A New Personalized Health System: The SMARTA Project

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Abstract. The growing number of elderly people with health issues is the consequence of the increase in life expectancy. Tele-homecare applications have already reported promising results on reducing health care costs and improving quality of life. In this study, we present the SMARTA platform (www.smarta-project.it): a fully integrated system capable to monitor its user's health condition. The latest telemedicine and wearable technologies have been used to make cooperating users and caregivers. The system integrates wearable (ECG and accelerometry), non-wearable (temperature, weight, blood pressure etc.) and environmental (light, refrigerator etc.) sensors.

Keywords: Telemedicine · Tele-homecare · Wearable · Accelerometry · ECG · Heart rate · Integrated system

1 Introduction

As reported in the fourth World Population Aging 2013 report [11], United Nations, NY, 2013, *"Population ageing is taking place in nearly all the countries of the world. Ageing results from decreasing mortality, and, most importantly, declining fertility. ... Globally, the number of older persons (aged 60 years or over) is expected to more than double, from 841 million people in 2013 to more than 2 billion in 2050."* (p. xii). Moreover, *"The older population is itself ageing. Globally, the share of older persons aged 80 years or over (the "oldest old") within the older population was 14% in 2013 and is projected to reach 19% in 2050."* (p. xiii).

Along with the increase in life expectancy, a growing number of elderly people with health issues and their related chronic co-morbidities is present as well [5]. To worsen the scenario, more than 50% of elderly patients receiving polypharmacy fail in adhering to the therapy when discharged from hospital [6], causing

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drug reaction and possible need of permanent hospitalization [1]. Such scenario represents an important issue for the public health systems and the economic development.

Even though telemonitoring is still being debated [4], especially for its unpredictable economical advantage, there are evidences of reduced costs for telehomecare applications [8]. In particular, they are found to reduce the use of hospitals, improving patient compliance, satisfaction and quality of life. Also, the use of current technology, *i.e.*, the Internet of Things paradigm, for health care applications at home, could help to restructure the old healthcare system, still based on a relationship between patient and physician in an ambulatory setting [9].

In this study, we present a fully integrated system, *i.e.*, the SMARTA platform[1], for monitoring the health of elderly people at their home with the aim of improving the quality of life and the subject compliance to therapies, as well as promoting their active aging. Such platform have been developed accordingly to the SMARTA project[2].

2 Methods

2.1 Main Scope

The SMARTA platform is designed to monitor the health status of the user by means of an integrated system. Moreover, the platform is meant to be used in cooperation with the physician or the caregiver. In particular, the physician defines the variables to be collected (*e.g.*, temperature, heart rate *etc.*) and the frequency of the measurements, and can visualize the time evolution of the measured quantities using a web-app application. On the user-side, an automatic notification system reminds the measurements to be performed and provides audio guidelines. The user can constantly see the scheduled tests without any interaction with the system.

Along with the monitoring of the health status, environmental variables are tracked as well. Tap water leakage, lights on, refrigerator door opening are several examples of environmental variables observed.

In the following sections, the hardware and software architecture of the SMARTA platform will be described. Figure 1 shows the scheme of the platform developed.

2.2 Hardware Architecture

The hardware architecture of the SMARTA platform is composed by: (i) wearable, non-wearable and environmental sensors; (ii) gateway and middleware; and (iii) user interface.

[1] Sistema di Monitoraggio Ambientale con Rete di sensori e Telemonitoraggio indossabile a supporto di servizi di salute, prevenzione e sicurezza per l'Active Aging.

[2] The work was supported by the project "SMARTA" (code: 40628684, www.smarta-project.it), funded by Regione Lombardia, Italy, through the call "Smart cities 2013".

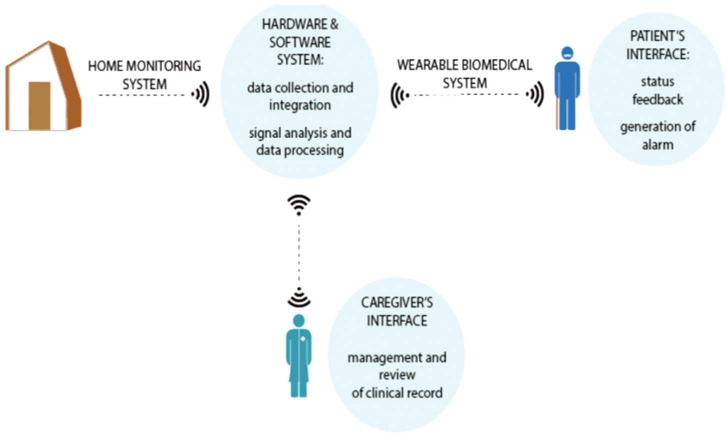

Fig. 1. SMARTA platform architecture.

First, sensors includes

1. a Bluetooth (ver 2.1) weight scale (UC-351PBT-Ci model, A&D Medical Inc., USA) for body weight measurement;
2. a multipurpose device (PC-304 Spot-Check Monitor, CMI Health Inc., USA) for measuring the heart rate, ear temperature, blood pressure, blood oxygen saturation and glycaemia;
3. a wearable fall detection device (SmartWalk, H&S Quality in Software Srl, Italy);
4. a wearable device named "SMARTA patch" for recording a single lead ECG (LSB=$4.8081e{-}05$ mV, 24 bit and sampling rate of 250 Hz) and 3D accelerometry (± 8 g, 16 bit and sampling rate of 52 Hz);
5. the Konnex (KNX) home automation system to monitor tap water, refrigerator and dishwasher.

