SASYR Symposium of Applied Science for Young Researchers

2nd Symposium of Applied Science for Young Researchers

BOOK OF ABSTRACTS 2022

June 22 , 2022

2nd Symposium of Applied Science for Young Researchers

Book of Abstracts

SASYR 2022

22 June 2022

IPCA INSTITUTO POLITÉCNICO DO CÁVADO E DO AVE

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Instituto Politécnico de Bragança — 2022
Campus de Santa Apolónia
5300-253 Bragança - Portugal
ISBN: 978-972-745-306-1

Book cover: Natália Santos, Instituto Politécnico do Cávado e do Ave

Welcome

This is the book of abstracts of the 2nd 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 centres: 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 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 2022 took place in a hybrid environment at Escola Superior de Tecnologia e Gestão of Instituto Politécnico de Viana do Castelo on the 22nd of June, 2022.

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ECG Classification with Deep Learning Models – A Comparative Study

Luís C. N. Barbosa[1], António Real[1], António H. J. Moreira[1], Vítor Carvalho[1], João L. Vilaça[1], and Pedro Morais[1]

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Abstract

The electrocardiogram (ECG) is the most common cardiological procedure to monitor non-invasively the electrical activity of the heart. It is a complex and non-linear signal, which is the first option to preliminary identify specific pathologies/conditions (e.g. arrhythmias) [3] . However, its processing is frequently performed manually, making it operator dependent. A multitude of algorithms to automatically process the ECG were presented [4]. Recently, Artificial Intelligence (AI), namely deep learning models, were proposed, showing state-of-the-art results. However, these models are frequently trained/tested in one specific database, not evaluating its result in other sources, as expected in the clinical practice [1] [2].

In this paper, we intend to study the robustness of the already described deep learning (DL) methods to the variation of data source. Moreover, we intend to evaluate the performance of these methods to classify different classes of pathologies. Three public databases of ECG signals were chosen, namely: MIT-BIH Arrhythmia Database (D1), European ST-T Database (D2), PTB Diagnostic ECG Database (D3). Three methods were considered for this study, namely: Convolutional Neural Network 1D paired with a Multilayer Perceptron (CNN 1D+MLP), Dense Model, Convolutional Neural Network 1D (CNN 1D). The performance of the selected methods in terms of classification metrics, such as accuracy, precision, recall, f1-score, and confusion matrix was assessed. The Fig. 1 shows some illustrative examples of the method's performance.

Overall, only the CNN 1D+MLP architecture demonstrated high robustness to the variation of the data accuracy, with similar accuracy to the databases D1 and D2. The remaining methods achieved unsatisfactory results when changing the database. No method was considered successful to the D3. As a conclusion, further studies to really evaluate the performance of state-of-the-art AI networks in real clinical situations are required.

Keywords: Deep Learning Methods · ECG Classification · ECG Databases

Acknowledgment

This work was funded by projects NORTE-01–0145-FEDER-000045 and NORTE-01-0247-FEDER-070200, supported by Northern Portugal Regional Operational Programme

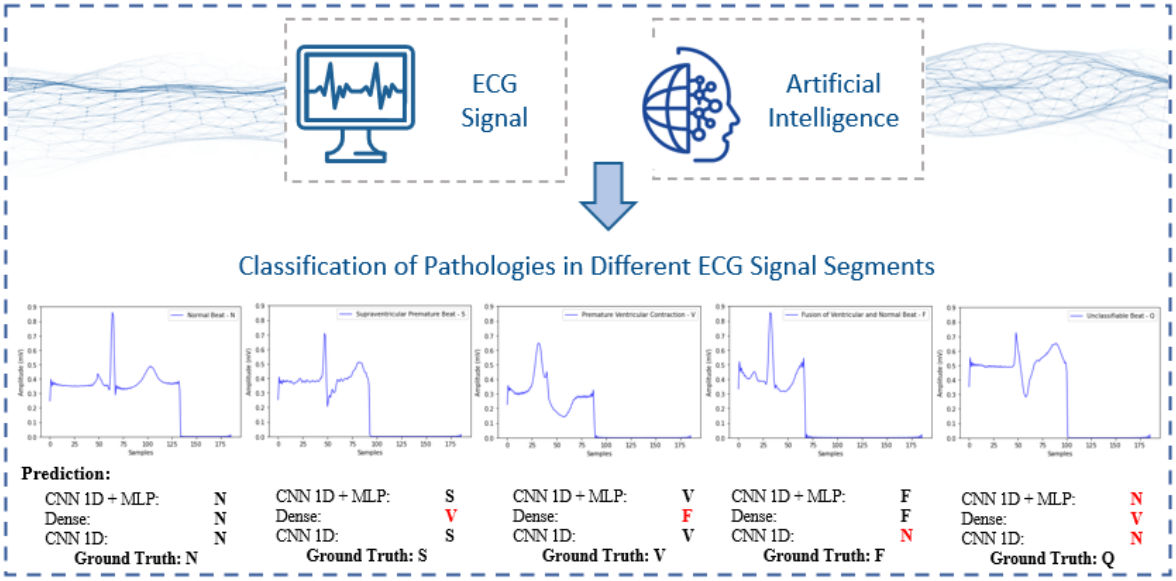

Fig. 1. Project Overview, containing examples of classification of different ECG signal segments by the three IA classifiers. (N - Normal Beat; S - Supraventricular Premature Beat; V - Premature Ventricular Contraction; F - Fusion of Ventricular and Normal Beat; Q - Unclassifiable Beat.)

Norte2020, under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER).It was also funded by national funds, through the FCT - Fundação para a Ciência e a Tecnologia (FCT) and FCT/MCTES in the scope of the projects UIDB/05549/2020, and UIDP/05549/2020 and LASI-LA/P/0104/2020.

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MCSFilter Performance: a Comparison Study

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Abstract

Optimization, together with process modelling and simulation, plays an important role in the industrial context because it is capable of generating considerable income or savings for the company.

The quality of an optimization algorithm and implementation is defined by its ability to determine an acceptable optimal solution and the time to reach this solution.

The algorithm used in this work is the MCSFilter [4,5]. This method is a multilocal method able to obtain local and global minimizers of a certain problem. The method does not use derivatives in this process and employs a multistart strategy coupled with a local coordinate search filter method to treat the constraints – simple bounds and/or general constraints. The MCSFilter method is a derivative-free method that can be used to deal with problems that involve discontinuous or non-differentiable functions.This kind of problems can formally be written as this:

$$\min_{x \in \Omega} f(x) \tag{1}$$

where the feasible region is given by:

$\Omega = \{x \in \mathbb{R}^n : l \leq x \leq u\,,\ g_i(x) \leq 0, i = 1, \cdots, k\}$ where l and u are, respectively, the lower and the upper bounds and g_i are the constraint functions.

These problems arise in many real situations, such as processes systems engineering, design and control, robotics, among other [6–8].

The initial implementation of MCSFilter in MATLAB has proved to be effective in applications whose details may be found elsewhere [1,2,7]. For more details about the algorithm, please see [4].

Further improvements included the implementation of the algorithm in C that resulted in a significant speedup compared with the original MATLAB implementation and the JAVA implementation [3] .

In this work, a new improved implementation in C was developed, using the previous JAVA code as reference. The objective is to compare the time needed by both implementations in C. A set of well-known problems were used to test and compare both implementations. These problems can be found in [4], respectively, from A1 to A18, and

they have different features: they are nonlinear problems, with simple bounds, with different dimensions (from 2 to 10), and a different number of solutions – some of them are local minimizers and other global minimizers.

Table 1 shows the results using this set of problems and were obtained in a Linux virtual machine (Ubuntu 20.04 64 bits, kernel 5.13) hosted in the CeDRI cluster, with 16 virtual CPU- cores assigned from an Intel Xeon W-2195 CPU, and 16 GB of RAM. The code was compiled using gcc (version 9.4.0) with the -O2 optimization level.

Regarding the stopping conditions, the following parameters were adopted for the execution of all problems: $\alpha_{min} = 10^{-5}$ for the local coordinate search filter and $\epsilon = 10^{-2}$ for the multistart part.

In Table 1, the first column identifies the problem, $Prob$, the second shows the known number of minimizers in the literature, min_{lit}. The third and the fourth columns display average values (from 100 executions for each problem) using the first implementation in C, $imp(1)$, related to the number of obtained minimizers, min_{avg}, and the execution time needed, t_{avg}, respectively. The next two columns show the same values, but now to the second implementation, $imp(2)$. Finally, the last column displays the speedup between both implementations given by $S = \frac{t_{avg}^{imp(1)}}{t_{avg}^{imp(2)}}$, being $t_{avg}^{imp(1)}$ the values in column four and $t_{avg}^{imp(2)}$ the values in column 6, for each problem.

Table 1. Results obtained from both implementations in C.

$Prob$ [4]	min_{lit} [4]	min_{avg} $imp(1)$	$t_{avg}(s)$ $imp(1)$	min_{avg} $imp(2)$	$t_{avg}(s)$ $imp(2)$	Speedup
A1	3	2,70	0,00126	2,96	0,00019	6,55
A2	6	4,60	0,00142	5,64	0,00019	7,42
A3	4	2,94	0,00311	3,49	0,00057	5,42
A9	760	20,03	0,00633	26,17	0,00295	2,15
A10	3	1,93	0,00095	2,21	0,00015	6,41
A11	4	3,85	0,00181	4,00	0,00033	5,55
A12	4	3,85	0,00169	4,00	0,00017	10,05
A13	8	7,50	0,00464	7,94	0,00041	11,24
A14	16	14,82	0,01239	15,91	0,00124	10,01
A15	32	29,46	0,03335	31,67	0,00359	9,29
A16	64	57,97	0,08533	63,13	0,01011	8,44
A17	256	225,53	0,54340	251,87	0,07396	7,35
A18	1024	884,00	3,21691	1002,53	0,47127	6,83

As it is possible to observe, the second implementation finds more minimizers than the first implementation in C. The new MCSFilter implementation in C is faster than the first one in C. Moreover, observing the last column, it is possible to reach the same conclusion since the speedup between both implementations for this set of problems varies between 2 and 11.

The improvements and the code optimization performed in this new implementation were successful, given the obtained results and its comparison to the old ones.

At this moment, the second implementation in C appears to be better than the first. Considering some characteristics of this method, namely the multistart part, the next

step (already under development) is to adapt the second MCSFilter code and develop a new parallel version. It will also be essential to enlarge the set of problems and use larger dimension problems to test the parallel version. It is expected that the parallel version overcomes the sequential version for larger dimension problems by far.

Keywords: MCSFilter method · Optimization · C language.

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Deep Learning Networks for Lesion Segmentation in Breast Ultrasound: A Comparative Analysis

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Abstract

Breast cancer is the most prevalent cancer among women and one of the leading causes of death worldwide [9]. In 2020, there were nearly 2.3 million new diagnosed cases and 685,000 deaths from breast cancer [9]. Although automatic lesion segmentation in breast ultrasound (BUS) images aids in the breast cancer diagnosis, this task presents various challenges, such as speckle noise, artifacts, shadows, and lesion variability in size and shape [8]. Recently, convolutional neural networks have demonstrated impressive results in medical image segmentation. However, the lack of public benchmarks and a standardized evaluation method hampers the performance comparison of the networks [9].

This work presents a benchmark of seven state-of-the-art methods for automatic breast lesion segmentation. The methods were evaluated on a multi-center BUS dataset composed of three public datasets. Specifically, the U-Net [8], Dynamic U-Net (DynUNet) [3], Semantic Segmentation Deep Residual Network with Variational Autoencoder (SegResNetVAE) [4], U-Net Transformers (UNETR) [4], Residual Feedback Network (RF-Net) [10], Multiscale Dual Attention-Based Network (MDA-Net) [5], and Global Guidance Network (GG-Net) [8] architectures were evaluated. The training was performed with a combination of the cross-entropy and Dice loss functions, and the overall performance of the networks was assessed using the Dice coefficient (DC), Jaccard index (JI), accuracy (Acc), recall (Rec), specificity (Spe), and precision (Pre). In addition, a new metric, "bad contours" (BC), is used to compute the percentage of cases that were unsuccessfully segmented based on the number of images with a JI inferior to 25%.

Table 1 summarizes the mean values of the calculated metrics for each network using the complete test set. Despite all networks having obtained Dice scores superior to 75%, the GG-Net and SegResNetVAE architectures outperform the remaining methods, achieving 82.56% and 81.90%, respectively. In addition, a second experiment was performed, where the unsuccessfully segmented cases were excluded from the test set. The six metrics computed in this experiment are presented in Table 2. The performances increased significantly, with GG-Net delivering the best results. Overall, the results corroborate the added value of deep learning strategies for BUS lesion segmentation and, ultimately, for breast cancer diagnosis.

Keywords: Breast Cancer · Ultrasound · Deep Learning · Lesion Segmentation.

Table 1. Quantitative comparison of the different methods.

Networks	Evaluation Metrics						
	DC	**JI**	**Acc**	**Rec**	**Spe**	**Pre**	**BC**
U-Net	76.9± 24.0	67.3± 25.6	96.7± 5.4	77.4± 25.5	97.8± 5.1	82.0± 23.1	8.2
UNETR	78.4± 25.0	69.7± 25.9	96.6± 5.7	79.4± 26.7	97.8± 5.1	81.7± 24.3	10.6
DynUNet	81.9± 23.4	74.1± 24.7	97.2± 5.0	83.5± 24.6	98.2± 4.6	83.5± 22.8	8.2
SegResNetVAE	81.9± 20.1	73.0± 22.1	**97.3± 4.4**	**84.6± 20.6**	98.1± 4.3	83.9± 21.1	**5.9**
RF-Net	76.2± 25.3	66.8± 26.4	96.4± 6.1	82.6± 32.2	96.4± 6.3	63.3± 33.7	22.4
MDA-Net	82.0± 23.0	74.0± 23.6	97.2± 5.1	83.9± 22.7	98.4± 4.4	84.8± 22.4	7.1
GG-Net	**82.6± 23.3**	**75.0± 24.1**	97.3± 5.4	83.6± 24.2	**98.4± 4.6**	**85.3± 21.9**	7.1

Table 2. Quantitative comparison of the different methods, excluding the unsuccessfully segmented cases.

