I hereby declare that I have read through this report entitle “Design of a Neural Network Based Fall Detection and Alert System” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : .....

Supervisor’s Name : .....

Date : .....

DESIGN OF A NEURAL NETWORK BASED FALL DETECTION AND ALERT SYSTEM

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitle “Design of a Neural Network Based Fall Detection and Alert System” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

To my beloved mother and father

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ABSTRACT

Accidental falls are considered the major cause of accidents that could lead to paralysis, accidental deaths or psychological damage. In most of the fall accidents, external support is crucial in order to prevent major injuries. Thus, a system that automatically detects fall event could help to reduce fall events and efficiently improve the prognosis of fall victims. This project proposes a neural network based fall detection and alert system with SMS alert and GPS function. A GY-80 10 Degree of Freedom (DOF) Inertial Measurement Unit (IMU) module is mounted on a wearable waist-worn device to continuously record body movements and detect body postures. The GY-80 10DOF IMU module consists of BMP085 barometer, HMC5883L magnetometer, ADXL345 accelerometer and L3G4200D gyroscope. For this project, we only use the accelerometer and gyroscope for the fall detection. The tri-axial accelerometer measures the static acceleration of gravity with high resolution (4 mg/LSB) which enables measurement of inclination changes less than 1.0°. The gyroscope is device that measure or maintains rotational motion. A new neural network algorithm has been developed to accurately distinguish falls from different postural transitions during activities of daily living (ADL) including standing, walking, jumping, running, sitting and lying. A body temperature and heart pulse monitoring device was developed for this system to assist the rescue team know the body condition of the user during the fall occurs. The application of the system is implemented on the Android platform. Once a fall accident happens, the alert system will be triggered and send emergency messages, the actual location and body conditions of the user to the recipient. Fall and ADL simulations were performed by a group of subjects to test and to validate the performance of the system. The experiment results showed that the proposed system could obtain sensitivity of 95.5%, specificity of 96.4% and accuracy of 96.3%.

ABSTRAK

Kemalangan jatuh dianggap sebagai punca utama kemalangan yang boleh membawa kepada lumpuh, kematian akibat kemalangan atau kerosakan psikologi. Dalam kebanyakan kemalangan jatuh, sokongan luar adalah penting untuk mengelakkan kecederaan serius. Oleh itu, satu sistem yang dapat mengesan kejatuhan secara automatik boleh membantu untuk mengurangkan kejadian jatuh dan meningkatkan prognosis mangsa jatuh. Projek ini mencadangkan satu sistem pengesanan kejatuhan dan sistem amaran berasaskan rangkaian neural.bersama dengan fungsi SMS dan GPS. GY-80 10 DOF Inersia Unit Pengukuran (IMU) modul dipasang pada pinggang pengguna untuk terus rekod pergerakan badan dan mengesan postur badan. GY-80 10DOF IMU modul terdiri daripada BMP085 barometer, HMC5883L magnetometer, ADXL345 akselerometer dan L3G4200D giroskop. Untuk projek ini, kami hanya menggunakan akselerometer dan giroskop untuk mengesan kejatuhan. Akselerometer mengukur statik graviti dengan resolusi tinggi (4mg/LSB) yang membolehkan pengukuran pengubahan kecenderungan kurang daripada 1.0°. Giroskop adalah peranti yang digunakan untuk mengukur atau mengekalkan pergerakan putaran. Algoritma rangkaian neural baru telah dibangunkan untuk membezakan jatuh dari postur yang berbeza semasa aktiviti kehidupan harian (ADL) termasuk berdiri, berjalan, melompat, berlari, duduk dan berbaring. Peranti untuk pemantauan suhu badan dan jantung nadi telah dibangunkan untuk sistem ini untuk membantu pasukan penyelamat tahu keadaan badan pengguna semasa kejatuhan berlaku. Penggunaan sistem ini dilaksanakan pada platform Android. Apabila kemalangan jatuh berlaku, sistem amaran akan mencetuskan dan menghantar mesej kecemasan, lokasi dan keadaan badan pengguna kepada penerima. Simulasi jatuh dan ADL telah dijalankan oleh sekumpulan sukarelawan untuk menguji dan mengesahkan prestasi sistem. Keputusan eksperimen menunjukkan bahawa sistem yang dicadangkan itu boleh mencapai 95.5% sensitiviti, 96.4%kekhususan dan 96.3% ketepatan.

