ME^{3}CA - Monitoring Environment Exercise and Emotion by a Cognitive Assistant

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Abstract. The elderly population has increased dramatically in today's society. This fact implies the need to propose new policies of attention to this group but without increasing social spending. Currently, there is a need to promote the care of elderly people in their own homes, avoiding being transferred to saturated residences. Bearing this in mind, in recent years numerous approaches have tried to offer solutions in this sense using the continuous advances in new information and communication technologies. In this way, this article proposes the employment of a personal assistant to help the elderly in the development of their daily life activities. The proposed system, called ME^{3}CA, is a cognitive assistant that involves users in rehabilitating exercise, consisting of a sensorization platform and different integrated decision-making mechanisms. The system tries to plan and recommend activities to older people trying to improve their physical activity. In addition, in the decision making process the assistant takes into account the emotions of the user. In this way, the system is more personalized and emotionally intelligent.

1 Introduction

Worldwide population is ageing fast and the tendency is that elderly people (65+) surpass the number of births [1]. This means that in the near future society will have difficulties in provide social care to elderly people due to the lack of funds (due to a decay in the number of people that is available to contribute monetarily) and the lack of social/medical workers, as demonstrated in [2]. This means that families will have complications in care for the elders themselves or through care services [2].

Social services are currently unable to provide care for the all elderly people who need them and this issue will be even more critical in the future [3]. Adapting these services will have a high cost due to the demand of infrastructures and specialised personnel [4]. By 2060 44.4 Million people of over 65 years will need assistance on their activities of daily living (ADLs) [5].

Aggravating this social issue is the increasing number of elderly people with cognitive issues such as Alzheimer's, as stated in the study [6]. Caring for people with these cognitive issues require special training, which currently people that have this training is scarce [4]. Furthermore, the level of attention that these elders need (medication intake and medical control - absence of medication can rapidly worsen the health condition [7]) makes it impossible for caregivers to care for more than one person [5].

One solution may be adapting the elder's home with technological devices and services so they are able to stay longer at their homes comfortably and safely. Moreover, keeping the elderly at their homes has great benefits [8] as the environment is familiar, they have to be less moved (increased fall risk) and their relatives and neighbours are able to visit them often. But keeping them at home has also issues, like stagnation and doing repetitive and unchallenging tasks (which are often associated with cognitive problems like dementia [9]). To overcome this issues exercises and activities may be used to engage the elderly into exercise physically and cognitively.

The exercises should be meaningful (or useful) to the elderly, and should have a positive impact in their life [9]. Apart from this, the exercises have to be carefully monitored, as well as the elderly (through sensor systems) and the environment (for outside exercises/activities).

To this, some solutions have been designed [10], like the Buddy robot [11] that displays human-like emotions and is able to give information about specific tasks and maintain a conversation fluently. Or the InTouch Health [12] that is a robotic tele-doctor armed with sensors, thus overcoming the need of a doctor's physical presence. More oriented to exercises is the PHAROS project [13] that uses a Pepper Robot to teach and evaluate physical exercises providing this information to the caregivers. Lastly there is the PersonALL project [14] that monitors the elder's behaviour and displays health-related suggestions searching for any decay of motor abilities.

The issue with these projects is that they fail to address two important aspects: emotions and environment. Emotions influence the physical health (like pain), thus negative emotions have a great impact physically [15]. In terms of the environment,the previously mentioned projects do not consider (or suggest) outdoors exercises. Thus, if these types of exercises are suggested, the quality of the environment (e.g. torrid or cold weather, air pollution) must be measured and the features of the exercise adjusted.

In this paper we present **ME^{3}CA**, which goal is to use emotions and the quality of the environment to change the decision-making process. This means that the suggestions are personalised and an emotional bond is created due to the display of human-like emotions by the assistant.

This paper is structured in the following way: section **??** presents the system description (detailing the hardware and software components); finally, section 3 presents the conclusions and the future work proposals.

2 System Description

This section presents our system, which has been divided into hardware and software. The hardware is in charge of the acquisition of biological signals and environmental conditions and the localised software as an external service that allows to generate and adapt a sequence of personalised exercises for each individual.