Networks	Evaluation Metrics					
	DC	**JI**	**Acc**	**Rec**	**Spe**	**Pre**
U-Net	82.0± 15.7	72.0± 19.6	97.7± 3.5	81.4± 19.4	98.5± 3.3	86.5± 13.9
UNETR	83.5± 17.02	74.5± 19.7	97.6± 4.0	83.7± 20.2	98.6± 3.4	86.1± 16.2
DynUNet	87.0± 13.9	79.1± 17.1	98.3± 3.0	88.1± 15.9	98.9± 2.8	87.9± 13.9
SegResNetVAE	86.4± 11.0	77.5± 14.9	98.2± 2.8	87.6± 14.2	98.7± 3.0	87.9± 12.5
RF-Net	77.6± 23.8	68.1± 25.3	97.1± 5.0	88.1± 25.3	97.1± 5.3	67.4± 30.8
MDA-Net	87.7± 10.3	79.3± 14.0	98.3± 2.6	87.9± 14.1	99.2± 1.5	89.8± 10.1
GG-Net	**88.3± 10.8**	**80.3± 14.4**	**98.4± 3.0**	**88.8± 14.8**	**99.2± 2.1**	**90.1± 9.3**

Acknowledgement

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020. The authors also acknowledge FCT, Portugal and the European Social Fund, European Union, for funding support through the "Programa Operacional Capital Humano" (POCH) in the scope of the PhD grants SFRH/BD/136721/2018 (B. Oliveira) and SFRH/BD/136670 (H. Torres).

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Inclusive Mobility through Multi-Path Routing Algorithm

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Abstract

Urban orientation is intrinsically linked to mobility and it refers to the ability of a citizen to know at every moment exactly where he is, whether or not he knows the city, and to be able to get directions to a desired location [3]. Permanent or temporary mobility disabilities includes several types of segments such as visually impaired people, wheelchair users, people with autism spectrum disorder, deaf people, pregnant ladies, elder or people with toddlers. For each of these segments, the concerns and precautions to take during a route are quite different. For visually impaired people, the lack or total absence of vision makes them less aware of what is happening around them. Adding the fact that they have limited or no access to positioning information using vision, all information given to them must be as precise as possible. Based on previous studies, people belonging to this segment should not be redirected to routes where emergency vehicles exist. On the other hand, when referring to people using a wheelchair, the main concerns are related with the type of surfaces on which they move and also the slope. In these cases, the preferred surfaces for mobility must be uniform, firm and smooth while generating adequate friction for a comfortable and stable ride [4]. In turn, when talking about people with autism spectrum disorder the main concerns are related to the bustle of the streets and here there is a need to avoid these types of places during a route.

In a previous work [5], a mobile application named Viana+Acessível was developed in order to help people with some type of disability to walk around the city using the most suitable route provided by the application. It was built to work specifically in the city of Viana do Castelo, in Portugal, where the streets of the historic center of the city were classified in a Geographic Information System (GIS) by the City Council together with the institutions that represent each one of the segments. In addition to the GIS, the A-Star algorithm was used to suggest the best path to the user. When starting the application, the user can choose one segment and then, all suggestions made by the app will take into account the chosen disability. After choosing the segment, the user can choose to show the points of interest of the city on a GIS map of Viana do Castelo, divided into five categories: culture, health, public services, transport or tourism. In addition, the user can also check parking spaces for people with disabilities and all taxi locations. For each of these locations, he can obtain specific information by clicking on the desired point or start navigating towards the chosen destination. The application, developed in React Native, is available for devices which runs an Android operation system or an Apple operation system. The initial version of the app allows users to

select a point of interest as intended destination whereas the starting location is always the user's current location.

The main contribution of this work is an extension of the initial work with a multi-path routing algorithm, considering that allowing the choice of a single destination might be limited in several scenarios. By this way, this work focuses on the possibility of the user to select several destinations and to obtain the most suitable route that goes through all of them. Some changes were needed regarding the app layouts. In addition, several algorithms are used and tested to understand which one has a better performance in this situation.

The first algorithm tested was the Genetic Algorithm which is a search heuristic that is inspired by Charles Darwin's theory of natural evolution.

The second algorithm tested was the Simulated Annealing Algorithm with linear and exponential approaches and is characterized by being a stochastic global search optimization algorithm.

To evaluate the performance of each algorithm, 100 runs were performed for 2, 4, 8, and 16 destinations. It means that for both Genetic Algorithm and Simulated Annealing Algorithm 100 executions were performed so that some analysis could be done to choose the best algorithm to be used in the application. For all scenarios (2, 4, 8 and 16 destinations) and for each algorithm, the average algorithm execution time, the standard deviation, the median value, minimum execution time and the maximum execution time were registered.

In general, the Simulated Annealing Algorithm variants presented better results and always suggest the shorter path when comparing to Genetic Algorithm.

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Animation Sequencing of Portuguese Sign Language

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Abstract

In Portugal, there is around 30,000 people that use LGP (Portuguese Sign Language) as their native language. Most of these individuals struggle to communicate with non-deaf people, and often times get isolated from their surroundings due to this language barrier [1]. And With the current state of technology, it is completely achievable to have an application that translates spoken languages into sign languages interpreted by a virtual character, an avatar. There are several projects that utilize this idea like, for example, the work done in the article "Avatars on Portuguese sign language" [3] in which they created a simple Avatar to use as a interpreter of sign language and used Microsotf kinnect to capture all the motions. There is also a A Real Time Bidirectional Translator of Portuguese Sign Language [4] that work both ways, that is, its translates text to sign language and sign language to text, using 5DT gloves. However this work aims to make a live translator for text and or audio, to sign language that can be implemented in a chat system, like Skype or Whats-App. This process can be divided into two sections, the translation part, that receives a text or an audio and determines which gestures, known as glosses, are required for the avatar to interpret, and the part that animates an avatar to show the deaf user what the translation is. This work shows the development of an application that receives glosses from the translation part, downloads the animations for those glosses from a database, animates an avatar using said animations, and sends the final result for the user to see. An essential part of this application is finding a 3D model avatar to use with Compatibility with both multiple software, a complete full body rig, including movable fingers and face mesh made to be animated with blend shapes.

Having a 3D model with said characteristics facilitates the development of the software, particularly the association of the several animations with the model. In order to save the rig, mesh and animations of the model its necessary to export them in a FBX file [2]. The model is exported with the mesh and rig in "T-pose", with the arms and fingers completely stretched out. The animations where created by transforming the joints in the body rig, mainly rotations. These are necessary because transforming the joints in the rig will also transform the mesh of the avatar accordingly making the animation clear for everyone to see. For the glosses to be perceptible by the deaf community the facial expression is a very important part. While the body of our avatar can be animated by transforming its joints, the face needs to be animated using Blend shapes. Blend shapes create the illusion that one shape changes into another in a natural-looking way by deforming the mesh in several ways. With this the 3D model will have two separate animations, being the facial animations and the body animations, that will run in tandem to provide the animation a more perceptible and natural feel.

Now comes the association of said animations with the base rig. In order to achieve that, a state machine [5] was created, which consists in a tree where animations are defined to states of the avatar. This state machine work very well for connecting the animations with the base rig. Having a state machine to handle the animations, is now possible to create a "Animation Override" , which, has the name implies, overrides the animation set in the state machine making it possible to modify any state in the state machine anytime. This can be done by changing the animations in the active overrider via a script. The second way to modify a overrider is preferred since the application will be in constant communication with a external server that possesses all of the animation files later in its development.

Since LGP is as complex as any other language, the dictionary will have a vast number of glosses, each taking a few kilobytes of storage, varying in size depending on the length of the animation. This would cause the application to go to the hundreds of megabytes of required storage. This means that the animations require to be stored outside the device. Although several options were considered, the selected one was to store asset bundles, that consist in a bundle of assets, in a server with a file system. Now that we have a way to compress the animations to smaller sizes that can be downloaded easily and quickly, a decision needs to me made on where to store these asset bundles. After considering several options such as MongoDB and MySQL, it was decided that the animations would be stored in a simple file system on a server accessed by a XMPP client, and a MySQL database that describes in which bundle is one animation and what the written value of said animation is.

Overall, the foundations are being put into place, being able to use a 3D avatar that translates to sign language the sentences that it receives in Portuguese and having somewhat natural transitions between the animations. Now its necessary that we start to capture all the motions used in LGP, and store them in the database, with the help of several LGP users, and to then test our Avatar and to see where it needs to be adjusted and if its "speaking" correctly.

Keywords: Avatar · Glosses · LGP · Animations · fbx.

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Applications of the Analog Ensembles Method to Meteorological Data Reconstruction in the Northeast of Portugal

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Abstract

The observation of weather states has always been a human need. Our most distant ancestors already tried to understand and predict the weather, but did not have reliable methods. In the 19th century, modern meteorology took its first steps: the French government, motivated by the sinking of ships near the coast of Crimea, because of a heavy rainstorm, created a network of 24 stations spread across Europe, which began to observe the weather. In recent years, due to computational advances, different methods of predicting weather states have begun to emerge, increasing the forecast extent and its accuracy.

The Analog Ensembles method (AnEn), introduced by Luca Delle Monache in 2011 [1], is a post-processing tool that has shown good results to improve whether predictions or perform hindcasting (reconstruction of missing meteorological data). The goal of this study is to use the AnEn method to perform hindcasting, in order to reconstruct past weather conditions in a specific area of the northeeast of Portugal and verify its similarity with the actual forecast.

The AnEn method uses a two different time series: one with historical data (from a predictor station) and another with observed data (concerning a predicted station). The historical data is complete, while the observed data is missing or sparse in the prediction period. In Figure 1, which illustrates the methodology, a number of analogs are selected from the historical data set, according to their similarity to a predictor value (see step 1). At the same time instant, but at the predicted station, the corresponding observed data is selected and is used to produce a predicted value (step 3). This process is performed successively until the end of the prediction period data, and thereby it is possible to reconstruct the full predicted data from station 2. The AnEn method also allows using more than one predictor station (or more than on variable from the same station); in this scenario, the data from the predictor stations (or variable) can be used either dependently or independently (i.e., with the analogs selected in different predictor series having to overlap in time, or not).

The data for this research comes from weather stations managed by IPB and located in the northeast region of Portugal, near the villages of Edroso (*latitude* : 41.912778;

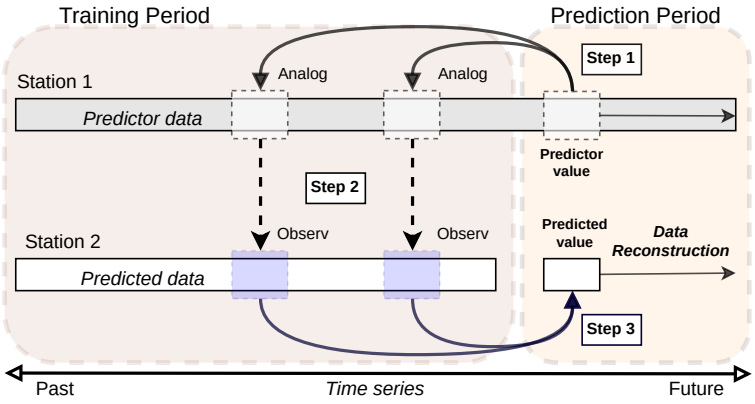

Fig. 1. Hindcasting with the Analogues Ensemble method.

longitude : −7.15283), Soutelo (*latitude* : 41.9211; *longitude* : −6.80852) and Valongo (*latitude* : 41.92305; *longitude* : −6.95083). Although reliable, the data series are often incomplete. To correct this problem, an interpolation was performed on the data, in order to standardise the sampling intervals to every 30 minutes. This interpolation process is limited to a maximum of 4 missing time intervals, since longer periods could distort the data too far beyond reality.

The AnEn simulations conducted were based on R [2] code adapted from previous work [3]. A new tool for the interpolation was also created in R. An algorithm for the conversion from csv to NetCDF format was developed (since NetCDF is the world standard format for meteorological data), and this conversion was performed for each station mentioned.

The year intervals were chosen based on the intersection between the weather station data. Then, the tests were run using the years of 2000 to 2006 as the predictor period, and the years 2006 to 2007 for the prediction period. As far as the climatic variables are concerned, the variables $PRES$ (Pressure), GST (Gust Speed) and $WSPD$ (Wind Speed) and $ATMP$ (Temperature) were used.

Table 1 presents the results of the experiments, which were divided into the error measures $Bias$ ($\frac{1}{n}\sum_{n}^{i=1}(x_i - y_i)$) and $RMSE$ ($\sqrt{\frac{1}{n}\sum_{n}^{i=1}(y_i - x_i)^2}$). Only Valongo was predicted, while Soutelo and Edroso stations were the predictors, either combined or not. These results were compared with previous work [3], in which the Ykt was predicted by the Dom and Ykr weather stations.

Soutelo and Edroso showed lower error rates in $WSPD$ and GST variables, while Dom and Ykr [3] showed superior performance in $PRES$ and $ATMP$ variables. In overall, using two stations simultaneously showed better results. In this scenario, the dependent-station method was also superior.

The data time intervals of the Dom and Ykr stations are shorter in comparison to this study (6 minutes versus 30 minutes), which promotes higher data resolution. Despite this, the prediction results obtained in the selected portuguese villages were similar to those observed at the stations of Dom and Ykr, indicating the effectiveness of the Monache method.

Variable	Dependency	**Soutelo**		**Edroso**		**Soutelo/Edroso**		**Dom/Ykr**	
		BIAS	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*	*BIAS*	*RMSE*
WSPD	Yes	-0.064	0.707	**-0.032**	0.851	-0.049	**0.670**	-0.206	2.075
	No					-0.061	0.725	-0.166	1.572
GST	Yes	-0.219	1.646	**-0.037**	1.870	-0.125	**1.467**	-0.530	2.197
	No					-0.141	1.644	-0.421	1.733
PRES	Yes	0.657	1.323	-0.832	2.008	-0.137	1.520	0.278	**0.497**
	No					**-0.061**	1.216	0.579	0.853
ATMP	Yes	-0.077	2.667	-0.142	2.690	-0.037	2.308	**0.001**	**1.071**
	No					-0.133	2.498	0.208	1.437

Table 1. Valongo variables predicted by Soutelo and Edroso. The results were compared to [3] (which predicted Ykt with the Dome and Ykr stations).

Therefore, the goal of this study was accomplished: the AnEn experiments with data from the stations in the villages of Edroso, Soutelo and Valongo were performed, and the results were compared with previous related work. Although the data series from the stations used in this study are not complete, they still managed to perform as well as higher data quality data series. To infer more reliable results, further tests with other variables and stations are needed.

Keywords: Analog Ensembles · Meteorological Data · Hindcasting.

