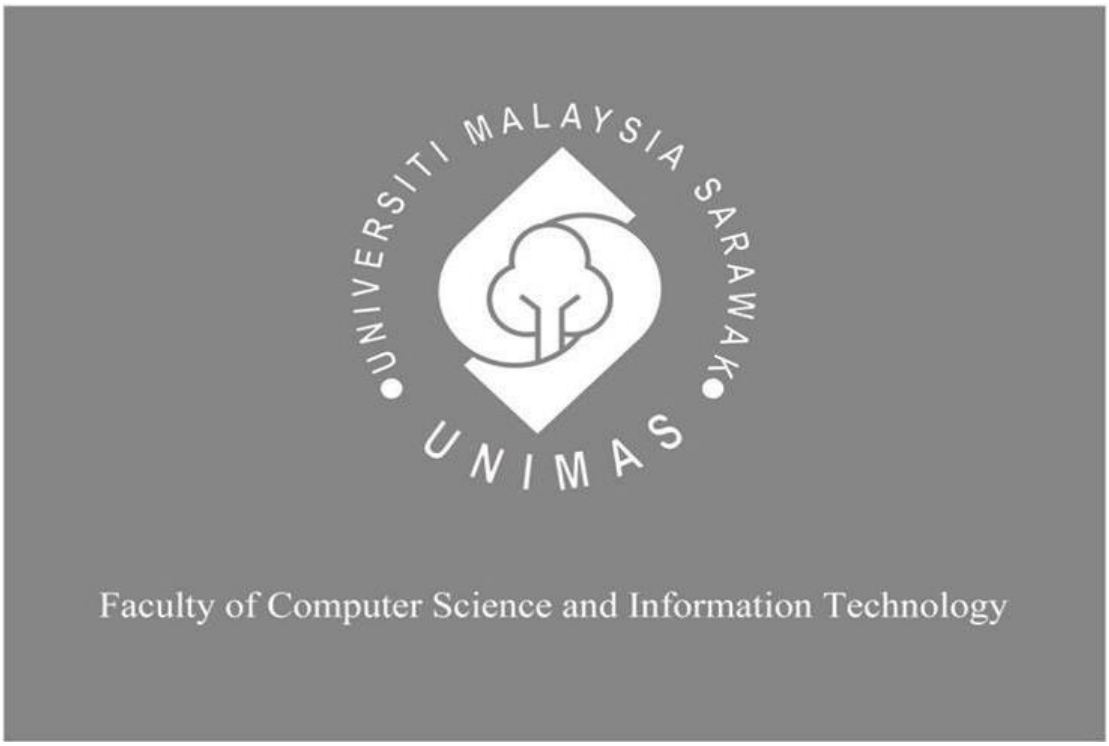


# *A WEARABLE DEVICE TO DETECT FALL*

ROXSHEN NASRUN GAI

Bachelor of Computer Science with Honours (Network Computing)

2020

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ROXSHEN NASRUN GAI

This project is submitted in partial fulfillment of the

requirements for the degree of

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(Network Computing)

Faculty of Computer Science and Information Technology

UNIVERSITI MALAYSIA SARAWAK

2020

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(ROXSHEN NASRUN GAI) (14 July 2020)

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# Abstract

A wearable device to detect fall is a fall detection system that can be wear by users. It is an Internet-Of-Things (IOT) that implement based on Arduino IDE. There are various method that can be use to develop this device such as Vision based method, Kinematic/Motion based method and Acoustic based Method. In this study, it use Kinematic/Motion based method which applied Accelerometer and Gyroscope Sensor as one of the main components to detect fall. Experiments were conducted by recording the values obtained from the Accelerometer and Gyroscope sensors. The readings for each fall were taken five times and then analysed to find the exact threshold of different types of fall. The results of the experiments were determined based on Receiver Operating Characteristic (ROC) method which was used to test fall action such as forward fall, backward fall, side fall and activities of daily life (ADL) such as sitting walking and running.

**Key words: Fall Detection System, Wearable Device, Kinematic/Motion Based Method, ROC Method.**

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Nowadays, the Internet of Things (IOT) is improving and developing rapidly throughout the times due to the demands of the society. Fall Detection Device is one of the applications that based on Internet of Things (IOT) which becomes more important as time goes by. According to the World Health Organization (WHO, 2018), it states that falls are the second leading cause of accidental or unintentional injury deaths worldwide. This shows that fall detection device is crucial in order to reduce the risk of deaths that caused by fall. This device can be the assistive technology which used by not only the elders, but also patients or any users that suffer the problem of falling often. In addition, it can act as monitoring and alerting system once it detects any fall action.

