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mHealth system for the Early Detection of Infectious Diseases using Biomedical Signals

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Abstract. Detection at an early stage of an infection is a major clinical challenge. An infection that is not diagnosed in time can not only seriously affect the health of the infected patient, but also spread and initiate a contagious approach towards other people. This paper deals with mHealth system for medical care and pre-diagnosis. The developed mHealth system use an Android App that collects physiological signals from the patients with a portable and easy-to-use sensors kit. The focus of the work is put on being able to build a low-cost system that using a very small amounts of data (one set record per patient and day). The processed data are uploaded to an online database to train a clinical decision support system to automatically diagnose infections. The mHealth system may be operated by the same personnel on site not requiring to be medical or computational skilled at all. The implementation takes five kinds of measures simultaneously (Electrodermal Activity, Body Temperature, Blood Pressure, Heart Beat Rate and Oxygen Saturation (SPO2)). A real implementation has been tested and results confirm that the sampling process can be done very fast and steadily Finally, the App usability was tested, showing a fast learning curve and no significant differences are observable in learning time by people with different skills or age. These usability factors are key for the mHealth system success

I. Introduction

Nowadays, societies are ageing causing the increment of the elderly and depending people amount [1]. This fact increases the medical assistance costs and pathology ordering. Automate monitoring and pre-diagnosis of infectious diseases could improve the life standards of these patients and reduce health costs.

Smartphone technology evolution has helped to decrease transcription errors and has made that biomedical data are available everywhere. On the other hand, healthcare personnel becoming familiarized increasingly with mobile applications (Apps), introducing them for different purposes such as drug reference search, disease diagnosis, medical calculator, and pregnancy wheel [2].

Since all these reasons, we develop an Android eHealth App that collects patient constants, processes the data, and fills an online medical database (DB). The App requires a sensors kit to take the different measures and a web portal to visualise the information. This set forms a system.

It is the first achievement of a wider international research initiative carried out by EU Member States and Associated Countries and the Community of Latin American and Caribbean States (CELAC) within the 7th Framework Programme for Research and Technology Development (FP7). The name of the project is the “Design and implementation of a low cost smart system for pre-diagnosis and telecare of infectious diseases in elderly people”, abbreviated SPIDEP.

The main aim of this paper is to propose an eHealth App assuming blind measurements and non-stop data collection, considerations that are not included in other Apps. To this end, the rest of the paper is structured as follows. In the Section 2, a brief review of the works and technological developments carried out in the world of electronic health related to this proposal is made. Section 3 describes the eHealth system design and its functionality. In Section 4 some results and usability are described. Finally, Section 5 concludes and shows possible further research lines.

II. Related work

e-health does not only enhance the classical approach of medicine but brings new paradigms that require attention. The pharmacological industry benefits from more realistic tests that burst the efficacy of the research process [3]. Another example is the participating medicine or patient-centric, based in the communication, empathy and collaboration between patient and practitioner. Doctors get patients to actively participate in the treatment, getting more mutual satisfaction [4].

The present system focus on the field of institutional care, by applying biosensors in a short fraction of time. The use of devices for monitoring in health care is becoming less intrusive and more usual for patients [5].

Cloud is advantageous as hides the technicalities and brings scalability. However, it requires attention to implement systematic security model approach [6]. It is also necessary to indicate that the fact of adding more functionality to the cloud platform, however does not show that the acceptance is immediate in clinical activity [7]. An extra effort of communication around any technical implementation is necessary to minimize the disruption. The issue of personal data and privacy must be always addressed as it normally becomes a barrier [8].

The online DB can be also monitored in real time for Telecare, so that immediate action can be taken when any change raises an alert [9]. One of the key concerns is to design good filtering policies so that keeping at a minimum the raising of false alarms. Remote care, or Telecare brings more effectiveness providing real time surveillance and releasing medical specialists, becoming more focused on their main tasks with their patients.

III. Design and functionality of the mHealth system

In this Section, we analyse the design and the functionality of the mHealth system proposed.

A. System Description

Figure 1 shows a schema of the existing devices of the considered system. It consists of a portable hub, sensors kit, an Android mobile device running the App, local DB, online DB, and a dedicated web portal.

The hardware with the biosensors that are deployed daily on patients connected to a hub that multiplexes the concurrent measures collected. The second element is the mHealth application, running on an Android-based tablet, which gathers and pre-process the data from the hub. The third element is the Clinical Cloud DB accessible via web by authorized users that collects the information from all the APPs deployed on the field.

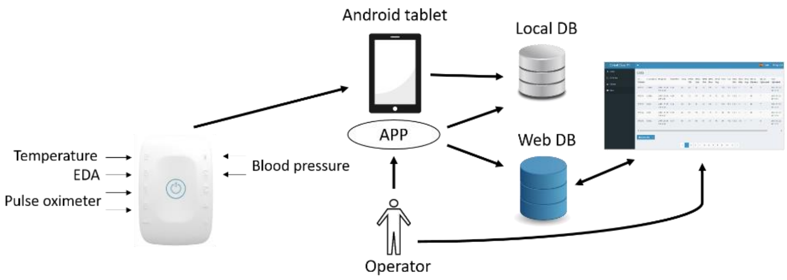


Fig. 1: A schema of the existing devices of the considered system.

