ARDUINO-BASED FALL DETECTION AND ALERT SYSTEM

by

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18556

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical and Electronics)

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS,

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PERAK

JANUARY 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and the acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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IZUAN ALIF BIN MOHD ARIFIN

ABSTRACT

Over decades, accident fall is believed to be the major cause of deaths and cause serious injuries to the elders. As their health performances turns down, they tend to have joint pains, cognitive problems and as well as the brain problems. They sometimes need support to keep standing and worse case, they need a caregiver. However, the cost of having a caregiver may burden the relatives. The caregiver also could not all the time that keep an eye on the elders and they might fall when they are alone. There are many devices that have been developed in order to cope with this problem. Some uses webcam and some uses pendant. However, there are drawbacks of using these approaches. In this project, a smart Arduino-based fall detection and alert system is developed to monitor elder activities and alert the respective person if there is any accident fall. Accelerometer and gyro sensor is used to tell the Arduino any changes in the elder’s activity that exceeds the threshold that has been set. This project developed a robust algorithm with a sensitive and an accurate result for fall detection device by more than 90%.

ACKNOWLEDGEMENT

First and foremost, I would like to thank all people that have supported me in completing my Final Year Report (FYP) for these two semesters. I would like to express my highest appreciation to FYP coordinators, Dr Azrina and Dr Norashikin for their guidance in making this FYP project.

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CHAPTER 1.0

INTRODUCTION

1.1 Background

Falling down has become one of the most essential factors that lead to death and serious illness to elders. Fail to get immediate medical assistant may worsen the impact of fall. It may leads to severe injuries and sometimes can cause death to them. The elders who choose to live alone have the most chances to be a faller. Nevertheless, the irrelevant costs of getting a caregiver for them may burden the spouse, children and relatives. Current technologies that able to monitor the elders activities also require high cost and sometimes unreliable and unpractical. So, in this project, a cost-effective yet reliable fall-detection embedded with alert system is proposed. It is to develop a fast response device towards falling events and alert the relatives or healthcare centre immediately, as soon as the falling event happened.

The most frequent incident always involves those ages above 65 years old. Globally, over 40% of senior citizen suffers at least a fall [1]. So does in Europe that recorded over 75% of the number of their medically assisted patients [2]. It leaves various impacts physically and mentally to those people that eventually lessen their life’s quality. In the high-income country like U.S., for the year of 2013 only, over 2.5 million of their senior citizen suffers nonfatal fall and that sum up a cost of more than 30 billion dollars and it is even worst in other classes of countries that has more than 80% fatal fall recorded [1,3].

While every people have chances to fall again from the first fall by twice, there are still half a number of older out of one over four that fall yearly refuses to refer to their doctor once they fall [4,5]. Annually, there are more than 800000 people warded for head injury and hip fracture and out of that number, at least 300000 are older that suffer hip fracture [6,7]. There are several factors underlined by the World Health Organization (WHO) that comprises of biological factors, behavioural factors, environment factors and socioeconomic factors. Biologically, a person’s health performance, decrease by every age increment. Thus, it declines the effectiveness of mental, physical and cognitive and it is worsen by critical illness. As the muscle weakening, the risk factor also increases associated with the environmental and behavioural risks.

Behavioural factors are much related with lifestyle, emotion and human actions. Taking alcoholic substances, stressful, and high impact activities exposes a person to more risky factors. Hazardous environment also has become an essential factor that contributes to fall. Home hazards also not an exceptional example. It includes narrow steps, slippery surfaces of stairs, looser rugs and insufficient lighting [8]. Socioeconomics risks is always define as the capacity of a person to afford a good environment, live in remote areas and less community resource especially healthcare related supports.

There were many approached and studies been conducted to come out with a reliable devices to monitor elders activities and any unexpected occurrence. Several technologies uses camera to keep track the activities of elderly people. However, to operate and to install the camera or webcam is away expensive and only applicable for certain enclosed indoor environment. The issue of privacy also has been a concern by most users where they feel unsafe and they feel that someone is watching them. Some used the Wireless Sensor Network (WSN) as a device to detect fall and alert to the caregiver. It is very effective that could detect over 90% of occurrence without acoustic interference and over 80% if there is any interference [9]. However, it is not really convenient for outdoor use. Pendant or wristband type of fall detection and alert system devices is the one that is highly commercialized nowadays but it always produces false alarm whenever there is random swinging and uncontrolled movement by the user.

1.2 Problem Statement

Elderly people who are living independently have a high risk of falling and injured themselves. Falling down and become unconscious can be fatal because nobody is aware of this falling event which may lead the faller to have more severe injuries. It is important to have a quick response and rescue time if falling event occurs. There are several technologies available to help detecting fall in elderly people. One of the systems for fall detection utilized the webcam that is attached to certain desired area that is frequently visited by the subject of events. It can monitor their action and movement. It worked by image recognition where the camera has been program to detect any occurrence that match their sample. However, due to a high cost to operate and to install and considering that it may need so many cameras to detect fall at every angle or every place that the elders always visit, it may not practically implemented. Hence, a more reliable device that has mobility to carry anywhere needs to be designed.

Currently commercialized fall detection systems available require the user to wear a wireless emergency transmitter such as pendant, necklace or wristband most of the time. There are drawbacks in wearable device where elderly people tend to forget to wear the device or unable to activate it after they become unconscious. There is a need for a device that can detect fall and transmit signal for help automatically without a push of a button. There are also some other options that experimentally proven and effective. However, the mobility of the method made it inconvenient and impractical to be commercialized. Besides, those devices can only cover certain enclosed area and easily affected by interference.

1.3 Objectives

- To develop an intelligent and effective fall detection system using smartphone and wireless sensor node for several falling position.
- To develop a reliable and cost efficient alert system complete with incident location tracker to alert nearest healthcare center and relative

1.4 Scope of Study

In this project, it is mainly focuses on the development of algorithm for fall detection in various falling position. Falling may occur in any factors especially to the elders who have a higher chance to fall. Some risky factors that always involve are declining physical capacity, cognitive impairment and hazardous environmental factors. Due to these factors, elders may randomly fall from any position. By using the data collected from sensors used in this project that are accelerometer and gyroscope, some reliable algorithm are developed for every falling position and an alert system is developed to urge the caregiver or nearby healthcare center to take prompt action.

The designed algorithm will then be implemented in an open source microcontroller, Arduino. The reason behind using this platform also in line with the objective of the project where to develop a reliable yet cost efficient fall detection and alert system. Instead, Arduino is an open source platform where any libraries can be accessed without a penny. It eventually may help in reducing the cost of prototyping the product. Thus, the selection of related software and hardware will be doing in designing stage.

CHAPTER 2.0
LITERATURE REVIEW

Despite all the falling issues among elders, there are a lot of studies carried out in order to come out with possible solution in various approaches. Abundant of products are available in the market purposely to tackle the issues and not to be forgotten to those who create product only for the sake of money. Eventhough some of the products proven to be quite effective to detect falling event and alert the caregiver, however there are still some loophole that need to be occupied. Most devices are able to detect the falling event but not all of them are able to detect pre-fall occurrence. To detect the pre-fall is actually away important as we could not expect the impact of fall. If we are able to detect the falling event earlier even before it happens, it could save more people. There are three approaches have been classified from various fall detection system devices that are ambient method, camera based method and wearable based method. Of all these methods, they serve the same purpose that are to provide a robust system, fast response and efficient.

