté. Impacts of information and communication technologies on nursing care: an overview of systematic reviews (protocol). *Systematic Reviews*, 4(1), 2015.

[13] Shmuel Reis, Adriaan Visser, and Richard Frankel. Health information and communication technology in healthcare communication: the good, the bad, and the transformative. *Patient Education and Counseling*, 3(93):359–362, 2013.

[14] Giuseppe Aceto, Valerio Persico, and Antonio Pescapé. The role of information and communication technologies in healthcare: taxonomies, perspectives, and challenges. *Journal of Network and Computer Applications*, 107:125–154, 2018.

[15] Marisa Esteves, António Abelha, and José Machado. The development of a pervasive web application to alert patients based on business intelligence clinical indicators: a case study in a health institution. *Wireless Networks*, pages 1–7, 2019.

[16] Kathrin M Cresswell and Aziz Sheikh. Health information technology in hospitals: current issues and future trends. *Future Hospital Journal*, 2(1):50–56, 2015.

[17] Michelle Ko, Laura Wagner, and Joanne Spetz. Nursing home implementation of health information technology: Review of the literature finds inadequate investment in preparation, infrastructure, and training. *INQUIRY: The Journal of Health Care Organization, Provision, and Financing*, 55:1–10, 2018.

[18] Quan Wei and Karen L Courtney. Nursing information flow in long-term care facilities. *Applied Clinical Informatics*, 9(02):275–284, 2018.

[19] Vahid Yazdi-Feyzabadi, Mozhgan Emami, and Mohammad Hossein Mehrolhassani. Health information system in primary health care: the challenges and barriers from local providers' perspective of an area in iran. *International Journal of Preventive Medicine*, 6, 2015.

[20] Mohammad Nabil Almunawar and Muhammad Anshari. Health information systems (HIS): concept and technology. *Computing Research Repository*, abs/1203.3923, 2012.

[21] Putu Wuri Handayani, Achmad Nizar Hidayanto, and Indra Budi. User acceptance factors of hospital information systems and related technologies: Systematic review. *Informatics for Health and Social Care*, 43(4):401–426, 2018.

[22] Mark A Musen, Blackford Middleton, and Robert A Greenes. Clinical decision-support systems. In *Biomedical Informatics*, pages 643–674. Springer, 2014.

[23] Christian Castaneda, Kip Nalley, Ciaran Mannion, Pritish Bhattacharyya, Patrick Blake, Andrew Pecora, Andre Goy, and K Stephen Suh. Clinical decision support systems for improving diagnostic accuracy and achieving precision medicine. *Journal of Clinical Bioinformatics*, 5(1), 2015.

[24] C Lee Ventola. Mobile devices and apps for health care professionals: uses and benefits. *Pharmacy and Therapeutics*, 39(5), 2014.

[25] Timothy Dy Aungst. Medical applications for pharmacists using mobile devices. *Annals of Pharmacotherapy*, 47(7-8):1088–1095, 2013.

[26] Francisca Fonseca, Hugo Peixoto, Jorge Braga, José Machado, and António Abelha. Smart mobile computing in pregnancy care. In Gordon Lee and Ying Jin, editors, *Proceedings of 34th International Conference on Computers and Their Applications*, volume 58 of *EPiC Series in Computing*, pages 219–224. EasyChair, 2019.

[27] Mirela Prgomet, Andrew Georgiou, and Johanna I Westbrook. The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. *Journal of the American Medical Informatics Association*, 16(6):792–801, 2009.

[28] Darrell West et al. How mobile devices are transforming healthcare. *Issues in Technology Innovation*, 18(1):1–11, 2012.

[29] Marie-Pierre Gagnon, Marie Desmartis, Michel Labrecque, Josip Car, Claudia Pagliari, Pierre Pluye, Pierre Frémont, Johanne Gagnon, Nadine Tremblay, and France Légaré. Systematic review of factors influencing the adoption of information and communication technologies by healthcare professionals. *Journal of Medical Systems*, 36(1):241–277, 2012.

[30] Birgitta Lindberg, Carina Nilsson, Daniel Zotterman, Siv Söderberg, and Lisa Skär. Using information and communication technology in home care for communication between patients, family members, and healthcare professionals: a systematic review. *International Journal of Telemedicine and Applications*, 2013, 2013.

