Arduino Based Fall Detection and Alert System

by

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16378

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Electrical and Electronic)

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CERTIFICATION OF APPROVAL

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Electrical and Electronic Engineering Programme
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(ELECTRICAL AND ELECTRONIC)

Approved by,

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(ZAZILAH BT MAY)

UNIVERSITI TEKNOLOGI PETRONAS

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PERAK

JANUARY 2016

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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NATTHAWIN VETSANDONPHONG

ABSTRACT

Falling down is among the major causes of medical problem that are faced by the elderly people. Elderly people tend to injured themselves from falling down more often especially when they are living alone. When a falling event occurred, medical attention need to be provided immediately in order to reduce the risk of faller from getting severe injuries which may lead to death. Several technologies have been developed which some utilized webcams to monitor the activities of elderly people. However, the cost of operation and installation is expensive and only applicable for indoor environment. Some user also worried about their privacy issues. Current commercialized device required user to wear wireless emergency transmitter in form of pendant and wristband. This method will restrict the user movement and produce high false alarm due to frequent swinging and movement of the device. This project proposed a fall detection system which is cost effective and reliable to detect fall and alert nearby healthcare center or relatives for help and support. For fall detection, accelerometer and gyroscope was used to detect acceleration and body tilt angle of the faller respectively. By coupling accelerometer with gyroscope, the accuracy of the system was improved due to reducing in false positives and true negatives. False alarm was minimized due to the device's position mounted on the upper trunk of the user's body. Alert system in form of Short Message Service (SMS) was transmitted to the concerned authorities. Moreover, this wearable device requires less implementation cost and provides a quick response. As a result, this fall detection and alert system has the sensitivity and specificity of 95% and 90% respectively. However, the limitation of this device is unable to detect a user falling against a wall and falling end in sitting position. Recommendation for future work is to develop an interactive display which enables users to input nearby healthcare centre and relative's phone number.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my deepest appreciation to those who support me in my Final Year Project (FYP). I always wanted to thank the FYP coordinators for their continuous support and guidance.

A special gratitude I give to my FYP Supervisor, Ms. Zazilah Bt May who invested her full effort in guiding me during my FYP. I would like to thank her for her enthusiasm, encouragement and support, which become my inspiration and motivation for me to successfully complete my FYP.

Not to forget, I would like to express to my family and friends for their love, encouragement and support that I received during my FYP. Last but not least, I would like to thank those who willing to perform testing on my fall detection and alert device.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Every country in the world was focusing on developing their nation which includes growing the country's population. According to the findings on world population by United Nations in 2015[1], the global population is expected to have an increment of more than 1 billion people within 15 years which can accumulated to 8.5 billion in 2030. The fastest growing population which currently comprising 12% of global population is the people who are aged 60 years old or above. This population is growing by the rate of 3.26% per year and expected to reach up to 1.4 billion in 2030.

With increasing number of older people, the demand for healthcare service increase rapidly. Most of the people aged 60 or above are hospitalized due to falls. A global report by the World Health Organization (WHO) [2] states that 28-35 percent of older people aged 65 and above experienced fall each year and it is increasing to 32-42 percent for those 70 years and above.

Elderly people who live independently are exposed to higher risk of falls. Besides that, falling down frequently may cause psychological and physiological damage that lead to severe injury and even death if medical attention is not provided immediately.

In order to reduce the risk of elderly people getting harm from fall, medical attention needs to be provided immediately. Therefore, a reliable fall detection system can help to detect fall in elderly people and contact the nearest healthcare service for help and support.

The fall detection system need to be user friendly which means it is easier to be used by the elderly people. The system also must not interfere and disturb activities of daily living (ADL) of elderly people. The system needs to be cost-effective and durable.

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 out there to help detecting fall in elderly people. One of the fall detection systems utilized the webcam to monitor the activities of elderly people and detecting fall. However, the cost of installation and operation is expensive and it is only applicable for indoor environment.

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.

Therefore, there is a need for a device that can detect fall and transmit signal for help automatically without a push of a button.

1.3 OBJECTIVES

There are few objectives to be accomplished by the end of this project. The aims of this project are:

- To develop an intelligent and effective fall detection and alert system using smartphone and wireless sensor node
- To develop a reliable and cost efficient fall detection and alert system
- To develop a fall detection system that is user friendly and without causing disturbance to activities of daily living of elderly people

1.4 SCOPE OF STUDY

- This project mainly focuses on development of algorithm for fall detection and alert system by using accelerometer and gyroscope.
- The algorithm was designed and implemented in Arduino platform.
- Selection of software and hardware was determined during the designing stage.

CHAPTER 2

LITERATURE REVIEW

Falling down is one of the major medical problems that faced by the elderly people. The consequences of falling may be fatal if there is no immediate medical attention provided. Hiring nurse and caregivers may be the best option to constantly monitor and support activities of daily living (ADL) of elderly people, but the cost would be very expensive.

Moreover, it is difficult for the caregivers to constantly observe and assist elderly people all the time. Falling event among the elderly people may occur when the caregivers are not around to supervise which lead to the issue of reliability.

Therefore, an intelligent fall detection system that is reliable and cost effective must be considered as an option to assist elderly people.

Currently available techniques that are used to design fall detection systems are classified into three categories which are camera based method, acoustic based method and kinematic based method. Figure 1 shows the three methods that are commonly used for fall detection system. Each method has its own advantages and disadvantages over another. All of these approaches helps to reduce the effort of nurse and caregivers to monitor daily activities of the elderly people. Furthermore, they provide proper medical attention urgently to the elderly in case of fall. Despite these advantages, there are still many problems and the state-of-the-art in fall detection is quite premature.

There are still need for massive research in order to come up with a system that can solve all the drawbacks of current traditional approaches. Method that can predict a fall before it actually occurs needs to be developed so that preventive measures can be taken quickly before any severe injuries happen.

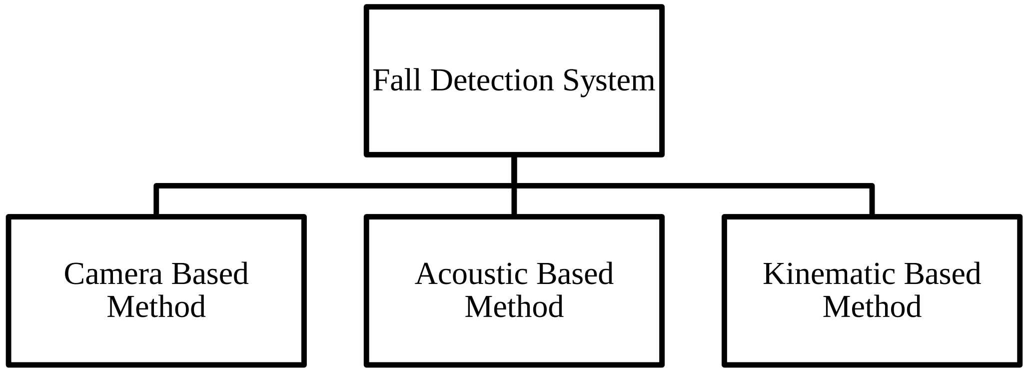

Figure 1: Fall Detection System methods

2.1 CAMERA BASED METHOD

This method utilized a few set of cameras and a microcontroller or a personal computer (PC) as the dedicated server. General idea is that the camera is used to capture video or image while transferring it to a PC for image analyzing and processing, segmenting people from background and therefore a fall detection system. This method only required single setup and can monitor multiple individuals.

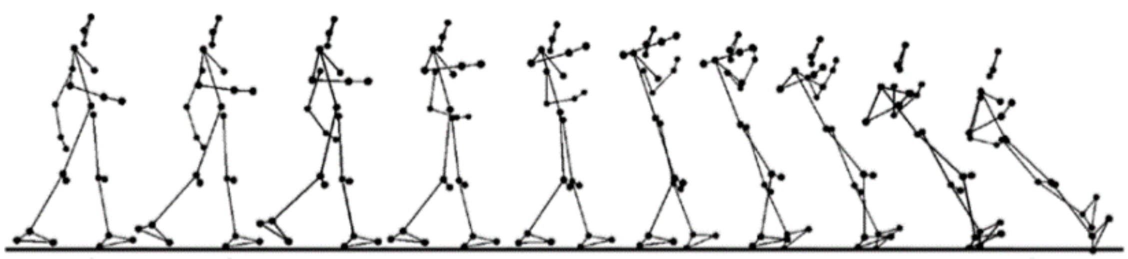

Figure 2: Posture recognition during falling

Yu et al. [3] proposed a fall detection system using camera-based method by performing posture recognition as shown in figure 2. In order to segment foreground region of a person's posture, background subtraction algorithm was implemented added with some postprocessing to improve the results. Surprisingly, the outcome from the experiment achieved a high rate of fall detection (97.08%) with minimum false alarm detection of 0.8%. Unfortunately, the drawback from this method is it having difficulty to detect fall when there are multiple moving objects and occlusions occur.

