Expert Systems with Applications 39 (2012) 5566–5575

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A system for ubiquitous fall monitoring at home via a wireless sensor network and a wearable mote

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ARTICLE INFO

Keywords:
Falls in the elderly
Fall detection
Accelerometer
Activities of daily living
Wireless sensor network

ABSTRACT

Accidental falls of our elderly, and physical injuries resulting, represent a major health and economic problem. Falls are the most common cause of serious injuries and are a major health threat in the stratum of older population. Early detection of a fall is a key factor when trying to provide adequate care to elderly person who has suffered an accident at home. Therefore, the detection of falls in the elderly remains a major challenge in the field of public health. Specific actions aimed at the fall detection can provide urgent care which allows, on the other hand, drastically reduce the cost of medical care, and improve primary care service. In this paper, we present a support system for detecting falls of an elder person by the combination of a wearable wireless sensor node based on an accelerometer and a static wireless non-intrusive sensory infrastructure based on heterogeneous sensor nodes. This previous infrastructure called DIA (Dispositivo Inteligente de Alarma, in Spanish) is an AAL (Ambient Assisted Living) system that allows to infer a potential fall. This inference is reinforced for prompt attention by a specific sensorisation at portable node sensor in order to help distinguish between falls and daily activities of assisted person. The wearable node will not determine a falling situation, it will advice the reasoner layer about specific acceleration patterns that could, eventually, imply a falling. Is at the higher layer where the falling is determined from the whole context produced by mesh of fixed nodes. Experimental results have shown that the proposed system obtains high reliability and sensitivity in the detection of the fall.

1. Introduction

1.1. Background

The main causes of serious injuries in the elderly people (above 65 years old) were the unintentional falls. Physical injuries resulting cause that much of the social resources in the national health insurance system are aimed at alleviating the consequences of these accidents. Approximately 25–35% of the elderly persons suffered at least one fall per year experiencing related injuries. Nearly 30–40% of these falls resulted in a visit to the emergency room for treatment where they were hospitalized (Brewer, Ciolek, & Delaune, 2007; Changhua Healthcare Quality, 2010). In particular, nearly 3% of the elderly falls were completely neglected for more than 20 min (Lindemann, Hock, Stuber, Keck, & Becker, 2005). These situations can endanger people fall, either serious accident or not. The estimated expenditure on medical care for the falls suffered by elderly residents and their related injuries will reach 32 billion euros in 2020 (Brewer et al., 2007). There is no doubt that falls and their consequences are one of the main items of expenditure for social security systems.

1.2. Motivation

The goal of the DIA Project (Fernández-Luque, Zapata, Ruiz, & Iborra, 2009) is to provide an infrastructure of networked sensors that supports multiple applications simultaneously. The sensor network, like DIA, would spread throughout the environment, whether it is any room of home, routing and linking motes to the base station. In general, motes can be divided into two types: (1) fixed/infrastructure motes, for example attached alongside the walls and corridors, doors and furnishings and (2) mobile motes, whose geographical position can change over time. The goal of this project is to provide alerts to caregivers in the event of an accident, acute illness or strange (possibly dangerous) activities, and enable monitoring by authorized and authenticated caregivers. The system facilitates privacy by performing local computation, it

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doi:10.1016/j.eswa.2011.11.061

supports heterogeneous sensor devices and it provides a platform and initial architecture for exploring the use of sensors with elderly people. We have developed a low-power multi-hop network infrastructure consisting of multisensor nodes (motes) that wirelessly communicate to each other and are capable of hopping radio messages to a base station where they are passed to a PC (or other possible client). In addition, wearable accelerometer-based technology can be used to complement the falling detection. The system learns the users behaviour patterns and advice when the currents differs significantly, but it takes some time to be accurately detected. Eventual signalling of a free fall and/ or impact events can significantly reduce the time to determine a falling situation. Besides, seniors who are living by themselves have problems when getting help after they fall and may not be able to describe where they are. Combined with the fall detection technology, localization can detect where the incident occurred and request the relevant services.

2. Fall detection and localization

The evaluation of an unintentional fall is complicated due to the subtle and complex nature of body movement of the individual. Body movement requires accurate and reliable measurement techniques. The location of fall sensors is critical because the location site of the signal detector to measure the phenomenon, such as the hip, trunk, wrist or head, will result in different patterns of signal. This has allowed a plethora of research groups to investigate related work of falls detection. Many of these groups have proposed different mechanisms to detect falls, but the efficiency of falls detection and reliability in falls recognition are always challenges. The most common warning system, panic push-button, is not an entirely satisfactory falls warning device, because in case of fainting or loss of consciousness following a fall, the push button cannot be activated. One solution to this problem involves the automatic detection of falls. In this case, after detecting a fall, the system automatically alerts the relevant support staff. It is important to provide reliable fall risk assessment tools first and then provide tools for monitoring of people in the high risk group. In other words, there are two applications of interest from the standpoint of control: (1) the detection of a person falling, and (2) the detection of falls, once they occur, by means of the context and behaviour patterns. In this work, we are focusing on the implementation of the latter.