[31] Panayiotis Ketikidis, Tomislav Dimitrovski, Lambros Lazuras, and Peter A Bath. Acceptance of health information technology in health professionals: An application of

the revised technology acceptance model. *Health Informatics Journal*, 18(2):124–134, 2012.

[32] Gregory L Alexander and Richard Madsen. It sophistication and quality measures in nursing homes. *Journal of Gerontological Nursing*, 35(7):22–27, 2009.

[33] Leonor Teixeira, Carlos Ferreira, and Beatriz Sousa Santos. User-centered requirements engineering in health information systems: A study in the hemophilia field. *Computer Methods and Programs in Biomedicine*, 106(3):160–174, 2012.

[34] John Øvretveit, Tim Scott, Thomas G Rundall, Stephen M Shortell, and Mats Brommels. Improving quality through effective implementation of information technology in healthcare. *International Journal for Quality in Health Care*, 19(5):259–266, 2007.

[35] J Tabibi, Amir Ashkan Nasiripour, Reza Baradaran Kazemzadeh, Ali Akbar Farhangi, and Parvin Ebrahimi. Effective factors on hospital information system acceptance: A confirmatory study in iranian hospitals. *Middle-East Journal of Scientific Research*, 9(1):95–101, 2011.

[36] Maryati Mohd Yusof, Anastasia Papazafeiropoulou, Ray J Paul, and Lampros K Stergioulas. Investigating evaluation frameworks for health information systems. *International Journal of Medical Informatics*, 77(6):377–385, 2008.

[37] Judith Sligo, Robin Gauld, Vaughan Roberts, and Luis Villa. A literature review for large-scale health information system project planning, implementation and evaluation. *International Journal of Medical Informatics*, 97:86–97, 2017.

[38] Júlio Duarte, Carlos Filipe Portela, António Abelha, José Machado, and Manuel Filipe Santos. Electronic health record in dermatology service. In *International Conference on ENTERprise Information Systems*, pages 156–164. Springer, 2011.

[39] Madison N Ngafeeson. Healthcare information systems opportunities and challenges. In *Encyclopedia of Information Science and Technology, Third Edition*, pages 3387–3395. IGI Global, 2015.

[40] Dean F Sittig and Hardeep Singh. A new socio-technical model for studying health information technology in complex adaptive healthcare systems. In *Cognitive Informatics for Biomedicine*, pages 59–80. Springer, 2015.

[41] Kathrin Cresswell and Aziz Sheikh. Organizational issues in the implementation and adoption of health information technology innovations: an interpretative review. *International Journal of Medical Informatics*, 82(5):e73–e86, 2013.

[42] Andre W Kushniruk, David W Bates, Michael Bainbridge, Mowafa S Househ, and Elizabeth M Borycki. National efforts to improve health information system safety in canada, the united states of america and england. *International Journal of Medical Informatics*, 82(5):e149–e160, 2013.

[43] Vassilios P Aggelidis and Prodromos D Chatzoglou. Hospital information systems: Measuring end user computing satisfaction (eucs). *Journal of Biomedical Informatics*, 45(3):566–579, 2012.

[44] Kathrin M Cresswell, David W Bates, and Aziz Sheikh. Ten key considerations for the successful implementation and adoption of large-scale health information technology. *Journal of the American Medical Informatics Association*, 20(e1):e9–e13, 2013.

[45] Iroju Olaronke and Ojerinde Oluwaseun. Big data in healthcare: Prospects, challenges and resolutions. In *2016 Future Technologies Conference (FTC)*, pages 1152–1157. IEEE, 2016.

[46] Suranga N Kasthurirathne, Burke Mamlin, Harsha Kumara, Grahame Grieve, and Paul Biondich. Enabling better interoperability for healthcare: lessons in developing a standards based application programing interface for electronic medical record systems. *Journal of Medical Systems*, 39(11), 2015.

[47] Olaronke Iroju, Abimbola Soriyan, Ishaya Gambo, and Janet Olaleke. Interoperability in healthcare: benefits, challenges and resolutions. *International Journal of Innovation and Applied Studies*, 3(1):262–270, 2013.

[48] José Machado, António Abelha, Jose Neves, and Manuel Santos. Ambient intelligence in medicine. In *2006 IEEE Biomedical Circuits and Systems Conference*, pages 94–97. IEEE, 2006.

