SMARTA: Smart Ambiente and Wearable Home Monitoring for Elderly

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Abstract. The last two decades show that population is continuously and gradually aging; in Italy, the percentage of over-sixties has increased since 1980 by more than 50 % while the over-eighties by more than 150 %. Aging causes a consequent psycho-physical decline which in many cases requires specific care and precautions by relatives. However, as can be easily inferable from the percentage of elderly just shown, today the national health-care systems are not able to manage and take charge of all these elders. More and more seniors are choosing to live alone, with all the problems related to emergencies and urgencies cases that can occur due to poor health status related to aging (falls, cardiovascular events, neurological events). In this case, providing health-care initiates to have its new challenges. One of the worst possible case of emergency in elderly living alone is bad injury within the home without the possibility for seeking a help. This paper presents a work related to this issue; project SMARTA, focused on biomedical and environmental monitoring for the active aging. The project is based on the use of biomedical sensors and sensorized garments for health status and cardio-monitoring, and accelerometers fixed on the floor for activity and fall detection. All this sensors are integrated in a system that is used for monitoring elderly both indoor and outdoor during their daily life thanks also to the connection over the Internet.

Keywords: Home monitoring · Fall detection · Wearable device · Accelerometers · Elderly · Active aging

1 Introduction

Data from the Eurostat estimations [1] shows that European population is constantly and progressively aging due particularly to low birth rates, ageing "baby-boomers" and rising life expectancy [2]:

- between 2010 and 2060, the number of people over 65 will grow from 17.4 % to 29.5 % of the total population. The number of people over 80 will nearly triple to 12 %;

B. Mandler et al. (Eds.) IoT 360° 2015, Part I, LNICST 169, pp. 502–507, 2016.
DOI: 10.1007/978-3-319-47063-4_54

- during the same time, the working age population in the EU is expected to decline by 14.2 %.

Pensions, health care and long-term care systems risk becoming unsustainable, with a shrinking labour force no longer able to provide for the needs of the growing number of older people. This aging population bring to an increase of request for medical care and hospitalization which bring the cost for the National Health-care System to grow; in 2006 the average hospitalization cost for one day amount to 674€ [3]. With this trend in population aging and health-care system cost rising, a new approach for the care of elderly people is mandatory in order to avoid a collapse of the National Health-care System. For these reason many countries are trying to find alternatives and strategies based on early de-hospitalization, tele-medicine and home-care services In this frame, assistive technology represents one of the best choice which allows for taking the cure, and especially the prevention, to the home of the patient. In fact prevention is the main strategy to be pursued in different disease at various age. It fits particularly with the concept of "active aging" that the European Union is promoting as a means of controlling health care costs and increase the quality of life [4]. Moreover active aging allows for reducing the risk of bad events like fall which in many case cause very serious consequences; among the elderly hospitalized after a fall, only half survive more than a year, while the multiple drops and instability precipitated admission to nursing home [5]. Project SMARTA has the aim to develop an integrated system which completes personal signals and data with environmental variables, thanks to wearable sensors and environmental sensors, for the fulfillment of a service/system which allows for:

- Monitoring vital signs and lifestyle (e.g. daily number of steps, sedentary, minutes of walk, heart-rate, glycemia, weight);
- Monitoring the rehabilitation process (e.g. monitoring of exercise);
- Detecting safety problem (e.g. falls and stumble detections).

On this way, the elderly alone at home is constantly monitored both from the physiological and environmental point of view. This monitoring gives the possibility to elderly to live a safer and active life, and to the caregivers (relatives and/or medical staff) to be able to intervene promptly in case of need, even if the senior is unable to ask for help.

2 SMARTA Project

The SMARTA system has an architecture composed by three main parts:

- The biomedical monitoring subsystem;
- The accelerometer based environmental subsystem;
- The hub for collecting, processing and visualizing data.

Figure 1 shows the main components of the system architecture with their relative puroposes and features.

