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The enthusiastic participation of all attendees at the Symposium brings great satisfaction to the DEI Management.

We would like to begin by expressing our sincere thanks to the ISEP Management Bodies, with a special mention to the Presidency's President, Maria João Viamonte, for her support and presence at the inauguration of the event. Our sincere thanks also go to the DEI Management team, in particular to Director Joaquim Filipe dos Santos, for his assistance in organising and facilitating the event's infrastructure.

Additionally, we would like to express our special appreciation to our esteemed guests, both speakers and panelists of the roundtable discussions, for their invaluable contributions to the Symposium. In particular, we want to highlight the significant role played by our colleague Constantino Martins in organising the roundtable.

We extend our gratitude to all the distinguished speakers who generously shared their wealth of experience and in-depth scientific knowledge, enriching the knowledge-sharing experience for all participants. A sincere thank you also goes out to the authors, the members of the Technical-Scientific Committee, the participants, and all those who contributed with their enthusiasm and dedication to make this event a success.

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Symposium's Vision

The Computer Engineering Symposium 2023 (SEI'23) serves as a dynamic hub where the latest breakthroughs, research findings, and innovative solutions in computer engineering converge, originating from the works of graduates, master's students, and doctoral candidates. It provides a fertile ground for students, professionals, and researchers to engage in lively discussions, exchange ideas, and explore emerging trends shaping the field.

At SEI'23, participants delve into a myriad of topics spanning various domains within computer engineering, drawing from the expertise and research efforts of bachelor's, master's, and doctoral candidates. From Artificial Intelligence (AI) and Machine Learning to Cybersecurity and Data Science, the symposium encompasses a broad spectrum of disciplines. Participants have the opportunity to explore advancements in Computer Networks, Cloud Computing, and Internet of Things (IoT), gaining insights into the transformative potential of these technologies.

Furthermore, SEI'23 acts as a catalyst for interdisciplinary collaboration, bridging the gap between theory and practice, with contributions from graduates, master's students, and doctoral candidates. Participants delve into areas such as Human-Computer Interaction (HCI), Software Engineering, and Embedded Systems, uncovering new possibilities for innovation and application.

Through SEI'23, we aim to inspire a new generation of innovators, empower future leaders, and drive meaningful progress in computer engineering, fuelled by the collective efforts of graduates, master's students, and doctoral candidates. By fostering a culture of collaboration, knowledge-sharing, and continuous learning, we contribute to the advancement of the field and its positive impact on society. Together, we chart a course towards a future where technology serves as a catalyst for positive change, with contributions from graduates, master's students, and doctoral candidates, and where innovation knows no bounds.

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Invited Speakers

Américo Amorim Pinto Ciberbit

Carlos Ribeiro ARS Norte

Marílio Cardoso Instituto Superior de Engenharia do Porto

João Fonseca FMUP

José Afonso Pedrosa CHSJ

Liliana Antão DEUS.ai

Luís Miguel Ferreira SPMS

Keynote Session

Bias Unmasked: Exploring Fairness in AI Systems



Liliana Antão
DEUS.ai

Biography

Liliana Antão is a Data Scientist at DEUS.ai, boasting a robust background in engineering and research with a focus on AI and machine learning. Currently pursuing a Ph.D. at the Faculty of Engineering, University of Porto (FEUP), Liliana explores the application of AI in human-robot collaboration. In her current role, she engages in diverse projects, spanning Natural Language Processing to AI model monitoring. Leveraging her expertise, Liliana is dedicated to propelling innovation and positive change in AI.

Round Table

DESAFIOS DA DIGITALIZAÇÃO NA SAÚDE

Moderator



Marílio Cardoso
ISEP

Biography

Marílio Cardoso has a BSc (5 years degree) in Electrical Engineering – Power Systems, School of Engineering (ISEP) of P.Porto and a PhD in Information Technology Research Research, at University of Santiago de Compostela. He is Adjunct Professor at ISEP. He has been instructor in several courses on energy efficiency and use of energy. Since 2008 he is member of ISEP Sustainable Commission and since 2020 he is deputy director of the department of Computer Engineering of ISEP. He authored or co-authored several conference papers and has participated in some international projects. His main interests are learning to code, innovative educational systems and solutions, centered in the teaching of computer science and also sustainability.

Participants



Américo Amorim Pinto
Ciberbit

Biography

Américo Amorim Pinto, an Engineering Informatics graduate from the Faculty of Sciences and Technology, University Nova de Lisboa, and an MBA executive from Porto Business School, serves as the CEO of Ciberbit since 2018. Previously, he held positions on the board of several companies within the Trofa Saúde Group and coordinated global information systems for the VNC group. Américo Amorim Pinto's professional journey includes years in consulting, contributing to national and international projects in Financial Business Intelligence and Data Treatment across sectors like Telecommunications, Banking, Insurance, Public Administration, and Industry.



Carlos Ribeiro
ARS Norte

Biography

Carlos Ribeiro, holding a degree in Business Informatics from the University of Minho, completed the Senior Management Course in Public Administration at INA in 2006. Since 2012, he has been a member of the Telemedicine Working Group under the Secretary of State for Health. Currently serving as the Technical Coordinator for the Information Systems Functional Area at ARS Norte, Carlos Ribeiro is directly involved in various Primary Healthcare Information Systems projects, and indirectly oversees hospital projects in the Northern region.



João Fonseca
FMUP

Biography

João Fonseca, Head of the Department of Community Medicine, Information, and Health Decision Sciences at Porto University Medical School (FMUP). A Full Professor ('Professor Catedrático') of Clinical Research, João is also a co-founder of MEDIDA, Lda, and leads the Allergy Unit at CUF Porto. As a researcher at CINTESIS and RiSE, he has contributed significantly, co-directing the Harvard Medical School Portugal Program in 2011-12 and serving on the Health Technologies Assessment Committee of INFARMED (Portuguese Medicines Agency) from 2016-22. His research interests encompass Patient-centered innovation, mobile Health, Patient-Reported Outcomes, health technologies assessment, and implementation science.



José Afonso Pedrosa
CHSJ

Biography

Afonso Pedrosa is the Director of the Data Intelligence Service at São João Hospital Centre and a member of the Working Group of the Portuguese Association of Hospital Administration (APAH) - Health Information Management. He holds a Postgraduate degree in Hospital Administration and a Bachelor's degree in Applied Mathematics, specializing in Computer Science.



Luís Miguel Ferreira
SPMS

Biography

Luís Miguel Ferreira, Executive Board Member at SPMS, holds a Ph.D. in Information Technologies and Systems from the University of Minho, School of Engineering. With a background in Mathematics and a Master's in Mathematics Teaching from the University of Porto, he also completed postgraduate studies in Healthcare Management at Católica Porto Business School. Formerly President of the Board of Directors at Hospital de Ovar, Luís Miguel Ferreira has been part of ministerial offices, including the Secretary of State for Budget (1999), the National Coordinator for the Lisbon Strategy and Technological Plan (2006-2009), and the Secretary of State for Energy and Innovation (2009-2011).

Papers



A Gamified Application for Multimodal Diagnosis and Monitoring of Neurodegenerative Diseases

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Abstract. The global aging population, a consequence of advancements in healthcare, has led to a surge in age-related diseases, particularly neurodegenerative conditions affecting over 30 million individuals worldwide. Presently, there is no cure for these diseases, and the financial burden on patients is exacerbated by intensive individual monitoring conducted by technicians. Some of these challenges can be effectively addressed using the here reported, named "Mentalist". The application, mainly tailored for individuals with Parkinson's but also adequate for other neurodegenerative conditions, is a non-invasive solution that can offer cost-effective monitoring of the disease, while fostering enhanced adherence to therapy. Inspired on guidelines and employing gamification techniques, the application integrates diagnostic assessments from the medical field. Using a Python/Flask backbone the application is platform agnostic and ensures scalability while relying in a robust framework. The interface prioritizes user-friendliness, with easy navigation and simplicity for patients with neurodegenerative diseases. Neurologists closely supervised the development, ensuring alignment with clinical practices. Expert evaluation affirms the application's significance, as it covers crucial aspects of diagnosis, monitoring, and rehabilitation, making it a valuable tool for daily clinical use. This innovative approach leverages technology to address the growing challenges posed by neurodegenerative diseases, offering a practical and impactful solution for healthcare professionals and patients.

Keywords: Neurodegenerative diseases · Digital Health · Gamification · Remote patient monitoring · Aging population.

1 Introduction

The improved healthcare services and living conditions around the world are contributing to an increase in the average life expectancy of the world's population. This has led to an increase in the prevalence of age-related diseases in society, especially neurodegenerative diseases (ND) [7], which are a group of pathologies that cause the deterioration and death of neurons in the brain, leading to a variety of impairments. Symptoms depend on the region of the brain that is being affected and may include memory loss, decreased cognitive ability, and abnormal movements [12]. Neurological diseases, which are mainly composed by

ND, have become a leading cause of disability in the world, reaching 11.6% of the dalys and 16.5% of all deaths, ranking second only behind cardiovascular diseases [4]. ND affect over 30 million people worldwide [3], and since there is currently no cure, these pathologies have devastating consequences for patients and their families, with almost 7 million people dying from it every year [1].

The literature states that the monitoring and training of individuals with ND can improve or, at least, stabilize, the cognitive and motor functions [6]. However, traditional approaches are expensive and inconvenient for patients and their families, which originates a reduction in adherence [11]. As a result, multiple digital approaches, which are more cost-effective and practical, are becoming increasingly relevant for rehabilitation [9].

These new types of approaches aim to decrease the costs on rehabilitation and follow-up, increase the number of available data for physicians, and increase patient motivation and adherence to treatment by using approaches that are more intuitive, accessible and interesting from the patient's point of view.

The digital smartphone stores are currently flooded with a variety of games, tests and tasks that claim to improve cognition domains, such as memory or processing speed, however, most of them are not supported by any scientific studies or designed for the specific needs of these patients [15]. On the other hand, applications developed specifically for these target groups seem to not have a lot of traction and market share.

Considering the problem at hand, there is evidence that there is room for new solutions that take advantage of the constant development of technology to facilitate the access to new types of healthcare, reduce expenses for rehabilitation, and make two-way communication between doctors and patients easier and simpler. The suggested solution is a web-based application that includes brain stimulation and enhance cognitive ability through games, common assessments used by doctors that can be filled online and the possibility to report their symptoms and medication times. Healthcare professional can then monitor the patient's evolution according to a set of parameters obtained from those interactions, study the effects of the medication on the patients' symptoms and adjust the medication accordingly. The application includes games, assessments and surveys used regularly by doctors in face-to-face diagnosis, information regarding the most common diseases and the presentation of the results for analysis by the responsible health professionals.

In next section a brief overview of the involved pathologies and the existing digital health solutions is provided. From this, the proposed application is described, extensively covering its main aspects and functionalities. The conclusions are finally provided along with some envisioned work.

2 Neurodegenerative Diseases

Neurological disorders are the main cause of physical and cognitive disability worldwide, affecting approximately 15% of the worldwide population, according to 2023 data [5]. The total number of patients have considerably increased

over the past 30 years. To properly evaluate these diseases it is important to understand how they affect humans and what are the main symptoms. A brief overview of Parkinson's and Alzheimer's, the most prevalent conditions, will be provided in the next two paragraphs.

Parkinson's disease (PD) exacts a considerable and growing burden on individuals, families, and healthcare systems worldwide. As a progressive neurodegenerative disorder, its prevalence is on the rise with the aging global population. PD is characterized by the degeneration of dopamine-producing neurons in the substantia nigra region of the brain, leading to a range of motor and non-motor symptoms. Beyond the classical motor impairments like tremors and bradykinesia, the physiological aspects of PD involve intricate disruptions in neurotransmitter regulation and neural circuitry. A deeper exploration of Parkinson's disease pathology and physiology is vital not only for unraveling the intricacies of the condition but also for advancing targeted therapeutic strategies and enhancing the overall quality of life for those affected by this challenging disorder.

As a prevalent neurodegenerative disorder, Alzheimer's disease (AD) imposes a profound impact on individuals, families, and global healthcare systems. The hallmark symptoms encompass memory loss, impaired reasoning, and changes in behavior. The physiological underpinnings of Alzheimer's involve disruptions in synaptic function, neurotransmitter imbalances, and inflammatory responses. As the world grapples with an aging population, showing that the complexities of Alzheimer's disease pathology and physiology becomes paramount for developing effective therapeutic interventions. A holistic comprehension of AD is essential not only for managing the current burden but also for shaping future strategies aimed at alleviating the impact of this pervasive and challenging neurodegenerative condition.

3 Development

For the development of the application, a set of 38 functional and 10 non-functional requirements were collected, based on information collected from doctors and patients. Functional requirements cover several features related with the diagnostic and monitoring of patients but also operational aspects, such as fail-safe operation and information security. Non-functional requirements covered easy of use, considering the target population, but also speed, among others. The user activities and application features were carefully planned to address the most wide variety of possibilities, covering distinct modalities and functional brain areas. Figure 1 shows an Activity Diagram constructed in UML notation that covers every potential navigation that occurs in the system, that is, how the user can perform all of its activities and use all the application features.

The application front-end also has a doctors' menu (not shown), where clinician can access their patients' records and their performance charts on each activity. For healthcare professionals, the information that is provided for each activity covers all the metrics that can be extracted, so the best perspective can be considered for each case.

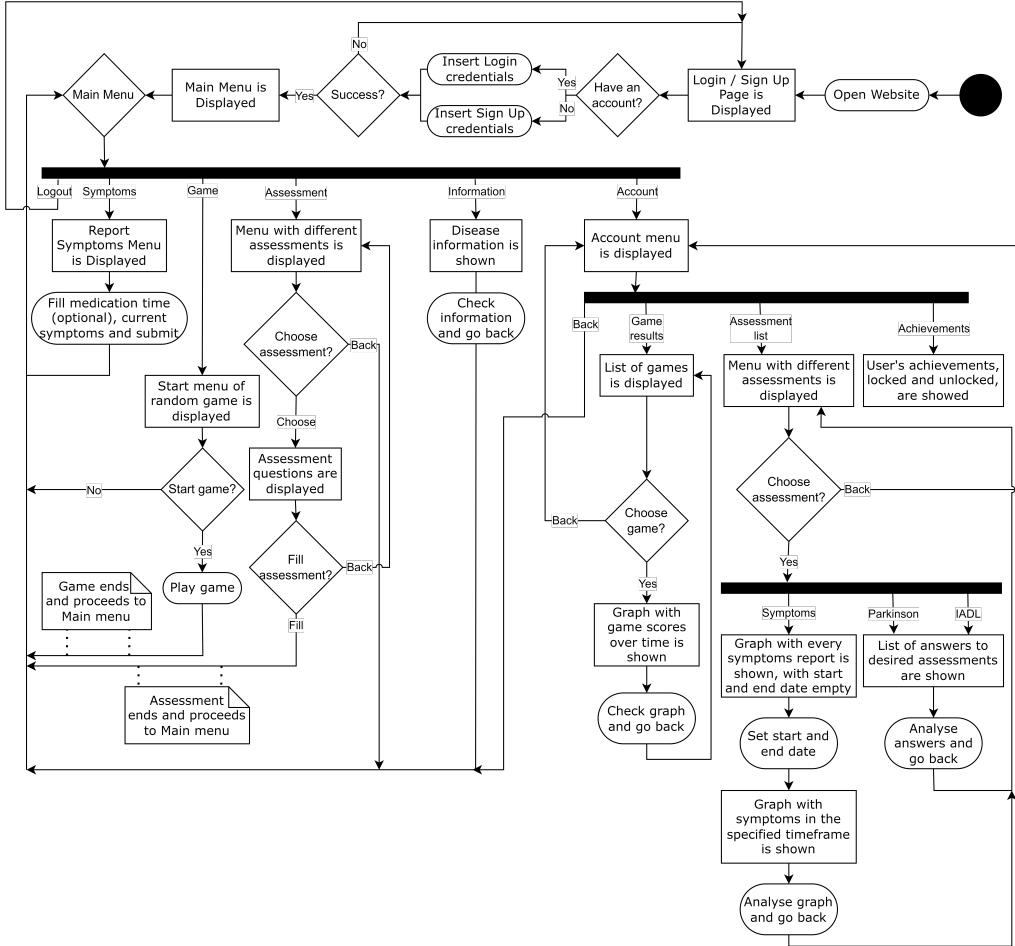


Fig. 1. Activity diagram for the proposed application.

The adoption of Python in conjunction with the Flask framework has supported the presented developments. This setup offers several advantages for web applications. Python's readability, simplicity, and versatility contribute to faster development cycles and a more intuitive coding experience. Flask, a modular lightweight micro-framework, seamlessly integrates with Python, providing a straightforward yet powerful foundation for web applications. Its minimalist design empowers developers to choose and integrate components according to project requirements, fostering flexibility and scalability. The extensive ecosystem of Python libraries and frameworks further enhances Flask's capabilities, enabling the incorporation of various functionalities with ease. Additionally, Flask's built-in development server simplifies testing and debugging processes. The combination of Python and Flask facilitates rapid prototyping, efficient development, and easy maintenance, making it an ideal choice for a diverse range of web applications, from small-scale projects to complex, feature-rich platforms.



Fig. 2. Registration, login and main menu.

4 Application

The application was developed with the purpose of being used by a Portuguese population and for this reason all the interface uses European Portuguese.

Fig. 2(a) displays the sign-up screen, where users are able to create their accounts. To log in, users can enter their email address and password or their username and password in the text fields displayed in Fig. 2(b). After a successful login or registration, user are redirected to the main menu of the application, Fig. 2(c), being presented with a variety of options. Related with the previous menu, users can logout by clicking in the last button of the main menu, with the text "TERMINAR SESSÃO" (END SESSION), returning to the authentication page. The remaining buttons on the screen allow to access different menus. The first button opens the page to report the symptoms and medication times, the "JOGAR" (PLAY) button redirects to the games menu, the "QUESTIONÁRIO" (QUESTIONNAIRE) button leads to the assessments menu, the "INFORMAÇÕES" (INFORMATION) button opens the information page and the "CONTA" (ACCOUNT) button opens the account options menu.

As specified, the main menu button "COMO ESTÃO OS SEUS SINTOMAS?" (HOW ARE YOUR SYMPTOMS?), opens the page responsible for collecting the user current symptoms and store the medication intake times. The button was added to the main page to make it as accessible as possible, as this feature

should be used frequently during the day. An example of the page filled in with the time of medication and current symptoms is displayed in Fig. 3(a).

Also from the main menu page, "JOGAR" (PLAY), leads to the games submenu, Fig. 3(b), where the user can choose the game to play. The first button, "ALEATÓRIO" (RANDOM), selects a game at random, while the others redirect to the desired game. The randomness of the game selection takes into account the device type, so that the balance game is not chosen for devices without the necessary sensors. In order, the buttons open the following games: reaction, tapping, memory, draw, balance and speech. The games play an important role in the application, retrieving parameters that can help characterize different symptoms of patients. The data obtained from each game session includes how long it took to complete the game and how well the player performed.

The first game developed has the objective of measuring the user's reaction time, a parameter that can be related to the processing speed and executive function. With the deterioration of the brain in ND, the reduction of neurons originates a slow down on brain availability, leading to a worse reaction time. Thus, would be expected to see an increase in the result of this game as the disease progresses. When playing, user is faced with a colored square which, after a random amount of time, changes its color. The user must touch as quick as possible after the color change in order to record the least amount of time. Another game, the tapping game, can be used as a diagnostic tool, since it allows to detect impairments in the motor function by analysing the user tapping ability. It is expected that the deterioration of the user ability in this game correlates with the deterioration in motor functions that patients suffer as the disease worsens. This game layout is similar to the Reaction Game, however, when the color changes, user have to tap on the screen as many times as possible during the following 10 seconds.

The memory game, as in Fig. 3(c) has the goal of measuring a common symptom of ND, but not as relevant for Parkinson's. Following the initial premises of this investigation, where the application would be suitable for the general ND, the game was created focusing on the Alzheimer's disease main symptom, the deterioration of the patients' memory. The game is the traditional memory game, where the user has to find the pairs of cards.

The kinematics of the drawing are effective at indicating physiological parameters, such as the amplitude of tremors, the main symptom of Parkinson's. The drawing game was included to see the evolution of the patients tremors with aging, since the drawing accuracy can be correlated with the disease current state. The spiral draw, as in Figure 4(a), is frequently used by physicians because it is a complex coordinated motor activity, which allows experts to predict and monitor the evolution of Parkinson's. The drawing game also included the "Clock drawing task", as in Figure 4(b).

The balance game was designed to measure patients' tremors more objectively than the drawing game. The user is asked to keep the device as still as possible while playing the game to receive the highest score. Any rotation or translation of the device will subtract from the initial total points. This game

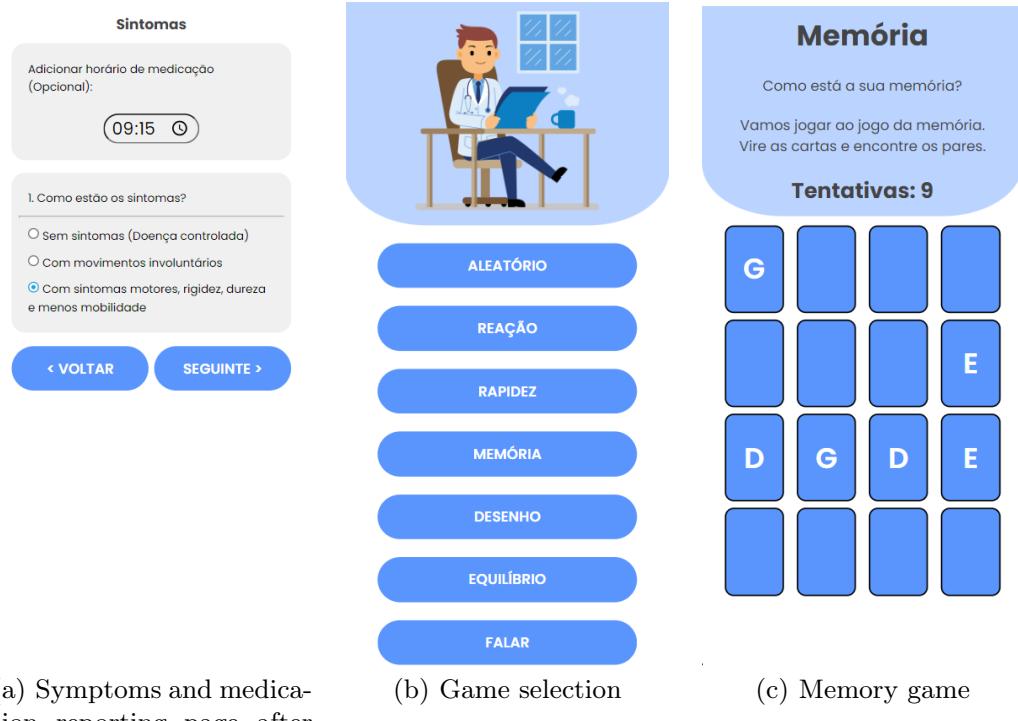


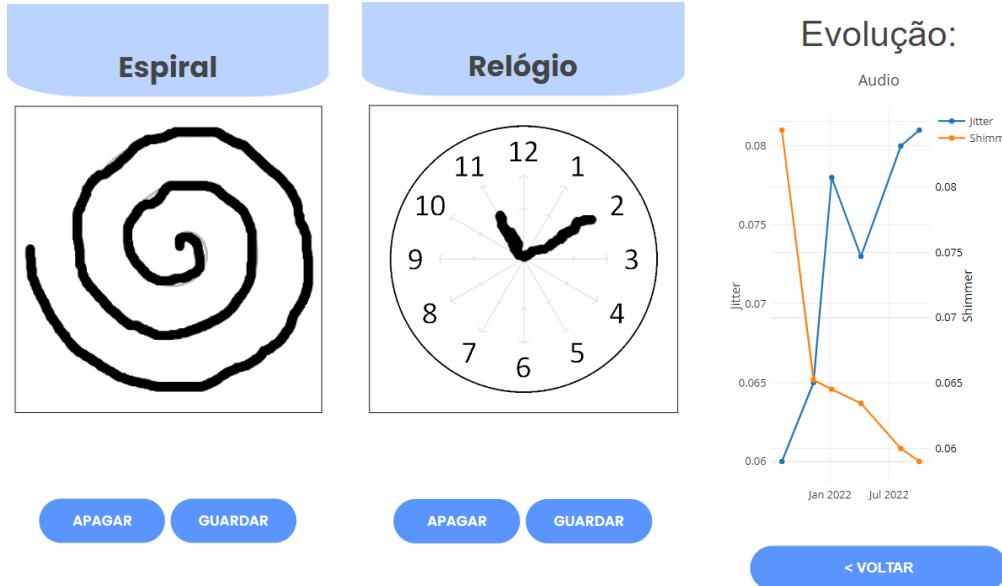
Fig. 3. Medication self-reporting and Games.

is only available for mobile devices due to the lack of accelerometers and gyroscopes on computers, therefore the application will be redirected to the games submenu if this condition is not met.

It has been demonstrated that speech can be used as an effective biomarker for the detection of several ND and also to track their progression [2, 13, 14]. For these purposes the user is asked to pronounce a sustained vowel /a/ during 5 seconds. With the recording, the *parselmouth* module is invoked to interface Python/Flask with a specific command line script that allowed the calculation of voice parameters, and with these provide an estimation of voice health.

The proposed application keeps track of the user scores for each game, which are simultaneously health indicators. These are graphically presented in the form of a time chart, facilitating the analysis of the evolution of the patients' symptoms, and therefore a better evaluation of the progress of the disease. The different games measure different parameters which result in different charts, such as the one in Fig. 4(c) about the speech game.

On the clinicians perspective, it is important that the application allows that patients can provide a self-report, especially in the days after therapy adjustment, allowing to establish a correlation with dosage and symptoms. The answers to commonly used medical assessments are useful for doctors to have at their disposal, regardless of how often they change. These assessments can also help



(a) Spiral drawing game. (b) Clock drawing game. (c) Game score evolution

Fig. 4. Games and scores.

to diagnose diseases in healthy people and monitor the evolution of patients. For these purposes, the standard UPDRS [8] scale is used, as well as other questionnaires used for the management of ND.

Finally, to increase the patient adherence to the application, gamification techniques were also incorporated, using some of the strategies described in [10]. Points and badges are tokens that can be collected by the user upon the completion of tasks or missions. Some of the achievements and how they are unlocked are described in Table 1, each being awarded with a corresponding badges (not shown).

5 Conclusion

In this paper, an innovative application designed for the multimodal diagnosis and monitoring of neurodegenerative diseases was presented, with a primary focus on Parkinson's and Alzheimer's patients. While the application's features were tailored for these specific populations, the versatility of most options enables seamless integration into the diagnostic framework of various other diseases.

Through the measurement of reaction time, speed, memory, drawing, balance, and speech, the application offers a comprehensive, multimodal approach to input, providing a nuanced exploration of numerous brain functions. The user's performance is tracked over time, offering valuable insights into disease

Table 1. List of achievements available in the app and how to unlock it.

Task	Achievement	Points
Player	Play at least one game.	5
Reaction	Play at least once the reaction game.	10
Speed	Play at least once the tapping game.	10
Memory	Play at least once the memory game.	10
Draw	Play at least once the draw game.	10
Balance	Play at least once the balance game.	10
Speech	Do at least once the speech test.	20
Master	Play all games at least once.	50
Assessment	Do at least one assessment.	20
Symptoms	Indicate at least once how you feel about your symptoms.	20
UPDRS	Perform at least once the UPDRS assessment.	20
Tasks	Perform at least once the daily activities assessment.	10
Daily mission	Perform a set of tasks for the day.	50

progression and serving as a tool to assess the efficacy of therapeutic interventions. Moreover, as part of an active aging program, the application serves as a motivational tool for users' wellness assessment, aiding in the early detection of symptoms and triggering alerts for further medical examination.

To enhance user engagement, gamification strategies have been incorporated, making the application not only clinically valuable but also enjoyable for users. Recognizing the importance of the medical practitioner's perspective, we integrated questionnaires commonly used in clinical practice. These questionnaires facilitate patient follow-up in a telemedicine setting, strengthening the application's utility for both patients and doctors.

Overall, the proposed application holds great promise in improving outcomes and reducing costs associated with neurodegenerative disease management. Looking ahead, future work will involve the incorporation of additional features to track a broader spectrum of symptoms and the expansion of language support to make the application more accessible globally.

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Automatic Concept Explanation

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Abstract. Technical terms are an essential part of all technical and scientific documentation, whether directed to education, to research or to labour. In education settings, there is a need to provide clear definitions of terms; using a glossary explaining the meaning of each technical term is paramount to enter a new study field. It is exactly at this last point that equity and inclusion issues originate. One cannot expect that a deaf person used to communicate via sign language can understand spoken language. When forcing deaf students to study via written spoken languages, we are putting them at a disadvantage and compromising equity. There is a need for a tool that can introduce and explain to deaf students technical or scientific concepts from specific areas of knowledge in sign language.

We expect that Information Extraction techniques can help generate explanations of concepts that do not exist in the sign language lexicon that can then be translated and played in sign language. The purpose of this paper is to present a solution that generates the explanations in textual. These explanations will be translated to sign language using the VirtualSign Application Programming Interface (API).

The developed solution involves an API designed to produce explanations for a word or concept, either by scraping online dictionaries or exploring text summarization. The API provides this information to a Web Application exposed to the users, and is responsible for receiving their input and displaying the information, along with the sign language translation using the VirtualSign avatar plugin.

The solution was tested and surveyed by end-users being deemed a valuable step toward inclusive education. The results of this survey are encouraging and motivate further work.

Keywords: Sign language · Automatic concept explanation · Web scrapping · Text summarization · API · Web application.

1 Introduction

According to the World Health Organization, as of March 2022, 1.5 billion people live with some degree of hearing loss, which leads to some having to resort to sign language to communicate [1].

Sign languages do not have a one-to-one correspondence between signs and words or concepts in spoken language, and sign language interpreters must have a deep understanding of both the sign language and the spoken language in order to accurately convey meaning. This problem is recurrent when it comes to scientific domains, for example, to understand a concept such as *nanotechnology*, for which there are no signs for, a sign language user has to access tools with content made for oral language users.

This project is the continuation of the work documented in "Explicação Automática de Conceitos" [2].

As it was already stated in the previous work, sign languages have a shorter vocabulary than oral languages because they rely on hand gestures, facial expressions and body language rather than sounds. This limited vocabulary is due to the physical constraints of conveying meaning through movement. Thus, concepts are the key aspect for meaningful learning [3], and the explanation of said concepts remains at the core of this paper.

Differences from the previous work include: fixing, polishing and implementing new features on the base provided. As well as deploying to production where it will be exposed to the target audience.

2 Related Work

Noraset Thanapon et al. [4] pursued a different method to accomplish a comparable objective. Thanapon employed a Deep Learning strategy, which employed a recurrent neural network (RNN) model with distributed representations of words, known as word embeddings, to produce dictionary representations. These models were trained on a pre-existing dataset.

Ni Ke et al. [5] also opted for a Deep Learning method that involved a RNN model to produce an interpretation of a given word or expression from "tweets", which are posts created by Twitter[6] users. The objective was to analyze non-standard expressions, including slang, featured in these posts. To train the RNN model, an online, user-contributed dictionary called Urban Dictionary [7] was utilized.

Giorgia Dinu et al. [8] attempted to create a sentence that accurately conveyed the meaning in a distributional vector. The method was evaluated in two test scenarios. The first scenario involved generating the phrase in English within a monolingual setting, while the second scenario was cross-lingual, in which the vector was initially used to generate the English phrase and then translate it to Italian.

William Dolan et al. [9] presented an automated approach to generate a lexical knowledge base using online dictionaries. The approach was utilized to

construct a directed graph that established semantic connections between words found in the Longman Dictionary of Contemporary English [10]. According to the authors, using a knowledge base offers more comprehensive information about a word's meaning compared to a typical lexical lookup.

Alan Akbik et al. [11] created an algorithm named Wanderlust, which automatically extracts semantic relationships from natural language text. The English Wikipedia [12] corpus was utilized to apply this algorithm and semantic relationships were obtained to populate a semantic wiki.

Atin Das et al. [13] proposed a theoretical model that resorts to Neural Networks to extract from an article what the authors refer to as "featured words". These "featured words" are the words that most accurately describe a particular article. As this is a theoretical study, there are no tests or specific use cases provided.

Amirata Ghorbani et al. [14] developed an algorithm that automatically extracts visual concepts and provides the data to a Machine Learning model, enhancing the model with concept-based explanations instead of feature-based explanations which are commonly used. One of the main drawbacks is it's functionality is restrained to only images.

Liana Ermakova et al. [15] proposed a system to simplify scientific literature. It is a three steps process that consists of: content selection, complexity spotting and text simplification. The study aims to make scientific papers easier to understand for everyone, including people not versed in scientific language.

In sum, the majority of works related to explaining a concept or word use Deep Learning and train neural networks to achieve a result. However, no works resort to Information Retrieval and Information Extraction to achieve the same goal.

3 Automatic Concept Explanation

The solution already existed and was improved upon. The main purpose of it remains the same but now it possesses more functionalities and its performance is improved.

The component diagram can be seen in Figure 1 below.

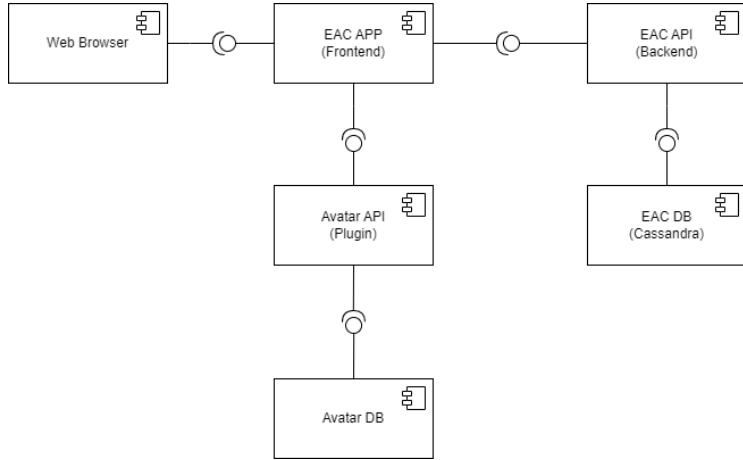


Fig. 1. Component Diagram

The work was performed on the EAC APP, EAC API and EAC DB components. EAC APP is the front-end application exposed to the user which implements the Virtualsign avatar developed by GILT. The avatar performs the sign language actions' by fetching what is present in Avatar DB.

The back-end service provides explanations to the front end. It is responsible for scraping online dictionaries, when requested, as well as Wikipedia pages when the summarization functionality is used. The explanations fetched from online dictionaries are stored in a Cassandra database, as well as auditing information from user actions.

This solution will provide explanations for a given word or concept and translate them to sign language with the help of an avatar installed via plugin on the front-end component.

It will fetch those explanations by web scraping online dictionaries and exposing those explanations to the user.

There is also the possibility to query for a summarization in an explanation. This is a slow process that will web scrape the Wikipedia⁵ page for the word queried and find similarities between the whole text of the page with the explanation clicked, in the hopes the explanation is clearer to the user.

3.1 Major Changes

Differences from the previous work include: fixing, polishing and implementing new features on the base provided. The base contained an outdated scraping mechanism for Portuguese online dictionary Priberam⁶ and the "skeleton" for the summarization algorithm.

The most notable change is the support for other language - sign language pairs. At the moment Portuguese, Slovenian, Greek, German, and Cypriot Greek

⁵ https://en.wikipedia.org/wiki/Main_Page

⁶ <https://dicionario.priberam.org/>

are implemented, each with their own online dictionary provided by the team of investigators and technicians around Europe involved with this project with ties to the deaf community.

There is also the addition of a functionality to rate the explanations positively or negatively, and these rating will impact the order they appear to the user in a new search.

