A clinically assisted collaborative system architecture for preventing falls in elderly people

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Abstract. Falls in older adults are not only frequent but also potentially disabling for them. Detecting and preventing these falls have an important impact in the life of the elderly people. This paper presents the architecture of a pervasive system designed to perform early detection of older adults in risk of falling or fell down. The system notifies the appropriate people or healthcare organizations in case of detecting a fall of the monitored person. This monitoring process produces minimum disruption in the life style of the elderly.

Keywords: Falls Prevention and Detection, Pervasive Healthcare.

1 Introduction

Advances in embedded systems and new communication technologies have opened many opportunities to address healthcare procedures, treatments and strategies to deal with several illnesses. For instance, wireless sensing technology has shown to be successful in monitoring elderly people suffering chronic diseases or living alone.

Falls in older adults represent one of the main causes of hospitalization, and they are also responsible not only of causing disabling fractures and other physical injuries, but also psychological traumas that reduce their independence and confidence [1]. Detecting falls using sensors is not a simple task, particularly if the solution should be pervasive, keep the privacy of the monitored persons and accurately recognize their current condition [2]. Detecting people in risk of falling is still more useful, but complex.

This paper presents the architecture of a pervasive system that helps prevent falls of older adults, by doing early detection of people in risk of falling. The system involves a combination of wearable sensors connected through a Body Area Network (BAN) and a smartphone that runs a software application. The former captures the information from a set of wearable sensors embedded in an ad hoc digital device, which is wore by the monitored person. Such information is sent to the software component running in the elderly smartphone, which is in charge of determining the current condition of the person (normal, with risk of falling, fell down). If the system detects a fall, it delivers alerts to the supporting people or healthcare organizations in order to obtain first aids as soon as possible.

2 Related work

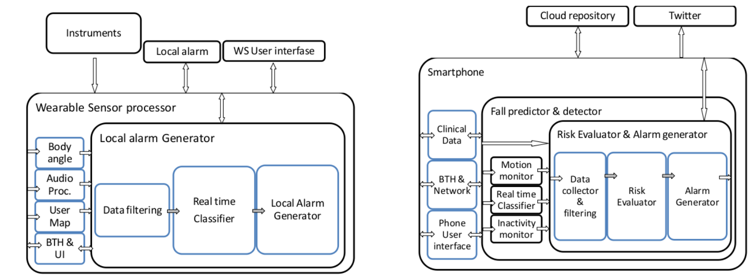
It has been shown that falls are one important cause of disability and also death in elderly people living alone [3]. Nevertheless, there is not a definite solution to this problem yet [**?**]. One possible approach to detect falls involves the use of wearable sensors (e.g. gyroscopes, accelerometers, or microphones) to collect data that helps identify falling situations [2]. These sensors can be used not only to detect falls, but also to identify periods with a high probability of falling; e.g. because the person periodically loses his stability when moving. In [1] the authors report a monitoring system to determine repetitive behavior patterns and falls in the elderly. In [**?**] a frail studio is presented. Frailty is a syndrome associated to the ederly that leads to falls. With the system proposed, a frailty coefficient is computed for instrumenting different prevention therapies. In [5] a mechanism based on the smartphone accelerometer is used to gather information that helps physicians to diagnose and treat cardiologic pathologies. In [6] it is proved that Bluetooth networks are useful for interconnecting wearable sensors, however these networks have not bandwidth enough for doing real-time monitoring of some pathologies; e.g. cardiovascular diseases. In fact, it is shown that most monitoring systems require performing a first processing of the collected data in order to reduce the information transmitted to the formal processing unit. In [7] the authors use NFC and RFID technologies to determine the localization of patients at a hospital, avoiding thus various patient identification problems. This type of technology has been successfully used for monitoring people activities. Clearly, there are several previous works related to the early detection of falls and monitoring diseases in elderly people. However, none of them present an integral, non-intrusive and self-trained system, able to be customized by a physician considering the patients features and also the situations to be detected.

