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4th Symposium of Applied Science for Young Researchers

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3 July 2024

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Welcome

These are the abstracts of the 4th Symposium of Applied Science for Young Researchers – SASYR. This scientific event welcomed works by junior researchers on any research topic covered by the following three research centers: ADiT-lab (from IPVC, Instituto Politécnico de Viana do Castelo), 2Ai (from IPCA, Instituto Politécnico do Cávado e do Ave) and CeDRI (from IPB, Instituto Politécnico de Bragança).

The main objective of SASYR 2024 is to provide a friendly and relaxed environment for young researchers to present their work, discuss recent results, and develop new ideas. In this way, this event offered an opportunity for the ADiT-lab, 2Ai, and CeDRI research communities to gather synergies and promote collaborations, thus improving the quality of their research.

The SASYR 2024 took place at Instituto Politécnico de Bragança, Bragança, Portugal, on the 3 of July, 2024.

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A Model Execution in the Cloud for Mobile Apps

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Abstract. Artificial Intelligence (AI) is a field that has gained a lot of interest from everyone in recent years. It quickly emerged as a technology used every day by all people on very different devices. This technology also gained a lot of importance on mobile devices in several distinct basis functions. Nevertheless, it became difficult to run AI models on these types of devices, due to the complexity of some AI algorithms. The Cloud infrastructure provides a promising solution, ensuring all the computational power on the server side, leaving the mobile application lighter. This paper discusses the benefits of the cloud and the advantages for mobile applications while providing an architecture using TorchServe as a tool to serve PyTorch models on the cloud. Running AI algorithms on the cloud can be seen as a promising approach to integrate computer vision algorithms in mobile devices.

Keywords: Artificial Intelligence · Mobile Apps · Cloud · TorchServe · Computer Vision

1 Introduction

Artificial Intelligence (AI) is becoming more and more important in people's daily lives [4]. This technology has a direct impact in several fields including healthcare, education, the industry, and in our daily lives through our smartphones [7]. The advance of AI allows the development of more complex models, becoming a focus on research and development [8]. AI is constantly being more integrated into mobile devices, optimizing several functionalities, which include virtual assistants, image and voice recognition, security and biometry, well-being applications, and language translation [2].

However, running these type of models on mobile devices is becoming an increasing problem, due to the hardware limitations of these devices, leading to several impacts on the performance in mobile environments and increased energy consumption. Consequently, researchers need to find new ways to solve and tackle this problem [10]. Cloud infrastructure emerges as an interesting solution, as through it, it is possible to execute a heavy model with all the computational power of a computer, opening new possibilities to execute complex models.

This paper discusses the advantages of the cloud infrastructure as a promising solution to incorporate Machine Learning (ML) on mobile applications. It is organized into three sections, including this introduction. Section 2 provides an architecture using the cloud infrastructure and a mobile application. Future work and research directions are described in Section 3.

2 Cloud Based Architecture

In the last few years, cloud computing has revolutionized the way data is stored and processed [5]. Instead of managing all data in a local machine, data can be accessed

remotely through the internet, bringing several advantages of scalability, flexibility, and easy management of high computational data and tasks.

TorchServe is a tool developed by PyTorch [9] and Amazon Web Services (AWS), to simplify the implementation of PyTorch models in production environments. It can serve multiple models exposed in a REST API, giving a lot of parameters to handle with the server options and custom services to handle the logic of the models served. Their architecture relies on a front-end to handle the requests coming from clients, model workers responsible for running the inference of the models stored, custom plugins defined by the user, and a model store which is a directory to store the files of the models [1].

By connecting a mobile application client via REST service, the client sends a POST request with data that will be the model input, for example, an image, if the application is for image processing or classification, or text if it is for Natural Language Processing (NLP). Figure 1 represents the overall architecture with a mobile application as a client.

Fig. 1: Architecture with a mobile client

3 Future Work and Research Directions

This paper discusses the evolution of AI and the development of more complex models as a big problem in the mobile environment. Cloud infrastructure was proposed as an excellent solution by balancing the computational power into the server side, taking apart the weight of running these models inside a smartphone. TorchServe provides an easy way to deploy models in production, by storing the model and exposing a REST API to communicate with an application client.

The paper serves as a base for the development of two different mobile applications, one for Human Action Recognition (HAR) [3] and the other for Facial Expression Recognition (FER) [6], which are both Computer Vision (CV) tasks. These apps can be applied in a variety of different contexts where these tasks are required. Through the use of the mobile device camera, the facial app should classify seven emotional states and the action app should be able to classify ten different human actions. In both cases, cloud infrastructure is very important as these models are very heavy to run directly in the application, due to the high quantity of data that has to be analyzed by these algorithms.

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Image transformer for FER under partial occlusion

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Abstract. Facial expressions, as a highly intuitive means of communication, play a fundamental role in human daily interactions. Within the realm of Facial Expression Recognition (FER), the advent of Virtual Reality (VR) headsets presents a challenge, as part of the face is occluded. To validate the efficiency of FER with part of the face hidden by the headset, this paper proposes an algorithm that accurately calculates the position and dimensions of VR goggles, adapting to variations in facial tilt and yaw. Utilizing Multi-task Cascade Convolutional Neural Networks (MTCNN) for landmark detection, the algorithm proposed in this paper enhances dataset construction by introducing occlusion effects. Experimental results showed a substantial improvement in FER performance under simulated VR headset conditions. Enhancing dataset realism makes the algorithm more robust and able to adapt to variations in facial tilt and yaw, highlighted by this improvement. These findings indicate that the algorithm can potentially enhance user interaction and experience in various real-world applications, such as gaming and virtual collaboration platforms.

Keywords: Facial Expression Recognition · Virtual Reality · Partial Occlusion · Occlusion Algorithm

1 Introduction

Facial expressions are a highly intuitive and effective way to communicate inner emotions, playing a fundamental role in human daily interactions. In the field of computer vision research, Facial Expression Recognition (FER) attempts to automatically analyze facial expressions from images, in order to discern individual emotional states. FER has undergone significant evolution over time and is now utilized in multiple fields, such as human-computer interaction [5], healthcare [3], education [2], and many more [4].

Despite making significant signs of progress, FER encounters practical challenges, notably partial occlusion, where facial features may be obstructed by movements such as hand gestures or head tilts, or temporary blockages like hair or scars, or within emerging Virtual Reality (VR) environments [1]. The growing importance of VR applications, particularly those involving facial expressions, underscores the need for FER systems to adapt to unique challenges posed by these immersive technologies.

Even though occlusion occurs frequently in real-world scenarios, there are no datasets that contain such images. To bridge this gap, this paper proposes an algorithm that introduces occlusion to the upper region of facial images, simulating the presence of VR goggles. Through simulating occlusion, the aim is to enhance dataset construction, providing a more comprehensive representation of the challenges encountered by FER systems in practical environments.

2 Methodology

With the increasing prevalence of VR goggles, particularly in fields such as education and healthcare, occlusions become more frequent, presenting a challenge for FER algorithms. In order to validate prediction results, an algorithm was developed, that introduces occlusion to the upper regions of facial images, simulating the use of VR goggles.

To replicate the effect of wearing VR goggles, concealing the upper portion of the face, particularly the eyes, was essential. Given the varying tilt and yaw of the face, the algorithm needs to accommodate changes in the eyes' relative position. This requires obtaining facial location and landmarks, including the eyes, nose, and mouth, a task facilitated by Multi-task Cascade Convolutional Neural Networks (MTCNN) [6]. MTCNN comprises three key components: a proposal network (P-NET) for predicting potential face positions and bounding boxes, a refined network (R-Net) to improve detection accuracy and consolidate predictions, and a similar network (O-Net) that further refines predictions and incorporates facial landmarks.

Algorithm 1 Occlusion algorithm.

procedure MAKEGOGGLES(sample, landmarks)
  $left\_eye\_x, left\_eye\_y \leftarrow landmarks[0][0], landmarks[0][5]$
  $right\_eye\_x, right\_eye\_y \leftarrow landmarks[0][1], landmarks[0][6]$
  $nose\_x, nose\_y \leftarrow landmarks[0][2], landmarks[0][7]$
  $middle\_x, middle\_y \leftarrow \frac{right\_eye\_x + left\_eye\_x}{2}, \frac{right\_eye\_y + left\_eye\_y}{2}$
  $googles\_width = 2.2 * \sqrt{(right_eye_y - left_eye_y)^2 + (right_eye_x - left_eye_x)^2}$
  $googles\_height = 1.5 * \sqrt{(middle_eyes_y - nose_y)^2 + (middle_eyes_x - nose_x)^2}$
  $rectangle = (0, 0, googles\_width, googles\_height)$
  $middle\_rectangle\_x, middle\_rectangle\_y = \frac{googles_width}{2}, \frac{googles_height}{2}$
  $angle = \frac{right_eye_y - left_eye_y}{right_eye_x - left_eye_x} * \frac{180}{\pi}$
  $rectangle = rectangle.rotate(-angle, (middle_rectangle_x, middle_rectangle_y))$
  $final_size = rectangle.size$
  $sample.paste(rectangle, \frac{middle_eyes_x - final_size[0]}{2}, \frac{middle_eyes_y - final_size[1]}{2})$

Beginning with the eye positions, the algorithm initially computes the midpoint between them and the distance separating them (Algorithm 1, code available in `https://github.com/SofiaRodrigues41737/Occlusion_Algorithm`). Subsequently, it proceeds to estimate the width and height of the goggles, setting them to 20% larger than the inter-eye distance and 150% of the distance between the eye line and the nose. The algorithm also calculates the tilt angle, utilizing this information to draw a gray rectangle atop the *sample* image. In instances where facial landmarks are unavailable, indicating the absence of identifiable facial features, the goggles remain undrawn (Figure 1).

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(a) FER2013 sample

(b) FER2013 with occlusion simulation

Fig. 1: FER2013 samples with and without occlusion

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Predictive Operator Assessment in Industry 5.0

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Abstract. The transition to Industry 5.0 underscores a critical shift toward human-centric manufacturing, motivating the need to bridge the gap in systems for the proactive assessment of human operators. To address that, this paper introduces a conceptual framework that integrates data collection, analytics, and targeted interventions to enhance the safety and well-being of operators in Industry 5.0 settings.

Keywords: Industry 5.0 · Predictive Assessment · IIoT.

1 Introduction

The paradigm transition from Industry 4.0 (I4.0)'s automation and digital interconnectivity to Industry 5.0 (I5.0) introduces a pivotal shift towards human-centric manufacturing processes, emphasizing sustainability and worker well-being [3].

That perspective shift increases the need to proactively assess human operators in the industrial environment, an under-explored domain.

Therefore, the first milestone of this work is developing a taxonomy of the critical human factors that should be tackled to improve operators' welfare. Then, our research merges I4.0's technological foundations with I5.0's principles to introduce a novel conceptual framework designed for proactively assessing all these aspects altogether, prioritizing our most valuable resource in the industry: human operators.

2 Related Works

The limited yet notable I4.0 literature that addresses human factors was leveraged to develop the taxonomy of critical factors influencing operators in industry illustrated in Figure 1. This will be the foundation of this work, defining the aspects the framework will address.

The authors described a more complete version of this work, including a comprehensive literature review, a more exhaustive explanation of these factors, and a detailed analysis of the framework's components, in [6].

3 Framework Architecture

The developed conceptual framework, illustrated in Figure 2, integrates a closed-loop system designed to enhance the safety, health, and well-being of operators in I5.0 settings by focusing on three interconnected modules:

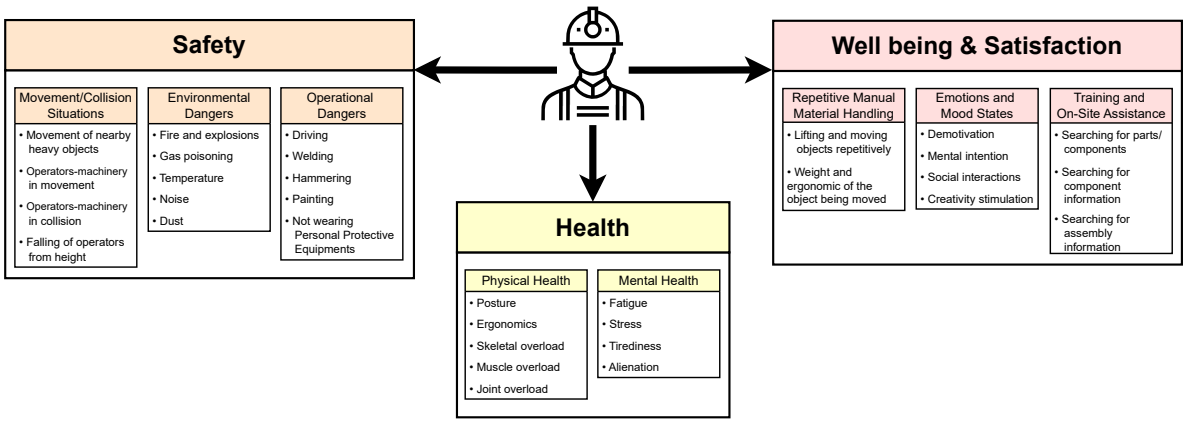

Fig. 1: Taxonomy of the human factors covered by the framework

1. **Data Collection Module**: This module uses a variety of IoT sensors [4], wearable devices [5] [7] , and imaging systems [2] to collect a comprehensive range of data, including physiological data and movements of operators, operational status of machinery, and environmental conditions
2. **Data Analysis Module**: This module processes and analyzes the collected data by combining machine learning techniques with human oversight to identify and predict risks and deviations from normal operational patterns, enabling the triggering of immediate responses to both prevent accidents and respond to incidents that have already occurred [5]. Additionally, digital twins are used to simulate various scenarios and forecast potential issues [7].
3. **Intervention Techniques and Predictive Assessment Module**: This module uses the insights generated from the Data Analysis module to implement targeted interventions that ensure the operators' safety and well-being. It monitors and predicts physiological and psychological states to preemptively address health risks [1], uses location data to enhance operators' safety in specific areas [2], and employs enhanced reality technologies to provide adaptive training and assistance in real-time [8].

4 Conclusions and Future Works

In this paper, we introduced a novel framework that integrates various I4.0 technologies into components specifically designed to proactively assess human operators, including predictive intervention techniques that actively respond to and anticipate operational conditions. Additionally, the closed-loop system enables the continuous evaluation and adjustment of these interventions. This work sets a new standard for predictive systems in industrial settings, advancing the alignment with the human-centric model of I5.0.

Future research must improve real-time data processing and aggregation techniques and develop adaptive interventions tailored to individual needs to enhance the framework's effectiveness and adaptability.

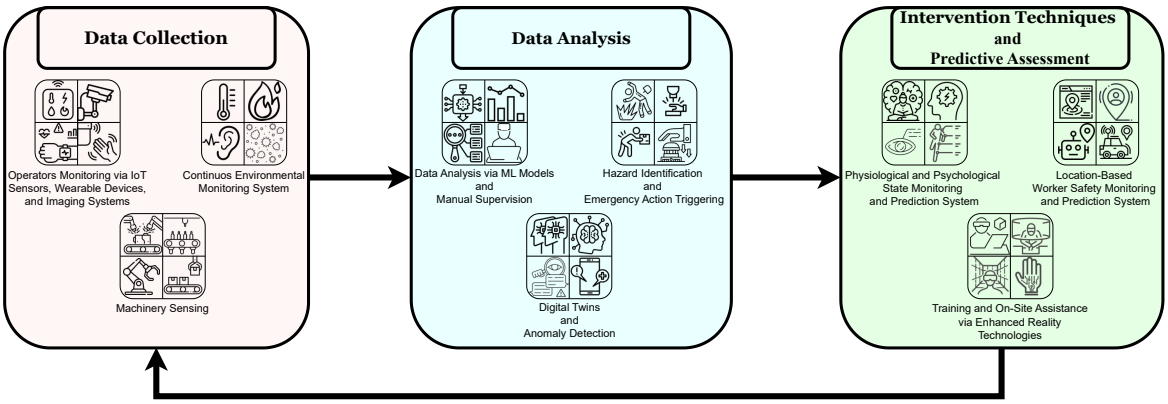

Fig. 2: Flowchart of the proposed conceptual framework

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RFID systems optimization for passive tags reading in multi-product applications

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Abstract. Radio Frequency Identification (RFID) technology has played a key role in optimizing inventory management in warehousing and logistics environments. Passive tags are widely used for modern inventory management, fast readability, low cost and accurate tracking of goods. However, challenges arise when reading multiple passive tags simultaneously due to interference. The read range of RFID tags varies based on factors including the type of tag, type of reader, position of the tags relative to the antenna, frequency and interference in the surrounding environment or from other tags/readers [3].
This study aims to optimize RFID systems by improving tag readability across various distances, orientations, and amidst material interferences in multi-product environments. We will carry out tests on RFID tags in terms of their distance, orientation in relation to the reader and material interference. Moreover, we intend to increase the efficiency of the system and the correct positioning of the tags on the product. For this, we will be exploring AI methods [5] to analyze RFID (RSSI, Phase) data and generate to most prominent place to ensure the best readings.