A database was also added to provide resiliency and a stable response time. Each scraping to an online dictionary will save the explanations to always keep the explanations updated.

With these explanations, audit of the ratings for each explanations is also saved in the database together with geolocation information. At the moment, no functionality uses this information and there is no requirement for it in the future.

3.2 Improvements

Besides the major changes mentioned in the previous subsection, there was an improvement behind the scenes for the whole solution.

The communication between the services was improved, and are open to future change instead of restricting to single functionality like it was before.

The performance of web scraping algorithm of the online dictionary Pribleram⁷ was improved, making it simpler to understand for future developers and faster.

The summarization algorithm was also improved, although it's still not 100% apt to provide a good user experience. The read and write operations were reduced from 3 to 1 as to improve response time but there is a technical limitation to keeping that 1 read-write operation which is time consuming.

There was also the introduction of an explanation's context to the user, which some dictionaries can provide to facilitate the understanding of the word searched.

3.3 Limitations

Currently the developed solution contains some limitation regarding the explanations of concepts queried by the user.

One of these limitations is the concept can only contain one word instead of multiple.

There is also the limitation around the summarization of explanations. This summarization can sometimes not yield results and, apart from that, take too long to provide them.

The response times for querying explanations are dependant of the online dictionaries added, which, if the online dictionary is slow, increase the response time of the solution making the user experience decrease in quality.

⁷ <https://dicionario.priberam.org/>

4 Evaluation

To evaluate the effectiveness of the solution in applying Information Extraction and Information Retrieval techniques to generate explanations for a given word and translate them to sign language, a survey was distributed to the team of investigators and technicians of this project.

The original goal was to provide this survey to deaf people , but due to some constraints in filling the Avatar database with sign language, which would provide a bad user experience, the team of investigators and technicians of this project, who deal with sign language daily, took the survey instead.

The survey contained the following affirmations:

- The information is presented in an organized matter.
- The graphics of the application are pleasant.
- The functionalities are well explained in the "Help" page.
- The functionalities are intuitive and easy to use.
- The explanations are accurate.
- The response time of the application is adequate.
- The ability to display explanation and context images are helpful in understanding their meaning.
- The explanation rating system is helpful.
- I would like to use this application in the future.
- I will recommend this application to my peers.

The survey's distribution to the teams mentioned previously provided 20 answers, rated 1 to 4 according to the following scale in Table 1.

Table 1. Survey Scale

Scale	Description
1	Completely Disagree
2	Disagree
3	Agree
4	Completely Agree

The answers are displayed in Table 2 below, followed by an analysis of the results.

Table 2. Survey Answers

Question	1 (%)	2 (%)	3 (%)	4 (%)	Average
Q1	5	10	55	30	3.1
Q2	0	5	80	15	3.1
Q3	0	10	60	30	3.2
Q4	0	15	50	35	3.2
Q5	0	10	80	10	3
Q6	0	25	70	5	2.8
Q7	0	10	55	35	3.25
Q8	5	30	50	15	2.75
Q9	0	15	55	30	3.15
Q10	0	10	45	45	3.35

Although there were few answers and the target audience was not as originally planned, the total average of all questions' average is 3.09 which is positive since it's slightly above the "Agree" scale.

The lowest average is regarding the utility of the explanation rating system, followed by the application's response time. This concludes that there's a clear need in improving the response time of the application and adding some enhanced purpose to the rating system, or remove it altogether in the future when a similar survey to this is presented to deaf people and the answers remain in the negative side.

However, the highest averages are regarding recommending this application to other users and the utility of presenting images to further understand an explanation. This observation leads to the conclusion that this functionality should remain and be improved in the future, for example, presenting images in the app directly instead of opening a new tab in the browser.

5 Conclusions and Future Work

This document presents a broad overview of this iteration of the project that was developed.

The development of this iteration was smooth since there was a good communication between the author and the teams involved in the project, greatly facilitated by the co-authors.

No major technical issues were blockers or a problem overall since they were always tackled in timely fashion.

The only unfortunate scenario was the target audience not being the intended from the start, but the effective target audience provided great feedback and insights on how to move on with the project in the future.

Regarding future work, there is already contemplated work for next iteration, as well as improvements that originated from the feedback provided.

There is a clear opportunity to increase the solution's value by coming up with a requirement that utilizes the auditing that is already being performed.

There is also the need to make the solution's summarization functionality ready for use as it's currently bad user experience.

There is a clear improvement to be made regarding the response times of the solutions, which was raised in the survey.

Finally there is a need to reevaluate the rating system functionality as, from the survey, it seemed to be unnecessary.

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Classification of Road Traffic With an Artificial Intelligence Model

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Abstract. In the context of an internship of the bachelor in Computer Engineering, a distributed system was developed encompassing a cross-platform mobile application capable of using the device's camera to classify the level of road traffic level on the street across the internship host company's office, using an Artificial Intelligence (AI) model pretrained by the author. A state of art on AI on the topic is presented, as well as an analysis of the captured use cases, requirements and design choices. For the development process of the AI model multiple hypothesis were formulated for hyperparameter tuning. ResNet Finetuning with 3-Fold Cross Validation was the model with better performance, which was further confirmed by a dedicated testing dataset, reaching 97% accuracy. Additionally, the development process is described for the Master Data Artificial Intelligence (MDAI) Service and the Mobile Application, which allows the user to take pictures and classify the traffic level.

Keywords: Artificial Intelligence · Neural Network · Convolutional Neural Network · Traffic Classification · Transfer Learning · ResNet · Vision Transformer.

1 Introduction

1.1 Context

Xarevision created a proposal for an internship consisting on the development of a mobile app that, using a camera to photograph the street across their offices, could classify the level of road traffic, by using a pretrained AI model served on a Web service, in one of three levels: Low Traffic, Medium Traffic or High Traffic.

This project was used as a proof of concept to improve the know-how within the company regarding AI, more concretely the use of AI frameworks and its integration in mobile apps, to develop software that leverages those technologies.

1.2 Methodology

The work method across the whole project was the Rational Unified Process (RUP). The RUP is an iterative software engineering process framework, aimed

at guiding and standardizing the whole software development process [11]. It has an object oriented approach and uses Unified Modelling Language (UML) as its main notation. It proposes an agile method, divided in iterations, to be able to accommodate changes in the requirements without a big cost.

For the development of the AI model, the author used the Cross Industry Standard Process for Data Mining (CRISP-DM), the de-facto methodology for data mining development, which is very similar to the RUP, but applied to Data Mining projects. It consists of six phases [20]: Business Understanding; Dataset Understanding; Dataset Preparation; Modelling; Evaluation; and Deployment.

The development process is not linear. Sometimes, after data collection, preparation or even some modelling, the requirements change, or the performance of the model is underwhelming, hence more data needs to be collected (or a completely different dataset), prepared and other models created.

2 State of Art

In this section, an overview of the state of art on road traffic classification is presented, as means of comparison to the system being developed.

In the current literature, vision-based traffic density estimation methods can typically be divided into two subtasks: vehicle detection and vehicle counting [12].

Vehicle detection is divided into traditional machine vision methods and complex Deep Learning (DL) [19] methods. Traditionally, techniques such as background subtraction, continuous video frame difference, and optical flow have been widely used. The use of Convolutional Neural Network (CNN) [6] in vehicle object detection, with its strong ability to learn image features, has achieved great success. DL based methods can be divided into two categories:

Two stage and *one stage* methods. **Two-stage** methods generate candidate object boxes using various algorithms and subsequently classify these objects using a CNN, such as Region-based Convolutional Neural Network (R-CNN) [4], Fast R-CNN [5] and Faster R-CNN [18].

One-stage methods, such as Single Shot Multibox Detector (SSMD) [13] and You Only Look Once (YOLO) [17] directly converts the object bounding box problem into a regression problem for efficient processing.

Vehicle counting can be divided into two approaches: vehicle counting based on the virtual detection area and vehicle counting based on vehicle tracking, which extracts the trajectory of each vehicle by matching vehicles detected in each frame of video sequences and counts the number of vehicles based on vehicle trajectories [12].

[16] pioneered in the use of Neural Network (NN) for traffic density estimation, using it to perform vehicle counting and classification tasks from video records. The author performed experimental results on the Istanbul Traffic Management Company (ISBAL) dataset and claimed that results were promising.

[22] used both deep learning and optimization-based methods to perform vehicle counts from low frame-rate, high occlusion videos. To avoid individual

vehicle detection or tracking, both methods mapped the dense image feature into vehicle density, one based on rank constrained regression and the other based on Fully-Connected Feed-Forward (FCFF). It ended up reaching a 5.31 Mean Absolute Error (MAE) on the FCFF.

[1] used two different deep learning techniques, YOLO and Deep CNN, to detect traffic congestion from camera images, classifying in either congested or not congested. The Support Vector Machine (SVM), a shallow algorithm [2], also was used as a comparison to determine the improvements obtained using deep learning algorithms. Occupancy data from nearby radar sensors were used to label congested images in the dataset and for training the models. YOLO and Deep CNN achieved 91.5% and 90.2% accuracy, respectively, whereas SVM's accuracy was 85.2%, showing the potential of DL for this task.

[21] proposed to use YOLOv3 Darknet-53 for vehicle detection and counting system. The results have shown that NN can provide higher detection and counting accuracies, reaching 92.3% and 93.2% respectively, especially for the detection of small vehicle objects.

[14] proposed a model based on an ensemble of the R-CNN and SSMD. Experimental results show that the model achieved promising results, with a Mean Average Precision (MAP) of 94%. It also showed that detection with thermal images was better than with visible images.

All the approaches have had its challenges, given different frame rates, occlusion levels or weather conditions of the data, but achieved great results. Many started from pretrained models and used transfer learning to detect vehicles, which shows the potential of the use of this approach for traffic density estimation tasks. From all the reviewed literature, few examples actually classified the traffic into levels, which is more similar with the use case of this project, but it still gave an insight of the current approaches.

3 Analysis and Design

In this section, the author will capture the requirement description and specifications as provided by the client as well as any further clarification on it, leveraging the power of the C4 Model and 4+1 views to present the system's architecture.

3.1 Functional Requirements

The use cases for the system consist of taking or uploading a picture, submitting, and getting a classification, as shown in the Use Case Diagram on Fig. 1.

It was decided that the flow of interactions with the system were to be similar to other apps that use camera, such as *WhatsApp*, where the user takes a picture, the picture is previewed, and then the user confirms by pressing a send button.

The traffic on the street across the company's offices should be classified as seen in Fig. 2. The queue starts at the traffic lights at the end of the street. The red zone should be classified as High Traffic, the yellow zone as Medium Traffic, and the green zone as Low Traffic.

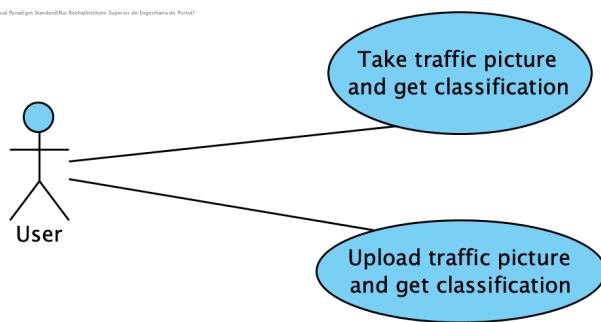


Fig. 1. Use Case Diagram

The queue should be considered as continuous, without big gaps between the cars, i.e., measuring how long a traffic queue is, instead of how many cars are in the picture.



Fig. 2. Street Traffic Classification Scheme: High Traffic (Red); Medium Traffic (Yellow); Low Traffic (Green).

3.2 System Architecture

The system was intentionally meant to be kept simple, with the primary focus being the development of the AI model, and really understanding the core concepts and frameworks around it. As such, the system's complexity primarily lies on the development process itself rather than on the number of use cases or architecture.

For the design of the TrafficFlow system, a combination of the C4 and 4+1 model were used, showcasing some of the most important Views for each of the levels of the abstraction, excluding code. Level 2 corresponds to the container layer of abstraction, showing all the different components of the distributed system.

Four containers can be identified: The Mobile App, the MDAI Service, the AI Model, and an optional Logger. Each container offers an Application Programming Interface (API) to be used by other components. The Level 2 Logical View of the system can be found in Fig. 3.

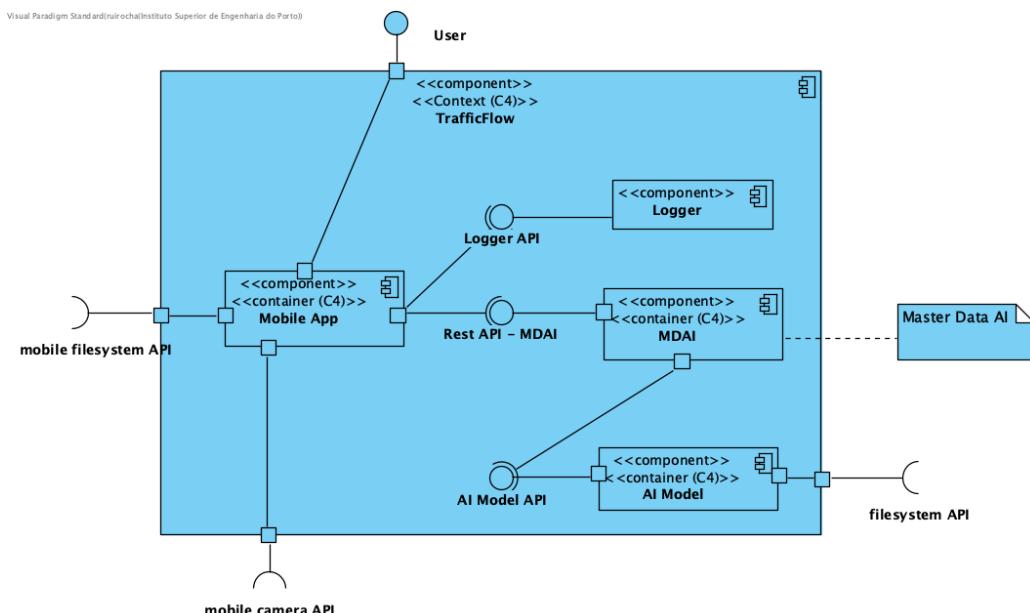


Fig. 3. Level 2 Logical View

The user interacts with the Mobile App to classify pictures. This Mobile App consumes the MDAI API, a service that is the Information Expert regarding the AI model and how to use it. The MDAI then uses the model to classify the pictures and respond to the Mobile App with the classification.

4 Development

This section delves into the process of creating the AI model, employing the CRISP-DM as the methodology for its development. The author provides a detailed account of the steps involved, from data collection and preprocessing to model training and evaluation.

4.1 Machine Learning Model

Dataset Preparation The understanding and preparation of the dataset were some of the longest phases. First, as there wasn't a fixed camera pointing to the street, the pictures had to be taken manually, which required leaving the premises of the office at specific times of the day when the traffic matched the conditions we needed. Then, optimal traffic conditions that accurately captured every desired class were not always available.

High or Low Traffic were the most frequent situations, whereas Medium Traffic was a far rarer phenomenon. Also, to have a good model, various weather situations had to be photographed, as well as times of day (excluding night, as it was deemed outside the scope of this project).

At the end of the data collecting process, the pictures were analyzed and some didn't match the requirements, such as having a car in each section (which would be qualified as high if the last car position were the requirement, but it shouldn't). As such, they had to be excluded. To obtain the final dataset, the map of sections was analyzed for each picture and, if the picture was a good match for the class, inserted into the respective folder.

At the end, we were left with 81 images for **High Traffic**, 23 images for **Medium Traffic** and 49 images for **Low Traffic**. There is a noticeable imbalance between the medium class and the remaining ones. As such, that had to be taken into account in the modeling phase, by using stratified sampling [8], i.e., splitting the train, validation and test sets taking into account the class proportions.

Modelling With such a small dataset, it was decided to use transfer learning, a technique where a pre trained model is used to adapt to specific requirements [19]. Pytorch has some pretrained models available, such as ResNet [9] and Vision Transformer (ViT) [3]. The former is a smaller model with a good error rate, while the latter is the state of art when it comes to CNNs, so there was a desire to compare the two. Then, for each model, the training methods were *Holdout* and *K-Fold* (3 and 5 folds), and the transfer learning techniques were *Finetuning*, i.e., changing the model parameters, and *Feature extractor*, i.e., freezing the model parameters and adding a final layer on the model that can be finetuned.

The first step was to define the global hyperparameters, as seen in Table 1. The chosen values for the hyperparameters are typical values seen when training DL models. These were not adjusted throughout the modelling given the good results obtained with the firstly tried ones, and the lack of computational resources to train more alternatives with Google Collab's offered Graphics Processing Unit (GPU).

Performance metrics are very useful to evaluate the generalization of the trained model and aid in the selection of the best one. When it comes to classification problems, many of the metrics are based on the confusion matrix [15].

The metrics used for these models were [10]: **Accuracy**, which measures the ratio of correct predictions over the entire set of data evaluated, **Balanced Accuracy**, which measures the ratio of correct predictions over the entire set of

Table 1. Global Hyperparameters

Hyperparameter	Value
Batch Size	4
Learning Rate	0.001 (only some finetuning)
Learning Rate Step Size	7
Learning Rate Step Factor	0.1
Momentum	0.9
Number of Epochs	25
Train/Test Split ratio	20%

data, corrected for unbalanced distributions of classes [7], and **F1 Score**, which is the harmonic mean of Precision (proportion of positives that were correctly predicted from the total positives) and Recall (proportion of positives that were correctly classified).

Results In Table 2 it is shown a summary of the training results, with the metrics for the better epoch of each model, and the total training time, with the top value for each metric represented in bold. Untested hypothesis are represented with an hyphen.

Table 2. AI Model Training Results

Model	Technique	Method	Train Time	Accuracy	Balanced Accuracy	F1 Score
ResNet-50	Finetuning	Holdout	15m 14s	0.9583	0.9629	0.9613
		K-Fold (3)	40m 53s	0.9756	0.9444	0.9748
		K-Fold (5)	118m 7s	0.96	0.9167	0.9583
	Feature Extractor	Holdout	14m 48s	0.9583	0.9629	0.9579
		K-Fold (3)	-	-	-	-
		K-Fold (5)	-	-	-	-
ViT-B-16	Finetuning	Holdout	27m 47s	0.88	0.8333	0.8771
		K-Fold (3)	-	-	-	-
		K-Fold (5)	-	-	-	-
	Feature Extractor	Holdout	29m 43s	0.84	0.6667	0.7673
		K-Fold (3)	-	-	-	-
		K-Fold (5)	-	-	-	-

The most promising models were the ResNet-50 trained with the Holdout method, both the finetuned and feature extractor, and the 3-Fold finetuned one. Even though the latter took longer to train, since it had overall better results it was the chosen model. Given that good results were obtained in the first models, and given that the K-Fold method was very time consuming, it was decided not to test the K-Fold method for the ResNet Feature Extractor, nor for any of the Vision Transformer models, unless the model showed great promise in the holdout training hypothesis.

Evaluation After choosing the best model from the validation set metrics, it was time to test the best model against new unseen data. The results were positive:

- **Accuracy:** 97%
- **Balanced Accuracy:** 92%
- **F1 Score:** 97%
- **Accuracy of Class "High":** 100%
- **Accuracy of Class "Medium":** 75%
- **Accuracy of Class "Low":** 100%

As expected, given its small size, the "Medium" class showed worse accuracy than the remaining classes (that had a perfect score), which shows on the balanced accuracy, with 92% against the 97% accuracy. If a larger dataset could have been gathered, specially for the "Medium" class, the model could be very high performant.

It could be considered weird how good the performance is for the "High" and "Medium" classes. But, considering that the pictures of our dataset were highly controlled and nitpicked, per company request, it is quite normal that the classification is very accurate. If an user takes a picture of the traffic that is not within those exact conditions, and instead with the cars spaced out, for example, the classification would probably not be as accurate, as the model was not trained for that.

Deployment For the deployment phase, the model was exported in torchscript format, to be loaded into the MDAI service, which fueled the Mobile App. The AI Classification API, MDAI, was implemented using Flask. The mobile App was developed in React Native, for the ease of writing code once, and being able to run both on iOS and Android. An example of each classification on the mobile app can be seen on Fig. 4.

5 Conclusions

The main goals of the project were defined on the beginning of the internship and didn't change significantly throughout. All the goals were concluded, such as learning about AI concepts and frameworks, learning about the development of mobile applications, training AI model, serving the model on a web service and creating the mobile app to take pictures and classify traffic level.

A disclaimer is needed that the app will not be very useful in the "real world". When looking at the Related Works section, it becomes clear that classifying traffic is not as simple as taking a picture and seeing how long a queue is. The speed and trajectory of the cars should also be taken into account to get accurate traffic classification. Those situations, though, were outside the scope of the project and were not pursued, since the goal was more to understand the power of AI for computer vision tasks, and the use of frameworks to serve these models.



Fig. 4. Mobile App Predictions: a) High Traffic Prediction; b) Medium Traffic Prediction; c) Low Traffic Prediction

Due to the small dataset, particularly the Medium Traffic level, the chosen model did not reach a big accuracy classifying that level, only reaching 75%. Still, it had an overall good accuracy, fulfilling the requirements.

In retrospective, the internship proved to be very fruitful, as the defined goals for the project have been accomplished in the desired timeline.

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Desenvolvimento de Aplicações de Gestão de Energia – Comunidades de Energias Renováveis

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Resumo. Este documento tem por objetivo descrever o trabalho realizado no âmbito da unidade curricular de Projeto/Estágio (PESTI) da licenciatura de Engenharia Informática do Instituto Superior de Engenharia do Porto. O projeto de estágio foi realizado na empresa ARMIS no Porto. O projeto tinha como objetivo o desenvolvimento de uma prova de conceito que explorasse as potencialidades de um módulo de gestão de comunidades de energias renováveis, sendo este, posteriormente, integrado numa aplicação de gestão e otimização de energia. O módulo desenvolvido deveria, resumidamente, permitir a monitorização e visualização das comunidades e dos seus membros, permitir a gestão das comunidades e dos seus membros, podendo ser adicionadas comunidades e membros e, por fim, permitir através de gráficos, visualizar a negociação do preço da energia bem como a performance de cada membro. A solução concebida, apesar de não contemplar a totalidade das funcionalidades inicialmente planificadas, permitiu avaliar as capacidades de um módulo de gestão de comunidades de energias renováveis, cumprindo, portanto, o seu maior objetivo.

Palavras-chave: ARMIS, Comunidades de Energia Renováveis, Autoconsumo, Gestão de Energia, Angular, .NET, MVC, OpenLayers, HTML, CSS

1 Introdução

Neste capítulo é introduzido o trabalho a realizar ao longo do estágio curricular. Inicialmente, é feita uma contextualização do estágio. De seguida, o problema é descrito e são referidos os seus objetivos e os contributos para as partes envolvidas.

1.1 Enquadramento

No âmbito da unidade curricular Projeto/Estágio da Licenciatura de Engenharia Informática, foi solicitada a realização de um estágio curricular. Este estágio foi realizado na empresa ARMIS, no Porto, e teve a duração de 4 meses, iniciando a 1 de março de 2023 e finalizando a 28 de julho de 2023.

O projeto realizado teve por base o produto de gestão de energia, que procura otimizar os consumos e as produções energéticas dos seus utilizadores. Com isto em mente, o produto apresenta como principais funcionalidades a possibilidade de visualizar produções e consumos energéticos, bem como prever os mesmos a curto e longo

prazo, gerir dispositivos elétricos num edifício e permite gerir comunidades de energias renováveis.

1.2 Descrição do Problema

Atualmente existe uma grande necessidade de desenvolvimento de software para comunidades de energias renováveis, uma vez que é uma área bastante recente, não existindo ainda muito software dedicado à gestão das mesmas.

Portanto, pretende-se o desenvolvimento de uma prova de conceito para gestão de comunidades de energias renováveis, de modo a permitir a avaliar as suas potencialidades.

1.3 Objetivos

Os objetivos podem ser divididos em comportamentais e aplicacionais.

Por um lado, os objetivos comportamentais consistem em desenvolver a capacidade de identificação de requisitos funcionais e não funcionais, aumentar o “know-how” relativo a comunidades de energias renováveis e de produtos de energia e, por último, adquirir experiência de desenvolvimento de um produto em contexto empresarial.

Por outro lado, os objetivos aplicacionais consistem em integrar na aplicação um módulo relativo a comunidades de energias renováveis, que possibilite monitorização e gestão das mesmas e dos seus membros constituintes, sendo possível visualizar consumos, produções e transições energéticas, bem como a sua previsão a curto ou longo prazo. Pretende-se também que sejam criados formulários para a criação de novas comunidades e membros. Por último, é também necessário possibilitar a visualização da negociação dos preços de energia bem como a performance de cada membro constituinte de uma comunidade de energias renováveis.

1.4 Contributos

Este projeto tem como resultado a criação de um módulo de gestão de comunidades de energias renováveis, que só por si apresenta vários benefícios.

Para a empresa, resulta na criação de um produto mais robusto e completo, capaz gerir e monitorizar comunidades de energias renováveis e permitiu a entrada da mesma num mercado bastante recente.

Para a sociedade, o módulo permite que cada utilizador tenha acesso a um conjunto de funcionalidades que se revelam essenciais para uma boa gestão, monitorização e funcionamento das comunidades e dos seus membros.

Para o ambiente, a existência de um produto de energia que apresente as funcionalidades previamente descritas é essencial para que exista cada vez mais interesse na utilização de energias mais limpas em detrimento de outras fontes de energia mais poluentes e possivelmente mais dispendiosas.

2 Estado da Arte

Neste capítulo é realizada uma contextualização sobre o tema principal deste projeto, o autoconsumo e as comunidades de energias renováveis.

O autoconsumo (AC) consiste no consumo de energia elétrica, produzida por uma ou mais unidades de produção para autoconsumo (UPAC), por parte de um ou vários autoconsumidores [1].

Por sua vez o autoconsumo pode ser de dois tipos: autoconsumo individual (ACI) ou autoconsumo coletivo (ACC).

- No ACI, o autoconsumo apenas é realizado numa instalação de utilização (IU), ou seja, quando uma UPAC está associada a um código de ponto de entrega (CPE)
- No ACC, o autoconsumo é realizado por várias instalações de utilização (IU), ou seja, quando uma UPAC está associada a mais do que um código de ponto de entrega (CPE)

A proximidade entre as UPAC e IU é, portanto, um fator determinante para o exercício da atividade de autoconsumo, seja este individual ou coletivo, podendo a ligação ser feita através de uma rede interna ou através da rede elétrica de serviço público (RESP) [1].

- No caso da rede interna, deve ser estabelecida uma rede particular limitada geograficamente pelo conjunto das instalações elétricas responsável pela ligação entre a UPAC e uma ou mais IU, podendo ou não ter ligação à RESP [1].
- No caso da RESP, para diferentes distâncias entre as UPAC e as IU devem ser cumpridos respetivos valores de tensão elétrica [1].

Uma comunidade de energia renovável (CER) é, segundo a definição da Direção-Geral de Energia e Geologia (DGEG), “uma pessoa coletiva, constituída mediante adesão aberta e voluntária dos seus membros, sócios ou acionistas, os quais podem ser pessoas singulares ou coletivas, de natureza pública ou privada, incluindo, nomeadamente, pequenas e médias empresas ou autarquias locais, por estes controlada” [1].

Uma CER é na sua essência uma forma de ACC pelo que ambos apresentam várias semelhanças e diferenças. Por um lado, tanto as CER como o ACC estão habilitadas a produzir, consumir, armazenar e vender energia aos seus membros ou terceiros, permite também aos seus membros partilhar e comercializar a energia produzida pela UPAC e aceder a todos os mercados de energia [1]. Por outro lado, uma CER, em oposição ao ACC, não necessita de um regulamento interno para o seu funcionamento, requisito obrigatório para o ACC [2]. Para além disso, a CER disponibiliza, não só a venda de excedentes energéticos produzidos, mas também um conjunto de outros serviços que o ACC não disponibiliza [2].

2.1 Tecnologias Existentes

O OpenLayers é uma biblioteca de JavaScript que tem como objetivo colocar mapas interativos em páginas web. É capaz de apresentar informação vetorial e markers

carregados de qualquer origem [3]. O OpenLayers foi desenvolvido para promover a utilização de informação geográfica em qualquer uma das suas formas [3].

3 Análise e Desenho da Solução

Neste capítulo consta toda a análise e desenho do módulo desenvolvido. Inicialmente, será apresentado o domínio do problema, bem como alguns detalhes a este associado. De seguida, serão expostos e especificados os requisitos funcionais e não funcionais do sistema. Por fim, é apresentado desde o desenho global da solução até aos casos de uso presentes no projeto.

3.1 Domínio do Problema

Nesta secção será abordado o modelo domínio do problema a resolver, acompanhado de uma análise ao mesmo, bem como a contextualização do modelo de negócio relacionado com o módulo a desenvolver.

O módulo desenvolvido para comunidades de energias renováveis representa um conjunto de novas funcionalidades para o produto de gestão de energia, pelo que foi necessário criar uma lógica de negócio para sustentar o desenvolvimento do mesmo.

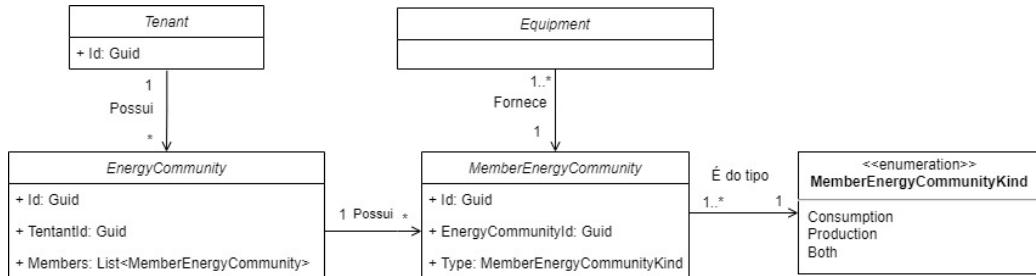


Fig. 1. Modelo de Domínio

Tal como é possível observar na Fig. 1, o modelo de negócio revolve, principalmente, em torno das comunidades e dos seus membros, uma vez que estas classes representam os conjuntos de dados mais manipulados ao longo do desenvolvimento. Neste projeto, a função de utilizador é responsável pela gestão e visualização de comunidades e membros, possuindo também várias comunidades de energias renováveis, que, essencialmente, representam um conjunto de membros. Por sua vez, os membros representam uma entidade mais complexa no contexto deste domínio, uma vez que podem desempenhar várias funções numa comunidade, a de consumidor, a de produtor ou ambas, sendo ainda portadores da informação relativa aos consumos e produções provenientes dos equipamentos de consumo e de produção. O *tenant* representa, essencialmente, um cliente que utiliza o produto. A existência do conceito de *tenant* pressupõe uma arquitetura *multi-tenant*, que permite que através de uma única instalação do produto num único servidor seja possível satisfazer vários clientes, uma

vez que apesar de todos estarem ligados fisicamente estão todos logicamente separados.

3.2 Desenho

Nesta secção consta todo o desenho da aplicação a desenvolver, visando fornecer uma visão detalhada da proposta de solução concebida para a resolução do problema proposto, bem como uma apresentação do padrão arquitetural usado. Recorreu-se aos modelos C4 e 4+1 para elaborar o desenho de todas as vistas consideradas essenciais.

O modelo C4 permite representar um sistema em quatro diferentes níveis de abstracção: contexto, contentores, componentes e código em que cada um deles apresenta mais detalhe e uma menor granularidade do que o nível anterior.[4]

O modelo 4+1 permite representar um sistema em cinco vistas diferentes (4+1): vista lógica, vista física, vista de processos, vista de implementação e vista de cenários. Neste modelo, cada vista representa uma perspetiva diferente do sistema em análise.

O MVC (Model-View-Controller) foi o padrão arquitetural aplicado no desenvolvimento do módulo para comunidades de energias renováveis e caracteriza-se pela divisão das responsabilidades da aplicação por três componentes: Model, View e Controller.[5] O Model é a parte do sistema que está encarregue de manipular a informação e que incorpora toda a lógica de negócio no modelo do sistema.[6] Por norma, os dados do Model encontram-se armazenados numa base de dados. O Controller é o componente que atua quase como um intermediário, uma vez que é o responsável por estabelecer a comunicação entre o Model e a View.[6] O Controller deve usar o Model para manipular a informação dele proveniente e comunicar com a View para criar uma *user interface*.[6] Por último, a View tem a função de fornecer ao utilizador a *user interface*, expondo assim toda informação por este pretendida.[7]

De seguida são apresentadas as vistas de implementação de nível 3, uma vez que permitem demonstrar de uma forma mais clara todo o fluxo dos casos de uso estipulados para o desenvolvimento do módulo para comunidades de energias renováveis.

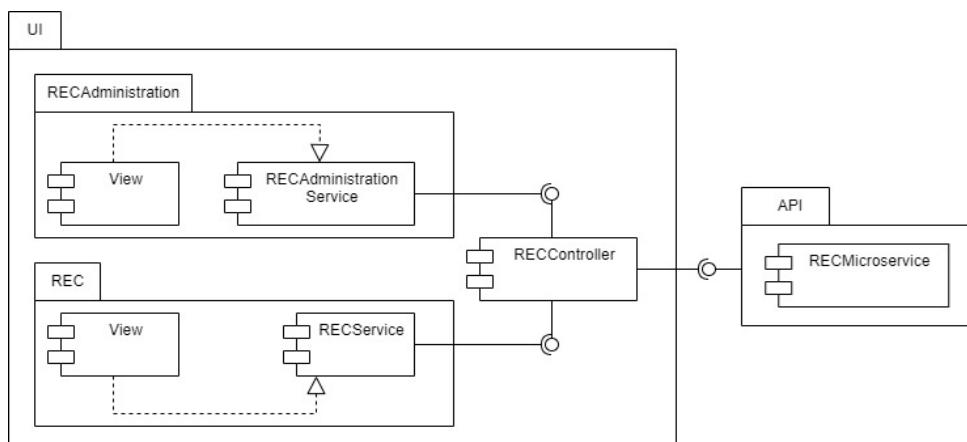


Fig. 2. Vista de implementação nível 3 do UI

A vista de implementação apresentada na Fig. 2 procura mostrar a estrutura da aplicação *front-end* desenvolvida no contexto do projeto de estágio. A *package UI*, no contexto do padrão arquitetural MVC, representa a View. Os componentes View, tanto no componente *RECAccount* como no componente REC apresentam o mesmo comportamento, tendo como funções apresentar ao *tenant* a informação recebida de outros componentes, receber a informação proveniente *tenant* e chamar os métodos dos componentes Service. Os componentes Service (*RECAccountService* e *RECService*) apresentam também ambos funções semelhantes e são essencialmente responsáveis por invocar os métodos do *RECCController* requisitados pelos componentes View. A utilização dos componentes Service garante a escalabilidade da aplicação, pois caso haja necessidade de criar outros ecrãs ou desenvolver novas funcionalidades que necessitem de invocar os mesmos métodos do *RECCController*, basta que essas novas classes instanciem os devidos serviços para terem acesso a esses métodos. Por último, o componente Controller (*RECCController*), que no contexto do padrão arquitetural representa o Controller, é responsável por disponibilizar os métodos da API e servir os componentes Service, de forma a responder aos pedidos do utilizador.

