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FALL DETECTION AND MONITORING SYSTEM USING TRI-AXIAL ACCELERATION SENSOR IN THE ELDERLY

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Abstract

Many elderly people are living alone in their homes. If the old people fall down, it may be tough for them to ask for help. The main objective of this article is to design a fall detection system at low cost for the old people. This article represents the design of fall detection system which detects fall using sensors and generates an alarm for help. Our proposed system is able to acknowledge a fall incident to the contact person such that the incident can be reported to the hospital as soon as possible, and to give essential medical treatments for the injured elderly. The design and implementation combine both hardware and software that work together in detecting and reporting a fall at home. The hardware part consists of the fall detection sensor that detects the body movements of the user to determine whether a person is falling or not while the software side consists of components that confirm the fall and triggers an alarm and sending a message. With a developed system, elder people and chronically ill patients could stay independently in their own home with care facilities and secure in the knowledge that they are being monitored.

Key words: Accelerometer, Acceleration, Arduino, fall detection, falls in the elderly, Threshold

Introduction

There are many old people who live alone when their children go out of home for work. This means that there is no one to help them if any kind of accidents happens during that time. If the elderly falls down and got injuries, they need to call their relatives to ask for help which is quite impossible. People with disabilities want to remain in home even when their health condition is not good enough. Because of this the tele-health service has been broadly implemented and used to help one to live independently and safely at home. Because of the problem of aging are increasing, the smart home based health monitoring has become major research area for embedded system computing.

Falls has become major problem for the elderly because they may cause significant illness and mortality. This is due to the complications arising from falls causing a significant decrease in serious injury, and an increase in the utilization of medical services. According to the research "Risk factors of home injury among elderly people in Bangladesh", out of 4842 respondents whose age is more than 60 years, 279 had faced many kinds of injury during the previous year. Falling is also the major cause of serious Traumatic Brain Injury (TBI). The most common types of injury were fall, cuts, and

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being struck by objects. The most of common injury locations were the kitchen, garden, bathroom/toilet, living room, bedroom, and stairs.

This paper proposed a system that is able to monitor the falling of elderly people and send an emergency SMS to the contact person stored in the system to request help. The idea of this research is to develop an intelligent and versatile home safety environment that could help the elderly and individual with disability live independently in their own home. This paper presents the architecture of a system and how it is integrated with monitoring system for fall detection. Elderly people face many problems because of being alone in their homes. Wearable based methods often rely on smart sensors with embedded processing. They can be attached to the human body or worn in their garments, clothing or jewelry. Tele health devices are used as a tool in monitoring patients and respond promptly to indicators of acute exacerbations. Monitoring the 'vital signs' of the patient at home is an important event of the smart home technology. When the preset parameters (physiological indices such as blood pressure, oxygen saturations, pulse, spirometer, temperature, ECG and blood glucose readings) are breached, alerts are sent to the health care professionals (such as community matrons, GPs and hospital consultants) via internet portal.

In recent years, mobile phones had been used as tools for encouraging physical activity and healthy diets, for symptom monitoring in diseases, for sending reminders to patients and for a range of other health problems. Phone is then connected to the monitoring system by using the TCP/IP networking method via Wi-Fi. A graphical user interface (GUI) is developed as the monitoring system. A different type of fall detection system has been designed which is shoe based using MMA7260Q tri axial acceleration sensor in (S.Y.Sim, 2011). They use the threshold value for detecting fall. If the sensor used on the heel cup of the shoes then the algorithm unable to detect fall. It detects jogging as fall. The power supply system is heavier that's why it will be difficult to carry for the user. In 2012 (Vo Quang Viet, 2012) a method is developed by analyzing the changing value of accelerometer of smart phone .Sometimes movement of phone measures as fall and create false alert. A smart phone based fall detection system is developed in 2012 (Melis Oner, 2012) which detects fall by reviewing users taken a step or not and tracks of the total number of steps . The algorithm is fit properly for counting steps but fails to detect fall accurately. In 2014 (Jin Wang, 2014) they proposed a home monitoring system for elderly by using temperature, humidity and pulse sensor to detect fall. The main drawback of this system is high implementation cost.