Keywords: RFID · Passive UHF tags · Deep Learning

1 Introduction

RFID technology utilizes electromagnetic fields to identify and track objects equipped with RFID tags. These tags hold data stored on a chip and are paired with an antenna for communication with RFID readers. RFID system consist of three main parts: an antenna, a transceiver, and a transponder. The combination of an antenna and transceiver is called RFID readers. Readers come in fixed forms, such as those found on shop security doors, or mobile versions, like handheld devices used for inventories purposes.

The transponder is embedded within the RFID tag itself. RFID tags are small devices consisting of an integrated circuit, antenna, and substrate. The section of the tag encoding identification information is called the RFID inlay. Tags can be passive (powered by the RFID reader), active (with their own power source), or semi-passive (battery-powered circuit, reader-powered communication). RFID operation involves the antenna activating RFID tags,through electromagnetic signals. Upon activation, tags respond by emitting stored information, which is then captured by RFID readers (see Fig. 1).

RFID finds extensive use in various applications, including inventory control, product identification, baggage tracking at airports, access control in buildings, and contactless payments (e.g., RFID cards in public transport or ATM cards). The ability to efficiently recognize and monitor objects makes it a valuable tool across numerous industries and daily life scenarios.

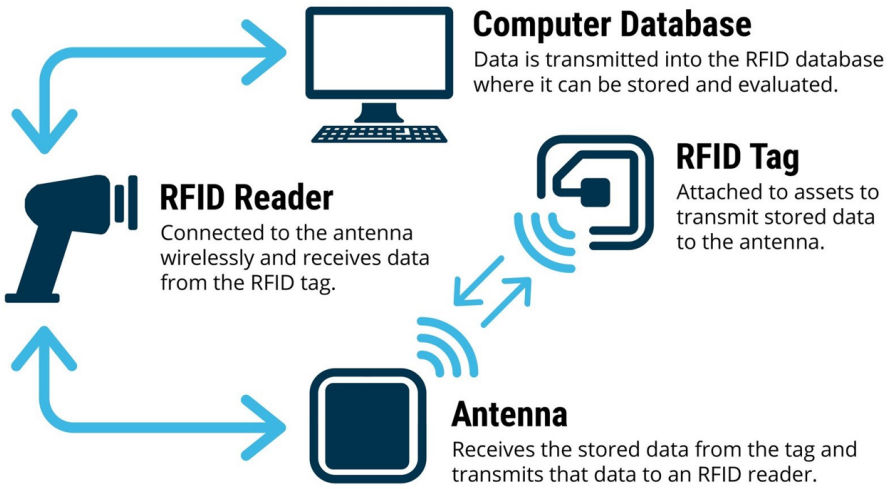

Fig. 1: RFID system [1]

The main problem is the difficulty in efficiently and accurately read passive RFID tags in environments where multiple products with different shapes, sizes and materials coexist. The simultaneous interaction of several tags, as well as signal interference caused by different materials [2], can result in high error rates, leading to problems in inventory management, such as incorrect stock records, difficulties in locating products and, ultimately, financial losses. In addition, optimising RFID systems for multi-product environments requires a careful approach when it comes to positioning antennas, configuring frequencies and selecting communication protocols.

2 Methodology and Expected Results

For inventory management, UHF (Ultra High Frequency) RFID tags are commonly used due to their higher frequency (typically between 840 and 960 MHz), offering a greater range and read rate. However, they are more susceptible to interference. Our study aims to optimize RFID reading by strategically placing tags on products for improved readability across various distances, orientations, and amidst material interference.The properties of RFID tags, such as size and encapsulation type, determine range and EPC (Electronic Product Code) code detection performance. Alignment with the antenna's centroid significantly influences the range, affected by the radiation patterns of both the RFID reader and tag antennas [6].

We set up a environment with 55 tags arranged in a 5x11 matrix (see Fig. 2), along with a Zebra FX9600 RFID reader and a fixed Zebra AN510 antenna. Experiments involve testing different material blocks (metal, organic, others) at varying distances and heights from the tags. We preprocess the tag readings, by resetting the value we are getting from the tags. Then we place the objects between the antenna and tags, and store RFID data (RSSI, Phase), considering other external factors that can influence

UHF's interaction matter/electromagnetic wave . This dataset captures combinations of interference, such as material and distance.

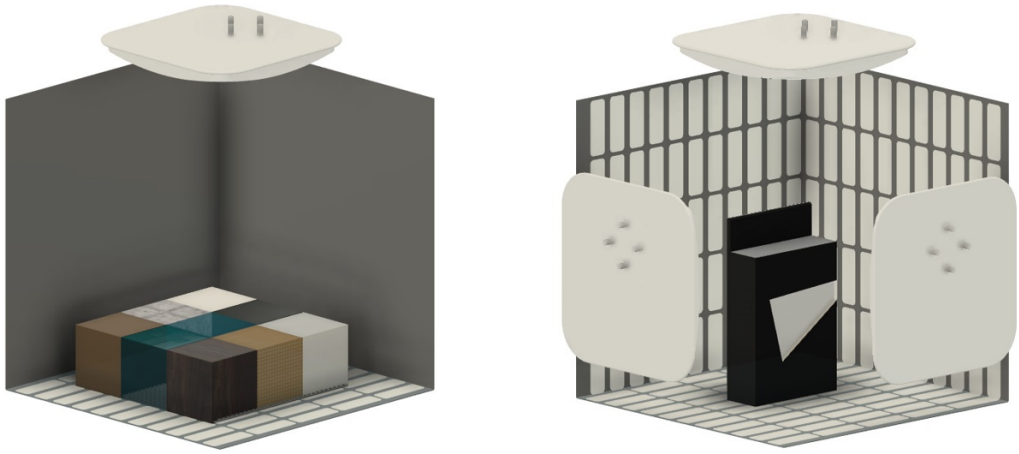

Fig. 2: 3D model of the environment created, for the material testing and the final product

Subsequently, we will create a neural network model suitable for regression or classification tasks [4]. It will take RFID data as input and predict optimal tag placement parameters as output. The evaluation of the model's performance will be done using metrics such as mean squared error and/or accuracy. We will then iterate on the model and training process to improve performance by experimenting with different architectures, hyperparameters, and training strategies. Once validated, we will deploy the model with an optimization algorithm to recommend optimal RFID tag placements using real-time data from the RFID system. With the AI-based approach, we can exam the effectiveness of various existing tag placement strategies and their limitations in multi-product environments.

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Front-End for number reading system

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Abstract. The article presents the development of a graphical user interface (GUI) for a number reading system, based on the App Designer tool of Matlab software. The developed GUI incorporates the reading system in order to facilitate interaction between the user and the system. The reading system converts a number entered by the user into a sound corresponding to its reading. Furthermore, the number entered will be automatically interpreted in the classes of units, dozens, hundreds, thousands, millions, dozens of millions or hundreds of millions. The GUI also has a field that displays the conversion from numeric representation to words representation. This conversion takes place through an algorithm developed during the GUI development phase. Finally, GUI was subjected to a quality assessment using the Mean Opinion Score (MOS) method. Each question was rated on a scale of 1 (very bad) to 5 (very good), resulting in a MOS GUI score of 4.50.

Keywords: Number reading system · Matlab · GUI.

1 Introduction

The process of automatically reading numbers is useful for different types of applications. For example, it is used in watches for the visually impaired, automatic attendance systems, voice interface systems with pre-recorded phrases involving numbers and even in general purpose TTS (Text-To-Speech) systems that require reading algorithms automatic numbers [1].

The term Front-End is used to refer to the GUI of an application. In this context, the GUI is the element with which the user interacts through buttons, images, interactive elements, etc. It is important to highlight that the term Front-End can also refer to the part of application development that involves the creation and management of the GUI. This part is responsible for the interaction between the user and the software, using technologies such as HyperText Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript (JS), among others [2].

The topic under discussion emerged as a continuation of a previous work by Lopes, 2015 [3] which has the theme Automatic Reading of Numbers. Therefore, the general objective of this work is to develop a Front-End for this automatic number reading system.

1.1 State of Art

In recent decades, several researchers have contributed to the evolution of reading systems to meet a wide variety of technological applications [4] [5]. Two highly reliable and widely adopted reading systems are described below:

- Google TTS (Text-to-Speech): service that synthesizes speech from text, allowing the reading of numbers and other texts with a variety of voices and languages;
- Amazon Polly: Text-to-speech service offered by Amazon Web Services (AWS).

2 Developed GUI

The development of a GUI must follow three important principles: 1) put the user in control, 2) reduce the user's memory load and 3) make the interface consistent [6]. The developed GUI facilitates interaction between the user and the reading system. The reading process occurs as follows: the user enters a number in the field marked *Insira o número aqui* and clicks the *Enter* button to process the number and reproduce the corresponding sound, using previously developed algorithms by Teixeira, et al., 2014 [7] and [8]. It is also important to note that the number entered will be automatically interpreted in the classes of units, dozens, hundreds, thousands, millions, dozens of millions or hundreds of millions. Therefore, the reading system converts a number entered by the user into a sound corresponding to its reading. Furthermore, an algorithm was developed to convert the numerical representation into words, presenting the result in the field *Número por extenso*. Figure 1 shows the final *output* of the developed GUI.

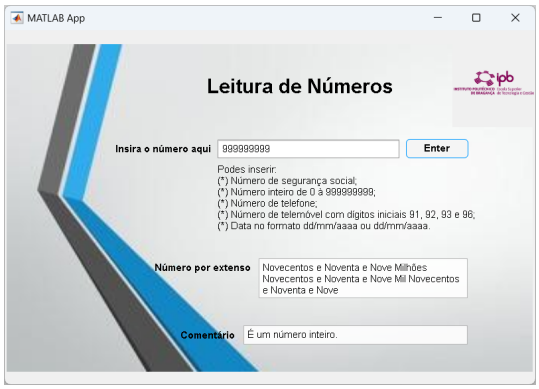

Fig. 1: Developed GUI.

The reading system was subjected to a hearing test, with the participation of fifteen individuals who were invited to evaluate the quality of the sounds of each of the five algorithms (whole numbers, cell phone numbers, telephone numbers, dates and social security numbers). After listening to the reproduction of twenty numbers, the individuals classified each of the algorithms using the MOS method on a scale from 1 (terrible) to 5 (excellent). The system developed by Lopes, 2015 [3] had an average score on the

MOS scale of 4.46. The grade was given for sound quality, audio perception and correct reproduction.

A test was carried out using Google Cloud's TTS (Text-to-Speech) function, during which a sample of each of the inputs supported by the reading system presented in this article was introduced. The samples used were: 963172877 (mobile phone number), 273589651 (network telephone number fixed), 12054789635 (social security number), 07/12/1975 (date) and 999999999 (integer).

The reading system presented in this article, compared to Google TTS (Text-to-Speech), has the following advantages:

– Reads numbers and, simultaneously, presents their equivalent in words;
– For each admitted entry, it has a specific reading form.

After development and testing, the GUI was subjected to a quality assessment using the MOS method. In this evaluation, 24 users participated, who evaluated the quality of the GUI based on the principles presented by Nielsen, (2024) [9]. To do this, users had access to the Standalone executable and received the link to a form consisting of 8 questions, created with the Microsoft Forms software. Each question was rated on a scale of 1 (very bad) to 5 (very good), resulting in a GUI MOS score of 4.50. Figure 2 shows the results of this evaluation.

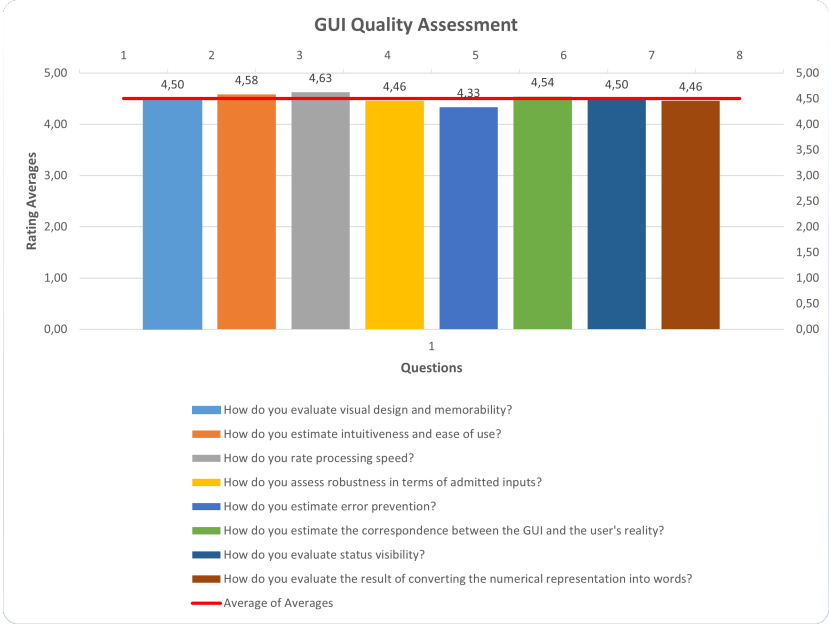

Fig. 2: GUI quality assessment.

3 Conclusions

The paper successfully demonstrated that through the interactive components that were appropriately selected and implemented, the developed GUI offers an interactive way for users to enter numbers, receive feedback on these numbers and convert them into words, accompanied by the reproduction of a corresponding sound. Overall, the

MOS score of 4.50 that the GUI obtained in the user evaluation demonstrated its effectiveness and efficiency. Furthermore, the reading system presented in this article proved to have some advantages compared to the Google TTS reading system.

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Interactive Game With An Equilibrium Sensor To Monitor Physical Health Parameters

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Abstract. This paper focuses on the development of an equilibrium sensor. The sensor developed is based on the use of two scales to assess the user's postural unevenness. Allied to this system is an interactive game that aims to monitor the user's balance using the sensor developed, in order to obtain an assessment of the user's general state of health. The results demonstrated that the users enjoyed the interactive game and wanted to play it once more. Additional research is required to fully validate the equilibrium sensor.

Keywords: Equilibrium Sensor · Interactive Game · Health Monitoring

1 Introduction

Balance is an essential human characteristic that plays a fundamental role in various daily activities, such as walking and preventing falls, making it essential for a better quality of life, especially in older adults [1]. Human balance is the result of several interconnected systems, such as the central nervous, vestibular, somatosensory, visual and musculoskeletal systems [5]. Any dysfunction in the aforementioned systems can cause balance disorders. Thus, the study of human balance is an indicator of the patient's state of health in relation to these systems. One well-known approach to assessing balance is centre of pressure analysis. This method is highly regarded and validated as effective in assessing balance [3, 4]. In addition, there is a significant correlation between the measurements obtained by this method and the individual's ability to predict future falls [6].

2 System Overview

One approach that will be studied is to assess a person's balance with the use of two scales. This device analyses the distribution of the load between the right and left limbs, providing an understanding of the user's body stability. During the assessment, the user places one foot on each scale, allowing each scale to record the individual readings of each limb. The difference between the values read by the scales will be used to evaluate the user's centre of pressure. Using this assessment method, the centre of pressure will only be assessed in the lateral direction of the user, but it is hoped that this method will remain an indicator of the user's balance. The main reason for this is that assessing the centre of pressure in two directions makes the system more complex, and removes the possibility of using commercial scales.

3 Experiments and Results

Figure 1 shows the interactive game developed. In this game, the character's position will correspond to the user's balance point. If the user's weight is placed on the left scale, the character will go to the left, if the weight is on the right scale, the character will go to the right. This interactive game features a system of coins, which can be acquired by the character travelling the correct path, and has the main objective of assigning a score to the user's performance and indicating the correct path to be described. The main objective of this test was to assess whether it was possible to evaluate an

Fig. 1: Interactive Game

individual's balance using two scales. The results collected do not allow this sensor to be validated to determine an individual's balance because the data collected does not cover a diverse group of individuals. All participants obtained the maximum score on the Berg scale [2], meaning they all had a good equilibrium. For this sensor to be validated is needed a group of participants with a lower score to compare with the sensor results, thus enabling validation.

Acknowledgements

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Role of Artificial Intelligence Systems in Pandemics: A Case Study of Elderly People

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Abstract. A study published in 2020 in the Journal of the College of Cardiology found an 11% rise in heart disease deaths during the COVID-19 pandemic. The pandemic has led to a surge in advanced chronic illnesses due to limited medical check-ups. To cope with these limitations and maintain good health, the demand for wearable health technologies such as smartwatches, sports devices, and vital sign monitors equipped with artificial intelligence has significantly increased. However, concerns have been raised regarding their accuracy and clinical implications, as their accuracy in diverse medical situations is not well-studied. Their potential public health and clinical impacts are yet to be fully explored.

Keywords: : Wearable Health Technologies · Artificial Intelligence · Epidemiology · Vital Signs · Cardiology · Public Health.

1 Background

Achieving a healthy lifestyle and increasing quality of life are widely discussed topics nowadays.

This is largely attributed to the fact that in the recent past, we have experienced a pandemic such as Covid-19, and for that reason have been deprived of earlier diagnosis, periodic checkups, and basic health care, degrading the health of the majority of the population [5], [7]. Currently, there are wearable technologies (such as smart watches, cell phones, tablets, computers, etc.) that are used in a healthcare context, which means that they assist in the diagnosis of certain conditions by carrying technology with intelligent systems capable of monitoring a basic set of vital signs [9], [3], [6], [1]. These devices satisfy the basic needs of the vast majority of their users by being easily usable, providing autonomous, simple, and easy-to-interpret monitoring, and giving a sense of security to the user [3], [2], [10].