[49] Miguel Miranda, Júlio Duarte, António Abelha, José Manuel Machado, and José Neves. Interoperability and healthcare. 2009.

[50] Luciana Cardoso, Fernando Marins, Filipe Portela, António Abelha, and José Machado. Healthcare interoperability through intelligent agent technology. *Procedia Technology*, 16:1334–1341, 2014.

[51] Hugo Peixoto, Manuel Santos, António Abelha, and José Machado. Intelligence in interoperability with AIDA. In *International Symposium on Methodologies for Intelligent Systems*, pages 264–273. Springer, 2012.

[52] R Rogers, Y Peres, and W Müller. Living longer independently - a healthcare interoperability perspective. *e & i Elektrotechnik und Informationstechnik*, 127(7-8):206–211, 2010.

[53] Sónia Pereira, Filipe Portela, Manuel Filipe Santos, José Machado, and António Abelha. Predicting type of delivery by identification of obstetric risk factors through data mining. *Procedia Computer Science*, 64:601–609, 2015.

[54] Ximeng Liu, Rongxing Lu, Jianfeng Ma, Le Chen, and Baodong Qin. Privacy-preserving patient-centric clinical decision support system on naive bayesian classification. *IEEE journal of Biomedical and Health Informatics*, 20(2):655–668, 2016.

[55] Claúdia Brito, Marisa Esteves, Hugo Peixoto, António Abelha, and José Machado. A data mining approach to classify serum creatinine values in patients undergoing continuous ambulatory peritoneal dialysis. *Wireless Networks*, pages 1–9, 2019.

[56] José Neves, Henrique Vicente, Marisa Esteves, Filipa Ferraz, António Abelha, José Machado, Joana Machado, João Neves, Jorge Ribeiro, and Lúzia Sampaio. A deep-big data approach to health care in the AI age. *Mobile Networks and Applications*, 23(4):1123–1128, 2018.

[57] David Arnott and Graham Pervan. A critical analysis of decision support systems research revisited: the rise of design science. In *Enacting Research Methods in Information Systems*, pages 43–103. Springer, 2016.

[58] Patrick Emanuel Beeler, David Westfall Bates, and Balthasar L Hug. Clinical decision support systems. *Swiss Medical Weekly*, 144(5152), 2014.

[59] Júlio Duarte, Maria Salazar, Cesar Quintas, Manuel Santos, José Neves, António Abelha, and José Machado. Data quality evaluation of electronic health records in the hospital admission process. In *2010 IEEE/ACIS 9th International Conference on Computer and Information Science*, pages 201–206. IEEE, 2010.

[60] José Neves, Manuel Santos, José Machado, António Abelha, Sollari Allegro, and Maria Salazar. Electronic health records and decision support local and global perspectives. *WSEAS Transactions on Biology and Biomedicine*, 5(8):189–198, 2008.

[61] Miguel Miranda, António Abelha, Manuel Santos, José Machado, and José Neves. A group decision support system for staging of cancer. In *International Conference on Electronic Healthcare*, pages 114–121. Springer, 2008.

[62] Yvonne O'Connor and Philip O'Reilly. Examining the infusion of mobile technology by healthcare practitioners in a hospital setting. *Information Systems Frontiers*, 20(6):1297–1317, 2018.

[63] Marie-Pierre Gagnon, Patrice Ngangue, Julie Payne-Gagnon, and Marie Desmartis. m-health adoption by healthcare professionals: a systematic review. *Journal of the American Medical Informatics Association*, 23(1):212–220, 2015.

[64] Rasool Nouri, Sharareh R Niakan Kalhori, Marjan Ghazisaeedi, Guillaume Marchand, and Mobin Yasini. Criteria for assessing the quality of mhealth apps: a systematic review. *Journal of the American Medical Informatics Association*, 25(8):1089–1098, 2018.

[65] Bruno MC Silva, Joel JPC Rodrigues, Isabel de la Torre Díez, Miguel López-Coronado, and Kashif Saleem. Mobile-health: A review of current state in 2015. *Journal of Biomedical Informatics*, 56:265–272, 2015.

[66] Siddique Latif, Rajib Rana, Junaid Qadir, Anwaar Ali, Muhammad Ali Imran, and Muhammad Shahzad Younis. Mobile health in the developing world: Review of literature and lessons from a case study. *IEEE Access*, 5:11540–11556, 2017.