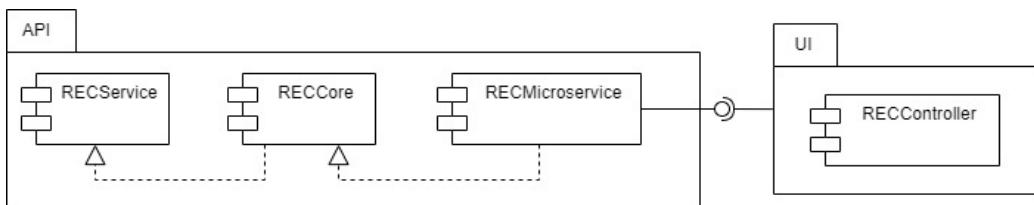


Fig. 3. Vista de implementação de nível 3 da API

A vista de implementação apresentada na Fig. 3 procura mostrar a estrutura da aplicação *back-end* desenvolvida no contexto do projeto de estágio. A *package API*, no contexto do padrão arquitetural MVC, representa o Model. Neste diagrama o *RECMicroservice* será o componente que recebe o pedido proveniente do UI e que por sua vez o redireciona para o *RECCore*. O *RECCore* representa o componente mais importante da API em análise, uma vez que é no *RECCore* que é estabelecida todas as regras de negócio associadas ao módulo desenvolvido, bem como a definição do modelo idealizado para a resolução do problema e dos respetivos *Data Transfer Objects* (DTO) e é também o responsável por aceder à interface disponibilizada pelo *RECService*, que permite a todos os outros componentes do *package* aceder à base de dados. Por último, o *RECService* é o componente responsável pela ligação à base de dados, sendo neste que é feita a implementação dos métodos que constam na sua interface.

4 Implementação da Solução

Neste capítulo consta a implementação do módulo desenvolvido. Inicialmente, serão apresentados os detalhes de implementação de um dos casos de uso mais relevantes,

bem como alguns detalhes a estes associados. Por fim, é feita uma avaliação da solução desenvolvida tendo em conta os resultados atingidos.

4.1 Descrição da implementação

Nesta secção serão apresentados os detalhes de implementação do caso de uso “Visualização da localização das comunidades e membros”.

Este caso de uso previa a criação de um mapa interativo, recorrendo para tal ao OpenLayers, e ao posicionamento no mapa das comunidades e dos seus membros, sendo os mesmos representados por ícones. De forma resumida e de um ponto de vista de implementação, para o desenvolvimento deste caso uso é essencial criar um mapa com recurso ao Openlayers, obter as comunidades e membros da base de, criar as respetivas *layers* no mapa, criar e a adicionar as *features* (comunidades e membros) ao mapa e por fim posicionar e estilizar o mapa na página web, utilizando HTML e CSS.

Inicialmente, a View invoca os métodos existentes no *RECSERVICE* de forma a obter a informação pretendida, neste caso uma lista de comunidades. Por sua vez, os métodos existentes no *RECSERVICE* chamam os métodos presentes no *RECCONTROLLER*, sendo para tal necessário passar o ID do *tenant* para o qual se pretende obter as comunidades.

```
[HttpGet("GetEnergyCommunities")]
0 referências
public async Task<IActionResult> GetEnergyCommunities([FromQuery] string tenantId)
{
    _logger.LogDebug("GetEnergyCommunities called");

    List<EnergyCommunity> energyCommunities = new List<EnergyCommunity>();

    try
    {
        string apiUrl = $"{_apiUrl}/EnergyCommunity/GetEnergyCommunities?tenantId={tenantId}";
        var apiResult = await APIHelper.CallAPIRest< IList<EnergyCommunity>>(Request, apiUrl);
        energyCommunities = apiResult.ToList();
    }
    catch (Exception ex)
    {
        _logger.LogError($"Error on GetEnergyCommunities: " + ex.Message);

        return StatusCode(StatusCodes.Status500InternalServerError, ex.Message);
    }

    return Ok(energyCommunities);
}
```

Fig. 4. Método *GetEnergyCommunities* do *RECCONTROLLER*

A Fig. 4 apresenta o método *GetEnergyCommunities* do *RECCONTROLLER* que é chamado pelo *RECSERVICE*. O método *GetEnergyCommunities* recorre a um pedido HTTP para comunicar com a API à qual faz o pedido, aguardando pela resposta. O pedido é recebido pelo Controller da API. Este Controller é o responsável por disponibilizar os seus métodos para que as suas funcionalidades possam ser acedidas através de pedidos HTTP. Por sua vez, este método devolve uma lista de comunidades em formato DTO, caso tudo decorra normalmente. Para tal, o Controller recorre à interface disponibilizada pelo serviço existente no Core para comunicar com as *gateways* existentes na camada Service, que por sua vez acedem à base de dados para obter toda a informação pretendida, neste caso as comunidades e os seus membros. Na *gateway*

a informação é recebida da base de dados, os objetos são criados no formato DTO e enviados numa lista no sentido oposto do fluxo previamente descrito.

Com toda informação obtida, é agora possível começar a criação do mapa bem como a visualização das comunidades e membros no mesmo.

```
createMap(): void {
    const coordinates = [-8.8646054, 40.0508646];
    const actualCoordinates = fromLonLat(coordinates);

    this.map = new Map({
        controls: defaultControls({
            zoom: false,
        }),
        view: new View({
            center: actualCoordinates,
            zoom: 8,
        }),
        layers: [
            new TileLayer({
                source: new OSM({ url: "https://a.basemaps.cartocdn.com/light_all/{z}/{x}/{y}.png" })
            })
        ],
        target: 'map'
    });

    this.map.on('postcompose', function () {
        let mapCanvas = document.querySelector('canvas');
        if (mapCanvas === null) {
            mapCanvas.className = "map-filter";
            mapCanvas.style.filter = "invert(1) opacity(0.4) drop-shadow(0 0 0 rgb(19, 50, 100)) brightness(1.7) contrast(1.5)";
        }
    });

    this.createLayers();
    this.makersActions();
}
```

Fig. 5. Método CreateMap

A Fig. 5 apresenta o método responsável pela criação do mapa onde será possível visualizar as comunidades e os seus membros. Para a criação do mapa foram indicadas as coordenadas para o centro, o nível de zoom e um *link* que continha o tipo de mapa que se pretendia apresentar. O método *createLayers* é o método responsável pela criação das *layers* que irão possuir as comunidades e das *layers* que irão possuir os membros. Durante a criação do mapa serão atribuídos valores de zoom máximo e zoom mínimo às *layers*, que por sua vez permitem alterar entre a visualização de comunidades e membros. Na prática atribuiu-se o mesmo valor para o zoom máximo da *layer* das comunidades e para o zoom mínimo da *layer* dos membros o que garante o comportamento desejado.

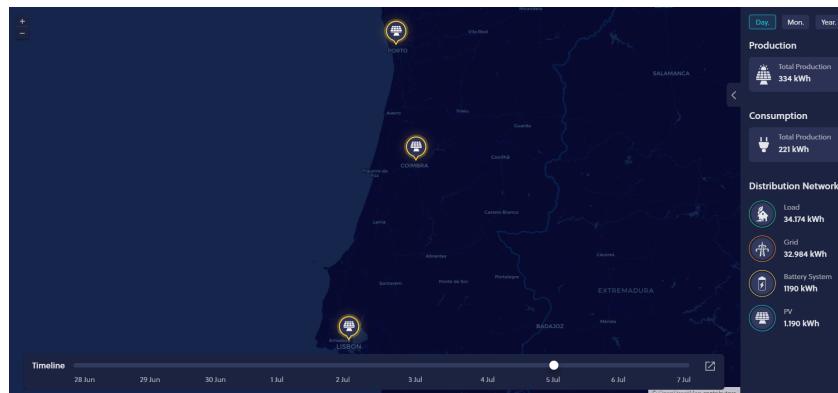


Fig. 6. Visualização das comunidades

A Fig. 6 ilustra o mapa resultado da resolução do caso de uso anterior. É possível visualizar as comunidades representadas sob a forma de *features*, uma vez que o zoom do mapa possui um valor superior ao valor do atribuído ao zoom mínimo da *layer* das comunidades e um valor inferior ao valor do zoom máximo da *layer* das comunidades.

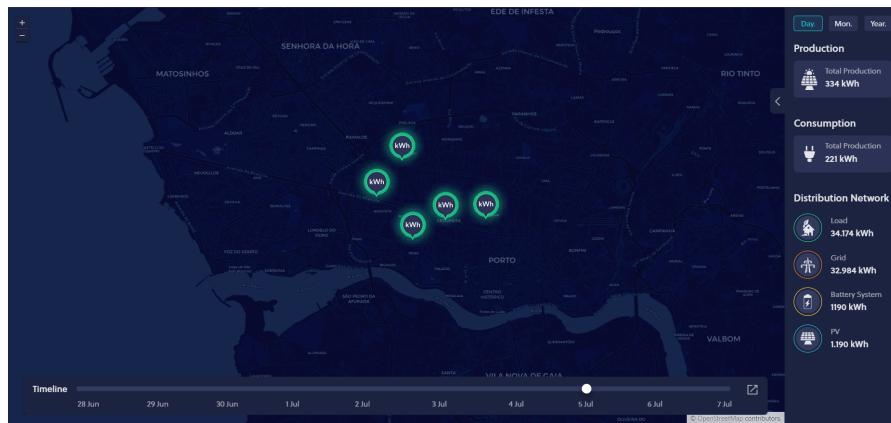


Fig. 7. Visualização dos membros

A Fig. 7 ilustra o mapa resultado da resolução do caso de uso anterior. É possível visualizar os membros das comunidades, representadas sob a forma de *features*, uma vez que o zoom do mapa possui um valor superior ao valor do atribuído ao zoom mínimo da *layer* dos membros e um valor inferior ao valor do zoom máximo da *layer* dos membros.

4.2 Avaliação da Solução

Nesta secção é efetuada uma avaliação da solução procurando-se saber se as funcionalidades implementadas resolvem efetivamente o problema.

Para a validação da solução foram realizados teste unitários à API que suporta as funcionalidades desenvolvidas, de forma a garantir o comportamento desejado. Os restantes tipos de testes foram desenvolvidos pela equipa de QA.

Para além do recurso a testes, uma das formas de validação da solução consistiu no uso extensivo das funcionalidades existentes no módulo desenvolvido.

Exemplificando, em toda a aplicação foi validada a disposição dos componentes tendo em conta diferentes níveis de zoom do *browser*, pelo que na grande maioria da aplicação estes apresentavam a disposição correta. O único problema ocorre quando em valores específicos de zoom o filtro de cores que afeta o mapa afeta também as cores das *features* nele presentes, alterando as suas cores.

Para concluir, considera-se que as funcionalidades implementadas no módulo desenvolvido resolvem o problema proposto.

5 Conclusão

Nesta secção são expostos os resultados obtidos para os objetivos definidos no início do projeto de estágio, bem como o seu grau de satisfação.

5.1 Objetivos concretizados

Todos os objetivos definidos foram alcançados com sucesso, tal como planeado inicialmente, com exceção do objetivo “Visualizar a negociação de preços de energia bem como a performance de cada membro constituinte de uma comunidade de energias renováveis”. Este objetivo não foi cumprido, dado que o desenvolvimento do objetivo “Criar formulários necessários para a criação de uma nova comunidade de energias renováveis bem como a gestão dos membros que a constituem” demorou mais do que o previsto inicialmente.

Apesar de todos os objetivos não terem sido alcançados a solução desenvolvida responde em grande parte ao problema inicialmente apresentado, permitindo avaliar as potencialidades de uma ferramenta de gestão de comunidades de energias renováveis, adicionando mais valor a um produto de gestão de energia já muito completo.

5.2 Limitações e Trabalho Futuro

Nesta secção, são evidenciadas algumas limitações do trabalho desenvolvido e dadas algumas sugestões de como poderá ser desenvolvido futuramente.

Como evidenciado na secção anterior a principal limitação revolve em torno do facto de um o objetivo não ter sido implementado

No que ao trabalho futuro diz respeito, gostaria de implementar o objetivo que não foi possível de desenvolver até à data de entrega do relatório de estágio. Para além disso, a possibilidade de no ecrã de visualização de comunidades e membros selecionar, através de um menu, uma comunidade que se pretende visualizar, sendo essa apresentada no mapa, penso que seria uma adição que em muito melhoraria a experiência do utilizador. Por fim, poderá também ser feita a adição do módulo desenvolvido ao produto de gestão de energia.

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Developing a game for WebXR with Godot to push boundaries

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Abstract. Virtual Reality (VR) technology has witnessed a surge in popularity due to its unparalleled ability to immerse users in virtual worlds. This paper delves into the dynamic realm of VR, exploring its increasing appeal and unique immersive qualities compared to other technologies. The focus of this study is the development of a game for WebXR, leveraging the Godot game engine. The goal is to stress test the Godot game engine and find its current capabilities while also pushing the boundaries of innovation within WebXR gaming, with a specific focus on the player's movement and game complexity.

Keywords: Multimedia, Game, Virtual Reality, WebXR, Godot, Game Development, Game Architecture, Game Design.

1 Introduction

1.1 Context

Virtual Reality (VR) is a technology that has been increasing in popularity over the years, having over 171 million users across the whole world [1] at the start of 2023, a huge leap from 2015, that had only 6700 users [2].

This increase in popularity, lead to the interest of Fabamaq, a company from Porto, Portugal, that focuses on the development of casino games [3]. Fabamaq saw the opportunity to develop an online casino that would make use of the technology, more specifically WebXR [4], [5]. Due to the company being in the process of migrating to use the Godot game engine [6], the question of whether it was possible to develop this online casino or not appeared.

This question gave birth to the project described in this paper, a game that was developed with the intention of testing Godot's capabilities as a tool to develop games for WebXR.

Having an interest in game development and in VR, made this an opportunity to try to push WebXR to its limits and see what was and wasn't possible inside of VR. This alignment of interests, lead to the acceptance of an internship in Fabamaq, and in consequence, the development of the project described in this paper.

1.2 Objectives

The primary objective of this project is to determine the feasibility of developing an online casino using the Godot and WebXR technologies. To achieve this, the project aims to develop a proof-of-concept game with the following specific objectives:

- Rigorously assess the capabilities of the Godot game engine: the project seeks to thoroughly evaluate and understand the performance and functionalities of the Godot game engine in the context of developing immersive WebXR experiences.
- Explore innovative concepts within the WebXR gaming domain: the project endeavours to explore and implement innovative gaming concepts within WebXR.
- Investigate the limitations of VR: special attention will be dedicated to exploring and addressing the challenges associated with VR-induced nausea a prevalent concern in the development of VR multimedia, caused by the perception of movement based on visual information, despite the lack of vestibular input [7]–[10].

1.3 State of The Art

In the initial phase of this project, an extensive study was conducted to explore the state of the art in WebXR development. Analysis was carried out on several projects, including “Above par-adowsky mini-gold” [11], “Moon Rider” [12], “A-Painter” [13], and some others, to understand the breadth and depth of experiences offered by these projects within the WebXR domain.

Table 1. Results of the analysis conducted about the technologies used in the development of WebXR projects.

Technology	Version	Ease of Use	Performance	Additional Notes
A-Frame	1.4.2	High	Low	Does not present a physics motor.
Babylon.js	5.57.1	Low	High	WebXR support in infancy stage.
Godot	4.0	High	Low	WebXR implementation in its infancy.
PlayCanvas	1.61.2	High	Medium	Small community, which leads to very little support.
Three.js	R150	Low	High	Requires a large amount of code.
Unity	2021.3.19f1	High	High	Presents a tax to casino games.

Upon review, it was observed that while these projects provided diverse experiences, they largely consisted of relatively simplistic and concise interactions. The experiences,

while showcasing versatility, often lacked depth in terms of immersive content and complexity, particularly in visuals and overall scope.

To assess the technologies utilized in the development of WebXR projects, the analysis was guided by the principles outlined in the “Unified Theory of Acceptance and Use of Technology”, albeit tailored to suit the context of this study. Table 1 presents a summarized result of this analysis. The technology observed that presents the highest potential for the development of WebXR, was Unity, presenting many functionalities that aid the developer while also showing a great performance.

1.4 The Game

The game is positioned within the shooter genre, specifically as a survival bullet hell, featuring a distinctive emphasis on movement within a sci-fi environment.

Within this bullet hell experience, players take control of a robot that is being tested for military purposes, tasked solely with survival. The game orchestrates a demanding examination of the game engine’s performance limits, as players face an onslaught of enemy drones and projectiles. The sci-fi setting introduces a novel dimension to movement, utilizing zero gravity to make players float instead of employing traditional walking or running mechanics. This not only contributes to a unique element to the gaming experience, but also amplifies the exploration of strategies to mitigate the common challenge of VR-induced nausea.

Taking control of a robot also allows the exploration of diverse game mechanics and controls. An instance of this is the main mechanic of the game, where the players can dynamically switch the mode of their hands’ functionality depending on the situation. One of the modes focuses on movement, while the other emphasizes offence. This nuanced approach to gameplay introduces a layer of complexity and strategic decision-making, further enriching the overall gaming experience.

Additionally, the use of enemies also allows for investigation in ways to develop and optimize the underlying Artificial Intelligence (AI), more specifically the pathfinding used by the drones. This aspect becomes crucial considering the freedom of movement in the zero-gravity concept, where drones can navigate in any direction, similar to the player.

2 Design

2.1 Component-Based Architecture

The architecture chosen for the development of the game was Component-Based Architecture (CBA) [14], focusing on constructing systems using independent and reusable components. This approach facilitates quick and smooth development, as components are designed with reusability in mind, reducing the time spent on developing similar systems and allowing for a concentrated effort on unique aspects of the game.

An illustrative example of the accelerated development under this architecture is evident in the design of enemy drones. Their behavior is mostly uniform, differing only in their interaction with the player, leading the movement and pathfinding systems to

be developed once and then applied universally to all drones. This not only streamlines the development process but also provides a straightforward method for creating new drone variations.

It's worth noting that while CBA offers notable advantages, considerations may arise in certain contexts, for instance the increase in the system's complexity. However, its adaptability and efficiency in fostering reusable components contribute significantly to the overall development process.

2.2 Game Flow

The game flow adopted for this project is represented in Fig. 1. The player starts by choosing to either start the game or look at a diagram with the game controls, when the game starts a timer begins its countdown. The player loses when hit by an enemy drone or when the timer runs out.

The addition of the timer was done to prevent a passive play style, where the player simply finds the most suitable room, preferably one with only one entrance, and waits for the enemies to come to the room and can easily dispose of them and survive for a long time. This gameplay is discouraged due to the objectives of this project of exploring the nausea-inducing problem that comes with VR development, since if the player doesn't move while playing, then the problem won't occur.

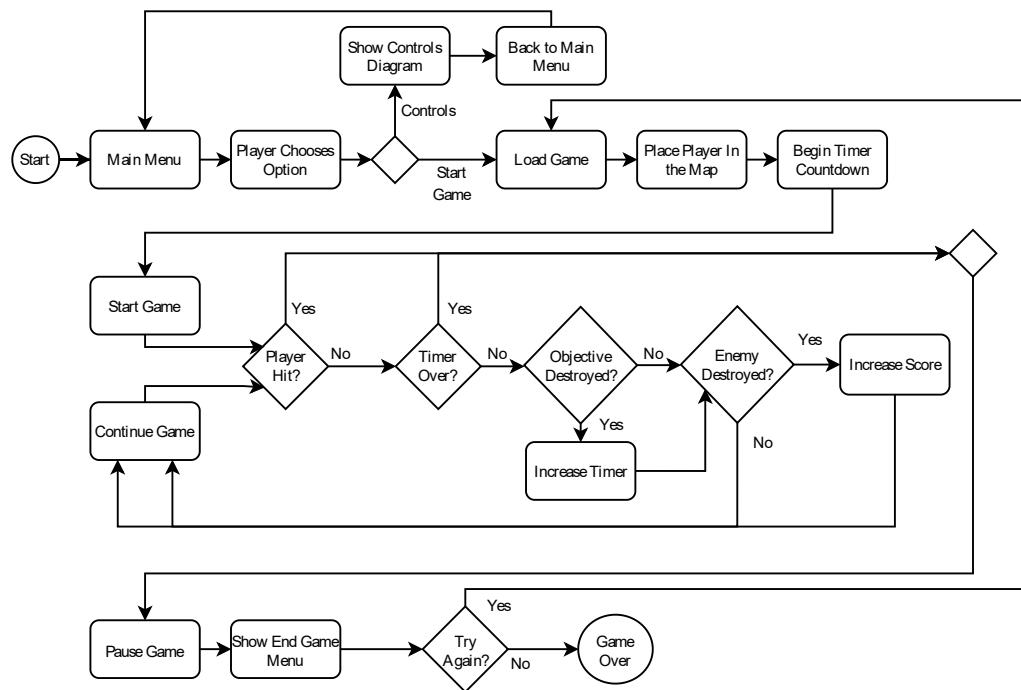


Fig. 1. Game Flow Diagram

2.3 Player Controls

The mechanics governing player control represent the core aspect of the game, involving the switching between two main hand functions: ‘Armed’ and ‘Unarmed’. Designing these controls posed a challenge, as they needed to be intuitive and engaging without causing confusion or being neglected by the player.

The ‘Armed’ hand function focuses on offense, while the ‘Unarmed’ function prioritizes movement. This intentional design choice grants players agency in how they approach the game, allowing them to emphasize either attack or mobility. Consequently, diverse play styles emerge among different players.

When in the ‘Armed’ state, the hand is equipped with a gun for shooting down enemy drones and objectives. Additionally, a thruster is available for adjusting movement. The thruster, limited by a charge, serves as a tactical tool for evading enemy projectiles, requiring strategic use and consideration of recharge times.

The ‘Unarmed’ function empowers the player to use their hand as a grappling hook, adding a dynamic layer to navigation. This function allows the player to throw their hand in a direction, get pulled toward surfaces, and grab onto them. An interesting mechanic is the ability to push surfaces before impact to change direction without losing speed, showcasing the depth of the gameplay.

To implement these functions effectively, a finite-state machine (Fig. 2) was designed. This finite-state machine limits the hand’s functions depending on its current state, ensuring that actions are contextually appropriate. For instance, the player can’t shoot the gun while in the ‘Unarmed’ state.

The introduction of the Boost and Brake mechanics required a hierarchical finite-state machine, allowing for precise control over when these actions can be performed, since they can’t be performed when in the ‘Grabbing’ state. This level of design sophistication ensures that the player’s experience remains cohesive and engaging throughout various gameplay scenarios.

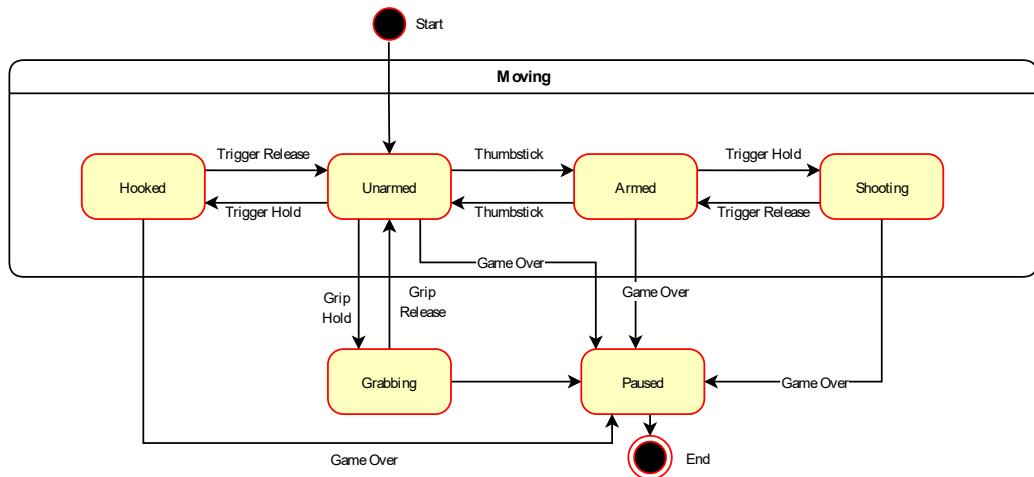


Fig. 2. State Machine of the player’s controls

3 Development

3.1 Implementation of Player Controls

Taking into consideration the hierarchical finite-state machine designed, the player controls began development by implementing the state machine itself. The way it works is by using a ‘StateMachine’ class that stores all the available ‘States’ using Godot’s node system to search for these, and then implementing a function that allows the transition between different states.

States when entered or exited call a function, that is mostly used to end sounds, animations or even to make sure the action being done is finished before transitioning to the next state.

To then use the abilities, like shooting, an ‘AbilityManager’ is used, which works in a similar fashion to the state machine but controls the abilities. Whenever a state receives a certain input, it makes a request to the ability manager, that will then tell the ability to activate. Even though this system might seem like unnecessary complexity, it allows for a better scalability as none of the states depend on the abilities and vice versa.

3.2 Player’s Radar

The player’s radar is a mechanic that allows players to know where the enemies are even when not looking directly at them. This mechanic was implemented as a way to prevent the players from losing the game by being hit from behind without knowing where the enemy was.

The radar makes use of an interface that is stuck in front of the player’s view, which simulates the vision a robot would have as can be seen in Fig. 3. It places points around a circle that indicate the direction of enemies, the bigger the point the closer the enemy is.

This was achieved by taking all the enemies’ positions, that are inside a certain area around the player, and making the orthogonal projection of this position into the plane where the interface is placed, then another orthogonal projection is done into the circle that defines the radar itself.

The radar is divided in two parts, the radar itself, that simply creates new dots and associates them to an enemy, and the dot which tracks the enemy and updates its own position and scale, while also destroying itself whenever the enemy is either destroyed or is out of the defined area. This was done to increase performance by using a process balancer, which will be described later in this paper.

3.3 Enemy Behavior

The enemy’s behavior was accomplished with the use of a behavior tree implemented with the addon ‘BeeHave’ developed by *Bitbrain* [15], used to reduce the amount of work necessary in implementing the system itself and allow the focus in the enemies’ behavior itself. The use of behavior trees makes the implementation of different enemy

behaviors faster and easier as certain behaviors are common to various types of enemies.

The enemy starts by checking if the player is in range, if not, then it will try to generate a path to the player's current position. This path is created using the a-star algorithm [16], which made it necessary to distribute a grid of navigation points around the map. A setup function was implemented to populate the map with navigation points that can be used by the enemies to calculate the path to the player. It works by following a simple flood fill algorithm and ray-casts that check for collisions to make the connections between points. Despite not being perfect and taking a long time to generate, it allows for a convincing way for the enemies to generate paths, since it is in a grid, enemies move uniformly, which given they are robots themselves, is perfect. A problem with this way of generating navigation points, is that it isn't dynamic, so the creation of moving platforms or closing doors isn't a possibility with this implementation.

The behavior tree itself, works by checking different conditions and changing the behavior of the enemy, accordingly, having that in mind, after checking if the player is in a certain range from the enemy, the common behavior in place would be to attack the player.

3.4 Performance Issues and Solutions

The biggest challenge while developing this project was the performance, despite everything, the fact that Godot is still in its infancy for WebXR development and the lack of performance given by the browsers themselves, lead to the difficult task of adding depth to the game while not worsening its performance.

While in other platforms, lack in performance can sometimes be overlooked, in VR the player will feel any fluctuation in performance, and it will in most cases translate into VR-induced nausea.

One way this project solves this problem, is by implementing a process balancer. This process balancer works by distributing the process of certain areas of the game by different frames, instead of processing everything, every frame.

This method is not perfect, especially with more sensitive parts of the game that need to be processed every frame, in those situations this method is not suitable, but for other areas it is perfect and greatly increases the game's overall performance.

Each enemy, other than being balanced by the process balancer, also limits its own process rate depending on its distance to the player, going up to 5 frames without being processed when far from the player.

The pathfinding is also greatly simplified, instead of always calculating an entirely new and complex path, when the enemy is far from the player, a simple path is calculated instead, and, even when creating more complex paths, the enemies always use half of the path that was previously created, economizing in a lot of computational power.

Another optimization is the use of Level of Detail (LODs) that render a more basic version of models when far from the player's view, and the use of occlusion culling that doesn't render parts of the map hidden to the player.

Finally, there is a hard limit to the amount of enemies that can be active at the same time, which also lead to the implementation of a system that teleports the enemies to a closer position to the player, either behind the player or near the objective.

4 Evaluation and Results

4.1 Weekly Feedback Sessions

Along the development of the game, weekly feedback sessions occurred, where the game's progress was presented to the research and development team of the company, in which the internship took place. These sessions involved playing and testing the game with the purpose of gathering feedback on the state of the game and steering its development in the right direction. The insights gained from these sessions played a pivotal role in refining various aspects of the game, contributing to its iterative development. Notable changes and optimizations were implemented based on the valuable feedback received from the team.

4.2 Testing Sessions

During the last week of the internship, final testing sessions were conducted with the help of volunteers from many departments of the company, who tested the game after its development. These tests were conducted in an isolated manner, with no influence from external individuals, and marked the volunteers' first experience playing the game.

After each session, volunteers were asked to fill out a survey addressing their experience with the game. The survey included questions such as 'What was your overall satisfaction with the game?' and 'How would you classify the level of nausea you felt during the play session?'.

The insights gathered from these testing sessions, particularly through the structured survey responses, were crucial for evaluating the results of the game and identifying areas that might benefit from improvement in future work. Analyzing the survey data revealed specific trends and valuable feedback, contributing to a comprehensive understanding of the game's reception and potential avenues for enhancement.

4.3 The Results

By analyzing the responses given to the survey, it is possible to draw some conclusions. In general, the game was well received, and the responses were mostly positive to most of the questions, indicating a successful achievement of the project's objectives.

However, it is worth noticing that, despite the overall satisfaction, there were areas of the game that could see improvement. The most common complaint was the lack of a tutorial, leading to some players being initially stuck without knowing how to navigate the game controls effectively.

From the total of 13 volunteers that played the game, when asked to classify the overall gameplay on a scale of 1 to 5, 84,6% of the volunteers answered with a 4, and

the remaining 15.4% answered with a 5, demonstrating an engaging and overall satisfactory gameplay experience.

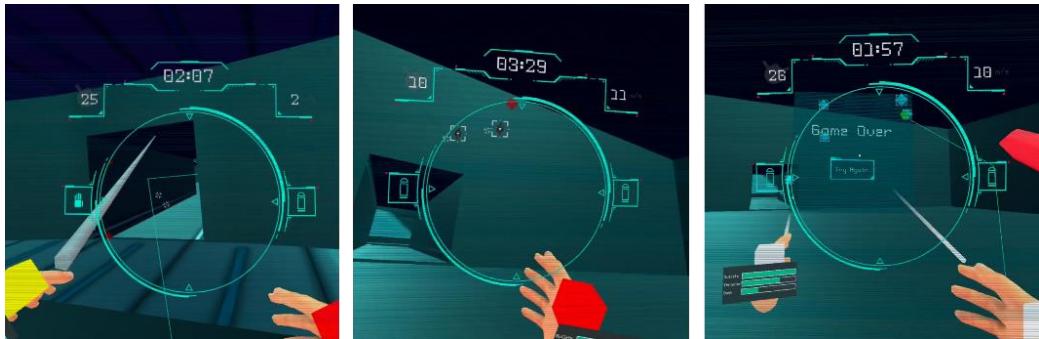


Fig. 3. Screenshots from a gameplay session of the game's final result.

Similar positive results were obtained when asked to classify the overall VR experience posed by the game, having 76.9% classifying it with a 4, only 7.7% classify it with a 3 and the remaining with a 5. This reveals that the innovative ideas this game brought are a positive addition to the WebXR gaming domain.

An important result to highlight is the levels of nausea experienced by players during the game, a crucial aspect of study in this paper. What was observed, was that 10 of the volunteers reported experiencing little to no nausea.

It's noteworthy that almost all volunteers played the game while sitting down, and the play sessions had a medium duration of 20 minutes. These results are indicative that, despite the unconventional movement mechanics employed by the game, positive player experiences were predominant.

Overall, when classified on a scale from 1 to 10, the game received a final rating of 7.76. Considering that the final product was a prototype and not a fully fleshed-out game, this rating indicates the potential of this idea.

In Fig.3. it is possible to see some screenshots taken during a gameplay session that illustrate the state of the game in the end of the internship described by this paper.

5 Conclusion and Future Work

In conclusion, this project successfully achieved its objectives of rigorously assessing the capabilities of the Godot game engine for developing WebXR games and pushing the boundaries of the WebXR game domain. Despite the Godot game engine being in its infancy for WebXR development, it has demonstrated the potential to deliver engaging experiences that captivate players in fulfilling ways. While other game engines may currently offer better solutions, the potential shown by Godot should not be understated.

The overall satisfaction expressed by players in response to this prototype indicates that the VR game domain still holds vast potential for innovation. Addressing the initial question posed in this paper regarding the feasibility of developing an online casino in

WebXR using the Godot game engine, the answer is affirmative. However, it is a challenging task that demands careful balancing of user immersion with performance.

Looking to the future, the prototype presented in this paper could be expanded to push the described limits even further. Observing the transition from a prototype to a fully fleshed-out game would offer valuable insights into the challenges and solutions that may emerge, paving the way for continued innovation in WebXR gaming.

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Exploring simulation using VR as a tool for teaching nursing acts

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Abstract. This paper introduces a project in which simulation in Virtual Reality was explored as a tool to support learning essential content for the performance of nursing acts. A qualitative interview-like survey was conducted to infer the target audience's needs. A virtual and immersive environment was developed to provide nursing students with a dynamic and motivating study format that favors applying and developing their knowledge of human anatomy interactively, through visualization and interaction with digital 3D models. The QEF framework results showed that the reached solution complies with the inferred needs and holds potential for further development. The devised VR application offers an innovative and technologically advanced solution for nursing education.

Keywords: Virtual Reality, Learning Technology, Health Technology, Simulation.

1 Introduction

In current nursing teaching practice, the most used resource for training intrusive nursing acts (which cannot be practiced on real patients) includes simulated scenarios using mannequins for each specific case (such as reanimation maneuvers, sutures, burn dressings, and anesthesia application). This involves significant financial resources, since the price of a Human Patient simulator Mannequin (HPSM) can range up to 126,000 euros, depending on the manufacturer and level of fidelity [1]. After researching present anatomical teaching practices, besides the high price of anatomical models on the market, other problems were identified, such as the sparse number of body donations for the study of human anatomy, and the source of the bodies [2].

When the recurrent use of human bodies for medical training began in Europe in the late Middle Ages, anatomists depended on the gallows, prisons, and asylums as sources of bodies [3]. In the 1960s, body donation started being a practice, dependent on the informed consent of the deceased during their lifetime [3]. Still, according to a 2016-2017 survey on the origin of bodies used in anatomy teaching in 71 countries, carried out by the Faculty of Medicine of Brandenburg, only 32% of countries exclusively used donated cadavers for anatomy teaching, with 26% using unclaimed bodies as their main source and 31% using unclaimed bodies as their exclusive source [3].

Portugal is still one of the countries that uses donated bodies as the main source of bodies, but not exclusively [3]. In 2016, Professor and Surgeon António Bernardes, from the Faculty of Medicine of the University of Coimbra, highlighted the “lack of cadavers to increase training”, enabling only “one dissection [to be] carried out once a year in classes for 300 students” [4].

Currently, most of the applications on the market already make use of non-immersive Virtual Reality, i.e., they provide a computer-generated environment that allows the user to be aware and keep control of their physical environment, using a computer or game console, screen, and input devices such as keyboards, mice, and controllers [5]. Therefore, it is advantageous to develop an application that facilitates the study of human anatomy through visualization and interaction with digital 3D models representing the various systems of the human body in an immersive way, i.e., providing a realistic, complete simulation making use of a head mount display (HMD) [5]. Focusing on the parts of the human body that nurses need deep knowledge of, like the muscular and vascular system, the solution presented in this paper would be valuable not only to nursing students but also as a further study tool to already in-job nurses.

Having this context in mind, this paper starts by briefly scaffolding the state-of-the-art on the use of Virtual Reality (VR) in anatomy teaching, followed by the approach taken to conceive the proposed solution focus. Then, after the overall description of the developed application, the results reached in the testing phase are analyzed and discussed. Finally, the planned future developments are pointed out.