However, it is important to alert the user to the poor accuracy of some of these devices, as well as the fact that these devices are mostly not equipped with artificial intelligence and the possibility of altering the ideal conditions, which affects the normal monitoring of clinical data.

In the literature some studies cover this theme, however, they fail to safeguard these and other limitations, leaving the performance of these devices behind.

Based on the population's awareness of the relevance of frequently monitoring clinical data during the pandemic, and to fill the gaps in the literature, the project "Study of the

impact of Artificial Intelligence systems against pandemic situations" was created. This study has the main objective of understanding how the implementation of systems with technologies with reliable artificial intelligence can positively impact access to screening and early diagnosis in a future pandemic situation [4], [8]. Combined with easy access to screening and diagnostics, stands the importance of promoting public health policies [9] capable of adding quality to the maximum number of people.

2 Methodology and Tasks

The first set of tasks is focused on analyzing the state of the art, while the second set is aimed at implementing theoretical concepts into a practical reality through technology implementation. This implementation will be done in two distinct phases: (i) using certified and regulated medical technology; and (ii) studying the impact of new technologies developed for this purpose. Finally, the last set of steps that will lead this work to success is based on the validation of the project, through studies in 3 pillars: (i) definition of the population and the condition under observation; (ii) clinical data acquisition protocols and finally, the (iii) epidemiological study with the main risks, limitations and impacts of the study on society.

Three institutions will be involved in carrying out various activities: the 2Ai laboratory at IPCA, which specializes in technology and artificial intelligence, the University of Santiago de Compostela, which specializes in epidemiology and public health, and Santa Casa da Misericordia, the non-academic entity who, besides being important in the acquisition of data (by providing the population of study), will be favored with my investigation, enhancing the monitorization and consequently prevent pathologies in its patients.

3 Expected Conclusions

In conclusion, it is anticipated that the research will be beneficial for society at large, extending beyond the clinical realm to potentially inform and enhance public health policy planning. While undoubtedly aiding in disease monitoring and management, this research also holds promise in shaping norms and regulations that can advance public health agendas. By providing valuable insights into health patterns and population needs, the findings of this research may guide the development of more comprehensive and proactive policies.

Acknowledgment

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Cybersecurity Maturity Level Assessment Tools in Industry 5.0: An Overview

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Abstract. As industries advance towards Industry 5.0, the seamless integration of Cyber-Physical Systems (CPS) security into human-centric manufacturing processes introduces unprecedented CPS security challenges. With the introduction of new physical assets on the shop floor (AGVs, Robots, Cobots, etc.), and novel cutting-edge technologies (AI, data analytics, IIoT, Blockchain, etc.), productivity and innovation in companies are being challenged at an everyday pace. However, at the same time, new and unexplored vulnerabilities emerge. This paper provides a comprehensive overview of cybersecurity maturity level assessment tools tailored for the Industry 5.0 landscape.

Keywords: Cyber-Physical Systems, CPS, Security, Cybersecurity, Industry 5.0, Framework, Maturity level

1 Introduction

The advent of Industry 5.0 signifies an important moment in the evolution of manufacturing, where the fusion of human expertise and cutting-edge technologies has ushered in an era of unprecedented innovation and productivity.
Industry 5.0 sets off a new wave of the industrial revolution by highlighting human-centric intelligent manufacturing. It seamlessly integrates humans, cyberspaces, and physical assets to optimize the entire product life cycle while ensuring the well-being of all stakeholders along the product value chain [3].

Presenting preliminary findings, this paper focuses on identifying common cybersecurity attack vectors in Industry 5.0 while examining available tools. These insights lay the groundwork for crafting a framework and roadmap tailored to the needs of manufacturing organizations.
For improved comprehension, the paper is structured as follows: an introduction, followed by the problem statement and motivation in section 2. This is followed by the state of the art literature review in section 3. Section 4 presents preliminary results, then section 5 - conclusions with a discussion on future work directions.

2 Problem Statement and Motivation

The motivation behind this work is to address the urgent need for identifying vulnerabilities in advance and providing a clear assessment of an organization's cybersecurity

posture. Effective maturity assessments are crucial to identify weaknesses, prioritize improvements, and develop strategic security roadmaps.
This study aims to provide robust assessment tools tailored to Industry 5.0, helping organizations enhance their cybersecurity resilience and ensure the continuity of operations.

3 State of the art literature review

In this chapter, we analyze historical security incidents and case studies to identify common attack vectors and potential consequences, as well as conduct an analysis of existing research tools for the cybersecurity maturity level assessment in the industry to enhance our understanding and conceptualize the future framework.
The research questions we are addressing are: "How can we assess the maturity level of cybersecurity in industrial cyber-physical systems in the context of Industry 5.0?"; "What tools do we already have to assess the maturity levels of cybersecurity in the industry in other studies?"; "How can we develop a framework to guide organizations in improving their security posture while embracing the principles of Industry 5.0?".

This study was performed in the Google Scholar and IEEEXplore databases with the search queries using the following combination of these keywords: Cyber-Physical Systems Security; Cyber-Physical Systems; Industry 5.0; industry; frameworks; maturity; cybersecurity.

4 Results(Preliminary)

In this study, we pinpointed eight more common cybersecurity attack vectors within the manufacturing sector: #1 Sensor Spoofing [6], [2], [5], [1]; #2 Actuator Tampering [6], [2], [1]; #3 Network Intrusion [6], [2], [5], [1]; #4 Firmware Manipulation [6], [2], [5]; #5 Data Integrity Attacks [6], [2], [5]; #6 Software Vulnerabilities [6], [2], [5]; #7 Supply Chain Attacks [2]; #8 Insider Threats [6], [2], [1]. In addition, we have identified some relevant tools from existing literature, focusing on the most relevant to our topic for in-depth analysis. Therefore, the future maturity level assessment tool will be grounded in the Foundation Requirements (FR) outlined in the ISA/IEC 62443 standards [4]. The core principles of Industry 5.0—human-centricity, resilience, and sustainability—are effectively aligned with the foundational requirements of the ISA/IEC 62443 series, making them an ideal framework for our assessment tool.

5 Conclusions and Future work

In this stage of the study, we have investigated prevalent cybersecurity attack vectors within the context of Industry 5.0 manufacturing and evaluated various tools for assessing maturity levels across multiple domains. Key aspects critical to our ongoing research have been highlighted and thoroughly examined.

Our future efforts will focus on developing a comprehensive framework for cybersecurity maturity level assessment. This framework aims to enable organizations to

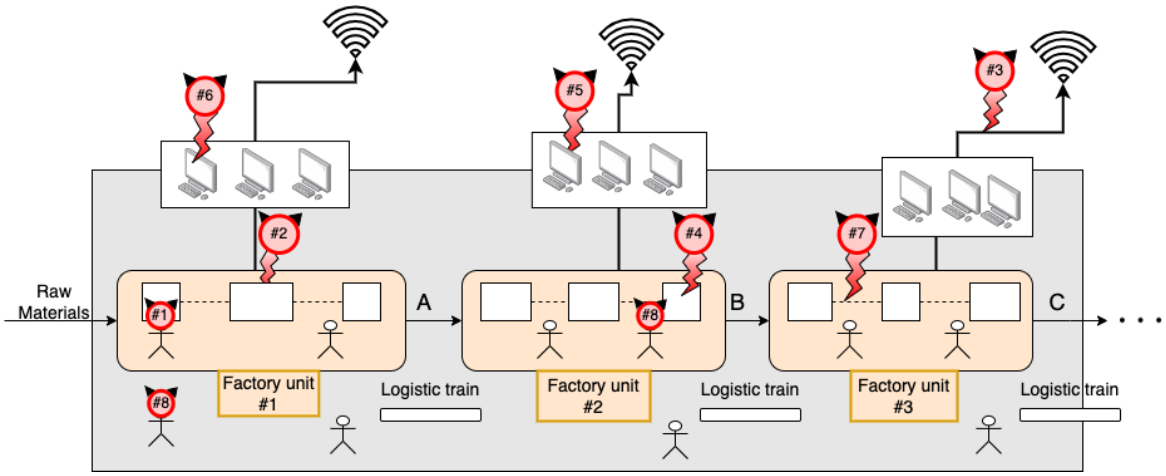

Fig. 1: Manufacturing process with some common vector attacks

effectively analyze their current cybersecurity posture, identifying both strengths and vulnerabilities. This proactive approach will facilitate strategic improvements and bolster overall resilience against cyber threats.

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Predictive model for preventing occupational accidents in the retail sector.

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Abstract. Occupational accidents continue to be a global concern for companies. Although several preventive measures have been implemented, accidents continue to frighten companies. Predictive analytics has emerged as a promising approach, especially in sectors such as construction and industry. However, this approach has not yet been explored in the retail sector, where the risks to workers are significant. This study intends to contribute to developing a predictive model for occupational accident risk in the retail sector based on machine learning algorithms. In this model, the purpose is to calculate the risk of these events for two consecutive days of work in different working periods and send alerts to the health and safety team of the leading retail company in Portugal. The model is built by analyzing several company databases and applying correlation and feature selection techniques to identify the variables with the most significant impact. These variables are then used to calculate the risk of accidents in each store and sector of the company, with a Multilayer Perception model reaching an assertion of 78%.

Keywords: Occupational Accidents · Data Analysis · Predictive Model · Machine Learning Algorithms.

1 Overview

Workplace accidents continue to be a concern, despite numerous efforts by companies to implement preventive measures [2, 3]. In 2021, Portugal recorded around 175,047 non-fatal work accidents. Three economic activities in particular, industry (44,187), construction (29,271), and the retail sector (24,349), stand out for the highest numbers of accidents. These values show an increase compared to the previous year, the pandemic year, and a decrease compared with the pre-pandemic period, according to the last data published by [1].

Predictive analysis using Machine Learning algorithms is a promising approach to deal with this problem [5]. Although recent exploration, these algorithms have demonstrated useful results in several areas, such as industry [5], and construction [4]. However, this strategy has still not been explored for the wholesale and retail sector.

Given these circumstances, this study aims to develop a forecast model to calculate the level of accident risk in the wholesale and retail sector on the current and next working day at different times. Databases from the leading food retail company in Portugal will be used, and they will be analyzed and integrated into a Multilayer Perception algorithm to determine the probability of workplace accidents occurring.

The remaining of the article is organized as follows. Section 2 presents the datasets and methods used, including the main results achieved. Finally, the study is concluded, and suggestions for future work are presented in Section 3.

2 Developing an Intelligent Safety System

Portugal's leading food retail company has several databases available for analysis, including accident and near-accident histories, ergonomic, hazard, and risk assessments, observation and implementation of preventive actions, training, audits, demographic data, and the number of daily transactions. These datasets comprise countless variables, accounting for 895 variables in total.

Correlation and feature selection techniques were used to reduce each dataset to the variables with the highest correlation with the accident events to deal with the high number of variables. Each identified variable was transformed into an impact variable, whereas the calculation was carried out using existing observations in proportion to the number of accidents. These values were normalized using the min-max approach. From the datasets, 34 impact variables were obtained, such as age, seniority, day of week and month of occurrence, number of transactions, risk evaluation, and risk level of each task, among others. The impact variables were combined in one dataset and applied to a Multilayer Perception (MLP) algorithm to calculate the probability of two possible outcomes: accidents or non-accidents.

The method adopted for assessing occupational risk for each store and work section corresponds to the product between the probability obtained by the MLP algorithm for each store and work section and the severity of the work section' risks.

Finally, this algorithm is implemented in the developed software to send alerts about the calculated risk level. Given the vast number of stores within the company, each with its own set of characteristics and varying amounts of data, setting a threshold percentage for high risk could cause some stores with less available information to never meet that percentage threshold.

Therefore, alerts are sent based on the difference in risk between the previous day's risk level and the current day's risk level. Table 1 represents the interval of levels to send the alerts.

Table 1: Alert trigger threshold.

Risk Level	**Interval for risk level**
Risk-free (r_f)	$0 \leq r_f < 0.02$
Moderate Risk (r_m)	$0.02 \leq r_m < 0.05$
High risk (r_h)	$0.05 \leq r_h \leq 1$

These alerts are designed to proactively prevent accidents by notifying those responsible for employee safety, including managers and the health and safety team.

3 Conclusion and Future Work

The presented approach uses data from a retail company in Portugal to find the probability of risk of accidents' occurrence on two consecutive working days. So far, the algorithm has demonstrated an assertiveness of 78%, obtained through a sensitivity analysis with the predicted values and the occurred accidents.

In the future, datasets on external factors, such as weather, traffic, and holidays, that can affect the employee's psychology will be included, in addition to information on the mental well-being of employees obtained through an iterative and anonymous platform. Furthermore, the aim is to identify the variables that increase the risk of accidents and implement preventive actions to avoid these events.

Acknowledgements

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Real-Time Classification of Olive Ripeness Using YOLOv9 in Olive Oil Mills

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Abstract. The olive tree has been integral to the Mediterranean culture and economy for millennia, with olive oil being one of its most renowned by-products. The ripeness of olives significantly impacts the quality of olive oil, traditionally determined through subjective methods. This study presents an advanced artificial intelligence system leveraging the YOLOv9 algorithm to identify and classify the ripening stages of olives in real-time within an olive oil mill. The presented model demonstrated an increase in precision, recall and mAP compared to the state of the art, highlighting its effectiveness in real-time applications.

Keywords: Olive Maturation Classification · YOLOv9 · Computer Vision

1 Introduction

Intrinsically linked to the culture and economy of Mediterranean countries, the olive tree and its by-products are undoubtedly a success story. Adapting over the millennia to a wide variety of environmental and geographical conditions, it is estimated that it has been cultivated for around 6000 years. Throughout this time, various techniques for the maintenance, extraction and processing of its by-products have been the object of study in order to optimize quantities and qualities of production, valuing the final product. Proof of these optimizations and valuations of by-products is the economic factor, where approximately 1.23 billion euros are moved annually between imports and exports.

One of the best-known by-products is undoubtedly olive oil highly associated with cuisine and the Mediterranean diet, it is also combined with the conservation of foods such as canned fish, used in the textile , cosmetics and pharmaceutical industries . In recent years, its consumption has almost doubled from the early 1990s to the 2020s. This product differs from other vegetable oils because it is extracted from a fruit, not a seed, giving it unique nutritional and sensory characteristics. Its quality is influenced by several factors, including the ripeness stage of the olive at the time of harvest, which directly affects the sensorial profile of the oil [3]. Traditionally, determining this stage of ripeness involved methods that can be subjective and imprecise, such as visual assessment based on the Ripeness Index in accordance with the guidelines of the International Olive Oil Council [1].

With the advancement of computer vision technologies as well as machine and deep learning algorithms, new methodologies have been explored in order to optimize the

process of detecting the maturation stage. Several studies have already presented the application of computer vision techniques combined with artificial intelligence algorithms to classify different stages of maturation as well as diseases or other defects in fruits. To this end, most studies have used algorithms such as Convolutional Neural Networks. These offer not only greater accuracy but also the ability to perform real-time analysis, open a world of possibilities.

As demonstrated by the work of Diaz et al. [2], pioneers in using computer vision techniques to classify the quality of table olives, neural networks with just one hidden layer could achieve 90% accuracy in classifying the four categories. Subsequent advances focused on the detection of characteristics and anomalies, such as external damage and maturation stages, demonstrating the feasibility of applying this type of technology in olive growing. As shown by Khosravi et al. [4] that real-time identification of ripening stages of olives on branches can achieve an overall accuracy of 91.91% using convolutional neural networks. In this way, this article addresses a method for identifying and classifying the ripening stages of olives in real-time in the olive oil mill, using the last version available of the You Only Look Once (YOLOv9) algorithm.

2 Methodology and Results

The methodology of this study was designed to develop and validate an artificial intelligence system capable of identifying and counting the number of olives at different stages of ripeness in real-time inside an olive oil mill. The dataset used was the same as the study presented in [5], which comes from the region of Macedo de Cavaleiros, Portugal, with images captured in a real environment in the olive oil mill without external lighting. Images were obtained using an RGB digital camera and were processed to create a fully annotated dataset in YOLO format. Note that in this format, in addition to the images, there is also a file in .txt format with notes referring to the label of the identified object and its bounding box coordinates.

The model chosen to carry out this identification/classification was the last model made available by the developers, YOLOv9. This model, based on convolutional neural networks, was chosen considering the optimizations compared to its subsequent ones, combining its effectiveness in high-speed processing and precision in real-time detection tasks. Its performance was evaluated using standard precision, recall, and average intersection-over-union precision (mAP) metrics. Implementation and training were carried out using advanced computational resources, such as Tesla T4 GPUs, ensuring efficient analysis and classification of captured data.

Table 1: Comparison of the results obtained by the YOLOv9 method with the state of art.