In order to detect the fall, the device must be able to detect the position and movement of the body. This can be done by detecting the changes of motion and also the acceleration in the device. Next, it will be recorded into a system and analyses whether it is really a fall action or not. Once it confirm, it automatically sent an emergency notification that contain the location of user. With the help of this reliable device, the process of monitoring of the users become easier because it is impossible to supervise them for 24 hours without the help of this device. Furthermore, it is wearable so that users can bring it anywhere they go and make sure that it do not cause discomfort to the user. Therefore, this research focuses on how to develop a wearable device to detect fall which able to alert people whom they want to alert once needed.

## 1.2 Problem statement

Every country in the world sure required a healthy citizen as they will be the one who contribute their efforts in developing nations. By doing so, the use of technology is one of the methods that can help people nowadays in monitoring their health. People can use it to monitor their blood pressure, blood glucose level and heart condition. In addition, technology can be used to detect fall because falling down is one of the common problem that required attention as it lead to unfortunate consequences. Fall detection device is use to detect fall type such as the falling forward movement, falling aside, falling backward, sitting, sleeping, squatting, upstairs, downstairs and praying (Jefiza, Pramunanto, Boedinoegroho, &Purnomo, 2017). It is important to know the movement and position of fall for the right use of methods and principles for the device. As there are many type of fall, it is challenging to ensure that the reading of the device is accurate. Sensors and algorithms of the device must be able to identify the accuracy of the fall. This is to prevent the wrong alert once it detects the fall action as the device function is monitoring and alerting.

There are methods that can be applied for the device such as Wearable Based System and Non-Wearable Based System. It is proven that the used of Non-Wearable Based is more powerful in detecting fall because the method is more to vision based where cameras is used and located strategically. But, it is high cost to develop it and also cause inconvenient and lack privacy of users because the system located inside the user's home. Therefore, it is more effective using a Wearable Based System because it requires low power consumption, small in size which is portable and low cost compare to the Non-Wearable Based System. For Wearable Based System, it considers the body movement, posture and acceleration for fall detection. In order to develop this wearable fall detection device, there are several components that needed for the features of fall detection and alerting. In this project, the research is focus on the wearable device to detect fall. The research questions are as follows:

i. How to classify types of fall?
ii. How to build a wearable device to detect fall?
iii. How to measure the performance of fall detector?

## 1.3 Objectives

Three objectives of this project are as follows:

i. To investigate methods that used to accurately detect fall.

ii. To implement the fall detection algorithm in a wearable fall detection device.

iii. To conduct experiments on the fall detection device by comparing threshold values of different fall types.

## 1.4 Methodologies

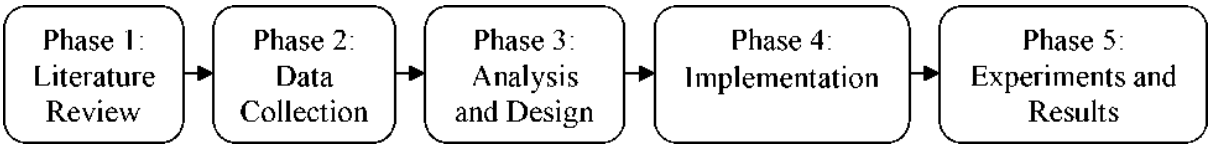


Figure 1.1 Research Methodology Phases

From the Figure 1.1, it shows the research phase that required in this project. In Phase 1, it explains and presents in detail about the background of the wearable device to detect fall where all of the information can be found from any project research that almost similar to this project. This means that, it can be summarizes in term of its features and methods that can be use in this project. In Phase 2, we will collect some information and interpret the types of fall that is suitable so that the detection of fall can be recorded accurately. This project will focus on the wearable based system method where it is more effective and convenient for users to use. In Phase 3, this is where we need to gather information and do the analysis on what hardware or component that suitable to be use in order to achieve the objective of this project. After that, we need to decide on the appropriate design that applying all hardware that has been selected. In Phase 4, the implementation will be done where all hardware will be assembled accordingly. Lastly, in Phase 5, an experiment will be conducted to study the performance of the device by recording the reading of accelerometer and gyroscope sensor. This sensor is use to detect the fall as the reading will show the body changes acceleration and body rotation speed. In this experiment, there will be specific threshold for identifying the fall action where it consider fall once the reading exceed the threshold.

## 1.5 Scope

This research is limited to the fall detection device that is wearable. This device will be designed and developed based on Arduino IDE. Fall action is detected by using accelerometer and gyroscope sensors. The reading of this sensor is taken and interpreted in order to identify types of fall. This fall detector device connected to Wi-Fi and experimented inside a room.