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UTeM	-	Universiti Teknikal Melaka Malaysia
ADL	-	Activities of daily living
DOF	-	Degree of freedom
IMU	-	Inertial measurement unit
SMS	-	Short Message Service
GPS	-	Global Positioning System
MEMS	-	Micro-electromechanical systems
AHRS	-	Attitude heading reference system
IDE	-	Integrated development environment
ANN	-	Artificial neural network
BPNN	-	Back propagation neural network
TCP/IP	-	Transmission Control Protocol/Internet Protocol
HTTP	-	Hypertext Transfer Protocol
IOT	-	Internet of things

CHAPTER 1

INTRODUCTION

1.1 Introduction

Fall accident is one of the health risks which frequently happens, especially for the elderly who over the age of 65 years old. There are about 33% of the elderly are reported experience fall injuries at least once per year and 68% hospitalization of the elderly are fall-related [1]. Moreover, there are some sports activities like hiking will cause serious fall injuries for people. Every year, fall accidents will cause about 10,000 deaths among human aged 65 years and above in United State [1]. Therefore, in this thesis, we study and design a high performance human fall detection and alert system to reduce the percentage of fall injuries and improve medical care.

Over the last decade, the approach on fall detection is normally categorized into ambient-based, vision-based and wearable device-based [2]. However, ambient-based and visual-based methods are unpractical and can be significantly affected by the external environment. The interference factors which exist in the visual-based method will increase the difficulty for fall detection and the recognition rate is just about 50% to 70% [2]. Wearable sensors-based approach works by measuring and processing the initial signal of human motion, such as the acceleration and the angular rate. However, there are some difficulty to classify between fall activities and other activities which have similar signal profile with fall, such as running and lying down. Some researchers proposed a method which predicts falls using threshold of the angle and time. Since the fall events occur randomly, this method is unstable and has low recognition rate. By applying the neural

network algorithm, the presence of falls can be accurately detected less than 400ms before the collision happens [2].

1.2 Motivation

The main motivation of this project is to design a real time human fall detection and alert device for fall injuries reduction and medical care improvement. The fall accidents are a major cause of accidents with an average of 1042 cases annually in Malaysia. [3]. At the same time, population aged 65 years and above in Malaysia has increased by 0.2 percentage from 5.8% in 2015 to 6.0% in 2016 and the population of elderly is anticipated to increment to 7% by 2020 [4] [5]. As previously mentioned, fall accident is frequently happening, especially for the elderly who over the age of 65 years old [1]. There are about 33% of the elderly are reported experience fall injuries at least once per year and 68% hospitalization of the elderly are fall-related [1]. Figure 1.1 presents the cause of accidents in Malaysia from year 2005 to the year 2009.

