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Smart Postural Monitor for Elderly People

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Abstract- Efficient, low cost and easily deployable monitoring systems for elderly people are becoming every day more and more important if considering that the increase in longevity has been raising the average age of the population all over the world. For elderly people, wrong postural behaviors can indicate a main and preliminary marker of disease. It is possible to recognize the signs of this kind of problems by developing smart home monitoring technologies: the body posture can be modeled using information resulting from specific low cost sensors embedded in a bed or an armchair. This paper presents a low cost Smartphone application, able to transform a bed or an armchair into an intelligent device. A friendly interface has been defined in order to make this application also suitable for unskilled users.

Keywords: elderly people assistance, postural monitor, smart device, smartphone interface

I. Introduction

The care of not-self-sufficient elderly people is often carried out in a discontinuous way, while the continuous monitoring for accidental illness or diseases can be pursued by dedicated persons even if the costs of such interventions are very high and not affordable by a large part of the social classes. In many situations, the person posture can be significant for understanding incoming problems and can be used as an information source to alert nurse or specialized personnel who take care of elderly people. Traditionally, the (temporary or permanent) care of elderly and disabled people has been always relied on family members, often, within the family household. Elderly people represent the faster-growing segment of population in the world [1].

Aim of the paper is to present a low cost and efficient approach that uses simple sensors placed under armchairs and/or beds to collect postural data, measure the activity of the elderly, highlight anomalous situations, and interpret messages from a prebuilt lexicon (i.e. conventional signs from the person sitting on the armchair can be represented by 2 or 3 repeated pulses used as a request for help). The activity of the patient is processed by a light algorithm and the data locally stored on the device. The information is transmitted by a Bluetooth wireless link from the sensor system to a smart-phone equipped with a specific application.

The choice of smart-phone is almost obvious, due to its large diffusion and the possibility of avoiding other costs for the monitoring system deployment. The Smartphone is characterized by a high capability in data connection, both local and global area services, and a large (3" or more) graphic display [3]. Also their operating systems have evolved with time, so that they can be considered as equivalent to small computers.

The acquired information can be sent via Bluetooth (short range, local) or using UMTS smart phone connection capability to a remote monitoring center (with medical or paramedical competences). At the moment, we are investigating the possibility to joint super teletext application of DVB-T channels, already available on large area, to a SMS message. The DVB-T systems are used to send a pre-coded set of signatures to each user. Using a short (and very cheap) SMS of 140 byte, a composition of the transmitted pre-coded signals can be sent to the monitoring center.

The proposed solution has to be equipped with a simplified, intuitive or personalized interface, which is adaptable to changing end-user abilities and requirements. Important issues are designed for the accessibility for all older adults [13].

The paper is organized as follows: In Section II related works are reported. The description of the proposed framework is summarized in Section III. The tracking system is described in Section IV. Finally, in Section V preliminary results and conclusions are discussed.

II. Related works

The importance of domotic applications for weak people category with the approach of Ambient Assisted Living (AAL) is demonstrated by the promotion and funding of research projects which meet the needs of elder people; at the same time these new applications can stimulate industries to develop projects on these challenging subjects (VI and VII framework Program of the European Union). One of the main areas identified is the information and communication technologies (ICT), in which our scientific contribution can be valuable. The AAL is one of the application areas of ICT; typical examples are wearable devices such as motion sensors, sensory systems return, multisensory integration (remote maintenance), etc. More generally, all the “personal health systems” are the subject matters of many research projects; the proposed system, designed to monitor the posture of an elderly or disabled person is fully part of this scenario [15].

In the last decade, a large number of methods for “contact free” measuring of sleep-quality and posture data has been developed, including photographic and video monitoring, motility beds [2]. Past works attempts have been made to deploy sensors in mattress to locate the persons on the bed and classify their behavior. Due to the real economic interests in monitoring elderly and disable people, a lot of patents have been recorded. In [4] a pressure-sensitive sensor pad is installed on the top of and across the width of a mattress. In [5], 1993, the authors proposed a patient position monitor system which consisted in an apparatus to monitor the position of a patient in relation to a bed. The system was able to detect if the patient was attempting to lift himself from the bed or was completely out of the bed. But only more recently several attempts have been made to develop ambulant monitoring methods which do not use ECG electrodes to record parameters of heart activity as in [6]. A number of papers deal also with specific dysfunctions and pathologies as in [7, 8.9].

