Metabolic.Care

A hardware and software platform to monitor and assess diabetic foot condition

Daniel Oliveira[1], Paula Sousa[1], Virginie Felizardo[1], Nuno C. Garcia[1], Celina Alexandre[1], Nuno M. Garcia[1,2]
[1]University of Beira Interior, Computer Science Department, Covilhã, Portugal
[1]Assisted Living Computing and Telecommunications Laboratory (ALLab), Instituto de Telecomunicações, Covilhã, Portugal
[2]Universidade Lusófona de Humanidades e Tecnologias, Lisbon, Portugal
{danieloliveira, paulasousa, virgine, ncgarcia, celinaalexandre, ngarcia}@it.ubi.pt

***Abstract* — This paper describes Metabolic.Care, a sub-project that integrates hardware and software with the main goal of implementing a solution that generates warnings for the diagnosis on patients with diabetic foot. This paper also describes the adopted strategies and best practices found to solve the problems.**

Keywords — medical image processing; interoperability of medical data.

I. INTRODUCTION

Health has been a major focus of Information and Communications Technologies (ICT) solutions aiming to improve the quality of personal healthcare and efficiency of operational processes, reducing costs and minimizing the number of potential clinical errors, and also allowing patients to have some control over their medical data and state of health. This kind of solutions is based on "the individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns", which is the current definition of quality of life proposed by the WHOQOL group in 1994 [1].

Currently, there are solutions that aim to meet these needs, and are focused on the patient, the healthcare provider, or both [2-6]. These solutions are, in most cases, platforms built on Internet-based integrative healthcare monitoring equipment, designed to provide healthcare management and services for individuals, families and communities, establishing systems of connected and interoperable health solutions. These platforms are, in most cases, implemented to allow access to them in a familiar environment, promoting independence and providing patients with the opportunity to get a personalized management of wellness and health.

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The remainder of this paper is organized as follows: this paragraph concludes section I, the Introduction; section II gives a brief description of TICE.Healthy project, its framework and goals; section III describes the sub-project Metabolic.Care; section IV presents the proposed solution; and finally, section V concludes the paper.

II. TICE.HEALTHY

TICE.Healthy [7] (2011-2014) is a project funded by the European Union and the Portuguese Government, anchored on the TICE.PT (Center for Competitiveness and Technology, Center for Information, Communication and Electronics Technologies) Program [8]. According to the official website, the main purpose of TICE.PT is to set up a framework that gathers TICE's main players in innovation processes, research and development, transfer of knowledge, advanced training, production of products and services, marketing and internationalization (further information available at [9]).

III. METABOLIC.CARE

Diabetes mellitus (DM) is one of the most common chronic diseases in nearly all countries. It is estimated, according to the International Diabetes Federation [10], that 2-10% persons with diabetes may develop foot ulceration during the disease course and this is the precursor to approximately 85% of lower extremity amputations. It was found that monitoring a foot's temperature may reduce the incidence of foot ulcers by more than 60% [11]. Since the early detection of diabetic foot isn't much explored, and like in other diseases or illnesses, self-knowledge can lead to behavioral changes that prevent worst case scenarios, in this particular case, an early detection of poor extremity vascularization of the feet might prevent necrosis of the tissue, which may eventually result in amputation [12].

Metabolic.Care (PPS#10) aims to develop and integrate a solution to monitor patients with metabolic changes, mostly related to DM, and provide feedback of the evolution of their symptoms. Jointly with the industry partner *Exatronic*, PPS#10 the proposal is the development of a prototype that, in the context of a formal medical consultation, allows accessing the patient's evolution of a diabetes-associated condition known as diabetic foot.

The first activity of this sub-project was the study of the state of the art regarding the available methods for

vascularization measurement/detection: thermal, barometric and oximetric. After literature review, the thermal method stood out as the most widely used and that presents good results, and was chosen as the right choice for the task at hand. Since it is a technique that detects small temperature variations in the human body [13], it allows thermal mapping of the feet which provides useful information for diabetic foot diagnosis, being used to detect disturbances in arterial circulation, assess microangiopathy and other changes, detect ulceration and re-ulceration risk areas, evaluate tissue vitality, diagnose osteomyelitis and monitor medical treatment response [14].

In a second phase, a survey of thermal-based techniques was done, and four techniques identified: electrical contact thermometry, infrared thermometry, infrared thermography and Liquid Crystals thermography.

After analyzing the advantages and disadvantages of the several techniques, it was decided to use the Liquid Crystals thermography method, since it presents a greater cost-efficiency, implemented in a physical platform, which will be addressed in more detail on the next section.

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It should be noted that this solution is not to be used alone or in a home environment, but rather to be used in a medical environment providing complementary technological means that enable a greater connection between physicians and patients, allowing a closer monitoring of the last, and provide them with an easier way to self-acknowledge the complications that they have and how they should handle them.

IV. Proposed Solution

The proposed solution for monitoring the diabetic foot is composed of a physical platform and a Hosted Application (external application) integrated in the eVida platform [15], a platform for the commercialization of products and services for Health and Quality of Life. eVida architecture and connection to external systems depicted in Fig. 1.