[67] Neil Foshay and Craig Kuziemsky. Towards an implementation framework for business intelligence in healthcare. *International Journal of Information Management*, 34(1):20–27, 2014.

[68] Wilfred Bonney. Applicability of business intelligence in electronic health record. *Procedia-Social and Behavioral Sciences*, 73:257–262, 2013.

[69] Aleš Popovič, Ray Hackney, Pedro Simões Coelho, and Jurij Jaklič. Towards business intelligence systems success: Effects of maturity and culture on analytical decision making. *Decision Support Systems*, 54(1):729–739, 2012.

[70] Marisa Esteves, Filipe Miranda, José Machado, and António Abelha. Mobile collaborative augmented reality and business intelligence: A system to support elderly people's self-care. In *World Conference on Information Systems and Technologies*, pages 195–204. Springer, 2018.

[71] Yichuan Wang, LeeAnn Kung, and Terry Anthony Byrd. Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. *Technological Forecasting and Social Change*, 126:3–13, 2018.

[72] Marisa Esteves, Filipe Miranda, and António Abelha. Pervasive business intelligence platform to support the decision-making process in waiting lists. In *Next-generation Mobile and Pervasive Healthcare Solutions*, pages 186–202. IGI Global, 2018.

[73] Andreia Brandão, Eliana Pereira, Marisa Esteves, Filipe Portela, Manuel Santos, António Abelha, and José Machado. A benchmarking analysis of open-source business intelligence tools in healthcare environments. *Information*, 7(4), 2016.

[74] Celina M Olszak and Kornelia Batko. The use of business intelligence systems in healthcare organizations in poland. In *2012 Federated Conference on Computer Science and Information Systems*, pages 969–976. IEEE, 2012.

[75] Saeed Rouhani, Amir Ashrafi, Ahad Zare Ravasan, and Samira Afshari. The impact model of business intelligence on decision support and organizational benefits. *Journal of Enterprise Information Management*, 29(1):19–50, 2016.

[76] Surajit Chaudhuri, Umeshwar Dayal, and Vivek Narasayya. An overview of business intelligence technology. *Communications of the ACM*, 54(8):88–98, 2011.

[77] Borut Hočevar and Jurij Jaklič. Assessing benefits of business intelligence systems–a case study. *Management: Journal of Contemporary Management Issues*, 15(1):87–119, 2010.

[78] João Ferreira, Miguel Miranda, António Abelha, and José Machado. O processo etl em sistemas data warehouse. In *INForum*, pages 757–765, 2010.

[79] Shaker H Ali El-Sappagh, Abdeltawab M Ahmed Hendawi, and Ali Hamed El Bastawissy. A proposed model for data warehouse etl processes. *Journal of King Saud University-Computer and Information Sciences*, 23(2):91–104, 2011.

[80] Salvatore T March and Alan R Hevner. Integrated decision support: A data warehousing perspective. In *AIS SIGDSS Pre-ICIS Workshop Research Directions on Decision Support*. Citeseer, 2003.

[81] Cesar Analide, Paulo Novais, José Machado, and José Neves. Quality of knowledge in virtual entities. In *Encyclopedia of Communities of Practice in Information and Knowledge Management*, pages 436–442. IGI Global, 2006.

[82] Ilse M Wallace. Is patient confidentiality compromised with the electronic health record?: a position paper. *CIN: Computers, Informatics, Nursing*, 33(2):58–62, 2015.

[83] Karim Abouelmehdi, Abderrahim Beni-Hessane, and Hayat Khaloufi. Big healthcare data: preserving security and privacy. *Journal of Big Data*, 5(1), 2018.

[84] Kuan Zhang, Kan Yang, Xiaohui Liang, Zhou Su, Xuemin Shen, and Henry H Luo. Security and privacy for mobile healthcare networks: from a quality of protection perspective. *IEEE Wireless Communications*, 22(4):104–112, 2015.

[85] Satish Misra, Thomas Lorchan Lewis, and Timothy Dy Aungst. Medical application use and the need for further research and assessment for clinical practice: creation and integration of standards for best practice to alleviate poor application design. *JAMA Dermatology*, 149(6):661–662, 2013.

