DEVICE FOR FALL DETECTION AND FALL IMPACT MINIMIZATION FOR OLD AGED PEOPLE

By

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Dedication

I want to thank myself for showing up every time, even when it was hard and felt almost impossible to complete. I want to thank myself for striving toward progress, not perfection.

--------------*Ifty*

I would like to dedicate this work to God, my honorable supervisor, and my parents. I am also deeply grateful to my group mates, whose support has been invaluable throughout this journey. Our respected supervisor, Halima Ma'am, has consistently guided and motivated us to achieve excellence in our work. It is with great appreciation that we dedicate this project to our supervisor Halima ma'am.

--------------*Arpon*

I dedicate this project to the elderly community who have inspired me to develop solutions for enhancing their safety and well-being. Their resilience and wisdom have always been a source of inspiration for me.

I am immensely grateful to my project supervisor "Dr. Halima Begum" ma'am, whose guidance and insights have been invaluable throughout the development process. I also wish to express my heartfelt thanks to my family for their unwavering support and encouragement, without which this project would not have been possible. Lastly, I would like to extend my gratitude to my team members, whose teamwork and dedication have been crucial to the successful completion of this project.

--------------*Rohit*

First of all, I'm deeply thankful to almighty Allah. Then I would like to thank my teammates for their dedication. Because of their great efforts, this project has been successfully completed. Finally, I would like to express my gratitude to our honorable supervisor, Dr. Halima Begum ma'am, for her constant support in our work.

--------------*Asif*

AUTHORIZATION

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KAZI IFTIER RAHMAN	ARPON PODDER
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EXECUTIVE SUMMARY

Falls are a leading cause of injury and disability among elderly individuals, often resulting in severe physical and emotional consequences. With the aging global population, the need for effective fall detection and impact minimization solutions is more critical than ever. This project aims to address these issues by developing an affordable, lightweight, and reliable device specifically designed for fall detection and impact minimization for elderly people. The proposed device integrates advanced sensing technology to detect falls in real time, using a combination of accelerometers and gyroscopes. In addition, the device will incorporate a GSM SIM800L module to send alert messages to caregivers and family members, ensuring timely assistance. We have picked Accelerometer Sensor-Based Fall Detection System which relies solely on accelerometers to detect sudden changes in motion or orientation, which are common indicators of a fall, Gyroscope Sensor-Based Fall Detection System which uses gyroscopes to detect rotational movement, offering a more detailed view of an individual's posture during potential falls and Combined Accelerometer & Gyroscope Sensor-Based Fall Detection System which integrates both accelerometers and gyroscopes, this solution provides more comprehensive data, allowing for better detection of falls by analyzing both linear acceleration and angular velocity. After testing these systems, we have selected the Combined Accelerometer & Gyroscope Sensor-Based Fall Detection System for its better accuracy in differentiating between normal activities and actual falls, thus reducing false positives and improving overall reliability. Our approach prioritizes both affordability and effectiveness to ensure that the device remains accessible to middle-class and lower-middle-class families. By replacing heavy air compressors with a more efficient inflation system and refining the design to reduce weight, the final prototype will significantly improve the comfort and usability for elderly individuals.

PART-A

This part contains the concept and the project proposal as prepared on EEE400A.

CHAPTER 1 PROJECT CONCEPT AND PROPOSAL

1.1 PROJECT INTRODUCTION

The alarmingly high prevalence of falls among older people and its negative effects on public health have drawn a lot of attention. According to the World Health Organization (WHO), falls are the second leading cause of accidental or unintentional injury deaths worldwide [2]. To address this pressing issue, researchers, healthcare professionals, and technology experts have been working tirelessly to develop effective fall detection and prevention solutions. The primary goal of the proposed fall detection and impact minimization system is to provide timely assistance when a fall occurs, ensuring prompt medical attention and reducing the potential for long-term consequences. These systems utilize various sensors such as accelerometers, gyroscopes, and pressure sensors to detect changes in motion and body position. Upon detecting a fall, they can automatically trigger alerts to caregivers, emergency services, or designated contacts, enabling a swift response and potentially saving lives. The device is equipped with mechanisms that reduce the impact of a fall, such as deployable airbags.

1.1.1 TARGET OF THE PROJECT

The target of the project, "Device for Fall Detection & Impact Minimization for Old Age People," is to develop a specialized wearable or assistive technology that can accurately detect and minimize the effect of falls among old aged people. The primary goal is to enhance the safety and well-being of senior citizens, reducing the risk of injuries resulting from accidental falls.