III. Description of the System

The proposed research concerns the development of new innovative technologies to improve the life quality of weak (disabled and elderly) people. It's clear how the proposed techniques can be easily used in other fields such as wellness, health (prevention in domestic falls of elderly people) to give quick and efficient responses to domestic care and assistance (behavior monitoring) in a generally framework of secure infrastructures [14].

The system consists in four resistive cells placed under the armchair or bed legs, a controller based on a RaspBerry SBC and a Bluetooth transceiver (figure 1). In the case of armchair the average weight distribution of the human body has been considered as shown in figure 2, that is: the legs are about the 20% of the total body weight, while each arm is about the 6% of the total body weight and the head is the 8-9%. Thus, the thorax and abdomen (including spine and pelvic bones) constitute about the 60% of the total. The controller allows for the acquisition of sensors data that are locally preprocessed and stored, waiting for being sent via Bluetooth. Additional modem/interface (Rj45, SMS, and GPRS etc.) can be added to SBC (single board computer) to send alert or alarm if required.

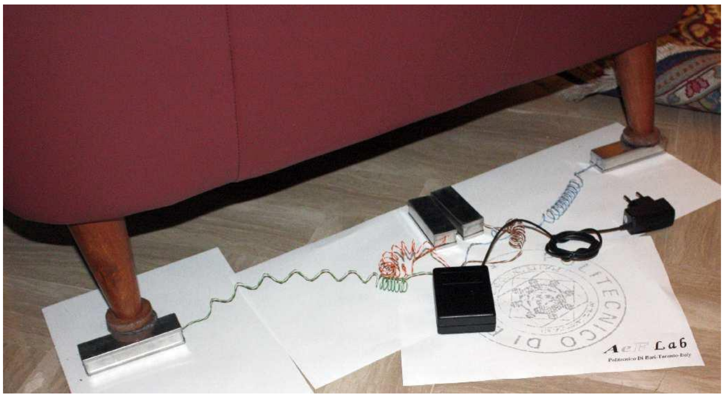

Figure 1: Armchair legs with sensor and Bluetooth unit (prototypal)

The prototype system is intended to transfer information from the local acquisition system via a Bluetooth link to the smart-phone as long as the smart-phone enters in the visibility of a Bluetooth neighborhood of the acquisition system. Due to the low power consumption, the Bluetooth radio subsystem is in operation mode only on request of the SBC for the data transfer. This requires a given duty cycle operation to be defined in order to become effective and ready for its working. The sensing subsystem is set in a sleep mode, also, to avoid data acquisition when out of place.

A Java application has been developed for the smart-phone to present results of the acquired data in visual way. Precise classification of the activity has not been carried out yet, even if different postures have been detected by the system and used to classify the people behavior.

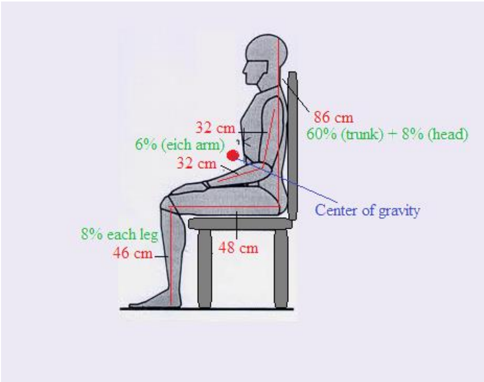

Figure 2: Center of gravity of a person in sitting posture. Body segmental Lengths are reported in red, while weight distributions are reported in green.