## 1.6 Significance of Project

Outcome of this project which is the fall detection system could help senior citizen that having risk in falling often and those who need medical attention such as people who suffered from broken hips in the past. The study of fall detection could also bring some understanding towards the development of analysis from experiments on how to detect the fall action for a wearable device by using accelerometer and gyroscope sensor. Furthermore, the project able to provide knowledge about classification on different types of fall which classify based on the results of the experiments. This will bring advantages to the society and researcher, which is to improve fall detection system in the field of medical or in healthcare industries.

## 1.7 Project Schedule

Refer to Appendix A.

## 1.8 Expected Outcome

The expected outcome of this project is a fall detection device that is built based on Arduino. This project will produce analyses on experiments that conducted to study about the fall actions when users use the device.

## 1.9 Thesis Outline

The remaining Chapters of the thesis are explained in brief:

Chapter 2: Background Study

In Chapter 2, it explains a detailed background for the study of fall detection device, all methods that used for fall detection device, comparison methods, existing system based on selected method for this study, placement of devices in term of wearable devices and classification of falls.

Chapter 3: Methodology

In this chapter, all methods involved will be described. It is important to be clear about the methodology of the research. The methodology that will be described in this chapter will explain the implementation of methods to achieve all objectives.

Chapter 4: Implementation

This chapter will contain the implementation steps that have been carried out to develop the device. Besides, the device developed according to the method that used in this research. The device tested on different types of fall in a preliminary experiment to investigate threshold for different types of fall.

Chapter 5: Experiments and results

For this chapter, it shows the performance of the device for different type of falls. Then, an experiment is conducted to investigate the reliability of the fall detection device. This experiment is conducted by using threshold from the preliminary in Chapter 4.

Chapter 6: Conclusion and Future Work

This chapter will summarize the collection of information that obtained from the experiment. In this study, the objectives of the experiment on the wearable device to detect fall had been achieved.

# CHAPTER 2

# BACKGROUND

## 2.1 Introduction

This chapter will explain the background study and the literature review of the project. The purpose for background study and literature review is to identify problems in existing system to improve the system. Besides, it also helps to discover the best method to achieve the goal of the project based on the research.

## 2.2 Background of Fall Detection System

According to (Heisler, 2019), a fall detection system have saves the life of a hiker who had fallen down a cliff. It begins when Prudenciano and Paige Paruso were hiking in Hartshorne Woods Park before that incident happened. Unfortunately, both of them got lost and fell from a cliff where Paruso luckily managed to land safely but Prudenciano fell into a river and crack his back as he landed on a rock. In this situation, he just screaming to get help because his injuries cause him cannot move his body. Thankfully, he was wearing an Apple Watch which having the fall detection system that able to detect fall actions and automatically call 911 for help.

Other than that, this fall detection system also has helped a 67-year old man who falls seriously in the bathroom which caused him unconscious. But, with the help of this system, he was able to be saved as the personnel emergency contact is automatically contacted and they able to arrived immediately 30 minutes later. Therefore, this fall detection system is very useful to decrease the risk of people getting harm due to fall. Fall not only caused physical injury, but also caused psychological damage which can lead to death when there are no immediate medical actions. It is important to have an immediate response on fall action which can rescue people's life.

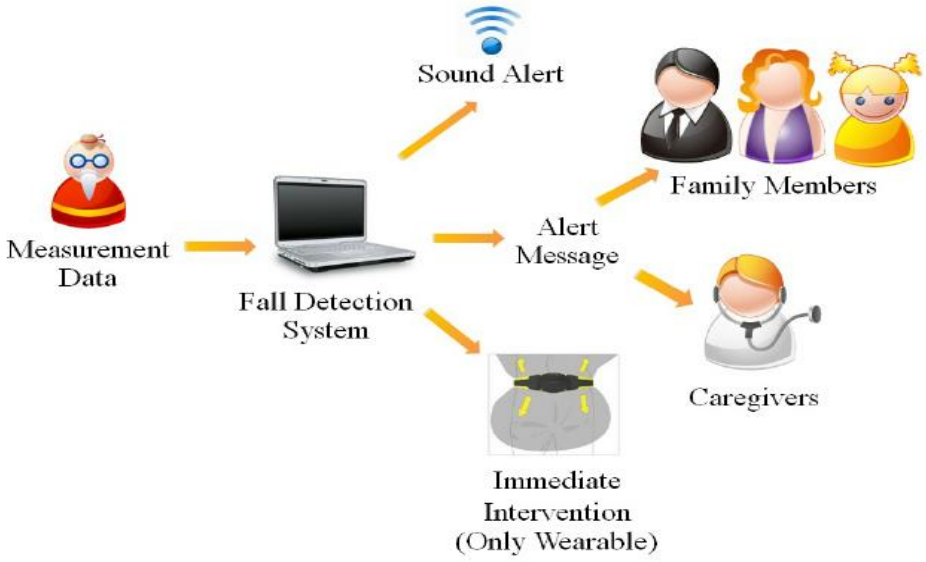


Figure 2.1 An overview of Fall Detection System (Pannurat, Thiemjarus, & Nantajeewarawat, 2014)