Model	Precision	Recall	mAP50
YOLOv9	0.735	0.833	0.8
YOLOv8 (SOA)	0.708	0.819	0.783

The results demonstrate that the proposed YOLOv9 model outperformed the results presented in the state of the art (SOA) of this dataset. As it is possible to verify

by looking at table 1, YOLOv9 managed to achieve higher values in all the chosen evaluation metrics compared to the YOLOv8 model. Although slight increases, but considering that the dataset was similar as well as the hyperparameters chosen to train the model, the increase compared to what was previously declared is notable. With this model it was still possible to reach a value of 0.474 with the mAP95, which indicates that practically 50% of objects are detected with a certainty greater than 95%. which, looking at the dataset and the difficulty of the problem, is a very satisfactory number. It was also possible to see that the problems presented by the authors persist due to the imbalance of object classes, with stage 1 continuing to be the most affected in terms of precision in its classification.

The main future work will undoubtedly be the improvement of this data, which despite already having many objects identified (approximately 2200) still has few images for either training or validation and testing. Another of the proposed works will be the generalization of the data set, with images from other points of the mill and even from other mills in order to make identification possible in any situation presented.

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Application Based on Time Series and Neural Networks to Predict Wind Generation

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Abstract. This paper explores the application of time series analysis and neural networks for predicting wind generation, considering factors such as weather patterns, historical data, and turbine specifications. Additionally, the paper discusses the databases to be utilized in the analysis, providing insights into their significance in enhancing prediction accuracy and reliability.

Keywords: Neural networks · Prediction · Wind power.

1 Introduction

Among the European Union's energy matrix, wind energy is the fastest growing segment, with a projected 400% increase in installed capacity between 2015 and 2050. [2]. Wind power represents the rate of kinetic energy flow carried by the moving air [6]. For forecasting wind power generation there are methods that can be classified into physical approaches, statistical, approaches leveraging neural networks and hybrid approaches. Physical methods heavily depend on numerical weather forecasting, constrained by sensors and monitoring devices installed within the wind power plant [9].

Maximum Power Point Tracking (MPPT) is a method utilized to improve the efficacy of wind power extraction by regulating the rotational speed of wind turbines through the incorporation of variable-speed turbine technology. In conventional MPPT control strategies, an error of at least 5% may happen [5], because determining variable wind speed is challenging due to its temporal and spatial distribution randomness. Consequently, an intelligent algorithm, which applies artificial intelligence, is incorporated alongside conventional MPPT to diminish error margins and improve system efficiency [1].

In terms of statistical aproaches, the California ISO prototype forecasting algorithm [8] for short-term wind generation utilized a Autoregressive Integrated Moving Average (ARIMA) model to calculate the forecasted growth/decline factor 2.5 hours ahead. The model's coefficients were dynamically adjusted for optimal accuracy, and a bias self-compensation scheme was integrated by introducing an extra term into the modified ARIMA model. The importance of incorporating forecasted weather parameters and unit status information into the model is highlighted [8].

Regarding hybrid aproaches, a type of Artificial Neural Network (ANN) called Long Short-Term Memory (LTSM) was applied with Seasonal Autoregressive Integrated Moving Average (SARIMA) to predict wind power of an offshore wind turbine in Scotland [10]. The study's results showed that the model is highly efficient with values

above 99% for all cases, considering different levels of approximation and detail components.

Decomposition strategies can be combined with hybrid models by decomposing the wind speed/power time series into several subseries with relatively stationary characteristics before further processing. Among the decomposition methods, wavelet transposition (WT) has been widely used currently. WT decomposes a signal into high and low frequency components, which makes them more stationary and easier to analyze [7].

2 Databases

Two databases were selected for this study, regarding wind power generation in Portugal: EMHIRES dataset Part I: Wind power generation [4] and Ember's monthly electricity generation data [3].

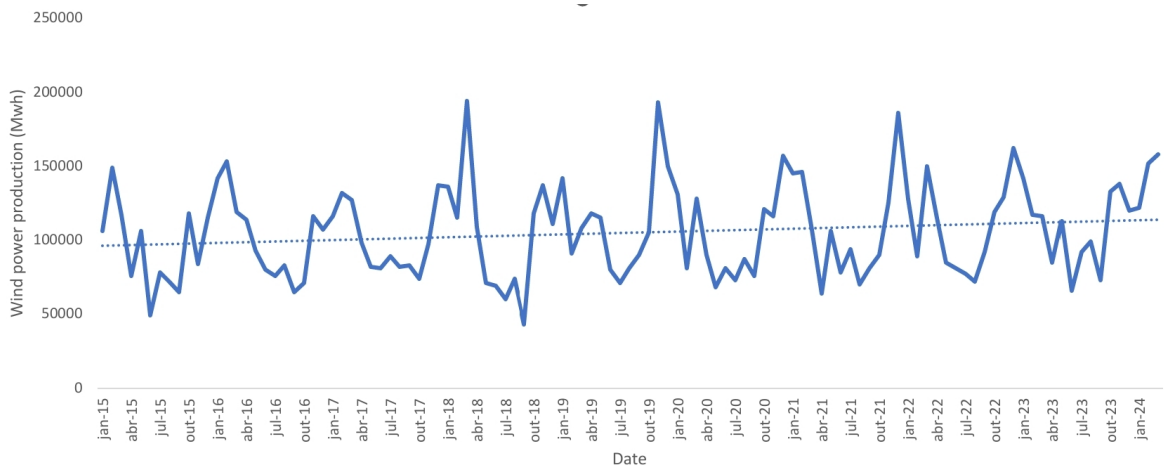

Fig. 1: Ember's monthly electricity generation data

Considering the monthly report and focusing on a period of approximately 10 years (2015 to 2024) it is possible to describe some properties of the time series, in which two properties are highlighted and must be considered when building the prediction model:

- Trend: Indicates that the time series is increasing over time, despite representing slow growth over the last 10 years;
- Seasonality: These are periodic fluctuations, events that repeat themselves at each identical period of time. In this case, the peak values occur between the months of December to April and the falling values between the months of June to October

3 Conclusion and future works

The study on different approaches contributes to define a great model of forecasting. The prediction of wind power generation is necessary to optimize the management systems

and gain efficiency while reducing costs of production. The hybrid methods showed to be the best in efficiency with less error rates. For future work, is intended to develop an algorithm using neural networks in order to create wind generation predictions, then apply and train the model on publicly available datasets with historical wind generation data.

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Unstructured data extraction with Ai-based approach to automatically integrate invoices data in ERP Systems

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Abstract. In today's world, most company's stands on an enormous amount of unstructured data. The manual analysis, extraction and organization of that data cost billions of dollars annually. With the use traditional information extraction techniques Companies become limited in their approach, nowadays with the gradual use of AI-based techniques this problems are less prominent. We can also see that most methods are still template based or rule based ones, focused in specific layouts not allowing to tackle complex document layouts.Therefore this project intends to develop a way to improve this extraction and organization of data from the Invoices that could, in present moment, be in a non digital form, mainly paper. The project aims to extract information from the tables of this documents and with the use of Computer Vision, and AI models digitize the information, this information is obtained with the use of Ocr Engine to be available in a more fast way, improving productivity and inserting this information in the Enterprise Resource Planning (ERP) system autonomously, modernizing the data management in the and reduce reliance on manual processes.

Keywords: Unstructured data · OCR · Table

1 Introduction

Nowadays most companies stand in a enormous amount of unstructured data, most methods to obtain the information from the documents such as invoices use OCR for the retrieval of the text information and template matching for the retrieval the importnat sections of the documents as said [2]. As for the tables present in the documents such invoices, their structure can vary in size and layout, placing a increased difficulty to retrieve the data that is contained on them. Therefore now, the techniques used for detection may include object detection models like Faster-RCNN (Region Based Convolutional Neural Networks) and Mask-RCNN and NLP-based methods that incorporate both textual and visual features [3]. This way, in this project we intend to focus only on the table present in this invoice documents and extract the information present in a quick and reliable way to them introduce in the ERP system of the company.

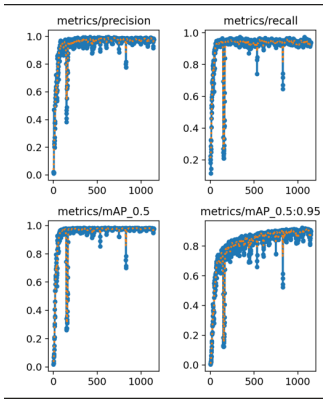
This ERP systems are the base system of many companies, these systems offer great convenience as they can manage the processes of many different departments such as manufacturing, purchasing, finance, engineering, and logistics through a single system and in a dynamic and automatic way. However, these processes usually aim to solve the main needs of businesses such as accounting transactions and logistics processes. If another need arises, software or an extension should be developed and integrated into the business system. The management and recording of incoming invoices automatically are one of these extensions that need to be developed. [1]

2 Methodology

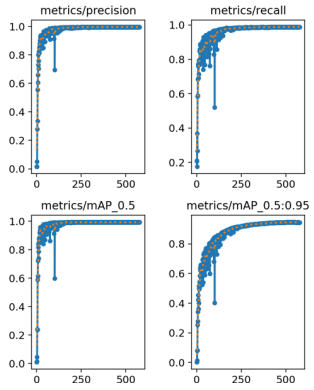
this way the project focused on table data extraction using Faster-RCNN for layout detection and OCR engines, such as EasyOcr and Tesseract OCR, for text extraction. Considering the variability of table information and layout,the YOLOv5x model is used for table layout detection, and is trained to identify the table components, such as columns, rows and header regions. The project began with a dataset of 160 manually labelled invoice images,that were expanded to around 2800 images through data augmentation techniques. These images, transformed through rotations, horizontal and vertical ones, scale alterations, and blur application, were divided into training (70%), testing (15%), and validation (15%) sets,providing a robust dataset for training. This approach ensures meaningful information extraction correlated with the table header.

3 Results

Finally after several iterations of training we achieve a reasonable result for both the 160 images dataset, and the 2000 images dataset, the results are illustrated in the Fig 1 and in the table 1



(a) Metrics of the original dataset



(b) Metrics of the Augmented Dataset

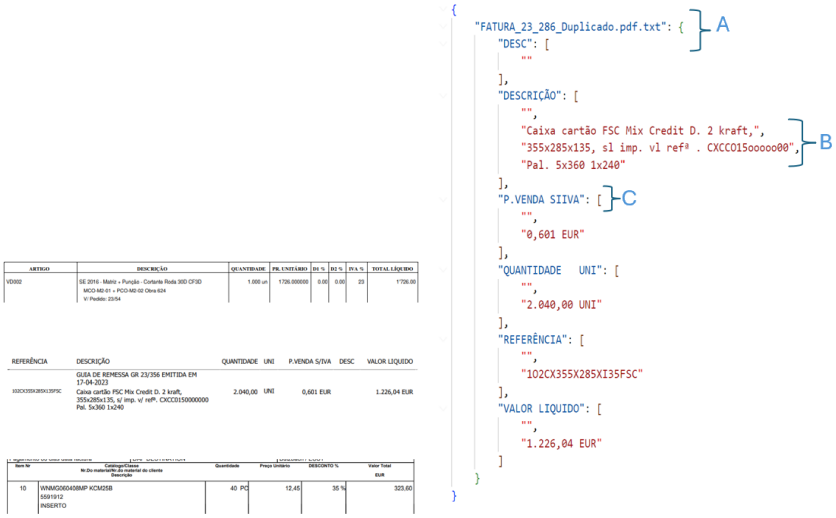
Fig. 1: Metrics improvement over time for the training of both networks

Results:	Precision	Recall	mAP_0.5	mAP_0.5:0.95
Original Dataset	0.97868	0.93955	0.97945	0.89871
Augmented Dataset	0.99602	0.98909	0.99361	0.94515

Table 1: Results of the training process of the Yolo Model.

As we can see with data presented in the table it is possible to train the network for the detection of the layout of the table. Despite of achieving some good results with

original dataset we can see that was possible to obtain some gains with the use of data augmentation, even tho that still has some space for a small improvement. After the layout comes the OCR engine that retrieves the data from the table by correlating the data in the table and the Header of the same. The result of this correlation is present in Fig 2.



(a) (b)

Fig. 2: Input and outputs of the pipeline, in figure a) are the examples of the lines of information to be analysed by the OCR engine and in the figure b) is the output of pipeline after the application of the OCR Engine.

As it can be seen in fig 2b the system outputs different 3 sections that are marked as A,B and C. In section A will always be the name of the file that the information was extracted, then there is 2 sections B and C, in section B will be the information extracted by the OCR Engine and in the section C will be presented the header section that is related with the information that was extracted from the invoice. As for the results of the models in the table structured layout detection and based on the information of the table 1, we can see that the best model is able to achieve a average precision of 0.99 in 50% intercession over union and a 0.95% in the Average precision of 95% intercession over union.

Acknowledgements

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EMG Signals and MMT Scores in Robotic Upper-Limb Rehabilitation

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Abstract. The integration of Electromyography (EMG) signals into rehabilitation practices has emerged as a cornerstone in physical therapy, providing invaluable insights into muscular activity. This paper explores the burgeoning synergy between EMG signals and technology-driven frameworks, offering a pathway to optimize the rehabilitation process. By leveraging EMG data to inform exercise-based therapies and establishing a direct scale of Manual Muscle Testing (MMT) scores for robotic assistive rehabilitation, we propose a paradigm shift towards more sophisticated operational modes for Upper-Limb rehabilitation. This integration promises to enhance the comprehension of muscular dynamics, thereby facilitating tailored interventions and fostering improved recovery outcomes for patients.

Keywords: Electromyography · Impedance · Rehabilitation · Robotics.

1 Introduction

The integration of Electromyography (EMG) Signals into upper-limb rehabilitation alongside robotics is crucial for understanding and improving rehabilitation processes. EMG offers direct insights into muscle activity and dynamics, aiding in the assessment of patient progress. This research explores integrating EMG technology into robotic rehabilitation systems to enhance data analysis and ultimately improve outcomes [2,4]. Surface EMG, a non-invasive method, is particularly effective for assessing muscle activity. By integrating EMG data, this approach enhances understanding of patient muscle activity patterns, facilitating the development of adaptive systems for rehabilitation.

The Manual Muscle Testing or MMT scores technique is a standardized method to evaluate muscle strength and function [6]. It involves applying resistance to specific movements initiated by the patient, graded on a scale from 0 to 5. This system quantifies muscle strength consistently, aiding in identifying weakness or dysfunction. MMT results inform treatment plans across clinical settings, including rehabilitation and sports medicine.

2 Methodology

2.1 EMG Validation

The BITalino board by Plux offers a versatile platform for comprehensive data acquisition of vital and biological signs. Its adaptability to diverse EMG technologies makes it ideal for capturing and analyzing EMG signals in research. Leveraging BITalino's capabilities allows researchers to explore various EMG applications, enhancing potential for robust data acquisition and analysis in studying muscular activity and rehabilitation outcomes.

We used Plux's software with their hardware to record and observe signals, and connected it to the BITalino device through their OpenSignals application. Our experimental setup involved using a smartphone to interface with the BITalino device for measuring muscular effort. Experiments were conducted at a standard physical training center, where we developed a specific test protocol. This protocol included three phases with different weights (8kg, 10kg, 12kg) and varying number of repetitions.

The exercise performed was the Concentration Curl. As Fig. 1 (A) illustrates, there are three main muscle groups that engage in this exercise.

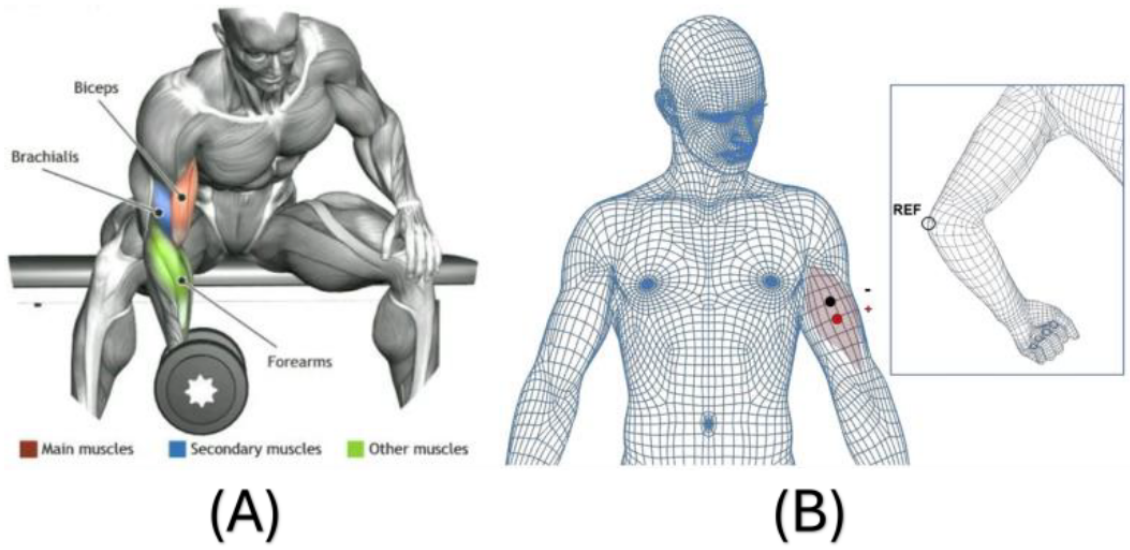

Fig. 1: (A). Exercise Representation [1]; (B) EMG Electrodes Placement [5].