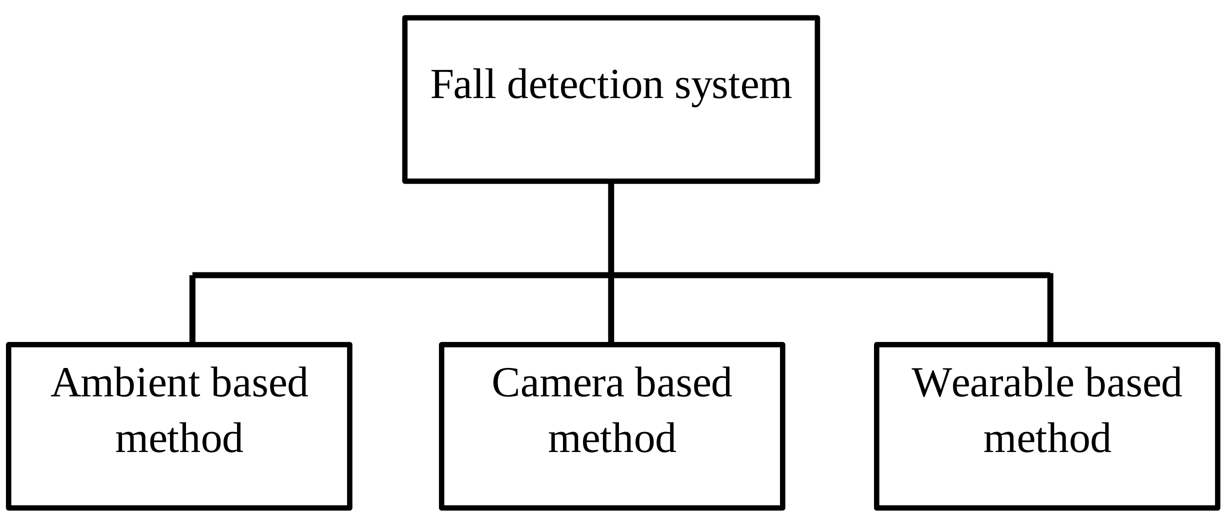


Figure 1: Types of fall detection systems

2.1 Ambient based method

2.1.1 Wireless Sensor Network (WSN)

D. et al. [9] proposed a fall detection system using Wireless Sensor Network (WSN). It is a non-invasive device or in other hands, it is a device that does not require the user to wear it wherever they go. It is a set of sensors called motes that are link or interconnected to each individual sensor. They are then linked to a main central sensor that capable of carry out data processing that is called as sink. Using the multi-hop communication, each mote that sense any event of interest will then send the data to sink through intermediate motes. The device is working by mean of cross-correlation between two signals which are the sample signal and the template signal. If the signal detected by the sensors has similarity with the reference signal, then the Mel-frequency Cepstral Coefficients (MFCC) of the falling sound is extracted. To compare series of event in a way that to conclude if there any falling events, Dynamic Time Warping (DTW) is used to create pattern for pattern recognition.

This device is capable of storing data collected from the event in its own cloud storage. This may ease the caregiver or doctors to monitor the pre-fall occurrence upon the faller. Hence, that special feature makes this device not only suitable for elder instead for children, disable and young adults. Eventhough has a high detection capability of 90% without acoustic interference and 83% with the presence of acoustic interference, the mobility of this device makes it not practically reliable at some particular times. Thus, the device only covers for certain enclosed area that if we want to widen the diameter of detection, it may not be a cost efficient device as it requires more sensors.

2.1.2 Doppler System

Arvindkumar et al. [10] proposed a fall detection system based on the Doppler radar. Doppler radar is widely applied in forecasting the weather by observing the parameter of moving objects such as speeds and velocity. So does in the system used in this research whereby the Doppler radar is associated with the BeagleBone Black acted as the central processing unit to synthesize the spectrum of reflected frequencies received in term of velocity and the direction of object of interest. The system is then connected to Voice over Internet Protocol (VoIP) services in order to convey the falling message to any predetermined phone user or the relatives of the objects of interest. This system utilised voice call over internet rather than conventional phone call that could cost more money. It detects every falling events based on the changes of frequencies of those stated parameter and the BeagleBone Black board will analyse the spectrum and activate the alert system if there is any occurrence. The board that connected to the home Wifi also can put the status online and alert the healthcare centre too instead of storing the pattern of fall for further use.

2.1.3 Fall detection using ultrasonic sensor

Huang et al. [11] investigated a fall detection system by using ultrasonic wave transducer that communicates with FPGA to monitor local behaviour of falling subject within a living community. The system is able to detect falling action and locate the subject of interest. It is a cost effective and fast response system that may alert the caregiver immediately to have prompt action upon the fell victim. The system also connected to computer so that the patient's health can be monitored closely.

2.2 Camera based method

2.2.1 Depth camera

Bian et al. [12] proposed a more robust fall detection system by using depth camera. It replaces the old technique used by most technology that using camera that is not resistance to light illumination and silhouette ambiguity. This depth camera complete with infrared LED that can remove silhouette ambiguity around object of interest. It can work within a very low level of light area. In the case of normal camera, it measures object of interest based on the color and light intensity difference between the object and the camera. Color and light intensity can be easily interfere by surround light illumination and can produce more shadow. This will make the recognition of image more difficult and will produce bad result since the camera unable to do a correct background subtraction and floor detection.

Unlike the depth camera, it can work even during a very fast light intensity changes such as switching ON and OFF of light. It improves the image recognition and can subtract background as well as detect floor in better quality. It capture image by tracking the body part and to produce the 3-D body joints, it uses improved randomized decision tree (RDT) algorithm. This RDT output then will be the input of support vector machine (SVM) classifier in order to carry out the detection of fall.

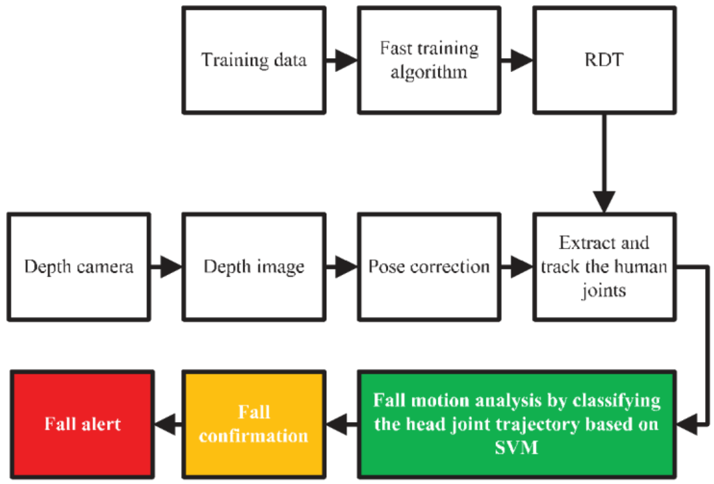


Figure 2: Flowchart of the fall detection using depth camera [12].