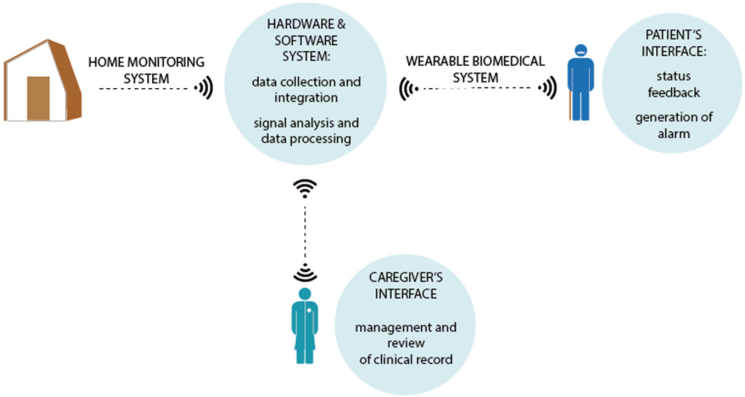

Fig. 1. Description of the SMARTA system.

2.1 Biomedical Monitoring System

The biomedical monitoring system is composed by different sensors for different measurement which data are aggregated by means of the hub. The sensors can be divided into two typologies: wearable sensors and non-wearable sensors. The wearable sensors are:Pulse oxymeter, Sensorized garment for ECG, Fall sensor. The pulse oxymeter is a commercial one which is able to transmit the spot acquire data to the hub wireless. The sensorized garment is composed by a belt with three textile electrodes. This kind of electrodes need neither for conductive gel nor adhesive: for this reason they are very useful for application with elders because they don't affect the skin or cause discomfort. The three electrodes allows for acquiring single lead ECG (Einthoven Lead I). The signal is acquired by a small device, shown in Fig. 2 at a sample frequency $FS = 512\,\text{Hz}$ with 24bit. The raw signal and the data processed can be stored in an internal flash memory or streamed trough Bluetooth connection. The same device has also a three axes accelerometer which is used for wearable fall detection. In this way the elderly is continuously monitored both in the house and outside. Figure 2 shows the three sensorized belts developed. The belts differ only for the material they are built; these belts are used in order to study both the quality of the signal both the comfort based on the material. Figure 2 reports the quality of the ECG signal recorder with the same electronics in the same condition; the first belt report a smaller signal then the second and the third (0.2 mV respect respectively to 0.5 mV and 0.6 mV); but quality is almost the same and allows for correctly processing the signal to extract the heart-rate [6]. The non-wearable sensors are instead commercial device like smart scales, gluco-meter, etc. that can be connected to the hub via Bluetooth connection in order to record all the data in the same database. The integration of this sensors is thought to be scalable; the subject can use one, two o no sensors according to his/her requirements.

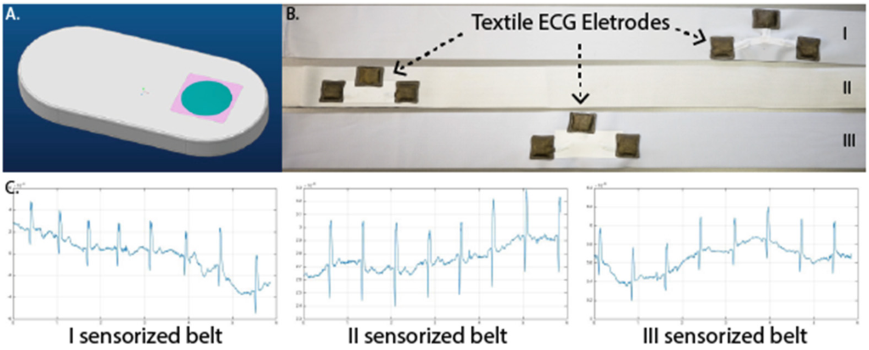

Fig. 2. The wearable system: A. The wearable device developed for the project; B. The three sensorized belts; C. The three ECG signals recorded using each belt.

2.2 Enviromental Monitoring System

The environmental monitoring system supports the biomedical monitoring system in the detection of ADL (Activities of daily living) also when the wearable devices are not used. The main idea of the environmental monitoring system is to use different vibration sensors located on the ground and to identify the type of activity starting from the vibration signals. At the current state of the art [7], there are different issues preventing the detection of ADL and elders fall from vibration signals: the first related to the force generated by subjects fall, which has only been studied by simulating falls of healthy subjects. The fall of elder people is expected to be very different, owing to their limited muscular force and to their reduced mental alertness. The second derives from the transmissibility of vibration trough the different kinds of residential floors, which has never been studied in the literature; since the position of the event (activity or fall) is unknown, the measured signal strongly depends not only on the activity but also on the floor mechanical characteristics. Finally, it is necessary to reduce the amount of information deriving from the vibration signal by using classifiers capable of distinguishing between ADL, falls and other possible events. We assume the floor response to vibration is linear in order to predict the vibration at any measurement position by characterizing separately the vibration transmissibility and the force generated by ADL and falls. The proposed approach is summarized in Fig. 3.

