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Wearable Monitoring of Elderly in an Ecologic Setting: the SMARTA Project

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Abstract: Nowadays many senior citizens chose to live alone but they become a new challenge for healthcare services. Many examples demonstrated the occurrence of advise events and that elderly are not capable of seeking for help. This paper presents a part of a project called SMARTA: an environmental tele-monitoring system with a network of sensors and wearable devices for security and prevention in Active Aging. Sensorized garments and accelerometers fixed on the ground implements an integrated sensors system for monitoring elderly indoor and outdoor for a smart house and a smart city. The system is composed by two parts: a wearable system which consists of a sensorized garment coupled with a small electronic unit which allows for non-intrusive continuous cardio-respiratory monitoring; a set of four accelerometers data-logger, placed on the room floor, which continuously record the movement and is able to control if there are people in the room and if there is a falling. These sensors are accompanied by other home-automation sensors, which indicated the presence of the elderly and the use of the different furniture in the home. All the sensory systems send data to a body/home gateway that collect data and redirects theme to a center, which store and elaborate them in order to extract alarm and implements the monitoring and intervention services. A clinical trial is testing the reliability, the acceptability and the performance of the system for the future implementation of new prevention system.

Keywords: elderly; tele-monitoring; fall detection; wearable monitoring.

1. Introduction

The last two decades show that population is continuously and gradually aging; Data from the Eurostat estimations [1] shows that European population is constantly and progressively become older; this is due particularly to low birth rates (typical phenomenon in rich countries), ageing "baby boomers" and rising life expectancy [2]. 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 case requires specific care and precautions by relative. 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. Pensions, health care and log-term care systems risk becoming unsustainable, with a shrinking labor force no longer able to provide for the needs of the growing number of older people. The trend in population aging and health-care system cost rising force hospitals to decrease hospitalizations, delegating the prevention and the treatment directly to the house. 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). One of the worst possible cases of these emergencies is bad injury within the home without the possibility for seeking help. In this situation, a tool that help elderly living alone safely become mandatory; wearable assistive technology represents one of the best choice which allows for taking care, and especially, if not prevent, to early intervene at the home of the patient. Prevention is the best and main strategy to be pursued and it fits particularly with the concept of "active aging" that the European Union is prompting as a mean to control costs while increasing the quality of life [3]. Starting from these key concepts, the SMARTA project aims at creating an integrated system, which merges personal data with environmental variables in order to develop a tele-monitoring system for contributing to keep the seniors active and healthy. SMARTA has three main objectives:

- Monitoring and subsidize active life;
- Monitoring the rehabilitation;
- Monitoring safety inside and outside the home.

2. The SMARTA Project

The SMARTA Project architecture consists into four main parts:

- The biomedical monitoring subsystem;
- The accelerometer based environment subsystem;
- The home-automation sensor/actuator network;
- The hub/server for collecting, processing and visualizing data.

Figure 1 summarizes the Smarta system components, with their relations, purposes and features.