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Feasibility Study on Automatic Surgical Phase Identification based on Speech Recognition for Laparoscopic Prostatectomy

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Abstract

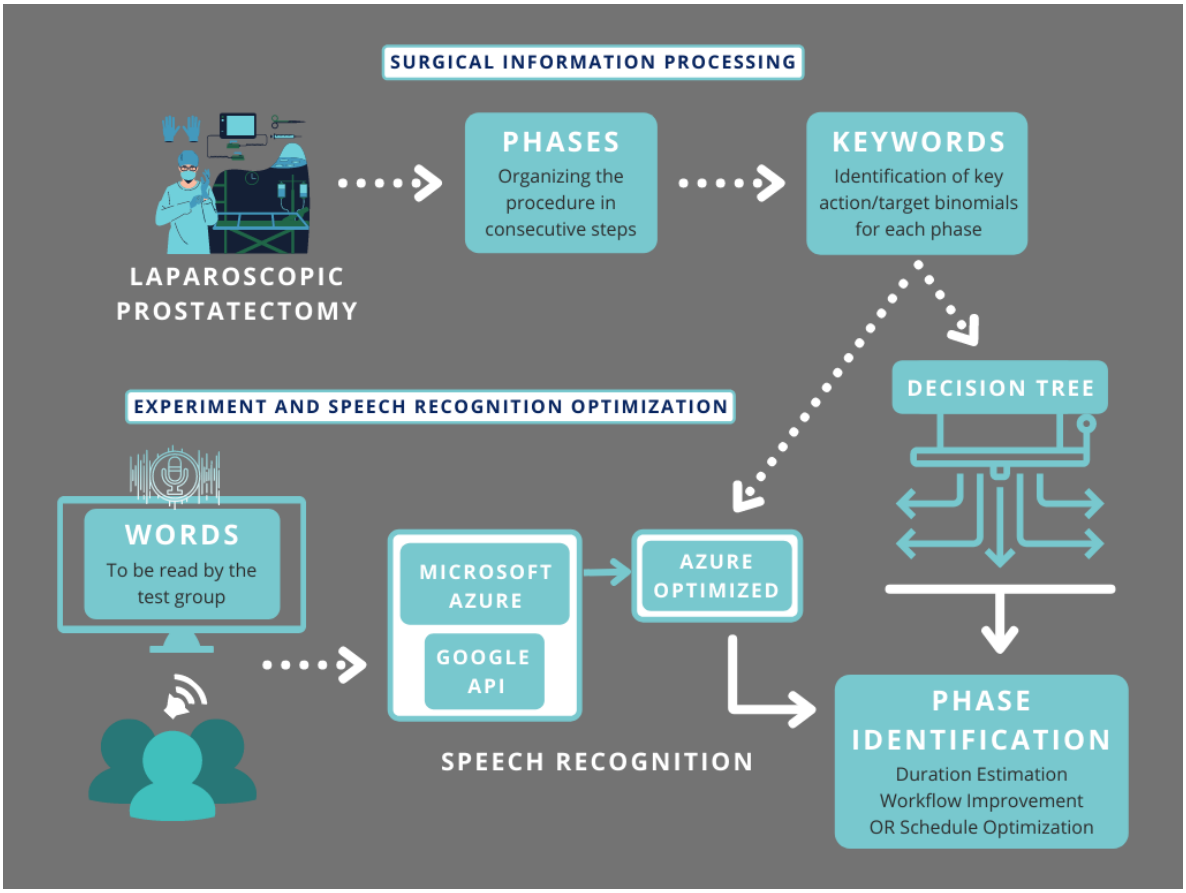

Fig. 1. Graphical representation of the development and implementation steps for the proposed application.

Prostate cancer is the second most frequent malignancy in men worldwide, with Laparoscopic Radical Prostatectomy (LRP) being the standard of care for patients with organ-confined disease, wishing to preserve erectile function [5]. Studies have shown

that variables such as Node Dissection, Gleason Score, Body Mass Index or Prostate Weight, may affect the duration of the procedure which causes major challenges for an efficient operating room (OR) schedule management [7]. Automatic Surgical phase identification, usually based in information from the endoscopic camera, allows for a more accurate and automated estimation of the surgery duration. This is usually employed with Deep Learning (DL) algorithms, like Convolution Neural Networks (CNN) [1]. However, using DL algorithms often requires large amounts of labeled data given as a training input. Moreover, such models are typically specific to the surgical procedure they were trained for [1]. One possible improvement for these methods is the introduction of speech recognition (SR) systems. Nowadays, SR is, not only, an essential part of everyday life but also, applied in several professional activities, including medical applications [6]. However, literature on speech recognition applied for surgical phase recognition is limited [3].

The described work aims at the implementation of a speech recognition (SR) engine for surgical phase identification, specifically optimized for Laparoscopic Radical Prostatectomy (LRP). For this application the performance of 3 engines was tested under different background noise and distance circumstances (1 m and 2 m): Microsoft Speech SDK (Azure); Google Speech Recognition API (Google API); and an optimization of the first (AzureGrammar), with the introduction of specific vocabulary. Action/target binomials, were used to identify the LRP surgical phases. The surgical phases considered for this work were defined based on the description made by Cadeddu et al. of the LRP procedure, with an extraperitoneal approach [2]. A total of 15 participants were selected to perform the tests. Each volunteer was requested to do a read out of the previously identified key action/target binomials for the different surgical phases. In Fig. 1, a graphical representation of the development and implementation steps for the proposed application is displayed.

Word Error Rate (WER) was calculated as the main comparison metric [4]. The values for the total WER indicate that AzureGrammar (specific vocabulary inserted) has superior performance, reaching a lower error rate of 29.25%, when compared to Azure and Google with 67.91% and 67.48%, respectively. Phase Accuracy Ratio (PAR), considering only the AzureGrammar SR engine, are 84% and 83%, for 1 m and 2 m, without background noise; 61% and 51%, for 1 m and 2 m, with background noise.

This study demonstrates that using a conventional SR engine, with specific vocabulary incorporated, has the potential to achieve an acceptable performance with minimal setup, possibly contributing for OR management optimization. Further studies should include participants with medical and surgical knowledge, preferably, in their native language, and in a live OR scenario with a fully optimized SR engine.

Keywords: Speech Recognition · Surgical Phase Identification · Laparoscopic Prostatectomy.

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Pushing Woodworking into the Digitization Age: the WW4.0 Project

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Abstract

Starting from the premise that technological advances in recent years have enabled the increase in industrial productivity then, industries that are more integrated into the technological environment tend to have more optimized and automated processes. Thus, they are able to offer more attractive prices to their customers, as well as greater control of their processes to make decisions that best fit the company's market strategy.

Currently, in the context of the small to the medium-sized furniture manufacturing industry, technological advances have brought an enormous contribution to the efficiency improvement of industrial-made products [1]. However, despite the extensive robotisation currently being felt in many of these industry activities, digitisation of the process loops is still in its early infancy.

In this frame of reference, the WW4.0 project, financed by the NORTE2020 Portuguese initiative, aims to develop a technological layer that aims to promote the digitisation of low throughput, high customization, and furniture industries. In particular, this project aims the development a methodology that will allow information aggregation from all the actions and operations associated with the manufacturing process. This will enable real-time knowledge regarding the current ongoing tasks, stock contents and raw materials existing on the "shop floor".

The WW4.0 project consortium is headed by the Mofreita and has, as partners, the CeDRI research centre, the MORE collab and NKA, an IT-based company NKA. Mofreita is carpentry located in "Macedo de Cavaleiros", a city in the northeast part of Portugal, and focuses on the development of customized furniture. Located in Bragança, Portugal, CeDRI is a multidisciplinary research unit fostered by the Polytechnic Institute of Bragança that promotes and applies technological solutions in the industry. MORE is a collab centre, also from Bragança, which provides scientific, technological and innovation consulting services to companies in both the public and private sectors. Finally, NKA is a technology company that designs and develops global IT solutions.

The management model, currently used in the company, is not fully digitised yet. Especially, on the company's shop floor where knowledge about processing times or real-time tracking of raw material is a very complex task. Those questions can be tackled through the actual concepts and technologies introduced by Industrie 4.0. This paradigm has leveraged the whole decision-making process by promoting information exchange and data analytics. In this frame of reference, the main goal of the WW4.0

project is to create a digital ecosystem that allows relevant information to be aggregated and employed to support the management tasks and promote a more integrated relationship with customers. In particular, this project is segmented into three major modules that, when integrated, constitute the proposed solution: Information aggregation and presentation platform, smart product, and finally, real-time tracking of furniture components and scheduling of raw materials.

The first module will be responsible for aggregating all relevant data for the production process, whether legacy data or new parameters, allowing complete information sharing between the various types of computer applications involved in the production process. In particular, the crossing of information about the raw material available in the stock at a given moment and the wood pieces to be processed. This will allow optimal management of the raw material, waste reduction and consequent minimization of production costs. The way this allocation will be done will follow the application of optimization algorithms whose main function will be the scheduling of the raw material.

The second is a digital representation of the product that will be achieved by applying the "digital twin" concepts, an emerging technology that has been widely developed within Industrie 4.0. The use of this technology will allow knowing, in real-time, at what stage the production process is, the remaining stages of the process, the materials spent and the materials still needed, creating the possibility of more efficient management. All the information will be processed using algorithms based on artificial intelligence in order to support decision making at various levels, from operational decisions (shop-floor) to strategic decisions (management).

The third module will lead to the implementation of real-time product tracking techniques (including bulk products). It is intended to update, in an automatic way, the stock database These actions will have impacts at various levels, including the reduction of material that is considered waste and the reduction of the time required to look for a given material/product in the warehouse.

All this information, provided by the solutions devised during this project, will allow promoting decision making in such a way as to adapt production control to the company's market strategies.

Keywords: Digitization · Wood work processes · Information technology · Traceability

Acknowledgment

The authors are grateful to the project WW4.0 (Wood Work 4.0), NORTE-01-0247-FEDER-072593, for supporting this work.

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Intelligent Digital Twin for Hyper Automation Manufacturing

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Abstract

The need for faster, flexible, efficient, and more autonomous production methods created the concept of Industry 4.0, which contains the idea of simultaneously managing the physical assets and their digital duplicate, a Digital Twin (DT) [7]. The use of DT systems brings multiple advantages as: i) increased speed on prototyping and design; ii) waste reduction; iii) reduced maintenance periods; iv) increased performance; v) etc. These advantages rose the interest in the topic in both academic and private fields, the latest centered around large companies [1, 9]. Implementation of DTs in SMEs (Small and Medium Enterprises) presents multiple challenges due to a sum of structural factors, such as being production focused, the lack of workforce to search and evaluate emerging technologies, reduced financial resources and reluctance to modernize procedures with tendency to only invest in consolidated solutions. Added to technical aspects from usage of old or obsolete machinery and use of manual or offline systems that difficult the interoperability [6, 10]. In order to tackle some technical challenges, the authors intent to develop a solution for a fast implementation and deployment of intelligent DT systems with 3D and IIoT (Industrial Internet of Things) capabilities. In this sense, a 3D scanner approach aided with AI (Artificial Intelligence) for automatic segmentation of key elements is to be developed based on photogrammetry taking advantage of the wide range of view and abundance of acquisition equipment (cameras). Complemented with a modular external IIoT device with multiple sensors, allowing to source real-time data to the DT system from existing machinery. A dynamic HMI (Human Machine Interface) with AR (Augmented Reality) abilities will also be researched, with the focus on adapting itself to display the most suited information to the necessities of different users [2–5, 8, 8, 11]. To validate the developed solution, multiple scenarios containing a human operator, 6 Dof (Degrees of Freedom) robot arm, a conveyor and a CNC milling machine will be idealized, each one with different objectives, from improving speed to reducing energy consumption.

Keywords: Digital Twin · Industry 4.0 · Artificial Intelligence

Acknowledgments

The authors gratefully acknowledge the financial support of the national funds (PIDDAC), through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES

under the scope of the projects UIDB/05549/2020 and UIDP/05549/2020, FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES under the scope of the project LASI-LA/P/0104/2020 and also by FCT – Fundação para a Ciência e Tecnologia in the scope of the individual research grant UI/BD/151296/2021, 2Ai – Applied Artificial Intelligence Laboratory, IPCA

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Architecture for Museums Location-Based Content Delivery using Augmented Reality and Beacons

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Abstract

Museums have a fundamental role in preserving and transmitting local culture [1]. With the careful preservation of documentation and artifacts, culture can be recorded and remembered regardless of its future. The past can be learnt by everyone and cultural backgrounds can be shared across generations. It is important to promote and develop museums environments where visitors are able to access space information and therefore have a more enriching visiting experience [2].

Several challenges arise in the indoor environment of a museum such as accessing more information of a given artifact, the unavailability of a guide when required or the need of an extra payment for a more individualized experience [3]. It is well-known that visitors often get bored which makes the task of capture the visitor attention a challenge, specially if they are children [4].

Therefore, addressing the different preferences of users during a visit is a challenge for museums. To address this issue, several applications exist that assist museums, by providing guided visiting experiences. However, in most of them, the information provided is static and does not prevent the visiting experience from being boring, except the ones that already uses new technologies such as augmented reality. To assure a better experience in the museums, the development of interactive, dynamic and personalized experiences becomes fundamental, combined with augmented reality that provides location-based content in an indoor environment. Involving the visitor in the tour, making him an element creator and contribute with further exposed content is another way to capture his attention. Telling stories about the space itself is yet another way to capture the visitor's attention. The story should be divided by the museum space to maintain the visitors interest by wanting to know the evolution of the story. The story style should also be compatible with the visitor segment (e.g. adult or child).

This case of study presents an architecture and preliminary results of an indoor content-delivery solution for the Foz-Coa Museum in Portugal, using augmented reality and mobile applications. This I&D project emerged with the specific necessity of providing guided visit experiences inside the museum in an interactive and dynamic manner, present specific details of the artifacts and provide guided visits, without the need of a human guide. Towards accomplish this objective, the project aims to tell a tale along the visit course and engage the visitor's at all moments, making him feel part of the story. The tale intends to be transmitted by a virtual character, using augmented reality.

The main contributions of this abstract are as follows: a technological architecture proposal for a location based content delivery solution in an indoor environment using Bluetooth beacons; performance analysis of a set of beacons; a comparative analysis of two 3D object reconstruction software tools to use the digitized models in content creation and object recognition; a comparative analysis of two Augmented Reality tools used to provide contents and create a digital environment of the museum.

The full case of study abstract features three main sections. The technologies section in which a contextualization about beacons properties and functionalities and a comparison of Immersal AR and EasyAR (Augmented Reality tools) are made. In proposed solution section describes the main architecture solution for museums location-based content delivery. At last is presented the preliminary results section in which the performance and effectiveness of Estimote proximity beacons are evaluated under different configurations.

The future work involves extending the tests of beacons under different contexts and with more recent hardware/software and the tests of 3D object detection using an augmented reality tool. It will also be developed the actual augmented reality app with content delivery to the Foz Côa museum.

Keywords: Indoor-Location · BLE Beacons · Augmented Reality.