The fall detection is mostly used in personal safety applications using a fixed sensor node mesh, where its primary purpose is to detect and alert about a fall that results in an injury. For these applications, a fall detection system must satisfy several properties: (1) the continuous monitoring should not be obtrusive and uncomfortable for the user, (2) all fall events that cause damage must be detected, (3) alerts should not be triggered during normal daily activities of the elder person, (4) the system should not require regular maintenance or special operating procedures.

Projects on home health monitoring and telemedicine have been performed for two decades with a fixed wireless sensor network. In the paper of Figueredo and Dias (2004), Eklund, Hansen, Sprinkle, and Sastry (2005), or Virone et al. (2006, 2008) home care system project was described. In this paper, we describe an ubiquitous assistential monitoring system at home. We have focused, in contrast, on the unobtrusive habitual activities signal measurement and wireless data transfer using IEEE 802.15.4 technology.

The main idea consists in monitoring the person living alone in his home without interacting with him. To start, it is needed to know if he is at home in order to activate the ubiquitous custodial care system. It is easy to know by the context if a resident is at home knowing that the entrance door was opened and movement in the hall was detected. By means of distributed sensors installed in each room at home we can know the activities and the elderly location.

On the other hand, as the pressure sensors are located in the bed and the favourite sofa in the living room, we can know more of where he is even if he is not in movement. All this sensory assembly will be ruled by an artificial intelligent software which will allow to learn of elderly diary activities. If the system detects a suspicious event, i.e., no-movement in rooms at 4 a.m and no-pressure in the bed, then the DIA system give an alert to the caregiver about possible fall.

On the other hand, there are three phases associated with a fall event that provide important cues for reliable detection of falls using wearable smart sensors: (1) dynamic changes in gait preceding a fall, (2) free fall phase, (3) impact of the body against the ground. The principle of operation of a fall detector relies on detecting one or more of these three phases together with the orientation of the detection device. Most approaches utilize acceleration spikes generated by the fall impact together with changes in orientation (Bouten, Koekkoek, Verduin, Kodde, & Janssen, 1997; Chen, Kwong, Chang, Luk, & Bajcsy, 2005). Inclination has been independently used as the determining factor in detection of falls (see, for example, Tamura, Yoshimura, Horiuchi, Higashi, & Fujimoto, 2000), which simplifies computational requirements but suffers from false alarms caused by normal daily activities. On the other hand, gait and postural measurements have been primarily used to assess risk of falls rather than to alert about an impending fall (Najafi, Aminian, Loew, Blanc, & Robert, 2002; Hassan, Begg, & Taylor, 2006).

The possibility of distinguishing the different types of falls is valuable in clinical trials to determine the incidence of falls and the costs associated with treatment of injuries they cause. Falls that do not require medical treatment are often not reported, but still very important to implement appropriate guidelines for the prevention of falls. However, the fall detection is mostly used in personal safety applications, where the main objective is to detect and warn about a crash that involved an injury. For these applications, a fall detection system must satisfy several properties: (1) continuous monitoring should not be uncomfortable for the user, (2) all fall events that cause damage should be detected, (3) should not be thrown alerts by normal daily activities of older people, (4) the system should not require frequent maintenance or special procedures.

In order to provide adequate medical care, we have proposed a method based on a wireless sensor network consisting of accelerometers attached to the wearer's body and a set of fixed motion and pressure sensors built into the environment and monitors the movement of the user and communicates information to a central processing station where the data are analyzed in order to reliably detect various types of falls that may occur. Wireless communication is used to provide continuous monitoring and minimal user location.

An approach inlaid two accelerometers into a wrist watch to tell three directions of falling. Due to the complexity of the arm movement, the success rate only reached 65% (Degen & Jaeckel, 2003). Another approach used a triple-axial accelerometer placed at the waist level to detect daily physical activities, but a quick sit down or a lie down posture would be mistaken as a falling in this system (Yang & Hsu, 2006). An important research proposed a pilot study with two accelerometers into the hearing aid housing and would be able to distinguish seven types of falling and five kinds of daily activities (Lindemann et al., 2005). It is a quite considerable design because the sensors are placed at the head level and the sensitivity and accuracy of fall recognition is raised more than that of previous studies. However, the integration period is set to in 1.5 s to calculate the velocity threshold. The period setting is an empirical value that the authors considered as the duration from the body's initial