The BiosignalsPlux (BPX) [10], hardware was selected for its versatility, ease of use, battery duration, or parallel data acquisition. After talking with expert medical staff, the physiological signals decided which must be recorded were body temperature, electrodermal activity (EDA), pulse oximeter, and blood pressure. The main aim was to get sufficient information for the pre-diagnosis through an expert system but reducing the measuring time to the minimum [11]. The electrocardiogram sensor could be included in a further version to also allow the pre-diagnosis of hearth diseases.

Fig.2: Adapted case for carrying biosensors and APP

Since Android Operating System (OS) is one of the most widely used with 86.1% of market share [12], the App was developed for running on this OS. Additionally, the App establishes the connection with BPX device via Bluetooth protocol automatically. The DB is designed to save both the data and the control parameters “Uploaded Flag” (UF) and “Deleted Flag” (DF). The UF parameter is set when a measure saved has been uploaded to the online DB. The DF parameter is set when the operator deletes the measure.

B. Data Manager APP

The APP is the core of the SaaS implementation. It gathers the vital signs from patients and pre-processes the signals into quantified values. It then checks that the taken measures are correct. The user then stores the values and uploads them when the tablet is connected to Internet. The APP can also work offline, given that the user must ensure the data will be uploaded whenever it is possible.

C. Online DB

The online DB is the source of knowledge. It is filled up with the data sent by the APPs running on the field. There is no limitation in the number of APPs feeding up the DB.

It is accessible via WEB with the user ID and password granted by the Administrator. SaaS authorized consumers have only-read privileges, so that they are not allowed for data change or deletion. The online DB collects the values of the biosensors, labelling with the patient id code, the institution id, the date, time and two flags, one to indicate whether the data was uploaded and the other should the record was deleted by the operator.

IV. Application design and operation

This eHealth App has been designed to be simple, fast to learn, and easy-to-use by non-skilled personnel. The App blinds the measure values to patient and operator. Thus, no immediate intervention is not allowed and the App does not stop collecting information. Additionally, according to privacy protection from international standards [13], patients are not recognized and only an “Id” is required.

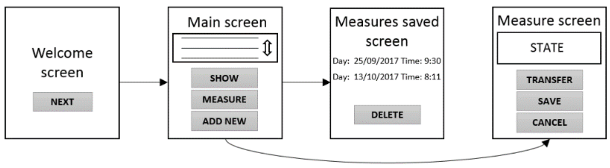


Fig. 3: Application use schema.

- *Welcome Screen: design and operation*

  Welcome Screen contains the logo and “NEXT” button to load the “Main Screen”. On the first run, the App requests the institution name.

- *Main Screen: design and operation*

  Before loading the "Main Screen", the App checks the measures saved pending to be uploaded and reports it. Additionally, it contains a scrollable list of stored patients. When the patient is selected, buttons "MEASURE" and "SHOW" are enabled. New patients are added with "ADD NEW" button. On the other hand, patients registered cannot be deleted to avoid missing data.

Measures can be taken offline as data can be saved in the local DB. Pending measures saved can be upload to the online DB. The App communicates with the online DB via the required DB connector.

- *Measures Saved Screen: design and operation*

  Measures Saved Screen provides a list of date and time information of each measure, blinding the values. "DELETE" button deletes the selected measure from the list, but not from the local DB due safety reasons, setting the DF.

- *Measure Screen: design and operation*

  BPX device is connected automatically when it is switched on. Once the sensors are placed on the patient, the operator can start data transfer with "TRANSFER" button. Data transfer duration is set to 10 seconds by default, which means, 1 frame per second as a sample rate. The frames with the embedded data read by the sensors are received, processed and saved in temporary arrays. Temperature values stabilization can take a duration longer than 10 seconds since the App waits until a stable value is reached. Hence, the data transfer time established by default can be extended. Temperature stable value is computed by comparing last received value with the previous value saved, stopping the process once the tolerance is reached. The lower tolerance is configured; the more time is needed to get stable values based on (1).

$$|current\ value - old\ value| < \text{tolerance} \qquad (1)$$

Figure 4 shows an example of temperature value and processing time necessary up to a stable value is found. In this example, the temperature reaches a stable value in 35 seconds.