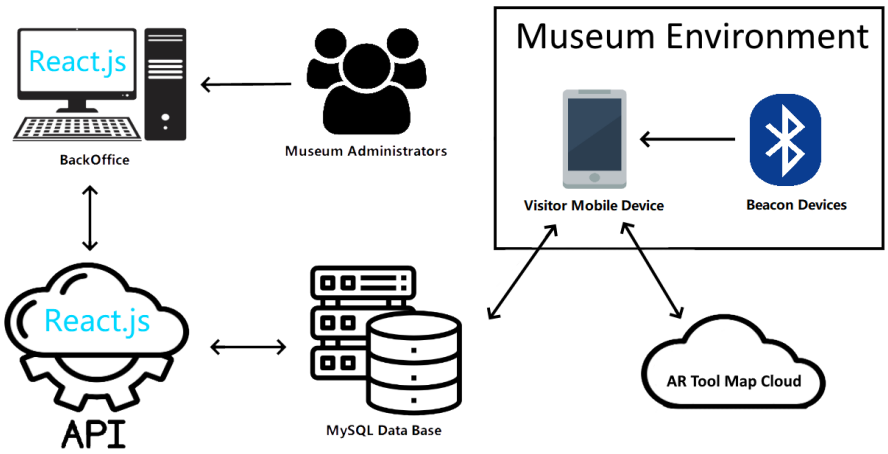

Fig. 1. Overall System Architecture.

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SMARTPHONEHEADSCANNER - Intelligent Solution for 3D Head Reconstruction on a Smartphone

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Abstract

Nowadays, the use of 3D scanners for medical procedures is restricted to medical facilities with access to resources and specialized teams capable of manipulating these devices [5]. 3D scanners are expensive devices applied to generate 3D data widely used in the medical field for the diagnosis and therapy monitoring of diseases and deformities in the human body, specifically in the case of Positional Plagiocephaly.

Positional Plagiocephaly [2] is a deformation characterized by a prominent asymmetrical distortion of a newborn's skull, often caused by its postural attitude. Since it is a deformation that progresses through time as the infant grows, frequent monitoring of this progress is critical for the success of the treatment. Therefore, the existence of mobile devices capable of following and recording the newborn's cranial evolution in its first months of life is fundamental so that parents can intuitively monitor the progress of this pathology.

In recent years, 3D reconstruction has evolved exponentially. However, only a few mobile applications can accurately reconstruct human heads. Thus, this project aims to develop a mobile application for scanning human heads from multiple images, guiding parents in acquiring the data, and finally storing the various scans so that parents can see the evolution of the newborn's skull.

To develop the project, several methods of 3D reconstruction from multiple images were explored and implemented [3], [4]. The selected approach [3] requires 2D images and their respective camera poses to reconstruct a volumetric field of radiance and density of the human head. Finally, the volume field is displayed using ray marching. Furthermore, intelligent solutions will be developed to guide the user in data collection. The yolov5 [1] algorithm will be retrained to detect human heads, and IMU data will be utilized to calculate the camera trajectory. A dataset will be acquired with a traditional 3D scanner and will include ground truth data from prototype heads and corresponding images acquired by a mobile device. This dataset will be used both in the development of the reconstruction methods and the validation of the system by comparing the smartphone reconstruction results with the groundtruth data.

The preliminary results achieved in a PC implementation in Fig. 1 show that the system is able to produce qualitatively good 3D reconstructions. The final results will be obtained during the testing phase to determine the application's ability to produce accurate 3D models and the efficiency and effectiveness of its implementation on mobile devices.

Keywords: 3D reconstruction of human bodies · Multi-View · 3D Scanning · Smartphone · 3D Deep Learning

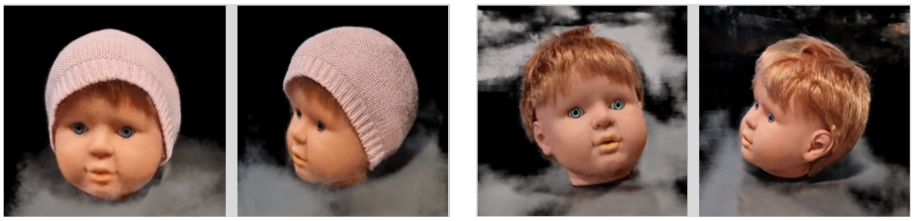

Fig. 1. Render of 3D reconstruction results of two distinct heads achieved with the PC implementation.

Acknowledgement

This work was funded by the project "NORTE-01-0145-FEDER-000045", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES under the scope of the projects UIDB/05549/2020 and UIDP/05549/2020.

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Power Flow Analysis Using the Newton Raphson Method

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Abstract

Power supply in the 1980s changed the way electric power systems (ESS) were implemented. The vertically implemented distribution was carried out with a monopoly with an entity responsible for several functional areas (production, distribution, competition at the production and distribution level) [14].

With the development of the demography and industrialization, the consumption of electric energy has increased dramatically. Access to electricity today is one of the determining factors for technological, economic and social progress in different countries. The International Energy Agency (IEA) predicts that global energy demand will increase by 37% by 2040 compared to the year 2014, although it expects annual growth to decline to 1% after 2025 [10].

The demand for electricity is not constant throughout the year. Energy consumption is seasonal, varies monthly and even weekly, being high at daily peak hours. The energy balance between production and consumption including the losses must be accomplished continuously, since the energy storage is limited. Bearing in mind these specifications, electrical grids must be adjusted to improve the potential of different electrical networks in different energy scenarios, i.e., it must be analyzed how the production and also the connected load must be managed to adequately operate the system while guaranteeing the technical limitations of the system elements [5].

Energy storage can be an important part of that energy equation. By adding the energy to the grid in peak hours or storing it when there is a surplus, the variable and/or intermittent effect of renewable energy generation can be mitigated, as the periods of generation with surplus and underproduction supply the periods of generation with deficit, as well as the cost of production. Energy storage, allows decreasing the production of conventional plants in peak hours, where it usually has the highest cost [1].

The planning and operation of the power system are very important, and the power flow analysis is used for this purpose. The problem is essentially the bus load level and the transmission system loading flow with the specific load schedule and generated generation schedule. Also, power flow studies are combined for expansion planning, system operation, power system optimization and real-time stability, emergencies and system investigation [3].

The complexity of the power flow problem is so high that the problem is addressed numerically. There are several methodologies to address the power flow: Gauss-Seidel,

Newton-Rapson, fast decoupled load flow (FDLF) and other methods using the node impedance matrix (Z). The choice of method depends on the topology, the type of network and the optimization objective.

Through studies [6] and [1], the Newton-Raphson method is indicated not only by the speed of convergence, but also by its low sensitivity to elements that can interfere with its convergence, such as the reference bus, for example.

Through Newton-Raphson's method, a very good response from the electrical system is found, but in some cases there are specific problems to be solved, such as high production costs or energy losses of the system. To solve this, the power flow is optimized through an optimization procedure, where a goal is defined and implemented while respecting the technical constraints of the components.

There are two main approaches to implement the optimal power flow (OPF): deterministic and heuristic. Deterministic methods in their original form disregard how uncertainties do not present a problem of planning the expansion of an electrical system and, therefore, the expected results of an analysis differ significantly from the reality of an evaluated system [8]. The heuristic methodologies determine optimal solutions through probabilistic rules, operating randomly, however, oriented, considering the uncertainties presented in the system [9].

In this work, the optimization procedure is to be implemented in a data set obtained from the power flow solved through the Newton-Raphson's method. The power flow solutions obtained in a steady state analysis, are achieved through the MATPOWER, which is a simulation tool gathering open-source Matlab language M-files [10].

Keywords: Power Flow · Newton Rapson · MATPOWER.

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Reading RFID Tags Using a Motorized System

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Abstract

The use of radio frequency identification technology (RFID) has grown significantly in recent years. Since some chips have now memory capability, it is possible to read and write them, easing the tracing of different parts/components. In addition, and in opposition to standard technology for identification, e.g. barcode, a RFID reader can detect multiple chips simultaneously. Our team is recently exploring the potential of passive RFID tags to be used for package tracing. However, since these chips use energy from electromagnetic waves for communication and to power themselves, the communication range is very low, which could be an obstacle for some applications. In this project, we present a proof-of-concept of a motorized system to increase the read volume of the traditional RFID readers. The system resembles a robot with a tool specifically designed to support the reader. It will have four degrees of freedom controlled by different servomotors that will allow the reader to move to different zones. The new concept was compared with the traditional static RFID reader. While the static reader showed a reduced detection volume, 8400 mm3, our approach proved, in our preliminary study, to guarantee an higher detection volume, 2.89×10^7 mm3, corroborating its potential to read RFID tags inserted into standard packages. Overall, the preliminary results show that our system has the potential to increase the detection range of RFID tags and to facilitate future package tracking systems.

Keywords: RFID · Industrial Design · Robot.

Acknowledgements

This work was funded by the project "POCI-01-0247-FEDER-047195-01", supported by the COMPETE – Operational Program Competitiveness and Internationalization,

Fig. 1. Exploded view of the robot

Fig. 2. Real robot system

under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020.

Optimization of an Ensemble of CNN for the Classification of Chronic Venous Disorders

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Abstract

Chronic Venous Disorders (CVD) of lower limbs are one of the most prevalent medical conditions, affecting 35% of adults in Europe and North America. The early diagnosis of CVD is critical, however, the diagnosis relies on a visual recognition of the various venous disorders which is time-consuming and dependent on the physician's expertise. Thus, automatic strategies for the classification of the CVD severity are claimed. This paper proposed an automatic ensemble-based strategy of Deep Convolutional Neural Networks (DCNN) for the classification of CVDs severity from medical images. First, a clinical dataset containing 1376 images of patients' legs with CVD of 5 different levels of severity was constructed. Then, the constructed dataset was randomly split into training, testing, and validation datasets. Subsequently, a set of DCNN were individually applied to the images for classification. Finally, instead of a traditional voting ensemble strategy, extracted feature vectors from each DCNN were concatenated and fed into a new ensemble optimization network. Experiments showed that the proposed strategy achieved a classification with 93.8%, 93.4%, 92.4% of accuracy, precision, and recall, respectively. Moreover, compared to the traditional ensemble strategy, improvement in the accuracy of 2% was registered. The proposed strategy showed to be accurate and robust for the diagnosis of CVD severity from medical images. Nevertheless, further research using an extensive clinical database is required to validate the potential of this strategy.

Keywords: classification · chronic venous disorder · convolutional neural networks · ensemble.

Acknowledgements

The authors acknowledge Fundação para a Ciência e a Tecnologia (FCT), Portugal and the European Social Found, European Union, for funding support through the "Programa Operacional Capital Humano" (POCH) in the scope of the PhD grants SFRH/BD/136721/2018 (B. Oliveira) and SFRH/BD/136670/2018 (H. Torres). Moreover, authors gratefully acknowledge the funding of the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by Northern Por-

tugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT and FCT/MCTES in the scope of the project LASI-LA/P/0104/2020, UIDB/00319/2020, UIDB/05549/2020 and UIDP/05549/2020. The authors would like to thank Ederson A. G. Dorileo, and co-authors for providing the ULCER dataset.

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Deep Learning Methods for Lesion Detection on Mammography Images: a Comparative Analysis

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Abstract

Breast cancer is the most prevalent and fatal cancer among women worldwide. In 2020, there were nearly 2.3 million new diagnosed cases and 685 000 deaths from breast cancer [9]. Thus, early detection of the disease is crucial for successful treatment and reducing the mortality rate [11]. Studies underlined that frequent mammographic screening can reduce the mortality rate by detecting breast tumors early before they spread to other healthy organs and tissues [7]. Nevertheless, mammographic screening is commonly manually analyzed by radiologists to detect and locate abnormal lesions, shapes, and types of any suspicious region in the breast. Although this process is considered crucial, it is challenging, time-consuming, and subject to inter and intra-variability among observers [2].

The robust segmentation of mammography images has been considered a backbreaking task due to: i) the low contrast of the lesion boundaries; ii) the extremely variable lesions' sizes and shapes; and iii) some extremely small lesions on the mammogram image [3]. To overcome these drawbacks, Deep Learning (DL) methods have been implemented and have shown impressive results when applied to medical image segmentation [1].

This work presents a benchmark for breast lesion segmentation in mammography images, where six state-of-the-art methods were evaluated on 1692 mammograms from a public dataset Curated Breast Imaging Subset Digital Database for Screening Mammography (CBIS-DDSM), and compared considering the following six metrics: i) Dice coefficient (DC); ii) Jaccard index (JI); iii) accuracy (Acc); iv) recall (Rec); v) specificity (Spe); and vi) precision (Pre). The base U-Net [8], UNETR [4], DynUNet [6], SegResNetVAE [12], RF-Net [10], MDA-Net [5] architectures were trained with a combination of the cross-entropy and Dice loss functions. Although the networks presented Dice scores superior to 86%, two of them managed to distinguish themselves.

In general, the results (Figure 1, Table 1) demonstrate the efficiency of the MDA-Net and DynUNet with Dice scores of 90.25% and 89.67%, and accuracy of 93.48% and 93.03%, respectively.

Keywords: Deep Learning · Mammography · Image segmentation · Breast cancer.

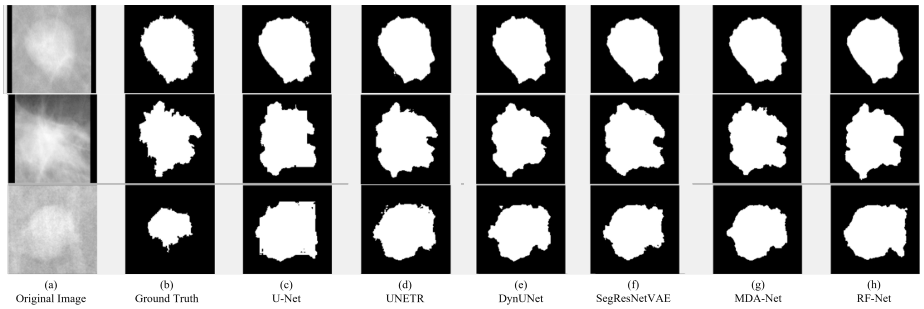

Fig. 1. Results of the networks evaluated on the lesion segmentation task. An example of good, median, and bad segmentation results are presented on the top, middle, and bottom line, respectively.