Khawandi et al. [4] used an automated monitoring system with face recognition feature to detect a fall in a certain area. The system utilized webcams to collect data such as the velocity of person's movement, position of the person, and distance between the person and the camera. Such data was used to perform image processing in order to determine whether the person is experiencing a fall.

Miaou et al. [5] proposed a fall detection system using a omni-direction camera and a dedicated pc server. The benefit of using omni-camera is that it can capture image in 360° simultaneously in one shot. This eliminates the blind spots problem faced by the conventional camera. The experimental results show a sensitivity of 78% without personal information and rise up to 90% with personal information. The drawback of this system is that the system requires the user to give the personal information such as height, BMI index which will increase the implementation cost.

Nasution et al. [6] suggested a fall detection system by using a fixed camera and a dedicated PC. Foreground is first segmented by subtracting the background from current frame. Next, feature extraction which includes vertical and horizontal projection histogram from the segmented foreground and angle between last standing posture with current foreground bounding box. Although the system can recognize 90% of the falls, occlusions problem still exists with this approach. Blind spot is also another major concern especially for approaches that uses only single camera.

Foroughi et all [7] have developed a new approach for a fall detection system that based on human shape variations. Combination of best-fit approximated ellipse around human body, projection histograms of the segmented silhouette and temporal changes of head pose are used to acquire clues for detection of different behaviors. Although the rate of success at 88.08%, occlusion problems persists to happen.

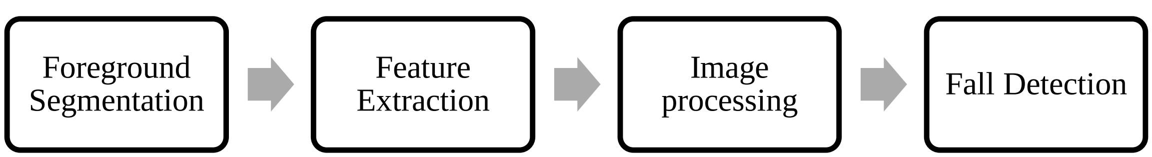

Figure 3: Common algorithm for camera based method

2.2 ACOUSTIC BASED METHOD

Acoustic and ambience sensors are used in this method to detect falls among elderly people. The cost for this method is relatively cheap compare to the camera based method due to low cost hardware and implementation. Examples of the sensors used are infrared sensors, vibration sensors and microphone. These sensors collect data and then transfer it to a microcontroller or a PC for processing. Detection of falls only activated when the data collected exceed a certain threshold or conditions set by the PC.

Winkley et al. [8] introduced Verity, an innovative system that utilizes state-of-the art (SoC) to measure ambient/skin temperatures, accelerations and heart rate for real time monitoring. The system consists of base station and direct monitoring device are able to outperform currently available classifiers with higher distinguishing capability.

Yun et al. [9] suggested an acoustic-FADE which comprising of microphone array that are arranged in uniform circular. Several processes include localization, beamforming and height information are used to determine the source of the sound produced and increase specificity and quality of the received signal. Fall detection was performed after the process of feature extraction and classification.

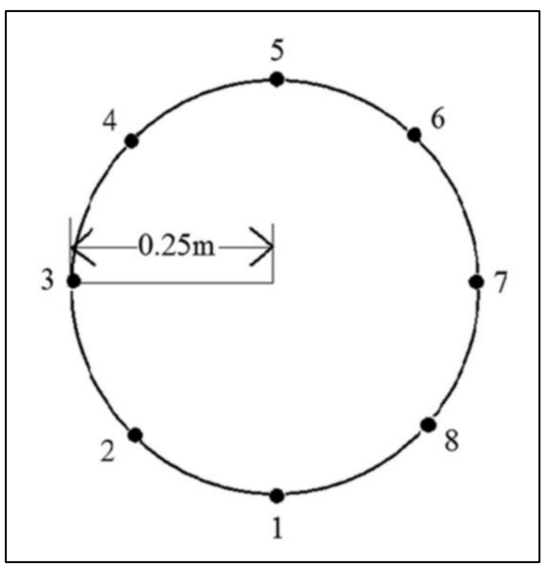

Figure 4: Acoustic circular microphone array configuration

In figure 4, small dots labelled one to eight are the omnidirectional microphones that uniformly distributed along a circle with a radius of 0.25m. Results from the experiment conclude that the system is not sensitive to the changing acoustic environment and floor materials.

Alwan et al. [10] came up with a fall detection system that monitoring the floor vibration caused by a fall. The system utilized a piezoelectric sensor coupled to the floor by means of spring arrangement and mass. The result from the experiment shows 100 percent true positive and no false alarms. However, the drawback from this method that it only can detect falls when elderly people fall down at that particular area. Moreover, the vibrations cannot be detected on all types of floor materials.

Popescu et all [11] proposed a fall detection system based on array of acoustic sensors. In order to differentiate a fall, the loudness and the height of the sound was used. The most important step is to remove the noise by mounting two microphones on vertical z-axis with 4 meters apart from each other. The system was able to achieve 70% with no false alarm. However, with a bit of adjustment, the system able to detect 100% but with penalty of 5 false alarms every hour. This shows that the system is not reliable in detecting falls.

2.3 KINEMATIC BASED METHOD

This method is commonly used and applicable for fall detection system. It is preferable due to low cost hardware implementation, and wearable sensor for fall detection either indoor or outdoor environment. Accelerometer and gyroscope are placed on part of the person’s body in order to differentiate fall from activities of daily living (ADL). Data collected by the accelerometer and gyroscope are transmitted to microcontroller to be processed. Since it is a wearable device, the range of operation is not a major issue anymore.

Li et al. [12] proposed a fall detection system that was both accelerometers and gyroscopes. There are mainly two types of human activities namely static postures and dynamic transitions. Examples of static postures are standing, lying, sitting and bending while dynamic transitions is the motion between static postures. There are two tri-axial accelerometers that are placed at the person's chest and thigh respectively in order to recognize the person's static postures. The result of the system is 91% sensitivity and 92% specificity. However, the drawback of this system is that it having difficulties in distinguish jumping onto bed and falling against a wall with seated position.

Igual et al. [13] differentiated the kinematic based systems into two which are threshold-based methods (TBM) and machine learning methods (MLM). Threshold-based methods are much simpler compare to machine learning methods. Because of this, the cost for implementation of TBM is cheap compare to MLM. Basic of TBM is that it uses threshold to differentiate a fall from activities of daily living (ADL). MLM require a set of data containing samples of falls and ADL in order to distinguish between the two. This method is more computational intensive hence, it is costlier.

Tong et al. [14] proposed an automatic human fall detection using tri-axis accelerometer and gyroscope. In order to retrieve acceleration data, the device have to be lightweight and can be placed at upper trunk of a human body. When the acceleration is higher than certain threshold, gyroscope will check for the orientation of the subject. The device come with a button used to eliminate false positive (ADL recognized as a fall). The result from this method is that the system has very fast response and fewer false alarms which are negligible.

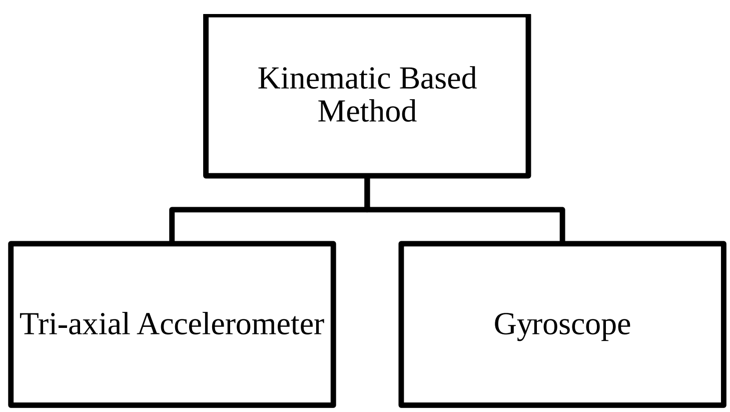

Figure 5: Common components used by kinematic based method

Bai et al. [15] suggested a fall detection system based on 3-axis accelerometer that already embedded in a smart phone which comes with GPS function. The system is a single unit device which can detect fall and alert nearby healthcare and relatives. The drawback from this system is that the power consumption by the smartphone is relatively high, which make the system only be active for certain period of time.

Bourke et all [16] proposed a fall detection system which used tri-axial accelerometer to detect fall and certain ADL. In order to determine the optimal place for the accelerometer, there are two possible position which are thigh and chest. Young volunteers simulate the falls and ADL were performed by 10 elderly persons. The result shows sensitivity of 100% but a few ADL wrongly classified as falls. The study also shows that chest is better position compare to thigh to place the accelerometer. Figure 6 shows the comparison of acceleration between chest and thigh sensor placement.