1.1.2 MOTIVATION BEHIND THE PROJECT

Walking is important for old aged people to stay healthy but they walk less because of the fear of falling. Each year, approximately 36 million falls are documented in the global elderly population [1]. Fall causes physical injuries and in some tragic cases, even loss of life. It increases the rate of hospitalization, expenses, societal challenges and mortality. Using this device can assure them that can walk safely without any serious injuries.

Family members and caregivers can't always be with the elderly, this system can provide assurance by timely notifying of any event of accidents which leads to quick hospitalization and avoid any risk, which can greatly reduce the risk of serious injury and death.
In most cases old people get dependent because of risk of falling and getting injured. So, they avoid social and family gatherings. Our project will assure their safety by fall detection and minimizing the impact. It will help to reduce their health injuries and even death.

1.1.3 APPLICATION OF THE PROJECT OUTCOME

Numerous fall detection devices exist in the market designed to identify falls among elderly individuals which is expensive. There are few companies in the market who are manufacturing these. The manufacturing companies are SKYLOTEC [11], S-AIRBAG ONLINE STORE [12]. However, only a limited number of these devices incorporate impact minimization or protection features, making them prohibitively expensive in our country. Our goal is to create a user-friendly, portable, and cost-effective device or system that addresses the concerns of families worried about the falls experienced by their senior members. The aim is to make this technology accessible to every household.

1.2 LITERATURE REVIEW

ACCELEROMETER GYROSCOPE VECTOR SIGNAL RESULTANT (AGVeSR): Sometimes accelerometer sensor is not sufficient for fall detection. Researchers combined accelerometer and gyroscope sensors to increase the accuracy rate of fall detection. They name the method "**Accelerometer Gyroscope Vector Signal Resultant (AGVeSR**)". The researchers, Maria Seraphina Astriani, Yaya Heryadi, Gede Putra Kusuma, and Edi Abdurachman, implement a formula.:

$$\mathbf{AGVeSR} = \sqrt{(|AX| + GX)^2 + (|AY| + GY)^2 + (|AZ| + GZ)^2}$$

Here acceleration is represented by the values AX, AY, and AZ in the accelerometer; and acceleration is represented by the GX, GY, and GZ in the gyroscope. This formula offers an advantage by working with absolute notation, which allows for detecting falls regardless of orientation. Here the researchers aimed to reach the maximum True position (TP) and minimum false position (FP) value as misclassified fall risk is more important than non-fall risk. They observed it gives better results (TP= almost 100% and FP =near 0) than using an accelerometer sensor only. The comparison figures are mentioned below.

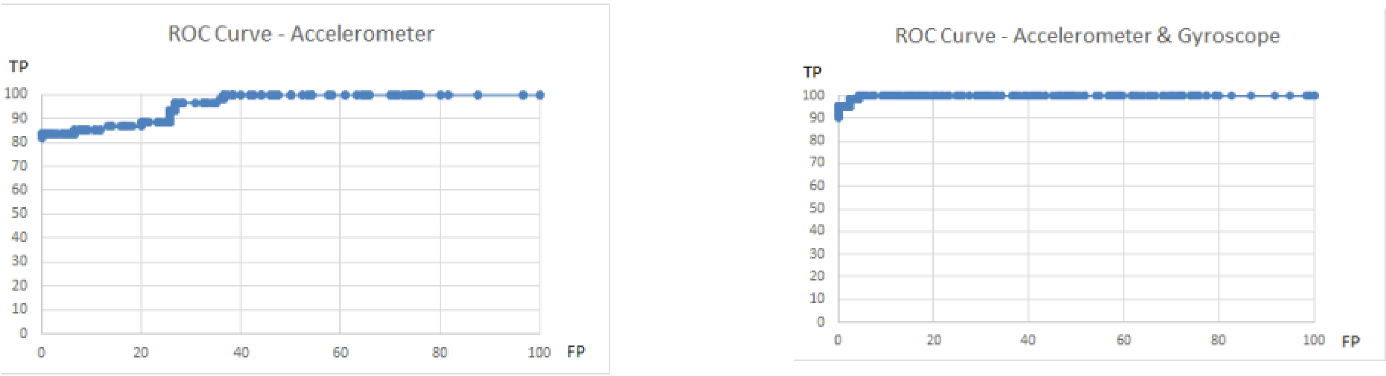


Figure 1.2.1: ROC Curve – Accelerometer and Accelerometer & Gyroscope [14]

Receiver Operating Characteristic (ROC) curve when Accelerometer and Gyroscope both are used.