Figure 2.1 show a general view of a fall detection system. Fall Detection System is an assistive device whose main objective is to alert when a fall event has occurred (Igual, Medrano, & Plaza, 2013). The figure also shows the flow of the fall detection device starts from the device detecting fall action and sent the measurement data to the fall detection system. Once the system detects a fall, there will be an alert sound produced and at the same time, an alert message is sent to family members and caregivers via message. The alert sounds can also alert people surrounding area in order to get help. Some fall detection system can also send alert messages that include fall actions and their locations.

According to research by (Yu, 2008), the detection methods are categorized based on device types into wearable, vision and ambient devices which their characteristics of fall are divided into three class such as fall from sleeping, fall from sitting and fall from walking or standing. Similar research by (Perry, Kellog, Vaidya, Jong-Hoon, Ali, & Sharif, 2009), provided a brief survey on methods for real-time fall detection, categorizing them into methods that measure only acceleration, use combination of sensors and do not measure acceleration where observed that every fall had a negative peak in the acceleration data; moreover, the acceleration change from positive to negative values and its speed were important for fall detection.

There are many researches about fall detection system which uses different method to predict different type of fall. Every method had its advantages and disadvantages. Figure 2.2 shows three methods that commonly used to design the system.

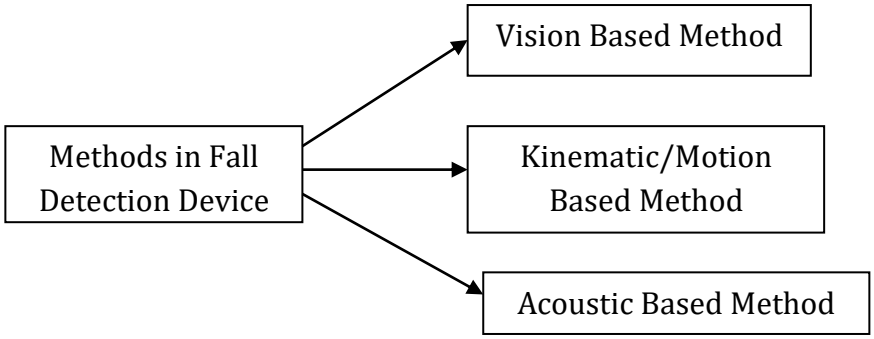


Figure 2.2 Methods to Design Fall Detection System

## 2.3 Vision Based Method

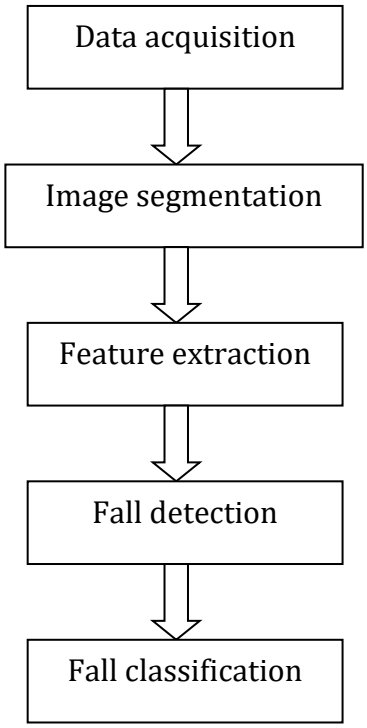


Figure 2.3 Five main stages in Vision Method

This method is based on the silhouette shape of humans. This means that data can be collected from camera to detect potential fall. From the Figure 2.3, the first stage is data acquisition where it getting video sequences or frames from cameras. For image segmentation, data or image is collected from the body silhouette of humans by removing the background. For feature extraction, it depends on the size of the silhouette and its position. As the size of the silhouette changes when distance of body to camera changes, five areas of human body which is from the five lines of silhouette's centre of gravity so that accurate size and position can be obtained. From the Figure 2.4, it shows how the feature is extracted. The first is vertical line and the other two line is 45° on each side of the first line. The remaining segments are 100° on each side of two line. According to (Fouzi, Nabil, Ying, & Amrane, 2017), it used a MEWMA-based for fall detection and used SVM-based the classification of fall.