Picture above shows the flowchart of the fall detection devices operation that uses depth camera. Eventhough this system has very less error of 2.1%, can produce a very accurate result of 97.9% and sensitivity of 95.8%, it is practically a non-invasive system. In some cases, the elders might not stay at certain area only. They could be walking somewhere around the place that is not covered by the camera vision. If more camera is used to cope with this issue, it will incur more costs that is practically inconvenient for commercialize use.

2.2.2 Histogram of Oriented Gradient (HOG)

Nadi et al. [13] proposed a robust system that extracted the HOG of human posture by using camera. It is done by comparing the current falling event with hundreds of recorded video posture and various degrees of a falling event. The system detected face and integrate it with the body posture of object of interest. These two parameters is then analyse by comparing them with hundreds of video with different posture in the database. The process is classes into two parts which are object detection algorithm that undergoes integral image, feature selection with adaboost and attentional cascade and histogram of oriented gradient. It started with the phase of face detection. It detects the condition of face of the falling object of interest and the algorithm will determine whether the face is reaction upon pre-fall or otherwise. The result will then integrated with the body posture and from there falling event is detected.

2.2.3 Dynamic stereo vision sensor

Belbachir et al. [14] developed a fall detection system based on the optical sensor chip. The sensor is sensitive to the changes of light intensity and two of this sensor are used which can render image with the size of 304x240 pixels each. The system is comprises of three main subsystem which are the two optical sensor chips, FPGA that carry out the image processing and matching the stereo with the image captured, and the wireless communication system to alert the caregiver. The system is more robust than the system that used normal camera as it can result to more than 90% of positive result. Hence, the system is more user friendly as it keeps the user’s privacy by not showing the real image of subject of interest. The stereo vision sensors are able to provide important information such as the distance of the subject of interest to the sensors and extracting 3D image that will allow the calculation of the object being calculated.

2.3 Wearable based method

2.3.1 Pendant

Ejupi et al. [15] investigated a new device that evaluated the sit to stand motion of the users. It is developed based on the wavelet-based algorithm that monitors inertial motion using a pendant-style device. The wavelet transform is a robust method which produces a great time and frequency localization. In facts, it is capable of analysing the multiresolution of moving sit-to-stand signals. The pendant device is embedded with barometric air pressure sensor as well as tri-axial accelerometer. It can be simply worn as how you worn a lanyard. This compact pendant that embedded so many sensors on a tiny device is very suitable for the elders as it would not burden them to wear it around the neck and it is good in order to maximize the functionality of the sensors. The sit to stand movement detection is developed by means of a special algorithm that manipulates the wavelet transformations upon the extracted user's movement data by half an hour basis.

2.3.2 Wearable Fall Detection Device

Rihana et al. [16] proposed a cost effective fall detection system that uses Arduino and accelerometer. These devices works with the GSM module in order to send message over the telephone network to alert the caregiver. Apart from the ability to detect fall and alert the caregiver, it also able to detect the orientation of the fall and monitor the geographic orientation of the user. It also has an ability to make an emergency call and has a false alarm in the case the device alert a non-falling event. It is capable of telling the caregiver if there is a case where the object of interest goes out of the ranged area. It is developed with three elements which are the fall state of art, system design and result analysis. The fall state of art is where all the algorithms are developed that considers all the possibilities of degree that is considered as a fall. The system design is where the block diagram of the system is arranged and the result analysis is where the output of the falling event is compared with the threshold acted as the reference or the benchmark of falling event.

2.3.3 Inertial measurement unit (IMU) with RF Transciever

Shastry et al. [17] carried out an experiment by using a common Inertial Measurement Unit (IMU) to detect the behavior the subject of interest. It is used with RF transceiver with Time-of-Flight (TOF) that communicates with another RF pair within range of a home size area. The experiment challenged the other available fall detection devices that used IMU as a tool yet does not given out the current information of the subject of interest and keen to have false positive. With this wearable IMU device, the position of the seniors can be localized and their position can be informed to then caregiver by using ZigBee protocol.

There are three algorithms being used in this experiment which are algorithm with simple threshold, algorithm with supervised Sum Vector Measurement (SVM) and one class SVM. The working principle of the system comprises of a tag wear by the target that contain IMU that extract the behavior of the target, beacon that will pass the falling information between other beacons that is then will be sent to a cloud storage server that keep and process the information to be sent to caregiver mobile phone. The beacons are placed within 25 feet each and the tag must be able to communicate with at least three beacons to maintain a good result. Upon tested, the best algorithm to be used with the system is the supervised SVM set of algorithm with the rate of 0.98.