A smart phone base fall detection system was implemented in 2014 (Yi-Nan Zhang, 2014) which detect fall and send location by message. It also shows the distance from the elder. (Chan, 2014) proposed a ZigBee-based location-aware fall detection system for elderly telecare that provides communication between the elderly and caregivers

when falls happen. The device has to analyze large amount of data to detect falls. The false alarms happened on lying on the bed with fast speed and going up and down stairs with normal speed which are recognized as normal falls. In 2013 (Lina Tong, 2013) detect and predict falls, a hidden Markov model (HMM)-based method using tri-axial accelerations of human body is proposed. The limitations of this thesis Simulation on human activity data set on young people. So the experiment results will be different in real world practice. This method must be tested on a variety of real-world falls, and the mathematical model and thresholds should be trained and reset based on the large real-world samples of the elders.

A novel method for automatic detection of fall event by using depth cameras was proposed by (Amir Davari, 2013). Depth images generated by these cameras are used in computing the skeletal data of a person. There are limitations in using skeleton data. It is not always reliable. Noise and limited range is its major limitations. Hence they must look for alternative features which are more reliable and available for detecting various events. A bed exiting monitoring system with fall detection function for the elderly living alone is proposed in 2016 (Changchun Lu, 2016). It was unable to detect accurate falls. Sometime fall can happen outside of the nearby place of bed the monitoring system cannot detect the fall. The monitoring system cannot monitor all the time. It is not designed for using outside of the home.

A three-step detection scheme called HONEY (Home healthcare sentinel system) which consisted of an accelerometer, audio, image and video clips is proposed in 2013 (Zhang,

2013). Its innovation was to detect falls by leveraging a tri axial accelerometer, speech recognition, and on-demand video. In HONEY, once the fall event was detected, an alert email was immediately sent and the fall video was uploaded to the network storage for further investigation. The sensitivity and specificity on real falls are much lower than that in an experiment environment was found in 2012 (Bagalà, 2012) by implementing an evaluation of accelerometer-based fall detection algorithms on real-world falls. This inspires researchers to take more real world scenarios into consideration. A system based on a 3-axis accelerometer embedded in a smart phone is illustrated which had a GPS function for the user was proposed in 2012 (Bai, 2012). However, due to the relatively high energy consumption of current smart phones, their system could only be active for 40 hours with foreground execution or at most 44 hours in background execution, which means continuation of this system is the most significant problem. A 2- component system is proposed in 2012 (Winkley, 2012) which had a based station and a direct monitoring device. In this particular system, ambient/skin temperatures were measured for real time monitoring. Experiments verified that the proposed classifier outperforms the conventional classifiers in its one-pass training and with higher distinguishing capability.

The Proposed Methodology

Our proposed method works as follows and is depicted in Figure 1

1. The elderly people wear fall detection sensor devices on their chest.
2. The sensor device runs an algorithm embedded with it to detect and measure the body position of the users.
3. If the sensor devices detect the body position in falling mode, the system will trigger the alarm.
4. To prevent false positive happen, a reset button to cancel the alarm is included, if the alarm does not cancel within 40 seconds by the user, the system will send an emergency SMS to the contact person.