2.2 MMT Characterization

EMG readings offer an objective alternative to the subjective Rating of Perceived Exertion (RPE) in rehabilitation assessment, particularly when introducing robotics to measure applied strengths. To broaden rehabilitation options, robotic arms should feature various modes of operation for enhanced patient engagement. The compliance of the KUKA iiwa lbr r800 robotic arm enables parameter adjustments like stiffness, crucial for resistance to deformations, ensuring precise movements [3]. Leveraging compliance, specifically the impedance mode, enables evaluation of different effort levels and enhances overall functionality, allowing to idealize a correlation with MMT scores and create operation modes.

3 Results

3.1 EMG Behavior Analysis

The usage of EMG readings allowed for an objective monitorization of the exercise performance, facilitating a deep comprehensive study of the evolution of the patient's

progress. Fig. 2 depicts the relevant role that EMG readings could play in a rehabilitation framework, ensuring precise execution and thereby enhancing awareness within robotic rehabilitation processes.

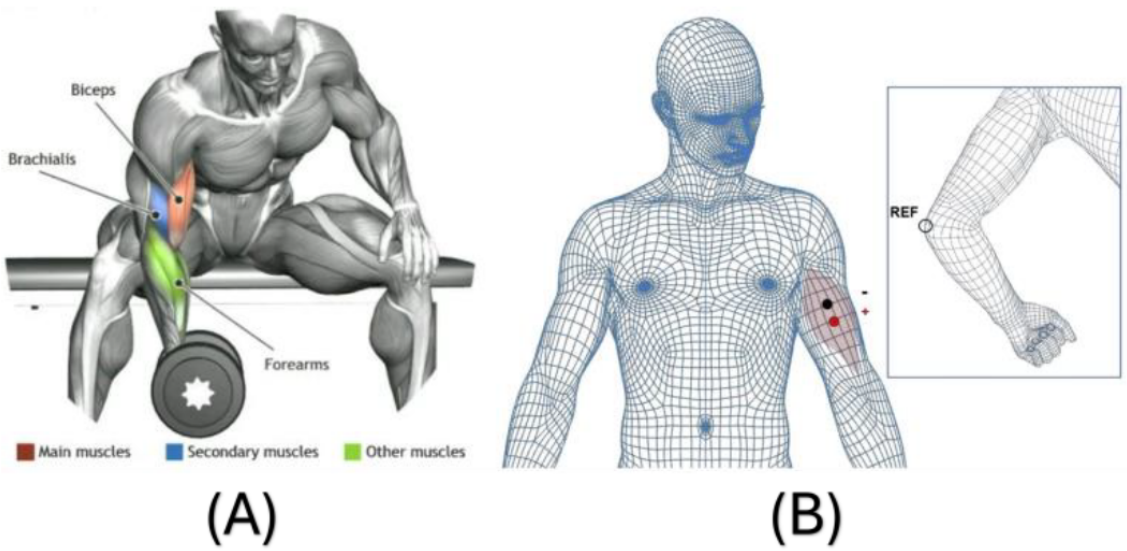

Fig. 2: EMG Recordings and Study Results

Fig. 2 shows the EMG activity during the Concentration Curl exercise, highlighting three main phases: the concentric phase, pause, and eccentric phase. This detailed analysis helps assess performance and is valuable for rehabilitation and recovery over time.

3.2 Robotic Operational Modes

After a series of tests tempering with the impedance mode, this approach proved to be the path towards a more robust exercise-based therapy. This allowed the identification of four operational modes with associated MMT scores, which guided, in a generalized way, the rehabilitation process during different phases of the rehabilitation and the patient's needs. The modes are described as follows:

– **Passive Mode:** The robotic arm executes the exercise along a predetermined path without patient interaction. The patient simply holds the handle, termed "Create conscious linkage", with an MMT score of 0.

– **Assistive Mode:** The robotic arm follows the path with minimal force applied to maintain the exercise. This establishes a minimum strength requirement for the patient, with forces exceeding this threshold allowing the robot to continue the exercise, referred to as "Induced active participation", with an MMT score of 1-2.

– **Active Mode:** The robot dynamically supports or applies strength throughout the movement, with varying levels of assistance, termed "Optimize motor control" with an MMT score of 3.

– **Resistive Mode:** Dynamic forces are implemented throughout the exercise to improve muscle power, with MMT scores of 4-5.

Acknowledgements

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iMath: an Intelligent System to Learn Math*

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Abstract. This paper introduces the iMath platform, designed to facilitate active learning in Mathematics education. The platform is under development and aims to be globally accessible within a few months. One goal is to provide an artificial intelligence-driven tool to support higher education students and lectures in mathematics. The platform will be freely available to users worldwide, offering innovative resources to change the way to teach and learn Mathematics.

Keywords: Mathematics · Higher Education · Active Learning.

1 Introduction

Today, things change fast. Thus, in this changing world, those who understand and dominate mathematics concepts have significantly enhanced opportunities and options for shaping their futures. Proficiency in Mathematics unlocks pathways to fruitful prospects while lacking it leaves these opportunities unattainable [3].

Technological tools and digital resources are significant in supporting active learning and enhancing student engagement in the educational process, particularly in subjects like Mathematics, which often presents significant challenges and is a frequent source of frustration for many students.

Considering this, the iMath project is being developed to provide an artificial intelligence-driven tool to support higher education students and lecturers in Mathematical content. The project offers a platform of resources, hands-on activities, and assessment tests. By incorporating these strategies and using artificial intelligence-driven tools, the iMath project can create a dynamic and engaging learning environment that empowers students to become active learners and develop a deeper understanding of mathematical concepts.

The iMath platform is addressed to math lecturers and researchers interested in optimization and learning algorithms and related topics, as well as students at the university level who are interested in improving their math skills through a learning environment based on the application of artificial intelligence. Therefore, iMath aims to add value, lowering the perception that mathematics is too hard and mitigating students' dropping out due to perceived obstacles to math.

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2 iMath Structure

The iMath platform is being developed, but its first version is already available at imath.pixel-online.org. Its final version will be divided into three main parts: Optimization and Learning, Online Resources, and the MathE tool, as detailed in the following. Figure 1 illustrates the iMath platform resources, described below.

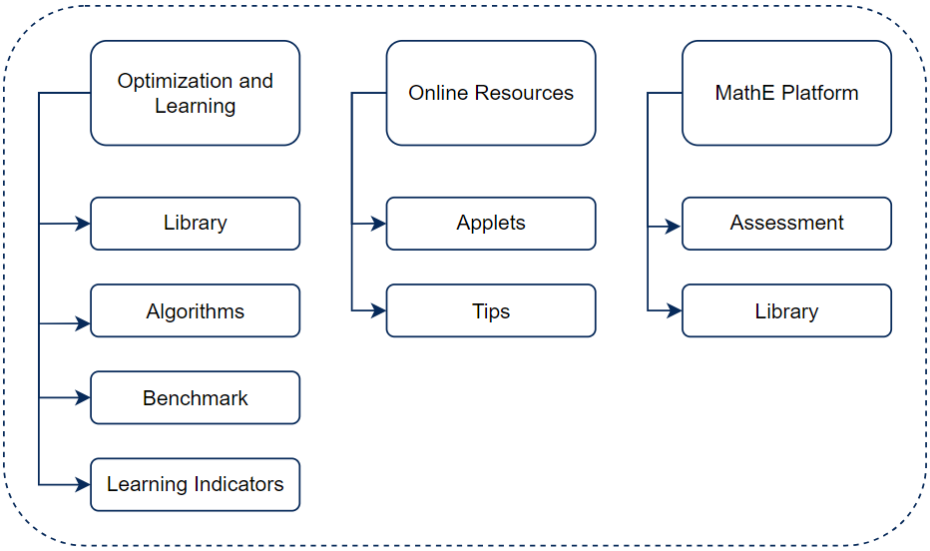

Fig. 1: iMath structure.

Optimization and Learning — offers a comprehensive set of literature resources covering optimization, learning methods, and models. Within the Library, users can access relevant scientific and academic publications. The algorithm section encompasses algorithms and terminology for machine learning and optimization. Additionally, the Benchmark section provides a database of benchmarks essential for evaluating the performance of learning and optimization algorithms. Lastly, the Learning Indicator section offers a database of performance metrics to assess students' progress throughout the math learning journey.

Online Resources — provides a range of applets and tips designed to tailor content related to optimization and learning topics to students' needs. The applets section offers tools to visualize mathematical concepts, aiding students in comprehension and instructors in effective explanation. Additionally, the tips section offers guidance on integrating artificial intelligence into educational settings.

MathE — is an educational tool that supports students in acquiring knowledge in a wide range of Mathematics's topics [1, 2]. The original MathE tool (mathe.pixel-online.org) offers a variety of multiple-choice questions, chosen randomly, to help students who attend college or have an interest in improving their skills through practice. Additionally, MathE provides supporting materials, including instructional videos and written resources, to reinforce students' understanding and confidence. The main goal in

the iMath project is to develop an algorithm, the so-called Optlearn, applied to MathE, such that it will guide students' learning processes through a dedicated recommender system. Taking into account a set of machine learning algorithms and optimization techniques, the MathE recommender system will dynamically select questions tailored to each student and specific learning moment. At this moment, some of these algorithms are being applied to define the difficulty level of each question, for each student, and which question should be answered next, by each student. The testing phase is ongoing with students from partner colleges and users from all over the world, and the results are being collected to analyze algorithm improvements.

3 Summary

Customized education based on active learning strategies has the potential to change the teaching and learning process creating a more equitable and effective educational system. Within the iMath platform resource, educators can create dynamic and interactive learning experiences that empower students to participate actively in their learning journey.

Finally, the iMath smart system – the MathE tool with the OptLearn algorithm – is expected to be completely implemented and distributed worldwide in a few months.

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Assessing Performance and Quality-of-Service in Industrial Networks in the Industry 5.0 Era

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Abstract. The advent of the Industry 5.0 era marks a transformative period in manufacturing, highlighting the importance of human-machine collaboration and real-time data processing. In this context, the reliability and performance of networking infrastructure become essential for ensuring smooth operations and optimizing productivity to its fullest extent. Industrial networks are rapidly adopting TCP/IP-based standards to meet the demands of real-time operations, particularly in Cyber-Physical Systems and Industry 5.0 environments. However, ensuring Quality-of-Service and network availability remains a challenge. This paper presents a framework for performance and availability assessment in current Industrial Networks and applications, addressing critical aspects of Quality-of-Service and network availability in Industry 5.0 environments. The framework's architecture comprises five layers, each serving distinct purposes in network management, data handling, processing, application development, and user interface. Preliminary results highlight key Quality-of-Service metrics such as latency, throughput, packet loss, and availability, providing insights into the challenges and opportunities in enhancing industrial network performance and quality of service.

Keywords: Industry 5.0 · Information Technology · Operational Networks · Quality of Service

1 Introduction

The advent of Industry 5.0 (I5.0) marks a significant shift in manufacturing, where human-machine collaboration [1] and real-time data processing redefine the future of industrial operations [2]. In this transformative landscape, the reliability and performance of networking infrastructure play a pivotal role in enabling seamless operations and ensuring the highest levels of productivity. Moreover, industrial networks are converging to TCP/IP-based standards at a fast pace while novel and disruptive application scenarios demand for higher performance while critical tasks are being performed with Collaborative Robots (Cobots) or Automated Guided Vehicles (AGVs)/Autonomous Mobile Robots (AMRs) with humans-in-the-loop. Such systems show a primary focus on optimizing infrastructure networking and communication needs to meet the demands of real-time operations of Industrial Cyber-Physical Systems (CPS) [3] and I5.0, which present operational focus on dependability, availability, cybersecurity and cyber resilience. The challenge is to develop a framework capable of addressing the critical aspects of Quality-of-Service (QoS) and network availability in I5.0 environments, by putting forward a framework for performance and availability assessment in current Industrial Networks and applications.

Following a review made in a previous work [4], QoS in the literature it's not well-defined, and most works show inconsistent use of terminology for the same metric (e.g.,

delay/latency, packet error/packet loss). Besides this, the works reviewed demonstrate a good relation with industry requirements, this is, they define metrics based on industry standards or requirements. Most of the works consider latency as one of the metrics that is important in accessing the QoS of a network or application in an industrial scenario.

2 Framework Architecture

The framework in development will consist of 5 layers, each representing a stage in the frameworks process. The first is the network management layer, responsible for the discovery, gathering of information and QoS adjuster in the network, as well as a background network metric reader. The second layer is the data layer, where all the resulting data from the first layer is stored. The third layer is the processing layer, responsible for performing the data analytics and data preparation. The fourth is the application layer, still in development, where the full stack framework will have the defining features. Finally, the fifth layer, the presentation layer, will feature the user interface bridging the user to the framework features and presenting the data. Figure 1 illustrates the layers and features. The OpenAI assistant intended use is to intelligently label new devices, and, with the metrics data, help to classify or predict the QoS of the network.

3 Preliminary Results

From the state-of-the-art, one of the most important results can be summarized with the Table 1, as it represents the obtained metrics from the works and the average values for each metric. This will later be used to define what are the minimum and maximum values in determining the QoS index (e.g., excellent, poor, normal) of the network. Also, it was identified that there is a high potential in the use of conventional wireless communications infrastructures (e.g. Wi-Fi, Bluetooth 5.0, Zigbee, etc.) typically used in Information Technology (IT) networks in an industrial context (i.e., Operational Tecnhology (OT) networks). In addition, the high availability of Industry 4.0 (I4.0) technologies on the factory floor, such as sensors/actuators, cobots, AGV/AMR, flexible digital manufacturing machines, etc., pose new challenges to the existing OT network infrastructures in these industrial scenarios.

Table 1: Quality-of-Service (QoS) metrics with description and average values [4].

QoS Metrics	**Description**	**Avg. Value**
Latency	Time it takes for a signal/packet to travel from the sender to the receiver.	<50ms
Jitter	Variation in the delay of received packets in a network.	<10 ms
Bandwidth	Maximum rate at which data can be transferred over a network.	>1000Gbit/s
Throughput	Actual amount of data that is successfully transmitted over a network in a given period.	>100Gbit/s
Overhead	Any additional data, time, or resources consumed in a system that is not directly related to the payload.	None Given
Packet Size	Amount of data that is transmitted as a single unit in a network.	24 Bytes
Packet Loss	When one or more data packets traveling from a source to a destination fail to reach their intended target.	<0.001 %
RSSI	Measurement used to quantify the strength of a received radio signal in a wireless communication system.	None Given
Priority	Assignment of importance or precedence to different tasks, processes, or data flows.	Not Applicable
Scalability	Ability to handle a growing amount of work or easily expand to accommodate a larger workload.	Not Applicable
Availability	Ability to remain operational and accessible for communication and data exchange.	>99.999%

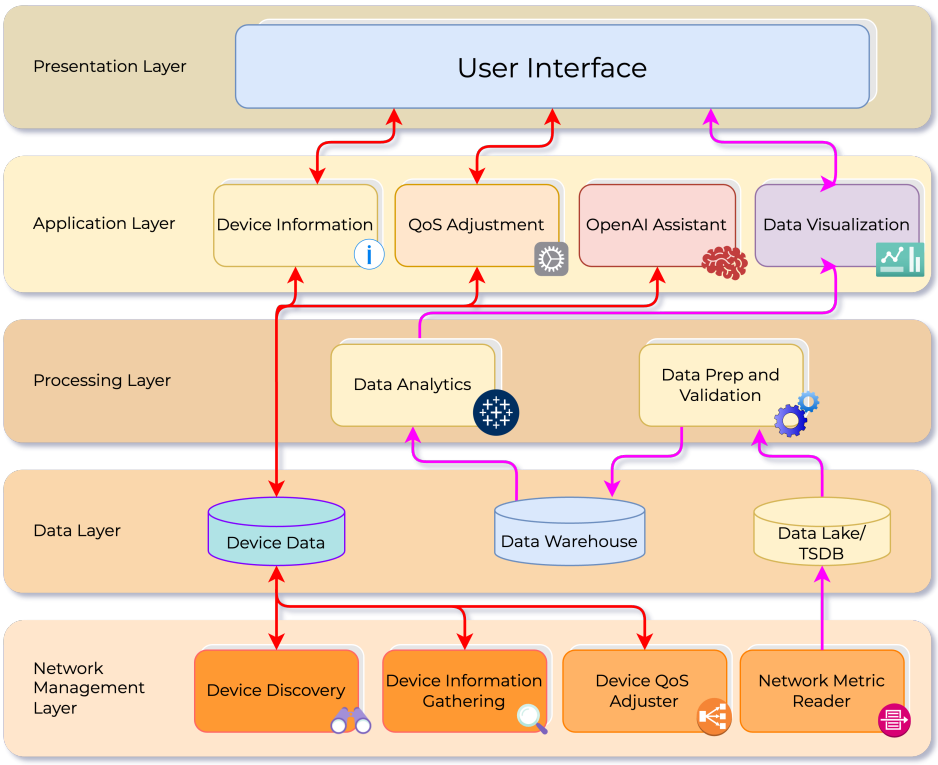

Fig. 1: Theoretical framework architecture

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Advancements in Uroflowmetry: A Systematic Review

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Abstract. This Study analyzes the current situation of lower urinary tract symptoms (LUTS) which are affecting a large number of people around the globe and are mostly affected by the aging population. Urinary incontinence, overactive bladder symptoms, voiding symptoms, and others cover a range of symptoms related to the bladder and urethra. Uroflowmetry is the most common method of diagnostics providing a complete urodynamic view of the patient.
Today, uroflowmetry data processing is conducted in a manual way that is but time-consuming and it features variations between professionals. Semi-automatic and automatic methods have been designed for this purpose even though their applicability for the diagnosis is somewhat limited due to shortage of the data and symptom overlap within various conditions. The novel schemes that can lead to better outcomes are more efficient diagnostics, have less variations and improve care of patients with LUTS.
The article describes the results of a systematic review of the literature published within the last eleven years and develops a classification of methods in accordance with the main principles they are based on. Its main contributions are about a deeper understanding of diagnostic and monitoring alternatives for LUTS, a classification process for urine flow measurements structure, and an analysis performance of the home and clinic uroflowmetry.
In summary, the study provides general knowledge regarding the most recent literature on monitoring the urine stream with the focus on the patients and the healthcare professionals in the selection of the technology for diagnosis and follow-up of LUTS.