2 State-of-the-Art of VR in Anatomy Teaching

Motivated by the COVID-19 epidemic, more and more innovative work has emerged in anatomy teaching, namely to facilitate remote teaching [6]. These works range from simulations of cadaver dissections to bone demonstrations [6]. In the pre-pandemic period, the use of this type of technology was a choice but with the changes in teaching in recent years, for some, these technologies are now an obligation, hence their importance [6]. Table 1 includes four studies that focused on anatomy learning, embracing VR.

Table 1. Work carried out to help learn anatomy, using VR, and respective studies.

Work Developed	Sample	Results Obtained
Anatomically correct simulation of the heart, in VR [7]	59 students, randomly distributed into control groups, carrying out the study independently, and variable groups, studying through the immersive VR experience, for 30 minutes [7]	After evaluating the students, students in the variable group got, on average, 23.9% more correct than students in the control group [7]
Interactive resource, using stereoscopy, for teaching neuroanatomy [8]	84 students were divided into 3 distinct groups: a group of “conventional methods”, a group of “interactive methods without using stereoscopy” and a group of “interactive methods using stereoscopy” [8]	After evaluating the students, it was concluded that the interactive methods groups obtained the best results, however there were no significant differences between these 2 groups [8]
Interactive 3D model of the musculoskeletal anatomy of the anterior compartment of the human forearm [9]	39 students were divided into 3 distinct groups: a “control” group, with no prior knowledge of forearm anatomy, a “conventional methods” group, taught through dissections and textbooks, and a “model” group, taught through of electronic resources [9]	After evaluating the students, it was concluded that the model group had much better results than the control group and that the results of the model group were similar to the results of the conventional methods group, revealing that the technology developed would be more effective than textbooks, but not as effective as dissections [9]
Interactive 3D visualization resource for learning vascular anatomy [10]	75 students [10]	After carrying out a questionnaire, answered by the students, a better performance in teaching through VR was reported, being beneficial compared to learning through anatomy books, but not standing out compared to teaching through dissection [10]

These studies demonstrate the feasibility and effectiveness of VR in anatomy teaching. However, the obtained results suggest that the use of VR technology should not replace dissection in the anatomical study but complement it.

Considering the state-of-the art research, an approach was defined to infer the target group's awareness and needs as to study possibilities.

3 Methodology

To assess the need for the proposal framed in this paper, the survey “Exploring simulation as a tool for teaching nursing acts” was structured in an interview format on Google Forms, and circulated among nursing students, nursing teachers, and nurses. The survey gathered 24 responses, distributed as follows: 9 responses from nursing students (37.5%), 1 response from a nursing professor (4.2%), and 14 responses from nurses (58.3%). Table 2 presents the 7 questions considered in the survey.

Table 2. Questions used in the survey-interview.

Nº	Question
1.	Do you have knowledge about digital tools to be used in teaching anatomy? If so, which ones?
2	Are you aware of digital tools to be used in teaching/practicing intrusive procedures (for the patient), such as sutures or administering vaccines? If so, which ones?
3	From your point of view, what resources are missing for teaching anatomy?
4	From your point of view, what resources are missing in the teaching/practice of intrusive procedures (for the patient), such as sutures or vaccine administration?
5	When teaching anatomy, and considering your experience, what type of application would it be interesting to use, making use of Virtual Reality? And what exercises or activities would be interesting to implement in this application?
6	When teaching/practicing intrusive procedures (for the patient), such as sutures or administering vaccines, and considering your experience, what type of application would it be interesting to use, making use of Virtual Reality? And what type of exercises or activities would be interesting to implement in this application?
7	From your point of view, would it be interesting to develop a specific game, which would contribute to teaching nursing practices, for example?

3.1 Survey's Results and Analysis

The responses to the survey were analyzed qualitatively, comparing the answers given by members of the same group of respondents, and then between the different groups of respondents to create a complete answer to each of the questions. After analyzing the responses, we concluded that most respondents do not have extensive knowledge about specific digital tools used in anatomy teaching nor in the teaching/ practicing of intrusive procedures. Nevertheless, there is a general awareness of the importance of and need for these tools in the educational and practical context. Regarding the use of VR in teaching anatomy or teaching/practicing intrusive procedures, participants showed interest in exploring applications that would allow visualizing structures of the human body in 3D.

4 The Developed VR Simulation tool

Considering the research in simulation applications, and the responses to the survey, a VR tool was developed using Immersive Virtual Reality aiming to:

1. Allow the visualization of digital 3D models, representing human anatomy;
2. Allow interaction with digital 3D models, rotating, increasing, and decreasing their sizes;
3. Present the nomenclature and respective description of 3D elements, selecting the desired items.

This section presents an overview of the developed tool, focusing on the scenarios the user may interact with.

The user is initially led to a virtual room, where authentication is required. Fig. 1 and Fig. 2 present two perspectives of the virtual environment created for the user's first interaction with the application. In this room, the user can *Sign Up* or *Log In*, as shown in Fig. 3 and Fig. 4.

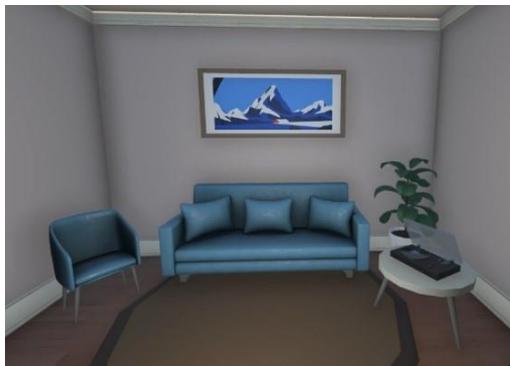


Fig. 1. A perspective of the initial room.



Fig. 2. Perspective of the laboratory entrance door.

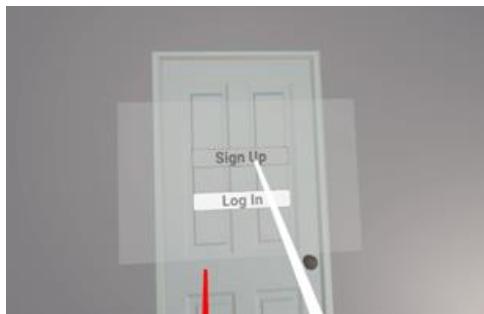


Fig. 3. Authentication menu: choose Sign Up or Log In.

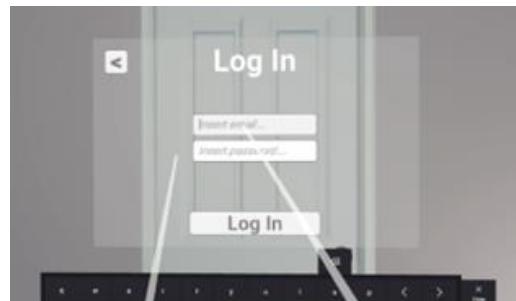


Fig. 4. Authentication menu: Log In.

After Log In, the user enters in a virtual laboratory (Fig. 5) where it will be possible to study using 3D anatomical models. Fig. 6 to Fig. 14 show examples of the im-

plemented scenarios, which may be (in the future) improved, adapted, or changed according to the concepts required in the nursing (or other) study field.



Fig. 5. Opening the door to the laboratory after Log In.

Three different types of models were included in the developed application: one model for studying the brain, one for studying angiology (blood vessels and lymphatic vessels), and another for studying myology (muscles and their appendages). The brain model was added despite overlapping nursing practices, because it was the most complete anatomical 3D model found for free. To demonstrate the possibility to provide labeled models in the application, it was fundamental to include a model that could be used as an example. This model was then the brain.

Fig. 6 and Fig. 7 present, respectively, the study menu in its initial state, and the whiteboard menu with the reference to the three models available for studying.



Fig. 6. Initial state of the study menu.

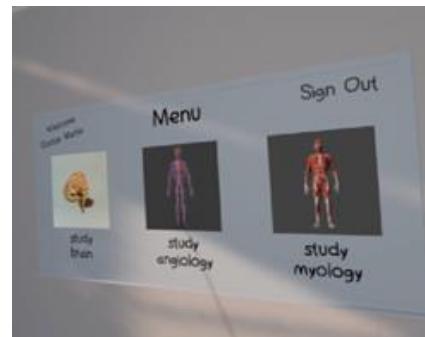


Fig. 7. Whiteboard menu showing the three 3D available models.

Fig. 8 displays the study menu, and the angiology model after selecting the “study angiology” option on the whiteboard menu, while Fig. 9 shows the study menu after selecting the “study myology” option on the whiteboard menu, and the myology model.



Fig. 8. Study menu and angiology model after selecting the “study angiology” option in the whiteboard menu.

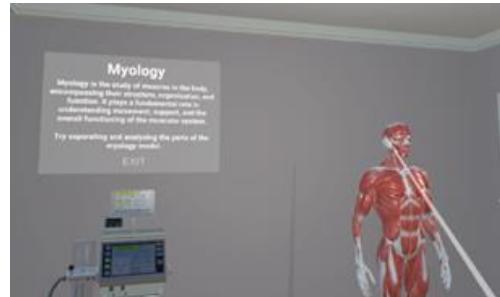


Fig. 9. Study menu and myology model after selecting the “study myology” option in the whiteboard menu.

In Fig. 10 and 11, it is possible to observe one of the 3D elements of the application being grabbed and rotated by the user.



Fig. 10. User grabbing an object



Fig. 11. User rotating an object.

Fig. 12 exemplifies the study menu of the general brain model with 3 size options. The same goes for the study menu of the specific brain model.



Fig. 12. General brain model study menu, with 3 size options.

Fig. 13 shows the labeling of a 3D element of the specific brain model, and Fig. 14 displays the labeling of a set of 3D elements of the overall brain model.

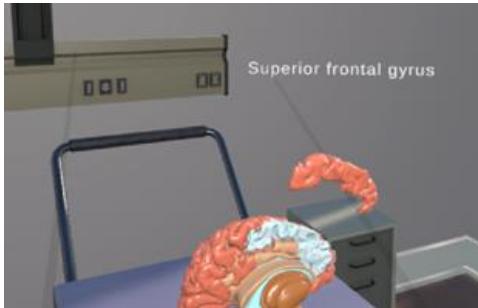


Fig. 13. Labeling of a 3D element of the specific brain model.

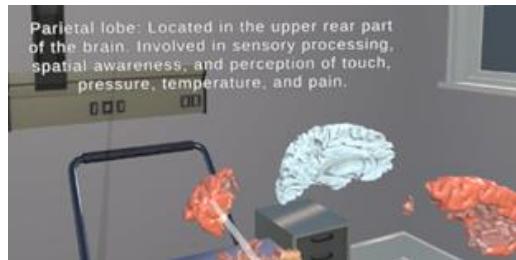


Fig. 14. Labeling of a set of 3D elements of the general brain model.

5 Evaluating the Proposed Solution

As soon as the development of the application was completed, the solution was evaluated using a quality scenario based on the Quality Evaluation Framework (QEF) [11]. The QEF quality scenario was created considering the functional and non-functional requirements for the developed proposal.

Participants from different areas – psychology, criminology, law, and computer science – were invited to test the application. Participants were asked to explore the app's features, interact with the 3D models, and provide feedback on their experience, rating each feature from 0 to 100 – with scores of 0, 25, 50, 75 or 100. Due to professional constraints and the testing phase timing, it was not possible to have the participation of nursing students, nursing teachers or nurses to carry out the functional tests.

Table 3 presents the QEF quality scenario used. The requirements were organized by factors, which in turn were organized by dimensions: Functioning (factors: Functional and Connectivity), Adaptability (factor: Versatility), Efficiency (factors: Strength and Consistency).

Table 3. Project Quality Evaluation Framework

q	D	Qj	Dimension	Qj	Wij (Factor Weight j in Dim i) [0;1]	Factor	r _{wjk} (requirement weight k in Factor j) {2, 4, 6, 8, 10}	Requirement	wfk % requirement fulfillment k) [0,100]
99%	98,1	Functionality	97,9	0,888888889	Functional		10	FF01 - Create Account	95
							10	FF02 - Log In	95
							10	FF03 - Enter inside a virtual environment	100
							10	FF04 - Walk on a virtual environment	100
							10	FF05 - Visualize digital 3D models representing human anatomy	95
							8	FF06 - Turn a digital 3D model	100
							4	FF07 - Increase/Decrease the size of a digital 3D model	100
							8	FF08 - Visualize the name and description of a 3D element	100
	100	Adaptability	100	1	Versatility		10	FC01 - The application must be compatible with Oculus Quest 2	100
	96	Efficiency	90	0,4	Strength		8	AV01 - Application is responsive	100
							8	ES01 - Application interface is quick	85
			100	0,6	Consistency		8	ES02 - The application interface should be easy to use and understand	95
							10	EC01 - Application runtime does not have errors, and unexpected errors should be well treated	100
							10	EC02 - Outputs according to user inputs	100
							8	EC03 - The application should provide an immersive and realistic experience to the user	100

The 99% average result led to the conclusion that the solution's evaluation was extremely positive. Still, to reach the 100% approval, improvements must be made in requirements FF01, FF02, FF05 and ES01, the latter being the one that needs to be improved the most.

6 Discussion

During the project implementation, the encountered limitations impacted on the options taken to develop the application prototype and its functionalities. These limitations were as follows:

1. Lack of budget, which hindered the purchase of high-quality 3D models. All models used were free of charge. This affected the variety and accuracy of the models available in the application.
2. Internet connection limitations at the development site prevented the VR glasses from properly connecting to the Internet. This restriction did not allow integrating the application with the authentication database, meaning that when running the application independently on the virtual reality glasses, it was not possible to Log In and access the virtual laboratory. Alternatively, the application was executed by connecting the virtual reality glasses directly to the computer, using a cable.
3. The reduced human resources (the application was developed by a single Informatics Engineering student) made the 3D models' labelling complex, which interfered with the complete and accurate understanding of the anatomical elements.

Considering those limitations, five solutions were pointed out. These will be explored in further developing the application:

1. Expansion of the 3D model library: It is essential to obtain resources to acquire high-quality 3D models, covering several anatomical areas relevant to the study of nursing (and/or other areas of knowledge).
2. Use of a stable internet connection: To allow authentication and access to the virtual laboratory, the application must be used in a location with good Internet connection, so that this aspect does not constitute a constraint. Another alternative would be to add the option to study as a guest, without the need to log in.
3. Multidisciplinary collaboration: To scale the proposed application development, we must establish partnerships with professionals in the respective area of knowledge, in this case healthcare personnel, namely nurses or anatomy specialists. This approach will allow the expansion of content and the inclusion of accurate information on all 3D elements used.
4. Additional resources: In addition to interactive 3D models, it is possible to consider including further resources such as explanatory videos, tests, or simulations of clinical situations.
5. Tests and evaluation: To guarantee the quality of the application and its growth, tests with students, teachers, and active staff in the considered knowledge area must be conducted (in this specific case, nursing students, teachers, and nurses).

Getting feedback from a broader sample of the target audience will assist in including scientifically rigorous and validated content in the application, correct any problems and identify areas for improvement.

The application is expected to overcome its limitations and evolve, becoming a more robust, comprehensive, and accurate learning tool in the nursing field.

7 Conclusion

This project intended to contribute to better training of future nurses, which would consequently result in a higher quality health service and a reduction in human error. We concluded that using VR as a simulation tool for teaching nursing acts is possible. The developed application considers theoretical teaching, based on the study of anatomical models but it could easily be adapted for practical study, using the models in practice simulation scenarios such as sutures and vaccine administration. This VR application allows students to become familiar with human anatomy, particularly in the areas of myology and angiology, which are fundamental in nursing practices. Students can study several anatomical models without being dependent on expensive mannequins, produced individually for each clinical situation. This enables a frequent and interactive study, helping also with memorization and with practicing invading nursing procedures such as sutures without inflicting pain.

Although the project was a success in many aspects, there is a lot of room for improvement and future developments. The addition of features such as multiplayer would allow students to study together with colleagues and teachers, making this application suitable for use in the classroom. By adding the possibility of testing the knowledge acquired in the application, students could test the consolidated knowledge. In addition to the necessary improvement based on the identified limitations, it is pertinent to expand the application to cover more areas relevant to nursing education, such as physiology, epidemiology, microbiology, nutrition and dietetics, pharmacology, pathology, among others.

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ME-AGS GENERATOR: aplicativo para a geração automatizada de ficheiros AGS4 em geotecnia

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Resumo. Este trabalho tem como objetivo destacar a importância da uniformização e digitalização de dados geotécnicos. Atualmente, o formato de dados AGS é o que é mais aceite pela comunidade geotécnica. Este formato foi desenvolvido pela *Association of Geotechnical and Geoenvironmental Specialists – AGS* (Associação de Especialistas de Geotecnia e Geoambiente – AGS), que reconheceu a carência de troca de dados entre empresas e instituições do ramo da geotecnia, há cerca de 20 anos. Com esta problemática bem identificada pelos técnicos da Mota-Engil: Engenharia & Construção, S.A. – Departamento de Geotecnia, foi encontrada outra dificuldade que se prende com a parte de inserção de dados em código AGS. Para este efeito foi criado e desenvolvido o ME-AGS GENERATOR, que possibilita inserir dados numa folha de Excel respeitante ao grupo do formato AGS que se esteja a trabalhar e cria, posteriormente, o ficheiro no formato “.ags”. O ME-AGS GENERATOR foi criado e desenvolvido no programa MS. Excel em linguagem *Visual Basic for Applications* proporcionando uma experiência mais familiar aos utilizadores na forma de inserir os dados. Uma vez que o nome dos diferentes cabeçalhos do formato de dados AGS é apresentado de forma pouco intuitiva, no desenvolvimento desta aplicação aprimorou-se a interpretação dos cabeçalhos por diferentes utilizadores, pelo que cada uma das diferentes ‘sheets’ apresenta uma “folha de rosto” com a tradução para português dos diferentes cabeçalhos do formato de dados AGS de forma a ser visualmente mais apelativo ao utilizador.

Palavras-chave: Dados geotécnicos, Uniformização, Digitalização, ME-AGS GENERATOR

1 Introdução

Na indústria geotécnica ainda não é totalmente percepível o que são dados geotécnicos, sendo que um arquivo em formato PDF, p.e., com várias informações geotécnicas não deve ser considerado como dados. Estes ficheiros possuem, na sua generalidade, uma grande quantidade de informação geotécnica valiosa, pelo que se tornam ineficientes e inutilizáveis pelo formato do ficheiro em que se encontram. Esta dificuldade de manuseamento dos dados através dos ficheiros em PDF (ou outro formato semelhante) vem

crescendo com a rápida evolução e desenvolvimento de programas de análise e modelação geoespacial [1] [2], tais como o GIS (Geographic Information System) e o BIM (Building Information Modelling). Se um técnico quiser utilizar a informação constante nestes ficheiros em softwares de modelação, p.e., terá de voltar a inserir novamente todos os dados relevantes. A nova inserção dos dados está diretamente ligada ao aparecimento de erros de transcrição e corresponde a uma perda de tempo avultada, o que nos dias de hoje pode trazer grandes prejuízos às empresas [3] [4].

Os indivíduos envolvidos na recolha e tratamento de dados geotécnicos trabalham os dados em diferentes formatos. Esta diferença acarreta inúmeras dificuldades na combinação da informação entre os membros da equipa e/ou entre as diferentes entidades envolvidas nos projetos. Esta dificuldade está relacionada com o facto de os dados geotécnicos serem mal arquivados e uma vez que uma investigação geotécnica é, normalmente, bastante dispendiosa e morosa, traz vários problemas às diferentes empresas do setor. Outra dificuldade está na incompatibilidade existente nos formatos dos ficheiros e nas informações de projetos anteriores. Posto isto, chegou-se, nos últimos anos, à conclusão de que há uma procura urgente em uniformizar a transferência de dados geotécnicos através de um formato bem estruturado e prático [3] [4] [5] [6] [7] [8] [9] [10] [11] [12].

Com a realização deste trabalho pretende-se reforçar a importância do formato AGS em transferência de dados geotécnicos e o desenvolvimento de uma aplicação informática, que possibilite introduzir dados em formato “.xls” e posterior criação de um ficheiro “.ags”.

2 Formato de dados AGS

A Associação de Especialistas de Geotecnia e Geoambiente (AGS – Association of Geotechnical and Geoenvironmental Specialists) reconheceu que no mundo geotécnico existe uma grande sobreposição de “formatos de dados associados que diferenciam na forma e no propósito, mas a maioria do seu conteúdo era comum” [4] e que atrasam o desenvolvimento de softwares específicos, pois cada um destes terá de estar adaptado aos diferentes formatos de dados. Assim, e de forma a interligar mais a geotecnia dos diferentes países, foi criado, em 1991, um grupo de trabalho que teve como principal objetivo: a criação de um formato digital de dados que torna uma transferência de dados o mais uniforme possível. Esta uniformização de dados possibilitará às empresas de desenvolvimento de software geotécnico uma maior facilidade na conceção destes programas. O desenvolvimento de um formato de dados global para a área da geotecnia foi, e ainda é, abordada por vários autores como sendo uma grande preocupação para o mundo geotécnico, nomeadamente, por [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13].

O AGS é um formato de dados que tem como principal objetivo a transmissão uniformizada dos dados. Este formato, na sua versão original, “obedece às práticas britânicas pelo que para a adoção do formato AGS internacionalmente é necessário o contacto com o secretariado da Associação de Especialistas em Geotecnia e Geoambiente (AGS – Association of Geotechnical and Geoenvironmental Specialists)” [4].

O formato de ficheiro do AGS4 cumpre uma série de regras muito específicas, que têm de ser obrigatoriamente seguidas na preparação destes ficheiros. Este utiliza uma série de grupos de dados em formato CSV – Comma Separated Values (Valores Separados por vírgulas). No entanto, o ficheiro não está 100% em conformidade com a especificação CSV RFC 4180, mas é comumente referido como ficheiro CSV [4]. Na Fig. 1, encontra-se um esquema demonstrativo da estrutura de um ficheiro AGS.

```
"GROUP", "GROUP 1"  
"HEADING", "HEADING 1", "HEADING 2", "HEADING n"  
"UNIT", "UNIT 1", "UNIT 2", "UNIT n"  
"TYPE", "TYPE 1", "TYPE 2", "TYPE n"  
"DATA 1", "DATA 1.1", "DATA 1.2", "DATA 1.n"  
"DATA m", "DATA m.1", "DATA m.2", "DATA m.n"
```

Fig. 1. Esquema demonstrativo da estrutura de um ficheiro AGS.

3 A aplicação informática: *ME-AGS GENERATOR*

Em prol da crescente evolução do formato digital “.ags”, houve a necessidade de facilitar a criação deste tipo de ficheiros. Assim, surgiu o interesse de desenvolvimento de uma aplicação informática, baseada em MS. Excel© e segundo a programação em VBA, que possibilite introduzir dados em formato “.xls” e posterior criação de um ficheiro no formato de dados “.ags”. Optou-se por criar a aplicação neste formato, uma vez que os técnicos estão familiarizados com o MS. Excel© e permite uma fácil compatibilidade à realidade de todos os softwares de processamento de dados geotécnicos (pormenores em [14]). No mercado existem algumas ferramentas semelhantes aquela que foi desenvolvida, nomeadamente, AGS 4.0 File Manager (AF Howland Associates – Geotechnical and Environmental Engineers); AGS 4 ON LINE Create, View and Edit AGS4 data file format (Massimo Moroni). O ME-AGS GENERATOR e a aplicação AGS 4.0 File Manager são aquelas que se adequam mais à realidade do dia-a-dia de um técnico, pois trabalham os dados em MS. Excel©. A nível de atualizações ou mesmo a nível de investimento por parte das instituições, o software ME-AGS GENERATOR, é aquele que melhor se adapta. Isto acontece, pois é gratuita e a estrutura da aplicação está conceptualizada de modo que qualquer técnico consiga atualizar os ficheiros de texto com as respetivas atualizações lançadas pela AGS.

Na criação e desenvolvimento da aplicação teve-se em consideração os seguintes objetivos:

- Criação de uma aplicação acessível e amigável ao utilizador (*user friendly*);
- Criação de folhas de rosto de forma a facilitar a leitura dos diferentes títulos do formato AGS;
- Elaboração de uma forma simples de atualizar a aplicação em versões mais recentes do AGS;
- Otimização do aplicativo de forma a poder trabalhar com versões futuras do AGS.

3.1 ME-AGS GENERATOR

Como referido anteriormente, a ME-AGS GENERATOR consiste numa aplicação do programa MS. Excel® em linguagem de programação denominada Visual Basic for Applications (VBA) que permite a criação de um código de forma que a aplicação informática tenha automações apropriadas ao que se pretende trabalhar. O objetivo principal é tornar a aplicação user friendly e de fácil adaptação. Uma vez que o formato de ficheiros AGS é um pouco confuso, pois tem um tipo de siglas específicas e de difícil compreensão, foi tida em consideração a utilização de terminologias em português e enraizadas no mundo da geotecnia, na fase de introdução dos dados.

Ao inicializar a aplicação, o utilizador irá ter automaticamente abertos quatro separadores (Fig. 2), denominados, Início; ListaABBR; ListaTYPE; ListaUNIT. Na folha de cálculo “Início” encontram-se três botões – INICIAR ME-AGS GENERATOR; EXPORTAR FOLHAS e IMPORTAR FOLHAS – que serão aqueles que comandam todas as operações da aplicação; Nas outras três sheets estão listados todos os parâmetros referentes às abreviaturas (ABBR), ao formato (TYPE) e às unidades (UNIT). Deste modo, é possível ao utilizador copiar o que pretende e colar na respetiva folha de cálculo de cada um dos grupos, reduzindo assim os erros de inserção de parâmetros.

Como referido, na folha “Início” encontram-se três botões que realizam tarefas distintas de forma ao utilizador introduzir os dados de forma expedita e intuitiva (Fig. 2). O botão:

- INICIAR ME-AGS GENERATOR:** permite criar o “Template” com os diversos separadores de todos os Grupos que pretende trabalhar e permite exportar esses mesmos separadores para um ficheiro no formato de dados “.ags”. Ao clicar neste botão aparecerá uma janela que contém dois separadores: “Regras” e “Template”. No separador “Regras” serão exibidas as regras mais importantes de forma que o utilizador seja relembrado. No separador “Template” encontrará as opções ilustradas na Fig. 3.

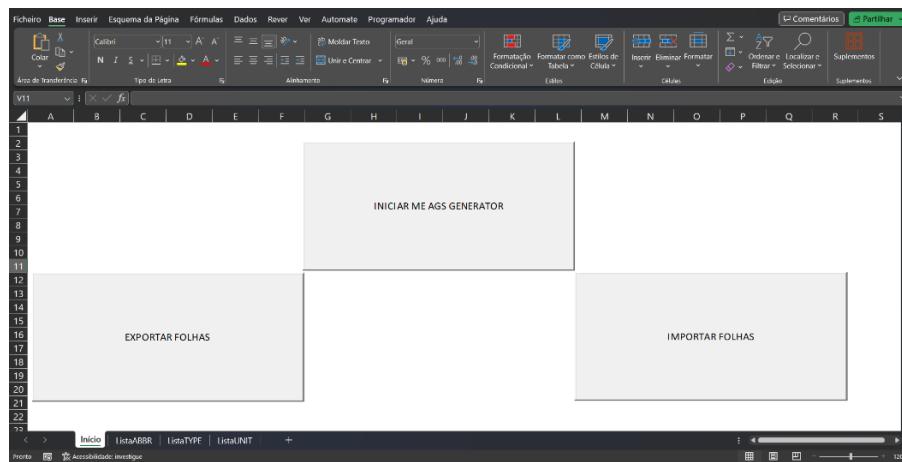


Fig. 2. Folha de abertura (Início) da inicialização da aplicação.

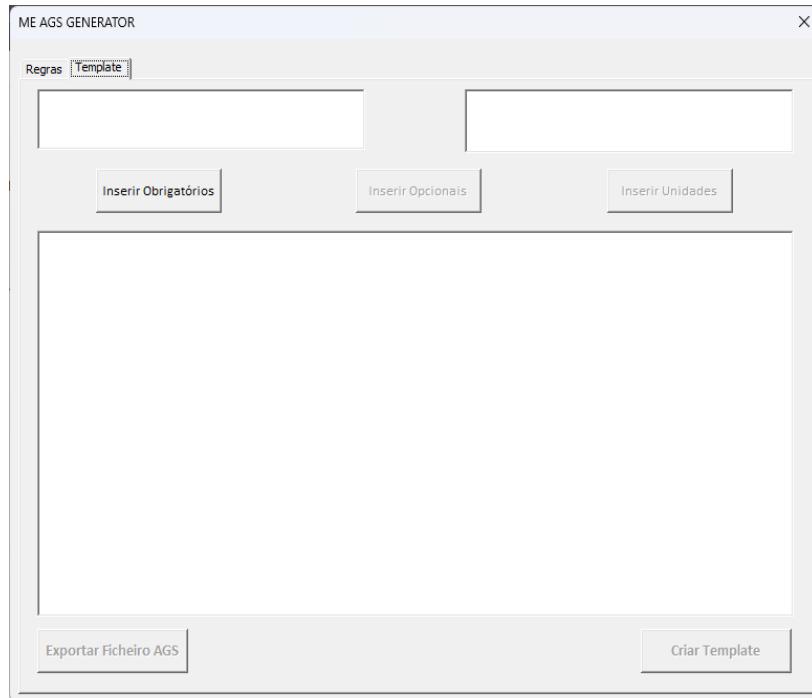


Fig. 3. Janela da aplicação que permite criar Template ou exportar para ficheiro AGS.

Na Fig. 3 é possível verificar que esta janela contém outros botões – Inserir Obrigatórios; Inserir Opcionais; Inserir Unidades; Criar Template; Exportar Ficheiro AGS – sendo que ao clicar no botão:

- **Inserir Obrigatórios** – é aberta uma janela, onde é solicitado ao utilizador que aceda à pasta da aplicação e adicione o ficheiro de texto “**Grupos_Obrigatórios**”.
- **Inserir Opcionais** – este botão está desativado por defeito, sendo que a sua ativação só é realizada após o utilizador inserir o ficheiro “**Grupos_Obrigatórios**”. É aberta uma janela, onde é solicitado ao utilizador que aceda à pasta da aplicação e adicione o ficheiro de texto “**Grupos_Opcionais**”.
- **Inserir Unidades** – este botão está desativado por defeito, sendo que a sua ativação só é realizada após o utilizador inserir o ficheiro “**Grupos_Obrigatórios**”. É aberta uma janela, onde é solicitado ao utilizador que aceda à pasta da aplicação e adicione o ficheiro de texto “**Unidades**”.
- **Criar Template** – este botão está desativado por defeito, sendo que a sua ativação só é realizada após o utilizador inserir o ficheiro “**Unidades**”. Isto acontece de forma a salvaguardar todo o processo de criação do Template.
- Após inserir os três ficheiros de texto na aplicação, o utilizador seleciona “Grupos Obrigatórios”, “Unidades” e todos os restantes Grupos que pretende adicionar ao seu trabalho. Com esta seleção realizada, o utilizador clica no botão “**Criar Template**” para obter as sheets com os diferentes Grupos.
- **Exportar Ficheiro AGS** – este botão permite exportar todas as sheets que estão abertas, a seguir às Listas, para um ficheiro no formato de dados “.ags”. De forma

a salvaguardar a correta exportação dos dados, este botão está desativado por defeito, sendo que a sua ativação só é realizada após o utilizador inserir o ficheiro de texto “**Grupos_Opcionais**” e só depois clicar no botão “**Exportar Ficheiro AGS**”. Este botão apenas irá funcionar se o Excel tiver, pelo menos, as sheets respeitantes aos Grupos Obrigatórios abertas. Posteriormente, ao selecionar este botão, as sheets serão automaticamente eliminadas da folha de cálculo da aplicação (com exceção das sheets Início; ListaABBR; ListaTYPE; ListaUNIT). Isto acontece para que o utilizador não tenha de apagar manualmente as sheets.

Na Fig. 4 é possível observar o aspeto da janela que permite criar o Template ou exportar as sheets para um ficheiro AGS, após a inserção dos três ficheiros de texto – Grupos_Obrigatórios; Grupos_Opcionais; Unidades. Na Fig. 4 ainda é possível verificar o facto de o botão “Criar Template” já estar ativado.

- b) **EXPORTAR FOLHAS:** permite exportar para um novo livro ou para um livro já existente as sheets dos diferentes Grupos, de forma a dar a possibilidade ao utilizador de introduzir os dados num novo livro. A funcionalidade de acrescentar separadores a um livro já existente apenas pode ser aplicada caso o utilizador decida adicionar novos Grupos que, p.e. tenham sido esquecidos ou até porque se realizou um ensaio, inicialmente, não previsto. Ao transferir as sheets para o novo livro, serão automaticamente eliminadas da folha de cálculo da aplicação. Isto acontece para que o utilizador não tenha de apagar manualmente as sheets.

Quando clicar neste botão irá ser aberta uma janela (Fig. 5).

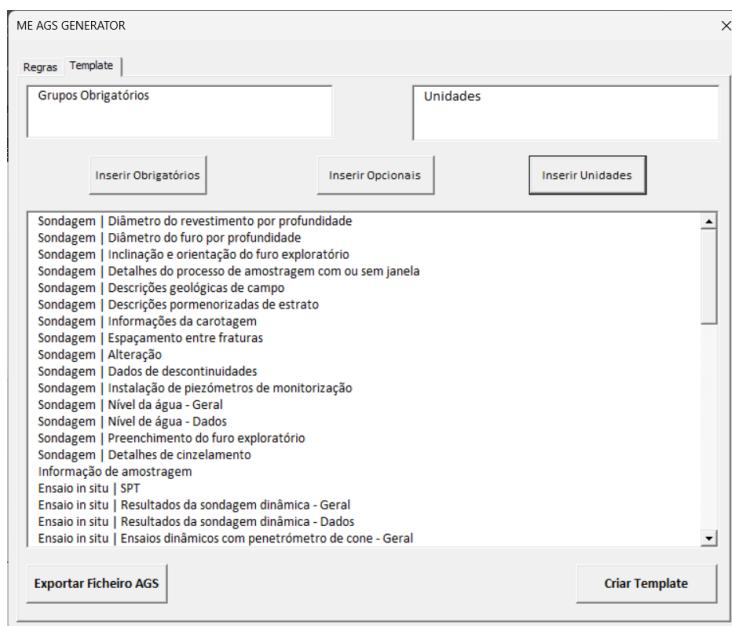


Fig. 4. Aspetto da janela que permite criar o Template ou exportar as sheets para um ficheiro AGS, após a inserção dos três ficheiros de texto – Grupos_Obrigatórios; Grupos_Opcionais; Unidades.

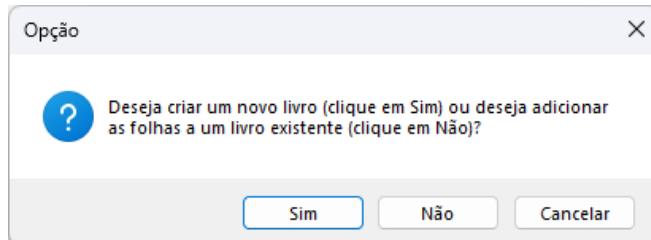


Fig. 5. Janela com as várias opções e exportação das sheets.