CHAPTER 3.0

METHODOLOGY

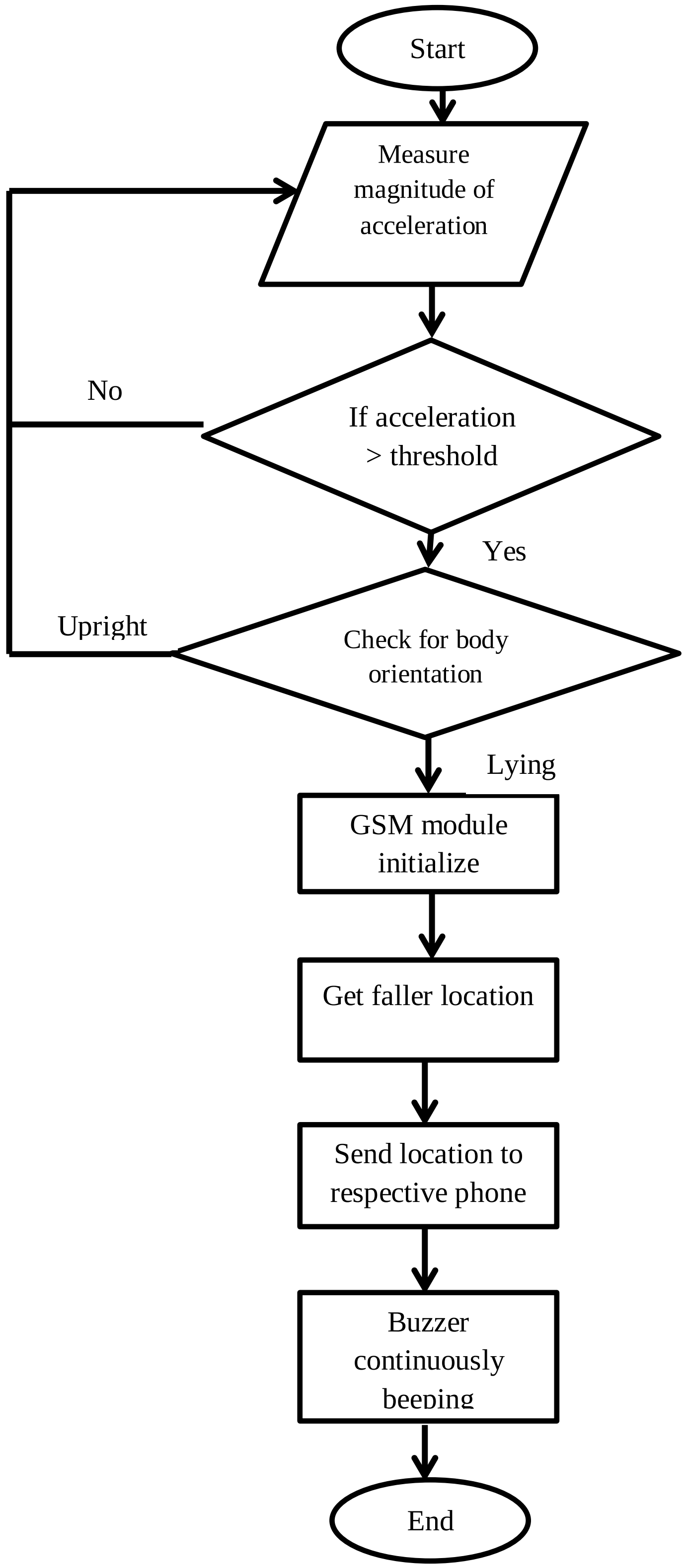


Figure 3: Flowchart of the fall detection and alert system

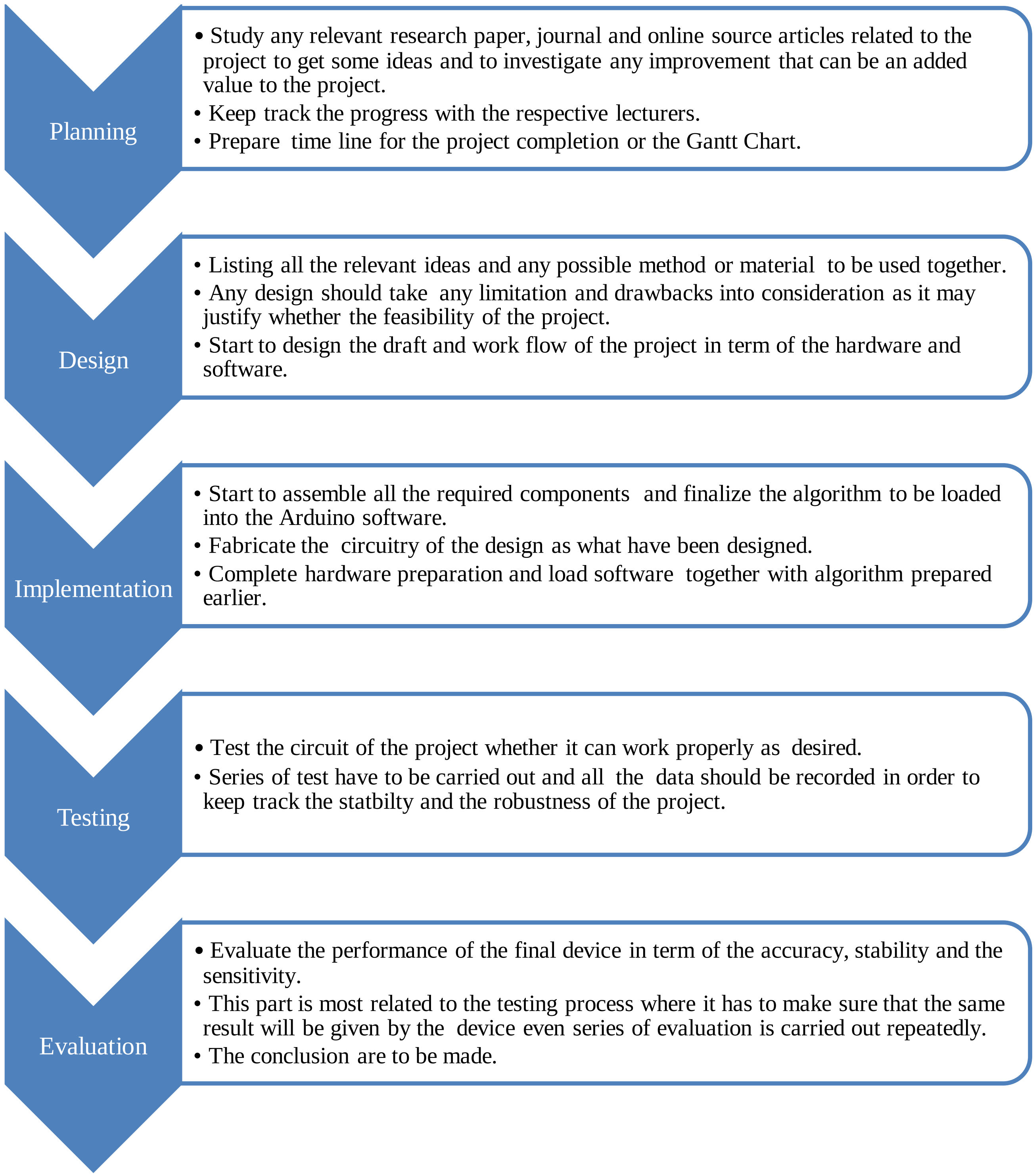
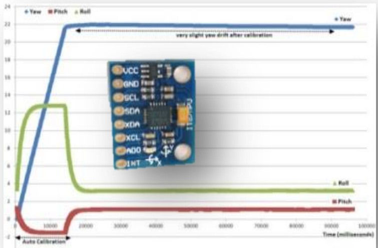


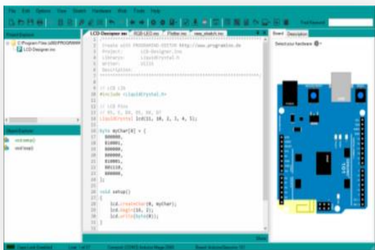
Figure 4: Five stages of work flow in the methodology

In this fall detection system device, the major parts are built with the Arduino microcontroller, the tri-axial accelerometer and gyroscope MPU 6050 Invensense and the SIM900a GSM module. The MPU6050 is communicated with the Arduino using the I^2C bus protocol through the SDA and SCL pins. It comprises of Micro-Electro-Mehanical System (MEMS) sensor chips that utilized Inertial Measurement Unit (IMU) in its motion tracking features. It has been chosen due to its low power consumption, low cost and high accuracy features that make up its handsome performance. It captures three axis at every each channels, the x,y and z with its 16-bits hardware analog to digital conversion.

Predefined offset has been loaded into the sensor so that it remains to remember its original position that has been set at the very beginning. In real time, the sensor will keep on measuring its magnitude of acceleration and compare with the threshold that has been set earlier (this threshold is set based on the series of fall tests carried out. From the tests, specific magnitude that defines the fall activities can be determined accordingly). If the system straight away detect fall prior to only one output value of the sensor, the system might not be as reliable as we desired as it could produce many False Negative (FS) output. So, in this case, counter has been used to check the subject's body orientation. If the system determined a fall, the buzzer will turn on and it started to trigger the GSM to send message to the concerned authority. The flow of the system is shown in the Figure 5.



As soon as the system is activated, the gyroscope will start to capture raw acceleration data depending on the movement of the object that it is attached with.



Arduino will take 20 sample data from the gyroscope and then it is compared with the threshold values that have been predefined in the Arduino.

If the Arduino detected any falling activities, it will trigger the GSM module to send a predefined message that has been loaded into the Arduino.