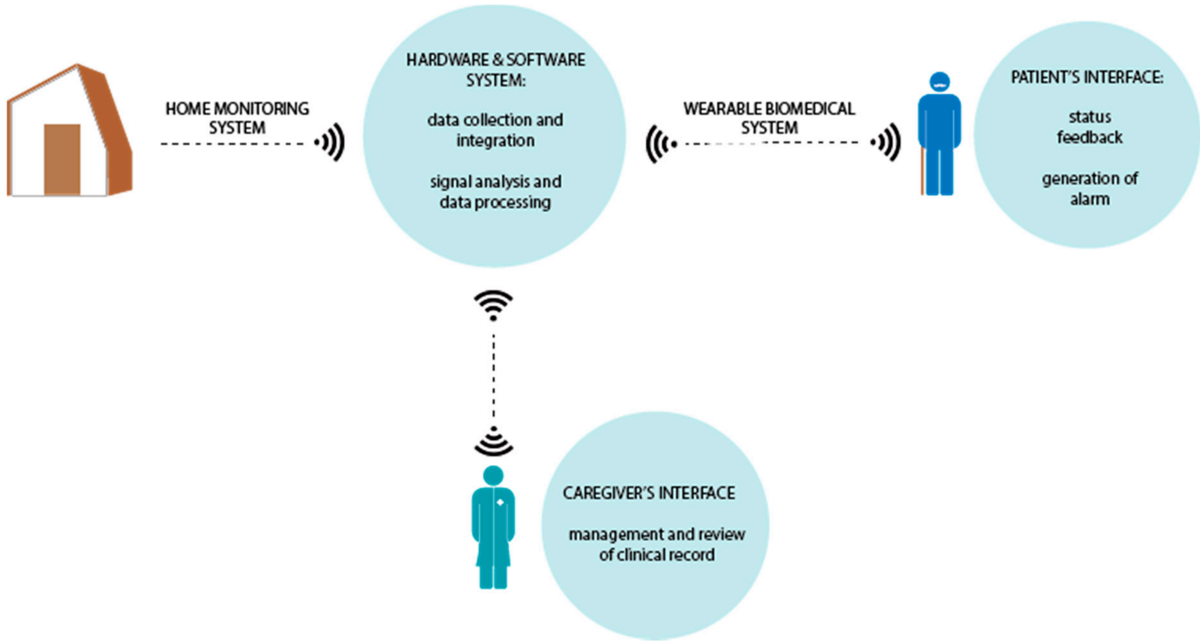

Figure 1. The SMARTA system components

2.1. The Wearable System

Wearable systems are mainly dedicated to non-invasive bio-signals (invasive measurements applied to biomedical devices and form strictly medical purposes) that can be collected onto the body surface (usually the skin) through specific sensors accordingly designed and built on the physical nature of the signal to be measured [4]. The SMARTA wearable system is composed by a custom sensorized T-shirt, which is designed with three integrated textile electrodes. These three electrodes are made by silver-based conductive yarns. The electrodes serve as ECG electrodes and are embedded into the T-shirt in order to record the Einthoven ECG I-leads. The conductive yarn itself has an electric resistance of 30 Ω/m, but creating a ribbon using more wire's fuzes the resistance between the electrodes and the device connection fall down to 1-5 Ω which is a value comparable with standard ECG electrodes. The sensorized T-shirt doesn't require conductive paste, but more the t-shirt is worn, more the signal quality improves; this is because the sweat helps to moisten the sensor that further improves electrical conductivity also reducing motion artifacts. The T-shirt has an ad-hoc structure with a lateral opening and it was designed specifically to facilitate the wearing. The device connects to the t-shirt by means of three snap buttons. Figure 2 shows the shape of the connection and the final form factor of the device. The device, developed by Flextronics, allows for recording the I-lead ECG at 24bit with a sample frequency of 512Hz. The data is recorded on the device and can be downloaded at any time by mean of Bluetooth 4 Low Energy. The device is able to record both the raw signal and the processed data (HR, R-R interval). The same device has also a three axes accelerometer, which is used for wearable fall detection and life tracker. In this way the elderly is continuously monitored both in the house and outside. In order to reach the majority of the seniors, the SMARTA project also includes sensorized textile belt, for the people that don't like or are not comfortable using the sensorized t-shirt. Figure 3 shows the three developed sensorized belts. All the three belt works but they are made from different textile in order to find the matching between performance and comfort. Figure 2 also shows the quality of the signals. Each belts is able to acquire good enough signal for heart-rate extraction. The wearable system includes also some other commercial devices that are connected with the SMARTA hub/server and that can be used for record different biomedical signal (SpO2 pulse oximeter, portable fall sensor, smart scale).

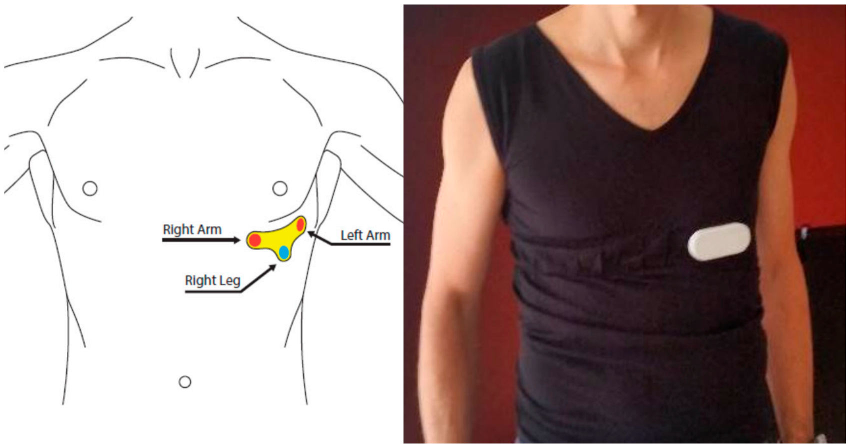

Figure 2. Sensorized t-shirt with the connection scheme.