The SMARTA patch is specifically designed for the SMARTA project (Flextronics Design Srl, Italy; Fig. 2). Its dimensions and weight are $78 \times 35 \times 11.5$ mm and 30 g, respectively. ECG signals are collected by using self-adhesive electrodes made of biocompatible material placed directly on the skin, or by plugging the SMARTA patch to a T-shirt (PoliMI Design, Italy), or a chest band for women.

Second, the gateway (Datamed Srl, Italy) collects the raw data coming from all the sensors using a Bluetooth Low Energy protocol, and communicates with the middleware, *i.e.*, a desktop PC configured with common web service settings, that is responsible of the storage and processing of the recorded data.

Third, the user interface is simply a personal computer with internet connection for the physician or caregiver and a touch-screen monitor, plugged to an audio system for interacting with the user.

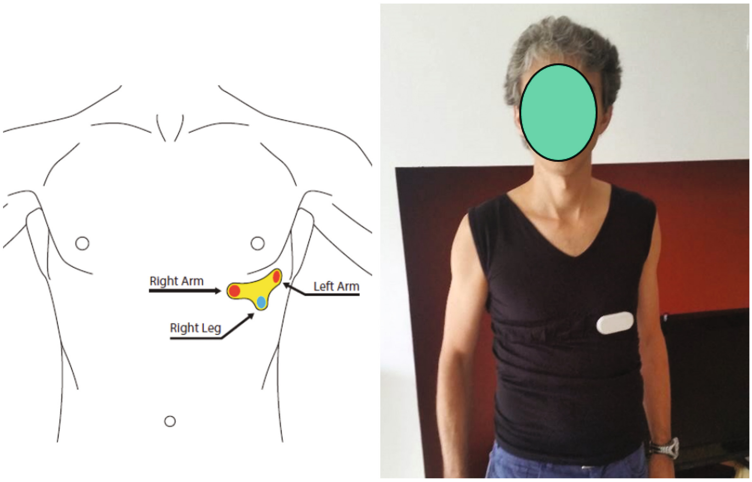

Fig. 2. The SMARTA patch. Left panel shows the approximate position of the SMARTA patch, while on the right panel, the real setting is shown (SMARTA patch + T-shirt).

2.3 Software Architecture

The software can be separated into four parts accordingly to the objective; specifically: (i) data transmission; (ii) data storage; (iii) data processing/data mining; and (iv) user interface.

First, data transmission is performed by integrating the Bluetooth proprietary protocols of the off-the-shelves sensors and by creating an *ad-hoc* Bluetooth Low Energy protocol for the SMARTA patch.

Second, data storage uses the SQL technology to keep track of the clinical information such as age, weight, height *etc*, at time of enrollment of the user, to store raw data from sensors and to schedule the tests to perform by the user.

Third, the data processing software library is meant to process the raw signals, *i.e.*, ECG and accelerometry, and to extract useful information for the physician or caregiver. In particular, the raw ECG signal is used to obtain the time evolution of the heart rate, while the accelerometry is employed to estimate the risk of falling accordingly to the Tinetti test [10], using an automatic intelligent algorithm [7]. Raw data are processed using a software library that integrates Matlab, C and Delphi routines.

Data storage and processing are performed on the middleware.

Finally, the user interface is based on a web-app application. The caregiver can manage the clinical information of the user, the scheduled tests and check the time evolution of the measured variables (such as ECG from wearable, blood pressure from non-wearable and light-on duration from environmental data). On the other hand, the user can visualize the tests to perform. The notifications of the tests for the user are audio messages.

3 Conclusion

In this paper, we described the hardware and software architecture of a new integrated system for tele-homecare monitoring and promoting active ageing: the SMARTA platform.

The prototype was tested at the Smart Home in the DAT department of Fondazione don Gnocchi (Milan, Italy) by enrolling 32 volunteers. The system obtained a good perception among the participants (results are out of the scope of this article). Also, its reliability was on average good, though some technical issues need to be fixed in future releases (*e.g.*, sensor disconnection). Overall, the system was highly appreciated by both physicians and users.

4 Future Works

Four main future activities might be performed to improve the SMARTA platform.

First, we tested whether actigraphy measured at the chest (accordingly with the position of the SMARTA patch) was capable to determine the sleep quality [2] (typically accelerometers are located on the wrist for this purpose). The research provided promising results but needed further investigation.

Second, we implemented a new system capable to detect falls using sensorized garments and accelerometers fixed on the ground [3]. In particular, the accelerometers located on the floor, after a calibration session meant to describe its material, were capable to detect vibrations propagated radially from the fall position.

Third, a cloud-based architecture for the data storage and data processing software would help data privacy and security.

Finally, a physical activity log system (such as number of steps, activity counts *etc.*) was also developed but still not integrated.

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