Table 1. Comparision of the different DL methods

Networks	Evaluation Metrics					
	DC	**JI**	**Acc**	**Rec**	**Spe**	**Pre**
U-Net	86,60	76,98	90,73	82,50	95,81	92,39
UNETR	89,59	81,65	92,96	87,80	95,84	92,72
DynUNet	89,67	81,82	93,03	87,84	95,96	92,87
SegResNetVAE	89,36	81,20	92,78	88,11	95,31	91,77
MDA-Net	**90,25**	**82,70**	**93,48**	**88,33**	**96,31**	**93,15**
RF-Net	89,56	81,60	92,92	87,28	95,99	93,04

Acknowledgements

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020
,UIDP/05549/2020 and LASI-LA/P/0104/2020.

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Autonomous Mobile Robot for Conventional Wheelchairs Transportation in Healthcare Institutions

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Abstract

Industry 4.0 presents itself as a new era in which the industry is led by technologies such as robotics, artificial intelligence, and device interconnection. The increasing implementation of robots in industries allows a better quality of service with high accuracy in less time. As a result, these advantages are now in other areas such as medicine or the military to mitigate problems.

In health institutions, the transport of patients is a recurrent, time-consuming, non-ergonomic task and requires the help of assistants [2]. There are solutions such as electric wheelchairs [3] that facilitate patient movement or intelligent wheelchairs [1] that transport patients to their destination autonomously, nevertheless, the high costs of these replacement wheelchairs are a financial obstacle for institutions.

This project aims to apply and explore an Autonomous Mobile Robot (AMR) to transport conventional wheelchairs in hospitals, clinics, etc., therefore, wheelchairs are not automated. This robot running the Robot Operating System (ROS) will attach itself autonomously to the conventional wheelchair, in a secure, easy, and fast link. The transport request commands will be given to the robot through a central application by the doctor or nurse and will be in constant communication with the institution's management system. This communication is essential to know information such as: which patient is transported, who requests transportation, and the various destinations such as treatment or diagnostic areas, outdoors, etc.

To validate the system, we will assess: 1) the effectiveness of the coupling system to the chair, 2) the usability (patient and safety system), and, finally, 3) the efficiency of the application set, a) management system, and b) transport system in typical use cases. The expected result of this project will be a ROS-based robotic system to help manage wheelchair transport in health institutions, increasing their availability and reducing the time required for medical personnel in these tasks.

Keywords: Autonomous Mobile Robot(AMR) · Transportation · Conventional Wheelchair · Health Institutions Management.

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Dynamic Waste Collection Strategy to Optimize Routes Using Open-Source Tool*

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Abstract

Cities throughout the world occupy around 3% of land area, but they are responsible for 60-80% of greenhouse emissions [3]. The current scenario is about to become worse if more solutions were not implemented to improve overall sustainability in cities. According to the statistics, most of the global population will be living in cities by 2050 (*ca.* 70%). One of the most complex systems in cities that often doesn't receive much resources and attention is the Municipal Solid Waste Management System (MSWMS). The world generates about 2.01 billion tonnes of municipal solid waste annually, and in most cases the waste is collected in a traditional way, in which drivers decide the path to be followed. This approach can lead to inefficient spending of fuel and time, nonetheless problems with overfilled dumpsters or even visits to empty ones [1].

Most studies approaching waste collection problems begins considering the Vehicle Routing Problem (VRP) initial formulation, adding more constraints to the problem as an attempt to reaching higher similarity with real problems of waste collection. From this attempt, formulations as Capacicated Vehicle Routing Problem (CVRP), Vehicle Routing Problem with Time Windows (VRPTW), and Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) arouses. Most recently, authors dealing with this problematic are using another name for the problem: Waste Collection Problem (WCP). There is no significant difference between WCP and VRP, only that the first one was created to specifically address problems of waste collection routes [2].

The waste collection problem is ruled by the objective of finding the best route to visit a set of locations using multiple vehicles. Even for computers, the utilization of exact methods to solve the problem can be impracticable due to the high running times

* This work has been supported by FCT - Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/05757/2020, UIDB/00690/2020, UIDB/50 020/2020, and UIDB/00319/2020. Adriano Silva was supported by FCT-MIT Portugal PhD grant SFRH/BD/151346/2021, and Thadeu Brito was supported by FCT PhD grant SFRH/BD/08598/2020. Jose L. Diaz de Tuesta acknowledges the financial support through the program of Atraccion de Talento of Atraccion al Talento of the Comunidad de Madrid (Spain) for the individual research grant 2020-T2/AMB-19836.

(computation time). On the other hand, metaheuristic algorithms can find acceptable solutions with low execution times, and thus, become the most practical choice. Algorithms in this class can be classified as population-based (*i.e.*, genetic algorithms and ant colony optimization) and trajectory-based (tabu search and simulated annealing). Recently, Google OR-Tools has shown the potential application to solve different variants of VRP problems through different solvers. In this tool, some search algorithms are available as an option to solve VRP variants, such as Simulated Annealing (SA), Tabu Search (TS), and Guided Local Search (GLS).

Increasing efforts focused on this research field contribute to developing innovative strategies with highly efficient solutions. Despite the clear development observed with the strategy to optimize waste collection system, most works are focused on big cities, and no models are built considering small towns. Furthermore, there is no mention of an upper limit of waste used by the algorithms to decide if a dumpster should be collected or not. The scenario shows opportunities to optimize waste collection systems in small cities (commonly disregarded for ICT implementation). The sustainable impact of implementing a smart waste management system in small towns can be lower than in big cities, but it still represents a remarkable improvement for interior societies. The implementation cost of smart devices, such as IoT boards equipped with level or weight measurements, is the hardest step in research that will deal with MSWMS in small cities. Moreover, this process could be expensive, consequently, not interesting for the companies. However, this threat can be faced as a challenge for researchers to develop solutions considering both cost and efficiency.

Thus, in this work, 10 waste paper dumpsters in the city of Bragança were chosen to study the influence of waste level in finding the best route for waste collection using the GLS algorithm. The problem was formulated as a CVRP, in which truck capacities are the constraint that determines when trucks should go to the central depot to empty the load. Furthermore, the optimization was evaluated upon three different strategies of dumpster selection for collection: the first considering only levels (regular approach), the second taking into account the level after 2 days (dynamic approach), and the traditional one, in which trucks collect the waste once each 2 days. Paper waste dumpsters were chosen in this study because paper waste has the highest generation, according to data provided by the company in charge of MSW management. The simulation was performed considering waste changes during 30 days, in which 3 trucks were responsible for waste collection. Waste changes through days were determined upon analysis of 150 m around each dumpster in a static approach (waste change daily is the same on different days for the same dumpster). In this regard, if a dumpster has a high concentration of populated area, the nearby daily waste oscillation will be higher. Two strategies for dumpster selection (regular and dynamic) for collection take into account the upper threshold of waste, which was considered as 70%, 80%, and 90% in this work.

The optimization algorithm returned daily distances traveled and load carried in each selection strategy for different levels, and the parameter Collection Efficiency (CE) was considered for comparison purposes. This parameter is the division of total load carried by the total distance traveled, and he was noted necessary due to the misleading conclusions that could be reached by separate analysis of distances and loads. CE values

were all higher considering 90% as maximum level in regular and dynamic strategy. For instance, traditional collection, regular, and dynamic approach were 0.0357, 0.0319, and 0.0537 m^3/km. The CE values shows that considering only levels for selection of dumpsters for collection is not enough since the best result in this approach did not overcome traditional collection result. On the other hand, considering waste level after 2 days to select dumpsters for collection resulted in a increase of about 50.42% in efficiency compared to traditional result. Analyzing daily distances and load carried revealed some key insights on why dynamic approach had better performance. The average load collected per collection day is 43.49% higher, and 47% less trips were done.

The results obtained in this work demonstrates the power of strategies for the proper selection of dumpsters to be collected. For future works, more sophisticated algorithms will be used for waste level forecast, using more realistic data of waste generation to create accurate models (*i.e.*, artificial neural network). Furthermore, the main goal is the assembly of a wireless sensor network to collect waste level in real-time, which can lead to a higher efficiency in decision-making regarding collection routes.

Keywords: Google OR-tools · Waste Collection Problem · Guided Local Search

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ECG classification using Artificial Intelligence: Model Optimization and Robustness Assessment.

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Abstract

The Electrocardiogram is one of the more complete exams for diagnosing pathologies regarding the cardiovascular system. Therefore, and based on the rudimentary methods of analyzing these exams in the past, computer-based approaches are now used in ECG (electrocardiogram) analysis. Smart technology systems have been designed over time to diagnose cardiovascular conditions through ECG analysis.

The current study evaluates the robustness and performance of one Artificial Intelligent (AI) system, based on a Convolutional Neural Network paired with a Multilayer Perceptron (CNN+MLP), to classify specific cardiac conditions in ECG signals. The paper assesses the robustness of the described AI model, by evaluating its performance in the classification of different classes. Moreover, it was studied the influence of the model's parameters in the result, namely: Train-Test split ratio, learning rate, optimization Algorithm, and a number of epochs.

After finding the optimal parameterization configuration that translates into a higher and better accuracy of the system, the results suggested that heartbeat classification based on CNN+MLP architecture is robust and capable to deal with the class increase. Our goal is to use outcomes and intelligent systems to automatically process ECG signals, and to directly identify specific medical conditions, and, for that, we intend to study the influence of the parameter's variation and confirm its robustness to the variation of the database configuration.

Keywords: Artificial Intelligence · MIT-BIH · CNN · Deep Learning.

Acknowledgements

The SAFHE work was funded by projects NORTE-01–0145-FEDER-000045, supported by Northern Portugal Regional Operational Programme Norte2020, and NORTE-01-0247-FEDER-070200, supported by Norte2020, under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). Moreover, it was also funded by national funds, through the FCT – Fundação para a Ciência e a Tecnologia within the R&D Units Projects UIDB/05549/2020 and UIDP/05549/2020.

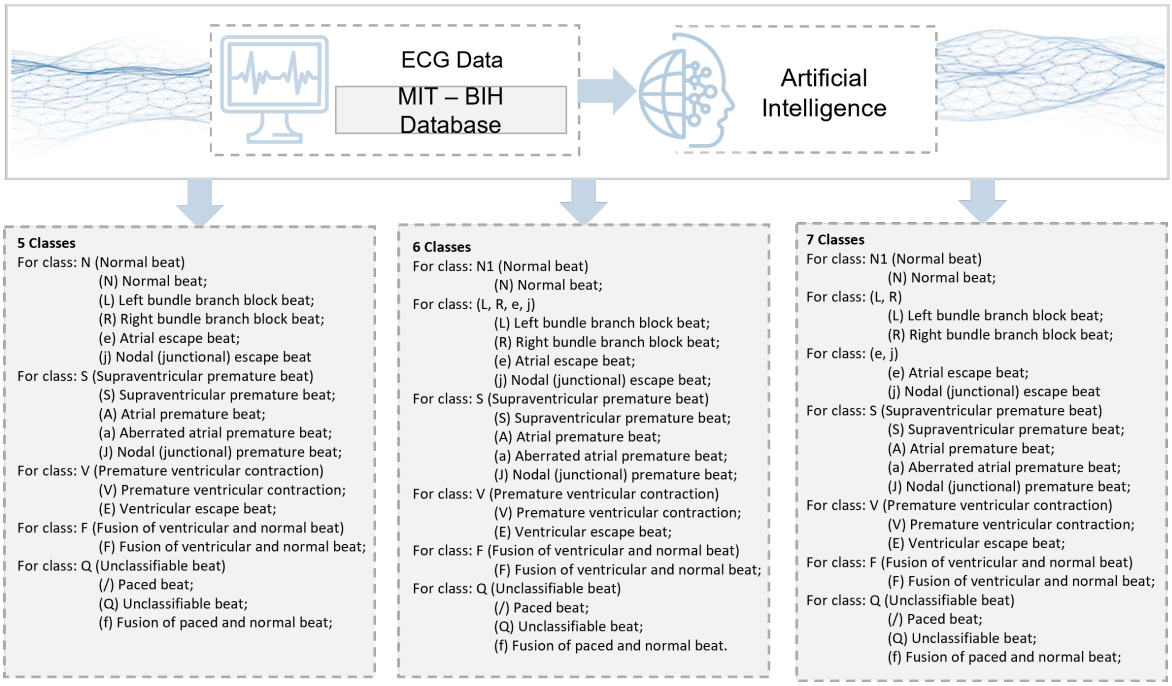

Fig. 1. Overview Project.

Advancing Digital Circular Economy in the Electrical and Electronic Equipment Value Chain

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Abstract

Climate change and environmental issues are hot subjects these days. The combustion of fossil fuels, deforestation, and the increasing demand for industrial and logistic operations have greatly contributed to this crisis [1]. The Electric and Electronic Equipment (EEE) industry generates enormous amounts of waste (e-waste), of which only 20% went through recycling routes until 2016. The rest ended up in dumpsites and landfills [2]. EEE devices include many toxic elements for individuals and the environment. Improper e-waste disposal can cause a variety of social and environmental issues. E-waste causes a huge economic loss and increases the scarcity of raw resources, in addition to environmental problems.

These days, the "take-make-dispose" pattern is still in use by supply chains in different areas [1], including the EEE sector [3]. Such economic structure is built on the assumption of abundant materials and the earth's strong regenerative potential. While the Linear Economy (LE) was a big success in the previous century, it is now causing lots of concerns, since it uses resources unsustainably and generates hazardous waste which negatively affects the environment [7]. The application of Circular Economy (CE) is an important way to reduce the environmental impacts caused in the EEE business sector. CE is an economic model that closes the loop of the old linear paradigm — "take-make-dispose" — in the production and consumption processes, by reducing, reusing, recycling, and recovering resources or components [5]. CE helps to transform the industry into a more sustainable and ecologically friendly approach. It attempts to eliminate material waste and reuse it in production processes, with the goal of reducing environmental pressure, while increasing innovation and economic growth [4].

For accomplishing a more sustainable approach, it is proposed the implementation of a traceability mechanism throughout the EEE value chain, to follow step by step an item or activity in the value chain. The traceability mechanism provides real-time traceability information about an item, offers a historical record about an object throughout the value chain, and optimizes processes in the supply chain. It can be achieved by using Blockchain technology (BCT) integrated with Internet of Things (IOT) technology.

On the one hand, Blockchain uses distributed ledger technology (DLT) for implementing a distributed database that allows participants to securely store information in real-time. At the same time, it provides a consensus mechanism for peer-to-peer transactions, therefore, eliminating the requirement for a middleman to process and preserve transaction data [6]. The use of BCT for traceability in a value chain brings two main

key features: 1) data immutability (it is near impossible to change registered data on the ledger); and 2) transparency (every asset transaction, i.e., item creation and its use for industrial or logistic activity, is registered in the blockchain) [1]. On the other hand, IOT facilitate in the connection between the physical and the digital worlds. IOT technologies are crucial to improving value chain management linked to real-time and product life-cycle traceability solutions. The data collected can be analyzed and can be used to optimize the value chain operational inefficiencies providing transparency, delivery optimization, and operational efficiency.