Na Fig. 5 é possível verificar que esta janela contém outros botões, sendo que ao clicar no botão:

- **Sim** – será criado um livro, com todas as sheets que estejam abertas na aplicação, a partir da folha ListaABBR até à última.
 - Desta forma permite ao utilizador ter acesso as Listas, no novo livro, e otimiza o seu processo de trabalho.
 - **Não** – será aberta uma nova janela, que possibilita ao utilizador selecionar o ficheiro Excel para onde pretenderá copiar as sheets. Este botão apenas funciona se existirem mais do que 13 separadores abertos, ou seja, os separadores com que se inicia a aplicação (Início, ListaABBR, LsitaTYPE e ListaUNIT) e os Grupos Obrigatórios. Isto acontece de forma que apenas seja utilizado para acrescentar sheets ao ficheiro onde se está a trabalhar e que não sejam novamente copiados, p.e. os Grupos Obrigatórios ou as Listas.
 - **Cancelar** – será cancelada a operação de exportar as sheets para outro Excel.
- c) **IMPORTAR FOLHAS:** Este botão permite importar, de outro livro, para o **ME-AGS GENERATOR** todas as sheets desse livro, com exceção da ListaABBR, ListaTYPE e ListaUNIT. Ao clicar neste botão será aberta uma janela, que possibilita ao utilizador selecionar o ficheiro Excel que pretende que seja importado para a aplicação. As sheets copiadas serão acrescentadas a seguir à última sheet desta aplicação (ListaUNIT). Para que este botão funcione corretamente é **obrigatório** que o ficheiro Excel, a importar, tenha como **três primeiros separadores** a **ListaABBR, ListaTYPE e ListaUNIT**.

3.2 Ficheiros de texto | “txt”

Os ficheiros de texto são de fácil utilização pelo que é possível abri-los e editá-los através do bloco de notas de qualquer computador, tornando-os, deste modo, na maneira mais prática de proceder às diferentes atualizações do AGS. Seguidamente foi necessário compreender a quantidade de ficheiros de texto que seriam necessários e qual seria a melhor estrutura interna destes para não os tornar confusos.

O AGS possuí grupos obrigatórios e grupos opcionais que serão selecionados e utilizados consoante o tipo de trabalho que se esteja a realizar, sendo que a estes grupos acrescem a parte dos formatos (Type) e unidades (Units) **que cada um dos cabeçalhos (Headings) dos diferentes grupos possui**. Com esta obrigatoriedade, foi estruturada a criação de três ficheiros de texto, nomeadamente, o **Grupos_Obrigatórios**; o

Grupos_Opcionais e o Unidades. O ficheiro Grupos_Obrigatórios agrupa todos os grupos obrigatórios; o ficheiro Grupos_Opcionais agrupa todos os restantes grupos deste formato; o ficheiro Unidades agrupa todos os tipos de unidades e formatos de todos os grupos, incluído os obrigatórios, neste formato de dados. Estes três ficheiros irão alimentar a aplicação que posteriormente os irá armazenar em memória de forma a poder abrir os diferentes grupos de trabalho e exportá-los para o formato “.ags”.

Como referido, foi necessário criar uma estrutura de escrita dos diferentes ficheiros de texto de forma que o VBA os consiga ler e interpretar, e de forma que seja possível a qualquer operador atualizar estes ficheiros. Assim, criaram-se as seguintes estruturas para os ficheiros anteriormente enumerados. No ficheiro:

Grupos_Obrigatórios.

```
nome_base,numero_folhas, nome_folha, numero_col_Obr, numero_col_NObr, coluna1_S, coluna1_E, coluna2_S, coluna2_E,..., nome_base, numero_folhas, nome_folha, numero_col_Obr, numero_col_NObr, coluna1_S, coluna1_E,...
```

Neste código optou-se por descrever todos os grupos de forma seguida, uma vez que terão todos obrigatoriamente que aparecer. No Quadro 6 encontram-se descritos os significados dos diferentes códigos.

Grupos_Opcionais.

```
nome_grupo, numero_folhas, nome_folha, numero_col_Obr, numero_col_NObr, nome_coluna1_S, nome_coluna1_E, nome_coluna2_S, nome_coluna2_E,...  
nome_grupo, numero_folhas, nome_folha, numero_col_Obr, numero_col_NObr, nome_coluna1_S, nome_coluna1_E, nome_coluna2_S, nome_coluna2_E,...
```

Este código é muito semelhante ao código do ficheiro “Grupos_Obrigatórios”, pelo que a grande diferença corresponde ao facto de que cada uma das linhas respeitante a um grupo diferente.

Quando o utilizador pretender atualizar os ficheiros de texto, é importante que tenha em atenção e atualize o número de cabeçalhos obrigatórios e não obrigatórios, pois só assim é que a aplicação saberá a quantidade de colunas que tem aquela sheet. Se for necessário acrescentar algum grupo obrigatório, é fundamental que no final do nome, em português e do cabeçalho, esteja um asterisco (*) para o software saber que tem de pintar aquela coluna a cinzento.

Unidades.

```
nome_ficheiro  
nome_folha, num_colunas, unit_col1, unit_col2, unit_col3, ..., type_col1, type_col2, type_col3, ...  
nome_folha, num_colunas, unit_col1, unit_col2, unit_col3, ..., type_col1, type_col2, type_col3, ...
```

O código utilizado neste ficheiro foi pensado para ser interpretado de forma semelhante ao ficheiro “Grupos_Opcionais”, na medida em que cada uma das linhas corresponde a um grupo diferente.

Quando o utilizador pretender atualizar os ficheiros de texto, é importante que tenha em atenção e atualize o número de colunas que aquela sheet contém, pois só assim é que a aplicação saberá a quantidade total de colunas.

4 Considerações finais

O formato de dados AGS apresenta uma terminologia e nomenclatura próprias que se traduz num código com condições muito específicas de escrita. Este código é muito semelhante ao formato CSV, sendo que as particularidades que apresenta são para uniformizar o registo de dados geotécnicos. A inserção de dados de forma manual por cada um dos diferentes utilizadores deste formato de dados está bastante associado à criação de erros. De forma a combater estes erros e a automatizar a parte de criação do ficheiro “.ags” foi desenvolvido o software informático – ME-AGS GENERATOR – que tem como propósito ser original, funcional e simples visando simplificar o trabalho dos técnicos na parte de introdução de dados geotécnicos e posterior criação de um ficheiro no formato de dados AGS.

A utilização desta aplicação por parte de entidades nacionais permite simplificar o quotidiano de quem necessita de criar ficheiros “.ags”. Em Portugal, quanto mais empresas e/ou instituições utilizarem o formato de dados AGS para arquivar ou transferir todas as suas investigações, maior integração para gerar uma base de dados nacional com todos os dados geotécnicos que potencializará esta indústria.

Como perspetivas futuras indica-se que se poderá continuar a desenvolver o software, na medida em que este apresente a possibilidade de ler ficheiros em formato “.ags” e convertê-los num ficheiro “.xls”, facilitando assim o manuseamento de dados.

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Performance Evaluation of the Ballerina Programming Language for Microservices Integration

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Abstract. This scientific paper presents an analysis of the Ballerina programming language's potential as an industry-level candidate for the development of integrated microservice systems. To assess its performance, a comprehensive testing suite consisting of various stress tests was designed to evaluate the language's capabilities under heavy usage scenarios. In addition, comparison tests were conducted, benchmarking Ballerina against the widely used C# language within the .NET framework. The results of the performance evaluation demonstrate that the Ballerina programming language is well-suited for the intended purposes of this study. When compared to the prevalent industry solutions, it exhibits noteworthy performance characteristics, while not displaying significant disadvantages in its utilization. This research highlights the potential of Ballerina as a promising tool for the development of integrated microservice systems, providing insights into its performance and suitability within the software development landscape.

Keywords: Microservices, Cloud, Responsiveness, Systems Testing, Stress Testing, Ballerina, Rest, Docker, Jmeter.

1 Introduction

Ballerina, a contemporary programming language designed for microservices, has swiftly risen among the top 100 most used programming languages since its inception in 2016 by WSO2, an enterprise software company. Positioned within the realm of cloud-oriented languages, alongside Java, C#, Node.js, and Ruby on Rails, Ballerina offers a unique focus on microservices development. The language's recognition and adoption has grown within the software development community, demonstrating its appeal to developers seeking efficient solutions for distributed systems. Recently entering the top 100 most used programming languages [14], Ballerina's presence underscores the escalating demand for specialized tools in domains like microservices and cloud-native architectures. As software developers increasingly engage in cloud-based applications and adopt a microservices architecture, Ballerina garners interest due to its inherent support for key microservices features. This support aids in managing the complexity of systems, allowing developers to concentrate on building essential functionalities.

1.1 Proposed Issue

This project seeks to analyse Ballerina's suitability for microservices development and deployment by creating an application for a sandwich shop. The application, featuring multiple services like Sandwich, Ingredient, and Review, aims to showcase Ballerina's capabilities in building scalable and flexible microservices-based applications. Using a microservices architecture, the application emphasizes modularity, scalability, and resilience, aligning with contemporary software design principles. The project sets practical objectives to develop the microservices-based application using Ballerina, with additional comparison against C#.NET under load. Utilizing the unique features of both languages, the project aims to contribute valuable insights to the Ballerina community, sharing its work in a public repository to facilitate learning and collaboration within the broader development community [1].

2 State of the Art

API Gateway Architecture. In contemporary software architectures, especially within the context of microservices and distributed systems, the API Gateway plays a pivotal role as a centralized entry point for client requests to backend services or APIs. This component serves to unify interfaces and manages interactions between clients and underlying services [2, 4]. The primary functions of an API Gateway encompass API Aggregation, Protocol Translation, Security and Authentication, Rate Limiting and Throttling, Caching, and Monitoring and Analytics. Overall, an API Gateway simplifies the management of complex distributed systems, enhancing scalability, resilience, and security while providing a streamlined experience for client interactions.

Aggregator Pattern. The aggregator pattern within an API Gateway facilitates the composition of different APIs and data aggregation from multiple services. Acting as a mediator, the API Gateway orchestrates interactions between clients and microservices, making parallel or sequential calls to gather necessary data and deliver a cohesive response. This pattern minimizes client requests, reduces network overhead, and allows customization of responses. Benefits of the aggregator pattern include reduced network traffic, simplified client interactions, and response customization. However, challenges arise in error handling, fault tolerance, caching, and data synchronization from multiple sources. Efficient optimization is crucial to prevent the aggregator from becoming a performance bottleneck [3].

Dedicated per Service Database. Adopting a dedicated database for each micro-service enhances data management efficiency. This approach aligns with microservice principles, promoting autonomy and decoupling. Separate databases support scalability and performance optimization for individual services, allowing independent evolution without affecting other services. However, challenges include ensuring data consistency across services and potential data duplication. Proper data synchronization mechanisms are crucial to maintain system consistency.

API Testing. API Load Testing, Soak Testing, and Spike Testing are crucial performance testing techniques evaluating API behaviour under various scenarios. API Load Testing assesses an API's performance under varying levels of simulated user traffic,

identifying capacity, response times, and performance bottlenecks. Soak Testing evaluates an API's stability and reliability over an extended period, ensuring stability under continuous usage. Spike Testing simulates sudden and extreme increases in user traffic to assess the API's ability to handle rapid load fluctuations. Collectively, these testing methodologies identify performance issues, ensure scalability, and optimize overall API performance, instilling confidence in delivering a high-quality user experience under diverse usage scenarios.

3 The Ballerina Language

Ballerina, meticulously crafted for cloud-native applications with a primary focus on integration and distributed systems, boasts a rich array of features tailored to excel in these domains [5]. Let's delve into the distinctive facets that make Ballerina a compelling language for modern application development.

3.1 Basic Features

Ballerina incorporates a robust set of basic features, including a concurrent model that supports scalable and efficient code. It embraces strong typing, enforcing type safety at compile-time with support for primitive types, structured types (objects, records, tuples), and union types. The language's service-oriented architecture provides a native syntax for defining services, endpoints, operations, and resource functions, seamlessly exposing services via various protocols like HTTP, gRPC, and WebSocket. Built-in concurrency constructs, integration and connector libraries, and a message-driven architecture further elevate Ballerina's capabilities.

Error Handling: Error handling is integral to Ballerina, featuring a robust mechanism centered around the 'error' type and the 'check' keyword. The explicit representation of errors allows developers to define and manage errors systematically. The 'check' keyword facilitates controlled error propagation, ensuring structured error handling within the codebase [9].

Concurrency: Concurrency in Ballerina is orchestrated through lightweight workers, offering a structured and efficient approach to parallelism and asynchronous operations. Workers enable concurrent execution, communication through message passing, and synchronization. Mechanisms like 'worker.send' and 'worker.receive' contribute to efficient resource utilization, enhancing performance and scalability in cloud-native applications.

Network Interaction: Ballerina facilitates network interaction through services and listeners. Services, defined with the 'service' keyword, encapsulate related functionality, while listeners serve as entry points for incoming requests. This combination empowers developers to easily build and expose network APIs. Notably, Ballerina simplifies API implementation by enabling HTTP caching by default in the 'http:Client,' optimizing service performance.

Testing Framework: Ballerina's comprehensive testing framework spans unit testing, integration testing, and end-to-end testing. The built-in framework supports assertion functions for verifying expected behaviour in unit tests. Integration testing features,

such as mocking and stubbing, ensure the coherent functioning of interconnected modules. End-to-end testing capabilities cover the entire workflow, simulating real-world scenarios. Integration with popular testing frameworks like JUnit enhances testing flexibility and compatibility, contributing to a robust testing ecosystem in Ballerina.

Development Tools and Environments. In addition to its core features, Ballerina offers a visual diagramming tool for modelling integration flows and a command-line tool for streamlined building and deployment to various cloud platforms.

Containerized Deployment. Ballerina supports flexible deployment options, allowing developers to deploy applications directly or utilize containers, such as Docker [10]. With built-in Docker support, developers can effortlessly build and deploy Ballerina services as Docker containers using the 'bal build' command. It also seamlessly integrates with Kubernetes, the open-source container orchestration platform. Through the Kubernetes extension, Ballerina provides constructs for managing Kubernetes resources. Notably, Ballerina automatically generates Kubernetes YAML files, simplifying the deployment process by eliminating manual resource creation and management.

4 Methodology

To initiate the project in Ballerina, a comprehensive familiarization phase was essential. Following a Proof-of-Concept (POC) approach, various tests were conducted to explore techniques for creating HTTP services, interaction methods in both REST and gRPC, and Java interoperability calls to existing libraries. This initial phase aimed to accumulate the necessary knowledge to construct functional services that accurately represent the Ballerina language, assess its usability as a development tool, and understand deployment mechanisms in a microservices architecture. Subsequent tests were designed in three distinct dimensions. Unit testing, utilizing the language's framework, aimed to validate individual components. Integration tests, facilitated by Postman, focused on assessing the seamless interaction between services. Load/stress testing, executed with JMeter, ensured adherence to non-functional requirements. For comparative analysis, one of the services within the system was replicated in another tech stack, specifically .NET C#, providing a baseline against a prevalent API and microservices development technology. The project's structure revolves around a series of developer milestones, each concentrating on specific objectives. Breaking down the project into manageable pieces ensures steady progress towards delivering a fully functional microservices-based application.

First Milestone: Develop the basic infrastructure, encompassing the microservices architecture and communication protocols. This phase includes setting up essential tools and frameworks such as Ballerina and Docker. By the milestone's conclusion, a basic application skeleton should be operational, enabling communication between services.

Second Milestone: Concentrates on core functionality development, enabling sandwich creation, ingredient listing, and order placement. Basic multilingual support is initiated to ensure application versatility. By the milestone's conclusion, a fully

functional Minimum Viable Product (MVP) capable of creating and ordering sandwiches should be realized.

Third Milestone: Focuses on refining and expanding application functionality, potentially adding new services like a Review service, or integrating with other languages or technologies. Load testing of the full system is conducted to ensure its capability to handle expected traffic, alongside responsive testing of individual APIs to guarantee correct performance.

For each milestone, a comprehensive set of tests, including both full system load testing and responsive testing of individual APIs, was executed. This iterative testing approach aimed to identify and address performance or scalability issues early in the development process, mitigating potential challenges that may have arisen later in the project lifecycle.

To ensure an equitable comparison between C# and Ballerina, both service instances were tested simultaneously, eliminating potential variability from CPU spikes and maintaining a consistent evaluation environment. Adhering to the non-functional requirement of response times under 3 seconds with 10 concurrent users, tests aimed for a throughput exceeding 10 simultaneous requests, with a focus on response time as the primary variable. For this the metric **Throughput** was measured and represents the average number of requests per second executed on the system in each test.

JMeter served as the testing framework, and all test definitions are available in the main project repository. Metrics in the Average, Min, and Max columns in **Table 1**, **Table 2**, **Table 3**, Represent the average of response time in milliseconds.

Table 1. Load Test (Ballerina)- 20s startup, peak at 50 users for 50s, end at 10s, totalling 90s.

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
HTTP GET - All Ingredients	1637	8	0	26	1.73	18.82042
HTTP GET - Sandwich by Name	1607	12	0	24	2.24	18.54373
HTTP POST - Create Reservation	1607	32	0	95	7.48	18.54095
TOTAL	4851	17	0	95	11.84	54.67332

Table 2. Soak Test (Ballerina)- Load of 50 users sustained for 8 minutes and 20 seconds (500 seconds).

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
<i>HTTP GET - All Ingredients</i>	12321	7	0	274	3.14	22.43735
<i>HTTP GET - Sandwich by Name</i>	12295	10	0	260	5.13	22.40551
<i>HTTP POST - Create Reservation</i>	12295	27	0	275	8.12	22.40457
TOTAL	36911	15	0	275	10.79	67.21736

Table 3. Spike Test (Ballerina)- A maximum of 1000 users created in two separate spikes for concurrent system stress, with 50 users maintaining constant load.

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
<i>HTTP GET - All Ingredients</i>	1134	94	0	448	84.87	53.06008
<i>HTTP GET - Sandwich by Name</i>	338	92	0	520	116.50	16.34825
<i>HTTP POST - Create Reservation</i>	274	207	0	915	236.34	13.24311
TOTAL	1746	111	0	915	133.31	81.69568

For the C# vs. Ballerina comparison, three test groups were devised: a Single HTTP GET method in each language, a Double HTTP GET method, and a Single POST method (see, respectively **Table 4**, **Table 5** and **Table 6**). The GET methods involved simple execution requests, exploring concurrent access to the same data, and observing the caching mechanism. The cache remained unchanged or disabled, aligning with industry standards. This choice served as a meaningful test for evaluating how different languages handle caching. The Double HTTP GET was devised for the purpose of creating extra stress on the system while the requests were being executed. For the Single POST method, the concurrent creation of a new entity (a Sandwich instance) and related data queries from the same database provided insights into language efficiency in this scenario. Executing all tests concurrently ensured a fair evaluation of overhead, reflecting representative response times indicative of computational performance.

Table 4. - C# versus Ballerina Single GET method

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
<i>BAL GET - Sandwich by Id</i>	1490	5	0	61	3.00	25.46312
<i>C# GET - Sandwich by Id</i>	1467	3	0	37	1.64	25.71293
TOTAL	2957	4	0	61	2.83	50.53319

Table 5. C# versus Ballerina Double GET method

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
<i>BAL GET - Sandwich by Id</i>	578	5	0	9	0.72	9.83478
<i>BAL GET - Sandwich by Name</i>	566	4	0	8	0.68	9.88733
<i>C# GET - Sandwich by Id</i>	549	3	0	5	0.55	9.63276
<i>C# GET - Sandwich by Name</i>	540	2	0	11	0.65	9.38918
TOTAL	2233	3	0	11	1.39	37.99493

Table 6. C# versus Ballerina Single POST method

	# Samples	Average [ms]	Min [ms]	Max [ms]	Std. Dev.	Throughput
<i>BAL POST - Create Sandwich</i>	1462	7	0	50	2.89	24.77588
<i>C# POST - Create Sandwich</i>	1444	9	0	57	4.33	24.54739
TOTAL	2906	8	0	57	3.80	49.20337

5 Discussion

In the context of system testing, Ballerina proves itself as a capable language for microservices development, displaying no significant performance overhead even during instances of CPU spikes. All conducted tests adhere to the non-functional requirements, ensuring response times below 3 seconds with over 10 concurrent users. The anticipated variability in CPU availability, identified during test planning, manifested in an unexpected momentary increase in response time, attributed to a synchronized CPU spike. This spike uniformly affected all processing responses, underscoring the importance of accounting for such variables.

Throughout the tests, which included two HTTP GET methods and one HTTP POST method executed concurrently, Ballerina showcased robust performance. The POST method, regarded as the most computationally demanding in the system, consistently delivered responses well within project limits. In the Spike test, the maximum response time for the POST method reached 915 milliseconds, with the highest average just below 750 milliseconds.

Meeting non-functional requirements, all tests maintained over 50 concurrent user requests per second, yielding response times below 1 second. Comparison tests with C# revealed distinct performance differences, as visualized in Annexes IV, V, and VI in the project's repository [15]. Ballerina consistently exhibited nearly double the average response time of C# across various tests. While this discrepancy suggests potential variations in implementation optimization or language maturity, the absolute differences, all below 3 milliseconds for both GET and POST methods, remain negligible. Importantly, they fall well below the 1% threshold of the project's 3-second response time requirement. Consequently, despite nuanced differences, the performance of both languages in the conducted tests can be deemed practically identical.

Transitioning to the discussion of Ballerina as an industry solution, its implementation focus centres on minimizing development time and code lines while ensuring a robust deployment process. Ballerina empowers developers with built-in support for distributed systems, service orchestration, and network protocols, streamlining the design and implementation of complex architectures. The language's rich feature set includes native microservices support, connectors for various protocols, and seamless integration with cloud platforms and APIs. Beyond functionality, Ballerina's tooling encompasses testing, debugging, and monitoring features, providing developers with comprehensive support for confirming and troubleshooting complex systems during development and deployment.

In terms of complexity, Ballerina adopts a minimalistic approach to reduce code complexity and boilerplate while maintaining expressiveness and power. The language achieves this through concise syntax and a focused set of keywords covering a broad range of functionality. A comparative analysis with C# reveals differences in complexity, where C#, while feature-rich, demands a deeper understanding of its extensive constructs and concepts. In contrast, Ballerina abstracts complexities associated with distributed systems through higher-level constructs like service-oriented programming and message-passing concurrency. This abstraction simplifies development and allows for quicker creation of applications with fewer lines of code.

Considering maintainability, Ballerina's concise and expressive syntax contributes to code clarity and well-defined functionality. Each line of code often represents a clear and focused task, leading to lower cyclomatic complexity compared to more verbose languages. However, Ballerina's relative novelty introduces challenges related to frequent breaking changes in updates. This dynamic development environment can hinder long-term stability and performance, necessitating an up-to-date language version for stability. Despite these considerations, Ballerina excels in offering a concise and expressive means of defining complex resources with minimal source code, promoting readability and maintainability. Careful code management and adherence to best practices become imperative to navigate the potential complexities introduced by Ballerina's concise nature. Ultimately, the choice between Ballerina and other languages hinges on project requirements, development team expertise, and the broader ecosystem surrounding the target platform.

6 Conclusion

In conclusion, it can be ascertained that while Ballerina may not be the optimal choice for computationally intensive tasks such as machine learning, computational fluid dynamics (CFD), or Big Data manipulation, it certainly stands out as a very acceptable solution for distributed systems tasked with data delivery and serving as a middleware between client systems and internal backend architectures, whether computational or persistence resources. The language's implementation style, although possessing distinctive attributes, proves straightforward for developers, offering valuable abstractions that alleviate the burden of crafting extensively repetitive, boilerplate code, commonly encountered issues in other programming languages.

Performance-wise, Ballerina aligns seamlessly with prevalent industry languages, executing its designated use cases with precision. It emerges as a language that fulfils its intended purposes effectively, with ongoing enhancements planned for its evolution. Notably, Ballerina has witnessed increasing adoption in recent years, underscoring its relevance and utility within the development community.

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Protótipos educativos para carregamento de telemóvel e medição da velocidade, distância e consumo energético de um ciclista

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Resumo. O ensino da engenharia está em mudança para novos paradigmas de ensino-aprendizagem. A Aprendizagem Baseada em Projetos ou Project Based Learning (PBL) é uma tendência crescente nos Programas do Ensino da Engenharia que alavanca os estudantes a encontrar solução para problemas reais. Este método tem diversas condicionantes, como a disponibilidade dos docentes para esta mudança ou a necessidade de investimento financeiro, mas têm surgido plataformas *low-cost* e *open-source* que diminuem estes constrangimentos. Uma destas plataformas de apoio à aprendizagem da eletrónica, programação e simulação está associada a um microcontrolador Arduino. Este trabalho integrou este modelo de aprendizagem activa e o uso deste microcontrolador no desenvolvimento de dois protótipos com vista a ajudar um ciclista. Um protótipo mede a velocidade, distância percorrida e gasto calórico durante a utilização da bicicleta, o outro protótipo carrega a bateria do seu telemóvel transformando energia mecânica em energia elétrica. No teste da prototipagem usou-se um rolador estático, uma bicicleta e um ciclista, que durante 2 minutos percorreu 1257,7 m a uma velocidade média de $37,7 \pm 6,9$ km/h, atingiu uma velocidade máxima de 52,1 km/h, consumiu cerca de 25 kcal e conseguiu carregar a bateria do telemóvel em 3%. O ciclista, que teve de realizar a prova, pertence a um grupo de estudantes do 1º ano de Engenharia de Sistemas da Unidade Curricular Laboratório de Engenharia 1.

Palavras-chave: Arduino, Project based learning, Velocímetro, Protótipo, Contador de calorias, Bicicleta.

1 ENQUADRAMENTO TÉORICO

1.1 Introdução

O ensino em engenharia está maioritariamente envolto em conceitos teóricos, prejudicando a ambientação à resolução de problemas reais. Assim, os paradigmas educativos centrados no desenvolvimento de competências (skills) emergentes e centrados no desenvolvimento profissional é considerado, para muitos especialistas, um fator chave para o sucesso do ensino. O método de aprendizagem ativa como o Problem-Based

Learning (PBL) consegue juntar com sucesso estes requisitos, usando problemas quotidianos de alguma complexidade para promover a aprendizagem de conceitos e princípios pelos alunos, em oposição à apresentação expositiva e direta de fatos e conceitos. O PBL promove o desenvolvimento de pensamento crítico, habilidade de comunicação oral/escrita, oportunidade de trabalho em grupo e, por isso, representa um enorme desafio para estudantes e docentes [1, 2, 3, 4, 5].

O uso do microcontrolador Arduino afirmou-se na última década como ferramenta *low-cost* para ensino na área da eletrônica, programação e controlo com sucesso, pois permite que qualquer docente ou aluno melhore os seus projetos por meio de uma placa eletrônica e tecnologia digital [6, 7, 8, 9, 10, 11, 12, 13].

Neste sentido, o presente trabalho refere-se a um relatório sobre o desenvolvimento de dois protótipos destinados ao melhoramento da prática do ciclismo: o primeiro integra um velocímetro, medidor de distância e contador de calorias gastas durante o percurso de um ciclista, e o segundo converte a energia mecânica usada pelo ciclista em energia elétrica, com vista a tornar possível o carregamento de um telemóvel. Este projeto usou uma placa de baixo custo Arduino num contexto de aprendizagem activa em PBL da unidade curricular Laboratório de Engenharia I (LENG1) do primeiro ano do curso da licenciatura em Engenharia de Sistemas (LES) do Instituto Superior de Engenharia do Porto (ISEP) no ano letivo de 2017/18.

1.2 Protótipo 1

Para o desenvolvimento do velocímetro utilizou-se a placa Arduino UNO R3 [13] programada com recurso a instruções desenvolvidas ou adaptadas pelos estudantes. Estas instruções foram criadas em sketch no software Arduino (IDE) versão 1.8.4. com os seguintes cálculos:

$$\text{Distância total (m)} = \text{Nº de voltas} \times \text{Perímetro da roda} \quad (1)$$

$$\text{Velocidade (km/h)} = \text{Nº voltas por segundo} \times \text{Perímetro da roda} \times 3,6 \quad (2)$$

Para determinar o Gasto calórico total, foi utilizada uma fórmula de Gil [14] disponível on-line que utiliza, além da Massa do ciclista (kg) e do Tempo (min) e um Índice de ajuste com base na velocidade do ciclista (ver Tabela 1).

$$\text{Gasto calórico total (kcal)} = \text{Tempo (min)} \times \text{Massa} \times \text{Índice} \quad (3)$$

Tabela 1. Índice de gasto energético em ciclismo

Velocidade	Índice
< 15 km/h	0,066
16 - 19 km/h	0,100
20 - 22 km/h	0,133
23 - 25 km/h	0,166
26 - 30 km/h	0,200
>30 km/h	0,266

Fonte: Adaptado de [14].

1.3 Protótipo 2

O carregador de telemóvel desenvolvido utilizou um dínamo de bicicleta acoplado a um regulador de tensão para permitir uma conversão de corrente alternada para corrente contínua e, adicionalmente, a estabilização da tensão gerada de forma a permitir um output de 5 V contínuo para o carregamento do equipamento móvel.

2 MATERIAIS E METODOLOGIA

2.1 Metodologia PBL e Arduino

A metodologia de ensino/aprendizagem implementada na UC LENG1 foi baseada em Project/Problem Based Learning e aplicada a 46 alunos que ingressaram no 1º semestre de 2017/18 do curso de Engenharia de Sistemas do Instituto Superior de Engenharia do Porto. O processo de integração dos alunos no curso inicia-se numa sessão plenária com apresentação individual e formação de grupos. Em seguida, os alunos realizam durante as 2 primeiras semanas um pequeno projeto inicial que visa a integração deles no Curso, instituição e cidade. Posteriormente, nas restantes 2 semanas, os alunos realizam um segundo projeto com foco na construção de um protótipo com Arduino.

O tema deste ano letivo 2017/18 foi a criação de 2 protótipos: um velocímetro, medidor de distância e medidor do consumo energético de um ciclista e outro com a possibilidade de carregar o telemóvel, convertendo a energia mecânica da pedalada em energia elétrica. No final da construção dos protótipos os grupos de alunos têm de realizar uma demonstração do seu funcionamento em prova prática com bicicleta e rolo estático, durante 2 minutos. Cada grupo apresentou os seguintes resultados:

- (i) Velocidades mínima, média e máxima;
- (ii) Desvio padrão da velocidade média;
- (iii) Distância percorrida;
- (iv) Consumo energético do ciclista.

Posteriormente, cada grupo de alunos teve de realizar uma apresentação pública dos resultados e elaborar um relatório tipo artigo.

2.2 Componentes usados nos protótipos

No carregador de telemóvel foi utilizado um dínamo (9€), uma ponte retificadora, estabilizador de tensão 5 V - 7805 (0,5€), breadboard 170 pontos (1,09€), condensador de 100 μ F 25 V (0,2 €) e ficha USB type A fêmea (2,03€). O investimento totaliza 12,82€ (IVA incluído).

No velocímetro foi utilizado uma placa Arduino UNO R3 (22,25€), uma breadboard 640 pontos (7,53€), um switch (sensor) magnético (2,5€), íman, resistências (1k Ω), 10 cabos jumpers (2 €), cabo USB, LEDs (0,20€), software Arduino (IDE) 1.8.4 (Fig. 1). O investimento atingiu 34,48€ (IVA incluído).

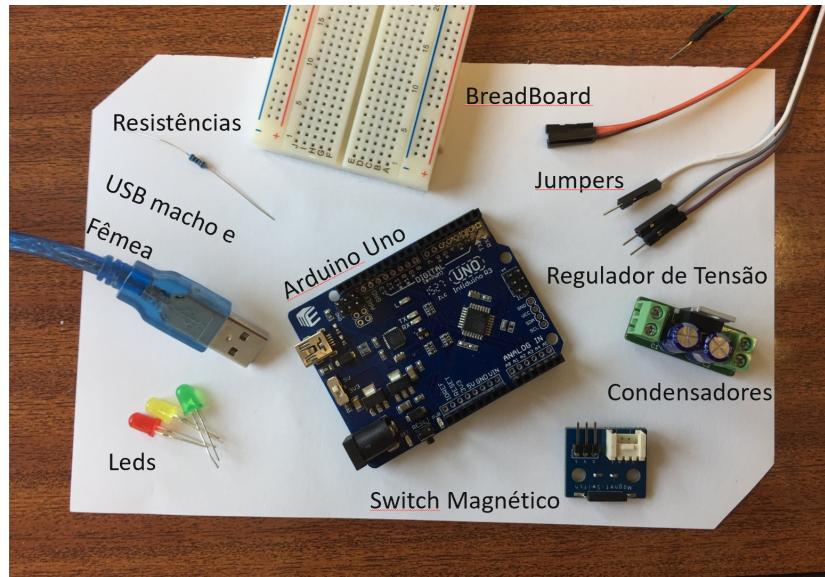


Fig. 1. Esquema de ligação do microprocessador aos LEDs e ao sensor magnético.

2.3 Desenvolvimento experimental

Protótipo 1.

O desenvolvimento do algoritmo baseou-se no princípio de um switch ‘sempre ligado’ que desliga com a proximidade do íman instalado na roda da bicicleta, facto que acontece quando se completa uma volta. O sinal ‘ligado’ representa-se por ‘HIGH’ e, contrariamente, representa-se por ‘LOW’. Com base neste princípio criou-se a variável ‘voltas’ que é incrementada sempre que o sensor devolve um sinal ‘LOW’. Neste sentido, para evitar falsas leituras foi necessário introduzir um delay de 100 ms entre contagens (ver código na Fig. 2).

Através deste método e sabendo o perímetro da roda utilizada, que neste caso foi de 2,072 m, determinou-se a distância percorrida (Equação 1).

```
void loop() {
    unsigned long currentMillis = millis();
    if(digitalRead(magnet)==LOW) {
        contp=contp+1;
        distotal=contp*per;
        //Serial.println(contp);
        delay(100);
    }
}
```

Fig. 2. Código para determinação da distância percorrida pelo ciclista em metros.

Na determinação da velocidade instantânea foi necessário introduzir no algoritmo um novo ciclo capaz de determinar o número de voltas a cada segundo. E de forma a visualizar o valor desta velocidade em tempo real foi criada uma instrução que apenas atualiza o seu valor quando há alteração. No cálculo da velocidade instantânea foi inserido um fator de conversão de m/s para km/h de acordo com a instrução (Equação 2).

Ainda foi introduzido um contador de calorias (Equação 3), tendo por base a velocidade instantânea do ciclista. As instruções de cálculo introduzidas no algoritmo estão de acordo com um índice obtido pelo valor da velocidade (ver Tabela 1), pela massa corporal do ciclista (75 kg) e pela conversão do tempo de segundos para minutos (Fig. 3).

```

if (currentMillis - previousMillis >= interval) {
    previousMillis = currentMillis;
    voltas=contp-conts;
    v=(voltas*per*3.6)/1;
    if ( v > vmax){
        vmax = v;
    }
    if(v>0 && v<15 ){
        calorias= ((0.066*75)* currentMillis/60);
    }
    if(v>=15 && v<19){
        calorias=((0.1*75)* currentMillis/60);
    }
}
if(v>=19 && v<22){
    calorias=((0.133*75)* currentMillis/60);
}
if(v>=22 && v<25){
    calorias=((0.166*75)* currentMillis/60);
}
if(v>=25 && v<30){
    calorias=((0.2*75)* currentMillis/60);
}
if(v>=30){
    calorias=((0.266*75)* currentMillis/60);
}

```

Fig. 3. Código para determinação da velocidade máxima e das calorias gastas pelo ciclista.

Adicionalmente, foi desenvolvido um protótipo indicador luminoso da velocidade instantânea com seis LEDs de cores diferentes: dois verdes, dois amarelos e dois vermelhos (Fig. 4).

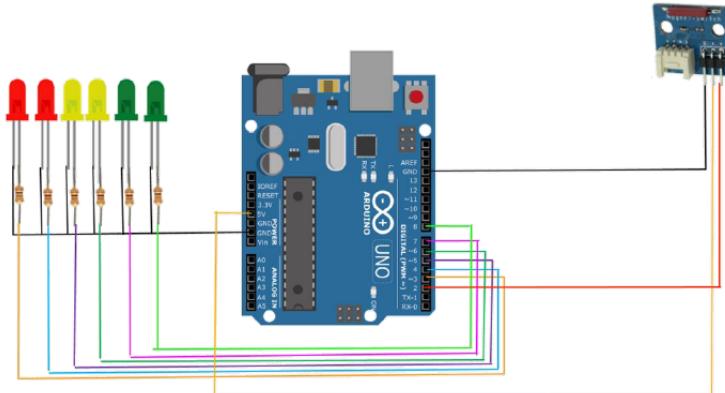


Fig. 4. Esquema de ligação do microprocessador aos LEDs e ao sensor magnético.