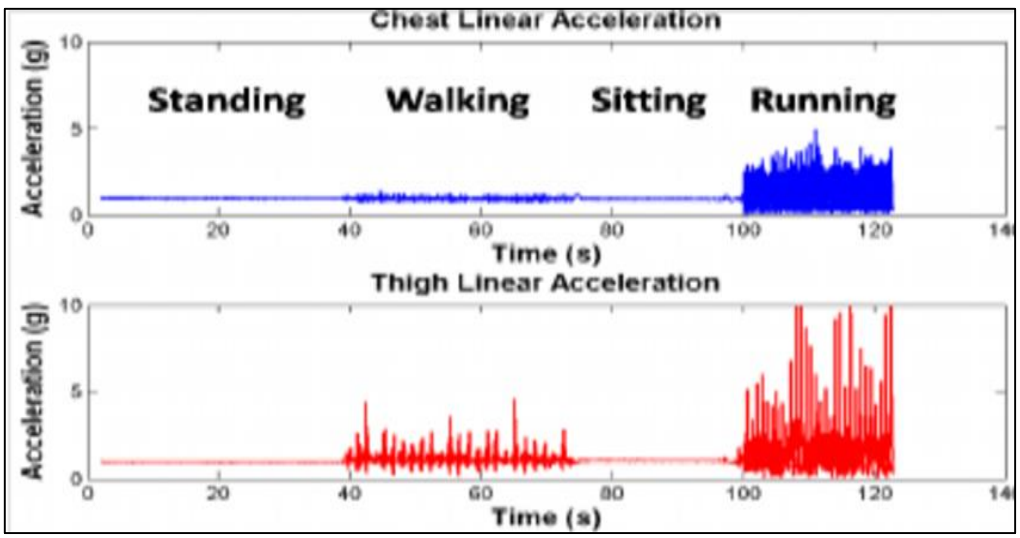

Figure 6: Linear Acceleration for Chest and Thigh during ADL

Based on figure 6, walking and running while wearing the accelerometer at the thigh causes linear acceleration to be higher. This may due to rapid movement of the user's leg while running and walking. Hence, the most suitable placement of the accelerometer is located on the chest.

Dinh et all [17] proposed a fall detection system using accelerometer and gyroscope combined with acoustic sensor for heart beat detection. The device is worn on the trunk and communicate wirelessly via Zigbee protocol. The system has a feature to alert the user to recharge the battery via Zigbee link when the battery is low. Five different algorithm are designed to be implemented and the result vary from 92% to 97%. It is concluded that by coupling accelerometer and gyroscope, the rate of detection can reach up to 97%.

Nguyen et all [18] used a mobile waist mounted device that can alert caregivers if user encounter emergency. The device comes with dual functions which are fall detection and heart rate monitoring. Tri-axis accelerometer and 3 channel ECG circuit are used to detect falls and heart rate respectively. The system not only utilized simple threshold algorithm but some supporting methods to improve the detection. The data is not process locally which improved the response time compare to locally processed system.

CHAPTER 3

METHODOLOGY

This project was divided into 5 stages namely planning, design, implementation, testing and evaluation. By splitting into 5 different stages, the flow of the project was more organized and systematic.

The first stage of this project is planning. In order to complete the project on time with limited budget, a proper planning is required. In this planning stage, Gantt chart and key milestone are the essential tools used to keep the project on track. The Gantt chart and key milestone prepared for this project are attached in the Appendix I. Besides, regular meeting with the supervisor is compulsory to update the progress about the project. Feedback from the supervisor helps to improve the project in term of functionality and method used. Useful information from the previous research paper, journals and online articles was extracted and gathered to be used as guidance for this project. During this stage, information such as acceleration and orientation of a person falling was directly referred to previous research paper.

Designing stage involves brainstorming ideas and solution to overcome the problem statement by this project. After conducting research during planning stage, multiple ideas are generated and become alternatives which each can be used to overcome the problem. By taking consideration of factors and limitation such as budget, time, and components availability, the best design was selected. In order to understand the process of the fall detection and alert system, a flow chart and pseudocode was designed and prepared. Components are selected based on their cost, availability, quality and compatibility. Positioning of the fall detection device on a person body are determined based on previous research paper and experimentation.

After finalizing the design and components selection, the next stage was the implementation stage. Components was purchased and arrived in expected time to avoid delay in the project. In this stage, fall detection and alert system was fabricated into a prototype. Besides that, programming code or algorithm are designed to be programmed into the microcontroller which in this case is Arduino UNO. It is important for the algorithm to be simple and easy to understand because it is easier to troubleshoot when a errors occurred.

Testing stage involves performing multiple of different test with the prototype. In order to ensure the prototype working as per design, several number of tests are performed includes front fall, back fall and side fall. During testing phase, acceleration and orientation data are acquired and to be compared with the acceleration value from previous research paper. Necessary modification and adjustment was done during this stage to achieve the best result.

Finally, the evaluation stage ensures the functionality of the fall detection and alert system. It is important to evaluate the performance of the prototype in term of reliability and accuracy. In this stage, the prototype need to reliable in detecting a person fall and accurately differentiate it from activities of daily living (ADL).