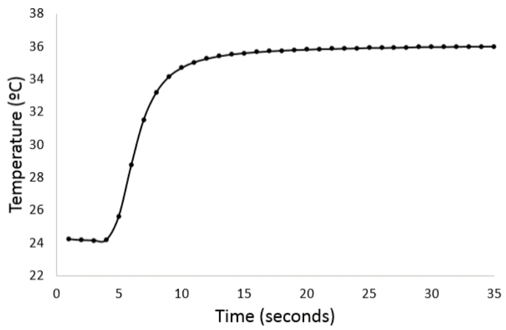


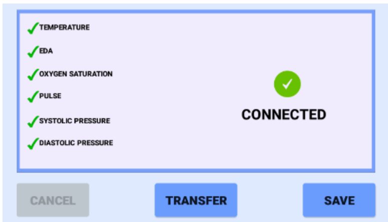
Fig.4: Temperature stable value reaching.

Each data saved are then checked whether it fit the human ranges for every magnitude. The decision ranges are showed in Table 1.

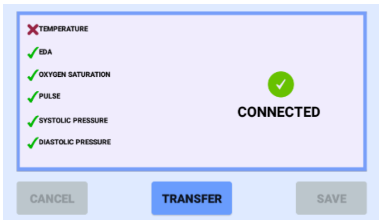
SENSOR	VALID MEASURE	WRONG MEASURE
Temperature	34ºC – 42ºC	<34ºC and >42ºC
EDA	>=0.2µS	<0.2µS
Oximeter	70%-100%	<70%
Pulse	>=30bpm	<30bpm
SYS pressure	>=30	<30
DIA pressure	>=60	<60

Table 1: Magnitude ranges

When more than 50% of the received frames are out of range, an error icon appears and the other measures cannot be saved. When all sensors provide valid magnitudes the "SAVE" button is enabled and all measures can be saved.



(a)



(b)

Fig. 5: Examples of correct (a) and wrong (b) measures

When the operator presses on the "SAVE" button, the App re-processes the array of frames for interesting values from all active sensors and saves them into local DB, adding the patient ID, date, and time information. The data obtained for each sensor is shown in Table 2.

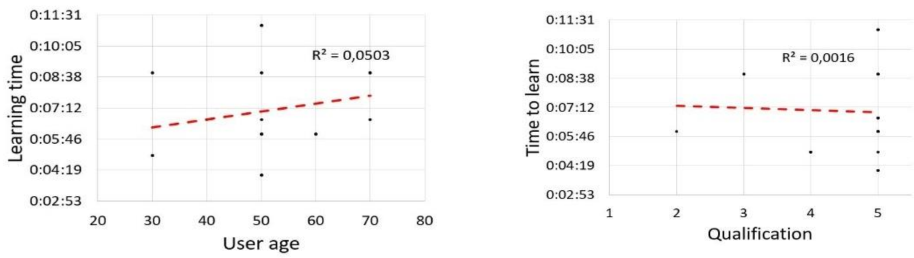
SENSOR	DATA OBTAINED
Temperature	Stable temperature value
EDA	Min, Max, Average
Oximeter	Min, Max
Pulse	Min, Max, Average
SYS pressure	Last value saved
DIA pressure	Last value saved

Table 2: Re-process obtained values.

V. Results

The medical personnel have checked the BPX sensors with certified medical equipment. The online DB info is correctly visualized on the Web portal. The usability of the App was tested through a trial performed with 18 volunteers practicing once or twice whom age ranges was from 20 to 70 years and their mobile familiarity was from 2 to 5 scale. The engineer explained how to place the sensors on the patient's bodies, how to use the App to collect the data, and, finally, how to upload the measures to the DB. Training task took on average 7 minutes. After the training, the deployment of the sensors on the patient took 1 minute and 55 seconds. Total time required for taking an average measure of 4:15 minutes with a dispersion of ± 2:21 minutes.

In Figure 6a we can observe that the learning process is nearly uncorrelated with the age of the volunteers, giving R2 = 0.05. Figure 6b shows that there is no significant relation between the digital literacy with the time to take measures.



(a) (b)

Fig. 5: Learning curve vs age (a) and digital literacy (b).

VI. Conclusions and further research lines

In this paper we provide a new eHealth system designed to medical care and pre-diagnosis for elderly and depending people diseases and that include an application developed for Android OS for. Based on the criteria of expert medical staff, body temperature, EDA, pulse oximeter, and blood pressure were considered as vital signs in the detection, blinding the measure values both to patient and to the operator. The App proposed is suitable for taking fast measures of these vital signs. Additionally, it leads to save easily data in an online DB and it makes data accessible in a Web portal. The App was designed to be simple, fast to learn, and easy-to-use by non-skilled personnel. Furthermore, the App establishes the connection with BPX device via Bluetooth protocol automatically. Measures can be taken offline and are saved in the local DB up to they are uploaded to the online DB, making that the App can be used anywhere in the world, even in rural areas. On the other hand, the App is reliable in the sense that when it receives frames are out of range the measures cannot be saved until all sensors provide valid magnitudes.

A possible further research line could be to apply pattern recognition to the clinical DB in order to improvement of disease diagnosis and treatment. Another possible further is to create expert system based on the measures taken by this App. Additionally, this expert system could be improved by including an automatic clinical records visualization system.

VII. Acknowledgments

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