Inertial Sensor-Based Fall Detection and Fall Prevention: Inertial sensor-based method of fall detection and fall prevention is getting more popular day by day. This method has numerous advantages because of its high accuracy, instant response, easier implementation etc. Even so this method has limitations also. In this case users need to wear the devices to be monitored which makes them uncomfortable sometimes if the device is heavy. And also, placement of sensor has a great impact on performance [3].

Accelerometer: Accelerometer senses acceleration, which is the rate of change of velocity. And falls are characterized by a sudden change in velocity. So, accelerometer can be used in fall detection [4].

Diana Yacchirema, Jara Suarez de Puga, Carlos Palau, Manuel Esteve has proposed a device of IoT-based system for fall detection. In their study they have implemented 3D-axis accelerometer embedded into a 6lowPAN device to collect the data of movement. For high efficiency they have used the machine learning model (Decision Tree) to process and analyze the readings coming from the sensor. In this study the total system has divided into four parts. They are-a wearable device, a wireless network, a smart IoT gateway, and cloud services. And in case of notifying the caregivers, family members and emergency services when fall occurs, it QoS mechanisms. The results from the experiment showed high success rates in fall detection. But their proposed system only uses a single type of sensor, 3D-axis accelerometer. This system may not be able to detect all types of falls [5].

***GYROSCOPE*:** Gyroscopes measure angular velocity which defines the rate of change of orientation. When a person falls, his/her body orientation changes rapidly. It can also detect sharp turns which also indicates fall of a person [8].

***SENSORS FUSION BASED FALL DETECTION AND FALL PREVENTION*:** According to study, a single sensor-based fall detection system has less reliability because of low accuracy and high false alarm. The performance of the system can be improved by combining two or more sensors. Combination of triaxial gyroscope, triaxial accelerometer and magnetometer was proposed in severe studies [3].

M. Irwan Nari et al. has proposed a system for fall detection system with gyroscope and accelerometer. They have designed the device for wearing in the waist. This system works with combinational value of two sensors. Here, threshold values are set to compare the readings coming from the sensors to detect whether fall occurs or not. If the fall occurs this system can notify the family members or emergency services. This system is also equipped with a push button for users so that they can push the button to alert if they are conscious. In this method they have used MPU-6050 which is a motion detector sensor embedded with 3 axis accelerometer and 3 axis gyroscope sensors. They have used an algorithm based on two parameters sensitivity and specificity [6].

Qiang Li, John A. Stankovic, Mark A. Hanson, Adam T. Barth, John Lach and Gang Zhou has proposed a system which can detect falls accurately recognizing body postures. This system can recognize postures like standing, sitting, bending and lying and does not give false alarm. This has made their system more accurate and reliable. Combination of gyroscope and accelerometer, this system measure both linear acceleration and angular velocity which made the fall detection algorithm more accurate. Also, they have tried to make the system less computational for getting fast responses from the system. Four thresholds were set in this method based on four body postures. When threshold values exceed, fall detects. They used TEMPO (Technology-enabled Medical Precision Observation) 3.0 sensor nodes because both acceleration and angular velocity is measured for detecting fall. They have developed an algorithm named three-phase fall detection by which they examined the values coming from the sensors with thresholds and gave results whether body transitions is intentional or unintentional [7].

1.3 STANDARDS AND CODES OF PRACTICES

BATTERY: IEC 60086 is a universal standard that prescribes battery producers to guarantee that batteries are replaceable concurring to the standard in terms of appearance, proficiency and execution. This can be expected to assist clients and producers of gadgets that utilize batteries. IEC battery standard certification shows that the battery meets the standard. In expansion, the switch permits the batteries to be utilized in an assortment of items. This implies you'll be able to increase appropriations and income. (See Details)

MEDICAL ELECTRICAL EQUIPMENT: IEC 60601-1-11 is a specific international standard within the IEC 60601 series that belongs to the safety and essential performance of medical electrical equipment and medical electrical systems used in the home healthcare environment. The standard outlines safety requirements to protect patients, users, and caregivers from electrical and mechanical hazards by fulfilling the requirements for insulation, grounding, protective earth, protection against electrical shock and equipment should be designed to withstand, such as temperature, humidity, and atmospheric pressure [13].

DUST & WATER RESISTANCE: IP53 Protected against limited dust ingress. Protected against water splashes at angles less than 60 degrees to vertical. IP54 Protected against limited dust ingress. Protects against splashes from all directions [15].

1.4 STAKEHOLDERS' EXPECTATIONS/REQUIREMENTS

There are basically three different kinds of stakeholders involved in this project. They are as follows:

- Specialists
- Old Aged People
- Caregivers

We visited old age homes to conduct the survey. There we talked to elders and caregivers about our project, in which we contacted 20 old aged people and 25 caregivers.