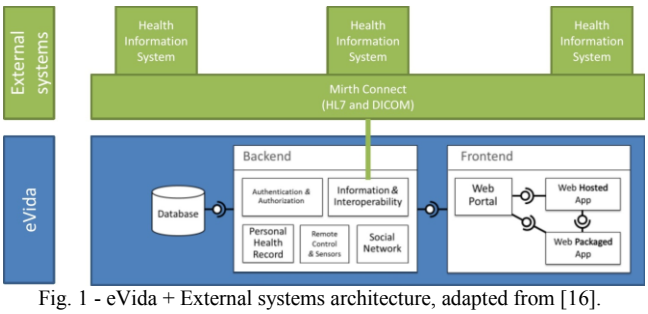

Fig. 1 - eVida + External systems architecture, adapted from [16].

The physical platform comprises an A3 scanner integrated in a platform with the top made of tempered glass, making it sturdy enough for a person to stand on top of, and the application that has several characteristics to achieve the proposed goals, such as:

- Be able to process thermographic medical images;
- Be interoperable with other eHealth systems;
- Have a friendly user interface;
- Be available online.

The working procedure of the solution will be explained in the next sub-sections.

A. *Medical appointment*

The procedure begins with a patient going to an appointment with his physician. During the appointment, the patient needs to be barefoot and climb to the physical platform to capture the thermal image of his feet. Afterwards, the physician uploads the image to the Hosted Application available through the eVida platform, along with relevant information acquired during the appointment.

B. *Image processing*

In this stage, the thermography images of the diabetic foot acquired by the platform have been analyzed, using several steps, in order to reach the objective of this project, in particular to allow the diagnostic, prognostic, monitoring, and to allow the registration and communication of medical information between health professionals and patients. For this, it is necessary the use of image processing and analysis algorithms.

The first step in the image analysis is the separation or segmentation of objects, in this particular case the feet from the image background. Since segmentation algorithms allow to find differences between the two feet, it makes possible the interpretation and grouping of contiguous pixels, thus it was used the Grabcut method [17].

This method is based in basic cuts, starting with a bounding box, predefined by the user, around the object to be segmented, calculating the distribution of colors of the object and the background, through Gauss model, allowing the construction of a random field over the pixels, designated Markov [18]. Along with an energy function that determines the connected regions, it calls to an optimization of the graphical cut.

After achieving the foot segmentation, it may be necessary to rotate the image in order to align the feet to the center, and thus split them in Regions of Interest (ROI). After this step, the corresponding ROI of each foot are compared, to identify if the feet of the patient present or not risk of developing diabetic foot problems. In case the patient has any kind of problem, an alert will be generated.

To compare the two feet, the distance of each pixel of each region of each foot was calculated; if this distance is higher than a given threshold, then that zone is classified as a risk region, because it would mean that both feet of the patient do not have the same temperature in the corresponding region, *i.e.*, the algorithm will be searching for asymmetries of the two thermographic images of the patient's feet.

After the image processing the image and relevant information of the patient are encapsulated in Digital Imaging and Communications in Medicine (DICOM) format and stored in the platform main database. The DICOM format and standard will be explained with more detail in the next section.

C. Interoperability and adopted eHealth standards

With the development of healthcare systems like Electronic Health Records (EHR) and Hospital Information Systems (HIS), the need for interoperability becomes a more evident necessity [19] that is recognized as one of the greatest hurdles that block emerging e-Health systems from not fulfilling the cost efficiency and improvements in healthcare that they aim to deliver [20]. Metabolic.Care solution proposes to solve the lack of interoperability problem with the use of two medical standards DICOM and Health Level 7 (HL7).

DICOM is a standard used to record medical images allowing its transmission and interpretation between healthcare and information systems. The DICOM object includes information related to the subject and circumstances of the recording of the image, *e.g.* performing physician name, patient name, acquisition date and time, institution name where the image was captured, and so on. For a full list check [21].

Although HL7 is a not-for-profit organization, its standards are recognized worldwide as one of the most used in e-Health [22]. It establishes how different systems should communicate between each other, while still being flexible enough to allow facility-specific needs for specialized data sets [23].

TICE.Healthy also uses a Resource Information Model (RIM) compliant repository to store the HL7 data along with a local URL to the DICOM images, since those are stored in a local repository. The communication with external applications is done via a broker, in the TICE.Healthy case, the Mirth Connect [24].

D. User-interface

While still under development, the user-interface has already a user friendly interface. Depending on the role of the user, it enables him/her to send images to the central database, access the evolution of the disease for a given patient, or review it.

E. Online availability

Since the application is integrated in the eVida platform as a hosted application, the application is always available online.

V. Conclusion

Tice.Healthy and Metabolic.Care plan to deliver a platform that helps patients with diabetic foot to timely monitor the evolution of the disease, by providing a platform using hardware and software that captures images of the feet using liquid crystal thermo-sensible sheets and a modified A3 scanner, along with an hosted application that allows the upload, the processing and the creation of alarms when there are differences in the image for the feet of the user, among other things.

The decision to use of medical standards such as DICOM and HL7 was taken to assure interoperability within the project but also to any other projects.

As the project has not finished yet, there are still some milestones for the remainder of 2014.

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