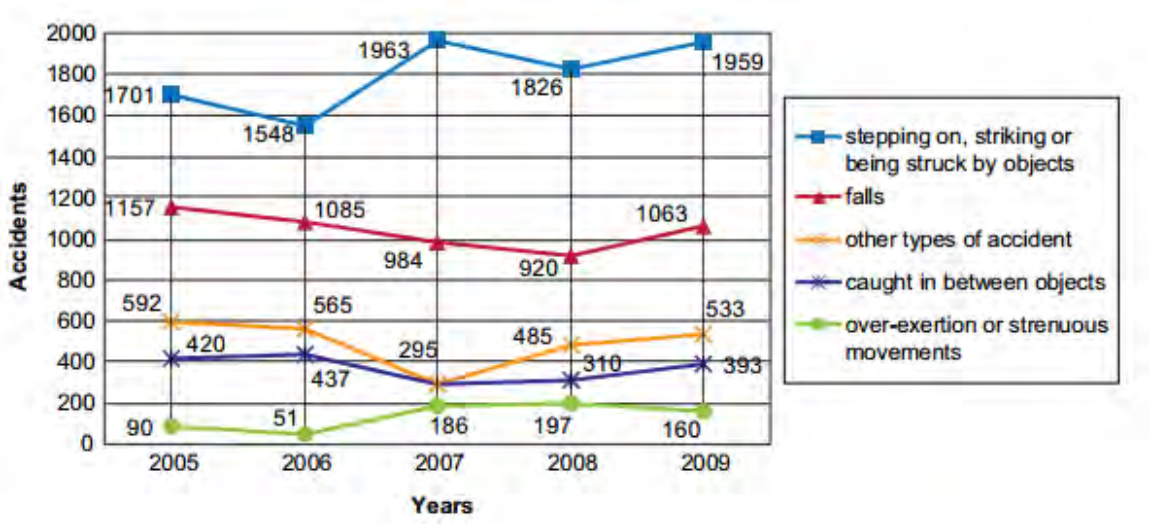

Figure 1.1: Cause of accidents in Malaysia (2005-2009) [3]

Moreover, falls can be a critical threat to the elderly who live alone. This is due to the injuries from a fall can lead to the risk of death or 'post-fall syndrome' if the victim unable receives any help immediately after a fall. Although the victim did not experience physical injury after a fall, it also may lead to psychological damage [6]. For those who experience serious fall, they might decrease their activities of daily living (ADL)

and self-care due to fear of falling again. This behaviour decreases their mobility, balance and fitness, leads to reduced social interactions, and increased depression. Figure 1.2 shows fall of the elderly.

Figure 1.2: Fall of elderly [3]

Falls are also consists of several types and can occur in different directions and at different speed. Faint falls and Crumble falls are examples of the unexplained falls. A faint fall happens where the victim loses his consciousness before the fall. Hence, the victim unable to seek any support on their own when falling. Generally, Faint falls occur at high speed and may cause critical injury for victims. On the other hand, Crumble fall is type of fall where the victim falls down slowly and sometimes takes the support of a wall or other objects. In order to distinguish the variety of falls, a fall detection algorithm is needed to separate different fall activities from other ADL.

There are plenty of possible solutions for reduce fall injuries, but none has been optimized. For examples, a physical alarm would be intrusive on the surrounding patients and a 24 hour call centre would be more costly. Therefore, this project will create a human fall alert application for Android smart phones which can be used at any place and also one of the lower-cost solutions. Furthermore, there are many reasons that fall accident occurs, for examples heart attack and heat stroke. So, knowing the cause of the victim's fall may be crucial to treatment. Therefore, our project includes a vital sign monitoring device to communicate with our fall detection system. When a fall accident happens, the body conditions of the victim such as body temperature and pulse rate will also send together with the alert message to the third party. This extra information will help the doctor and rescue team to know the conditions of the victim during the fall occurs.

1.3 Problem Statement

Accidental fall is one of the major causes of accidents that may lead to paralysis, accidental deaths or psychological damage. This type of accident has frequently happened among the elderly. For example, when the elderly alone at home, he suddenly falls down and loses consciousness, but no people found out and aware about this accident. This may cause they miss the best rescue time. Moreover, there are many reasons for the fall accident, such as heart attack and heat stroke. However, the doctor or the rescue team unable to know the reasons of fall for the victims immediately during the treatment.

Over the last decades, the fall detection and alert system can be used efficiently for reducing the dangers of the elderly falling. A fall detection device can be based on measurements of a number of different sensors. However, there are pros and cons regarding the utilization of different sensors in the system. For examples, the acoustic sensors and visual sensors may lead to some problems when implemented in the system. The acoustic noises that occur in the surrounding will easily influence the acoustic system [1]. The performance of the fall detection decreases due to the disturbance of acoustic noises. For visual-based sensor, the system's performance can be greatly affected by the external environment for examples due to lighting conditions, camera quality, background and occlusion size [1]. To overcome the limitations of acoustic and visual-based methods, wearable-based sensors will used in the system.