Keywords: Uroflowmetry · Lower Urinary Tract Symptoms · Measurement · Diagnostic.

1 Introduction

According to estimates, 2.3 billion people worldwide, or 45.8% of the total population, suffered with lower urinary tract symptoms (LUTS) in 2018 [3]. This represents an 18.4% rise from 2008. Furthermore, due to the age-related nature of LUTS in both genders, an increase in its prevalence and severity is anticipated in the near future [1]. Uroflowmetry, which offers a comprehensive picture of the patient's urinary function and makes it possible to prevent intrinsic problems in a straightforward and cost-effective manner, is the most widely used method of diagnosing LUTS [2].

At the moment, uroflowmetry analyzes the data manually. This is the conventional approach, but it has a number of disadvantages, including the length of time needed to evaluate a patient and the varying viewpoints of intra- and inter-observers about the same instance. Due to these limitations, semi-automatic and automatic techniques have been developed to aid in the process; nonetheless, their utility is diminished by a deficiency of data and several lesions exhibiting identical symptoms. By lowering variability and cutting down on diagnostic time, these innovative approaches have enhanced the care and management of LUTS patients.

The methodologies used to evaluate urine flow were compiled by means of a comprehensive review of recent processes published in the literature, which is presented in this paper. The different approaches were categorized according to their theoretical underpinnings.

2 Methodology

2.1 Search strategy

The IEEE, PubMed, and Scopus databases were searched with computer assistance by the first author. The time frame for the search was January 2013–January 2024. The papers selected based on the selection criteria were carefully read and investigated, and all titles and abstracts discovered using the search terms were examined.

2.2 Selection criteria

Papers that were published before the chosen analysis date, duplicates, or not in the English language were all methodically removed. By carefully assessing the remaining papers according to their titles and abstracts, we were able to identify the ones that were pertinent to our investigation. Articles unrelated to urine flow measurement were immediately eliminated from consideration. After that, we focused only on articles that discussed data processing and urodynamic techniques. However, because they weren't compatible, larger-scale research that weren't limited to measuring pee flow were turned down.

2.3 Search results

Following a comprehensive scan of the database, a substantial corpus of 3369 papers was discovered. During the first screening stage, 2301 articles were removed for a variety of reasons, such as being written in a language other than English, duplicate content, or obsolescence. After a careful review of the abstracts, 980 more publications were not included in the final selection because they did not meet the predefined requirements, i.e., they had nothing to do with urine flow monitoring methods. This thorough screening method left us with 88 papers for in-depth full-text study. Of these subsets, only 46 were subjected to a comprehensive assessment; these 46 were the basis for our comprehensive analysis in this study.

Acknowledgment

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A personalized digital health assistant for lifelong self-care

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Abstract. Non-communicable diseases (NCDs) are the leading cause of disease burden and disability in Europe. NCDs account for 80% of the overall burden and most avoidable premature deaths. This disturbing reality is a call for action. The solution must be centered on prevention by inspiring healthier lifestyles, promoting physical activity, better nutrition, mental health awareness, and elevating overall self-knowledge. With this work, it is projected the development of an intelligent assistant that provides health expert recommendations, knowledge and promotes the execution of physical activity. Through the addition of the Large Language Model (LLM), the assistant will have an improved ability to talk with users and provide tailored recommendations. Ensuring the health journey remains not only personalized but also highly effective in reducing the risk of getting NCDs. The study suggested that the methodology implemented has the potential to be integrated into a real use case of a health assistant but more studies are required.

Keywords: Large Language Model · Chatbot · Disease Prevention · Artificial Intelligence · Public Health.

1 Introduction

Non-communicable diseases (NCDs) are diseases that are not spread through infection. There is a significant link between the number of cases of NCDs and lower levels of self-knowledge and self-care, particularly in terms of nutrition, physical activity, and good mental health practices [1]. Nowadays, a wide range of action is being taken not only by the World Health Organization but by many other stakeholders, which proves the importance of this problem [3].

The promotion of physical activity has two strategies that seem highly effective. One is self-monitoring behavior, and the other is feedback behavior [4]. That can be strengthened by using smartphone applications and wearables like smartwatches and smart bands. They reduce the burden of manually adding every single point of data, even if the person fails to enter data the application, will provide updated feedback on the physical activity performed [2].

Another way to take advantage of the feedback behavior is to display patient-reported outcomes measures (PROMS). These measures provide a easy and straightforward way to communicate with users about their health status, helping them realize how bad or how good their health status is.

2 Methodology

2.1 LLM model

The building of the LLM model begins with the literature review to identify the most suitable model for the use case. After that evaluation, the model selected was LLaMA-3

70B due to being an open model and its good performance in answering general theme questions making it a suitable model for the use case.

To aid the model in answering health questions, a Retrieval-Augmented Generation (RAG) approach was used. Where the identified health-related literature is split into small chunks and incorporated into a vector. When a user queries the assistant, the RAG system will search the vector for related chunks and provide them to the LLM model, this way providing additional context.

In Fig. 1 we can see a schematization of the steps the query takes until is processed the response.

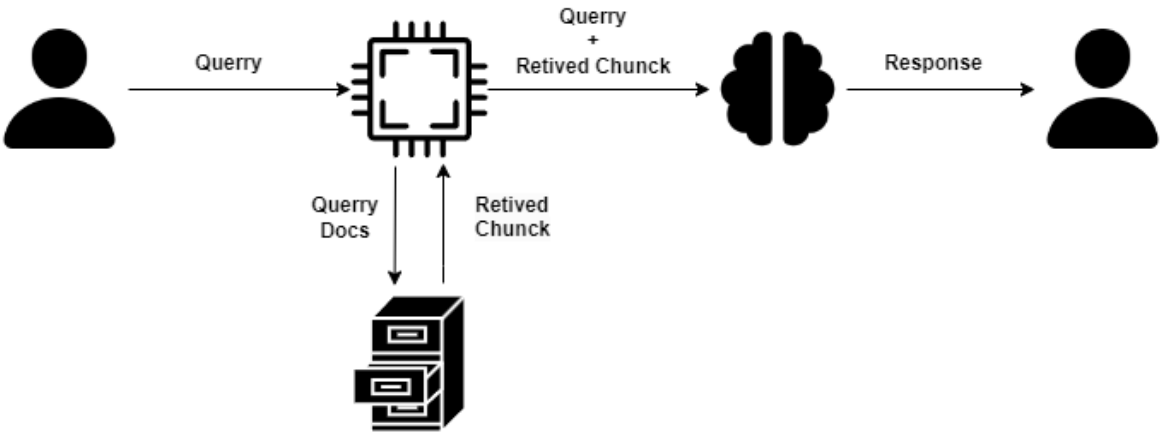

Fig. 1: An illustration of Retrieval-Augmented Generation (RAG) technique.

2.2 Mobile application

To enable user interaction with the assistant model developed, a mobile application was designed and developed using the Unity game engine. This application integrates with the API of the AI model, allowing users to submit queries and receive responses through an intuitive interface. Special care was taken to ensure the efficient handling of API calls to not overload the server.

In Fig. 2 we have a screenshot of the app developed which we can see in the center panel, the conversation history with the assistant. In the below part of the screenshot, we can see the input box and the submit button allowing the user to easily formulate and send questions to the assistant.

3 Conclusion

This study had the aim of collecting the initial performance of the system having the main focus on the feasibility of the current methodology. The system was evaluated on its ability to answer health questions, to do that a private dataset was used. This dataset is composed of 15 health questions and answers.

Fig. 2: Unity mobile applications developed.

The data suggests the assistant developed can answer the health questions with good accuracy. Also, the app developed provides an easy way to interact with the LLM model. Make it plausible that this LLM model has the potential to be integrated into the health assistant but more studies need to be done.

Acknowledgements

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Gym Mobile Personal Assistant

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Abstract. Artificial Intelligence (AI) has revolutionized the fitness industry, reshaping our mindset towards physical conditioning and well-being. Particularly in mobile applications, AI offers a range of significant benefits for fitness enthusiasts. Powerful tools such as PyTorch and TensorFlow have been essential in overcoming the challenges of implementing AI on mobile devices and simplifying integration into fitness apps. With advanced technologies like YOLOv8 and BlazePose, these apps can be further enhanced, providing a richer and more efficient user experience. This paper explores the tangible benefits of using PyTorch and TensorFlow, along with YOLOv8 and BlazePose, to develop native AI-powered fitness apps. These technologies empower developers to create smarter and more personalized mobile applications, harnessing the full potential of AI. By integrating these tools into native development environments, developers can expand the capabilities of mobile fitness apps and unlock new opportunities for innovation and differentiation in the market. Considering this, this paper considers the integration of these technologies in a future mobile application, that will be named AutoGym.

Keywords: Artificial Intelligence · Mobile Applications · Computer Vision · Fitness · Sports

1 Introduction

Machine Learning (ML) is a subset of Artificial Intelligence (AI) focused on creating systems that learn and improve from data without explicit programming [1]. Instead of following specific instructions, ML systems use algorithms to analyze data, identify patterns, and make predictions or decisions. Computer Vision (CV), a field of AI, employs ML and neural networks to teach computers to extract meaningful information from digital images, videos, and other visual inputs, and to take actions when issues are detected [3]. CV enables computers to see and understand similarly to human vision relying on cameras, data, and algorithms instead of biological components like retinas and optic nerves [4].

2 Proposed Approach

Skeleton extraction plays a crucial role in the proposed application, enabling a precise understanding of users' posture and movements during any action. This section describes the methods and techniques used for efficient skeleton extraction from images or videos. Skeleton extraction identifies and tracks key points of the human body, such as joints and limbs, from visual data. This information is essential for assessing the form and correct execution of certain actions. While commonly used to track human posture and movements in contexts like posture analysis, gesture recognition, and computer

animation, skeleton extraction is not limited to the human body [2]. Model execution software refers to programs or libraries designed to load, interpret, and execute ML models on specific devices, such as computers, mobile devices, embedded systems, and others. This software is essential for implementing ML models in production environments, where models need to run in real-time or on devices with limited computational resources. TensorFlow Lite or PyTorch Mobile are ideal solutions for running these models on mobile devices. TensorFlow Lite is an optimized version of the TensorFlow framework for mobile devices and embedded systems. They allow ML models to run on devices with limited processing resources, such as smartphones, IoT devices, and microcontrollers. Key features and advantages include size and performance optimization, support for hardware acceleration, easy integration into various platforms, and support for various ML model types. PyTorch Mobile is an extension of PyTorch that enables the execution of ML models on mobile devices, offering a flexible and easy way to implement models on smartphones and other portable devices. Direct integration with PyTorch allows models trained in PyTorch to be easily converted and run on mobile devices using PyTorch Mobile [5]. AutoGym aims to create exoskeleton detection for users to analyze body movements and activity during exercise, offering a variety of hints and a real-time classifier to indicate correct execution, along with a repetition counter, all within a single application. This proposal aims to break the paradigm of home fitness applications with real-time corrections through interactive feedback. Using advanced AI algorithms, AutoGym adapts to users' needs, individual physical capabilities, and training objectives. The application offers a more immersive experience, promoting safe and efficient exercise practice at home. Benefits include preventing injuries during exercises through real-time corrections from posture to execution. Figure 1 shows how the exoskeleton is constructed, and Figure 2 shows the graphical representation of the information collected by YoloV8 along with the frequency spectrum for the right shoulder (a), right elbow (b), right side of the hip (c) and right knee (d).

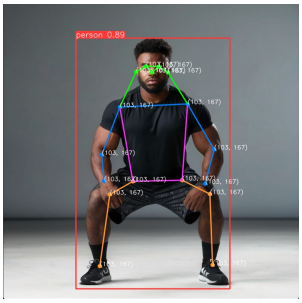
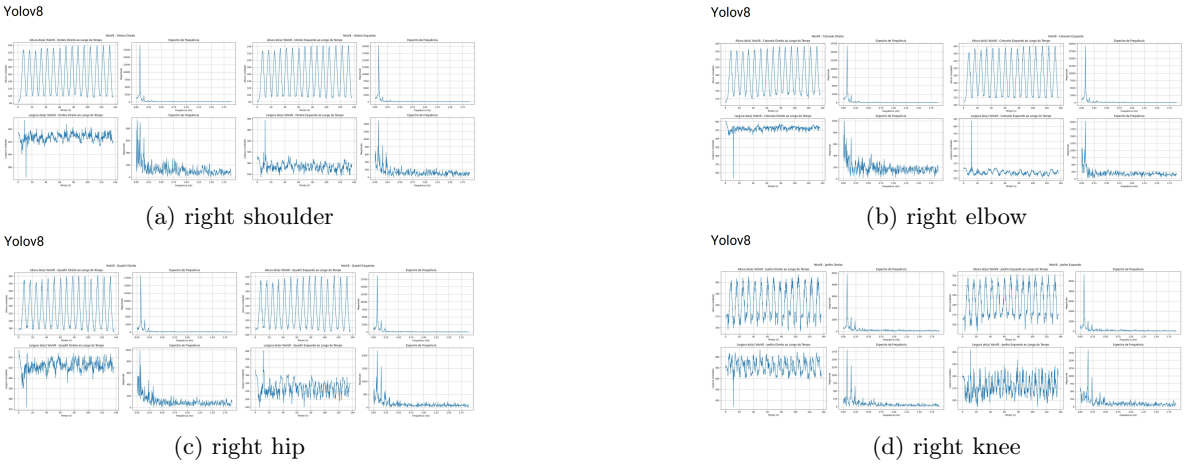


Fig. 1: Squat Frame - Data to be gathered.

3 Future Work

While discussing the evolution of AI and its application to mobile app development, this work starts by building a native Android application AutoGym, that includes fine-



(a) right shoulder

(b) right elbow

(c) right hip

(d) right knee

Fig. 2: Three simple graphs

tuning the models using thousands of data points collected by professionals and focusing on developing a mobile application to achieve the best possible detection results.

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Soccer Field Areas Segmentation with YOLO Instance Segmentation

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Abstract. Soccer video analysis is a complex field within computer vision research, involving various tasks such as player detection and tracking, player performance analysis, and team behavior analysis. A critical component of such systems is the image semantic segmentation module, which accurately delineates elements within each frame, specifically the soccer field. This segmentation module serves as a foundational processing step, enabling spatial understanding of player positioning and facilitating tasks like camera calibration for 3D tracking.
Our method directly infers the areas of the soccer field in the image, using one CNN named YOLOv8s Instance Segmentation [3].
The output produces visually convincing results and achieves a Precision of 93.6%, Recall of 92.0%, mAP50 of 94.6%, and mAP50-95 of 84.5%.

Keywords: Soccer video · Field segmentation · Field areas segmentation · YOLO Instance Segmentation · YOLOv8.

1 Methodology and Results

This paper continues our previous work on soccer pitch markings segmentation in [5] and [4].

1.1 Dataset

The dataset used is the SoccerNet Camera Calibration 2023 Dataset [1] with an image resolution of 960x540 and it consists of 26 classes, where 20 classes relate to field lines and the remaining 6 classes relate to goal posts. Each annotation consists of a point list forming a line and the points may be used to draw the ground truth masks, although the sequential order of points is not guaranteed.

1.2 Ground truth generation

We identified six area classes for segmentation: Goal, Goal area, Penalty area, Penalty arc, Centre circle, and Whole field. To generate ground truth masks for rectangular areas (Goals, Goal areas, Penalty areas, and Whole field), we determined the camera's general viewpoint (typical main camera perspective or if the image was taken from a camera positioned behind the goal, either focusing on the same side's goal posts or the opposite side's goal). Initially, we checked for the presence of two main transversal lines in the image. If these lines were annotated, we utilized them as reference lines, modeling them using the classic line equation to compute their slope (m) and intercept (b) from the point coordinates, aiding in determining the camera viewpoint.