Os LEDs acendem numa ordem crescente de velocidade instantânea em intervalos de 5 km/h. Assim, o primeiro LED, verde, acende a 5 km/h, o segundo, verde, acende a 10 km/h e assim sucessivamente até que o último, vermelho, acende quando é atingida a velocidade de 30 km/h.

Protótipo 2.

O dispositivo desenvolvido contém um dínamo acoplado à roda da bicicleta que converte energia mecânica em energia elétrica. Criou-se um dispositivo com regulador de tensão para evitar sobrecargas acima dos 5 V e com uma entrada USB que permite a ligação de um cabo que carrega a bateria do telemóvel (ver Fig. 5).

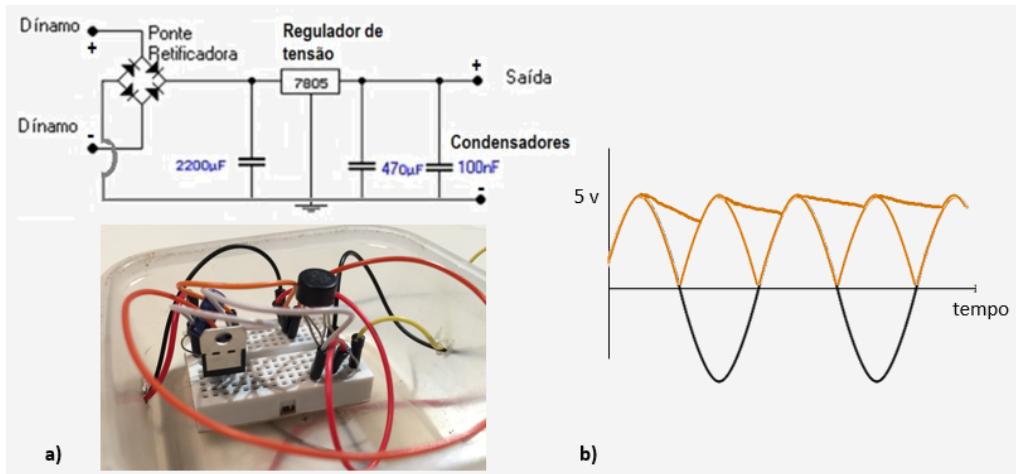


Fig. 5. Esquema elétrico e montagem do regulador de tensão

O dinamo produz uma tensão alternada que é convertida para contínua, conforme esquema elétrico apresentado na Fig. 5a, e em seguida o seu valor é estabilizado no dispositivo para 5 V (Fig. 5b).

3 RESULTADOS E DISCUSSÃO

Os protótipos foram testados em sala de aula numa bicicleta colocada sobre um rolo estático, e cada ciclista (estudante) teve de pedalar durante de 2 minutos (Fig. 6).



Fig. 6. Imagem de um momento da prova

Nesta prova mediu-se: a) distância percorrida, b) velocidade instantânea, máxima e média com menor desvio padrão, c) contador de energia gasta pelo ciclista e d) quantidade (%) de carregamento do telemóvel.

a) Distância percorrida

A distância percorrida durante 2 minutos foi de 1257,7 m.

b) Velocidade

A máxima velocidade alcançada foi de 52,1 km/h e a velocidade média foi de 37,7 km/h com um desvio padrão de 6,9 km/h.

Na velocidade média foi possível observar três momentos: momento inicial em que o valor foi aproximadamente 41 km/h, a cerca de 120 s diminui para 34 km/h e, nos últimos 10 s, baixa para valores de 28 km/h (Fig. 7).

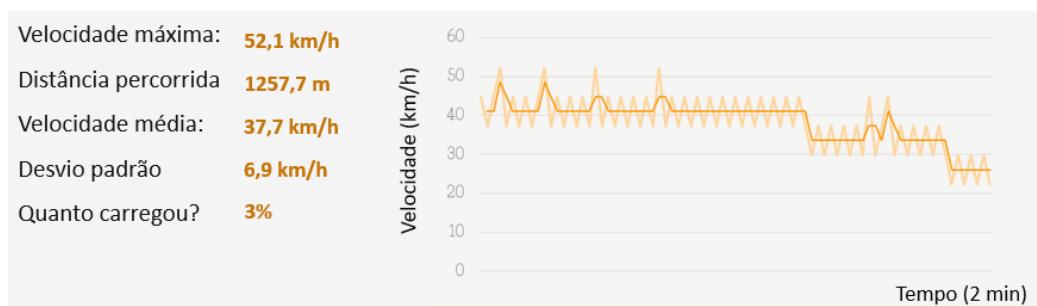


Fig. 7. Velocidade instantânea em função do tempo (linha espessa e clara) com indicação da tendência central (linha fina contínua e escura).

O velocímetro apresentou à partida uma dificuldade com a utilização da função millis() e reinício do seu valor a cada passagem. Para a evitar, criou-se um algoritmo que incluía dois ciclos em vez de um, no primeiro tinha a instrução da contagem de voltas e distância percorrida, e no segundo, a instrução para o cálculo da velocidade instantânea, com base no número de voltas por segundo (como explicado na metodologia).

De forma a tornar o protótipo mais apelativo, o grupo criou um mostrador dinâmico do valor da velocidade com um conjunto de LEDs (Fig. 8) e corrigiu a ponte inicialmente selecionada para a estabilização da tensão, introduzindo uma retificação.



Fig. 8. Velocímetro – painel dinâmico com cor.

c) Contador de Gasto energético (calorias)

O contador foi desenvolvido usando diferentes fórmulas para cálculo do consumo de energia de acordo com o índice de massa corporal e a velocidade instantânea do ciclista [14][15]. No algoritmo que contém a Equação 3, o valor da energia gasta variou entre 20-30 kcal em 120 s (Ver Fig. 9).

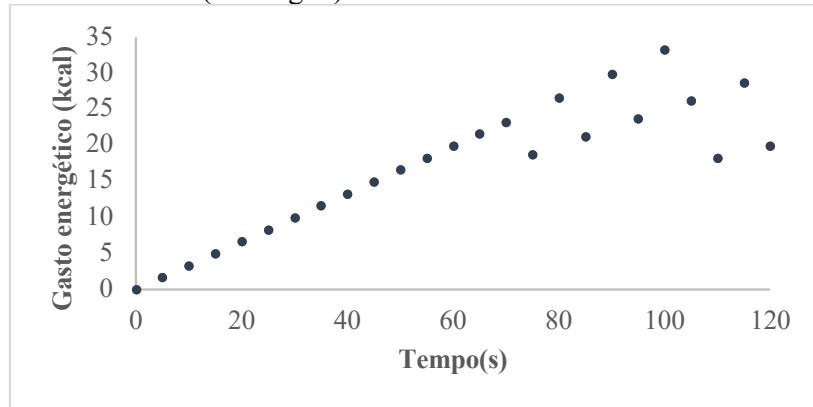


Fig. 9. Evolução temporal do Consumo de Energia gasto pelo ciclista durante a prova.

d) Carregamento do telemóvel

No início da prova o indicador de bateria estava em 75% e no final a 78%, o que corresponde a um aumento de 3%.

4 CONCLUSÕES e SUGESTÕES

Os estudantes conseguiram em 2 semanas realizar os 2 protótipos com recurso à placa Arduino e realizar a prova na data predefinida com sucesso. Ultrapassaram algumas dificuldades como: no 1º protótipo de medição da velocidade do ciclista foram resolvidos problemas de conversão de energia alternada em contínua, falsas leituras do *switch* magnético na contagem de perímetros da roda da bicicleta e problema nas estimativas do consumo energético em função da massa e velocidade do ciclista; no 2º protótipo foi necessário introduzir uma ponte retificadora e um condensador para regular a tensão elétrica a 5 V.

Na prova deste grupo de trabalho, o estudante (ciclista) pedalou durante 2 minutos, percorreu 1257,7 m a uma velocidade média de $37,7 \pm 6,9$ km/h, atingiu uma velocidade máxima de 52,1 km/h, consumiu cerca de 25 kcal e conseguiu carregar a bateria do telemóvel em 3%.

Este projeto da UC de LENG1 conseguiu usar uma estratégia de ensino-aprendizagem inovadora e disruptiva, despertando os estudantes para a realidade da vida profissional, simulando a resolução faseada de um problema real, concebendo, implementando e operando dois protótipos construídos pelos próprios. Na opinião dos alunos, o modo de funcionamento da UC ajudou a sua integração na turma e escola, e foi fator importante de motivação para a aprendizagem.

Como sugestões de melhoria propõe-se: i) inclusão de um botão de *reset* ou *blank* de forma a iniciar nova contagem; ii) possibilidade de personalização do perímetro da roda e da massa corporal do ciclista; iii) introdução de sensor biométrico de alerta da temperatura corporal.

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Raise Penetration Tests with Machine Learning

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Abstract. This paper embarks on an in-depth exploration of integrating machine learning (ML) techniques into penetration testing, specifically targeting web application security. It introduces a prototype tool crafted to streamline the detection of vulnerabilities in web applications. This integration not only augments the efficiency but also significantly elevates the effectiveness of security assessments. The prototype employs a Decision Tree Classifier within its core AlgorithmML module to intelligently recommend appropriate tools for distinct phases of penetration testing. Further, the system's modular design, encompassing the Pentest Tool and ReportGenerator modules, demonstrates remarkable flexibility and adaptability, crucial for keeping pace with the rapidly evolving landscape of cyber threats. The prototype's effectiveness is evaluated through a series of tests, showcasing its capabilities in enhancing cybersecurity strategies. This paper not only contributes to the field by presenting a novel approach to automating security assessments but also opens avenues for future research in the seamless integration of machine learning with cybersecurity frameworks, ultimately aiming to fortify web applications against the growing sophistication of cyber threats.

Keywords: Machine Learning · Penetration Testing · Automated Security Assessment · Decision Tree Classifier

1 Introduction

1.1 Problem Description

The central issue addressed during the internship pertained to enhancing intrusion testing through the integration of machine learning techniques. In the realm of cybersecurity, penetration testers assume the role of attackers to identify security vulnerabilities within systems. Acknowledging the rapid evolution of technology, it has become increasingly evident that machine learning offers a promising avenue for automating penetration tests by identifying data patterns. This internship aimed to explore the synergy between intrusion testing and machine learning to elevate the efficiency and efficacy of security assessments.

1.2 Objectives

The primary objectives encompassed a comprehensive exploration of techniques to bolster cybersecurity within ocean and space software projects. These objectives were as follows:

- To examine existing methodologies and techniques that could be employed to augment security within ocean and space software projects.
- To conduct an in-depth investigation into the state-of-the-art approaches within the domain, focusing on the integration of machine learning techniques to enhance security testing.
- To develop tools tailored for penetration testing purposes, contributing to the arsenal of security assessment resources.

2 State of the Art

Concepts and techniques of machine learning in security testing related to the work are presented in the following section.

2.1 Concepts and Machine Learning Techniques in Security Testing

Supervised Learning (Classification): This technique involves training ML models on labeled datasets. It's particularly useful in intrusion detection, malware classification, and phishing detection, aiding in the identification of vulnerabilities in web applications [10].

Unsupervised Learning (Clustering): Utilizes unlabelled datasets to discover hidden patterns. Penetration testing helps in anomaly detection and identifying unusual behaviours that might indicate security breaches [9].

Reinforcement Learning: This approach involves training models through trial and error, receiving feedback in the form of rewards or penalties. It's valuable in adaptive penetration testing, allowing systems to learn the most efficient strategies for uncovering vulnerabilities [8].

Anomaly Detection: A method to identify unusual events or patterns, crucial for uncovering novel threats or vulnerabilities that haven't been previously documented [7].

Deep Learning: Involves multi-layered neural networks, effective in large-scale, high-dimensional data analysis. It's used in malware detection, network intrusion detection, and identifying data exfiltration [6].

Feature Selection: This process involves selecting a subset of relevant features to improve ML model performance, particularly important in intrusion detection, malware classification, and vulnerability assessment [5].

Ensemble Learning: Combines multiple models to improve overall performance. It's used for more accurate predictions and robustness in detecting complex vulnerabilities [4].

2.2 Security Testing Automation Tools Using ML

Bellow's study compares open source and commercial penetration testing tools using machine learning:

Open Source Tools:

- DeepExploit [11] : Uses reinforcement learning for vulnerability detection.
- caffe [12] : A deep learning framework, applied in intrusion detection.
- OWASP - Nettacker [13] : Employs decision trees and random forests for vulnerability classification.

Paid Tools:

- Nessus Professional [14] : Uses advanced algorithms for vulnerability detection.
- Core Impact [15] : Exploit modules and automated testing capabilities.
- Acunetix [16] : Uses algorithms for web-based vulnerability identification.
- Burp Suite Professional [17] : Uses advanced algorithms for web vulnerabilities.
- Rapid7 Metasploit Pro [18] : Library of exploit modules and automated testing.

2.3 Case Studies Highlighting ML Applications in Security

The following applications employ different machine learning techniques in security testing:

- Deep Learning for Intrusion Detection: Utilizing stacked autoencoders and deep belief networks for enhanced detection rates[3].
- Machine Learning for Web Application Penetration Testing: Employing algorithms like Random Forests and K-means clustering to automate and improve efficiency [2].
- Reinforcement Learning for Post-Breach Testing: A novel approach for automating post-exploitation phases in penetration testing [1].

3 Problem Analysis and Solution Design

The task of ensuring cybersecurity in an organization's systems is both crucial and complex. Penetration testers have traditionally been the front-line defence, actively targeting these systems to evaluate their robustness against potential cyber threats. However, the manual nature of this approach, coupled with the vast array of security vulnerabilities and the tools needed to address them, presents a significant challenge.

3.1 Aims and Objectives

In the expansive realm of the digital world, the urgency of strengthening software against cyber threats can't be overstated. Inspired by the internship title "Raise Penetration Tests with Machine Learning," the focus is on enhancing conventional penetration testing by harnessing the power of machine learning. The main goals are centered around this concept.

Objective 1: Tool Recommendation Through ML Rationale: Traditional penetration testing often hinges on the tester's personal experience when selecting tools, which might not always ensure optimal outcomes. Machine learning's capability to recognize and predict patterns can revolutionize this process.

Methodology:

- Creation of a dataset with parameters such as Target, Vulnerability, Tool, and Phase. This dataset serves as the knowledge base from which the machine learning model learns.
- Implementation of the Decision Tree Classifier, an interpretable model, to suggest tools. Leveraging historical data and learned patterns, the prototype can make informed tool recommendations, ensuring a tailored approach to each unique scenario.

Objective 2: Automated Tool Execution Rationale: Once tools are recommended, their efficacy is predicated. Automating this process ensures that tools are deployed systematically and consistently.

Methodology:

- Upon tool suggestion, the system is programmed to execute the recommended tool for the specified phase, be it Information Gathering, Reconnaissance, Discovery and Scanning, Vulnerability Assessment, or Exploitation.
- A script is responsible for initiating the security testing tool. It manages input parameters, like target details and the testing phase, and captures the tool's output. Placeholders may parse this output, ensuring that vital information is retained and organized for subsequent phases.

Objective 3: Report Generation Rationale: Penetration tests, despite their thoroughness, derive their true value from the insights they deliver. These insights, distilled in the form of reports, aid stakeholders in understanding vulnerabilities and crafting countermeasures.

Methodology:

- Leveraging data collated from the previous phases, a comprehensive report is auto-generated. This report is not a mere aggregation of data but an insightful narrative that delineates vulnerabilities, the tests conducted, tools employed, and potential solutions.
- The prototype ensures that these reports are both detailed and digestible, making them invaluable tools for cybersecurity strategy formulation.

3.2 Functional Requirements

UC1 - Upon receiving a target IP or address, the system first suggests a suitable penetration testing tool for the specified phase, then autonomously executes the tool, and finally compiles a detailed report of the findings.”

The diagram presented in Fig.1, illustrates the order in which components interact with one another, effectively presenting the sequence of operations and the flow of data between them based on the use case presented in the previous section.

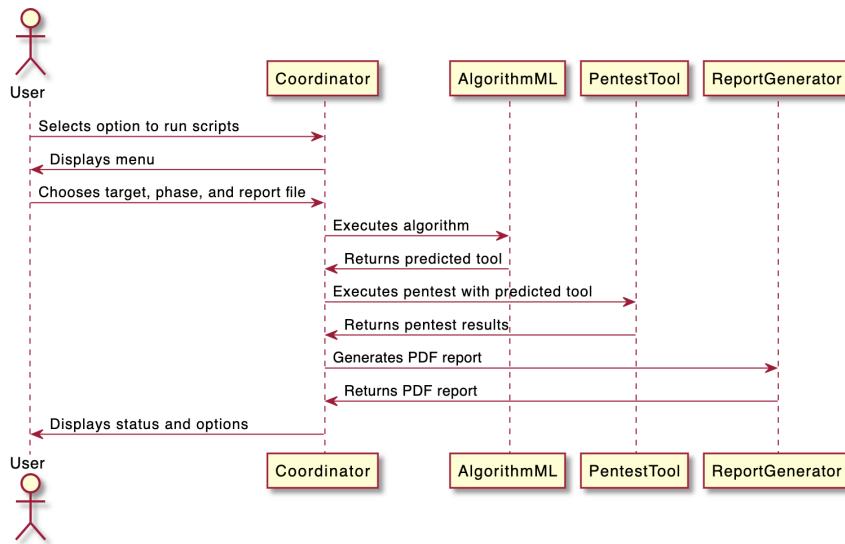


Fig. 1. Sequence Diagram

4 Solution Implementation

4.1 Overview

Penetration testing requires solutions that are not only strong but also effective and adaptable, due to the rapidly evolving threat landscape. This idea is central to the development of this solution, which was designed to exploit the power of machine learning in order to help with recommendations on security tools.

4.2 Solution Breakdown

The following solution presented below is divided into four main components, divided into their responsibility.

AlgorithmML: The core of the solution lies in the AlgorithmML module, designed to leverage machine learning for the task of tool recommendation. Multiple iterations culminated in the final selection of the Decision Tree Classifier. This classifier, when trained on the curated dataset, predicts and recommends a tool for a specific phase and target in the penetration testing process.

PentestTool: Serving as the execution phase of the solution, PentestTool bridges the gap between recommendation and action. Once a tool is recommended, this module takes over by initiating the tool, executing the necessary tests, and capturing the results. Acting as a mediator, interfacing with external penetration testing tools such as Nmap, and integrating their functionalities within the underlying system.

ReportGenerator: Given the multifaceted nature of penetration testing tools output, the produced results can span across a broad spectrum. The Report-Generator held the task of aggregating the incoming information from multiple tools and compiling it into a single report. Addressing the challenge posed by varied tool outputs, ensuring consistency and clarity in the final reports generated.

Coordinator: The Coordinator, as the name suggests, seamlessly ties all the aforementioned modules together. Offer the user a centralized means to control the entire system, enabling the selection and execution of specific tasks within the system—be it running the AlgorithmML, initiating a penetration test via the PentestTool, or generating a report file.

4.3 Used Technologies

- Programming Languages: Python was used due to its extensive support for machine learning libraries and ease of integration with cybersecurity tools.
- Machine Learning Libraries: Libraries such as scikit-learn for algorithms and data processing and pandas for data manipulation.
- Penetration Testing Tools: Integration with tools like Nikto, NMAP, or OWASP ZAP for the actual penetration testing phases.
- Reporting: FPDF library used for report generation.

4.4 Internal workings of the solution

In the class diagram presented below in Fig.2:

The Coordinator class acts as the command centre, managing the interplay between other classes – The functions displayMenu(), chooseTarget(target: string), choosePhase(phase: string), chooseReportFile(reportFile: string), handle the interaction with the user; – The functions executeAlgorithm(), executePentest(tool: string), generateReport(), trigger the execution of each module; – The functions displayStatusAndOptions(), reRunFailedScript(script: string), are responsible for logging and error recovery;

The AlgorithmML class takes the responsibility of training machine learning model and dataset analytics – The functions trainModel() and preprocessNewData(newData: dictionary), handle the machine model training and preparation of new data for prediction; – The functions predictTarget(model: Model, target: string) and predictTargetPhase(model: Model, target: string, phase: string), trigger prediction according to the input supplied by the user;

The PентestTool class executes penetration tests in accordance with the predicted tool and respective phase – The function runTool(target: string, phase: string, tool: string, reportFile: string), handles the execution of the tool; – The function parseOutput(tool: string, output: string): Parses the output of the executed tool for report generation;

The ReportGenerator class handles the report generation phase. The function extractCommand(output: string) extracts and handles the parsed output from the previous phase; The function generatePDFReport(inputFile: string, outputFile: string) triggers the report generation;

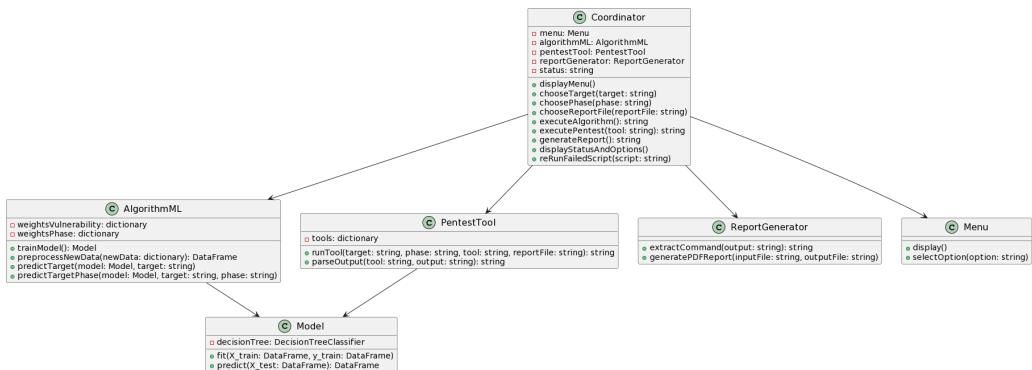


Fig. 2. Class Diagram

4.5 Tests

During the research, extensive penetration tests were executed on a server to assess the prototype's capability in a real-world environment. These tests were designed to evaluate the tool's effectiveness in identifying a wide range of web application vulnerabilities. Unit tests ensured individual components, such as the Pентest Tool's interaction with NMAP and the Report Generator's data formatting capabilities, functioned accurately in isolation. The integration testing phase focused on the interoperability between different modules, like the AlgorithmML and Pентest Tool, verifying seamless operation during orchestrated tasks. Functional testing aimed to ascertain the system's overall performance, developing scenarios to confirm the prototype met all user requirements from start to finish. Throughout these stages, the prototype demonstrated effective interfacing with NMAP, accurate report generation, and efficient coordination between components, with some minor adjustments implemented in order to refine the interactions and output formatting.

Evaluation and discussion

Experiment 1: Tool Recommendation Accuracy

- Objective: Determine AlgorithmML module's accuracy in recommending tools based on a provided dataset.
- Data/Model Used: Subset of the dataset with varying targets and vulnerabilities. Results:
- Results: AlgorithmML module correctly recommended tools in 119 out of 147 cases, achieving 80.95% accuracy.

Experiment 2: Supervisor's Evaluation on User Experience and Report Clarity

- Objective: Assess the usability and clarity of the generated reports through tasks.
- Data/Model Used: Feedback from the organization's supervisor.
- Results: The supervisor found the console-based interface manageable but noted that a guided user interface might offer a more streamlined experience. Suggestions were made for improvements, emphasizing the need for better error handling and highlighting discovered errors on reports generated.

Final Analysis

Certain evaluations were partially conducted or not performed due to constraints.

- Depth of Vulnerability Analysis: The solution focused on tool recommendation and orchestration, not deep vulnerability assessments. Evaluations didn't probe this aspect.
- Real-world Application Testing: Evaluations were controlled for safety and ethical considerations. Real-world application testing requires permissions and ethical considerations.
- Supervisor's Feedback on User Experience: The complexity of the subject influenced the supervisor's feedback. The prototype was initially designed with users familiar with pen-testing in mind, but due to constraints, the interaction was primarily console-based.

In the end, the solution achieved primary objectives, but discrepancies offer valuable insights. Software development is dynamic; outcomes validate hypotheses.

5 Conclusion

In conclusion, the research objectives were successfully met. An ML module was developed, identifying 81% of security breach patterns. Comprehensive reviews of specific security methodologies provided valuable insights. The integration

of machine learning into security testing led to important understandings and pointed out areas for more exhaustive future testing. Lastly, a prototype for ML-enhanced penetration testing was created, demonstrating the feasibility of ML in security tools and highlighting potential improvements.

5.1 Limitations

Accuracy Constraints: Even with the integration of Machine Learning models, bear in mind that no model can guarantee 100% accuracy. There is always a margin of error, especially when dealing with dynamic security threats.

Tool Specificity: The research primarily focused on a limited amount of security testing tools. Being this choice intentional, considering the scope, it also limits the comprehensive applicability of the findings.

Data Dependencies: The efficiency of Machine Learning models was contingent on the quality and volume of data available for training. In scenarios where data was scarce or not representative, the efficacy of the model-making predictions was stately compromised.

5.2 Future Work

Automation Overhaul: The main enhancement would be the complete automation of all project phases, not requiring manual oversight and interventions.

Advanced Reporting: Augmenting the report generation process to include better summaries and major vulnerabilities discovered would provide stakeholders with a more concise view of potential security threats.

Data Enrichment: The need to expand the dataset by incorporating more features and tools is unequivocal. This would allow better tool prediction and more nuanced security insights.

Support Extension: In future iterations, there should be a consideration of enlarging support for a wider array of security tools and techniques, therefore broadening the scope of security coverage.

Report Refinement: The generated PDF reports' format and structure need enhancements, to ensure clarity, conciseness, and coherence.

5.3 Final Thoughts

Bearing in mind the construction of a Proof of concept capable of providing not only predictions but also tools for execution and reporting, the work accomplished was triumphant.

Nevertheless, the room for improvement is great, from the applied machine learning model which could be further explored, to penetration test tool integration expansion.

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Revisão Sistemática e Meta-análise: Estudo exploratório de bibliotecas em R

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Resumo. A revisão sistemática e a meta-análise são processos estruturados de grande relevo em estudos científicos nas áreas da Bioinformática e das engenharias em geral. A revisão sistemática é uma forma racional de organizar evidências científicas relativas a um determinado tópico de forma a assegurar a cobertura abrangente da área em estudo. A meta-análise é uma técnica estatística para agregar evidências de diversas fontes independentes. Existem várias ferramentas disponíveis para auxiliar os investigadores na condução de estudos de revisão sistemática e meta-análise. Neste trabalho, estabelece-se um ranking destas ferramentas com base na sua popularidade e discute-se em maior detalhe a utilização do R neste âmbito. O R é uma linguagem de programação muito utilizada para processamento estatístico que inclui várias bibliotecas e funções especificamente orientadas para os estudos de revisão sistemática e meta-análise.

Palavras-chave: Programação R, Bibliotecas R, Revisão Sistemática, Meta-Análise.

1 Introdução

A revisão sistemática consiste num processo de pesquisar, selecionar, avaliar, sintetizar e relatar as evidências científicas sobre uma determinada pergunta e/ou tópico. A revisão sistemática é considerada uma forma racional de organizar, avaliar e agregar as evidências científicas evitando enviesamentos que possam surgir quando se recorre a metodologias menos estruturadas [1,2,3].

A meta-análise é uma técnica frequentemente usada em diversas áreas do saber, e tem vindo a ser amplamente utilizada em estudos médicos, especialmente em revisões sistemáticas de ensaios clínicos nos quais os doentes são distribuídos aleatoriamente por dois ou mais grupos de tratamento. Para fazer a meta-análise, é necessário recorrer a ferramentas estatísticas que sejam adequadas ao tipo de dados recolhidos no estudo. A este respeito, refira-se o caso particular da homogeneidade entre os estudos que condiciona o tipo de modelos estatísticos a utilizar: se se observar homogeneidade, os modelos de regressão com efeitos fixos são apropriados, caso contrário, quando

for assumida heterogeneidade entre os estudos, os modelos de efeitos aleatórios são mais adequados [4].

Pretende-se com este trabalho identificar e descrever as bibliotecas disponibilizadas pelo *R* que possam ser exploradas para a realização de estudos de revisão sistemática e meta-análise de um determinado tópico. O ponto de partida para este trabalho consistiu numa breve descrição dos conceitos “revisão sistemática” e “meta-análise” complementada com a análise de dois artigos de revisão destes temas [1,2].

Uma vez adquirida uma percepção preliminar sobre os tópicos relacionados com revisão sistemática e meta-análise identificou-se um conjunto de palavras-chave que sintetizam esta área. Estas palavras-chave foram usadas para identificar artigos relevantes para este trabalho em motores de pesquisa de artigos científicos. Foi utilizado essencialmente a PubMed e o GoogleScholar.

Existem várias ferramentas para apoiar estudos de revisão sistemática e meta-análise, algumas delas disponíveis gratuitamente. Irão ser abordados, neste artigo, alguns aspetos relacionados com 27 destas ferramentas. Posteriormente, irá ser efetuado um estudo exploratório mais detalhado da linguagem de programação *R* e das bibliotecas (pacotes) do *R* direcionados à revisão sistemática e meta-análise. O *R*¹ é uma linguagem de programação para processamento de dados muito popular na comunidade científica, sendo uma das ferramentas mais utilizadas para realizar este tipo de estudos. No entanto, é relevante conhecer outras ferramentas que disponibilizem funcionalidades semelhantes e conhecer, em geral, as alternativas disponíveis.

Neste trabalho começa-se por identificar as ferramentas frequentemente descritas na literatura, estabelecendo o *ranking* destas ferramentas, em função da sua popularidade, para perceber o posicionamento do *R*. Depois de adquirida esta percepção geral do universo das ferramentas para revisão sistemática e meta-análise, irão ser analisadas as bibliotecas que o *R* disponibiliza para este tipo de estudos.

O objetivo principal deste trabalho consiste em introduzir os investigadores no universo das bibliotecas do *R* para executar essa análise. Espera-se com este trabalho adquirir uma visão sustentada da popularidade das ferramentas mais utilizadas para fazer revisão sistemática e meta-análise de estudos clínicos e descrever de forma sintética as bibliotecas do *R* utilizados para este efeito. Adicionalmente, este trabalho fornece também uma introdução aos estudos de revisão sistemática e meta-análise.

Este artigo está estruturado em quatro secções. A esta breve introdução segue-se uma discussão da popularidade das ferramentas, na Secção Estado da Arte. Na Secção Bibliotecas do *R* para Apoio à Revisão Sistemática e Meta-Análise apresentam-se as bibliotecas do *R* disponíveis para cada uma das fases de um estudo de Revisão Sistemática. Na última secção são apresentadas algumas conclusões sobre o trabalho desenvolvido salientando os pontos mais importantes deste trabalho.

¹ <https://www.r-project.org/>

2 Estado da Arte

Existem várias ferramentas disponíveis para suportar estudos de revisão sistemática e meta-análise. Numa análise preliminar, identificaram-se 20 das mais populares (Tabela 2 e Tabela 1). Para perceber da popularidade destas ferramentas fez-se uma pesquisa no PubMed² – motor de pesquisa sobre o repositório MEDLINE de artigos de investigação em biomedicina – pelo nome de cada uma delas, contabilizando-se o número de publicações que as referem ao longo dos últimos três anos, 2020–2022, no âmbito dos temas “Systematic Review” (Tabela 1) e “Meta-Analysis” (Tabela 2).

Tabela 1 Número de artigos existentes na PubMed que referem cada uma das ferramentas no âmbito do tema Systematic Review (considerando exclusivamente as vinte mais populares).

Rank	Software	2020-2022	2020	2021	2022	VMA	VMP
1	R	6.219	1.725	2.158 ↗	2.336 ↗	306	17%
2	RevMan	3.308	1.041	1.123 ↗	1.144 ↗	52	5%
3	Stata	3.237	921	1.088 ↗	1.228 ↗	154	16%
4	Comprehensive Meta-Analysis	729	221	257 ↗	251 ↘	15	7%
5	Excel	420	102	143 ↗	175 ↗	37	31%
6	Meta Easy	205	62	77 ↗	66 ↘	2	5%
7	SPSS	153	42	60 ↗	51 ↘	5	14%
8	SAS	144	41	42 ↗	61 ↗	10	24%
9	GRADEPro	138	34	52 ↗	52 ↔	9	26%
10	Meta-DiSc	131	38	38 ↔	55 ↗	9	22%
11	Forest Plot Generator	84	22	31 ↗	31 ↔	5	20%
12	MedCalc	59	14	23 ↗	22 ↘	4	30%
13	MetaXL	57	8	23 ↗	26 ↗	9	100%
14	OpenMeta[Analyst]	52	17	22 ↗	13 ↘	-2	-6%
15	EpiMeta	45	11	15 ↗	19 ↗	4	32%
16	Meta-Analyst	37	12	13 ↗	12 ↘	0	0%
17	JBI SUMARI	27	5	10 ↗	12 ↗	4	60%
18	Jamovi	11	0	1 ↗	10 ↗	5	-
19	Meta-Essentials	11	3	5 ↗	3 ↘	0	13%
20	JASP	6	0	1 ↗	5 ↗	3	-

A popularidade destas ferramentas no âmbito dos temas “Systematic review” e “Meta-analysis”, bem como a tendência atual para a sua utilização podem ser mais

² <https://pubmed.ncbi.nlm.nih.gov/>

evidentes se analisarmos as variações médias do número de referências no PubMed em valor absoluto (VMA) e em valor percentual (VMP).

Tabela 2 Número de artigos existentes na PubMed que referem cada uma das ferramentas no âmbito do tema Meta-Analysis (considerando exclusivamente as vinte mais populares).

Rank	Software	2020-2022	2020	2021	2022	VMA	VMP
1	R	6.524	1.870	2.255	2.399	265	13%
2	Stata	4.289	1.263	1.423	1.603	170	13%
3	RevMan	4.077	1.272	1.348	1.457	93	7%
4	Comprehensive Meta-Analysis	1.121	339	404	378	20	6%
5	Excel	281	66	105	110	22	32%
6	Meta Easy	274	79	106	89	5	9%
7	Meta-DiSc	191	67	56	68	1	3%
8	SAS	148	43	51	54	6	12%
9	GRADEPro	133	33	50	50	9	26%
10	Forest Plot Generator	108	29	39	40	6	19%
11	SPSS	83	24	29	30	3	12%
12	MedCalc	71	17	28	26	5	29%
13	MetaXL	69	13	23	33	10	60%
14	OpenMeta[Analyst]	68	21	29	18	-2	0%
15	EpiMeta	59	20	18	21	1	3%
16	Meta-Analyst	55	19	22	14	-3	-10%
17	MetaGenyo	16	7	7	2	-3	-36%
18	Meta-Essentials	15	4	6	5	1	17%
19	JBI SUMARI	11	3	6	2	-1	17%
20	Jamovi	9	0	3	6	3	-

De uma forma geral observa-se o aumento do número de referências a estas ferramentas na literatura o que pode significar um interesse crescente na comunidade científica nos estudos de Revisão Sistemática e Meta-Análise ao longo dos últimos três anos. O número de referências a estas ferramentas no PubMed aumentou 23% (1.220 referências) entre 2020 e 2022.

As primeiras 10 ferramentas no *ranking*, tanto no que se refere aos estudos de Revisão Sistemática (Tabela 1) como aos que se referem à Meta-Análise (Tabela 2), aumentaram a sua popularidade de forma consistente ao longo dos três últimos anos à excepção de alguns casos, como, por exemplo, o caso do *Comprehensive Meta-analysis* e do *Meta-Easy*, cujo número de referências decresceu de 2021 para 2022. No top 10 encontram-se as ferramentas de processamento estatístico mais comuns em estudos científicos, como sejam o *R* e o *Stata* [5], a par de outras muito populares para

o utilizador mais comum, como seja o *Excel*. É de salientar também o facto de o *SPSS*, uma das ferramentas mais populares para o processamento de dados estatísticos na comunidade científica, não constar do top 10 do tema “Meta-Analysis” (Tabela 2).