This work aims to take the advantages delivered by BCT and join it with IOT technology for advancing digital circular economy in the Electrical and Electronic Equipment (EEE) value chain. By integrating BCT and IOT technology in an EEE value chain can boost operation optimization and efficiency, decreasing human errors in inventory management and giving product traceability throughout its core value chain stages: 1) e-waste collection; 2) e-waste storage; 3) manual sorting, dismantling, shredding; 4) mechanical separation; and 5) recovery. The final customer closes the loop in a CE model because they are responsible for providing the End-of-Life (EoL) EEE for recycling. It's likely that an incentive structure is required to entice the ultimate consumer to participate in the process, as this is critical to the model's success. The results obtained are still preliminary, i.e., a state-of-the art survey and a conceptual architecture proposal. Future work includes the back-end application development (smart contract included), high fidelity prototyping, and the front-end application development.

Keywords: Circular Economy · Value Chain · Traceability · Sustainability · Blockchain · IoT · Electric and Electronic Equipments

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Kidney Segmentation in 2D Ultrasound Images Using Deep Learning

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Abstract

Ultrasound (US) is a medical imaging modality widely used for diagnosis, monitoring, and guidance of surgical procedures [10,14]. However, the accurate interpretation of US images is a challenging task, closely associated with the operator's skills [1,5]. Recently, portable 2D US devices enhanced with artificial intelligence (AI) methods to identify, in real-time, specific anatomies are widely spreading worldwide. Nevertheless, the number of available methods that effectively work in such devices is still limited, failing to segment relevant anatomies to daily practice [3,6].

In this work, we evaluate the performance of the U-NET architecture to segment the kidney in 2D US images. To accomplish this task, we studied the possibility of using multiple sliced images extracted from 3D US volumes to achieve a large, variable, and multi-view dataset of 2D images.

The proposed methodology was tested with a dataset of 66 3D US volumes, divided in 51 for training, 5 for validation, and 10 for testing. From the volumes, 3792 2D sliced images were extracted (Figure 1). Two experiments were conducted, namely: (i) using the entire database, which contains slices with and without kidney (WWKD); and (ii) using images where the kidney area is greater than 500 mm2 (500KD). Finally, an additional validation was performed using images acquired with a 2D US probe. An average error of 2.88 $\pm$ 2.63 mm in the testing dataset was registered. Moreover, in a proof-of-concept experiment with real 2D images (acquired with a 2D US probe) (Figure 2), it demonstrated the feasibility and potential of our training strategy with multiple 2D slices extracted from 3D US volumes.

In short, the proposed method proved, in this preliminary study, its high accuracy and corroborated its potential clinical interest. Further studies are required to evaluate the real performance of the proposed methodology.

Keywords: Kidney Segmentation · Deep Learning · Real-time

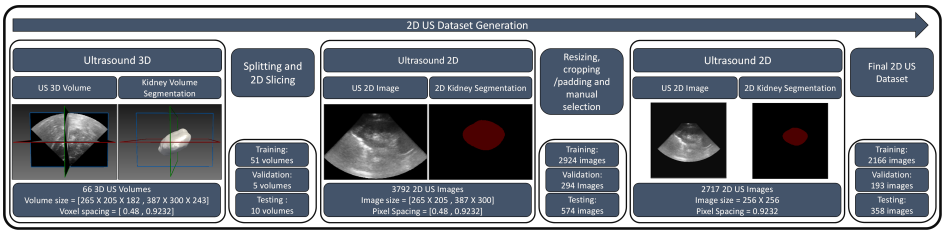

Fig. 1. Preparation of the 2D dataset.

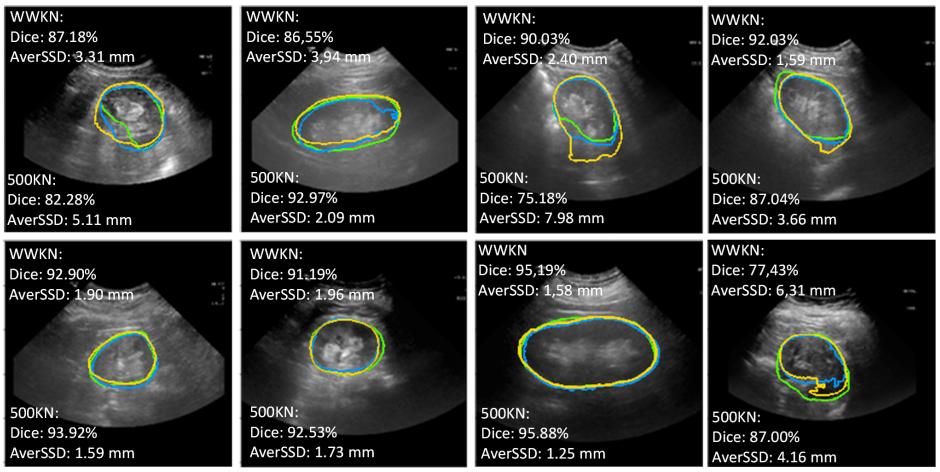

Fig. 2. Segmentation in images acquired with a 2D US probe. (Green contour – manual label; Blue contour – WWKN; Yellow contour – 500KN).

Acknowledgements

The authors acknowledge the company KARL STORZ SE & Co. KG for their support of this research. This work was supported by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", under the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also supported by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020. The authors also acknowledge FCT, Portugal and the European Social Fund, European Union, for funding support through the "Programa Operacional Capital Humano" (POCH) in the scope of the PhD grants SFRH/BD/136721/2018 (B. Oliveira) and SFRH/BD/136670 (H.R. Torres).

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A sensorized needle guide for ultrasound assisted breast biopsy

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Abstract

One in every eight women will get breast cancer during their lifetime [2]. Therefore, the early diagnosis of the lesions is fundamental to improve the chances of recovery. To find breast cancers, breast screening using techniques such as mammography, MRI [3] and ultrasound (US) imaging scans are often used.

When a lesion is found, a breast biopsy is performed to extract a tissue sample for analysis. The breast biopsy is usually assisted by an US to help find the lesion and guide the needle to its location. However, the identification of the needle tip in US image is challenging, possibly resulting in puncture failures, thus, several techniques were proposed for enhancing it during intervention [1] . In this work, we intend to study the potential of a sensorized needle guide system that provides information about the needle angle and displacement in respect to the US probe.

Laboratory tests were initially conducted to evaluate the accuracy of each sensor in controlled conditions. After, a practical experiment with the US probe, working as a proof of concept, was performed. The angle sensor showed a root mean square error (RMSE) of 0.48 degrees and the displacement sensor showed a RMSE of 0.26mm after being calibrated. For the US probe tests, the displacement sensor shows high errors in the range of 1.19mm to 2.05mm due to mechanical reasons.

Overall, the proposed system showed its potential to be used to accurately estimate needle tip localization throughout breast biopsies guided by US, corroborating its potential clinical application.

Keywords: Breast cancer · Breast Biopsy · Ultrasound · Needle guide · Sensors.

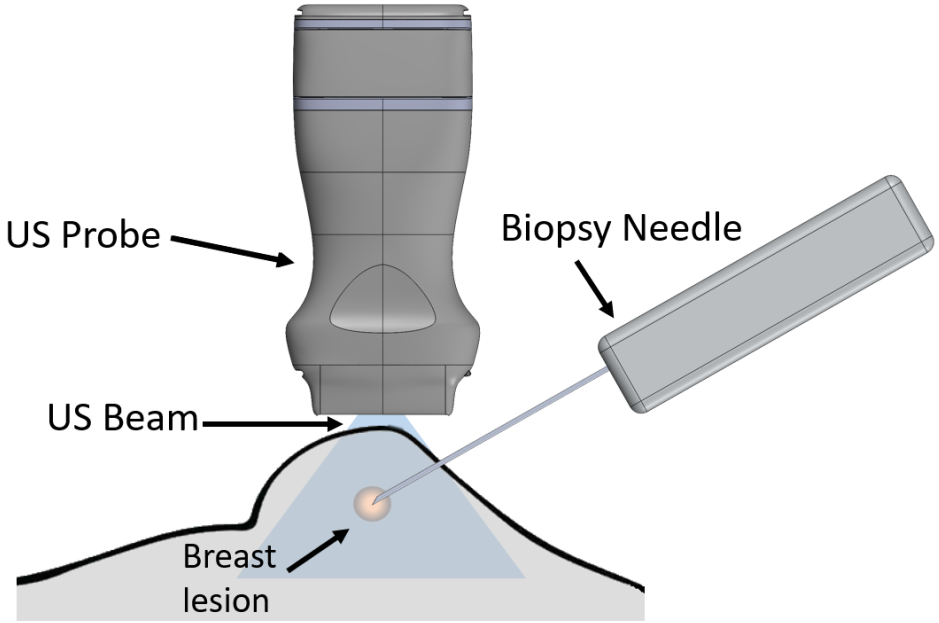

Fig. 1. Overview of ultrasound-guided breast biopsy with core needle.

Acknowledgements

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020
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Tissue-Mimicking Materials for Breast Phantoms: Synthetic Materials for Ultrasound Imaging

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Abstract

Breast cancer is one of the most diagnosed cancer in the world, according to the World Health Organization (WHO), it is estimated that in 2020, out of eight diagnosed cancers one is breast cancer [14]. Biopsy is the gold-standard diagnostic procedure to determines the existence of cancer [10]. Phantoms are models composed of materials that mimic human tissues, having same or similar acoustic properties [1]. Since 1960, phantoms have been used for characterization, calibration and testing new systems (e.g., cardiac motion evaluation, percutaneous access) [1,11]. Nowadays, ultrasound (US) phantoms are used for technical training in clinical procedures (e.g., biopsies and anesthesia) [1,6,11]. The common tissue mimicking materials (TMMs) used for the construction of phantoms are biological materials such as agar and gelatin, due to the similar of properties to human tissues (Table 1) [1,6], they get better results mimicking human tissues but they have the disadvantage of suffering dehydration, decomposition and they are prone to be a good environment for bacterial growth, besides, they have lower temporal stability and higher mechanical fragilities [1,9].

A common alternative to organic materials to create a realistic phantom it's the synthetic materials. They present lower speed of sound (SoS) and attenuation coefficients however by adding additives it's possible to change this characteristic to achieve closest properties to human tissues [1]. Specific criteria were established to narrow down the research about the best synthetic material to create a durable, easy to store and simple to fabricated phantom. Four synthetic materials were found, the base components of these four phantoms were ballistic gel, gel wax, SEBS and silicone. The materials were investigated and cross-compared (Table 2) [2–5,7,8,8].

The material that had the best results was the ballistic gel-based phantom. It had a speed of sound and attenuation coefficient similar to the breast tissue. Moreover, it does not dehydrate and can be stored in room temperature, it is thermoreversible, the production process is simple, and the product life is estimated to be up to three years.

Table 1. Acoustic properties of breast tissue. Source: Adapted from [1,13].

Tissue	Velocity (m/s)	Density (Km/m3)	Attenuation (dB/cm MHz)	Acoustic Attenuation (MRayl)
Breast	1510	1020	0.75-24dB/cm 1-10MHz	1.54

Table 2. Comparison of materials.

	Silicone [3, 12]	**Ballistic Gell** [3, 12]	**Paraffin (Gel) Wax** [2]	**SEBS** [5, 8]
Curing Process	24h	12h	4h	4h
Product life	3650 days	1095 days	365 days	270 days
Component amount	4	3	3	3
Speed of sound	1290 m/s	1537 m/s	1445 m/s	1480 m/s
Reusability	No	Yes	Yes	Yes
Storage requirements	Room temp.	Room temp.	Room temp.	Room temp.
Attenuation coefficiente	∼0.10-12-99dB/cm 1-5MHz	1.07∼14dB/cm 1-12MHz	0.71-9.93dB/cm 3-9MHz	0.59-26.96dB/cm 1-10MHz

Keywords: Breast Phantom · Synthetic Materials · Tissue Mimicking Materials.

Acknowledgements

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020
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Validation of a Robotic and Game-Based Framework for Upper Limb Rehabilitation

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Abstract

Traditional rehabilitation methods tend to be tedious and repetitive not only to the patient but also the physiotherapist. Moreover, the exercises require the therapist to manually move the patient affected limb continuously through many repetitions which can become tiresome.

Currently, the integration of robotic systems in rehabilitation is very promising as robots can reduce the therapist workload while ensuring repeatability and can increase the intensity of the exercises in a controlled manner [**?**]. Also, the use of games and VR has been an attractive solution to motivate and increase the commitment of patients during long periods of rehabilitation [**?**, **?**].

The aim of this work is to develop a framework that controls the KUKA LBR iiwa 7 R800 collaborative robot arm using the popular Unity3D game-engine.

The KUKA LBR iiwa 7 R800 is a collaborative robot with 7 degrees of freedom and reach of 800mm. It has a force sensor in every joint which makes possible to accurately estimate the external force applied on the robot's flange [**?**]. The force applied by the patient on the robot could be helpful to quantify the effort made during the training session.

The Unity engine allows to create many genres of games in both 2D and 3D perspectives while also being popular and free. As a result of this and since it also has been used by various researchers [**?**, **?**] it shows to be a good solution to integrate serious games for rehabilitation.

It was developed a test interface in Unity to demonstrate the framework's functionalities but more importantly to validate the communication protocol and verify if it stays stable and responsive in different network configurations.

The framework main functionalities range from allowing the therapist to design an exercise for a patient by moving the robot by hand, add motion overlay to change the robot's movement throughout the circuit, configure the robot's velocity and number of repetitions and generate a training report that could be useful to the therapist (Fig. 1.). It is expected that the creation of a framework that joins a robotic system with a game-engine platform helps the further development of patient customized rehabilitation solutions that integrate both technologies.

The framework response time was tested in three network configurations to verify if it is secure for medical use. The first is defined as a minimum load state as the system was tested with a direct Ethernet connection between the computer and the robot. At

the second level, both devices were physically connected to a router, thus considering a low load state on the network. At the third level, it was connected a smartphone on the previous configuration that transmitted real-time video data to the computer while the tests were carried out. This was considered as a medium traffic level on the network.

Overall, the framework's general delay stays below 80ms and it can soft-stop the robot's movement in less than 100ms even in the worst case tested. Also, the framework reaction time to communication errors stays on average at 300ms. This study shows that the framework is responsive even in critical situations for a procedure where a small delay on the response time is not serious such as a rehabilitation system.

The framework shows to be viable to integrate in a medical environment safely if it is established a direct connection or there is minimal traffic on the network. Results showed that an increase in network traffic produces higher and more unpredictable response times so it is not advised to run the framework in a busy network.