In images with left-side annotations, we determine the camera perspective by assessing the positioning of key lines. The "left main transversal line" is identified as the closest line to the "Side line left," while the "right main transversal line" is closest to the "Middle line." We then compare the intercepts (b values) of these lines. If the intercept of the "left main transversal line" is higher, the image is from a camera behind the left goal, pointing to the left side of the pitch. Otherwise, we examine the slope (m) of the "right main transversal line." If the slope exceeds a low threshold, the image is from the main camera. Otherwise, it's from a camera behind the right goal, still focused on the left side of the pitch.

For images with annotations of the the right side, the approach is similar. However, instead of comparing intercepts (b) with the left limit of the frame, we utilize intersections of lines with the right limit of the frame.

With this understanding, we verify if the area for mask generation aligns with annotated lines. Depending on the previously predicted camera viewpoint, we then establish line intersections accordingly.

To create the ground truth masks for circular areas we simply fill the polygon defined by the points list.

1.3 Network training

We tried to find the best balance between performance metrics and processing time. For that we tested two different networks, YOLOv5s [2] and YOLOv8s [3].

The networks were trained after freezing the backbone layers on both YOLOv5 and YOLOv8 Instance Segmentation. We used the default value of batch size 16, 100 epochs and used the image resolution of 960 so that the network input size matches the largest dimension of the dataset images. We save a checkpoint with the model weights for the best validation loss value at the end of each epoch. The rest of the training hyperparameters were the default values used by both YOLOv5s and YOLOv8s Instance Segmentation.

1.4 Results

The graphics card used for training and inference is a NVIDIA RTX 3080. As Table 1 shows, the model from YOLOv5s already yields satisfying results. However, the model from YOLOv8s obtains excellent results without compromising too much the inference time of each frame. The best model has an inference time of 6.9 milliseconds, which is adequate for real-time segmentation, given that the frame rate of a soccer stream is usually 50 frames per second (20 ms/frame).

As shown in Fig. 1, the best model produces visually convincing results with accurate segmentation and high confidence levels for the detected areas.

Acknowledgments

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Table 1: Experiment results for the test set with different YOLO Instance Segmentation networks.

Model	**Box**				**Mask**				**Time(ms)**
	Prec.	Rec.	mAP50	mAP50-95	Prec.	Rec.	mAP50	mAP50-95	
YOLOv5s	0.856	0.836	0.879	0.687	0.796	0.738	0.759	0.568	5.2
YOLOv8s	0.939	0.932	0.96	0.9	0.936	0.92	0.946	0.845	6.9

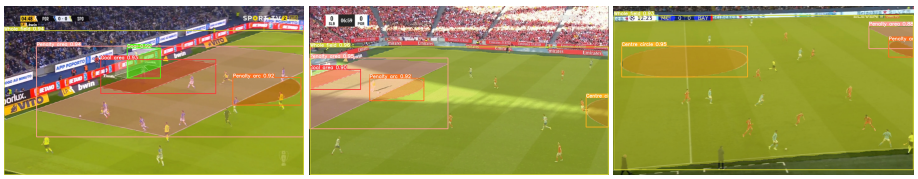

Fig. 1: Predicted images from different viewpoints with YOLOv8s Instance Segmentation.

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Simulation of Routing Systems for Multiple Autonomous Robots in Industrial Environments

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Abstract. Industrial automation is a growing trend in the world due to it's benefits in increasing efficiency of production. The same can be said of the simulations of these automation process, which greatly reduces the cost associated with trying different approaches. However there is no general framework for testing and validating different algorithms for path planning, so this work is being developed as a case study on the simulation of various routing and scheduling algorithms for multiple autonomous robots in a warehouse scenario.

Keywords: Agent Based Simulation · Path Planning · Multiple Autonomous Robots

1 Introduction and Contextualization

The implementation of automation in the industry is a growing priority, with an estimated amount of 1.1 trillion dollars being spent each year on digital factory transformation [3]. This investment occurs as the industry perceives it's benefits, as a report by the same accounting firm in 2018 [4] shows an expected increase in revenue of 2.9% and a decrease in costs of 3.6% per year due to automation.
With this high demand for automation there is also a growing demand for ways of simulating and validating these systems to avoid unnecessary costs in their implementation. Consider warehouse automation, where there is a need to optimize routes and task scheduling for multiple agents in order to move resources around in a known environment, such as the ones seen in [5] and [2]. Currently there is not a generalized way of simulating and validating these different algorithms in different scenarios, as each author builds their own tools and scenarios.
Considering the potential of this field in the industry, this work is being developed as a case study on the simulation of systems of multiple autonomous robots in a warehouse setting.

2 System Architecture and Development

The simulation model is being built as an Agent Based Model, where each actor in the system is modeled as an independent agent who perceives changes in the environment and then follows its own internal logic to execute actions upon that same environment. These actions and reactions upon a common environment for all agents results in the final simulation, where emergent behavior and unexpected effects may be observed.

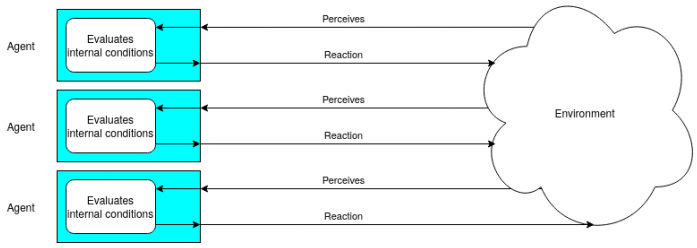

Fig. 1: Interactions on an Agent Based model

In the proposed warehouse setting we have the autonomous robots as our main agents, capable of moving around the open space and making active decisions based on local conditions. These agents are capable of collecting resources and transporting them to machines, where these resources become unavailable for a set amount of time, and after which they are released. The simulation is considered finished after all resources have been processed and placed in their final position.

To model and simulate this environment we are using the GAMA [1] Platform, as GAMA is a powerful open-source modeling and simulation tool with a focus on Agent Based Modeling. A noteworthy feature is the ability of individual agents to interact with the outside world using standard network protocols such as TCP, UDP and MQTT, among others.

3 Results

An initial model was built in the Gama platform representing a scenario where four resources must be processed one time by any machine before being dropped at their final destination. This simulation was useful to determine the software's capabilities for 3D visualization as well as the available options for modeling movement in open spaces and for conducting interactions between agents.

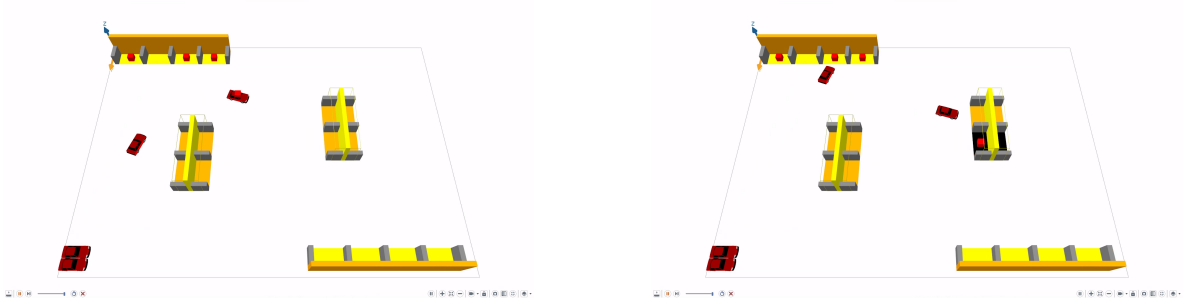

Fig. 2: Simulation showing the transportation and processing of resources

Explorations were also made with the built-in solver for ordinary differential equations by simulating the movement of differential wheeled robots, and the ability of

agents to communicate with outside programs was tested by exchanging messages between the robots inside the simulation and a python script running on the same machine through TCP packets.

4 Conclusion and Future work

In conclusion, there is space for a comparison of performance for different algorithms for path planning in warehouses and the initial simulations show that the GAMA platform can be a useful tool in it's development. Future work will involve the adjustments of physical interactions between agents to better represent real world conditions and the utilization of GAMA's network protocols to interact with the simulation during execution, as that would allow the simulation of arbitrary path planning and scheduling algorithms without embedding their logic inside the model, as well as allowing these algorithms to communicate with simulated agents using the same protocols used in real-world situations.

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Printable piezoresistive sensors based in PDLG polymer composites for urinary catheter applications

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Abstract. Nowadays there is a great demand for new and improved methods to treat chronic disseases such is the case of the Hinman syndrome or non-neurogenic bladder. The procedure normally used is the Clean intermittent procedure that involves a huge number of complications and the incorporation of small piezoresistive sensors in the urinary catheter can be seen as viable option to developed a path to avoid injuries during the procedure. Another focal point is the use of a natural polymer the Poly(D, L-lactide-co-glycolide) (PDLG) to promote a replacement of the typically used synthetic polymers, this is executed having in regard the ecological goals of the European union to promote a low carbon economy. In this context, the aim of this work was first to study a natural polymeric composite the (PDLG) with different concentration of Carbon-nanotube and implement it in the urinary catheter. In the end was developed a proof of concept where and the study of piezoresistve effect is evaluate.

Keywords: piezoresistive sensors· printing techniques· urinary catheters

1 Introduction

In today's world the incorporation of digital methods in the health sector is in a increasing rate and the Internet of Things concept is becoming more relevant. This area is described as the use of electronic devices to capture vital health information. [5] The development of smart devices that can bring direct information to the patient and that reduces the need for the direct interaction between patient and doctor are some of the main enhancements. A great number of diseases involve the constant use of a specific treatment in order to avoid future complications to the patient, such is the case of the Hinman syndrome or non-neurogenic bladder a voiding dysfunction of the bladder of neuropsychological origin, that is characterized by an absence of a neurological communication between the brain and the bladder causing an abnormal function of this one and if not treated can originate a chronic renal insufficiency. The normal procedure used is the Clean Intermittent Catheterization (CIC) to drain the urine through the placement of a urinary catheter in the urethra [2]. This method has a certain set of health complications namely urethritis or inflammation of the urethral meatus due to the constant insertion of the catheter, urethral bleeding due to trauma, strictures or

infections are some major disadvantageous. Epididymitis a genital infection is also a normal problem that can surge this is widely present in men/children's who used this method [1]. This type of evidence supports the need for an upgrade to the procedure. Piezoresistive sensors can be seen as a possible option, this is already used in different sets of biomedical applications and where studied in the specific field of urinary catheters. The principle of function is based on the quantification of the force applied when occurs a change in the electrical resistance due to an application of an external force. A proper placement of small piezoresistive sensors in the urinary catheter can be used to create a path during the procedure in order to avoid possible health complications in the patient. Aside this and having in regard the demand of the European Union for the implementation of low carbon foot print circular economy is important to study natural polymers that are biodegradable and bio compatible that are abundantly available [3]. PDLG a polymer aproved by the FDA surges as an interesting approach. That is why the aim of this study was to develop piezoresistive printable sensors of PDLG with different percentages of CNTs and elaborate a proof of concept and study the change in ohmic resistance of printed catheter sensors when an alteration of the deformation angle is executed. [4]

2 Experiments and Results

First the selected polymers of PDLG and the corresponding composites were prepared with different % 0; 0,5; 1; 2; 3 and 5 weight percentage (wt. %) of CNT by the method of solvent casting. In order to determined the most proper composite to be printed in the catheter, a proper assessment was made to determine the electrical and mechanical properties and the selected sample of 1 % was printed by spray printing technique. A proper setup was elaborated to measure the alteration of the voltage across the terminals of the piezoresistive sensors printed (which depends on the sensor‘s ohmic resistance variation). In accordance with the alteration of the angle as seen in figure 1. A study of the variation of the voltage (V) in accordance with the alteration of the angle was executed in order to evaluate the performance of the printed piezoresistive sensors as seen in fig 1. The setup was developed in order to mimic the normal procedure that a patient does when they introduced the catether in the urethra, the pathway of this one has a specific curvature. To measure with precision the angle a potentiometer was placed in the measuring model. To determine the changes in resistance produced by the piezoresistive material in voltage using the ohms law an acquisition signal plaque was developed.

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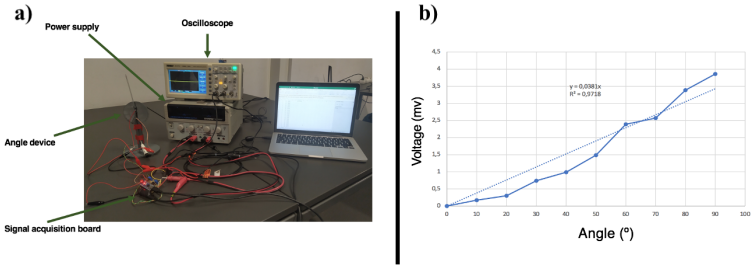

Fig. 1: - a) Scheme of the setup used for the measurement of the voltage across the printed piezoresistive sensor terminals according to the catheter deformation angles b) voltage values at piezoresistive sensor terminals printed as a function of the catheter deformation angles

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RFID Performance Evaluation in Dense Tag Environments

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Abstract. This study investigates the effectiveness of RFID technology in tracking and monitoring the palletization process when dealing with a large amount of products. The research utilized euro-pallets and two types of boxes: a smaller box containing bike pedals (15.5 × 22.5 × 24.5 cm) and a larger box with bike wheels (70 × 80 × 30 cm). Two separate tests were conducted: one during the assembly of the boxes onto the pallet, and another when the assembly process was completed and the pallet was fully loaded. The study employed four antennas, including two Zebra models (AN440 and AN510) and one Reader Fx9600. The results emphasize the importance of proper antenna placement for effective RFID tag detection and the necessity of tag validation. After validating all the tags used and associating some motion to the pallet, a 100% reading effectiveness was achieved. Future work suggests integrating a picking list to enhance efficiency and further optimize operations. This would streamline the palletization process and improve overall productivity.

Keywords: RFID · Product tracking · Data Analysis · Logistics.

1 Introduction

Ensuring accurate product tracking during palletization is crucial for optimizing logistical operations [4]. This research delves the effectiveness of RFID (Radio-Frequency Identification) systems in enhancing palletization processes in dense readings environments [2].

The study comprises two phases: monitoring pallet assembly and completed palletization. Four antennas were deployed, including two Zebra models (AN440 and AN510), and one Reader Fx9600. Materials consisted of 21 boxes (70 × 80 × 30 cm) of bike wheels and 120 boxes (15.5 × 22.5 × 24.5 cm) with 4 bike pedals each, totaling 480 RFID tags.

2 Development

This study integrated four antennas, strategically positioned at varying angles to enhance RFID tag detection efficiency [6]. The configuration, as depicted in Figure 1, involved two antennas AN440 set at a 90º angle to each other, with the remaining two antennas positioned oppositely. This arrangement aimed to ensure comprehensive coverage for optimal tag readings [4]. Moreover, human interference poses a challenge to RFID readings, necessitating the deployment of multiple antennas at diverse orientations to mitigate signal disruptions caused by human proximity. To further enhance tag detection capabilities, a rotating platform was utilized to facilitate RFID tag readings

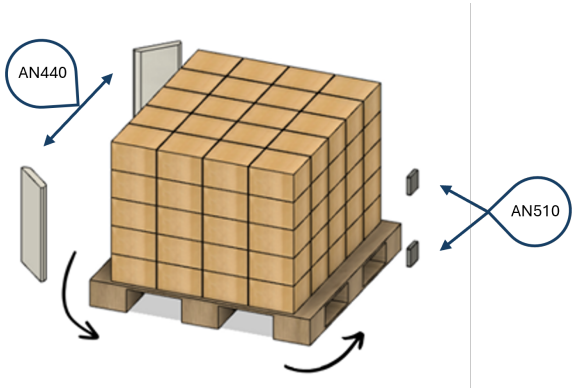

Fig. 1: 3D representation of the pallet with bike pedals boxes. In the picture its possible to see the four antenna placement as well the pallet rotation.

as the pallet rotates, offering improved detection compared to stationary conditions [5]. In the palletization process involving 480 RFID tags, it was observed that the RFID system registered 474 readings, indicating a discrepancy. Subsequently, an issue arose concerning the RFID tags, with instances of empty tags being detected. Despite their outward appearance of functionality, these tags failed to emit any detectable signals, necessitating individual tag validation to identify malfunctioning units within the inventory. The data presented in Table 1 offers a comprehensive summary of the readings obtained during the two conducted tests. Notably, following the identification and elimination of empty tags, a significant milestone was achieved: 100% reading effectiveness was realized in both test scenarios. This outcome highlights the critical role of tag validation procedures in enhancing the operational efficiency and reliability of RFID systems in palletization processes.

Table 1: Comparison of RSSI (db's) signal between test scenarios a) and b) for the two materials used in this study)

	Max	**Min**	**Mean**
Pedals a)	66	44	54,81
Pedals b)	66	52	58,57
Wheels a)	64	43	53,05
Wheels b)	66	52	58,48

Within Table 1, the delineation of "a)" corresponds to the pallet assembly process, while "b)" pertains to the pallet's readiness for shipment. The data presented in the table is expressed in decibels (dB). The data within the table illustrates RSSI (Received Signal Strength Indication) values, with an upper threshold of 80 dB. Ideally, in an optimal setting, these values would tend towards zero. Values ranging between 67 and 80 are considered poor, while those between 45 and 67 are deemed normal. Good values typically fall between 45 and below. The results highlight favorable outcomes within the specified parameters, indicating the effective performance of the antennas.