A Tabela 3 apresenta o posicionamento relativo das 10 ferramentas mais populares comparando-as para os dois temas em análise “Revisão Sistemática” e “Meta-Análise”. O *R* destaca-se como a ferramenta mais popular com um número total superior a 6 mil referências no PubMed ao longo dos últimos três anos em ambos os temas (*Systematic Review* e *Meta-Analysis*).

Verifica-se que o *Stata* e o *RevMan* são também bastante populares ocupando a segunda ou a terceira posição no ranking das ferramentas mais mencionadas em publicações PubMed dos últimos três anos. Observa-se também que o número de vezes que cada uma destas ferramentas (*R*, *Stata*, *RevMan*) é mencionada em publicações ao longo dos últimos três anos é consistentemente crescente.

Tabela 3 Variação Média do número de referências PubMed entre 2020 e 2022

Software	<i>Systematic Review</i>			<i>Meta-Analysis</i>		
	Rank	VMA	VMP	Rank	VMA	VMP
R	1	305,5	17%	1	264,5	13%
Stata	3	153,5	5%	2	170,0	13%
RevMan	2	51,5	16%	3	92,5	7%
Comprehensive Meta-Analysis	4	15,0	7%	4	19,5	6%
Excel	5	36,5	31%	5	22,0	32%
Meta Easy	6	2,0	5%	6	5,0	9%
Meta-DiSc	10	8,5	22%	7	0,5	3%
SAS	8	10,0	24%	8	5,5	12%
GRADEPro	9	9,0	26%	9	8,5	26%
SPSS	7	4,5	14%	11	3,0	12%
Forest Plot Generator	11	5	20%	10	5,5	19%

O *Excel* apresenta a maior taxa de crescimento médio ao longo dos últimos três anos em termos percentuais. No entanto, esta ferramenta ocupa a posição 5 no top 10 de ambos os temas com uma base de utilizadores na ordem das centenas, uma ordem de grandeza inferior ao topo do ranking.

Observa-se que, de uma forma geral, as ferramentas mais utilizadas para “Systematic Review” e “Meta-Analysis” são as mesmas; o top 10 de ambos inclui unicamente 11 ferramentas distintas. O *Forest Plot Generator* aparece em décimo primeiro lugar no ranking das ferramentas utilizadas para revisão sistemática e em décimo lugar no ranking das ferramentas utilizadas para meta-análise. O *R* é a ferramenta mais popular verificando-se uma tendência crescente da sua utilização de forma consistente desde 2020. O *R* disponibiliza uma vasta gama de bibliotecas para apoiar este tipo de estudos. O *R*, o *Stata* e o *RevMan* partilham o top 3 e destacam-se das restantes quer em

termos percentuais, quer em termos absolutos do número de utilizadores e da taxa de crescimento nos últimos três anos.

3 Bibliotecas do *R* para Apoio à Revisão Sistemática e Meta-análise

Existe uma grande variedade de bibliotecas no *R* para revisão sistemática e meta-análise [6] (Tabela 4).

Tabela 4 Diferentes bibliotecas utilizadas em *R* para realizar a revisão sistemática e meta-análise.

Biblioteca	Descrição
litsearchrR	Fornece várias funções de apoio ao planeamento de uma análise sistemática da literatura científica sobre um determinado tópico. Disponibiliza também funcionalidades de Scoping – procura breves da literatura existente sobre um determinado tópico.
Metafor	Consiste numa coleção de funções que permitem calcular vários tamanhos de efeito ou medidas de resultado, ajuste igual, modelos de efeitos fixos, aleatórios e mistos. Permite também criar vários tipos de gráficos meta-analíticos.
OrchaRd	Permite que os utilizadores criem gráficos contendo intervalos de confiança e intervalos de previsão em torno de estimativas pontuais.
RevTools	Pode ser usado para visualizar padrões em dados bibliográficos, selecionar ou excluir artigos ou palavras de forma interativa.
Metacor	Faz o cálculo de estimativas de efeitos fixos e aleatórios para meta-análises com correlações.
Metagen	Implementa análise inferencial no modelo de meta regressão de efeitos aleatórios.
Metatest	Faz o ajustamento e teste de modelos de meta-regressão.
Compute.es	Fornece um conjunto abrangente de funções para derivar ou converter estatísticas geradas de trabalhos relatados em estudo publicado na literatura para todas as estimativas comuns de tamanho de efeito, juntamente com suas variâncias, intervalos de confiança e valores de prova.
Metasens	Implementa métodos estatístico avançados para modelar e ajustar o enviesamento de estimativas em meta-análise.
Bspmma	Gera modelo semi-paramétricos Bayesianos para meta-análise.
Metaviz	Disponibiliza uma coleção de funções para criar gráficos de dados resultantes de estudos de meta-análise de uma forma visual apelativa, fácil de ler e rica em termos da informação apresentada.
ExclusionTable	Permite manter o controlo sobre os indivíduos que são excluídos em função de determinados critérios de exclusão.
PupilometryR	Integra num mesmo workflow várias etapas do processamento de dados, incluindo limpeza dos dados, pré-processamento, análise e visualização de resultados.
robvis	Produz estatísticas relacionadas com a avaliação do enviesamento dos dados.

Uma revisão sistemática é um processo estruturado [7] com várias etapas: (1) Identificar a questão de investigação, (2) Definir os critérios de inclusão e exclusão, (3) Pesquisar a literatura, (4) Selecionar estudos, (5) Extrair dados relevantes para a questão de investigação, (6) Avaliar a qualidade e (7) Sintetizar e apresentar resultados.

Descrevem-se nesta secção algumas das bibliotecas da linguagem *R* que podem apoiar o investigador em cada uma das fases de um processo de revisão sistemática e meta-análise. As bibliotecas aqui discutidas não esgotam o universo vasto das bibliotecas do *R* disponíveis para este tipo de estudos³ [10] mas cobrem funcionalidades de relevo.

3.1 Identificar a questão de investigação

Identificar a questão de investigação é uma tarefa fundamentalmente cognitiva. Não foram identificadas funções no *R* que possam apoiar este processo.

3.2 Definir os critérios de inclusão e exclusão

Para compilar uma amostra dos artigos relevantes de forma sistemática devem definir-se critérios de inclusão e exclusão que guiam e condicionam o processo de identificação e recolha das fontes a considerar no estudo. Estes critérios podem basear-se em vários fatores, tais como a data do artigo, tipo de publicação, localização geográfica do estudo, características demográficas dos participantes, entre outros. Não se identificaram funções no *R* que possam apoiar este processo.

3.3 Pesquisar a literatura

A pesquisa de literatura é um trabalho realizado por via das plataformas de acesso a repositórios de conhecimento científico como, por exemplo, a PubMed e o Scopus. Embora o *R* disponha de bibliotecas para fazer o download dos documentos disponíveis na internet – biblioteca *downloader*, por exemplo – a sua utilização para este efeito não é muito eficaz dado que requer a identificação prévia do URL dos documentos ou das pastas onde estes se encontram.

3.4 Selecionar estudos

Na fase de seleção de estudos faz-se uma análise preliminar do conjunto dos documentos que foram compilados a fim de identificar o subconjunto destes que contêm informação de relevo e que devem ser analisados em detalhe. A pesquisa manual, não automatizada, de publicações científicas na área da medicina pode ser muito exigente e demorada. As áreas de *text mining* – processamento automático de coleções de documentos de texto – e de *information retrieval* – recuperação de informação – fornecem métodos para automatizar a extração de informação a partir de coleções volumosas de documentos sendo populares em diversas áreas de engenharia, em particular na

³ <https://CRAN.R-project.org/view=MetaAnalysis>

engenharia informática. O *R* disponibiliza um conjunto de bibliotecas que implementam métodos das áreas do processamento automático de texto e recuperação de informação e que podem ser úteis nesta fase de um estudo de revisão sistemática. Destas, podemos salientar: *tm*, *OpenNLP*, *languageR* e *koRpus* (Tabela 4). Para além destas bibliotecas de âmbito geral, existem outras mais diretamente orientadas para estudos de revisão sistemática, tais como a *litsearchrR* e a *RevTools*.

A biblioteca *litsearchrR* facilita o desenvolvimento de estratégias de procura rápidas, objetivas e reproduutíveis usando *text mining* e redes de co-ocorrência de palavras-chave para identificar termos importantes a incluir numa estratégia de procura [11]. Esta biblioteca permite gerar pesquisas booleanas em vários idiomas e obter medidas que avaliam a qualidade de uma pesquisa. A biblioteca *RevTools*⁴ oferece um ambiente em open source de fácil utilização. Permite a visualização de padrões bibliográficos e a manipulação interativa de documentos [12].

3.5 Extrair dados relevantes para a questão de investigação

O *R*, sendo um ambiente de programação orientado para o processamento estatístico, inclui de base as funções e as estruturas de dados que são utilizadas para este tipo de processamento, tais como, processamento de dados omissos e valores infinitos, o cálculo de estatísticas descritivas e a análise univariada e multivariada.

Para além destas funcionalidades generalistas, o *R* disponibiliza ainda funções com maior especificidade. A função *filter_data* da biblioteca *PupilometryR* é utilizada na aplicação e documentação de critérios de inclusão e exclusão para conjuntos de dados clínicos ou epidemiológicos. Espera-se que em muitas análises determinados critérios de inclusão/exclusão possam ser aplicados sequencialmente. Esta função permite que os analistas especifiquem as funções de filtragem na ordem em que devem ser aplicadas. O output da função *filter_data* é uma lista contendo o conjunto de dados recém-filtrado e um relatório do total de observações para cada critério. A biblioteca *ExclusionTable* permite filtrar os indivíduos da amostra em função de determinados critérios de inclusão e exclusão. A biblioteca *RevTools* poderá ser útil também nesta fase dado que disponibiliza funções para visualizar padrões em dados bibliográficos, selecionar ou excluir artigos ou palavras de forma interativa e gravar os resultados para análise posterior. Esta biblioteca oferece funcionalidades para manipulação de dados, mineração e visualização de textos, deteção de duplicados, filtragem de artigos e distribuição de tarefas pelos membros da equipa de investigação [12].

3.6 Avaliar a qualidade

A qualidade dos estudos de revisão sistemática depende, em grande medida, da consistência dos vários trabalhos analisados e das amostras em que estes se baseiam. Deste ponto de vista, é importante avaliar o risco de enviesamento presente.

A biblioteca *robvis* do *R* – Risk-Of-Bias VISualization – disponibiliza funções para o cálculo e apresentação de indicadores de avaliação do risco de enviesamento [13]. A

⁴ <https://revtools.net/> (acedido em abril de 2023)

biblioteca *robvis* pode ser utilizada para analisar o risco de enviesamento diretamente no *R* ou através das aplicações disponibilizadas on-line⁵ pelos autores de [13] para investigadores que não dominem a programação.

3.7 Sintetizar e apresentar resultados

A biblioteca *metafor* [14] consiste numa coleção de funções que permitem ao utilizador calcular tamanhos de efeito e outras estatísticas assim como criar vários tipos de gráficos meta-analíticos. Para além do *metafor*, existe um conjunto vasto de bibliotecas do *R* para o cálculo de estatísticas, construção de modelos e realização de testes em estudos de revisão sistemática e meta-análise, tais como a *metacor* [15], a *metagen* [16], a *metatest* [17] e a *bspmma* [18] que se focam na análise de correlações e meta-regressão. A biblioteca *compute.es* [19] foca-se essencialmente no cálculo dos tamanhos de efeito. A biblioteca *metasens* [20] disponibiliza funcionalidades orientadas para a análise de sensibilidade. As bibliotecas *orchard* [21], *metaviz* [22] e *robvis* [13] permitem construir gráficos adequados para a meta-análise.

4 Conclusões

Existem várias bibliotecas de *software* e aplicações para suportar o investigador na realização de estudos de revisão sistemática e meta-análise, observando-se na literatura um acréscimo da sua utilização, que se comprova pelo número de vezes em que têm sido citadas nas publicações PubMed ao longo dos últimos três anos, 2020-2022.

O *R*, uma linguagem de programação muito utilizada a nível científico para processamento estatístico, é bastante popular no tratamento dos dados em estudo de revisão sistemática e meta-análise. Existem bibliotecas *R* particularmente orientadas para as três últimas fases de um estudo deste tipo (5 - Extração de dados relevantes, 6 - Análise da qualidade do estudo e 7 - Síntese e apresentação de resultados). Não existem bibliotecas *R* especificamente orientadas para as primeiras fases deste tipo de estudos (1 - Identificar a questão de investigação, 2 - Definir os critérios de inclusão e exclusão, 3 - Pesquisar a literatura, e 4 - Selecionar estudos). No entanto, o *R* disponibiliza várias bibliotecas que podem ajudar também nestas fases, tais como, aquelas que se dedicam ao rastreamento da web, particularmente relevantes para a fase 3, e aquelas que se dedicam ao *text mining* e à recuperação de informação, relevantes na fase 4.

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ServiceNow® Advanced Integration

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Abstract. This paper describes the Proof of Concept (PoC) of a new state-of-the-art remote signing solution in the ServiceNow environment, replacing a native legacy implementation.

This challenge resulted in the integration between ServiceNow® and DocuSign® and the engineering of an automated flow.

The final solution consists in an end-to-end remote signing use case in which companies are able to request, securely retrieve and archive signed documents and their certificates in a fully automated way all inside the ServiceNow platform.

Users interact with an easy-to-use widget in the ServicePortal® of a ServiceNow® instance, obscuring the complexity of the interaction between said platforms.

When the signing process is completed, the signed document is safely stored in the ServiceNow® instance together with its digital certificate, assuring its legal validity.

This solution added great value to the organization by simplifying a then error prone business process and vastly improving the organization internal processes efficiency and legal soundness.

Keywords: Process Optimization, Service Management, Remote Signing, Information Security

1 Introduction

1.1 Context & Motivation

The project presented in this paper was developed in the context of a curricular internship at the Service Management division of Deloitte Portugal.

Service Management is a technical discipline that rethinks and improves the business processes of organizations.

Its motivation was the engineering of a state-of-the-art end-to-end remote signing solution in the ServiceNow® environment in order to replace a native legacy module.

To achieve this goal, it was decided to integrate ServiceNow® with DocuSign®.

The signing process is one of the most prone to errors given the need to interact with users, in which the slightest error may invalidate the integrity of documents, representing a risk factor for organizations.

Due to these reasons, DocuSign® was chosen given its reliability and advanced features.

With this integration, the whole process is radically simplified, strengthened and far less prone to costly errors that can jeopardize an organization's legal assurance.

2 State of the art

One of the strongest trends in today's business environment is the digitalization and automation of business processes.

Handling and signing of legal documents are two paramount processes companies rely on. For this purpose, there are countless software solutions each of them taking a different approach. Most of them are not well integrated with the technology solutions used in the day-to-day operations of modern organizations.

ServiceNow® is a market leader^[1] in the Service Management segment, helping organizations automate business process, improving their efficiency.

DocuSign® is an innovative company in the Digital Signing space trusted by FORTUNE 500® companies which by making available the eSignature® REST API^[2] allows for the deployment of both highly complex and yet secure signing use cases.

In order to achieve a solution that satisfies the requirements conveyed in the context section (1.1), there is a need to design and implement a controller that manages the entire sequence of actions.

For this, many frameworks could have been chosen, but FlowDesigner® and DocuSign Spoke® were selected.

FlowDesigner®^[3] presents itself as the native platform to develop and test automations in the ServiceNow® environment, therefore making it the most reliable.

This way, the backbone of the solution described in this paper is a flow in flowDesigner®.

DocuSign Spoke® is a 3rd party module that provides the ability to implement the eSignature REST API® to securely interact with DocuSign®.

3 Solution Design

In this section, the design of the implemented solution is exhibited.

For this purpose, two diagrams (Fig. 1 and Fig. 2) are displayed in section 3.1 to facilitate its understanding.

A system context diagram, Fig. 1, is provided to showcase all the components of the solution, as well as the main interactions between them.

Additionally, a sequence diagram, Fig. 2, is presented in order to dissect the whole sequence of events of the use case.

3.1 Problem Domain

The sequence of actions and components of the proposed solution are illustrated in the system context diagram presented in Fig. 1. It displays in a clear and easily understandable manner, the entire signature process.

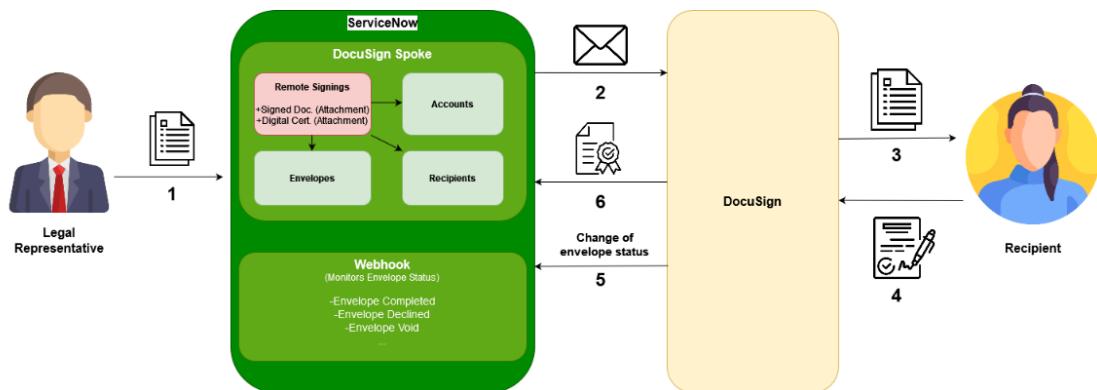


Fig. 1. System context diagram. Represents the main components and their interactions

Fig. 1 provides a macroscopic view of the system, where it can be observed that the system is comprised of two main entities, a ServiceNow® instance and the DocuSign® platform along with two human actors, a company's legal representative and a recipient (signer).

As subcomponents, DocuSign Spoke® and Webhook can be identified.

DocuSign Spoke®.

DocuSign Spoke® is a plug-in, available in the ServiceNow Store® that allows for the development of actions that interface with DocuSign®.

It allows for the customization of eSignature® REST APIs to ensure an efficient and secure communication between the platforms.

This way, four tables are used in the DocuSign Spoke® scope, which are Remote Signings, Accounts, Envelopes and Recipients.

Remote Signings is a purposely built table that aggregates all the signing requests initiated by the representative and allows for the monitoring of their status.

In addition, in the case of success, easy access to the signed document along with its digital certificate.

Accounts, Envelopes and Recipients are default tables of the spoke.

Accounts table stores the authentication details for the DocuSign® account of the organization.

Envelopes table stores the envelopes that are automatically created by the spoke when a new signing request is submitted.

Recipients table stores the recipients of the submitted signing requests.

Webhook.

Webhook[4] is a callback function based in the HTTP protocol that facilitates the communication between information systems.

Webhooks are event-driven, establishing a communication link between two systems, exchanging information when a certain event or change occurs.

In the context of this project, a webhook is established between a ServiceNow® instance and a DocuSign® account the moment DocuSign Spoke® action forwards the envelope to DocuSign®.

Its main function is to notify the ServiceNow® instance of any changes to the envelope status of a signing request. The main events being the successful signing or the rejection of a document by a recipient.

4 Solution Implementation

In this section it is succinctly described the main steps taken to implement the design unveiled in section 2.

4.1 Set-up of secure information exchange infrastructure

This section is an overview of the main procedures taken to ensure a secure and reliable connection between the ServiceNow® instance and DocuSign®.

- Installation of DocuSign Spoke® from the ServiceNow Store®^[5].
- Set-up of DocuSign Developer® account (DocuSign's platform back-end)
- Registration of the ServiceNow® instance in DocuSign Developer® and generation of RSA key pair
- Creation of X.509 certificate signed by the RSA private key executing the following command in a GNU/Linux® based OS:

```
openssl req -new -x509 -key privatekey.key -out certificado.pem  
-days 1095
```
- Creation of PKCS 12 archive that aggregates the private key and the X.509 certificate, executing the following command:

```
openssl pkcs12 -export -in certificado.pem -inkey privatekey.key  
-certfile certificado.pem -out pkcs12.p12
```

- Creation of JKS (Java KeyStore®) from the pkcs12 archive previously created, executing the following command:

```
keytool -importkeystore -srckeystore pkcs12.p12 -srcstoretype  
pkcs12 -destkeystore jks_cert.jks -deststoretype JKS
```
- Submission and validation of JKS X.509 certificate in the DocuSign Spoke® in the ServiceNow® instance.
- Creation of JWT (JSON Web Token) Signing key to establish a secure communication between DocuSign Spoke® and DocuSign®.

- Creation of JWT Provider in order to generate tokens using the JWT Signing Key previously created, which are used by DocuSign Spoke® so that a secure connection between the platforms is established.
- Registration of DocuSign® as OAuth Provider, by inputting the integration key.
 - Integration key is a GUID that identifies the ServiceNow® instance in the DocuSign® platform in order to obtain access tokens to this platform
 - Configuration of OAuth Entity Profiles
- Creation of OAuth Credentials by entering a connection URL:
`https://demo.docusign.net`

4.2 Flow in FlowDesigner®

This section is dedicated to the analysis of the flow developed in flowDesigner® in order to achieve the desired automation.

In a ServiceNow® environment a flow is an entity that holds the following properties:

- Automates business logic for an application or process
- It's an automated sequence of actions that executes every time a condition occurs
- It's repeatable
- Executes the same pre-defined process every time it is triggered

Fig. 2 shows a sequence diagram of the end-to-end signing process and in section 4.2.1 the implemented flow is explained in-depth.

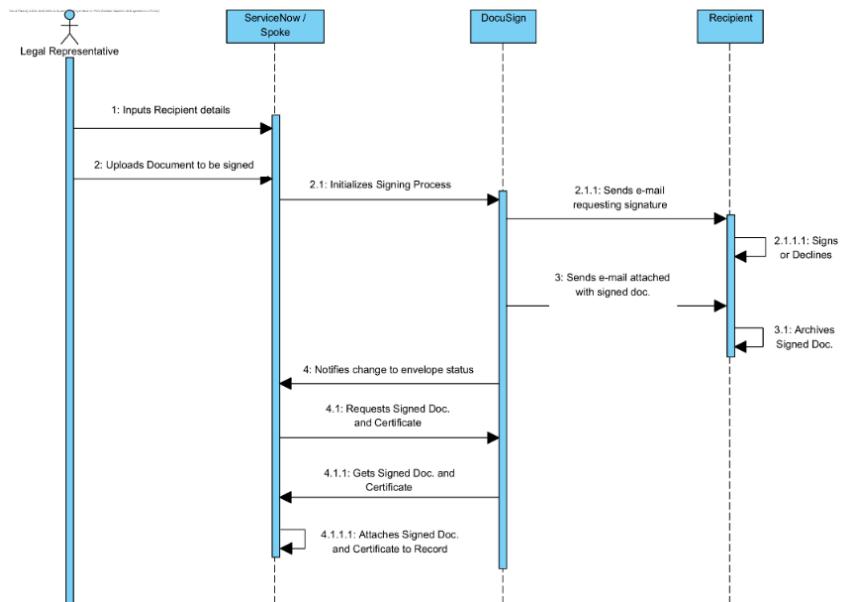


Fig. 2. Sequence diagram. Represents the end-to-end signing process

Flow, Subflow, Action.

The flow is comprised of three parts, Flow, Subflow and Action.

The reason why a two flows architecture was selected (flow and subflow) and not just one is due to the fact that subflows do not have the ability to be invoked when an external condition occurs, only flows do.

This way the only responsibility of the main flow is to be triggered when a new Signing Request record is added to the Remote Signings table and retrieve its data.

The request corresponds to a user inputting a document and the signer details via a dedicated widget in the ServicePortal®.

Each submission creates a new record in the Remote_Signings table, automatically creating an envelope that is safely stored in the Envelopes tables of the DocuSign Spoke®.

The Subflow, which holds the core functionality of the solution now invokes the customized Action which establishes a connection to DocuSign®. Said action securely sends the created envelope to DocuSign®.

When this connection is established, a Webhook is set up between the two services. This Webhook is responsible for listing to changes on the envelope status from DocuSign® and passing this information to the DocuSign Spoke®.

In the case of successful signing, the Webhook notifies the Spoke®, which then retrieves the signed document and its certificate from DocuSign® and attaches them to the record. Following this, it updates the status of the envelope to “Completed”.

In contrast, if the Recipient rejects the document, the Webhook returns this change to the Spoke®, which updates the envelope status to “Declined”.

To finalize, all this interaction is logged into the ServiceNow® log tables in order to facilitate possible troubleshooting.

5 Demo of interaction

In this section, it is showcased the interaction of the users (Legal Representative and Recipient) with ServiceNow® and DocuSign®. In Fig. 3 it is shown a flowchart of the end-to-end signing process.

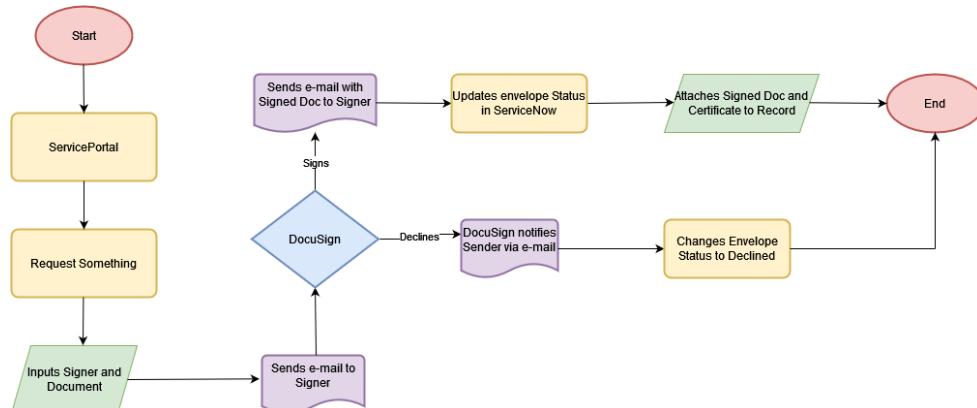


Fig. 3. End-to-End flowchart of process

As can be observed in Fig. 3, the Legal Representative starts by accessing ServicePortal®^[6] in which he/she selects the “Request Something” sub-menu having access to the dedicated “Send a Document for Digital Signature” item, displayed in Fig. 4.

He/she then inputs the desired recipient and submits the document, as shown in Fig. 5. Following this action, an e-mail is sent to the recipient notifying of the pending signing request.

By accessing the hyperlink provided in the e-mail, he/she reads the contract. In case of agreement with the terms, signs the document through the DocuSign UI and the status of the request is changed to “Completed” as shown in Fig. 6.

If he/she declines the terms, the status of the Remote Signing request is changed to “Declined”, as displayed in Fig. 7.

5.1 Demo of Successful Signing

In this sub-section are demonstrated the three most relevant stages of the user interactions with the platforms.

- 1) Menu item of ServicePortal® providing access to the signing request form

The screenshot shows a menu item titled "Send a Document for Digital Signature". Below it is a sub-item titled "Send Document for Digital Si...". A tooltip explains: "This form is used to send a document to be digitally Signed by a Recipient". At the bottom of the menu item is a "View Details" button.

Fig. 4. ServicePortal Menu item

- 2) Submission of document and recipient details

Fig. 5 displays the dedicated UI of ServicePortal® in which the Legal Representative inputs the recipient and the contract.

The solution was tested to support documents in .pdf .pdfa .docx .jpg .png formats.

The screenshot shows a form titled "Send Document for Digital Signing". It includes a sub-instruction: "This form is used to send a document to be digitally Signed by a Recipient". There are two required fields: "Please enter the e-mail of the Recipient (Signer)" containing "Joao Miguel Rolo da Mata" and "Please submit the document to be signed (.pdf or .docx format)" containing "consulting_contract.pdf". Below these fields are "Upload" and "Delete" buttons.

Fig. 5. Submission of document and recipient details

- 3) After successful signing, the Remote Signing record is attached with the signed document and its digital certificate (Summary)

The screenshot shows a 'Remote Signing' interface. At the top right is a blue 'Open Record' button. Below it, under 'Manage Attachments (2):', there is a thumbnail of a PDF file named 'consulting_contract.pdf_signed'. To the right of the thumbnail are '[rename]' and '[download]' buttons. Below this, a section titled 'Summary [rename][download]' contains the following information:

Signer1	Joao Miguel Rolo da Mata
Attachment	* consulting_contract.pdf
Envelope	ba6156b9-0370-4cde-bfc6-32f2c577d05b
Status	completed

Fig. 6. DocuSign Spoke® successfully updates status

5.2 Demo of Refusal to Sign

If the Recipient of a Signing Request declines to sign, the Webhook receives this update and DocuSign Spoke® updates the status of the envelope to declined.

The screenshot shows a 'Remote Signing' interface, identical in layout to Fig. 6, but with a different status. The 'Status' field now displays 'declined' instead of 'completed'.

Fig. 7. Updated Record

6 Performance and Secureness

In this section it is analyzed the performance and reliability of the integration in study.

For this analysis, Performance and Secureness were taken into account and are analyzed separately, respectively in sections 6.1 and 6.2.

6.1 Performance and self-evaluation

To test the performance of the integration, three experiments were repeated in order to measure time of execution of the main stages of the signing process. Table 1 presents the time duration of each stage and their averages.

Table 1. Time duration of each stage of the process and their averages

As can be observed in Table 1 the average time duration for the end-to-end signing

	Creation Sign. Req.	Reception DocuSign® e-mail	Sigs or Rejects	Update envelope status	Reception e-mail with signed doc.	Total Time
Try 1 (s)	0.00	14.78	16.10	0.00	6.72	37.60
Try 2 (s)	0.00	12.05	14.59	0.00	7.85	34.49
Try 3 (s)	0.00	15.43	12.48	0.00	8.62	36.53
Avg. (s)	0.00	14.09	14.39	0.00	7.73	36.21

process is around 36 seconds. This analysis excludes the time it takes to review the document and make the decision to sign or reject.

As self-evaluation, the obtained average time duration is adequate, given the expected latency of the interaction between two independent information systems.

6.2 Secureness

As it is patent in section 4.1 of this paper all the effort was made to ensure the secureness and reliability of the information exchange of the entire solution.

As described in said section, all the communication between the services is encrypted and signed by a JKS certificate generated in an offline system, ensuring maximum security.

The connection is secured by a *JWT Provider* that generates tokens using the JWT Signing Key previously created, that are used by the DocuSign Spoke® to establish a secure connection between systems.

6.3 Generalization of Results

The solution was designed and tested as a standalone product. Nonetheless it can be part of a larger use case. For instance, the final stage of delivery of a software product which requires the signing of the EULA (End User License Agreement) contract.

7 Conclusions

As a retrospective it can be said that the solution described in this article satisfies the functional and non-functional requirements requested by the stakeholder.

Its use significantly decreases the average time of the signing process and prevents costly errors.

As recommendation for future development, it is advised a study on the technical and usability implications of a multi-document and multi-recipient solution.

This study is highly anticipated due to the ever-increasing complexity of document handling use cases in the enterprise environment. Nevertheless, it is also technically challenging due to the need to implement and test more advanced functions of eSignature® REST API.

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Visualizador 3D de Modelos BIM para Gestão Energética

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Resumo. A questão do impacto ambiental tem originado uma preocupação cada vez maior com o consumo e gestão da energia, pelo que soluções de *software* para este problema são cada vez mais comuns. Este artigo descreve o trabalho realizado no contexto de uma dessas soluções de gestão de energia, mais especificamente na gestão de *smart buildings*, tendo consistido no desenvolvimento de um Visualizador 3D que permite importar e navegar edifícios na primeira pessoa. O visualizador permite ao utilizador navegar o edifício, como num videojogo, assim como interagir com os equipamentos eletrónicos que se encontram no seu interior. Deste modo, a informação é oferecida ao utilizador de uma forma mais interativa, promovendo a sua adaptação, no futuro, para Realidade Virtual.

Palavras-chave: Building Information Modeling, Industry Foundation Classes, Visualização 3D.

1 Introdução

A adoção da tecnologia no dia-a-dia trouxe ao ser humano um nível de conforto inicialmente inimaginável. Permitiu a realização de tarefas de uma forma cada vez mais rápida e prática e por vezes até, outrora impossíveis, tornando-se por isso indispensável. Embora apresente diversas vantagens, a adoção da tecnologia tem também uma enorme desvantagem – o impacto no Planeta. De facto, o consumo energético mundial continua a atingir valores record, ano após ano, levando a que a boa gestão energética e o aumento da eficácia dos sistemas sejam da mais elevada prioridade.

Os conceitos de *smart buildings* e de *building automation* são exemplos da mesclagem da tecnologia no dia-a-dia e descrevem a integração dos vários sistemas de um edifício (e.g. HVAC, iluminação), numa infraestrutura controlada por *software*.

Este artigo descreve o trabalho realizado no âmbito do desenvolvimento de um produto de *software* que tem por objetivo controlar estas infraestruturas. O produto consiste numa Web App que oferece várias páginas de controlo a um gestor de edifício, nas quais são apresentadas informações sobre os sistemas energéticos do edifício, sendo o Visualizador 3D uma destas páginas.

O módulo de visualização 3D desenvolvido oferece ao utilizador uma nova dimensão da informação. Em particular:

1. Fornece um método alternativo de visualização da informação;

2. Possibilita a obtenção da informação (e.g. estado, consumo, produção) relativa a cada equipamento eletrónico, em tempo real;
3. Permite a interação com os equipamentos (e.g. ligar, desligar);
4. Permite a navegação do utilizador pelo edifício, simulando a sua presença física.

2 Estado da Arte

A indústria de Architectural Engineering and Construction (AEC) tem sofrido uma grande evolução nas últimas décadas graças à evolução do *software* utilizado pela mesma. No entanto, algumas das suas metodologias e hábitos mantêm proximidades com as raízes dos processos Vitorianos [1].

Esta indústria envolve, pela sua natureza, diversas áreas de trabalho, cada uma com os seus requisitos e necessidades, resultando em produtos de diversas dimensões e níveis de complexidade. Para tal, é necessária uma interoperabilidade entre estas diferentes áreas que seja capaz de responder às diferentes necessidades e permita o trabalho conjunto de forma eficaz.

Os conceitos apresentados de seguida têm um objetivo comum que visa responder a esta necessidade de partilha de informação e levar a uma evolução da indústria, partindo da elaboração de processos e metodologias que permitam agilizar e simplificar o processo da criação de produtos, cumprindo os objetivos que lhes são impostos.

2.1 BIM – Building Information Modeling

O termo BIM - Building Information Modeling (ou Model) resultou de uma evolução de várias décadas que começou com o Building Description System (BDS) nos anos 70, um sistema de computador que fornecia ferramentas para a criação de modelos de representação de edifícios. Criado por Charles “Chuck” Eastman, o BDS tinha como objetivo “a criação de uma base de dados que contivesse toda a informação geométrica, espacial e propriedades de um grande número de elementos físicos, organizados no espaço tal como num edifício” [2]. Da evolução deste primeiro sistema surgiram outras metodologias, nomeadamente Building Product Model (BPM) e Product Information Model (PIM) que acabariam por dar origem ao termo BIM, aquando da sua junção.

Devido à larga escala de possíveis aplicações de Building Information Modeling é raro o *software* que seja capaz de tirar proveito de todas as suas funcionalidades optando por norma por fornecer ferramentas capazes de satisfazer um objetivo, como por exemplo a modelação de um edifício, a criação de documentação para um projeto ou um estudo energético de um modelo, etc.