Within seconds, the caregiver will start to receive a rescue message and they can start to take a prompt action.

The victim can be rescued immediately and less severe injury will occur and critical impacts can be reduced.

Figure 5: The flow of the falling system device

In order to determine the specific parameter of a falling activity prior to the body orientation, and to recognize reliability of the devices, we must have to carry out the test upon the subject's Activities of Daily Living (ADL). The simulation of fall and Activities of Daily Living (ADL) is the study of series of body position resultant from fall occurrence. During fall, a body experiences a free fall that will result to random direction of the body to fall. For this purpose, numbers of free fall tests from any random direction has been done on mattress to avoid any fatal impact. From this tests, the sensitivity of the devices is determine with some measureable parameters such as True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN). There some body orientation that is considered as significant position that will determine device's reliability such as walking, sitting, bowing, sides falling and lying.

As shown in Table 1, at every tests, both negative and positive condition of the fall detector must be done and these associated with the condition whether there is fall occur or not. For true positive (TP), it means that the system detects a fall when it really occurred. For true negative (TN), the system does not detect a fall when there is no fall. For false positive (FP), the system detects a fall when there is no fall and for false negative (FN), the system does not detect a fall when there is a fall.

		Condition	
		Present	Absent
Test	Positive	True positive	False positive
	Negative	False negative	True negative

Table 1: The tabulation of sensitivity test parameters

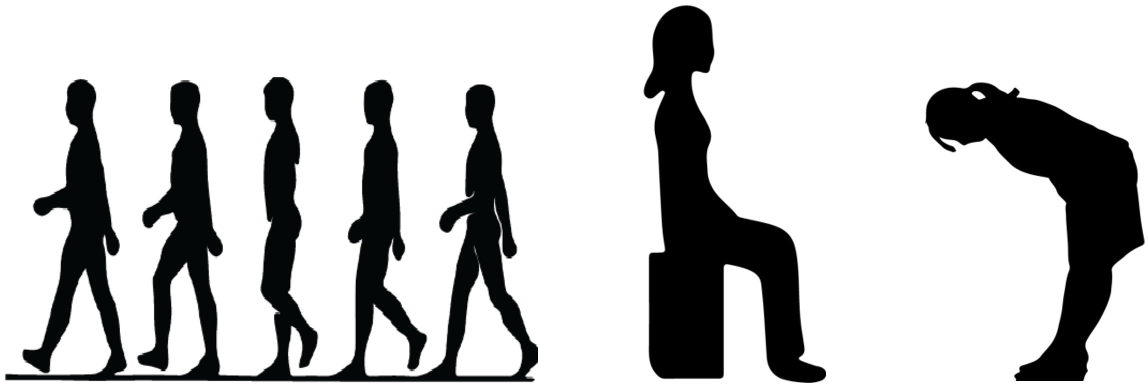


Figure 6: Sitting, lying and bowing positions

Figure 7: Walking, front and back fall and sides fall positions

Based on the Figure 6 and Figure 7, there are six types of body position that is determined to be necessary and critical to be tested with the device. Prior to this test also, the sensitivity of the device can be determined. In Figure 6, there are walking body position, sitting body position and bowing body position. These positions will tell us the best area to wear the device on the body. While in Figure 7, the three falling body positions are the most frequent position that will occur during a fall.

3.1 Algorithm

Based on the study, in order to detect a fall, there are 5 different parameters that can be utilized and to compared with certain threshold value that can be obtain from several tests. They are parameters of sum vector magnitude (SVM), differential SVM (DSVM) of acceleration, angle, gravity-weighted SVM (GSVM), and gravity-weighted DSVM (GDSVM). In this experiment, one of the parameter is used that is the Sum Vector Magnitude (SVM) which is obtained from the combination of x, y and z components of a moving object. The parameters are calculated using the following equations [18].

Sum Vector Magnitude:

$$A_{SVM}(i) = \sqrt{\ A^2{}_X(i) +\ A^2{}_y(i) +\ A^2{}_z(i)} \qquad (1)$$

Differential Sum Vector Magnitude:

$$A_{DVSM}(i) = (((A_X(i) - \ A_X(i-1))^2 + \ ((A_y(i) - \ A_y(i-1))^2 \ + \ ((A_z(i) - \ A_z(i-1))^2)^{1/2}$$
(2)

Gravity – Weighted Sum Vector Magnitude:

$$A_{GVSM}(i) = \frac{\theta(i)}{90} \times A_{SVM}(i) \qquad (3)$$

Where θ is obtained from:

$$\theta(i) = \tan^{-1}\left(\frac{\sqrt{A^2{}_y(i) + A^2{}_z(i)}}{A_X(i)}\right) \times \frac{180}{\pi} \qquad (4)$$

Differential Gravity – Weighted Sum Vector Magnitude:

$$A_{GDVSM}(i) = \frac{\theta(i)}{90} \times A_{DSVM}(i) \qquad (5)$$

3.2 Components selection

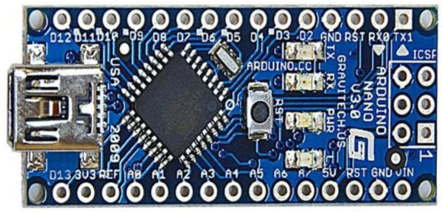
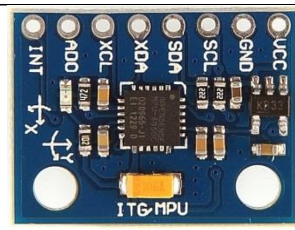
Components	Diagram	Justifications
Arduino Nano		• Open source • User friendly • Low cost (RM25)
MPU 6050 SHIELD		• Compatible with arduino • Dual functions (contains gyroscope and accelerometer) • Cost (RM19)
GSM/GPRS MODULE		• Compatible with arduino • Able to transmit SMS • Cost (RM70)
2500 mAH POWER BANK		• Rechargeable • Long lasting supply • Cost (RM30)
SIM CARD		• Used with the GSM module • Cost (RM3)

Table 2: The list of components used in the project

3.3 Budget

Components	Costs (RM)
Arduino Nano	**25.00**
MPU 6050 SHIELD	**19.00**
GSM/GPRS MODULE	**70.00**
2500 mAH POWER BANK	**30.00**
SIM CARD	**3.00**
TOTAL	**147.00**

Table 3: The budget for the device

Commonly, commercialised fall detection device charged the user on monthly basis where averagely it can goes up to RM200 per month. Based on Table 3, it is clearly stated that this Arduino based fall detection device costs not more than RM200 and it does not require the user to subscribe on monthly basis.

The budget allocation for this project is RM500 and this project does not even exceed the budget allocated. The subsequent costs that need to be bear by the user is just the cost of the prepaid prior to the how frequent the alert system utilised the credit balance.

CHAPTER 4.0

RESULT AND DISCUSSION

The Arduino based fall detection and alert system comprises of three main subsystems that make the whole system. The data acquisition system is made up of an Arduino compatible sensor module, the MPU6050 made up of accelerometer and gyroscope that gather all the data depending on its positions. The alerts system is made up of the GSM module that capable of transmitting simple message to the concern authority and the buzzer indicates that the user has surely fall. All these subsystems are connected with an Arduino microcontroller that acts as the processing unit for the data acquisitions and the data transmissions. Figure 8 shows how all the subsystem are connected and communicated with the Arduino.