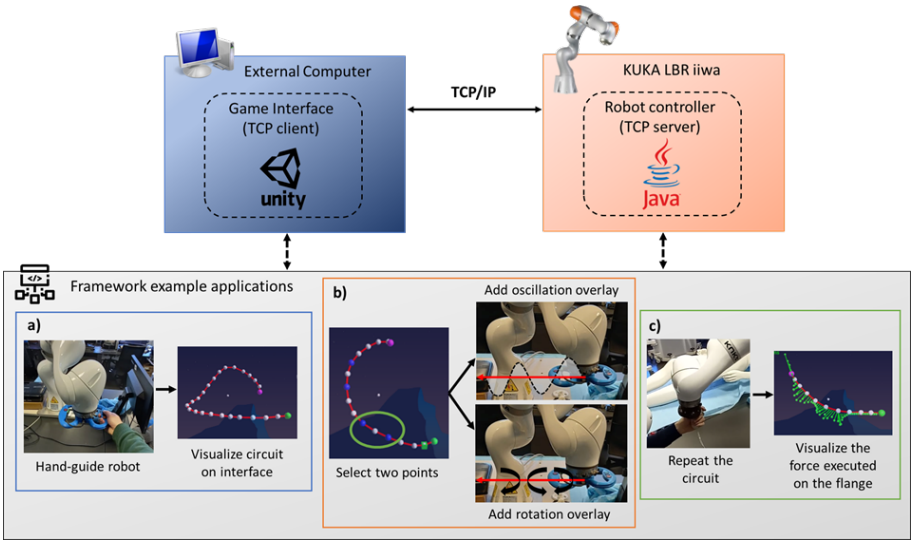

Fig. 1. Framework overview. (a) Example of hand-guiding the robot to create an exercise and visualize it on the interface. (b) The therapist can select two points on the circuit and add a movement overlay to the robot. (c) Example of doing a training session and having a report which shows the force pattern executed by the patient during the training.

Keywords: Upper Limb Rehabilitation · Communication Framework · KUKA LBR iiwa · Unity · TCP/IP

Acknowledgments

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds,

through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020. The authors also acknowledge Fundação para a Ciência e a Tecnologia (FCT), Portugal and the European Social Found, European Union, for funding support through the "Programa Operacional Capital Humano" (POCH) in the scope of the PhD grant SFRH/BD/136721/2018 (B. Oliveira).

Application of 2D Packing Algorithms to the Woodwork Industry

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Abstract

The paper's objective is to solve the well-known, well-studied problem of 2D Packing applied to the Wood Work industry to reduce waste through a more efficient reintegration of raw materials into the production cycle for this multi-objective strategy, evolutionary and learning processes are explored throughout the problem-solving process.

The Wood Work 4.0 (WW4.0) project aims to develop new approaches to manufacturing furniture, mainly in Small and Medium Enterprises (SMEs). As a sector that modernized by introducing new machines and processes, the management of the internal processes is still at a very archaic stage and impacts the overall operation of the system. Thus, the WW4.0 project aims to develop new approaches that allow the total digitization of the internal processes of the furniture production chain in such a way that integrates them into a global approach.

The 2D packing problem merges the WW4.0 project with the development of optimization algorithms for the scheduling of raw material according to the reference produced at a given moment. With this, it is intended to reduce the waste from cutting wood, be these regular or irregular-shaped cuts. That said, the study offers numerous advantages such as the reuse of raw material, less labor effort at the factory floor level in terms of the search for raw material, such as the positioning of the cut itself, and a possible and subsequent full automation of this area of work.

The problem of 2D Packing is searching for the ideal packing sequence for a set of 2D objects. This problem is considered NP-complex and has a high computational cost. As mentioned above, the objective is to optimize the positioning and use of the raw material to cut using multi-objective strategies and evolutionary and learning processes. This way, the search for papers relevant to the work was carried out.

Zhao et al. (Zhau et al., 2022) [3] present a learning method to solve the 2D packing problem with 2D rectangular objects. The sequence of objects represents the solution, and the layout is built sequentially, piece by piece. Centroid positioning rule techniques are explored with a lower value for the part's positioning, and then the Q-learning method is applied. Three groups of conditions are defined for the test. The computational results show that the Q-learning approach produces better compactness compared to the stochastic sequence in the layout of the parts.

Gomez and Terashima-Marin (2017) [2] propose three multi-objective evolutionary algorithms to identify sets of hyperheuristics to approximate the Pareto front. Namely, Non-dominated Sorting Genetic Algorithm-II, Strength Pareto Evolutionary Algorithm,

and Generalized Differential Evolution Algorithm. The algorithms were extensively explored in a large set of 2D Packing problems with convex and non-convex irregularly shaped objects under different conditions and configurations. The study presents an analysis where the robustness and flexibility of the strategies outlined are evaluated, obtaining encouraging results compared with a set of simple heuristics usually used in this type of problem.

Fang et al. (2021) [1] propose a strategy based on the Particle Swarm Optimization algorithm where he obtained efficient results with a reduced execution time. Hybrid strategies have been explored with promising results.

As we can see in the research summary, the state-of-the-art is quite advanced when understanding regular shapes but less developed regarding irregular shapes. However, it did not evolve into an algorithm that reuses raw material based on collecting and storing data, which is the study's final objective.

For successful completion of the project, the primary strategy will be the analysis and resolution of each of the topics:

1. Create a matrix representation of the wooden board to be cut.
2. Identify the objects to cut in that matrix and optimize their positioning using optimization tools such as genetic algorithm and particle swarm optimization, among others.
3. Create a database to store all information regarding the leftovers (waste storage represents leftover boards that have already been cut but can be used for some other cuts, reducing waste).
4. Explore multi-objective strategies and measures to assess the robustness and efficiencies of the strategies developed.
5. Optimize the procedure for identifying boards located in the leftovers regarding information like area, dimensions, thickness, material, and direction of the wood veins.
6. Explore the behavior of optimization algorithms in solving 2D packaging problems and incorporate learning strategies to predict parts destined for permanent waste.

Future work includes the performance evaluation of the developed algorithms using actual data.

Keywords: Optimization · Combinatorial Optimization · Packing Problems · 2D Packing.

Acknowledgement

This work was supported by Norte 2020 Portuguese Program under the grant Norte-01-0247-FEDER-072593 and FCT — Fundação para a Ciência e Tecnologia within the Project Scope UIDB/05757/2020.

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Ultrasound Training Simulator Using Augmented Reality Glasses: an Accuracy and Precision Assessment Study

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Abstract

Although ultrasound (US) imaging has historically been seen to be harmless, its use is heavily reliant on the operator [5]. This is owing to the poor image quality and artifacts, such as speckle noise, shadows, or signal dropout, which limits interpretation and may mislead diagnosis. As a result, there has been an upsurge in research of US simulators for medical training in recent years [6]. The use of simulators to train physicians has proven its effectiveness, but most of them require specific facilities and hardware.

In the last few years, augmented reality (AR) has gained relevance to simulate real scenarios which can avoid large setups and broaden medical training to more physicians. These systems work by layering virtual information over a real image [3]. Moreover, an AR system can also track the movements of objects using cameras and display the information over them, eliminating the need for the user to shift the attention from the object's movements [4]. Systems that use AR techniques for US navigation employing head-mounted displays were already developed decades ago [2] [1].

This work proposes a new framework for the training of US images acquisition and interpretation. It consists of a custom-made application that runs on AR glasses (Microsoft HoloLens 2) and interacts with a US simulator application. The AR glasses track the orientation of a QR code mounted on a US probe, communicating its orientation with the US simulator application. This allows the physician to interact with a US probe seeing in real-time the US image in the physician's field of view. The QR code tracking assessment of the AR glasses was conducted by measuring the orientation accuracy and precision when compared with the measures of an electromagnetic tracking device (i.e., NDI Aurora).

The proposed solution presented a good performance, rendering the US image in AR glasses with real-time feedback. Moreover, it can track the QR code on the US probe with an accuracy of 0.755^{o}, and a precision of 0.018^{o}. Overall, the proposed framework presents promising results and the use of AR glasses as a tracking device reached a good performance.

Keywords: Ultrasound Simulation · Augmented Reality.

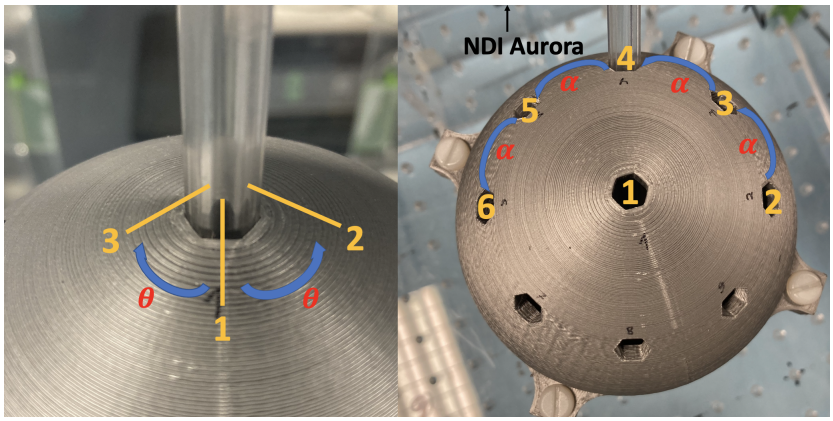

Fig. 1. Measured rotation along the US probe's central axis represented by θ on the left. Representation of the 6 different positions tested and the movement used to calculate the accuracy represented by α.

Fig. 2. *

Table 1: Orientation accuracy measured between different positions. (Mean ± Standard Deviation)

Position differences	**Accuracy**		
	Ground-Truth	***NDI Aurora***	***HoloLens***
α2 - 3	45º	44.64º ± 0.16º	44.6º ± 1.00º
α3 - 4	45º	43.54º ± 0.07º	42.63º ± 0.66º
α4 - 5	45º	44.14º ± 0.44º	44.39º ± 0.56º
α5 - 6	45º	44.09º ± 0.86º	44.28º ± 1.20º
Θ1 - 2	60º	60.55º ± 0.21º	59.79º ± 0.26º
Θ1 - 3	60º	60.51º ± 0.14º	60.22º ± 0.12º

Fig. 3. *

Table 2: Orientation precision measured at each position (Mean ± Standard Deviation)

Precision	
NDI Aurora	***HoloLens***
0.0094º±0.0063º	0.0180º±0.0217º

Acknowledgement

This work was funded by the projects "NORTE-01-0145-FEDER-000045" and "NORTE-01-0145-FEDER-000059", supported by the Northern Portugal Regional Operational Programme (NORTE 2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT (Fundação para a Ciência e a Tecnologia) and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020.

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A Mobile Digital Assistant for Treatment Monitoring

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Abstract

The implementation of digital assistants in healthcare has been a development focus in recent years [3], the need to use this type of systems has increased due to population growth and the consequent overload of health systems. In this perspective, the treatment and monitoring of patients is one of the areas that can benefit from the integration of digital assistants [1]. Patients can have a much closer and constant monitoring with the support of intelligent systems. Doctors and caregivers are thus, able to automate tasks such as monitoring patients and the creation of electronic reports. Despite all the assistants already developed [3], the digital assistants dedicated to treatment monitoring still lack customization and adaptability to the user. The lack of usage simplicity and privacy also seems to constrain the adherence and acceptability of digital assistants [4]. In order to assess the issues above, this project plans to develop a mobile digital assistant, which uses neural networks to evaluate a patient's health condition and evolution in an ongoing medical treatment at home. The digital assistant communicates with the patient through a chatbot using the state-of-the-art algorithm DIET Classifier [2] to interpret the user's sentences, it also enables the patient to complete daily and weekly assessment tasks, as well as the monitoring of general the well being. The medical staff is able to monitor the evolution of the patient's treatment and customize it accordingly. Early testing results show good acceptability of the digital assistant, with a System Usability Scale of 80 points. They also show a preference in the usage of the digital assistant to realize the daily assessment scales over the classic paper questionnaire, even though the completion times were higher in the mobile application.

Keywords: Digital Assistant · Artificial Intelligence · Natural Language Processing · Health Chatbots.

Acknowledgments

This work was funded by the project "NORTE-01-0145-FEDER-000045", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT - Fundacao para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020.

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ARTIFICIAL INTELLIGENCE SYSTEM TO DETECT AND DEBLISTER MEDICATION FOR SMART PILL DISPENSER

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Abstract

Previous research found current state-of-the-art medication support devices still have some flaws that could be addressed, such as the time-consuming task of manual deblistering to fill the dispenser and the degradation of the drugs' potency due to their exposure to environmental factors. [8]. To ease these issues, a system to deblister and dispense medication was previously proposed [7].

The achievability of deblistering the medications at the time of dispensing was verified through deblistering tests. Those tests aimed to assess the forces required to extract pills from their blister packs; And were conducted with a custom punch and backplate with orifices developed for said tests. At the end of the pill deblistering tests, collected data showed lower compression values were needed to extract pills in a given position relative to the punch. As the conducted tests requiring manual positioning of the blisters beneath the press yielded successful results, the automation of the blister placement was necessary to develop the automatic pill dispenser. Therefore, a system to detect pills and automatically find the coordinates that allow for the lowest pill extraction force is proposed. Ultimately this system will be responsible for detecting tablets from a given blister pack so they can be correctly placed, according to test results, under the deblistering punch.

The proposed system will be based in current image processing machine learning algorithms as several works present in literature [10], [6], [3], [2], [5]. These systems are generally applied in pill production lines in order to avoid defects [3], [1], [4] and in medical environments where the correct identification of medication is required [2], [9]. As such, the proposed system will be capable of distinguishing individual pills inside blister packs, allowing for the detection of almost empty and empty blister packs; This will allow for half-full blister packs to be inserted into the device reducing medicine waste, as the system will be capable of detecting the remaining pills. The developed pill detection system will be subject to trials using collected blister pack samples of different shapes and sizes to assess its capabilities. Then, after merging it with a deblistering press, tests on the efficacy and efficiency of deblistering will be undertaken.

This system will allow seamless integration of the deblistering process into the medication dispenser device. It will allow for the timely and correct deblistering of pills for patients; it will keep medicine protected inside their blister packs, and even allo

Keywords: mHealth · OCR · Medical Analysis · AI.

Acknowledgements

This work was funded by the projects "NORTE-01-0145-FEDER-000045", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020.

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Smart Scan of Medical Device Display to Integrate an mHeath

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Abstract

The daily monitoring of the physiological parameters is essential for monitoring health condition and to prevent health problems. This is possible due to the democratization of numerous types of medical devices and promoted by the interconnection between these and smartphones. Nevertheless, medical devices that connect to smartphones are typically limited to applications provided by manufacturers, using proprietary protocols, which poses a problem to data integration.