[86] R Hevner Von Alan, Salvatore T March, Jinsoo Park, and Sudha Ram. Design science in information systems research. *MIS Quarterly*, 28(1):75–105, 2004.

[87] Ken Peffers, Tuure Tuunanen, Marcus A Rothenberger, and Samir Chatterjee. A design science research methodology for information systems research. *Journal of Management Information Systems*, 24(3):45–77, 2007.

[88] Salvatore T March and Veda C Storey. Design science in the information systems discipline: an introduction to the special issue on design science research. *MIS Quarterly*, 32(4):725–730, 2008.

[89] Alan Hevner and Samir Chatterjee. Design science research in information systems. In *Design Research in Information Systems*, pages 9–22. Springer, 2010.

[90] V.K. Vaishnavi. *Design Science Research Methods and Patterns: Innovating Information and Communication Technology*. CRC Press, 2007.

[91] T.M. Connolly and C.E. Begg. *Database Systems: A Practical Approach to Design, Implementation, and Management*. International Computer Science Series. Addison-Wesley, 2005.

[92] M. Widenius, D. Axmark, and K. Arno. *MySQL Reference Manual: Documentation from the Source*. O'Reilly Series. O'Reilly Media, Incorporated, 2002.

[93] John L Viescas and Michael James Hernandez. *SQL Queries for Mere Mortals: a hands-on guide to data manipulation in SQL*. Pearson Education, 2014.

[94] Gustavo Alonso, Fabio Casati, Harumi Kuno, and Vijay Machiraju. Web services. In *Web Services*, pages 123–149. Springer, 2004.

[95] D Booth, H Haas, Francis Mccabe, E Newcomer, I M. Champion, C Ferris, and D Orchard. Web services architecture, w3c working group note. *Concurrency and Computation: Practice and Experience - CONCURRENCY*, 2004.

[96] Quan Z Sheng, Xiaoqiang Qiao, Athanasios V Vasilakos, Claudia Szabo, Scott Bourne, and Xiaofei Xu. Web services composition: A decade's overview. *Information Sciences*, 280:218–238, 2014.

[97] Francisco Curbera, Matthew Duftler, Rania Khalaf, William Nagy, Nirmal Mukhi, and Sanjiva Weerawarana. Unraveling the web services web: an introduction to soap, wsdl, and uddi. *IEEE Internet Computing*, 6(2):86–93, 2002.

[98] Lorna Jane Mitchell. *PHP Web Services: APIs for the Modern Web*. O'Reilly Media, Inc., 2016.

[99] Kishor Wagh and Ravindra Thool. A comparative study of soap vs rest web services provisioning techniques for mobile host. *Journal of Information Engineering and Applications*, 2(5):12–16, 2012.

[100] Snehal Mumbaikar, Puja Padiya, et al. Web services based on soap and rest principles. *International Journal of Scientific and Research Publications*, 3(5):1–4, 2013.

[101] Fatna Belqasmi, Jagdeep Singh, Suhib Younis Bani Melhem, and Roch H Glitho. Soap-based vs. restful web services: A case study for multimedia conferencing. *IEEE Internet Computing*, 16(4):54–63, 2012.

[102] Bonnie Eisenman. *Learning react native: building native mobile apps with javascript*. O'Reilly Media, Inc., 2015.

[103] Erik Johansson and Jesper Söderberg. Evaluating performance of a react native feature set, 2018.

[104] Niclas Hansson and Tomas Vidhall. Effects on performance and usability for cross-platform application development using react native, 2016.

[105] Facebook. React Native. http://facebook.github.io/react-native/, 2019. Accessed: 2019-04-26.

[106] Microsoft Corporation. What is power BI. https://powerbi.microsoft.com/en-us/what-is-power-bi/, 2019. Accessed: 2019-05-28.

[107] Catherine Elizabeth Kendig. What is proof of concept research and how does it generate epistemic and ethical categories for future scientific practice? *Science and Engineering Ethics*, 22(3):735–753, 2016.

[108] Boonyarat Phadermrod, Richard M Crowder, and Gary B Wills. Importance-performance analysis based swot analysis. *International Journal of Information Management*, 44:194–203, 2019.