Data collected from both sensors can be major issues as to where the level of accuracy can be used to detect fall signals. Most of the researches use the threshold of the angle and time in the fall detection algorithm. Since the fall events occur randomly, this method is unstable and has low recognition rate. Therefore, the neural network algorithm which can easily learn and recognize the pattern of falls and other ADL is applied in the system. The accuracy of the human fall alert system is extremely correlated to the positions of the sensors. The complexity of activities done by our wrist will lead to high rate of fall detection if compare to the motion of other parts of our body such as head and waist. Moreover, the device on people's head will influence aesthetics [7]. Since the waist is the centre of gravity on the human body and truly reflects the posture of the trunk, waist worn is selected for our system design.

1.4 Objectives

The main objectives of this project are listed below:

1. To design and develop a fall detection system using both accelerometer and gyroscope sensors.
2. To implement neural network algorithm in order to accurately distinguish between falls and different postural transitions during activities of daily living (ADL)
3. To design a vital sign monitoring device which consists of a pulse sensor and a temperature sensor in order to improve the emergency alert system.

1.5 Scope

The scope of the project focuses on the development of a human fall detection and alert system with a neural network algorithm. An Intel Edison with Mini Breakout Board and GY80 10 Degree of Freedom IMU module are used in this project. GY80-10 DOF Inertial Measurement Unit module consists of a L3G4200D (3-Axis Gyroscope), ADXL345 (3-Axis Digital Accelerometer), HMC5883L (3-Axis Magnetometer) and BMP085 (Barometric Pressure Sensor). However, only the accelerometer and gyroscope of the GY80 IMU module are utilized in this project. The accelerometer is being used in this project to measure the static acceleration of gravity for different activities while the gyroscope is used to measure angular velocity. The fall detection algorithm was developed and programmed into an Intel Edison board. The application of the system is implemented on the Android platform. The GPS and SMS function of the smart phones used in the Android Application as an emergency alert system. Besides that, an extra feature which consists of body temperature and heart pulse rate monitoring also include in this system to improve the alert function. Experiments and simulations of falls were carried out with 15 subjects to test the performance and validity of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over the past decades, many researchers developed the system to detect the presence of fall and then send an alert signal to the third party. This chapter presents a review of literature on the study related to the problem of falls in the world and various approaches to fall detection. Apart from that, wearable fall detection system and health care system will be further explained and analysed based on researchers' findings. This chapter aims to provide the overview of the ideas and background information in the report. Furthermore, this review reveals new ways to interpret and identifies any gaps in knowledge and research on the fall detection.

2.2 Study of Fall

Before starting to develop the human fall alert system, it is important to know and comprehend the meaning of the term of fall. The content of this thesis work will be easier to grasp once the understanding of the event of a fall is established. There are several of ways of defining a fall by different people. The World Health Organization defines a fall as an event when a person coming to rest without intention on the ground, floor or other lower level [8]. Falls are the major cause of inadvertent injury in elderly. A serious fall without any immediate detection and treatment might cause injury or accidental death. Even if the falls did not cause serious injury to the elderly people, falls also can cause lack of confidence and scare of falling. The fear of falling might cause them to become less active over time, which rise up their risk of falling [8]. To identify and address the factors that

contribute falls, the elders are encouraged to discuss all falls that occurred, including those which not cause any injury with their medical practitioners or other health professional [8]. With the advent of the technology, many fall detection and alert approaches were proposed to reduce the fall fatalities.

2.3 Methods for Fall Detection

In the last year, there are several of methods were developed for fall detection. The approaches on fall detection are generally classified into three different categories based on the deployed sensor technology, which are ambience device approach, vision-based approach, and wearable devices approach. Table 2.1 compares the advantages and disadvantages of the three major fall detection methods.