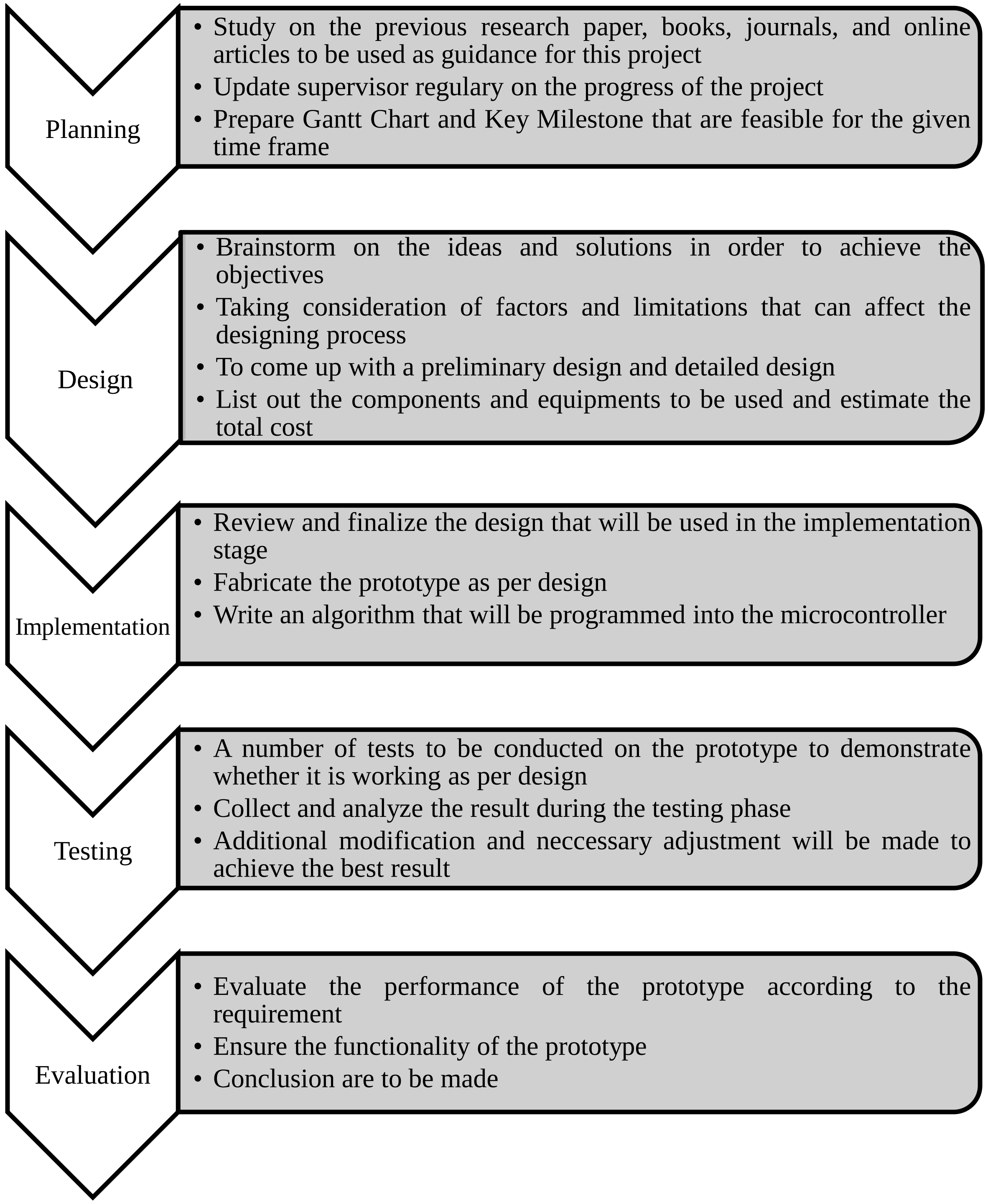

Figure 7: Five stages in methodology

3.1 FLOW CHART

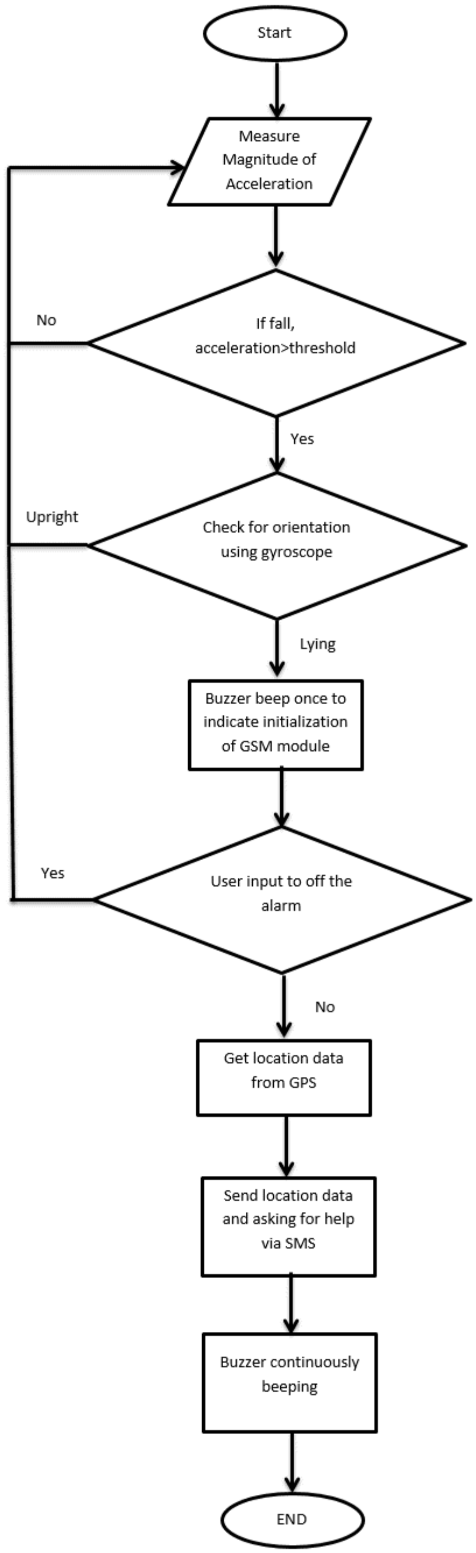

Figure 8: Flow Chart for Fall Detection and Alert System

Based on figure 8, Arduino based fall detection and alert system will start to continuously monitor the magnitude of acceleration of the user. The component that was used to measure acceleration is MPU 6050 Accelerometer. Since it can measure acceleration in three axes, the algorithm used only focuses on total acceleration despite the direction by using following formula:

$$\text{Sum Vector Magnitude of Acceleration} = \sqrt{x^2 + y^2 + z^2}$$

Where x, y and z is the magnitude of acceleration in its respective direction.

When the magnitude of the acceleration is higher than the threshold, the microcontroller will check for orientation of the user by using gyroscope that came together with MPU 6050 Accelerometer. There are two possible outcomes from the gyroscope which is either upright or lying down. If the user is standing upright, the device will continue to monitor the acceleration. However, when a fall occurred and the user is found to be lying down on the ground, the buzzer will beep once to indicate initialization of the GSM module to start sending alert to nearby healthcare centre and relatives. When there is a false alarm, user able to reset the device once hearing the first beep from the buzzer.

When the user is unconscious after falling down, microcontroller will attempt to obtain location data from the GPS module and send it together with the alert message to the concerned authorities. After that, buzzer will beep continuously trying to wake up the user. The moment when the user fell down unconsciously until alert message is sent takes up to 20 to 30 seconds.

3.2 COMPONENTS SELECTION

Components	Diagram	Justification
Arduino UNO R3		• User friendly • Easy to program • Available locally • Cost only RM 39
5000 mAH Power Bank		• Required to use batteries so that user can move around freely • Rechargeable • Last up to a day • Cost RM 54
Accelerometer + Gyroscope Shield		• Compatible with Arduino • Single device with dual functions • Cost RM 19 • Available locally
GSM/GPRS/GPS Shield		• Compatible with Arduino • Single device with 2 functions • Can directly send alert via GSM network • Cost RM 200
SIM Card		• Can be used with GSM Shield to directly alert without through mobile phone. • Cost RM 5

Table 1: Components Selection

3.3 BUDGET

Components	Price (RM)
Arduino UNO R3	39.00
5000 mAH Power Bank	54.00
Accelerometer + Gyroscope Shield	19.00
GSM/GPRS/GPS Shield	200.00
SIM card	5.00
Total	317.00

Table 2: Budget

Based on the total amount calculated in the table 2, it is still within the budget (RM 500) allocated for this project. Current commercialized mobile fall detection system provides monthly plan with the charge of RM 200 each month. The monthly plan includes 24 hours' command center protection, unlimited button pushes to call for help and works on the go.

On the other hand, Arduino based fall detection and alert system only bears the yearly cost of RM 33 to be registered on GSM network. Besides, this device also works on the go and alert nearby healthcare center and relatives when a fall occurred.

CHAPTER 4

RESULTS AND DISCUSSION

The fall detection and alert system can be divided into four subsystems which are location tracker, device positioning, fall detection system and alert system.

4.1 LOCATION TRACKER

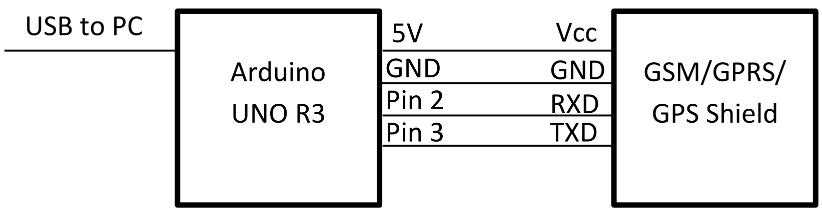

Figure 9: Connection between Arduino with GSM/GPRS/GPS shield

Figure 9 shows the connection of Arduino UNO with GSM/GPRS/GPS shield. In order to get the location data from the shield, an algorithm is uploaded to the Arduino. This enables the location data to be transferred from the shield to Arduino and finally displayed in the serial monitor.

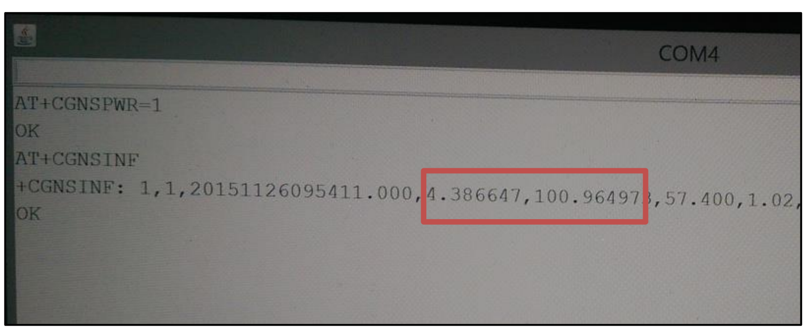

Figure 10: Serial Monitor

Based on the figure 10, the values in the red box indicate the latitude and longitude respectively. The values are then inserted in Google search engine and it shows the current location where the device located. The result had shown in figure 11.

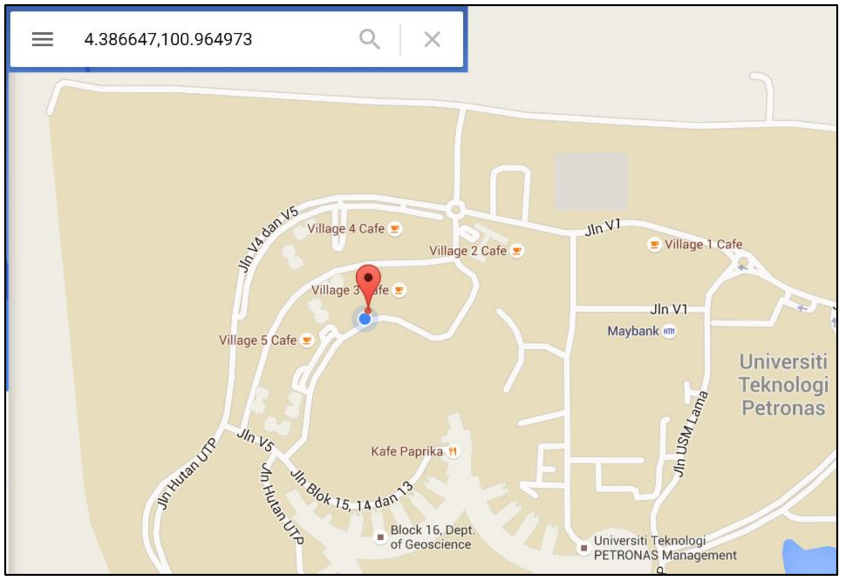

Figure 11: Location tracker

Therefore, this concludes that the shield is able to track the location of the device accurately.

