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Human fall detection on embedded platform using depth maps and wireless accelerometer

Bogdan Kwolek [a,*], *Michal Kepski* [b]

[a] *AGH University of Science and Technology, 30 Mickiewicza Av., 30-059 Kraków, Poland*
[b] *University of Rzeszow, 16c Rejtana Av., 35-959 Rzeszów, Poland*

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ABSTRACT

Since falls are a major public health problem in an aging society, there is considerable demand for low-cost fall detection systems. One of the main reasons for non-acceptance of the currently available solutions by seniors is that the fall detectors using only inertial sensors generate too much false alarms. This means that some daily activities are erroneously signaled as fall, which in turn leads to frustration of the users. In this paper we present how to design and implement a low-cost system for reliable fall detection with very low false alarm ratio. The detection of the fall is done on the basis of accelerometric data and depth maps. A tri-axial accelerometer is used to indicate the potential fall as well as to indicate whether the person is in motion. If the measured acceleration is higher than an assumed threshold value, the algorithm extracts the person, calculates the features and then executes the SVM-based classifier to authenticate the fall alarm. It is a 365/7/24 embedded system permitting unobtrusive fall detection as well as preserving privacy of the user.

1. Introduction

Assistive technology or adaptive technology is an umbrella term that encompasses assistive and adaptive devices for people with special needs [1,2]. Special needs and daily living assistance are often associated with seniors, disabled, overweight and obese, etc. Assistive technology for aging-at-home has become a hot research topic since it has big social and commercial value. One important aim of assistive technology is to allow elderly people to stay as long as possible in their home without changing their living style.

Wearable sensor-based systems for health monitoring are an emerging trend and in the near future they are expected to make possible proactive personal health monitoring along with better medical treatment. Inertial measurement units (IMUs) are low-cost and low power consumption devices with many potential applications. Current miniature inertial sensors can be integrated into clothes or shoes [3]. Inertial tracking technologies are becoming widely accepted for the assessment of human movement in health monitoring applications [4]. Wearable sensors offer several advantages over other sensors in terms of cost, weight, size, power consumption, ease of use and, most importantly, portability. Therefore, in the last decade, many different methods based on inertial sensors were developed to detect human falls. Falls are a major cause of injury for older people and a significant obstacle in independent living of the seniors. They are one of the top causes of injury-related hospital admissions in people aged 65 years and over. The statistical results demonstrate that at least one-third of people aged 65 years and over fall one or more times a year [5]. An injured elderly may be laying on

* *Corresponding author*. Tel.: +48 17 8651592.
E-mail address: bkw@agh.edu.pl (B. Kwolek).

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the ground for several hours or even days after a fall incident has occurred. Therefore, significant attention has been devoted to developing an efficient wearable system for human fall detection [6–9].

1.1. IMU based approaches to fall detection

The most common method for wearable-device based fall detection consists in the use of a tri-axial accelerometer and a threshold-based algorithm for triggering an alarm. Such algorithms raise the alarm when the acceleration is larger than a threshold value [10]. A variety of accelerometer-based methods and tools have been proposed for fall detection [11]. Typically, such algorithms require relatively high sampling rate. However, most of them discriminate poorly between activities of daily living (ADLs) and falls, and none of which is universally accepted by elderly. One of the main reasons for non-acceptance of the currently available solutions by seniors is that the fall detectors using only accelerometers generate too much false alarms. This means that some daily activities are erroneously signaled as fall, which in turn leads to frustration of the users.

The main reason of high false ratio of accelerometer-based systems is the lack of adaptability together with insufficient capabilities of context understanding. In order to reduce the number of false alarms, many attempts were undertaken to combine both accelerometer and gyroscope [6,12]. However, several ADLs like quick sitting have similar kinematic motion patterns with real falls and in consequence such methods might trigger many false alarms. As a result, it is not easy to distinguish real falls from fall-like activities using only accelerometers and gyroscopes. Another drawback of the approaches based on wearable sensors, from the user's perspective, is the need to wear and carry various uncomfortable devices during normal daily life activities. In particular, the elderly may forget to wear such devices. Moreover, in [13] it is pointed out that the common fall detectors, which are usually attached to a belt around the hip, are inadequate to be worn during the sleep and this results in the lack of ability of such detectors to monitor the critical phase of getting up from the bed.

In general, the solutions mentioned above are somehow intrusive for people as they require wearing continuously at least one device or smart sensor. On the other hand, these systems, comprising various kinds of small sensors, transmission modules and processing capabilities, promise to change the personal care, by supplying low-cost wearable unobtrusive solutions for continuous all-day and any-place health and activity status monitoring. An example of such solutions with a great potential are smart watches and smartphone-based technologies. For instance, in iFall application [14], data from the accelerometer is evaluated using several threshold-based algorithms and position data to determine the person's fall. If a fall is inferred, a notification is raised requiring the user's response. If the user does not respond, the system sends alerts message via SMS.

Despite several shortcomings of the currently available wearable devices, the discussed technology has a great potential, particularly, in the context of growing capabilities of signal processors and embedded systems. Moreover, owing to progress in this technology, data collection is no longer constrained to laboratory environments. In fact, it is the only technology that was successfully used in large scale collection of people motion data.

1.2. Camera based approaches to fall detection

Video-cameras have largely been used for detecting falls on the basis of single CCD camera [15,16], multiple cameras [17], specialized omni-directional ones [18] and stereo-pair cameras [19]. Video based solutions offer several advantages over others including the capability of detection of various activities. The further benefit is low intrusiveness and the possibility of remote verification of fall events. However, the currently available solutions require time for installation, camera calibration and they are not cheap. As a rule, CCD-camera based systems require a PC computer or a notebook for image processing. While these techniques might work well in controlled environments, in order to be practically applied they must be adapted to non-controlled environments in which neither the lighting nor the subject tracking is fully controlled. Typically, the existing video-based devices for fall detection cannot work in nightlight or low light conditions. Additionally, the lack of depth information can lead to lots of false alarms. What is more, their poor adherence to real-life applications is particularly related to privacy preserving. Nevertheless, these solutions are becoming more accessible, thanks to the emergence of low-cost cameras, the wireless transmission devices, and the possibility of embedding the algorithms. The major problem is acceptance of this technology by the seniors as it requires the placement of video cameras in private living quarters, and especially in the bedroom and the bathroom.

The existing video-based devices for fall detecting cannot work in nightlight or low light conditions. In addition, in most of such solutions the privacy is not preserved adequately. On the other hand, video cameras offer several advantages in fall detection over wearable devices-based technology, among others the ability to detect and recognize various daily activities. Additional advantage is low intrusiveness and the possibility of remote verification of fall events. However, the lack of depth information may lead to many false alarms. The existing technology permits reaching quite high performance of fall detection. However, as mentioned above it does not meet the requirements of the users with special needs.

Recently, Kinect sensor has been proposed to achieve fall detection [20–22]. The Kinect is a revolutionary motion-sensing technology that allows tracking a person in real-time without having to carry sensors. It is the world's first low-cost device that combines an RGB camera and a depth sensor. Thus, if only depth images are used it preserves the person's privacy. Unlike 2D cameras, it allows tracking the body movements in 3D. Since the depth inference is done using an active light source, the depth maps are independent of external light conditions. Owing to using the infrared light, the Kinect sensor is capable of extracting the depth maps in dark rooms. In the context of reliable fall detection systems, which should work 24 h a day and 7 days a week it is very important capability, as we already demonstrated in [21].