The ground vibration transmissibility has been experimentally identified in more than 30 rooms of residential buildings. Results showed that the transmissibility is averagely lower than one and depends on the ground covering (parquet/tiles) and on the room geometrical characteristics. The time history of the force generated by falls of subjects and of a crash test dummy has been characterized on a force platform. The acceleration of different points of the platform has been measured as well.

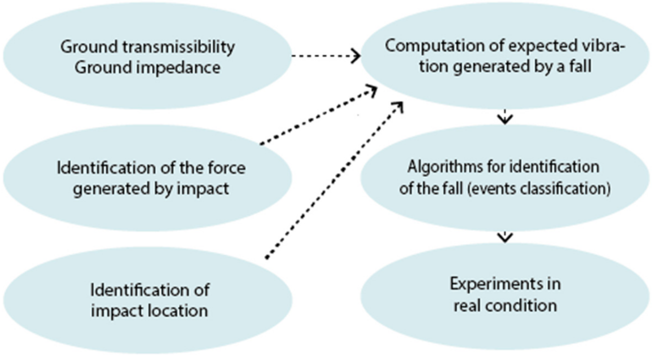

Fig. 3. Summarized proposed project protocol for the environmental subsystem.

2.3 The Hub

The hub is composed by two parts: the smart-phone and the server. The smart-phone has a triple purpose, the collection of the data from Bluetooth devices (like the wearable garment, the smart scale, etc.), the transmission of the data to the central server (Fig. 1) and the generation of alarm, the visualization of the state of health for the elderly users. The server gathers all the data, process it and eventually transmit the alarm directly to the elderly and to the care-givers. Both the smart-phone and the server are connected over the Internet; this approach allows to keep the connection with the care-givers always on. All the collected data are transmitted to the server which stores them in order to create an historical. The history an all the generated alarm can be visualized online by the care-givers.

3 Conclusion

The technical tests to match textile sensors (belt) and wearable device were successful. Subjects wore the three belts in a random order and without gel on the sensors. ECG tracks were clearly detected and waveform preserved (2). The HR computation as requested by clinicians was available for most of the time and comparable to previous literature findings [6]. The belts have different elasticity and transpiration characteristics but same textile sensors. The preliminary wearability judgements on short duration test were comparable. A light preference for the belt III was expressed but this need to have confirmation with 1-week test in the clinical trial setting. To have immediate best results in terms of electrode-skin coupling, a second test was carried out by wetting the electrodes of the belt with few drops of water before wearing them. The noise on the ECG tracks reduced significantly as expected. This effect is usually produced by skin perspiration in few minutes after belt is worn by people. This effect will be evaluated during the next long term test in the future clinical trial.

Technical in-lab test for the environmental subsystem evidenced that the peak force ranges between 2 and 10 times the static weight of the subject; this could be useful for discriminating between falls and normal activities. Preliminary tests outlined that the difference between the measured acceleration and the acceleration predicted using the fall force and the platform impedance is averagely lower than 20 %. Furthermore, the simultaneous usage of three or more accelerometers allow locating the position of the subject, allowing a more robust identification of the type of the event.

Even this sub-system, and the integration with the hub/server and the usability test with elderly users during different scenarios (nursing home, rehab center), will be evaluated during the next clinical trial.

Acknowledgment. Authors thanks in particular all partners of the project (www.smarta-project.it): DATAMED S.r.l., FLEXTRONICS DESIGN S.r.l., ARGONET S.r.l., SOFTWARE TEAM S.r.l., EELECTRON, Fondazione Don Carlo Gnocchi Onlus, UNIMI Dipartimento di Informatica, CoDeBri. This research has been supported by Lombardy Region in the frame cluster of research for Smart Cities and Communities.

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