This paper proposes an intelligent scanning system to simplify the collection of data displayed on different medical devices screens, recognizing the values, and optionally integrating them, through open protocols, with centralized databases. To develop this system, a dataset comprising 1614 images of medical devices was created, being the images obtained from manufacturer catalogs, photographs and other public datasets. Then, three object detector algorithms (yolov3, SSD 320 × 320 and SSD 640 × 640) were trained to detect digits and acronyms/units of measurements presented by medical devices. These models were tested under 3 different conditions to detect digits and acronyms/units as a single object (single label), digits and acronyms/units as independent objects (two label), and digits and acronyms/units individually (fifteen labels). Models trained for single and two labels were completed with a convolutional neural network (CNN) to identify the detected objects. The most promising approach was the use of the SSD 640 × 640 for a fifteen labels, with a resulting precision of 96,39%. To group the recognized digits, a condition tree based strategy on density spatial clustering of applications with noise (DBSCAN) was used.

Lastly, the entire developed system would be validated by integrating it into an application and tested by a group of volunteers.

Keywords: mHealth · OCR · Medical Analysis · AI.

Acknowledgements

This work was funded by the projects "NORTE-01-0145-FEDER-000045", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020.

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On feasibility of Post-Quantum Cryptography algorithms on constrained devices

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Abstract

Quantum computers are a very strong possibility regarding performing certain types of calculations that will overthrow Rivest-Shamir-Adleman (RSA) Algorithm and Elliptic Curve Cryptography (ECC), two of the most used cryptography schemes. The National Institute of Standards and Technology (NIST) estimates that large-scale quantum computers will be available as soon within 15 years from now. This technology is viewed as a disruptive innovation that will most probably overcome the many limitations over the big data era. Nowadays, Google says its quantum computer was able to perform a calculation in 200 seconds that would have taken 10,000 years or more on a traditional supercomputer. Probably this is not 100% accurate, since IBM rushed to say that to perform the task, a traditional supercomputer could only take 2.5 days or less. According to The Software Alliance [4], cybercriminals stole 423 million identities in 2015. In 2018, data breaches exposed five billion records, which was a drop from the 7.9 billion records that were compromised in 2017, but is still no small number. The threats to data security continue to multiply: in 2019, the top cybersecurity concerns include relatively new types of threats, such as form-jacking, cross-site scripting XSS attacks, and AI botnets. Consumers are not the only losers when data is compromised — companies often lose employee data as well. Assuming that the world's most valuable resource is no longer oil, but data, and since data is just one click away for many parties, including state sponsored ones, the importance of unbreakable cryptography schemes and Post-Quantum Cryptography (PQC) ones are in the world agenda. Dang et al. [11] indicates the importance of developing new cryptographic algorithm standards that assure resistance to quantum computer attacks and have the capability to run on today's hardware. The United States of America envisioned, via NIST since 2016, and pushed forward a Post-Quantum Cryptography Standardization [18] effort, aiming on developing a new public-key cryptography standards that will specify one or more additional unclassified, publicly disclosed digital signature, public-key encryption, and key-establishment algorithms that are available worldwide, and are capable of protecting sensitive government information well into the foreseeable future, including after the advent of quantum computers. Presently, a Round 3 winners where announced in Public-Key Encryption/KEMs: Classic McEliece [2], CRYSTALS-KYBER [7], NTRU [10], SABER [12] and Digital Signatures : CRYSTALS-DILITHIUM [7], FALCON [14] and Rainbow [13]. In addition, the following eight candidate algorithms will advance to the third round (alternate candidates) in Public-Key Encryption/KEMs: BIKE [5], FrodoKEM [3], HQC [1], NTRU Prime [15], SIKE [16] and in digital signatures: GeMSS [8], Picnic [9] and

SPHINCS+ [6]. Since having access to a quantum computer has proven to be very difficult task, the contribute that one might do to study, investigate and produce practical results in the field of PQC algorithms, is to study this matter in some IOT used devices (ex: different generations of Raspberry Pi's, other constrained devices) since PQC is all about designing cryptographic solutions that can be used in traditional computers and can prove to be strong and resistant against quantum and traditional cryptanalysis. One thing is to develop quantum-proof cryptographic algorithms and another thing is having the ability to implement those PQC algorithms on hardware that is being used today. According to Kannwischer [17] et al. for 11 PQC schemes, the available implementations require more memory or depend on libraries (external) which makes them unsuitable for embedded devices. So it's very important to test and verify which post-quantum cryptography algorithms can be used targeting the security of today's data in the future. So as Dang et al. [11] strongly suggests and justify the use of soc platform and design methodology, indicating the potential of substantial speed-ups instead of purely software implementations. As so, three domains of expertise are being targeted today: the theoretical one, the hardware one and the software one. This research contributes to the NIST project third PQC standardization by assessing the platform and resources requirements (on constrained hardware, such as Raspberry Pi's, and software implementations available for the public) as for the successful implementation of the Classic McEliece, CRYSTALS-KYBER, NTRU and SABER algorithms, all round 3 NIST algorithms finalists of Public-key Encryption and Key-establishment.

Keywords: Post-Quantum Cryptograhic Algorithms · RSA · ECC · NIST · Classic McEliece · CRYSTALS-KYBER · NTRU · SABER.

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Insertion of RFID Tags into Plastic Parts Using Ultrasonic Welding

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Abstract

The radio frequency identification (RFID) technology has been used mainly to manage products and have stock control in real time [1–3].

RFID tags are commonly used in the form of tags positioned outside the object or are also usually seen on smartcards that are built through layers of plastic and inside there is a layer with the RFID.

However, the RFID insertion strategies are still sub-optimal, thus, there has been attempted to create methods to insert labels during the plastic injection process. Even so, must of the available strategies do not satisfy the needs of large companies, since they are not standard.

So, the objective of this study is to present a proof of concept of a new RFID tags insertion strategy adapted to plastic parts. The system uses a robot to pick up an RFID chip and insert it into a cavity of a mold. Then it will take some of the same material and with an ultrasound welder the plastic material will be melted to close the structure.

For this project, we started by carrying out some experiments to understand the limitations of chips, such as: maximum distance that can be detected, maximum temperature without damage when subjected to a welding process. With these experiments we will validate our proof of concept with the workflow shown in the Figure 1.

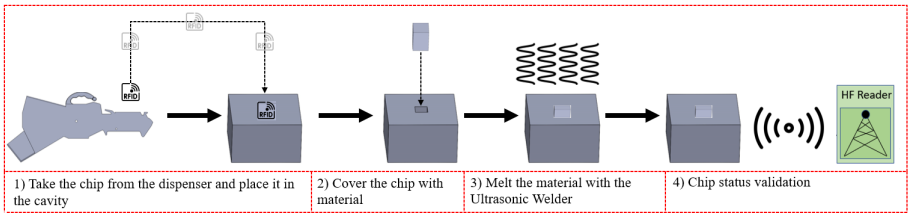

Fig. 1. Idealized insertion process workflow

In this investigation we were able to conclude that chips are detected at greater distances if they are centered with the reader's antenna, moreover, it was possible to prove that they withstand high temperatures.Also, through a vacuum system and ultrasonic welding, it was possible to validate our proof of concept, as the chips, after being inserted into the parts, remained functional. However, the pieces, as we can see, always have a mark related to the ultrasonic welder, which for more aesthetic cases may be an obstacle.

Overall, the current results corroborate the potential of this technique for the insertion of RFID in standard processes of the plastic industry.

Keywords: RFID · Plastic Injection · Ultrasonic Welding.

Acknowledgements

This work was funded by the project "POCI-01-0247-FEDER-047195-01", supported by the COMPETE – Operational Program Competitiveness and Internationalization, under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020, UIDP/05549/2020 and LASI-LA/P/0104/2020.

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VR Serious Game to Treat Schizophrenia

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Abstract

Schizophrenia is a psychiatric disorder which, despite the fact of it has been researched since the 19th century and with the evolution of technology, has not yet found a cure. In the past, there was a lack of information about this mental illness, and people were considered insane and committed to psychiatric centers [1]. With the advance of research, some types of schizophrenia have been identified, each with its own particular symptoms.

Treatment processes were done through electroconvulsive therapy, a technique that applied shocks to the patient in order to obtain an antipsychotic response, with research until these days to analyze its effectiveness. Another alternative was the use of antipsychotic medicines, but their effect was partially functional [2]. Schizophrenia can be hereditary or environmental, but it is known that the earlier it is discovered, the better the effectiveness of the treatment, because as time goes by the symptoms get worse.

Technology has been a great helper in the healthcare field for mental illness. Various systems are used as aids in sharing information, treatments, and therapies. Apps, websites, serious games, and various technical gadgets enable more effective and accurate results [3].

With the principle of making information about mental illnesses more accessible, people can have a better comprehension of the details of a patient with psychological problems, as well as the patients can understand better their particularly difficulties.

Since the 90's, Virtual Reality (VR) has been a great helper in the treatment process of patients with psychological problems. This is due to the great immersiveness provided, placing the patient in various scenarios so that, with medical monitoring, he or she is exposed to situations that stimulate the brain to make decisions. With training in everyday tasks, the patient is proposed to accomplish simple goals and with the tranquility of being in a controlled environment.

A possibility of using VR applications is with serious games that enable a robust, immersive and secure experience. Studies prove the effectiveness of using VR games for people with schizophrenia for their motor and cognitive stimulation [4]. A major goal of advancing research and development in the treatment of people with mental illness is to reintroduce them back into society, interacting and contributing with others [5].

The present work aims to optimize and produce scenarios of a serious game, and improve its immersiveness, enabling the capture of feedbacks, by configuring sensors that can monitor the user of the application for changes in the game in real time, making it possible to have better control over the player's experience. With this, progressing

research into the improvements of virtual reality when applied to the treatment of people with schizophrenia.

A virtual scenario based on the Marques station in Porto, Portugal was created for this [1]. Blender was used to generate the 3D modeling, while Unity was used to build the other features, such as virtual reality integration. Benches, televisions, garbage cans, food machines, lighting objects, signposts, NPCs (non-player characters) in the station or on the train, tracks, the train with four cars, and the station itself are all included in the scenario.

The player begins on the station platform, with the purpose of waiting for the subway to arrive, boarding it, traveling to the next station, and exiting through the designated regions, requiring the user to accomplish a series of regular daily tasks. This presents a series of challenges for a patient with schizophrenia who may experience stress if he or she encounters an NPC, is in closed spaces, or has to complete each objective within a particular period of time.

The experience is created using virtual reality glasses, such as the Meta (Facebook) Oculus Quest 2, which immerses the player in the environment and allows interaction through its controls.

The usage of a haptic vest is an intriguing aspect of the research, as haptic gadgets significantly boost immersiveness, which benefits the project and leads to better patient treatment outcomes [6]. The project will use the TactSuit X40 model, built by bHaptics, and includes forty vibro-tactile motors. A poll was conducted with twelve students who played our game with the vest (for the time being, the testing are being conducted with persons without schizophrenia), and the majority of them assessed the immersiveness of the game with the vest, as well as their response, as good to excellent. The majority of them stated that the vest did not cause them any discomfort.

Other essential elements include the methods for receiving data from users both during and after the game. The project will make use of an Apple Watch Series 6 smart watch that can detect heart rate. The information will be recorded in a real-time database and used by the application to tailor the game to the user's preferences. As a result, if the player's heart begins to race, an NPC may approach him to try to calm him down. Also, employ cameras to record the player's motions on video and examine whether their body movements indicate any discomfort from the user so that the game can be comforted. The users of our game displayed a variety of emotions, some good and some bad, including anxiety, claustrophobia, apprehension, tranquillity, happiness, and relaxation, according to the same research cited previously.

The problems we encounter in this project are tailoring the serious game to each patient and ensuring a high level of immersion, with the goal of assisting them in speeding up their treatment and improving the efficacy of their outcomes. Another goal is to create new surroundings and methods for helping schizophrenia patients overcome obstacles in their daily lives and reintegrate into society. In addition to exploring ways to use virtual reality to elicit curiosity and positive feelings in those who use it, consequently advancing technology and health-related sectors.

Keywords: Virtual reality · Schizophrenia · Mental illness · Health care · Serious game.

Acknowledgments This work is funded by the European Regional Development Fund (ERDF) through the Regional Operational Program North 2020, within the scope of Project GreenHealth - Digital strategies in biological assets to improve well-being and promote green health, Norte-01-0145-FEDER-000042.

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Intelligent System for Real Time Monitoring of the Head Pose of Newborns

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Abstract

Deformational plagiocephaly (DP) is an asymmetrical distortion of an infant's skull that affects 1 in 5 newborns, with an even higher prevalence in prematurely born infants (38%). Besides cosmetic concerns, newborns with deformities can also experience development delay [1].

Currently, it is accepted that one of the major causes of DP is a preferential head positioning [1]. Thus, the goal of this research lies in the development of an intelligent system to monitor newborn's head pose and to automatically generate alerts when needed.

The system will be composed of an RGB camera, an intelligent system capable of determining the head pose in real time and an app that will show all essential data as well as alarms to reposition the baby.

To develop an intelligent monitor system, it becomes necessary to create datasets of the subject of study. Thus, it will be developed a synthetic setup for data collection, where an engine will simulate the head rotation in a mock model. Subsequently, a neural network will be trained to identify facial landmarks on the baby's face and later the head pose estimated from the spatial relation between all landmarks. Concerning the head pose estimation, it relies on the identification of head rotation based on the spatial relation between multiple head landmarks. Due to possible occlusion of some landmarks, the method will be trained to predict the head pose from a subset of all landmarks.

The final software was validated in two ways. The first validation used a new mock model, working as a proof of concept of the accuracy and feasibility of the described methodology in a baby, which may improve the current clinical practice. The second validation was made using adult people and the groundtruth was creating using polhemus. Polhemus is a tridimensional eletromagnetical capturing device that can determine the position and rotation of a sensor [2]. The sensor of polhemus was applied in the subject's head to determine the real head pose and compare it with the system prediction. Overall, the proposed software was developed to promote smart self-monitoring of head development, preventing possible pathologies.

Keywords: Deformational plagiocephaly · Head pose · Artificial Intelligence · Deep Learning.

Acknowledgments

This work was funded by the project "NORTE-01-0145-FEDER-000045", supported by Northern Portugal Regional Operational Programme (Norte2020), under the Portugal 2020 Partnership Agreement, through the European Regional Development Fund (FEDER). It was also funded by national funds, through the FCT – Fundação para a Ciência e Tecnologia and FCT/MCTES in the scope of the project UIDB/05549/2020.

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