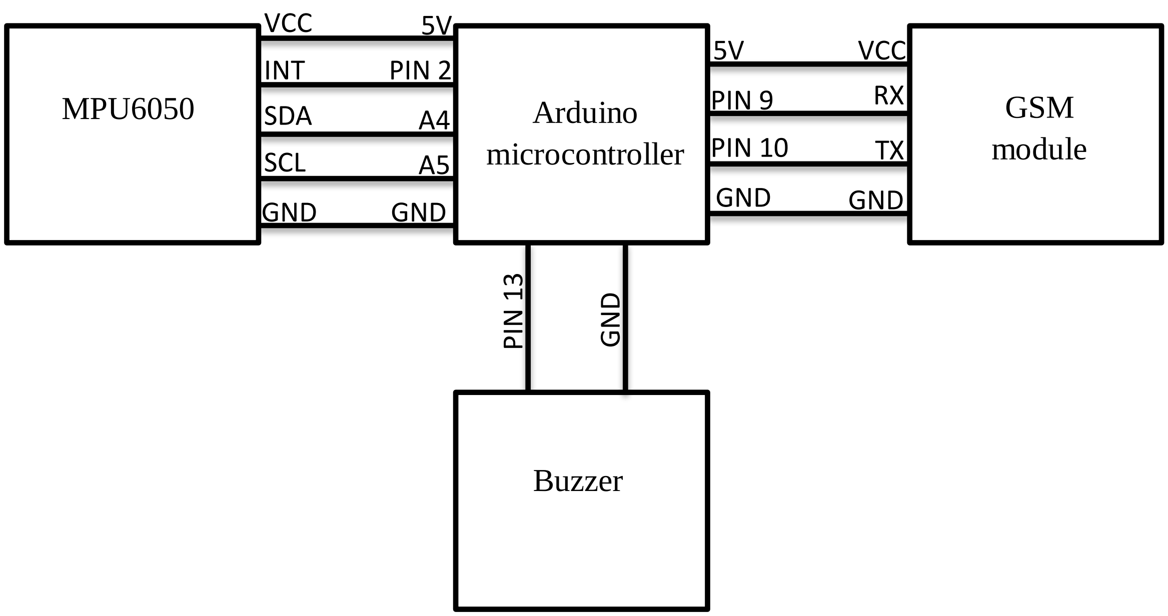


Figure 8: The connections of subsystems with the microcontroller

Figure 9 shows the complete subsystems of the Arduino based fall detection and alert system that contain the Arduino microcontroller, GSM module, MPU6050 tri-axial accelerometer and gyroscope and the LED that replacing the buzzer functionality.

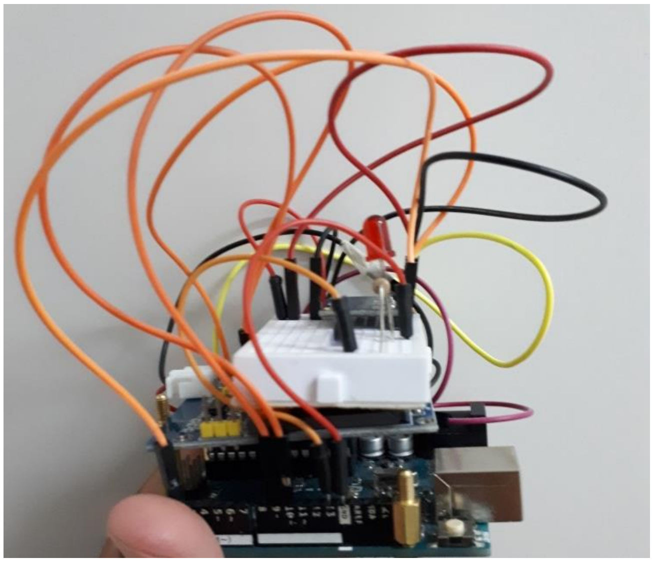


Figure 9: The assembly of the circuit

4.1 Device positioning

Based on Figure 10, the fall detection device is placed at the waist area of the body. It can be worn together with belt around the waist. This position was chosen due to its capability to cancel the false negative of the device.

Figure 10: Waist strap

The position of the device is a very crucial element to be considered. It determines the reliability of the device as the sensor module is very sensitive towards changes in its positions. For that reason, waist strap is away better than a pendant, a series of test has been done with respect to every each body positions. Each body positions were given ten times of tests that sum up of 60 test been carried out. Table 4 and table 5 show the true and false comparison between pendant and waist strap. The device is design in such a strap belt that can flexibly fit around users' waist. To proof that

	TP	TN	FP	FN
Falling sample	48	52	8	12

Table 4: Tabulation of pendant positioning

Based on the Table 4, it is clearly shown that when using a pendant, the system does not detected 12 activities that are recognize as a fall (FN) out of the 60 tests. This is more frequently to happen when the user is falling towards front and side due to the changing in position of the pendant following the current body positions. It also clearly shown that the system detects eight falls when there is no fall recorded (FP). This case frequently happen during the user is walking or running and also when they bent their or in bowing position.

	TP	TN	FP	FN
Falling sample	58	59	1	2

Table 5: Tabulation of waist strap positioning

Table 5 shows an improved result when a waist strap is used for the fall detection device system. It obtains less False Positive (FP) and less number of False Negative (FN). However, this result is ideally to happen when the waist strap is wear exactly around the waist and the result may be vary if it is wear above that level.

4.2 Fall detection

Table 6 shows that in normal upright body position during walking, the peak acceleration of the activities is determined at around 1G with orientation of almost 90° that indicates that the body is straight upright.

4.2.1 Normal walking body positioning

Trial	Peak acceleration	Orientation (°)
1	1.10	91
2	1.05	90.5
3	0.93	89.8
4	1.02	91
5	0.99	90

Table 6: Peak data values of body position during walking

Figure 11 shows that the normal body position during walking and standing is close to 1G ($9.81ms^{-2}$) indicated that it is almost the same as atmospheric pressure under ideally 90° orientations (considering the user's body position is straight upright).

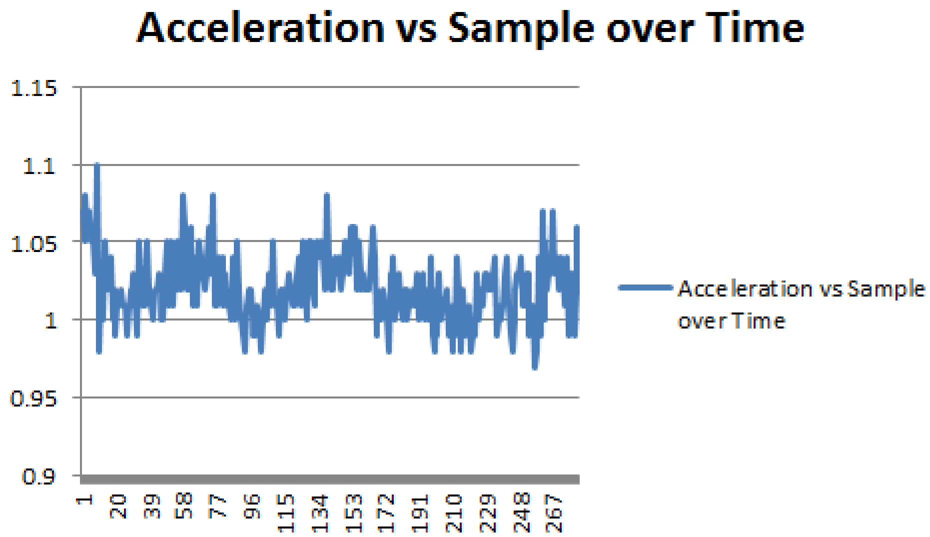


Figure 11: The graph of normal walking user

Table 7 shows the tabulation of five sample of peak acceleration that is randomly taken during the user is at front fall position.