3 Discussion and Related Work

The study's focus on the effectiveness of RFID technology in tracking and monitoring palletization processes addresses significant logistical challenges. However, it's important to note that RFID data is often influenced by various factors, including the line of sight (LoS) between the reader and the tags, and the geometry of tag placement. Consequently, achieving 100% reading effectiveness is not always deterministic but rather stochastic, influenced by variables and potential noise.

Previous studies have highlighted these challenges. For instance, Pinto et al. (2023) evaluated the maximum operating distance in commercial off-the-shelf (COTS) RFID tags for smart manufacturing, emphasizing the need to understand the limitations and capabilities of RFID systems in different settings [1, 3]. This work aligns with our findings, reinforcing the importance of robust validation procedures to mitigate the inherent variability in RFID readings.

In conclusion, while our study demonstrates high reading effectiveness through practical testing and tag validation, acknowledging the stochastic nature of RFID systems is crucial. Future research should continue to explore methods to minimize variability and enhance the reliability and efficiency of RFID technology in logistical applications.

4 Conclusion and Future Work

The findings of this study demonstrate the efficacy of the RFID system in very dense reading environments. The data presented in Table 1 illustrates the RSSI values obtained during the pallet assembly and shipping processes. The results indicate that the system performed effectively within the specified parameters, with RSSI values ranging from 45 to less, indicating good signal strength. The study's outcomes underscore the importance of meticulous tag validation procedures in optimizing the operational efficiency and reliability of RFID systems within palletization processes. The findings also highlight the potential benefits of integrating RFID technology in palletization operations, including improved inventory management and logistical efficiency.

Acknowledgments

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Conditioned Play Audiometry - A mobile implementation

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Abstract. This paper presents an appealing mobile implementation of the Conditioned Play Audiometry (CPA). The objective of the application is to minimize the stress associated with hearing assessment among young patients (2-5 years) to be able to perform the exam and achieve the expected results in a more comfortable way. The application features a simple and straightforward UI and presents a report at the end. The application is currently in alpha testing, with beta testing scheduled to begin at the end of Q3 2024.

Keywords: Audiometry · Gamification · Hearing loss · Healthcare

1 Introduction

The pure-tone audiometry exam is an important auditory diagnostic test, as it allows the examiner to determine the patient's hearing threshold by comparing the results with standard values. The threshold at each frequency is determined by the minimum level of intensity required to be heard at least 50% of the time [1]. In Portugal, there is no specific legislation establishing a standard to be followed when performing the test, only professional regulations [2]. That's why widely used guidelines, such as the American Speech-Language-Hearing Association - ASHA guidelines, end up being adopted in Portugal.

Diagnosing hearing loss in children can sometimes be difficult, either because they can't concentrate for long periods on a particular task or because their cognitive development doesn't yet allow them to perform the test as expected. However, there are some adaptations of traditional audiometry that can be used with children in such cases. These include observing their behavior to a sound or using games to condition them to respond [4].

In the case of Conditioned Play Audiometry (CPA), which is mostly used with children aged 2 to 5 years, a simple game is used to elicit a yes/no response from the child for each sound presented. It's only possible to use just four frequencies (500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) in order to maximize the child's attention span, with the intensity going up to 20dB, which is already considered normal [3, 5].

To the best of our knowledge, there is not an available mobile adaptation of the CPA that follows the ASHA guidelines. Therefore, the main objective of this project is to present a more attractive adaptation of the exam that can hold the attention of the younger public while minimizing the stress associated with hearing assessment.

2 Materials and methods

The development of this application consisted of the following steps: 1. Strategy; 2. Analysis and planning; 3. UI/UX design; 4. Application development; 5. Testing. The first step was to identify the problem and review the solutions already available on the market. In the second step, the objectives and goals were defined. The third step involved creating a series of interactive mockups to evaluate the concepts and identify the necessary UI/UX adjustments. In the fourth step, the solution was implemented using the Unity game engine. In the fifth and current step, usability and functionality tests are being carried out with volunteers from our research center to correct bugs and improve the UI/UX. Later, still in the fifth step, external tests will be carried out. A certified audiologist was integrated into our team and was consulted through all the steps of the development.

This game aims to assess, in a playful and attractive way, the ability to hear sounds of different intensities and frequencies. Four frequencies are used: 500Hz, 1000Hz, 2000Hz, and 4000Hz, each with two sound intensities, 20dB and 30dB, resulting in 8 sound variations.

The gameplay is divided into two levels, one for each ear assessment. Each level presents 12 clickable objects, from which 8 emit a short beep with the aforementioned specifications and 4 were included without any linked sound, in order to detect whether the user was answering randomly. After clicking an object, a prompt is presented and the user should either choose if the sound was heard or not. At the end of the game, after completing the second level, an overall score varying from zero to three stars is shown and a more detailed report can be accessed with the data of each level/ear. We opted to not put any kind of timer in this game to keep the user focused on the task and not rush.

To reach a wider target audience, the game is being developed for iOS and Android devices and it will be available in English, Portuguese, Spanish, and French. This application is being developed as a part of a bigger project that encompasses a series of minigames related to the healthcare of the auditory system, thus it will be available in that particular context. At the time of submission of this paper, alpha testing is being conducted.

3 Conclusion

This paper presented the development lifecycle of a gamified version of audiometry aimed at young children ranging from 2 to 5 years old. This project aims to improve the experience for the children while retaining the original characteristics of the audiometry exam. The Audiometry exam can be an important tool in the assessment of hearing but can be challenging due to short attention spans or insufficient cognitive development. By adapting this exam to make it more attractive for children, we aim to minimize the stress associated with hearing assessment and encourage more active and accurate participation from them.

One point that could be seen as a limitation of this game is actually inherited from the traditional audiometry exam, namely the requirement for phones to properly evaluate

each ear. The UI/UX design of the application has been kept as simple as possible so that it can be easily adapted for more intensive assessments (if required).

The application is currently in alpha testing, with beta testing scheduled to begin at the end of Q3 2024.

Acknowledgements

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A Cybersecurity Framework for IoT-enabled Smart Environments

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Abstract. As the Internet of Things (IoT) expands, smart environments are becoming integral parts of our daily lives, offering unprecedented levels of connectivity and convenience. However, these benefits also bring significant cybersecurity challenges. This research intends to address the many aspects of cybersecurity challenges inherent in IoT ecosystems through a systematic methodology. This approach involves a literature overview, framework development, use case analysis, threat assessment, vulnerability exploration, and the definition of risk mitigation strategies. The preliminary findings highlight the importance of cybersecurity frameworks that can adapt to the shifting threat landscape while also combining principles of user-centric design, operational efficiency, and collaborative policymaking. Moreover, the exploration of cutting-edge technologies like artificial intelligence (AI), blockchain, and edge computing demonstrates promising paths for reinforcing security measures within IoT environments.This approach underscores the critical importance of proactive measures, interdisciplinary teamwork, and ongoing technological advancements in fortifying the strength and durability of IoT-enabled smart environments against a variety of cyber threats.

Keywords: cybersecurity framework · Internet-of-Things · IoT · vulnerabilities · smart environments · cyber-physical systems · CPS.

1 Introduction

The integration of Internet-of-Things (IoT) devices into our everyday environments, from homes and offices to factories and cities, is rapidly transforming the way we interact with and manage our surroundings. Imagine living in a home where your lights, thermostat, and security system are all connected and can be controlled remotely through your smartphone. Or picture a factory where machines communicate with each other to optimize production processes and minimize downtime. These scenarios represent just a glimpse of the potential of IoT technology in creating smart environments. However, with this increased connectivity comes a significant challenge: cybersecurity. As the web of interconnected devices expands, it inevitably amplifies vulnerabilities to cyber threats such as unauthorized access, data breaches, and malicious attacks. Ensuring the security and integrity of these interconnected systems is crucial to reaping the benefits of IoT technology while mitigating potential risks.

Recent research in cybersecurity for IoT-enabled smart environments underscores the pressing need for multifaceted approaches to address the evolving challenges in securing interconnected systems. Researchers advocate for Industry 4.0-compatible cybersecurity frameworks, integrating standardized protocols while carefully balancing security and functionality [1], emphasizing human-centric design [2]. Insights range from threat

identification in large-scale IIoT systems [1,3] to Edge-AI/Edge-ML threat detection [4]. Continuous monitoring and clarifying ownership processes are crucial to streamline security protocols [5]. Regulatory frameworks evolve for compliance and cybersecurity alignment [6]. Raising awareness focuses on user-centric design through intuitive dashboards [2], promoting cybersecurity literacy, and role-based visualizations to empower users with knowledge and skills essential for navigating the evolving landscape of smart environments cybersecurity, as discussed by Jesus et al. [5]. This synthesis highlights the necessity for comprehensive frameworks, proactive threat detection, and user-centric awareness initiatives to effectively address the evolving challenges within IoT-enabled smart environments.

2 Research & Development Methodology

The selected methodology uses a systematic approach to address cybersecurity challenges in IoT-enabled smart environments [1–6], as shown in Figure 1.

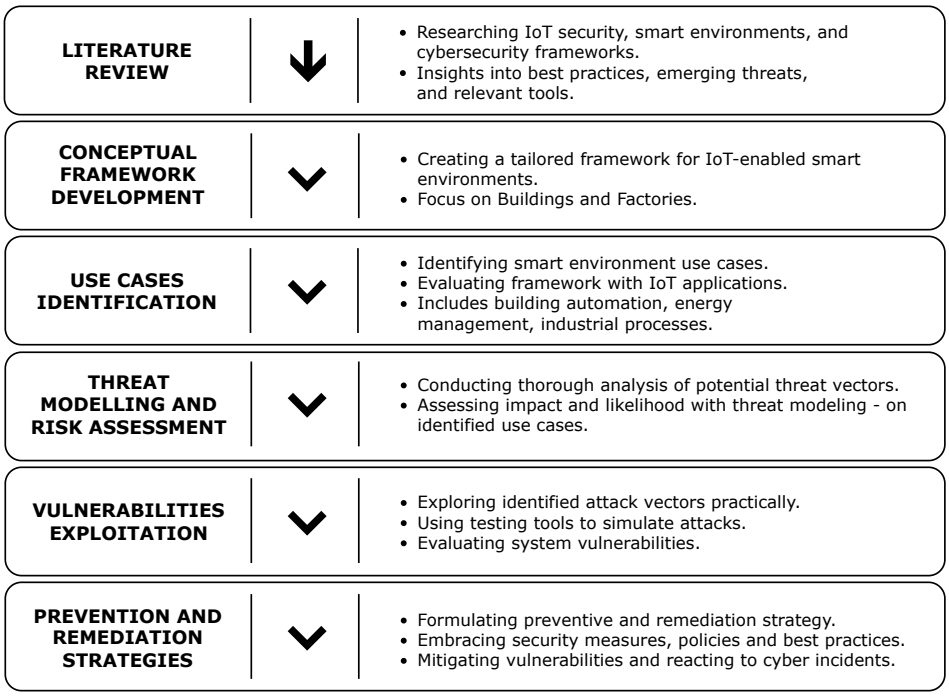

Fig. 1: Research and Development Methodology.

3 Preliminary Results

Insights from literature shape an initial cybersecurity framework roadmap for smart environments, as shown in Figure 2. Through detailed analysis, relevant contributions were grouped into four phases, systematically addressing diverse cybersecurity aspects. The initial phase refines understanding of cybersecurity risks. Subsequent phases prioritize tailored solutions, promote holistic cybersecurity measures, and encourage exploration of innovative technologies. This approach aims to dynamically address evolving cybersecurity challenges while promoting innovation and collaboration within IoT ecosystems. In sum, preliminary results emphasize proactive cybersecurity measures, interdisciplinary collaboration, and technological innovation to safeguard IoT-enabled smart environments against cyber threats, requiring continued R&D efforts.

Fig. 2: Cybersecurity Framework Roadmap for IoT-Enabled Smart Environments.

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A Deep Learning Strategy for LAA Device Sizing in 2D TEE

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Abstract. Occluding the Left Atrial Appendage with percutaneous devices is now a standard clinical practice for patients with non-valvular atrial fibrillation to reduce the risk of stroke. These devices have pre-defined models in terms of size and require therefore, during the intervention, extraction of specific measurements of the LAA. Manual device sizing is the standard practice, however semi-automatic methods have also been explored for 3D medical images. Recently, the authors have researched the potential of deep learning methods to automatically segment the LAA in 2D transesophageal echocardiographic (TEE) images. In this study, a pipeline to extract the clinical measurements is described. A total of 6 different input methodologies were studied, 4 of them individually and the remaining 2 combinations of the above. Three metrics were used to evaluate the performance of each methodology: the first was the angulation between the Ground Truth and the Predict, the second was the distance between the midpoint of each line, and the last was the difference in the length of each line. The results showed a reasonable performance from all the methodologies. The results showed the promising performance of artificial intelligent models to automatically process 2D TEE images during the LAA closure intervention.

Keywords: Left Atrial Appendage Closure · Deep Learning · 2D Transesophageal Echocardiographic.

1 Introduction

The Left Atrial Appendage (LAA) is a small structure attached to the left atrium (LA). It is now known that the LAA is the source of thromboembolism in around 90% of patients with non-valvular atrial fibrillation (NVAF). Percutaneous occlusion of the LAA, in which a percutaneous device is placed in the communication between the LA and the LAA, blocking blood flow, is a permanent surgical option to reduce the risk of stroke in patients with NVAF and a contraindication to oral anticoagulant therapy. The device must be sized to ensure a perfect fit, which requires pre-analysis through medical imaging [3]. Currently, all the extraction and analysis of the respective indices are carried out manually, and some studies have tried to compare different medical imaging modalities and see which gives the best results for evaluating the measurements. Concerning the two most widely used methods for surveying clinical indices, 2D-TEE and 3D-TEE, Goebel et al. [2], showed that 3D-TEE is not only more accurate but also more reliable for evaluating clinical indices than 2D TEE. Different methods have been explored, including the use of 3D printing to take measurements of the anatomy of the LAA [5]. A semi-automatic method was explored by Morais et al. [4], who created a methodology in which 3D-TEE images were used to predict the clinical indices relevant to the respective sizing. However, to the author's best knowledge, no relevant work using the most common imaging modality for LAAC, i.e. 2D-TEE, was explored. In particular, we are studying the potential of deep learning methods to automatically enhance the 2D boundaries of the LAA and estimate the relevant measurements. Previous studies already addressed the boundary extraction stage. Concerning the device sizing, in this work, we study the possibility of extracting the landing zone from 2D TEE images.

2 Methods

Fig.1 shows the entire methodology adopted in the study. In summary, starting from automatic labels obtained through our previous contribution [1], a second deep learning model in is used to estimate the most relevant clinical metric for LAA occlusion, i.e. the landing zone, which is clinically represented as a line in a specific anatomical position into the LAA. To obtain optimal performance, we created several databases with different inputs, where specific features are enhanced to facilitate the clinical metric extraction. nn-Unet arthitecture was used as a reference training model, having as central task the extraction of the landing zone line from a set of image inputs.

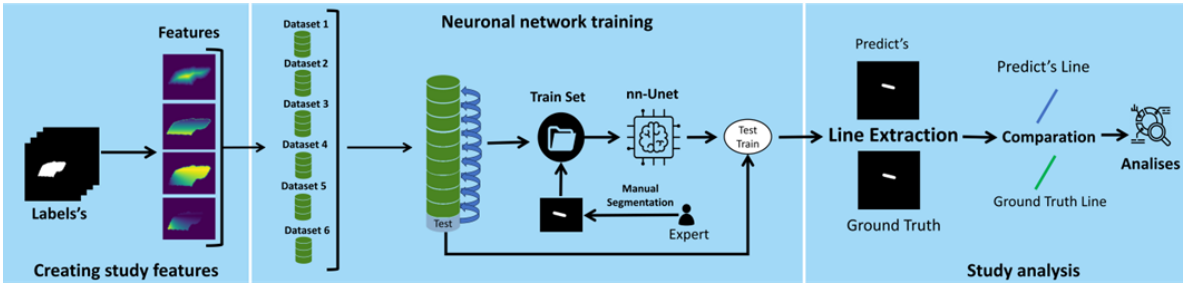

Fig. 1: Graphical summary of the methodology study.

3 Results

Once all the respective training sessions had been carried out, we submitted test images corresponding to each trained neural network and assessed the performance of the predicted LZ lines. In our analysis, two independent studies were realized. One where perfect LAA contours are assumed, i.e. manual contours delineated by one expert (henceforward designated as Manual), and a second were automatic contours are used. Concerning the manual dataset, tests carried out regarding the combination of characteristics 1,2,3, reported an average error in terms of angle was 12.43^{o}, with an average distance of 4.74 mm from the midpoint and, finally, 2.1mm difference in length and distance between lines. As far as the automatic dataset is concerned, the results are slightly different. In terms of angular error, it presented the smallest error of 9.82^{o}. The other metrics perform better, with 3.43 mm and 1.34mm error in the midpoint and distance from the line, respectively.

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