4.2 DEVICE POSITIONING

The positioning of the fall detection device plays an important role in this project. Correct placement of the device will increase the reliability of the fall detection system. Currently commercialized fall detection systems available are in the form of pendant and wristband. Table 3 shows the advantages and disadvantages for using pendant and wristband.

	Pendant	Wristband
Advantages	• Easy to wear and remove	• Easy to reach • Easy to wear and remove
Disadvantages	• Affect daily life activities • High false alarm rate due to device swinging	• High false alarm rate due to frequent hand movement

Table 3: Comparison between pendant and wristband

Both pendant and wristband has a high false alarm rate due to movement during performing daily life activities although they are easy to wear and remove. Therefore, in this project, the proposed method to be used is a body strap. The advantage of this body strap is that it can reduce false alarm rate due to less movement from upper trunk of the body. Besides that, it's also easy to wear and remove especially for the elderly people and patients.

Figure 12: Body Strap

4.3 FALL DETECTION SYSTEM

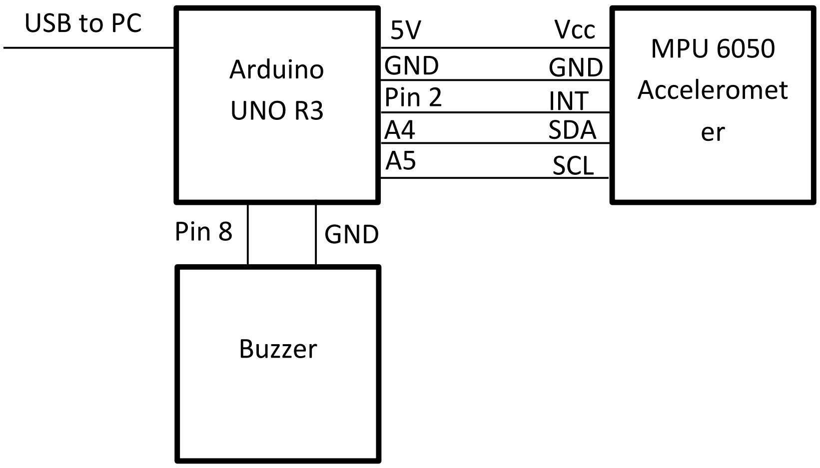

Figure 13: Connection between Accelerometer and Arduino

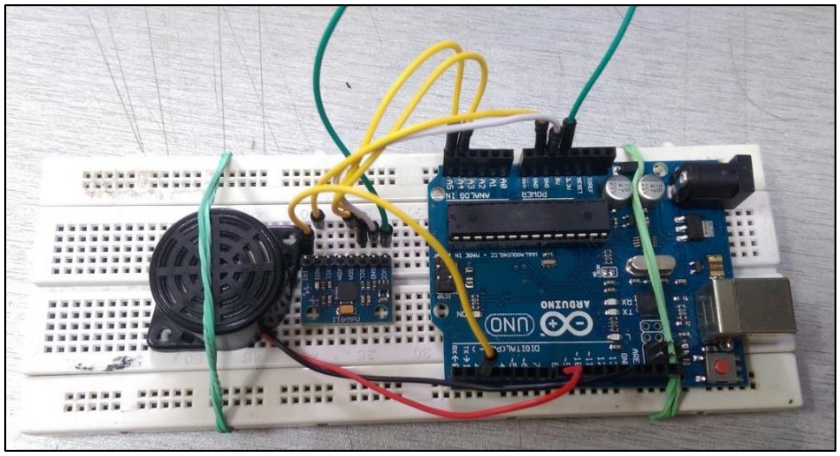

Figure 14: Fall detection configuration

Figure 13 shows the connection between Arduino UNO, MPU 6050 Accelerometer and a buzzer. These components are used to detect fall of the user before proceeding to alert the nearby healthcare for help. Physical connection between Arduino and MPU 6050 accelerometer is shown in figure 14.

Few experiments were conducted by using MPU 6050 Accelerometer as the data collector for acceleration and orientation while performing daily life activities and falling scenarios. In order to obtain the data, the author is required to demonstrate some of the common fall motions while wearing the accelerometer sensor.

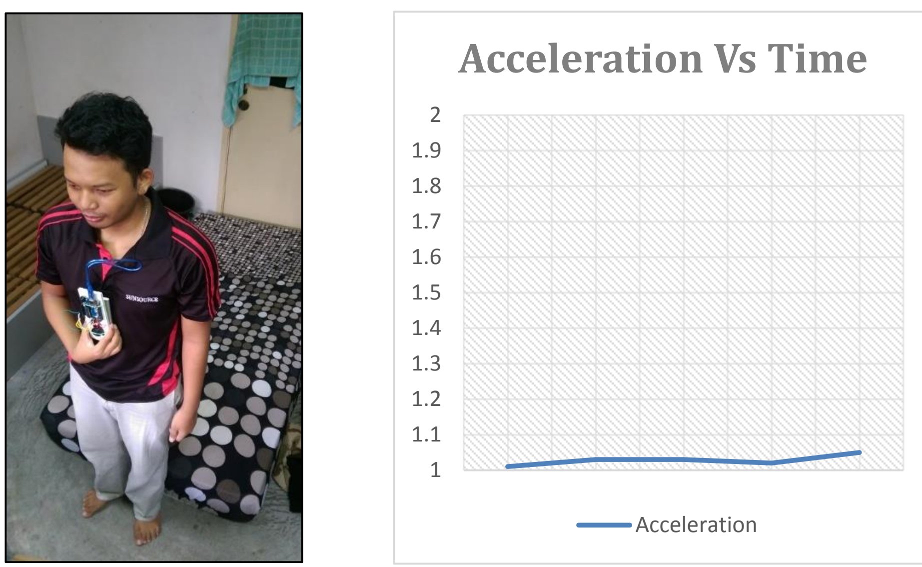

Figure 15: Acceleration data while standing

Figure 15 illustrates the user standing still while holding the sensor board in order to capture the acceleration data. Based on the graph in figure 15, the acceleration while standing still is close to 1 G (9.81 ms^{-2}) . On the other hand, MPU 6050 Accelerometer also comes with a gyroscope which can be used to detect the orientation of the user. In this case, the row value reading from the gyroscope is approximately 85°.

When a fall occurred, the measured acceleration by the sensor need to be higher than a certain threshold in order to trigger the alarm which in this case the buzzer. There are several common fall motions that was demonstrated by the author in order to determine the acceleration threshold which includes falling backward, falling sideway and falling forward.

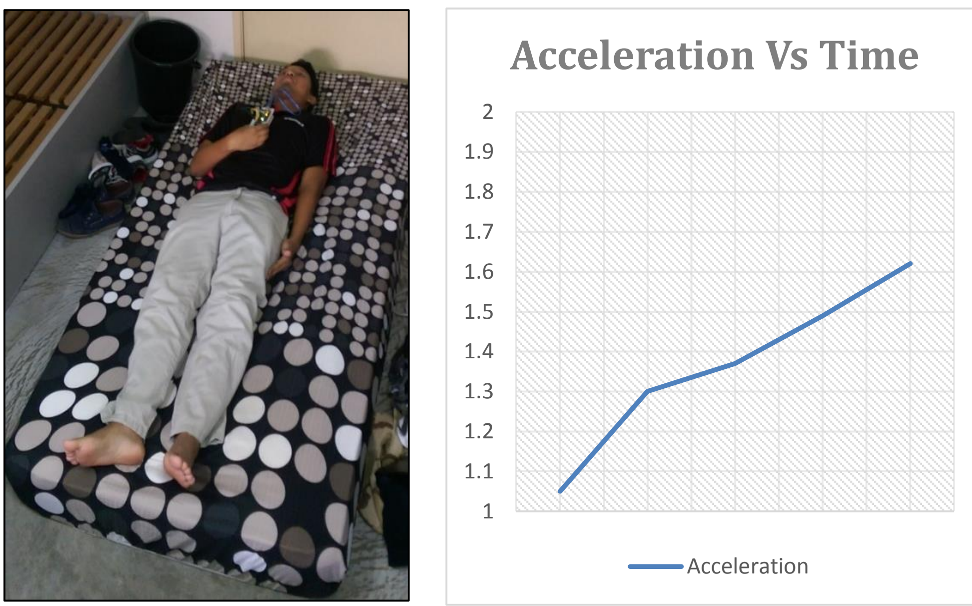

Figure 16: Acceleration data while falling backward

Figure 16 shows the user has demonstrated a falling backward while holding the sensor board. From the graph in figure 16, the acceleration slowly increase as the user is falling backward. The peak acceleration for falling backward can reach up to 1.62 G (15.89 ms^{-2}) . Meanwhile, the reading from the gyroscope measure row value approximately 5°. This row value indicate that the user is lying flat on the ground. Similar results were observed after repeating falling backward motion for 5 trials. The results were shown in table 4.