4.2.2 Front fall body positioning

Trial	Peak acceleration	Orientation
1	1.89	5.62
2	1.92	4.35
3	1.95	5.56
4	1.98	6.01
5	1.93	6.22

Table 7: Peak data values of body position during front fall

Figure 12 shows the graph plot for a front fall. Upon demonstration, the graph shows that the acceleration is linearly increase when the user is falling to front. The highest peak acceleration recorded is approximately to 1.98G (19.4238ms^{-2}) with an orientation of 6.01 degree.

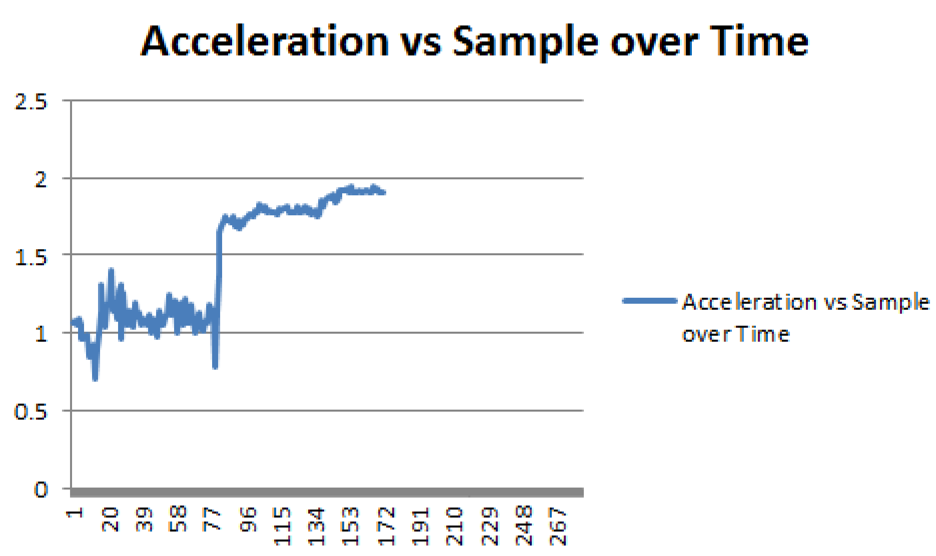


Figure 12: The graph of a front fall

Table 8 shows the tabulation of five sample of peak acceleration that is randomly taken during the user is at back fall position.

4.2.3 Back fall body positioning

Trial	Peak acceleration	Orientation
1	2.01	4.93
2	1.98	5.01
3	1.99	4.98
4	2.02	5.02
5	1.97	5.01

Table 8: Peak data values of body position during back fall

The device is tested to get the reading of falling backward. Based on the acceleration data recorded, the peak acceleration went up to 2.02 G (19.8162ms^{-2}) during the body orientation is 5.02 degree towards the back.

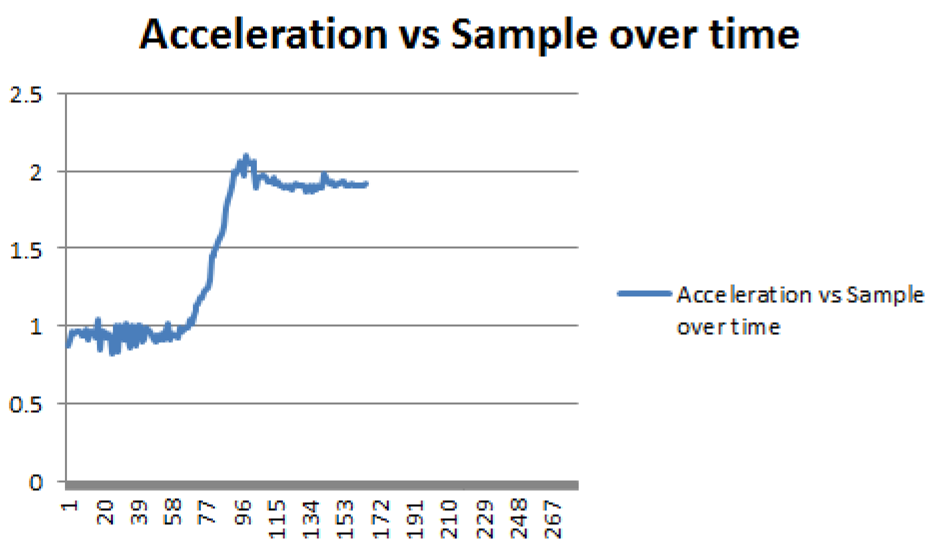


Figure 13: The graph of a back fall

Table 9 shows the tabulation of five sample of peak acceleration that is randiomly taken during the user is at sides fall position.

4.2.4 Sides fall body positioning

Trial	Peak acceleration	Orientation
1	1.78	7.02
2	1.79	6.59
3	1.73	6.32
4	1.74	5.77
5	1.77	6.42

Table 9: Peak data values of body position during sides fall

Figure 13 demeonstrate the plot of the peak acceleration of the system when the user is falling towards the side way. The peak acceleration recorded is 1.79 G (17.5599ms^{-2}) with the body orientation of 6.59 degree.

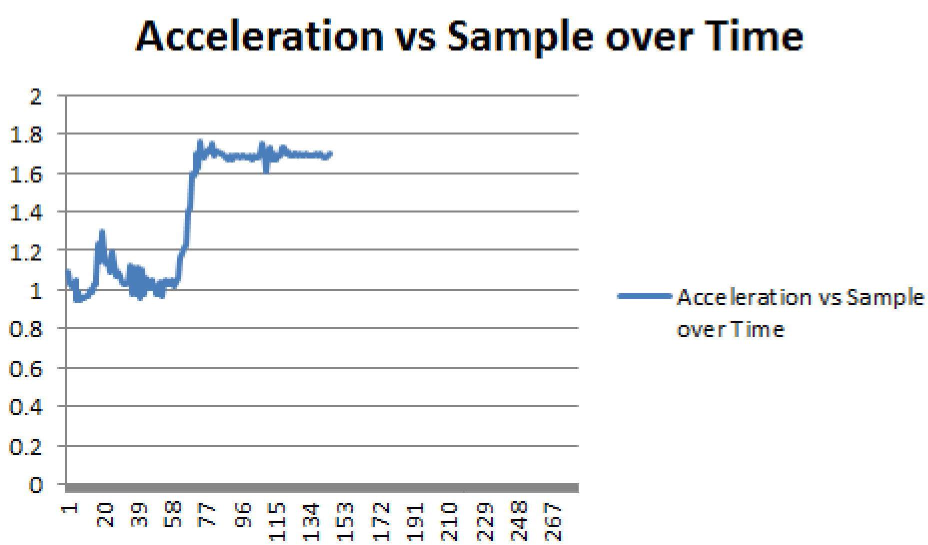


Figure 14: The graph of a side fall

Table 10 shows the tabulation of five sample of peak acceleration that is randiomly taken during the user is at vertical free fall position.