[109] Joseph William Bull, N Jobstvogt, A Böhnke-Henrichs, A Mascarenhas, N Sitas, C Baulcomb, CK Lambini, M Rawlins, H Baral, J Zähringer, et al. Strengths, weaknesses, opportunities and threats: A swot analysis of the ecosystem services framework. *Ecosystem Services*, 17:99–111, 2016.

[110] A. Sarsby. *SWOT Analysis*. Spectaris Limited, 2016.

[111] GJ Hay and G Castilla. Object-based image analysis: strengths, weaknesses, opportunities and threats (swot). In *Proc. 1st Int. Conf. OBIA*, pages 4–5, 2006.

[112] Emet Gürel and Merba Tat. Swot analysis: A theoretical review. *Journal of International Social Research*, 10(51), 2017.

[113] Paul Legris, John Ingham, and Pierre Collerette. Why do people use information technology? a critical review of the technology acceptance model. *Information & Management*, 40(3):191–204, 2003.

[114] Fred D Davis. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, pages 319–340, 1989.

[115] Fred D Davis, Richard P Bagozzi, and Paul R Warshaw. User acceptance of computer technology: a comparison of two theoretical models. *Management Science*, 35(8):982–1003, 1989.

[116] Mark Turner, Barbara Kitchenham, Pearl Brereton, Stuart Charters, and David Budgen. Does the technology acceptance model predict actual use? a systematic literature review. *Information and Software Technology*, 52(5):463–479, 2010.

[117] Filipe Portela, Manuel Filipe Santos, José Manuel Machado, António Abelha, José Neves, Álvaro Silva, and Fernando Rua. Intelligent decision support in intensive care: towards technology acceptance. 2012.

[118] Tero Pikkarainen, Kari Pikkarainen, Heikki Karjaluoto, and Seppo Pahnila. Consumer acceptance of online banking: an extension of the technology acceptance model. *Internet Research*, 14(3):224–235, 2004.

[119] Jen-Her Wu and Shu-Ching Wang. What drives mobile commerce?: An empirical evaluation of the revised technology acceptance model. *Information & Management*, 42(5):719–729, 2005.

[120] Viswanath Venkatesh and Fred D Davis. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, 46(2):186–204, 2000.

[121] PC Lai. The literature review of technology adoption models and theories for the novelty technology. *Journal of Information Systems and Technology Management*, 14(1):21–38, 2017.

[122] Viswanath Venkatesh and Hillol Bala. Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, 39(2):273–315, 2008.

[123] Viswanath Venkatesh. Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information Systems Research*, 11(4):342–365, 2000.

A

QUESTIONNAIRE TO ASSESS THE NEEDS AND CHALLENGES ENCOUNTERED IN THE NURSING HOME

Table 2.: Questionnaire to assess the needs and challenges encountered in the nursing home

Question
1. What is the current state relatively to the adoption of Information and Communication Technology in nursing homes? Justify the reasons associated with the current state of the adoption of technology in nursing homes.
2. In your opinion, what are the current needs, relatively to the adoption of Information and Communication Technology, of health professionals working in nursing homes? Justify to what extend Information and Communication Technology could help overcome the challenges and difficulties these health professionals may encounter.
3. Which are the relevant data that should be stored in databases in order to develop this type of solution. Justify the relevance and how these data could be used.
4. Which are the tasks and services performed by health professionals in nursing homes that would benefit from emerging technologies? Justify your answer.
5. In your opinion, which are the clinical and performance indicators that should be created? Justify how each indicator would be relevant.
6. Which are the features that should be integrated in a mobile application that has as main purpose to assist health professionals working in nursing homes? Justify how each feature would be relevant and necessary.
7. Which are the ethical issues underlying the proposed solution and which may arise during its design, development, implementation, and use?

Question
8. In your opinion, how this type of solution would benefit health professionals working in nursing homes and which are the long-term impacts of the mobile application? Justify your answer.

B

QUESTIONNAIRE BASED ON THE TAM3 TO ASSESS THE ACCEPTANCE OF THE MOBILE APPLICATION

Table 3.: Questionnaire based on the Technology Acceptance Model 3 to assess the acceptance of the mobile application

Question	**1**	**2**	**3**	**4**	**5**
Perceived ease of use					
The mobile application is easy to use.					
I can easily manage the residents of the nursing home at the point-of-care with the mobile application.					
I am able to easily have access to information with the mobile application.					
I am able to easily record information with the mobile application.					
I can easily manipulate information with the mobile application.					
I am able to easily schedule tasks and record their execution with the mobile application.					
The mobile application is not confusing and I can easily recognize where I am and navigate through it.					
The information is displayed in the application in an appealing, organized, and understandable way.					
The mobile application is visually appealing.					
The terms and language used in the mobile application are understandable and adequate.					