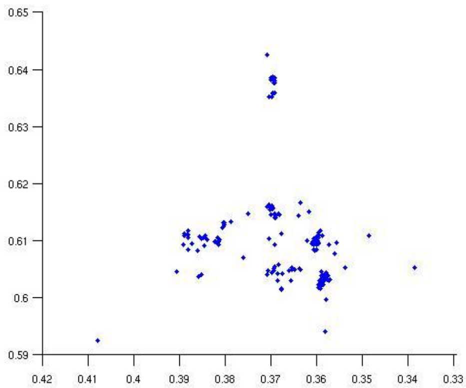

Figure 3. Centroid position and the armchair (in y-axis the depth and in w-axis the width, both in meters)

At the moment detecting the presence and motion of a person on the chair is feasible and traceable [10-11]. Once the measurement time series is complete, a filtering procedure is applied with a specifically designed low pass filter. Basically, low frequencies refer to stationary cases and are important for measuring the weight of the person and slow movements; high frequency terms can be originated by accidental events coming for example from objects dropped on the chair. Higher frequency terms may correspond also to changes in postures and activities on the armchair and they are considered as important information to preserve and process. High frequency terms are normally affected by noise, so that a proper design signal bandwidth and preprocessing filter is required.

In the preliminary test the sampling frequency is set to 1 Hz and the observation period to 30 minutes. During these 30 minutes, the patient can stand still or move for a certain number of times. The system sends the information to Smartphone. The signal is represented by emoticon (facial expression) used to show how often the elderly has changed the position on the bed or on the chair. We have chosen six kinds of emoticons:

- for motionless state in half hour;
- for 1 movement and/or stable body centroid;
- for 2 movements and/or slow body centroid movement;
- for 3 movements and/or body centroid movement;
- for 4 movements and/or fast body centroid movement;
- more than 5 movements and/or trembling.

The visualization of the classification system should be easily understandable by any user, so that synoptic time visualization has been used. A hypothetical string that provides easy visual information on sleeping or sitting mode could be presented as in figure 4.

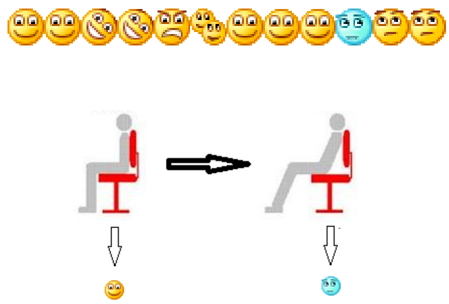

Figure 4: Visual information by emoticon interface of an elderly person in sitting posture.

IV. The proposed Tracking System

In this paper the posture of the sitting person on the armchair is not estimated in a precise way: the total body mass can be distributed in several parts on the base of the statistical body mass distribution. From this perspective, for sitting people, the changes in the body mass centroid positions can be mapped to specific motion of the body parts. In the paper we have considered the average weight distribution of the human body as described before in figure 2. A graph based approach has been used in the mapping definition of possible positions of the body on the armchair, in this way it is used to represent the articulated motions of body parts with reference to fixed bone articulations in order to define possible shifting of each body part centroid [12]. The centroid positions have been computed using the force centroid measured on the four legs of the armchair as follows:

$$x_G = \frac{\sum_{i=1}^{4} F_i \cdot x_i}{\sum_{i=1}^{4} F_i} \quad \text{and} \quad y_G = \frac{\sum_{i=1}^{4} F_i \cdot y_i}{\sum_{i=1}^{4} F_i} \qquad (1)$$

where x_i and y_i are the coordinates of the four armchair legs in the given reference system and F_i the measured forces. Figure 3 reports the filtered output of the body centroid estimations acquired from the data corresponding to several different postures. This information is then used in the classification system to define the activity and eventually to provide alarms.

V. Preliminary results and Conclusions

In a preliminary test, the four sensors are placed under the armchair feet as shown in figure 1. A male adult of about 95 kg weight spent 3 hours on the armchair (45 kg) watching television. According to [7], most of the time the weight was distributed symmetrically between right and left, 70% given by the sum of trunk and chair back translated on the rear of the armchair. The total weight measured by the sensors is about the weight of the stair plus the weight of the person during the slow movements, with no postural changes - trunk and arms remained to the rear armchair, no significant changes are observed in weight distribution. A moderate right/left change in weight distribution has been observed. A significant change is present when the person gets up from the armchair: a sudden change from rear to front feet distribution and an extra measurement on the front feet is recorded.