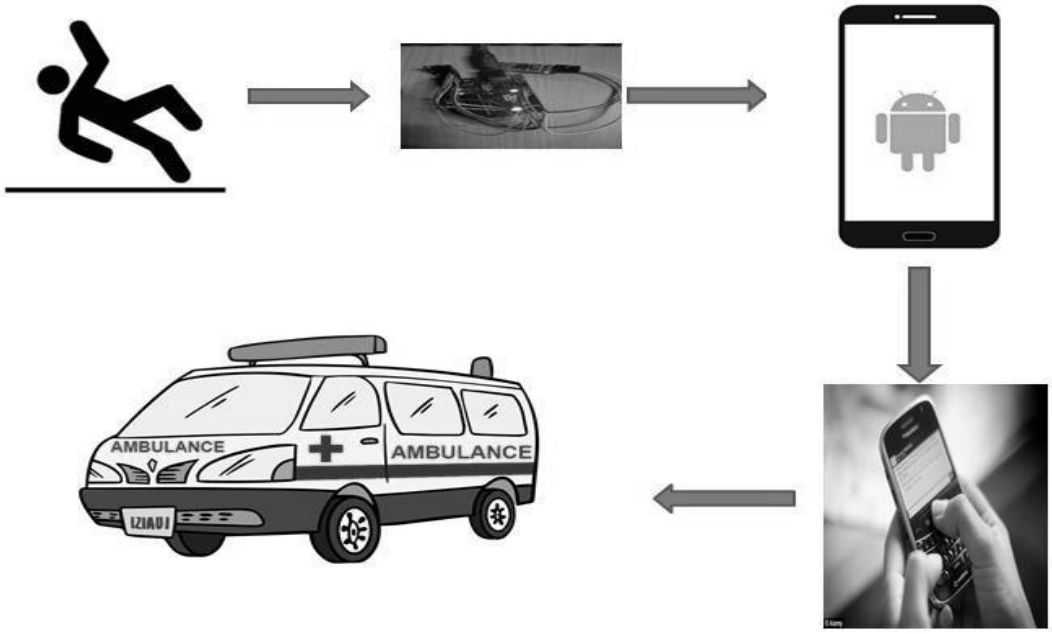

Figure 1: Falling story board

In this proposed system tri-axial accelerometer is used to detect free fall of a person. Tri-axial accelerometer can sense the motion of objects through its tri-axial values. X-axis, Y-axis and Z-axis given data are used for detecting fall using fall detection algorithm. By the algorithm free falls can be detected. If a fall is detected then a signal will be sent to a nearby device.

Then an alarm will be generated for 40s. If the alarm is not stopped then it will be considered as a serious fall. A message will be sent to predefined emergency contact. After getting data from the accelerometer, the data processing phase handles the analog to digital signal conversion and memory allocation. Furthermore, the results of the data

processing and feature extraction phase are calculated using the fall-detection algorithm. The fall detection alarm can be classified into two types based on level of emergency. One is the normal fall alarm that occurs during non-serious falls, and in this case the user can cancel the alarm manually. The other is the critical fall alarm indicating the fall is sufficiently serious to cause fatal injury, and in this situation the faller requires immediate help. If major injury occurs the victim cannot stop the alarm then it will be considered as serious fall.

During the first phase, the value of A of tri-axial accelerations was adopted as the threshold in fall detection. Let *A* be defined as:

$$A=\sqrt{x^2 + y^2 + z^2}$$

Where a_x, a_y and a_z are the accelerations of the *X*-axis, *Y*-axis, and *Z*-axis respectively. If *A* exceeds the maximum value or threshold value of ADLs, the critical fall alarm is detected. The maximum value of ADLs is then set as the fall detection threshold. Values are different at different body position. The walking, sitting, running values are different. But when a fall occur massively change in value happens. The change is detected as Fall Detection.