Trials	Peak Acceleration (G)	Orientation (°)
1	1.62	4.97
2	1.60	3.89
3	1.67	6.25
4	1.57	4.36
5	1.59	5.14

Table 4: Falling backward result

Based on table 4, the average value for the peak acceleration and orientation can be easily calculated which are 1.61 G and 4.922 ° respectively.

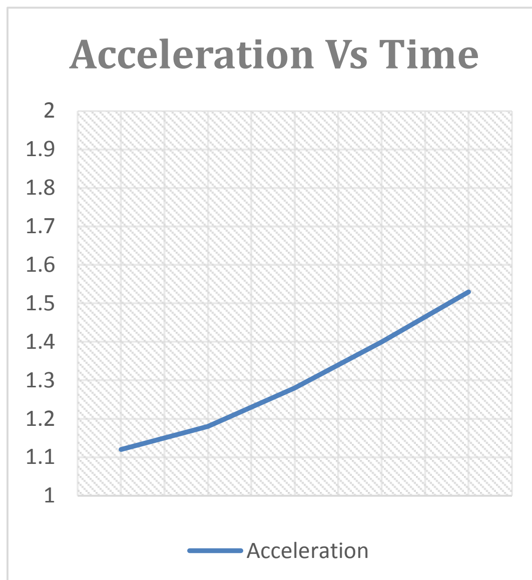

Figure 17: Acceleration data while falling sideway

In figure 17, the user has demonstrated a falling sideway motion while holding the sensor board. Based on plotted graph in figure 17, the acceleration increase linearly as the user is falling sideway motion. The highest acceleration recorded for falling sideway approximately 1.53 G (15.0 ms^{-2}). On the other hand, the gyroscope shows row value of 3°. The falling sideway motion was repeated for 5 trials and the results were shown in table 5.

Trials	Peak Acceleration (G)	Orientation (°)
1	1.53	3.02
2	1.46	5.78
3	1.59	3.24
4	1.51	3.45
5	1.48	4.88

Table 5: Side falling result

Based on table 5, the average value for the peak acceleration and orientation was calculated to be 1.52 G and 4.07 ° respectively.

Based on figure 18, the user has demonstrated a falling forward motion while holding the sensor board. From the plotted graph in figure 18, the measured acceleration rises linearly while the user is experience falling forward motion. The peak acceleration measured for falling forward is 1.45 G ($14.22\, ms^{-2}$). The measured value of acceleration is smaller compare to values from falling backward and falling sideway motion. This may due to the acceleration reduced when the user bending his knee while falling forward. Meanwhile, the gyroscope shows row value of 2.69°. Similar results were shown after 5 trials of falling forward motion and tabulated in table 6.

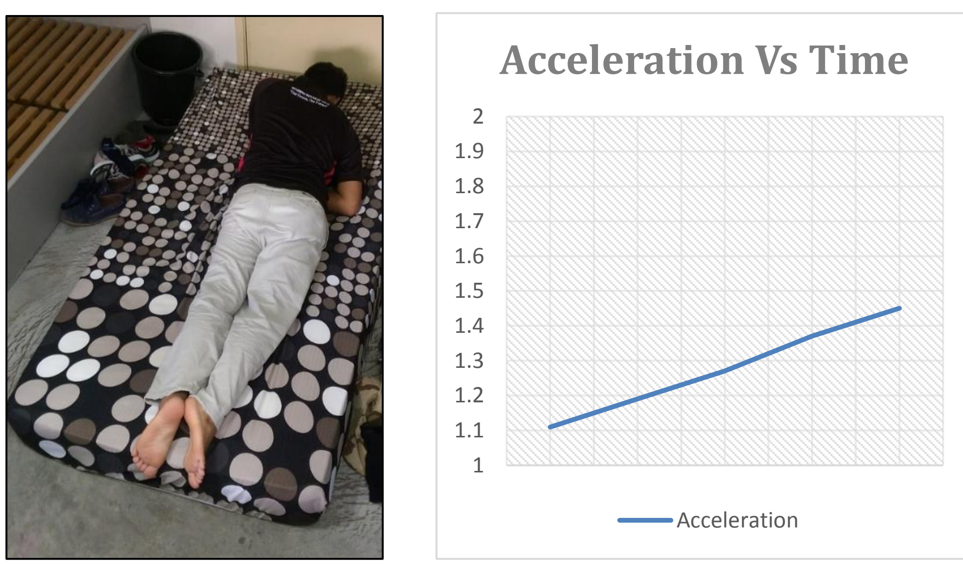

Figure 18: Acceleration data while falling forward

Trials	Peak Acceleration (G)	Orientation (°)
1	1.45	2.69
2	1.39	3.56
3	1.49	7.13
4	1.54	4.08
5	1.43	5.22

Table 6: Falling forward result

Based on table 6, the average value for the peak acceleration and orientation was calculated to be 1.46 G and 4.54 ° respectively.

Average peak acceleration for forward fall, backward fall and side fall were tabulated in the table 7.

Types of Falls	Average Peak Acceleration (G)	Orientation (°)
Forward Fall	1.46	4.54
Backward Fall	1.61	4.92
Side Fall	1.52	4.07

Table 7: Average peak acceleration for three types of falls

Based on table 7, the average value for average peak acceleration and orientation can be calculated to be 1.53 G and 4.51° respectively. This means that the acceleration threshold that to be applied is 1.53 G in order to trigger the alert system. Based on the orientation value, it is concluded that lying down position is below 10° and standing upright position is higher than 85°.

It is important for the fall detection system to be reliable in order to detect a fall experienced by the user. Therefore, a performance evaluation was conducted in order to test the reliability of the system. There are four possible outcomes from the reliability test:

- True Positive (TP): System able to detect it when a fall occurred.
- False Positive (FP): System detect a fall, but it didn't happen.
- True Negative (TN): System doesn't detect fall when it didn't happen.
- False Negative (FN): System doesn't detect fall when it happens.

There are total number of 20 falling down motion which consists of falling backward, falling forward and falling sideway are demonstrated during this reliability test. Besides that, the user also performed 20 activities of daily life (ADL) which includes walking, running, sitting and laying. The result were shown in Table 8.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Activity</td></tr>
<tr><td>FALL</td><td>ADL</td></tr>
<tr><td rowspan="2">System's detection</td><td>FALL</td><td>19 (TP)</td><td>2 (FP)</td></tr>
<tr><td>ADL</td><td>1 (FN)</td><td>18 (TN)</td></tr>
</table>

Table 8: Activity vs System's detection

In order to evaluate these four scenarios, there are two criteria proposed which are:

- Sensitivity: It is the capability to detect a fall.

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

- Specificity: It is the capability to detect only a fall.

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

By using the above formulas, the sensitivity and specificity of the fall detection system can be calculated.

$$Sensitivity = \left(\frac{19}{19+1}\right) * 100\%$$

$$Sensitivity = \ 95\ \%$$

$$Specificity = \left(\frac{18}{18+2}\right) * 100\%$$

$$Specificity = 90\%$$

Based on above calculations, it is concluded that the sensitivity and specificity of the fall detection system are 95% and 90% respectively. This means that 95% of the falls was detected and ADL was properly classified. This test shown that the fall detection system is reliable in detecting a fall. Besides that, a reset button can be pressed in case there is a false alarm occurred.

4.4 ALERT SYSTEM

After a fall is detected, it is important to alert nearby healthcare centre and the user's relatives regarding the fall. An example of short message service (SMS) is sent from the GSM/GPRS/GPS shield to the relative's phone is shown in figure 19.

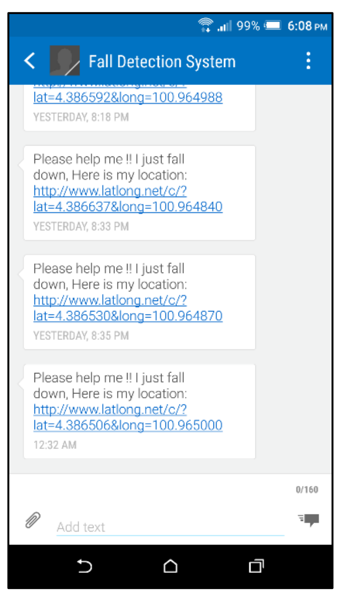

Figure 19: SMS received

Whenever a fall is detected, the first beep from the buzzer indicate that the initialization of GSM/GPRS/GPS Shield to start sending SMS. However, in case of false alarm, the user can stop sending the SMS by pushing the RESET button after hearing the first beep. On the receiving side, user’s relatives can personalize their phone SMS notification tone to differentiate it from normal SMS and set its priority.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

As conclusion, there are three techniques that are used for fall detection system which are camera based method, acoustic based method and kinematic based method. Each method has its own advantage and disadvantage.

The benefit of using camera based method is that the user is not required to wear any device in order to detect fall. This method also can detect fall for multiple users in a room where the camera is installed. However, the drawback of this method is that it only can be used in indoor environment. In order to have a reliable detection, the cameras have to be installed in every room. User also concern about the privacy due to placement of camera.