2.2 IFC – Industry Foundation Classes

A iniciativa IFC surgiu a partir de um consórcio liderado pela Autodesk, com o objetivo de criar um modelo de dados para a indústria de AEC que permitisse a partilha de informação de edifícios de um modo universal. Desse consórcio, originalmente designado International Alliance for Interoperability (IAI) e posteriormente renomeado buildingSMART, resultou o Industry Foundation Classes (IFC).

O modelo de dados IFC tem como objetivo “definir uma especificação para a partilha de dados durante a duração do projeto, globalmente, abrangendo todas as matérias e aplicações técnicas” [3], que tal como referido anteriormente, pode nem sempre ser possível utilizando apenas o conceito BIM devido às suas diversas aplicações e limitações do *software* BIM-ready.

Partindo dos objetivos definidos torna-se evidente a sobreposição dos conceitos IFC e BIM. Charles Eastman refere que “a utilização de IFC deve ser considerada suficiente para que uma análise, design ou *software* seja, considerado BIM, mas não deverá ser um requisito obrigatório” [4] reforçando assim a ideia de que o padrão IFC constitui uma extensão da ideia BIM sendo considerado um dos padrões do openBIM.

2.3 Aplicação de BIM e IFC à gestão energética

A utilização de BIM e IFC aplica-se por norma na área da Arquitetura e da Construção, mas a sua capacidade de conter toda a informação relativa a um edifício permite outros casos de uso que dependam dessa informação [5, 6]. Em termos de *software* que utiliza BIM e IFC, conhecido por BIM-ready, existem vários produtos que se encaixam nesta categoria, desde visualizadores e carregadores de modelos que permitem editar e integrar com os mesmos, a programas que permitem a criação de ficheiros BIM e IFC. No âmbito do projeto descrito neste artigo, o estilo de produto de interesse é o que pretende a utilização destes conceitos para a gestão energética de edifícios.

Em 2017, Tristan Gerrish et al. [7] concluíram que fora do contexto académico, este tipo de *software* ainda não se encontrava disponível, embora o seu potencial fosse evidente. Os autores referem a adoção de BIM no Reino Unido para todos os edifícios públicos, de modo a cumprir os seus objetivos da redução de CO₂ até 2050.

Por norma, a utilização do BIM para a gestão energética de um edifício [8] baseia-se em simulações resultantes do estudo das propriedades físicas do edifício, havendo por vezes discrepâncias entre a realidade e os resultados obtidos. Um dos problemas dos estudos energéticos de um edifício é a questão da subjetividade, pois diferentes arquitetos podem ter diferentes ideias relativamente às necessidades energéticas de um edifício, por exemplo em questões térmicas [9]. Embora este problema possa ser combatido com a utilização de modelos BIM contendo toda a informação térmica das paredes de um edifício, a simulação continua dependente da informação do sistema de Heating, Ventilation, and Air Conditioning (HVAC) que por vezes precisa de ser adaptada para ser compatível com o motor em uso para a realização da simulação [9].

Da análise e estudo destes problemas surgiu uma metodologia adequada ao estudo e manutenção energética dos edifícios utilizando BIM, que combate a subjetividades dos processos e a manutenção e monitorização constante dos consumos e produções de cada edifício, de modo a correlacionar os dados reais com os previstos.

Embora as soluções apresentadas sejam discutidas e teorizadas em diferentes contextos, a grande maioria dos produtos BIM-ready ainda não satisfazem estas necessidades, focando-se apenas na representação térmica dos edifícios que depois serão alvo de estudo. Na pesquisa realizada, não se encontrou outro produto de *software* capaz de oferecer as funcionalidades desenvolvidas neste projeto. Não se identificou outro caso

de integração de técnicas e modelos BIM num gestor de energia que oferecesse as funcionalidades pretendidas, embora existam soluções limitadas ao espaço em 2D.

3 Análise do problema e desenho da solução

Tendo em consideração que o projeto descrito neste artigo foi realizado a partir de uma aplicação já em desenvolvimento, a análise do problema e o desenho da solução já se encontravam parcialmente realizados, nomeadamente no que se refere ao levantamento de requisitos e ao modelo arquitetural a adotar.

3.1 Requisitos funcionais e de qualidade

Da análise já existente e de diálogos com os elementos da equipa de desenvolvimento identificaram-se, para este projeto, os requisitos apresentados de seguida.

Requisitos funcionais:

- O utilizador deve ter a capacidade de visualizar modelos 3D dos edifícios.
- O utilizador deve conseguir navegar os modelos 3D através do input de teclas e/ou botões na tela.
- O utilizador deve conseguir interagir com os equipamentos elétricos clicando nos mesmos, podendo obter informação, visualizar o seu estado e ter acesso a controlos dos mesmos.
- A visualização deve ser atualizada automaticamente de modo a representar visualmente os valores e estados reais dos equipamentos, em tempo real.

Requisitos não funcionais:

- O sistema deve carregar modelos dinamicamente, i.e. quando o utilizador (já autenticado) carrega num site, o modelo deverá aparecer sem qualquer outro input.
- O visualizador deve ter bom desempenho de modo que a navegação possa ser feita sem se tornar desorientadora ou cansativa, i.e. não deve travar, apresentar movimentos bruscos ou incurrir grande tempos de espera ao utilizador.

3.2 Design arquitetural

A arquitetura da Web App é baseada em MVC com microsserviços (cf. Fig. 1). O visualizador é um módulo da UI com um microsserviço para a importação e carregamento de informação de modelos de edifícios, bem como dos equipamentos que neles se encontram.

Nesta solução, o microsserviço desempenha o papel de *Model* visto conter toda a lógica de negócio e de domínio para a componente do visualizador. Por outro lado, a *View* e o *Controller* encontram-se ambos no UI.

De modo a respeitar a arquitetura MVC e em particular a abstração de lógica da *View* foi necessária a criação de uma camada intermédia, denominada *Engine*. Esta camada é responsável por todo o processamento relativo à renderização 3D.

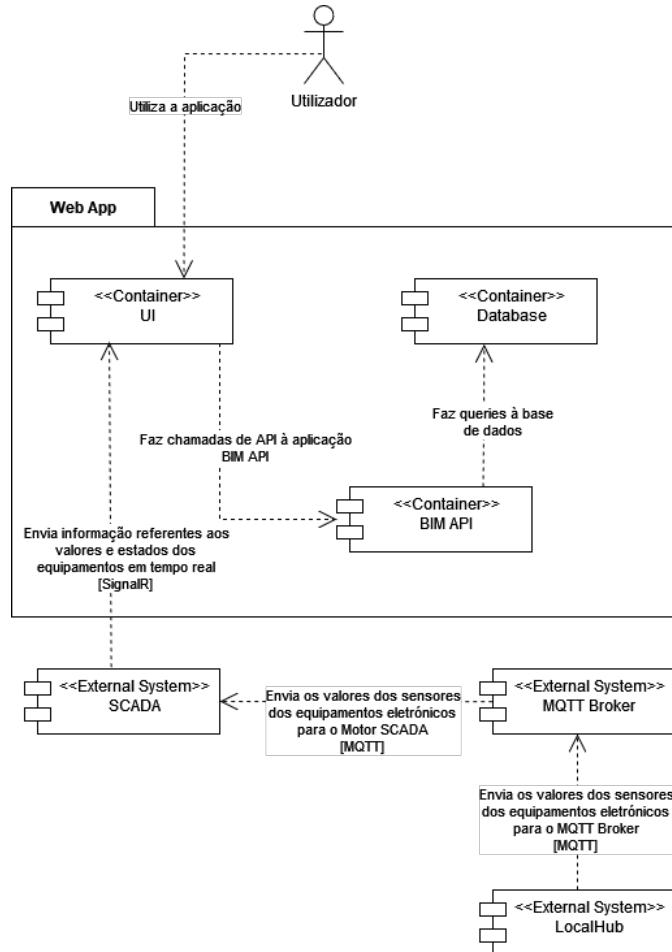


Fig. 1. Vista lógica do sistema

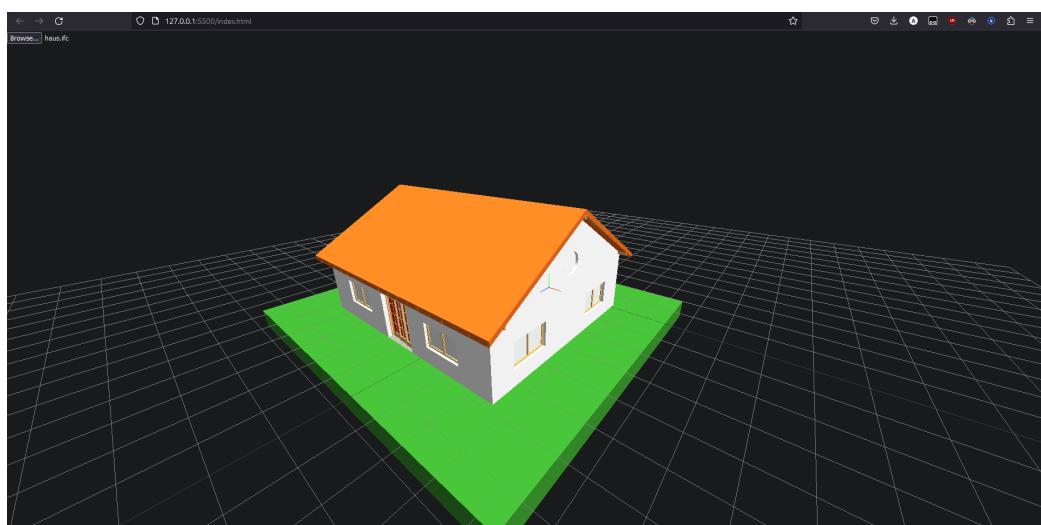


Fig. 2. Prova de Conceito do Visualizador 3D

4 Prova de Conceito

A prova de conceito desenvolvida e ilustrada na Fig. 2 é capaz de carregar ficheiros IFC e apresentá-los num *browser*.

4.1 Movimentação

Por defeito, o IFC.js utiliza *OrbitControls* para a navegação que, embora simples de implementar e fáceis de usar, são muito limitados no seu movimento. Estes controlos permitem, como o nome indica: (i) orbitar à volta de um ponto no espaço 3D, utilizando o botão esquerdo do rato; e (ii) ter a função de *pan*, ou seja, arrastar a câmara para a esquerda, direita, cima e baixo, com o botão direito do rato. Oferece ainda *zoom* usando o *scroll* mas este encontra-se limitado ao ponto alvo, neste caso o ponto que a câmara orbita, ou seja, não passa para lá do mesmo, o que não permite andar com a câmara diretamente em frente. A sua simplicidade é algo que os torna ideais para observar um objeto ou um edifício, por exemplo, mas devido às limitações que impõem, tornam-se inadequados quando se pretende navegar nos 6 eixos de movimento.

Para que o utilizador possa visualizar uma divisão e interagir com os equipamentos presentes na mesma é necessário que o movimento do rato não interfira com a imagem, exceto quando pretendido. Por exemplo, quando o utilizador segura o botão esquerdo do rato. Para resolver esta limitação adotou-se a utilização de *EventListeners* que registam quando o utilizador carrega nas teclas. O esquema de controlos é semelhante ao utilizado, por exemplo, num videojogo, mas sem qualquer utilização de motor de física.

Por outro lado, o objetivo do controlo do rato é permitir que o utilizador consiga movimentar a câmara em todas as direções, mas mantendo controlo independente sobre o apontador do rato. Para tal, a utilização de uma câmara em pivô é ideal porque permite a câmara rode sobre um ponto sempre que pretendido.

Esta solução foi conseguida utilizando os *OrbitControls* referidos. Colocando o ponto de órbita da câmara de *orbit* nas coordenadas da câmara da qual pretendemos visualizar a cena e conectando as suas orientações é possível obter a rotação pretendida (cf. Fig. 3).

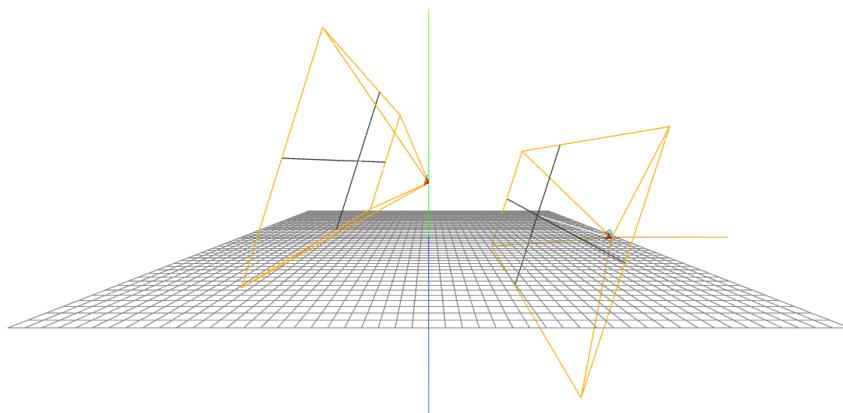


Fig. 3. Solução de controlo de câmara em primeira pessoa

4.2 Colisões

Durante testes funcionais da movimentação identificou-se o problema de o utilizador conseguir atravessar o modelo do edifício, o que era por vezes desorientador pois afetava a percepção do espaço onde o utilizador se encontrava. Por esse motivo, optou-se por implementar colisões que mais realisticamente simulassem a travessia que se realizaria dentro do edifício.

Para tal, começou-se por limitar o movimento da câmara no eixo vertical de modo que não fosse possível passar do valor 0, ou seja, não permitisse que a câmara ficasse debaixo do chão. De modo a impedir que a câmara atravessasse o modelo BIM criou-se uma terceira câmara, denominada câmara de colisões, com o objetivo de validar o movimento pretendido pelo utilizador.

Esta terceira câmara partilha coordenadas com a câmara de visão do utilizador e contém uma *mesh Sphere* na sua posição. Sempre que o utilizador se pretende movimentar, a câmara de colisões sofre o movimento aplicado, seguida da esfera, e verifica-se se a esfera entrou em contacto com o modelo. A utilização de uma terceira câmara em vez da aplicação do movimento diretamente na esfera deve-se ao facto de a *mesh Sphere* não conter a propriedade de direção. Isto significa que, quando se aplica uma translação positiva no eixo dos x, independentemente da direção para onde o utilizador se encontrar virado, a esfera movimentar-se-ia sempre na direção x positivo. Sendo assim, a utilização de uma terceira câmara permite copiar a direção da câmara pivô e aplicar o movimento consoante a direção da câmara do utilizador, sendo a esfera posteriormente transportada para a posição da câmara de colisões, onde se realiza a verificação da condição.

4.3 Apresentação de informação sobre os equipamentos

Na Fig. 4 encontra-se representada a solução de apresentação de informação de um equipamento ao utilizador.

Quando um equipamento é selecionado surge um menu, relativo a esse equipamento. O menu apresenta-se sobreposto a toda a visualização e contém a informação relevante, assim como o botão de acesso aos controlos do equipamento. Esta informação é obtida através dos *datapoints*, em tempo real.

5 Conclusões

O trabalho descrito neste artigo resultou num Visualizador 3D que cumpre todos os objetivos definidos e que oferece ao utilizador uma nova dimensão para obtenção de informação. A adoção de um motor de física com o objetivo de obter uma simulação ainda mais realista será possível no futuro. No entanto, esse não foi o foco do trabalho descrito neste artigo.

No futuro pretende-se ainda que o projeto seja adaptado para realidade virtual, usando como base toda a informação obtida durante o desenvolvimento deste trabalho.

Este projeto serviu também como validação de algumas das utilizações teorizadas do BIM, demonstrando mais uma vez a versatilidade desta tecnologia.



Fig. 4. Menu de informações sobre um equipamento

Em suma, da realização deste projeto conclui-se que a utilização de BIM é possível e útil, pois permite a inclusão de informação relativa aos equipamentos, a qual nem sempre se encontra disponível em tecnologias de visualização 3D tradicionais.

Para além disso, o facto de se tratar de um *standard open-source* garante maior interoperabilidade com vários modelos de edifícios, facilitando deste modo o trabalho dos arquitetos que irão elaborar os modelos, e tornando-se deste modo uma mais-valia na difusão do produto no mercado e, por conseguinte, potenciando a sua atratividade.

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Your Financial Spot - Mobile Application for Financial Management in Real Time

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Abstract. Currently, there is a growing need for improved financial literacy and management tools, so, this paper presents the development of a Progressive Web Application (PWA) designed to empower users to achieve better control over their finances. Conventional banking applications often lack essential features for personalized budgeting and transaction categorization, or even the necessary information for good financial management. Considering this problem, nBanks aims to bridge this gap by offering a PWA for mobile devices. The main objective of this application is to allow users to consolidate and manage multiple bank accounts, categorize transactions, create customized accounts and objectives, and gain a comprehensive view of their financial portfolio. The Frontend is built using the Angular framework, while the Backend is structured using the .NET Core framework with a Micro-Service Architecture. This way, the work culminated in a user-friendly prototype that empowers individuals to take control of their financial well-being by providing a versatile and accessible platform for financial management.

Keywords: Financial Management, Progressive Web Application, Mobile Application Development, Software Architecture.

1 Introduction

The institution nBanks is a Portuguese Fintech established in 2018, focusing its work on the Open Banking concept, which means that the main objective is to offer its clients the freedom of choice to access all the necessary information for independent financial management.

The start-up began by creating a solution, for corporations, in the format of a web application, which allows their users to manage their finances. This way, the company has excelled in the automation and simplification of manual processes, becoming a major player in markets, mainly in the African continent [1].

Now with their position solidified, nBanks is thinking about expanding their solutions to the private/individual market, meaning that they offer the possibility of everyone managing their finances, through a mobile application.

2 Problem

In the context of nBanks' expansion into the private sector, a critical challenge emerged: the pervasive issue of mismanagement of finances among individuals. This problem is particularly acute in countries like Portugal, where a significant portion of the population struggles to comprehend the intricacies of their financial matters.

To tackle this overarching problem, the primary objective was to develop a solution in the form of a mobile application. The identified problem revolves around the inherent difficulties individuals face in overseeing and optimizing their financial portfolios, with many people lacking the tools and knowledge to manage multiple bank accounts efficiently, leading to a lack of financial control and awareness. By addressing this problem and financial illiteracy, the application aims to equip users with the means to proactively take charge of their finances.

In essence, the challenge was not only to create a mobile application but, more importantly, to bridge the gap in financial literacy and empower individuals to navigate the complexities of their financial portfolios with ease.

3 Objectives

Considering the magnitude of the proposed project, nBanks set the main objective as the creation of a prototype of the mobile application, which should have the principal functionalities, for example, the visualization of various bank accounts, the creation of virtual accounts (custom accounts created by the user) and the manual categorization of transactions.

Furthermore, the company proposed a set of secondary objectives to achieve during the project, with those being:

- Analysis of the proposed solution.
- Analysis of similar works and the market.
- Documentation of functional and non-functional requirements.
- Documentation of the chosen Software architecture.
- Utilization of the current Backend, with the minimum number of changes.
- Documentation of the implementation.
- Development of components in Full-Stack mode.
- Development of tests for the created components.

4 State-of-the-Art

During the last decade, there has been an increase in the use of smartphones as a mechanism for the practice of various activities, such as the daily management of tasks and finances, writing notes, and using the Internet and social networks.

With the said increase, a phase of emphasis on developing mobile applications started, hence generating new concerns to be considered when creating these applications, with some of the main concerns coming from their characteristics, such as the

Operating System¹ (for example, iOS, Android, Windows Phone), the screen dimensions, the device's processing capabilities, and the constant evolution of the market.

With the dominance of Android and iOS [2, 3], most of the mobile applications are created aiming their use through devices that are controlled by these OS, ignoring the existence of others, possibly making the solution not work correctly on those.

Furthermore, Android and iOS have notable differences between them, not only in visual terms but also in technical ones, leading to one of the main challenges of Software Development for mobile platforms [4]: How to abstract development from the specificities of the different OS? This question has various possible responses, with those being the native, hybrid, and web application concepts.

4.1 Mobile Application Development Paradigms

There are various questions related to Mobile Application Development, mainly due to the problem of creating a solution that can be used in more than one OS. This discussion field can be divided into three big areas, the native, hybrid, and web approaches.

The native approach corresponds to developing for a specific OS, resulting in a development process with many support tools (normally directly related to the OS) and in a product with a fast performance [5]. However, the native approach, most of the time, is related to low portability, i.e., it is very hard to make it work in more than one OS, causing the previous related challenge [4].

With these challenges, other philosophies arise, the hybrid and web approaches, which try to increase portability, by abstracting the characteristics of the various OS previously mentioned. Although the approaches have similarities, they end in these points, as the hybrid application, normally, has more support, more appropriate tools, and a higher performance, when compared to the web applications [5]. Besides this, web applications make extensive use of the Internet and are, most of the time, hosted on websites, which is not verified on the hybrid or native approaches.

Table 1. Comparison between the Mobile Application approaches [5, 6]

	Native	Hybrid	Web
Support	Advanced	Advanced	Regular/Limited
Portability	None	Possible	Possible
Security	Exposed	Exposed	Very Exposed
Performance	High	High	Low
Appearance	Consistent	Consistent	Inconsistent

Comparing the mentioned approaches, it is possible to infer that they have their advantages and disadvantages, denoting that in the fields that “web applications receive low scores, the native and hybrid applications receive high scores”, and vice-versa [5].

Through the interpretation of **Table 1**, it is possible to conclude that the less positive characteristics of the web application, and because they are websites in the format of an application, the debate is focused on the choice between the native and hybrid

¹ Operating System (OS): program responsible for the device's resource management.

approaches. As stated, and shown in the table, these two approaches have high performances, but there are differences between them, which can be explained by the way that they function.

Native applications, generally, have a higher performance than hybrid ones, relative to the execution time of operations, and with the increase of the made operations, the difference increases considerably since there is an “external layer and web motor that composes the User Interface” of hybrid applications, which leads to very complex interfaces being related to higher execution times [7].

Other differences between the native and hybrid approaches are also noticed in the way that the development is carried out because different tools and programming languages are used. For the native approach, the languages vary relatively to the OS, making it possible to connect Java and Kotlin with Android, and Objective-C and Swift for iOS, which tries to use their respective OS to the fullest [8]. On the other hand, the hybrid applications focus on interoperability and portability, so they normally use, HTML5, CSS (or another type of style sheet), and a framework for Frontend development [8], such as Angular, Vue, React, or Svelte [9].

Table 2. Comparison of execution time (in ms²) between Frontend frameworks [9]

	Angular	React	Vue	Svelte
Insert (ms)	52.75	30.96	25.36	31.26
Edit (ms)	896.76	17.86	20.64	885.03
Remove (ms)	23.83	7.39	33.33	22.97
Compile (ms)	8.70	3.96	3.07	1.61

Represented in **Table 2** are the results obtained from a study on the performance of the previously stated Frontend frameworks, relative to domain operations (insertion, edition, and removal) and the compilation time [9]. The study concluded that React consistently showed the best results, resulting in a more fluid application and that Angular would, generally, be the framework to take more time to realize an operation.

In hybrid development, it is also necessary to consider that the hybrid application concept is very vague and that there are various types of hybrid approaches, which can be more appropriate for some scenarios.

4.2 Hybrid Approaches

There are many approaches to the development of hybrid applications, with them differing mainly on how the application is executed, i.e., if it uses interpreters or if it uses frameworks to build a native application through a hybrid one, for example, through Cordova.

Considering this, the main hybrid approaches are Progressive Web Applications (PWA), Model-Driven (MD), Cross Compiled, Interpreted Approach, and Hybrid Approach [10].

² ms: milliseconds

Of the mentioned approaches, PWA is the one that stands out the most, since it is a web application, executed by the browser, which pretends to offer an experience like a native application. This definition has led some specialists to consider PWA as being part of the hybrid approaches [10], and others consider it as being a more advanced web application [11], or even to consider that it does not belong to either of the groups, being a new alternative on the mobile development approaches [12]. Some of the main characteristics of PWA are the use of Service Workers and Cache [11, 12, 13].

The Service Workers are of extreme importance to PWA, being a script executed by the browser in the second plan, independent from the web page that the user is currently in. This script interacts with the application in an event-coordinated mode because it is listening for certain events that might occur on the application page, or from other sources (for example, a server), these events are called fetch and push, respectively [14]. This means that the Service Workers allow the PWA to offer notifications (generally detected by the push event), the second plan synchronization, and also the possibility of offline access, due to the existence of a Cache that can be used instead of a server (in case of communication error) [15].

Within the mentioned approaches, it is also interesting to refer to the development of Model-Driven (MD) applications, since they generally use Domain-Specific Languages (DSL), simplifying the creation of the application. Also, the MD approach, sometimes, allows for non-technical collaborators to participate actively in the development, because the use of a graphical DSL, such as Münster App Modeling Language (MAML), allows them to generate applications through models and a graphical editor that does not require programming techniques [10, 16].

5 Strategy

This chapter describes how the problem was approached, from how the system was designed, i.e., the used software architectures, and how the solution would logically connect with the rest of the nBanks system. It also explains how the designed solution was put in place and the main points of interest of the implementation phase.

5.1 Design of the System

The design process started with the choice of the Software Architectural Design Model, which was the C4 Model, assisted by the 4+1 Views Model, resulting this way in a “C4+1 Views” Model. The C4 Model was used to elaborate the architecture of the solution in different abstraction levels, with C1 being the most abstract, and C4 the least abstract and most detailed [17]. On the other hand, the 4+1 Views Model was used to describe the solution from different perspectives: Implementation, Logical, Physical, Process, and Scenario (represented by the “+1” in the name) [18].

Even though all the named views were designed, for this paper, there will be a focus on the Logical Views, as they explain the logical structure of the solution, and how it interacts with the already existent Backend of nBanks. Considering this, on the first level (C1), it was considered how the nBanks “global” System interacted with the

“exterior”, concluding that it would make use of an external Open Banking API, developed by GoCardless (previously known as Nordigen).

Relatively to C2, it is important to denote the designed view, represented by **Fig. 1**, which represents the Software Architecture of the nBanks System. This way, it was concluded that it uses a Micro-Services approach because instead of creating a single component for all services, they opted to divide them into various logical components that interact with each other [19].

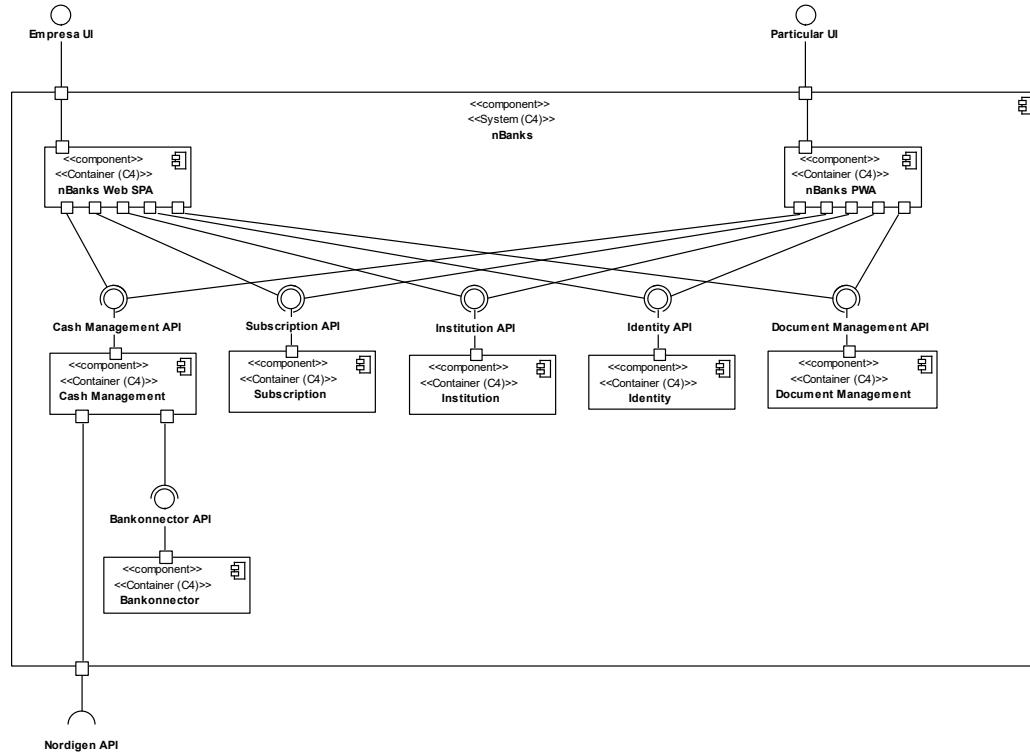


Fig. 1. Logical View of nBanks System on C2.

The presented containers interact with each other, with the top ones being, respectively, the Frontend of the web application and mobile application. The middle ones represent the Backend, where it is important to highlight the “Cash Management” container, because it is responsible for the financial operations, i.e., it controls the communication with the Bank Institutions. For the said communication, the container uses the previously mentioned external API, or the “Bankconnector” API, which is the “in-house” alternative (functioning through Robotic Process Automation Services).

For the third level (C3), the main objectives were to explore the architecture of the PWA and how the Backend containers were structured. Relative to the PWA, it was decided to use Angular Architecture [20], since one of the organization’s objectives was the use of the Angular framework. Still, it was necessary to consider that this architecture suffers from a notation problem because it is not clear how the application

works, so, to create the Logical View, the MVC³ Model was used, applying to it the Angular concepts of component, template, and service.

Continuing C3, the Backend containers were structured through the Layered Architecture, meaning that some of the SOLID principles are not directly obliged and that the current servers might be resistant to alterations and additions. To improve on these points, nBanks could think of implementing the ONION Architecture, which applies more SOLID principles, like the Dependency Inversion Principle [21]. Although such a change could result in a better and more flexible solution, it is necessary to consider that such an alteration could lead to the disruption of business processes and hinder the survival of the organization [22].

5.2 Implementation

The organization nBanks intended the creation of a financial management mobile application, opting for the hybrid approach, because it would allow the small team, of two interns, to develop a solution that could be used in various Operating Systems.

Furthermore, as described in the State-of-the-Art section, it was necessary to decide the hybrid approach to use, culminating in the decision to create a Progressive Web Application (PWA). This decision came from the fact that a PWA is very similar to a web application, like the Single-Page-Application (SPA) that is already in use by the company.

To implement the PWA it was necessary to decide the frameworks and programming languages to use while taking into account that nBanks did not intend to add more frameworks or languages to their Technological Stack. This fact led to the choice of the Angular framework, which is already in use for the mentioned SPA. Even though Angular is a tool with lots of support and functionality, it was necessary to make some additions to it, via external packages.

The used external packages were “moment.js”, Bootstrap 5, and “swiper.js”. The “moment.js” package was employed to present the dates and intervals in the best and most standardized way. On the other hand, “swiper.js” permitted the creation of carousels, where data (for example, bank accounts) could be dynamically presented and selected intuitively. Bootstrap 5 had a significant role in assuring the standard look of the User Interface, but to further this guarantee, it was necessary to create “Shared Components”, which were common components that would be used in more than one place, such as buttons, forms, and cards.

Another important part of the created PWA was the “Shared Services” that corresponded to services that were used globally on the application, like authentication, authorization, translation, and presentation. The presentation service was put in use due to the way that the routing was designed as there are some components where the main menu should not be shown, so it is necessary to hide it.

The routing of the solution consisted of a hierarchical system, represented in **Fig. 2**, composed of various parent and child components, this way, through the *router-outlet* of Angular, it was possible to make main components, such as “Financial

³ MVC: Model-View-Controller.

Management”, where certain interface components were present, allowing them to be shared by their child nodes, for example, “Bank Accounts”. This originated the problem solved by the presentation service because the child nodes of “Bank Accounts” should not display the components of “Financial Management”, being necessary to hide them.

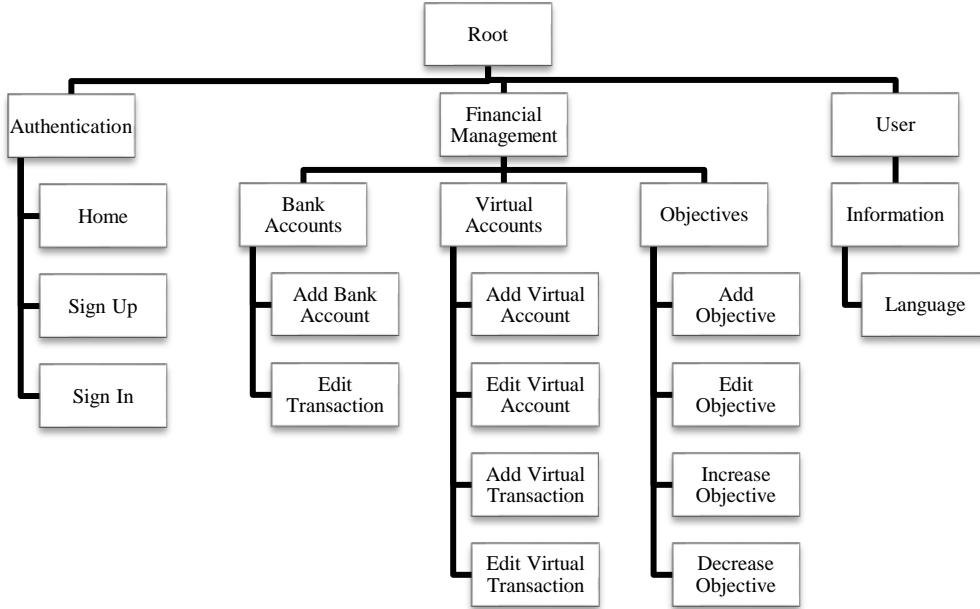


Fig. 2. Schematic of the Solution’s Frontend Routing Hierarchy.

Another point of interest in the solution was the implementation of a translation service, which allows the application to be used in various languages, at this moment: Portuguese; English; and French. To do so, it was necessary to use the concept of i18n [23] and the binding mechanism provided by Angular [24]. This process resulted in the removal of any hard-coded text from the HTML documents, and in the use of the previously mentioned translation service, to obtain the necessary phrase, in a JSON configuration file (one for each one of the idioms), ordered hierarchically by component.

Relatively to the Backend, the objective of nBanks was to use the already existent one, with as few changes to it as possible. The objective was achieved, with a negligible number of changes to the Backend servers, which are implemented with the .NET Core (C#) framework. For the communication Frontend-Backend, at this moment the prototype is using HTTP, but in the future, it will be necessary to change it to a more secure protocol, to mitigate the occurrence of security problems.

6 Conclusions

This section describes the achieved objectives, detected limitations and potential future work to do on this project.

Relatively to the objectives, during the project, it was possible to achieve the main point: the development of a PWA that allows its users to manage their bank accounts

and create their custom accounts. This was achieved through the completion of most objectives set by nBanks, e.g., documenting the software architecture, researching the state of the mobile development market, and so on.

Still, one of the objectives was not accomplished, the use of real data, because, at this moment, the solution uses fictional data, obtained with OpenAI's tool, ChatGPT, which allows the generation of random, but believable, information in high quantities. This is due to the existence of doubts about the application's security, and the fragility related to financial information, so, firstly, it will be necessary to guarantee the security, and only after that, it will be possible to conclude this objective.

The future work will pass through several topics: more tests; security and usage of real-world data; and more functionalities. Although the solution was evaluated, through unitary, integration, and functional tests, it is necessary to test it more intensively, and perhaps create performance tests. Considering that the solution is a prototype, it only has a small set of functions, so, in the future, nBanks will add other functionalities, and with so re-evaluate the requirements, analysis, and system design, to see if any changes are needed.

The main limitation comes from the application being a PWA, which impedes the usage of certain OS functionalities that could be useful to increase the quality and value of the offered project, so a possible part of the future work would be to research how it is possible to surpass this obstacle. Another found limitation was the need to use the already existent Backend of nBanks, because, at this moment, the problem context is appropriate to do so, but in a future phase, it might be necessary to create another Backend specialized for the private market.

In conclusion, the offered solution responds to the problem and achieves the objectives proposed by nBanks, but it has a large room for expansion, not only through the addition of new functionalities but also through the improvement of the current product.

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