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Smartphone Based Data Mining for Fall Detection: Analysis and Design

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Abstract

Falls can be devastating to the affected individual, yet a common event and hence one of the major causes of injury or disability within the aged population in Malaysia and worldwide. This paper aims to detect human fall utilizing the built inertial measurement unit (IMU) sensors of a smartphone attached to the subject's body with the signals wirelessly transmitted to remote PC for processing. Matlab's mobile and the Smartphone Sensor Support is used to acquire the data from the smartphone which is then analysed to design an algorithm for the detection of fall. Falls in human are usually characterized by large acceleration. However, focusing only on a large value of the acceleration can result in many false positives from fall-like activities such as sitting down quickly and jumping. Thus, in this work, a threshold based fall detection algorithm is implemented while a supervised machine learning algorithm is used to classify activity daily living (ADL). This combination has been found effective in increasing the accuracy of the fall detection. The aim is to develop and verify the high precision detection algorithm using Matlab Simulink, followed by a few real time testing.

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Keywords: fall detection, machine learning, supervised learning, cellular phone, smartphone

1. Introduction

In Malaysia, people with disabilities can be considered as a part of the most vulnerable minority group within the Malaysian population [1]. World Health Organization (WHO) and World Bank (2011) estimated that there are approximately 15% of the world population having some form of disability. According to the Malaysian Department of Social Welfare in December 2015, there were 305,640 disable people in Malaysia. Among them, 27,363 are visual 39,303 hearing, 180 speech, 106,252 physical, 117,699 learning, 2,130 mental and 12,713 multiple disable people [2]. Thus, standing balance for elderly and in post-acute stroke is a part of physical disabilities faced by physiotherapists. Usually stroke patients showed excessive postural sway and instability [3]. Therefore, this problem can potentially cost individuals more money and eventually burden the national economy and destabilize the society. In this context, assistive devices that could ease this significant wellbeing are a dire social need.

Existing fall detection approaches can be explained and categorized into three different classes depending on the different detection methods used. They are: (*i*) device based, (*ii*) ambience sensor based and (*iii*) vision based. The wearable devices can be further classified into (*a*) posture based and (*b*) motion based devices. The ambience based devices can be further classified into (*a*) presence- and (*b*) posture- based sensors. The vision based systems, on the other hand, can be further categorised into three classes depending on (*a*) shape change, (*b*) inactivity and (*c*) 3D head motion.

Wearable devices are based entirely on sensing the acceleration since fall is primarily characterized by large accelerations. Various distinctive methodologies for automatic detection of falls have been reported in recent years [4]. Some rely on the

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orientation of the body relative to the ground or near horizontal orientation of the subject, following the fall [4]. Most fall-detection frameworks rely on detecting the stun experienced by the body upon fall using accelerometers [4-6]. Some recent studies implementing fall detection using tri-axial accelerometers have reported better results in detection of fall than the previous systems. These wearable devices have their advantages as well as disadvantages. The largest advantage is the lower cost of wearable device. Installation and setup of the design is also not very complicated. Therefore, the devices are relatively easy to operate. The disadvantages include intrusion and fixed relative relation with the subject, which could cause the device to be easily disconnected. Such disadvantages make wearable devices an unfavourable choice for the elderly [7].

Ambience based devices are based on sensing the vibrational data. The detection of the events and changes using vibrational data can be useful in many ways such as monitoring, tracking and localisation. A completely passive and unobtrusive system was introduced in [8] where the authors have developed the working principle and the design of floor vibration-based fall detector. In this approach, the detection of human fall is estimated by monitoring the floor vibration patterns, since floor's vibration signature generated by human fall is different from normal activities, such as walking. With these approaches pressure sensors are used to sense high pressure of the object due to the object's weight for detection and tracking. It is very cost effective and less intrusive for the implementation of surveillance systems. Still, it has huge disadvantages of sensing pressure of everything in and around the object and generating false positives, which leads to low detection accuracy [7].

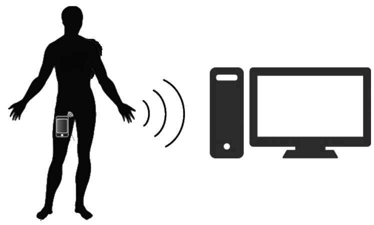

Fig. 1. System Design

Vision based approaches are based on using cameras. Nowadays, the application of such approaches are on the rise, especially in home assistive systems, as they convey multiple advantages over other systems. Cameras can be used to detect multiple events simultaneously with less interruption. Image analysis requires efficient and accurate shape modelling methods. Mihailidis [9] placed a video camera on the ceiling and developed scene algorithms to detect a fall. The system which was tested on 21 volunteers carrying out simulated falls, was reported successful in detecting 77% of falls. This approach, learned through extended observation such as the interpretation of human activities in a scene, provides contextual representation of activities. Vision based systems tend to deal with intrusion better than the other approaches, yet it also introduces some ethical issues concerning the confidentiality and privacy of the user.

Recently, there is a growing interest for identifying and detecting fall events using an inertial measurement unit (IMU) which is a combination of accelerometers, gyroscopes and magnetometers [10]. Various studies have shown that the IMU based wearable systems can be effectively used to recognize fall events by examining the impact of the body with the ground and the body orientation prior to, during, and following the fall. However, the techniques fail to bolster pervasive fall detection since they require particular hardware and software, which causes increase in cost and limits commercial sustainability. Smartphone is still not being used widely in comparison with the previous categories according to the several studies conducted on fall detection recently. In fact, this is a relatively novel technology considering the fact that the first study using smartphone only appeared in 2009 [11]. Although these studies still need to incorporate a more exhaustive evaluation, there are signs that this area is in fact an emerging field [12].

Universal fall detection can be achieved by taking advantage of a widely available technology, such as smartphones. Smartphone based fall detection techniques possess immense potential as they are ultra-portable, widely available while packed with high quality sensing and processing ability, featuring embedded motion sensors, increasingly powerful microprocessors, considerable memory capacity, open source operating systems, and telecommunication services, making them ideal for easily programmable and customizable for fall detection [11, 13].

Fall is usually characterized by larger acceleration and hence accelerometer can be easily used for its detection. However, such approach is prone to false positives as tasks like sitting down quickly or jumping may result in larger values of accelerations. Existing acceleration based fall detection solutions can be divided into two categories. The first category only analyses acceleration to detect fall while the second category utilizes both acceleration and body information to detect fall. The second category possesses increased accuracy and sensitivity in detection of human fall [14]. In this work, we propose to implement the latter category and compile the statistics of the output from the combination of various motion and set threshold to detect fall.

The ultimate objective of the overall design is to develop a wearable device that can be donned and doffed very easily, rendering it as a feasible safety device for day to day regular user activity. Since smart phones are widely used and are packed with high quality sensing elements, it holds promising potential to make use of such highly available, ultra-portable, hi-tech piece of equipment in detecting falls in vulnerable group humans, e.g. in elderly or geriatrics.

2. Methods

2.1. Hardware Platform

The design of the proposed fall detection system involves utilizing smartphone which incorporates a powerful central processing unit (CPU), adequate memory capacity, flexible software environment, and built in sensors. To acquire acceleration,