Question	1	2	3	4	5
The use of the mobile application is effortless and is not time-consuming.					
Job relevance					
The mobile application is relevant and appropriate to perform my job-related tasks.					
Output quality					
The mobile application is capable of assisting me at the point-of-care.					
The mobile application is capable of assisting me while I perform my job-related tasks.					
Result demonstrability					
The features provided by the mobile application are useful to perform my job-related tasks.					
Computer self-efficacy					
I could use the mobile application to perform my job-related tasks if there was no one to tell me what to do as I go.					
I could use the mobile application to perform my job-related tasks if I had never used an application like this one before.					
I could use the mobile application to perform my job-related tasks if someone showed be how to use it first.					
I could use the mobile application to perform my job-related tasks if I had used a similar application before this one to do the same job.					
Perceptions of external control					
The nursing home has the available resources to enable and assist the use of the mobile application.					
Computer anxiety					
I am fearful and have apprehension resulting from the possibility of using the mobile application.					
Perceived enjoyment					

Question	1	2	3	4	5
The use of the mobile application is enjoyable and not unpleasant.					
Experience					
I have had experience, in the past or currently, with applications similar to this one.					
I have had experience, in the past or currently, with information technology solutions.					
Voluntariness					
The use of the mobile application is voluntary and results of my own free will.					
Perceived usefulness					
The use of the mobile application is useful in my job.					
The use of the mobile application can improve my job performance.					
The use of the mobile application can help me perform my tasks more quickly.					
The use of the mobile application can help me have access and manipulate information at the point-of-care.					
The mobile application can help me manage the residents of the nursing home at the point-of-care.					
The mobile application is useful to schedule my job-related tasks and record their execution.					
The mobile application addresses my job related needs.					
Behavioural intention					
I intend to use the mobile application to assist me at my job.					
I intend to use the mobile application to help me perform my job-related tasks.					
Use behaviour					
I intend to frequently and consistently use the mobile application to assist me at my job.					

Question	1	2	3	4	5
I intend to frequently and consistently use the mobile application to help me perform my job-related tasks.					

C

PUBLICATIONS

C.1 PREDICTING POSTOPERATIVE COMPLICATIONS FOR GASTRIC CANCER PATIENTS USING DATA MINING

AUTHORS: Hugo Peixoto, Alexandra Francisco, Ana Duarte, Márcia Esteves, Sara Oliveira, Vítor Lopes, António Abelha, and José Machado

TITLE: Predicting Postoperative Complications for Gastric Cancer Patients using Data Mining

CONFERENCE: 10th EAI International Conference, INTETAIN 2018: Intelligent Technologies for Interactive Entertainment

YEAR OF PUBLICATION: 2018

ABSTRACT: Gastric cancer refers to the development of malign cells that can grow in any part of the stomach. With the vast amount of data being collected daily in healthcare environments, it is possible to develop new algorithms which can support the decision-making processes in gastric cancer patients treatment. This paper aims to predict, using the CRISP-DM methodology, the outcome from the hospitalization of gastric cancer patients who have undergone surgery, as well as the occurrence of postoperative complications during surgery. The study showed that, on one hand, the RF and NB algorithms are the best in the detection of an outcome of hospitalization, taking into account patients' clinical data. On the other hand, the algorithms J48, RF, and NB offer better results in predicting postoperative complications.

KEYWORDS: Data Mining, Clinical Decision Support Systems, CRISP-DM, Gastric Cancer, WEKA.

STATE OF PUBLICATION: Published

C.2 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 of the 5th International Conference on Information and Communication Technologies for Ageing Well and e-Health

YEAR OF PUBLICATION: 2019

ABSTRACT: The rapidly aging population has been a matter of concern over the years since this problem 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 any time, 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.3 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 International Journal of Reliable and Quality E-Healthcare

YEAR OF PUBLICATION: 2019

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.4 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

SPECIAL ISSUE: Architectures and Platforms for Smart and Sustainable Cities

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 in the facility in order to better 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: Submitted