2.3.1 Ambience Device Approach

This kind of fall's detection approach utilizes multiple sensors to collect the data related person when the person is close to the sensors. The ambient device falls detection techniques include the acoustic-based and vibration-based methods. An acoustic-based fall detection system (acoustic FADE) that utilized a microphone array and beamforming was developed by Li et al [9]. The acoustic data in real environment were collected using the Microsoft Kinetic. This acoustic fall detection system able to achieve 80% accuracy under moderate background noise (SNR = 0 dB) and strong interference (SIR = −5 dB). For vibration-based fall detection, Zigel et al. [10] Proposed an automatic detection system using a combination of floor vibration and sound sensors, resulting in sensitivity of 97.5% and specificity of 98.6%. Sensitivity refers to the percentage of true falls that are accurately detected by the system while the specificity refers to the percentage of false fall alarms among ADL samples. The formula used to calculate these two parameters are shown in equation 3.11 and 3.12. The evaluation of the fall detection performance will further discuss in section 3.11. In their work, spectral and temporal features were extracted from the sensor's signals. Then, fall and non-fall activities were classified using a Bayes' classifier. Figure 2.1 shows the fall detection and classification block diagram for the system. However, ambient-based approach has low accuracy and high rate of false alarms.

This kind of methods unable is visually verified by a caregiver. Furthermore, these techniques are costly and easily inference by environment.

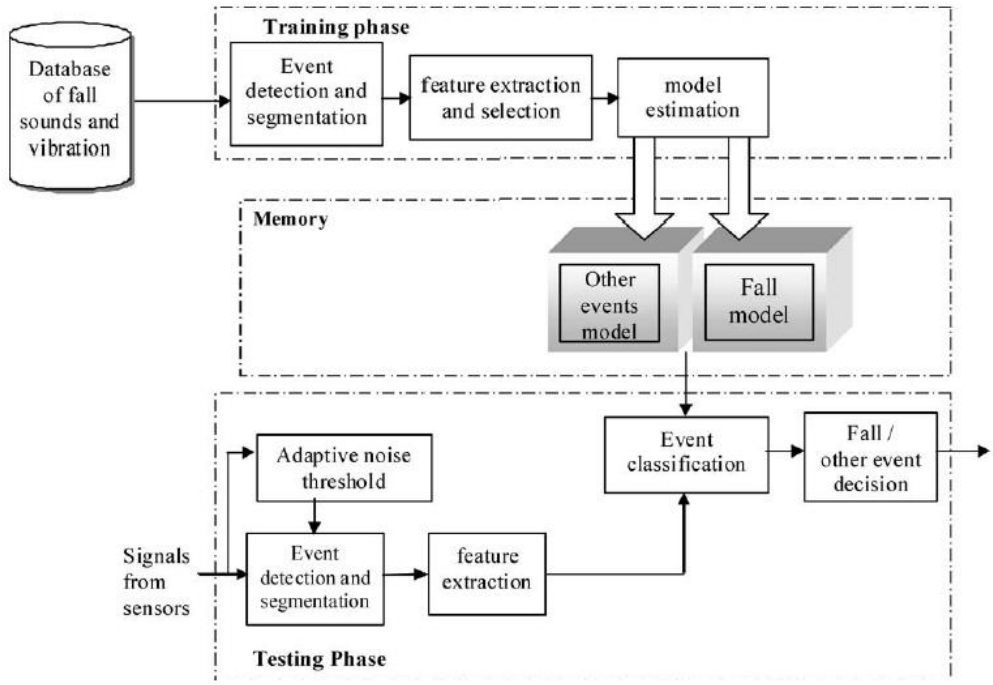

Figure 2.1: Block diagram for vibration-based fall detection system [10]

2.3.2 Vision-based Approach

With the rapid growth of the image recognition technique, computer vision method had been widely utilized in the fall detection system. This solution detects the presence of the falls using the extracted information from the captured image or video. In the study of fall detection using vision-based sensors, Yu et al [11] developed a vision-based fall detection system based on posture recognition with high sensitivity of (97.08%) and high specificity (99.2%). Yu and his research team applied a background subtraction algorithm in the fall detection system to extract the foreground human body and some post-processing was applied to improve the background subtraction results. Figure 2.2 and 2.3 shows the schematic representation and the flowchart of Yu's fall detection system respectively.