Fall Detection Algorithm

```
1: initialize the port_number and acceleration value
2: while true
3:    read data from sensor
4:    update acceleration = A=√(x^2 + y^2 + z^2)
5:    if acceleration is greater than or equal 6.0
6:          update min = true
7:    end if
8:    if min is true
9:       if acceleration is less than or equal 13.5
10:            update max = true
11:       end if
12:   end if
13:   if min and max both are true
14:      send fall detection message to android device via Bluetooth communication
15:      update max = false
16:      update min = false
17:   end if
18: end
```

Results and Discussion

We implement the fall detection system through a fall detection device and android applications. Fall detection algorithm detects falls from the data comes from acceleration sensor which provides different values in three different directions. Acceleration sensor gives data from different body movements. It gives different value at different position of body. When the person is sitting it will give normal value, when the person is standing then it will give normal value .The value of walking from the acceleration sensor is normal. If the free fall happens then the threshold value will be high and the fall will be detected. After detecting fall it will trigger an alarm .The alarm will be continued for 40 sec if the person is physically okay then he will be able to stop the alarm. If the alarm is not stopped then a fall detection message will be sent to the given contact for help. We complete the system through hardware and software implementation.

In the implementation of fall detection system the hardware part detect the fall through the acceleration sensor and the fall detection algorithm. Arduino UNO board is used for hardware implementation that is represented in figure 2. Bluetooth module is also a part of hardware implementation. It is attached to the Arduino UNO board passing the falling signal.

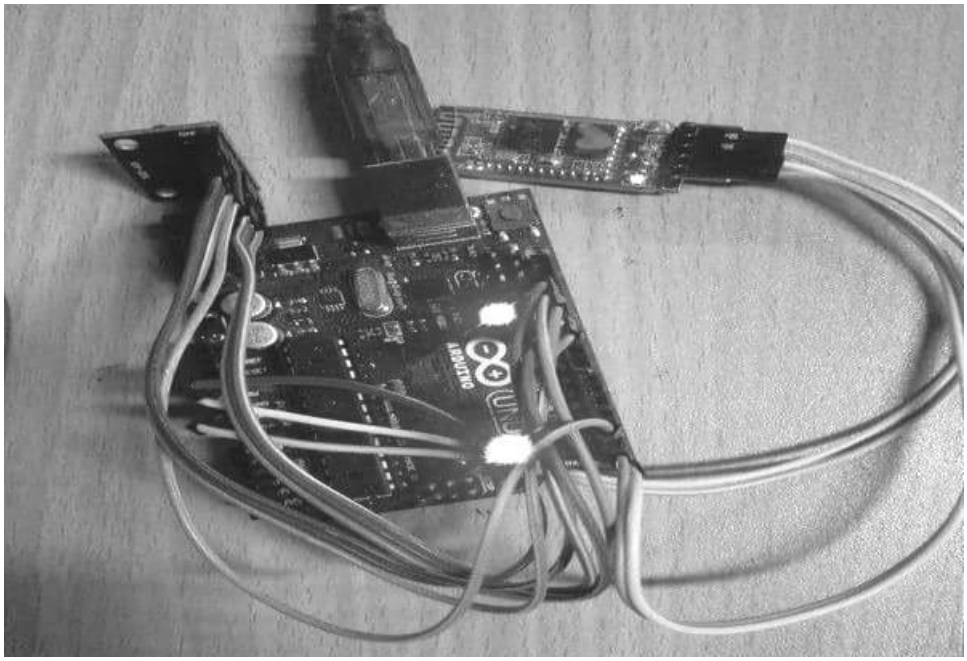

Figure 2: Top view of the hardware of the fall detection sensor system

After detecting fall, a fall detection signal will send to smart phone (android) application via Bluetooth communication and prior connection should be established using activity in smartphone shown in figure 3. Smartphone has to pair with Bluetooth module HC-05 and after being connected the device will start to passing data to smartphone device.

Figure 3: Connection setup screen

An alarm as shown in figure 4 will generate for 40s to check the condition of fall. If the person face serious fall then he will be disable to stop the alert and an alert message will be sent to the emergency contracts. Otherwise user can stop the alarm by pressing "STOP ALARM" button.

Figure 4: Screen after fall detection

The user will be able to set the message body and the emergency number who will get the emergency request through an activity shown in figure 5.