Acoustic based method is cheaper and simpler compare to camera based method because of inexpensive hardware. This method removes the privacy concerns that are faced by the user with camera based method. The disadvantage of acoustic based method is that there is excessive noise present in the living environment that may disrupt and interfere with the system. The sensors use also have limited range and only feasible in indoor environment.

The kinematic based method is best technique compared to the other two methods. The system is inexpensive because there is no requirement for installation. The user can freely perform activities of daily living (ADL) while being monitored without concerning about privacy either indoor or outdoor environment. However, this method utilized accelerometer and gyroscope which are sensitive to movement. This may cause a few false alarms while the user is performing ADL (sitting down quickly).

As for this project, the fall detection device is attached to a person body using body strap. This method is based on kinematic technique which utilized accelerometer and gyroscope. Besides that, this project included an alert system and location tracking. After detecting a fall, GPS was used to determine the location of the user and alert the concerned authorities via GSM module. The device has the sensitivity and specificity of 95% and 90% respectively. This shows that the fall detection and alert system is reliable in detecting fall and alert nearby healthcare centre and relatives. Hence, this device is a single unit device that comprised of 3 different subsystems which are location tracker, fall detection and alert system.

6.0 REFERENCES

[1] United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241.

[2] World Health Organization: WHO Global Report on Falls Prevention in Older Age, Nonserial Publication Series. World Health Organization (2007)

[3] Miao Yu, A. Rhuma, S. Naqvi, Liang Wang and J. Chambers, 'A Posture Recognition-Based Fall Detection System for Monitoring an Elderly Person in a Smart Home Environment', IEEE Transactions on Information Technology in Biomedicine, vol. 16, no. 6, pp. 1274-1286, 2012.

[4] S. Khawandi, B. Daya and P. Chauvet, 'Implementation of a monitoring system for fall detection in elderly healthcare', Procedia Computer Science, vol. 3, pp. 216-220, 2011.

[5] S. Miaou, Pei-Hsu Sung and Chia-Yuan Huang, 'A Customized Human Fall Detection System Using Omni-Camera Images and Personal Information', 1st Transdisciplinary Conference on Distributed Diagnosis and Home Healthcare, D2H2, Arlington, USA, April 2-4, 2006.

[6] A. Nasution and S. Emmanuel – “Intelligent Video Surveillance for Monitoring Elderly in Home Environments” – International Workshop on Multimedia Signal Processing (MMSP), Greece, October 2007.

[7] H. Foroughi, A. Rezvanian, A. Paziraee – “Robust Fall Detection using Human Shape and Multi-class Support Vector Machine” – Sixth Indian Conference on Computer Vision, Graphics & Image Processing. Bhubaneswar, India, Dec 16-19, 2008.

[8] J. Winkley, P. Jiang and W. Jiang, 'Verity: an ambient assisted living platform', IEEE Transactions on Consumer Electronics, vol. 58, no. 2, pp. 364-373, 2012.

[9] Yun Li, K. Ho and M. Popescu, 'A Microphone Array System for Automatic Fall Detection', IEEE Transactions on Biomedical Engineering, vol. 59, no. 5, pp. 1291-1301, 2012.

[10] M. Alwan, P. Rajendran, S. Kell, D. Mack, S. Dalal, M. Wolfe and R. Felder, 'A Smart and Passive Floor-Vibration Based Fall Detector for Elderly', 2nd International Conference on Information & Communication Technologies, vol.1 , pp. 1003-1007, 2006.

[11] M. Popescu, Y. Li, M. Skubic, M. Rantz, "An acoustic fall detector system that uses sound height information to reduce the false alarm rate" Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE 20-25 Aug. 2008. Pp. 4628-4631

[12] Q. Li, J. Stankovic, M. Hanson, A. Barth, J. Lach and G. Zhou, 'Accurate, Fast Fall Detection Using Gyroscopes and Accelerometer-Derived Posture Information', 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks, Berkeley, CA, 2009.

[13] R. Igual, C. Medrano and I. Plaza, 'Challenges, issues and trends in fall detection systems', BioMedical Engineering OnLine, vol. 12, no. 1, p. 66, 2013.

[14] L. Tong, W. Chen, Q. Song and Y. Ge, 'A research on automatic human fall detection method based on wearable inertial force information acquisition system', 2009 IEEE International Conference on Robotics and Biomimetics (ROBIO), Guilin, China, December 19-23, 2009.

[15] Y. Bai, S. Wu and C. Tsai, 'Design and implementation of a fall monitor system by using a 3-axis accelerometer in a smart phone', 2012 IEEE 16th International Symposium on Consumer Electronics, pp. 1-6 , Harrisburg, PA, June 4-6, 2012.

[16] Bourke AK, O'Brien JV, Lyons GM. Evaluation of a threshold based tri-axial accelerometer fall detection algorithm. Gait Posture 2007, vol. 26, no. 2, pp. 194 - 199

[17] A. Dinh, D. Teng, L. Chen, Y. Shi, C. McCrosky, J. Basran, V. Del, "Implementation of a Physical Activity Monitoring System for The Elderly People With Built-in Vital Sign and Fall Detection", 2009 Sixth International Conference on Information Technology: New Generations

[18] T. Nguyen, M. Cho, T. Lee, Member, IEEE, "Automatic fall detection using Wearable Biomedical Signal Measurement Terminal", 31st Annual International Conference of the IEEE EMBS, Minneapolis, Minnesota, USA, September 2-6, 2009

7.0 APPENDICES

APPENDIX I

GANTT CHART AND KEY MILESTONES (FYP I)

Category	Details	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Planning	Selection of Project Topic	■	■												
	Searching for Research Paper		■												
Proposal	Background Study			■	■										
	Problem Statement			■	■										
	Objectives & Scope of Study			■	■										
	Literature Review				■	■									
	Methodology					■									
	Conclusion & Recommendations						■								
	Prepare Extended Proposal						■								
	Extended Proposal Submission							△							
Design	Design Approach					■	■	■							
	Listing Components							■	■						
	Budget							■	■						
	Procurement Process								■						
	Flow Chart								■						
	Proposal Defense									△					
Implementing	Write algorithm										■	■	■	■	
	Wiring Diagram Each Subsystem										■	■	■	■	
	Testing by Subsystem:											■	■	■	
	GPS											■			
	GSM											■			
	Accelerometer												■	■	
	Gyroscope												■	■	
	Prepare Interim Report											■	■		
	Submission Interim Report Draft													△	
	Submission Interim Report														△
	Prototype Construction														■

LEGEND: ■ PROCESS △ KEY MILESTONE

APPENDIX II

GANTT CHART AND KEY MILESTONES (FYP II)

		Week														
Category	Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Testing	Testing by Subsystem:															
	Location Tracker	■	■							■	■					
	Alert System							■	■	■	■					
	Fall Detection System			■	■	■	■	■								
	Device Positioning	■	■							■	■					
	Combined Subsytems Testing									■	■	■	■	■		
Evaluation	Progress Report								Δ							
	Electrex											Δ				
	Draft Final Report													Δ		
	Final Report & Technical Paper														Δ	
	Viva															Δ
	Final Report (Hardcover)															

LEGEND: ■ PROCESS Δ KEY MILESTONE

APPENDIX III

PSEUDOCODE

1. START
2. Initialize accelerometer and gyroscope.
3. WHILE (TRUE)

    Get magnitude of acceleration from 3 three axes, Ax, Ay, Az.
    Get angle of rotation with respect to z-axis, θ.
    Compute the sum vector of magnitude (SVM).

    $$SVM = \sqrt{Ax^2 + Ay^2 + Az^2}$$

    WHILE (SVM > 1.53 AND θ < 10°)

        Buzzer beep.

        WHILE (Flag = 1)

            Initialize GPS module.

            WHILE (GPS STATUS = OK){

                Get latitude and longitude from GPS antenna.

                BREAK.}

            Initialize GSM module.

            WHILE (GSM STATUS = READY AND GPS STATUS = OK){

                Send emergency text message with value of latitude and longitude to recipient.

                Flag = 0

                Display sent message.