4.2.5 Vertical free fall body positioning

Trial	Peak acceleration	Orientation
1	2.22	85
2	2.27	77
3	1.98	82
4	2.02	88
5	1.99	62

Table 10: Peak data values of body position during vertical free fall

Vertical free fall is one of the most concern body position because of the its position that difficult to determine whether there is a fall or not. Most fall with this position will remain the body position keep upright that makes the device difficult to recognize the occurrence. According to Figure 13, it show that the peak acceleration is 2.22G (21.7782 ms^{-2}) with the body orientation os 85 degree which is almost the same as the user is standing or walking.

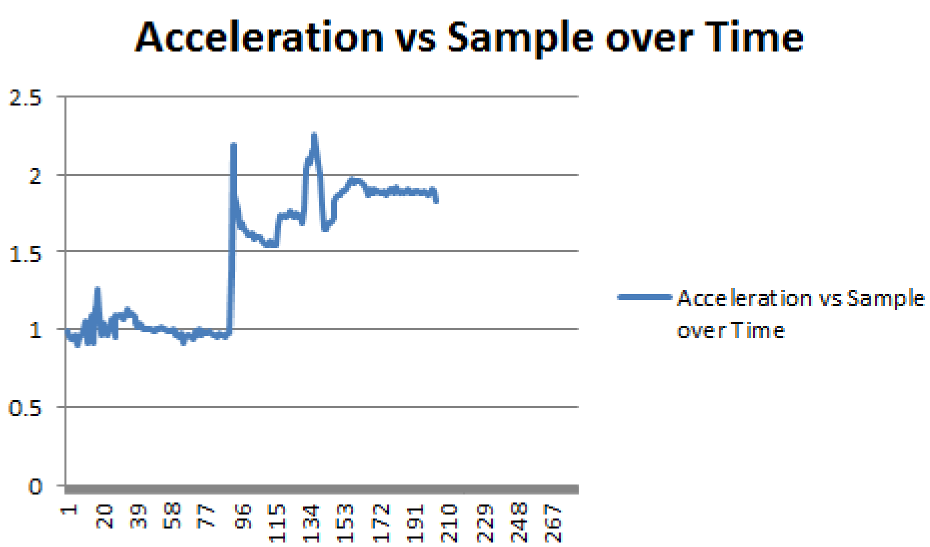


Figure 15: The graph of a vertical free fall

Upon all the tests carried out, the value of the threshold that being the set point for the falling event to occur can be set. Based on the average peak acceleration of each body position prior to its type of fall, the threshold is set to be between 0.8G to 1.6G depending on the type of fall. The threshold is set minimum so that it can detect the fall faster than the actual fall occur. So, the rescue can be delivered to the victims even faster.

4.3 Device reliability test

In order to determine the device reliability in term of its sensitivity and specificity, the result of the fall can be calculated by using following formula. It is based on the ADL of the user that has been demonstrated upon the series of fall carried out earlier.

$$\text{Sensitivity} = \frac{TP}{TP+FN}$$

$$\text{Specificity} = \frac{TN}{TN+FP}$$

Based on the tests, the sensitivity of the device is 96.67% while the specificity of the device is 98.33%.

4.4 Alert system

Figure 16 shows the alert system in term of Short Message Service (SMS) sent to the concern authority mobile phone. This is done using the GSM module whereby as soon as the microcontroller detect any fall with a correct fall body orientation, it will trigger the GSM module to send a message to the caregiver.

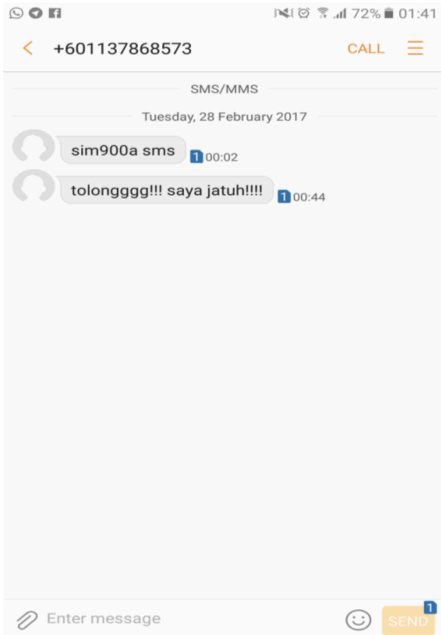


Figure 16: The figure of message sent from the GSM module to mobile phone

CHAPTER 5.0

CONCLUSION

In conclusion, the fall detection and alert system using Arduino managed to detect event of occurrence in any direction either the subject is fall horizontally or vertically. It working principle that uses acceleration changes and angle changes should be sensitive enough to determine any changes upon these parameters. As an invasive wearable fall detection devices, it can well suit with the user’s activity of daily life (ADL). Wearing this device at the trunk area could reduce the false angle detection by the gyro sensor.

Besides, it does not cost much as compared to the other commercialized fall detection devices in the market. In fact, it may reduce the cost of having a caregiver for the elders. It is comparable and much better than the camera based methods as it can be worn anywhere anytime. Thus, it does not limit the user’s movement and keep the user’s privacy. The use of Arduino is the best approach in this project as it does not cost much money and it is an open source that does not require us to spend some money for any particular software or hardware.

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APPENDIX

Gantt Chart 1

ACTIVITIES	WEEK													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Project Identification														
Project Title Identification														
Project Title Allocation														
Report Writing														
Extended Proposal Review with Supervisor														
Submission of Extended Proposal														
Fall Detection and Alert System Application														
Proposal Defence														
Optimization’s Studies														
Report Review with Supervisor														
Interim Report Submission														

Gantt Chart 2

ACTIVITIES	WEEK														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Project Identification															
Report Writing															
Studies of Fall Detection and Alert System															
Progress Report Review with Supervisor															
Progress Report Submission															
Development of Fall Detection and Alert System															
Troubleshooting															
Pre-SEDEX															
Report Review with Supervisor															
Submission of dissertation (soft copy)															
Viva															
Submission of dissertation (hard bound)															

Project Gantt Chart

ACTIVITIES	WEEK																											
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Project Identification																												
Literature review	■	■	■	■	■	■	■																					
Identify method of fall detection				■	■	■	■	■	■																			
Identify work of scope and methodology					■	■	■	■	■																			
Programming microcontroller					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
Prototyping and tool setting												■	■	■	■	■	■	■	■	■	■	■	■	■				
Prototype testing																			■	■	■	■	■	■	■			
Prototype improvement																							■	■	■	■	■	
Project submission																											■	■