3 System Architecture

The proposed system for detecting falls and vulnerable situations in elderly people has two main components: a BAN that interconnects a set of wearable sensors and a collaborative application that runs in the elderlys smartphone. This latter determines the current probability of fall risk in the older adult that is being monitored. It uses the data collected from the sensors, which is processed and transmitted to the smartphone through the BAN. This solution requires that the monitored person wears a digital device that implements the BAN and embeds most of the sensors.

This device can be attached to the people belt producing minimum disruption to the user. The system collaboratively balances the computational load, optimizing thus the energy consumption of the BAN and the smartphone application. Figures 1.a and 1.b show the architecture of both, the master wearable sensor (the digital device that represents the main component of the BAN) and the collaborative application running in the smartphone. The master wearable sensor (Fig. 1.a) embeds several small, lightweight and efficient (in terms of energy consumption) sensors, which usually have limited capability for data processing and exchange. This master sensor is implemented as an integrated circuit, designed to accomplish one or more activities. In this case, the component includes a pulse meter, a gyroscope, an accelerometer, a microphone, the BAN-user-interface and a Bluetooth interface to keep a communication link with the smartphone. It also includes the logic to locally detect falls and instability patterns in the monitored people.

The wearable master sensor captures the body inclination and other clinically typified movements, which commonly precede a fall in impaired persons or people suf-



(a) (b)

Fig. 1: (a) Architecture of the master wearable sensor, (b) Architecture of the smartphone software application

fering certain pathologies. In order to do that, the data captured from the sensors is classified by the real-time classifier, which builds an inference table based on classical algorithms for decision making. Such a data is transmitted to the smartphone and processed accordingly. The software components monitoring the people motion and inactivity (Fig. 1.b) process this information trying to identify vulnerable or potentially vulnerable situations and alerting the person about the risky situation. Long periods of inactivity indicate potential problems and eventual falls. The application running at the smartphone periodically records the user status in a server that may be hosted in the Cloud. If the system detects a vulnerability situation or a fall, it notifies the relatives or healthcare emergency services about this situation. The target of these notifications and the channel used with that purpose can be set during the deployment of the system. The communication channels include sms, email and some social networks and instant messaging systems, like WhatApp. A detailed description of this system is available in [7].

In order to determine the level of vulnerability of a person in a certain time instant, the system uses an inference matrix that was filled using results of clinical studies. The columns of the matrix corresponds to clinical variables that contributes to identify instability of people; e.g. Orthostatic Hypotension. The rows of the matrix indicate four movements that also help identify the people instability; e.g. from-sit-to-stand. Therefore, each cell establishes (based on clinical studies) the level of risk that a from-sit-to-stand movement represents for a person having orthostatic hypotension for example.

The physician can configure the solution for a certain patient (i.e. an older adult) by instantiating the clinical variables according to the results of the tests performed to that person. The sensors identifies the movements done by the elderly and based on the recognized movement determine the current level of fall risk for that person. Computing the risk indicators, based on the elderlys movements and the clinical variables for such a person, it is possible to determine the instability level of that older adult. This value is used to determine the next action to be performed by the system.

4 Conclusions

This paper presents the architecture of a pervasive system designed to prevent and detect falls in elderly people. Based on empirical, clinical and inferred data, the system deter-

Motion	PHT	Incontinence	Medication	TSS>12s	Walker	Bath	Bedroom
Sit to Stand	H	H	H	H	H	H	M
Inctivity	H	M	L	L	L	L	L
Walking	L	H	M	L	M	H	L

Table 1: Inference Table

mines the level of fall risk of the monitored person, and eventually it delivers alerts to make the older adult aware of such a situation, preventing thus a possible accident. The system utilizes both, real-time and stored information, to accurately determine when delivering an alarm according to the elderly current activity and his clinical diagnostics. If the fall is not avoided, an alarm is delivered to supporting people and healthcare emergency services to reduce the latency in the medical attention of the elderly. The system implementation uses existing technology and it is currently in the first evaluation phase.

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