                BREAK.}

4. STOP

APPENDIX IV
PROGRAM CODE

```
#include "I2Cdev.h"
#include "MPU6050_6Axis_MotionApps20.h"
#include "SIM900.h"
#include <string.h>
#include <SoftwareSerial.h>
#include <TinyGPS.h>
#include "sms.h"
TinyGPS gps;
SoftwareSerial ss(4, 3);
#if I2CDEV_IMPLEMENTATION == I2CDEV_ARDUINO_WIRE
#include "Wire.h"
#endif
SMSGSM sms;
static void smartdelay(unsigned long ms);
int numdata;
boolean started=false;
char smsbuffer[160];
char n[20];

//debug begin
char sms_position;
char phone_number[20]; // array for the phone number string
char sms_text[100];
int i;
int flag=1;
//debug end

MPU6050 mpu;
//MPU6050 mpu(0x69);
#define OUTPUT_READABLE_REALACCEL
#define LED_PIN 13 // (Arduino is 13, Teensy is 11, Teensy++ is 6)
bool blinkState = false;

// MPU control/status vars
bool dmpReady = false;  // set true if DMP init was successful
uint8_t mpuIntStatus;   // holds actual interrupt status byte from MPU
uint8_t devStatus;      // return status after each device operation (0 = success, !0 = error)
uint16_t packetSize;    // expected DMP packet size (default is 42 bytes)
uint16_t fifoCount;     // count of all bytes currently in FIFO
uint8_t fifoBuffer[64]; // FIFO storage buffer
```

```
// orientation/motion vars
Quaternion q;           // [w, x, y, z]         quaternion container
VectorInt16 aa;         // [x, y, z]            accel sensor measurements
VectorInt16 aaReal;     // [x, y, z]            gravity-free accel sensor measurements
VectorInt16 aaWorld;    // [x, y, z]            world-frame accel sensor measurements
VectorFloat gravity;    // [x, y, z]            gravity vector
float euler[3];         // [psi, theta, phi]    Euler angle container
float ypr[3];           // [yaw, pitch, roll]   yaw/pitch/roll container and gravity vector
int buzzer=8;
double ax;
double ay;
double az;
double SVM;
// packet structure for InvenSense teapot demo
uint8_t teapotPacket[14] = { '$', 0x02, 0,0, 0,0, 0,0, 0,0, 0x00, 0x00, '\r', '\n' };
// ================================================================
// ===               INTERRUPT DETECTION ROUTINE                ===
// ================================================================
volatile bool mpuInterrupt = false;     // indicates whether MPU interrupt pin has gone high
void dmpDataReady() {
   mpuInterrupt = true;
}
// ================================================================
// ===                      INITIAL SETUP                       ===
// ================================================================

void setup() {
   // join I2C bus (I2Cdev library doesn't do this automatically)
   #if I2CDEV_IMPLEMENTATION == I2CDEV_ARDUINO_WIRE
      Wire.begin();
      TWBR = 24; // 400kHz I2C clock (200kHz if CPU is 8MHz)
   #elif I2CDEV_IMPLEMENTATION == I2CDEV_BUILTIN_FASTWIRE
      Fastwire::setup(400, true);
   #endif
   // initialize serial communication
   // (115200 chosen because it is required for Teapot Demo output, but it's
   // really up to you depending on your project)
   Serial.begin(115200);
   while (!Serial); // wait for Leonardo enumeration, others continue immediately
   // initialize device
   Serial.println(F("Initializing I2C devices..."));
   mpu.initialize();
   // verify connection
   Serial.println(F("Testing device connections..."));
   Serial.println(mpu.testConnection() ? F("MPU6050 connection successful") : F("MPU6050 connection failed"));

   // load and configure the DMP
```

```
  Serial.println(F("Initializing DMP..."));
  devStatus = mpu.dmpInitialize();

  // supply your own gyro offsets here, scaled for min sensitivity
  mpu.setXGyroOffset(-21);
  mpu.setYGyroOffset(6);
  mpu.setZGyroOffset(61);
  mpu.setXAccelOffset(427);
  mpu.setYAccelOffset(-174);
  mpu.setZAccelOffset(972); // 1688 factory default for my test chip

  // make sure it worked (returns 0 if so)
  if (devStatus == 0) {
    // turn on the DMP, now that it's ready
    Serial.println(F("Enabling DMP..."));
    mpu.setDMPEnabled(true);

    // enable Arduino interrupt detection
    Serial.println(F("Enabling interrupt detection (Arduino external interrupt 0)..."));
    attachInterrupt(0, dmpDataReady, RISING);
    mpuIntStatus = mpu.getIntStatus();

    // set our DMP Ready flag so the main loop() function knows it's okay to use it
    Serial.println(F("DMP ready! Waiting for first interrupt..."));
    dmpReady = true;

    // get expected DMP packet size for later comparison
    packetSize = mpu.dmpGetFIFOPacketSize();
  } else {
    // ERROR!
    // 1 = initial memory load failed
    // 2 = DMP configuration updates failed
    // (if it's going to break, usually the code will be 1)
    Serial.print(F("DMP Initialization failed (code "));
    Serial.print(devStatus);
    Serial.println(F(")"));
  }
  // configure LED for output
  pinMode(LED_PIN, OUTPUT);
  pinMode(buzzer, OUTPUT);
  ss.begin(9600);
}

// ================================================================
// ===                    MAIN PROGRAM LOOP                     ===
// ================================================================
```

```
void loop() {
  // if programming failed, don't try to do anything
  if (!dmpReady) return;

  // wait for MPU interrupt or extra packet(s) available
  while (!mpuInterrupt && fifoCount < packetSize) {
   break;
  }
  // reset interrupt flag and get INT_STATUS byte
  mpuInterrupt = false;
  mpuIntStatus = mpu.getIntStatus();

  // get current FIFO count
  fifoCount = mpu.getFIFOCount();

  // check for overflow (this should never happen unless our code is too inefficient)
  if ((mpuIntStatus & 0x10) || fifoCount == 1024) {
    // reset so we can continue cleanly
    mpu.resetFIFO();
    Serial.println(F("FIFO overflow!"));

  // otherwise, check for DMP data ready interrupt (this should happen frequently)
  } else if (mpuIntStatus & 0x02) {
    // wait for correct available data length, should be a VERY short wait
    while (fifoCount < packetSize) fifoCount = mpu.getFIFOCount();

    // read a packet from FIFO
    mpu.getFIFOBytes(fifoBuffer, packetSize);
    mpu.resetFIFO();

    // track FIFO count here in case there is > 1 packet available
    // (this lets us immediately read more without waiting for an interrupt)
    fifoCount -= packetSize;

    #ifdef OUTPUT_READABLE_REALACCEL
      // display real acceleration, adjusted to remove gravity
      mpu.dmpGetQuaternion(&q, fifoBuffer);
      mpu.dmpGetAccel(&aa, fifoBuffer);
      mpu.dmpGetGravity(&gravity, &q);
      mpu.dmpGetLinearAccel(&aaReal, &aa, &gravity);
      mpu.dmpGetYawPitchRoll(ypr, &q, &gravity);
      Serial.print("ypr/Acce \t");
      Serial.print(ypr[0] * 180/M_PI);
      Serial.print("\t");
      Serial.print(ypr[1] * 180/M_PI);
      Serial.print("\t");
      Serial.print(ypr[2] * 180/M_PI);
```

```
Serial.print("\t\t");
Serial.print(aaReal.x);
Serial.print("\t");
Serial.print(aaReal.y);
Serial.print("\t");
Serial.print(aaReal.z);

ax=(aaReal.x)/16384.0;
ay=(aaReal.y)/16384.0;
az=(aaReal.z)/16384.0;

SVM = sqrt(sq(ax)+ sq(ay)+ sq(az))+ 1.0; // 1G is at atmospheric
Serial.print("\t");
Serial.print(SVM);
Serial.print("\t");

float flat;
float flon;
unsigned long age, date, time, chars = 0;
unsigned short sentences = 0, failed = 0;
gps.f_get_position(&flat, &flon, &age);
Serial.print(flat,6);
Serial.print("\t");
Serial.print(flon,6);
Serial.println()
smartdelay(1);

while (SVM > 1.6  && (ypr[2] * 180/M_PI)< 10 )
{
  digitalWrite(buzzer, HIGH);
  delay(500);
  digitalWrite(buzzer, LOW);
  delay(300);
  while (flag == 1)
  {
    if (gsm.begin(9600))
    {
     Serial.println("\nstatus=READY");
      started=true;
    }
     else
     Serial.println("\nstatus=IDLE");

    if(started)
    {
     String help = "Please help me !! I just fall down, Here is my location: http://www.latlong.net/c/?lat=";
     char helpp[] = "Please help me !! I just fall down, Here is my location: http://www.latlong.net/c/?lat=";
```

```
                String help1= "&long=";
                char help11[] = "&long=";
                char lat[15];
                char lon[15];
                dtostrf(flat,5,6,lat);
                dtostrf(flon,5,6,lon);
                String helped = help + lat + help1 + lon;

                char helpme[120];
                char helpmepls[120]={0};
                strcat(helpmepls,helpp);
                strcat(helpmepls,lat);
                strcat(helpmepls,help11);
                strcat(helpmepls,lon);
                helped.toCharArray(helpme,115);

                Serial.println(helped);
                Serial.println(helpme);
                Serial.println(helpmepls);
                sms.SendSMS("0163053892",helpmepls);
               }
               flag = 0;
               break;
             }
           }
        #endif
        // blink LED to indicate activity
        blinkState = !blinkState;
        digitalWrite(LED_PIN, blinkState);
    }

}
static void smartdelay(unsigned long ms)
{
  unsigned long start = millis();
  do
  {
    while (ss.available())
      gps.encode(ss.read());
  } while (millis() - start < ms);
}
```