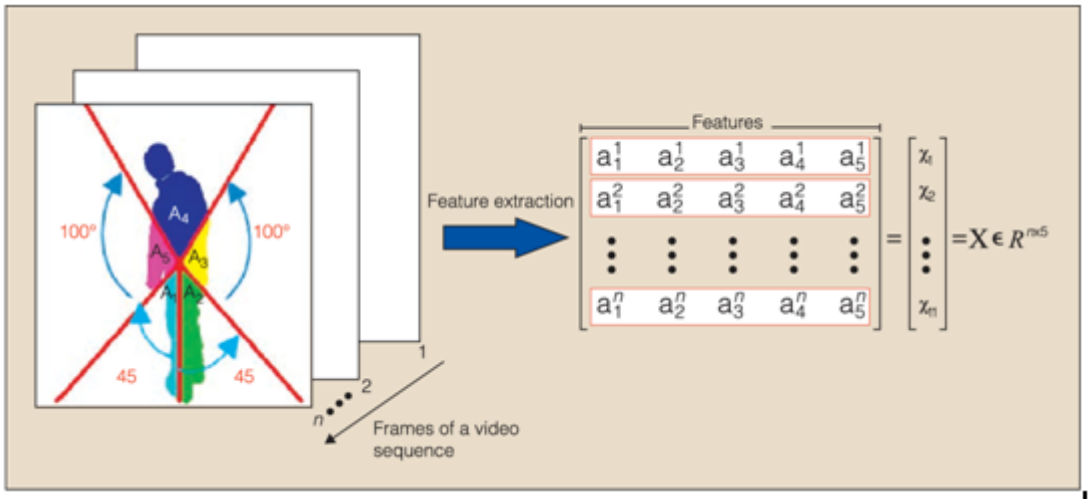


Figure 2.4 Extraction of feature (Fouzi, Nabil, Ying, & Amrane, 2017)

### *2.3.1 MEWMA-Based for Fall Detection*

Multivariate Exponentially Weighted Moving Average (MEWMA) is a technique of monitoring scheme that detect fall effectively because it really sensitive to any small shifts or changes. MEWMA statistic is a time-weighted average of all previous observations. MEWMA chart is used for monitoring the mean of a multivariate normally distributed process (Haq & B.C. Khoo, 2018).

### *2.3.2 SVM-Based for Classification of Fall*

Support Vector Machine (SVM) can be applied to classify fall types. The principle of the SVM is to transform the feature's space into a higher dimensional space using a kernel function where transformation allows the obtaining of data approximately linear, and then defining the optimal separating hyper plane in the transformed space to classify different samples (Fouzi, Nabil, Ying, & Amrane, 2017). SVM is a linear and nonlinear classifier. Three kernels functions can be used for classification process such as linear, polynomial and radial basis.

## 2.4 Kinematic/Motion Based method

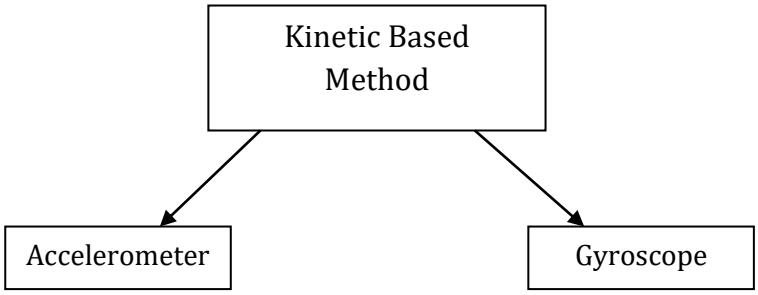


Figure 2.3 Sensors that used in Kinematic Based Method

Kinematic Based Method detects fall actions by sensing motion or movement of human. Accelerometer and Gyroscope commonly used for fall detection because of the affordable cost to implement it and it is a wearable sensor that can be placed on human body. These sensors can obtain kinematic data from the movement of human. Accelerometer is a motion sensor that can measure the acceleration (change in speed/velocity divide time) forces that are static or with movements such as free fall (Goodrich, 2013). Next, Gyroscope is a sensor that can measure the orientation and angular velocity of an object that is the change of the rotational angle of the object per unit of time (Elprocus, 2013). This means that, it can sense the posture of the body when fall. According to research by (Igual, Medrano, & Plaza, 2013), techniques that use for fall detection are Threshold-Based Method (TBM) and Machine Learning Method (MLM).