On the other hand, we visited 5 psychotherapy centers for our project survey. From there we collected a total of 5 responses.

- ***PRICE:*** They didn't want to purchase yet another expensive, impractical gadget, therefore they were rather concerned about this aspect. They therefore desired it to be accessible. According to caregivers, old aged people will buy and use if the device is worth approximately 10,000 BDT – 15,000 BDT. It will fall within the acceptable range and widespread use of it can be ensured.
- ***NOTIFICATION SYSTEM:*** According to the survey of caregivers, the response of SMS based notification is more than the response of apps-based notification. 56% of the total responses are in favor of SMS based notification and 44% are in favor of Apps based response.

  According to the survey of specialists, they all expressed their opinion on SMS based notifications. According to their opinion, apps-based notification can't alert if there is internet problem. Also, this system will not work for many people who don't use smart phones. So, they expressed their opinion on SMS based notification.
- ***SUITABLE BODY PART FOR WEARING THE PROPOSED DEVICE:*** Since we intend to make this device for the old aged people, we will try our best to keep the device lightweight. Because they can move easily by wearing this device. According to a survey of older people, most of them suffer from back, leg and head injuries by falling. We will try to implement the proposed device to prevent head, leg and back injuries through fall impact minimization.
- ***EXPACTATION FROM THE PROPOSED DEVICE:*** We asked this question to old aged people, caregivers & specialists. They said the device is better if it is light, the device is better if it is fast, 2-way communication, a call system, informing doctor, GPS tracking alarm

system, blood pressure monitoring and many more. We will try our best to fill up as much as possible.

1.5 PROJECT REQUIREMENTS

During starting a new project, it's important to identify what is needed to complete it successfully. After surveying the stakeholders, we received their requirements, e.g portability, cost perspective, notification alert system, battery backup. We make our proposed project user-friendly. After conducting research and survey, we have a clearer understanding of the requirements for our project. Our intended need is summarized below.

- ***BATTERY:*** Our proposed device is portable so we need the battery to be removable and rechargeable. The battery needs to be low weighted as well so that the device can be carried it. We should avoid using batteries with higher power backup than we need. We need to select a battery which has all these criteria in a balanced manner.

- ***RESPONSE TIME:*** The device must respond instantly to ensure timely detection of fall. If the device cannot respond rapidly, it will not be able to notify the caregiver and family member. The device should detect the fall within 10 seconds of its occurrence. For faster response of the device two factors should be considered. They are:
    - Sensor sensitivity and accuracy
    - Algorithm efficiency

  We need to focus on these factors to reduce the response time of the device. Our goal is to detect the fall within 10 seconds or less than 10 seconds. The faster response time of the device could be major factor for saving a life.
- ***NOTIFICATION:*** An efficient notification system is required to ensure that caregiver and family members are immediately informed about a fall. The device should send real-time notification to the caregiver and family members. Once fall is detected, the notification to caregiver and family members should be sent within 5 seconds. They can be notified in two ways. They are:
    - Apps
    - SMS

We have chosen SMS as our notification system. Because there is a disadvantage of app-based notification is connectivity. If any of the person (Caregiver or Family member) is not connected to the internet he/she cannot be notified about the fall. Then it can be a great disaster.

- ***WEIGHT:*** The device should be lightweight and comfortable as it is a wearable device. The device will be worn for a long period of time by the user. So, the device should weigh no more than 200 grams to ensure comfort of the user. We will design the device in a way that it does not exceed the weight limit of 200 grams. If the device is heavier than 200 grams, it may discourage the user to wear. And also, it can create discomfortness. So, it will make the user comfortable to wear it for a long period of time.
- ***DURABILITY:*** The device must be durable because it's everyday wear. It should be able to handle extreme weather conditions. It should be safe from scratches, water drops etc. We will also make sure that the device will be water resistant.
- ***COST EFFECTIVENESS:*** Cost effectiveness is the major factor in making wider use of the device. The device should cost 10,000 to 15,000 BDT according to stakeholder's response. We will try our best to design this device in a way that it will not exceed the amount. So, they can buy and use it without facing any difficulties.