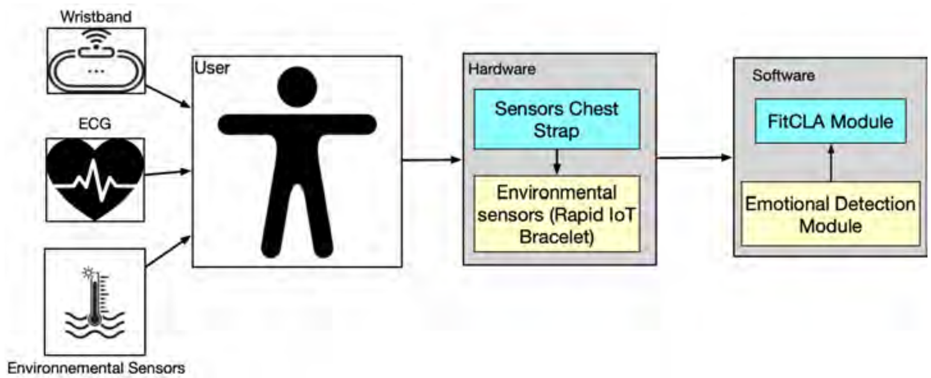

Fig. 1: System's components.

The hardware part has been divided into two systems. The first one is a set of biosensors that allows to capture a set of biosignals. These can be used to adapt the exercises dynamically, as well as to perceive the evolution of the emotion of the person. The second system is composed of a device that incorporates environmental sensors such as temperature, humidity, light intensity, air quality and CO2 levels. Using this information our system can adapt the sequence of exercises, so that the final experience obtained by each user of our system is the most appropriate sequence of exercises depending not only on the physical evolution of the person during the sequence of exercises, but also the evolution of their emotions.

Figure 1 shows the different components forming the ME^{3}CA system. This components can be classified in the following groups:

- User: this is the main part of the system as it is not only the source of the input sensor data, but also the goal of the actions carried out by the system.
- Hardware: This group is formed by all the different sensors that can be used to perceive the evolution of the person to the exercise sequence. In fact, this sensors are grouped in two different artefacts: the *Sensors Chest Strap*, formed by a set of sensors that will go in the user chest, and they even could be linked to a slim-fit exercise t-shirt; and the *Sensors Wristband* formed by a set of sensors collocated in a wristband weared by the user.
- Software: This group is formed by all the software modules in charge of calculating information and using this information to create and / or adapt the exercise sequence of a user according to his user profile and dynamic evolution. This modules are: *Empathy Module* according to the sensor information,

calculates the current user's emotion; and the *FitCLA* which calculates the proper exercises sequence or adapts the current one according not only to the user profile, but also his current physical and emotional stress.

In the following subsections, the hardware and software parts of the ME^{3}CA system are detailed.

2.1 Hardware Description

This section presents the description of the hardware, which has been divided into two sub-systems. The first is composed of a chest belt, which incorporates a series of sensors. These allow us to acquire the signals of ECG (electrocardiography), EDA (electrical activity of the skin). The second is composed of a bracelet, which incorporates sensors of temperature, humidity, motion detector, fall detector, air quality and CO2 levels. The data acquired by the two systems are sent to a web service, to be analysed in depth. Using AI techniques such of Deep-Learning[16], or Neuronal Networks [17], it is possible to recommend the physical activities, as well as, the monitoring of the same one allowing the modification of the activity in real time.

To acquire these signals, the chest strap needs a communication interface between the skin and the capture device. This interface is achieved through electrodes, which are made of stainless steel.

The arrangement of the electrodes is equal to a triangle, this triangle is known as the *Einthoven* triangle (Figure 2). It allows us to capture the standard bipolar leads, which are the classic electrocardiogram leads, recording the potential differences between the electrodes located at the different extremities.

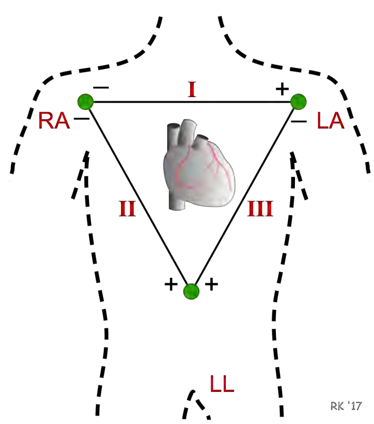

Fig. 2: *Einthoven* triangle.