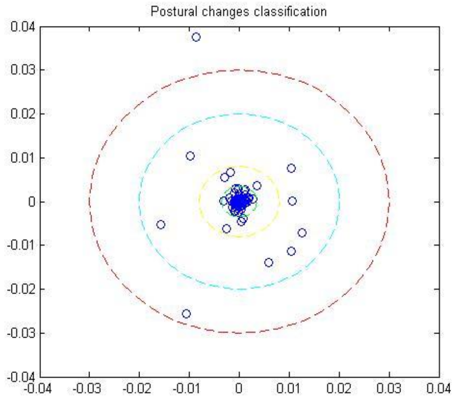

Figure 5: Warning regions for the derivative of the centroids

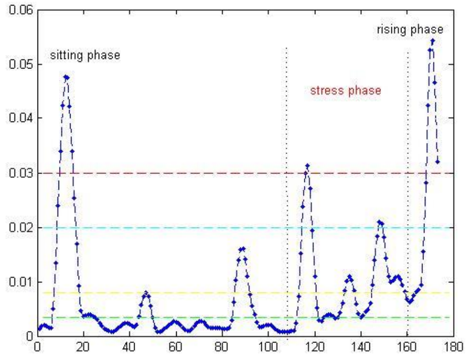

Figure 6: Stress detection phase

Preliminary results of the estimated postures adhere to the real ones, showing the feasibility of the proposed approach. At the moment a preliminary analysis has been conducted on the acquired data. During the acquisition phase, the person on the armchair has initially simulated a normal behavior, while, during the final recording phase a stress condition has been simulated to test the ability of the available information to detect such kind of behaviors. By observing the normal condition histogram of the sitting person, thresholds have been defined to segment the changes in postural motion into possible warning regions, of course considering the frequency and the intensity of postural changes. In figure 5 the warning zones have been segmented on the derivative of the postural centroid in the time domain and a time weighted representation of the intensity of postural changes has been used to detect stress phases.

In figure 6 the time evolution of the warning signal generated on the filtered intensity of the derivative signal in the postural centroid positions is reported to show how the defined thresholds can help to define warning signals and classify the activity of the person on the armchair. Future developments of the proposed technique will address the definition of an intelligent system able to describe the activity class such as hands shaking, legs movements, rapid and frequent changes of position and so on.

At the moment, the developed system is standalone, but the project focuses on the definition of a distributed monitoring system for elderly people monitoring. In this view, alarms can be made available on a general infrastructure based on the joint use of DVB-T channels for the downlink to the end user and a simple and effective uplink made up of sms cellular phone facility. With the advent of the terrestrial broadcasting system for television in Europe, digital broadcasting channels often have problems in lack of digital contents to be transmitted over the several new available TV channels. Thus, from this fact it follows that experiences of different use of DVB-T channels are rising up to ease life to DVB-T end users and create a smart and integrated communication system with other per-user communication links such as the internet access available on every user smartphone.

The idea is simple and first experiments are being setup to test the possibility of the joint use of super teletext application, already available on the set top box. The user information acquired by sensors under the armchair is sent to a central monitoring system data base where processing facilities are available and a warning system is setup to detect anomalous conditions of the elderly patient. Such information can be both vehiculated by DVB-T network in a per-user format and made available on the super-teletext application at home for the registered users. As the coverage area of a DVB-T transmitter is several squared kilometers, the application can be readily made available for free use to many end users. Privacy of the information can be assured by a java application extracting only the information content of each user basing on its PID. Moreover, a possible messaging system can be used to inform the person who takes care of the patient, of the warning condition and, in recognized critical situations, also an alert message can be provided to the medical unit to take decision about immediate intervention.

The system prototype is being developed at Politecnico di Bari and the test of the complete system will be carried out quickly with the aid of a local broadcaster.

VI. Aknowledgments

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