2.2. Home Automation

The SMARTA system has been developed to be integrated in an existing home, which already includes some piece of home automation and sensors. In particular the smart home is the "Casa Domotica" in the DAT department of Fondazione don Gnocchi (Milan, Italy). All these home automation devices (sensor on the fridge door, one the tap, on the cocker and on the different doors) are wrapped and connected to the SMARTA system by means of specifically developed software. The integration of these devices in the SMARTA allows for the reliable and specific detection of activities and alarms inside the house.

The SMARTA system also records all the signals generated by the home automation system in order to create a log in which it is possible to look at all the movement into the house.

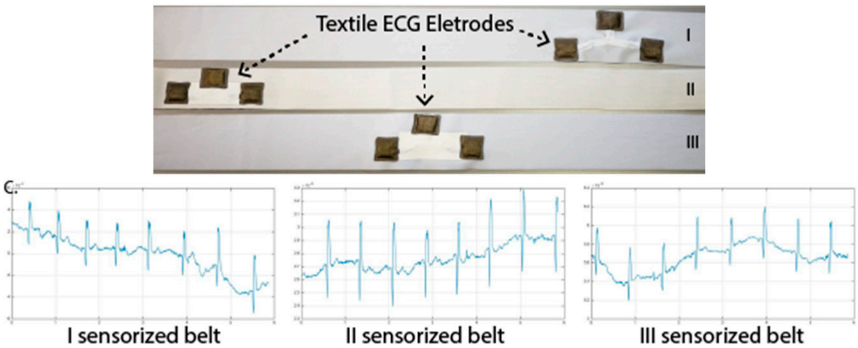

Figure 3. Three sensorized belts tested and related acquired signals.

2.3. Environmental Monitoring System

In many cases home automation system and devices can be simply installed in old house, due to both purchase and maintenance costs for adapting the existing plant. In order to reach the majority of the people and simplify the installation in already existing house, we search for the possibility to use accelerometer applied to the rooms' floor for detecting life activity. The environmental monitoring system is also able to support and/or work in place of the monitoring system in the detection of ADL (Activities of daily living) when this one is forgotten. At the current state of the art [6] there are different issues preventing the detection of ADL and elderly fall:

- the force generated by subjects falling. The fall of elderly people is expected to be very different, due to their limited muscular force and their reduced mental alertness: all the studies are made by simulating falls with healthy subjects.
- the transmissibility of vibration through different kinds of residential floors. Since the position of the event (ADL or fall) is unknown, the measured signal strongly depends on the floor mechanical characteristics.

We experimentally identified the vibration transmissibility in more than 30 rooms of residential buildings. Results showed that the transmissibility 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. This, assuming that the floor response to vibration is linear, will allow for creating classifiers capable of distinguishing between ADL, falls and other possible events.

2.4. The SMARTA Hub

The hub consists into two parts: the smart-phone and the computer server. The first one is thought to work outside the home while the second one has the aim to collect data into the home and guide the user during the rehabilitation exercise. The hub gathers all the data, process it and eventually generate and transmit the alarm directly to the elderly and to the care-givers.

3. Results and Conclusions

We tested the t-shirt and the belts both in laboratory and with elderly people. They appreciated both the solution which shown optimal signal recording capability. However, the questionnaires collected after the test suggest some modification to the closure system of the t-shirt which, in for some people, results very difficult to use due to straits in movement due to muscular problem. Despite this minimal wearing critic, the sensorized garment is felt comfortable and ECG signals were clearly detected, the waveforms preserved and the HR computation was available for most of the time and comparable with standard ECG acquisition. Tests on environmental system have been conducted in laboratory; they evidenced that the peak force ranges between 2 and 10 times the weight of the subject: this could be very useful for discriminating between falls and ADL. The tests also shown that the simultaneous usage of three or more accelerometers allows a more robust identification of the event type and locating the position of the subject. Three tests have been performed in the "Casa Domotica"; all the three tests were successful and demonstrated the capability of the system in gathering data, processing them and generating log and alarm. Further tests will be carried out in a different environment in order to test the capability and the reliability of the SMARTA system without the Home Automation component.

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Author Contributions

Giuseppe Andreoni was in charge of the original idea of the paper: he revised the related literature and started proposing, discussing and reviewing the technological and design issues of wearable systems. He contributed in writing the first draft of the paper and he revised the final version.

Carlo E. Standoli contributed in proposing, discussing and reviewing the design issues of wearable systems. He contributed in writing the related parts of the paper and he revised the final version.

Paolo Perego contributed in proposing, discussing and reviewing the technological issues of wearable systems and home monitoring system. He contributed in writing the related parts of the paper and he revised the final version.

Conflicts of Interest

The authors declare no conflict of interest.

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