D1 or I: Potential difference between right arm (RA) and left arm (RL). Its vector is in the 0^{o} direction.

D2 or II: Potential difference between right arm (RA) and left leg (LL). Its vector is in the 60^{o} direction.

D3 or III: Potential difference between left arm (RL) and left leg (LL). Its vector is in the 120^{o} direction.

The data acquired by the chest belt is made using an Arduino 101. Using the analog-to-digital conversion pins, the system is able to convert the analog heart signal to a digital one. The ECG signal acquisition system has a sampling rate of 250 to 300 samples per second and uses a Butterworth [18] band-pass filter with 100 and 250 Hz cut-off frequencies. Just as a Butterworth filter rejects a 50 Hz band, this filter allows us to eliminate electrical noise.

This digital data is then used to calculate the beats per minute, as well as to make telemedicine applications. In turn, the chest belt has two communication systems. The first one is a Bluetooth communication system of low consumption or BLE (Bluetooth Low Energy) and a Near Field Communication (NFC) system. The Bluetooth communication system allows the chest belt to send the digitalized data to a smartphone in streaming, while the NFC system allows the transfer of such signals to other systems with NFC communication.

Fig. 3: Rapid IoT development Board.

The bracelet, on the other hand, has been developed using the Rapid IoT development system (Figure 3) of the NXP[3] company.

[3] https://www.nxp.com/support/developer-resources/rapid-prototyping/nxp-rapid-iot-prototyping-kit:IOT-PROTOTYPING

Fig. 4: A view of all the components: Chest Strap, bracelet and smartphone APP.

A new app allowing to connect the bracelet to an smartphone has been created using this development system (Figure 4). This app allows to acquire and to observe the signals in our phone. At the same time, it is possible to configure the app, so that it sends the information acquired to our web service. In this way, the acquired information can be stored in a database for later analysis. At the same time, our web service uses these data, to enhance the respective recommendations of activities.

Once the signals have been acquired and pre-processed, they are sent to the web-service. This web-service uses different AI tools to analyse the signals and to try to detect emotional states, stress, or heart problems such as arrhythmia, tachycardia or bradycardia.

2.2 Software Description

To suggest exercises, it is used the FitCLA [19, 20, 13], a cognitive assistant that profiles the users and adapts the exercises suggestion according to their cognitive and physical impairments (e.g. memory loss, assisted mobility). It prompts the users, using the wristband, with a suggestion at determined times. Furthermore, the caregivers can visualise the configurations and progression through a friendly website.

It uses the sensors available as a evaluation process, verifying if the user is performing the exercises within the expected parameters. Moreover, with the emotional information, obtained from the emotional detection module. This module use deep learning techniques to recognise the emotion ([21]). The FitCLA is able to adjust classification of the exercises according to the emotional reactions of the users. Studies show that activities and exercises that involve cognitive and physical functions improve greatly their physical condition, memory ability and happiness levels [22, 23].

The FitCLA is composed of the agenda manager (keeps the information of each user and manages the scheduling of information), the activities recommender (selects an activity/exercise from the database according to the algorithm's parameters), the module manager (the gateway for coupling new features) and the message transport system (communicating process of the different agents). The FitCLA tightly integrates with the hardware available (wristband, chest strap, and virtual assistant) using them to improve the suggestions and to communicate with the users.

3 Conclusions and future work

A cognitive assistant platform that aims to help people exercise has been presented in this paper. ME^3CA generates and adapts personalized exercises sequence for an individual, in this case, an elderly person at his/her home. To do this, the system incorporates a set of bio-sensors integrated in a chest strap and in a wristband. These sensors capture information that can be measured in the form of physical stress while a user is doing exercises, also, it is able to perceive the emotion of the person.

Currently, the approach is being tested in *Centro Social Irmandade de S. Torcato*, which is a daycare centre in the northern area of Portugal. For the time being, the robot is being used with a small number of patients and always under supervision of caregivers. As future work, we want to integrate new functionalities in order to detect whether the suggested exercises are completed by the user in a satisfactory way.

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