Figure 5: Window for set message and emergency contact

The figure 6 describes the changes happen in acceleration data with time during fall. Major changes happen of X-axis, Y-axis and Z-axis. The Y-axis values are negative and a sudden change happens in the values of Y-axis. X-axis and Z-axis values starts towards positive dimensions. The Y-axis values go towards negative dimensions. The flow of curve of three colors describes all the changes of three axes. The acceleration data of those three axis use positive and negative dimensions during flow with respect to time during lying time. A sudden change happens at the time of fall. The sudden change is the reason behind the detection of free fall. The change doesn't happen during walking, sitting, lying or other movements. The change of curve is detected as free fall. If a fall is detected then the device will pass a signal. Tri-axial accelerometer passes the sensor data and algorithm detects the fall.

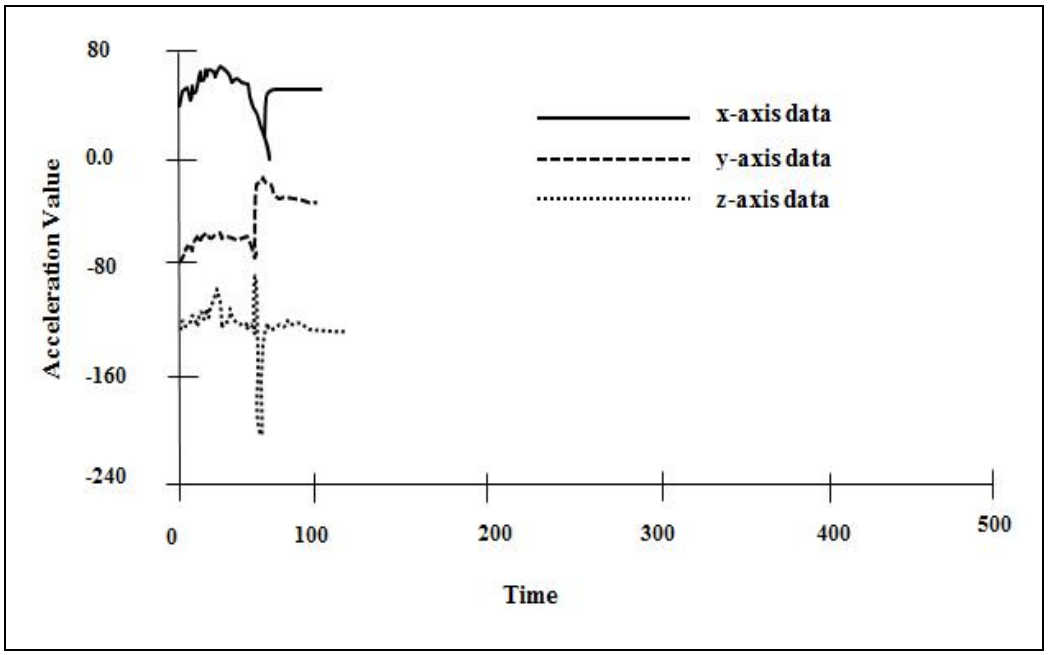

Figure 6: Curve during fall

Conclusion

This thesis presents the design and implementation of a fall detection system. This system is useful for the elderly people who live alone at home to ensure their personal safety, in which the system will inform the contact person after a fall incident happened. Ambulance department will also be contacted to arrive at the falling location and give medical treatment to the elderly as soon as possible. Fall detection sensor system uses a sensor device, a hardware that detects the body position and motion, which then communicates with the system (the software part) to send out an emergency SMS to the contact person if falling is detected. The system would only send the signal for calling ambulance after the alarm is triggered by the sensor for 40 seconds. Increased awareness of the occurrence of falls among the elderly and enrollment of efforts to prevent or diminish such events are highly needed in order to improve the quality of life for elderly people and provide them with convenient fall detection and prevention techniques. Despite the considerable achievements that have been accomplished on the field of providing multiple solutions for elderly fall monitoring, detection, and prevention in the recent years, there are still some clear challenges to overcome.

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