1.6 PROJECT MANAGEMENT

1.6.1 PROJECT PLAN

CPM DIAGRAM

Table 1.6.1.1: Project Activities (CPM)

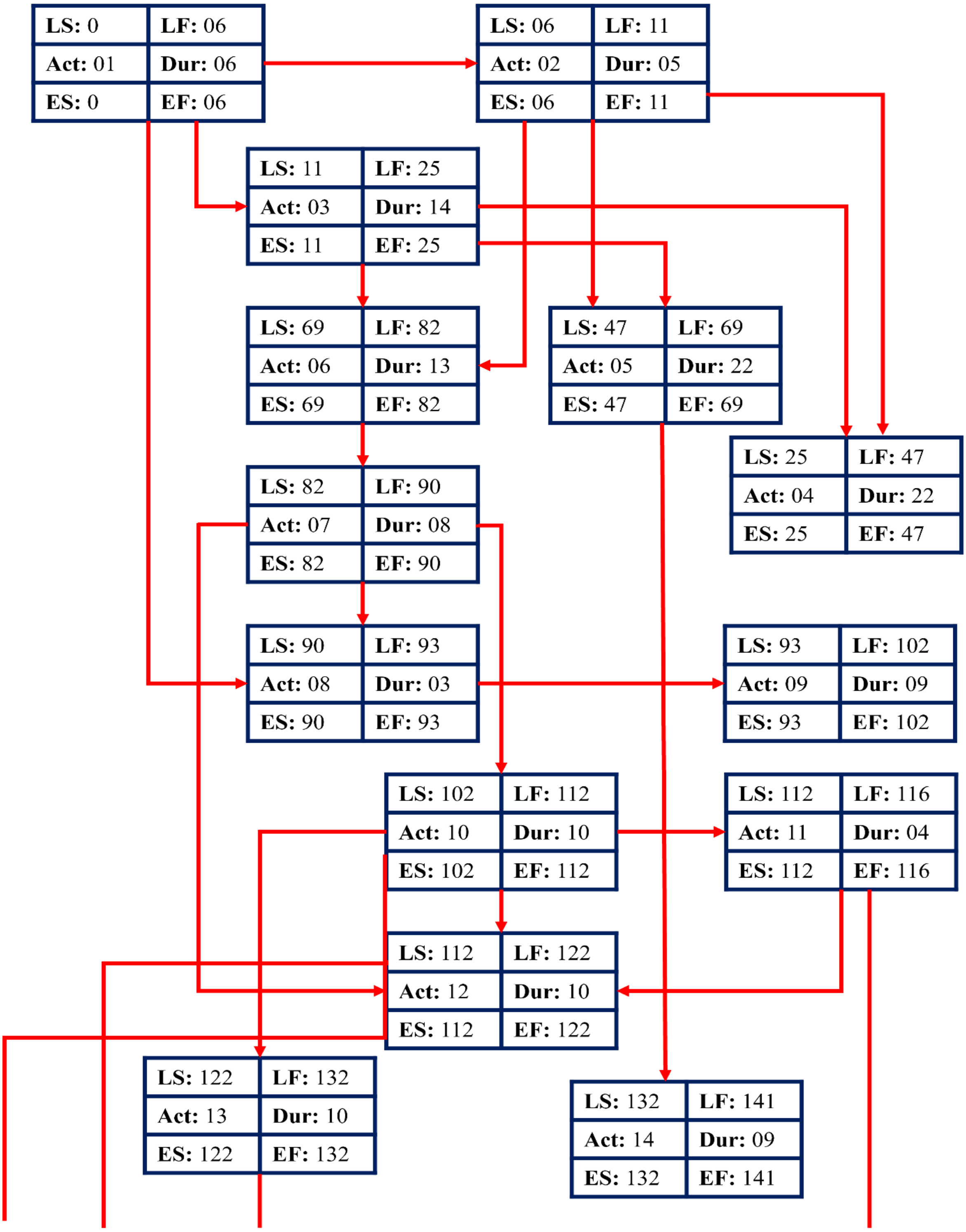
ACTIVITY NO.	ACTIVITIES	DURATION (DAYS)	PREDECESSOR
PART-A			
01.	Initial Topic Selection	06	…….
02.	Discussing with Supervisor and Getting approval from the Supervisor	05	01
03.	Getting Approval from the EEE Dept	14	01, 02
04.	Literature Review	22	02, 03
05.	Analysis Social Impact	22	02, 03
06.	Identifying Stakeholders & Preparing Questions for Stakeholders	13	02, 03
07.	Taking Feedback from the Stakeholders	08	06
08.	Preparing Project Plan	03	01, 07
09.	Identifying Standard Code of Practice	09	08
10.	Project Requirements Finalization	10	02, 07
11.	Project Resource List and Budget Analysis	04	10
12.	Project Specifications and Local Market Analysis	10	07, 10,11
13.	Product Life Cycle	10	10
14.	Effects on Environment, Sustainability, Health and Safety Issue	09	05
15.	Risk Management	14	10, 13
16.	Preparing Report and Submission	06	5, 11, 12, 14

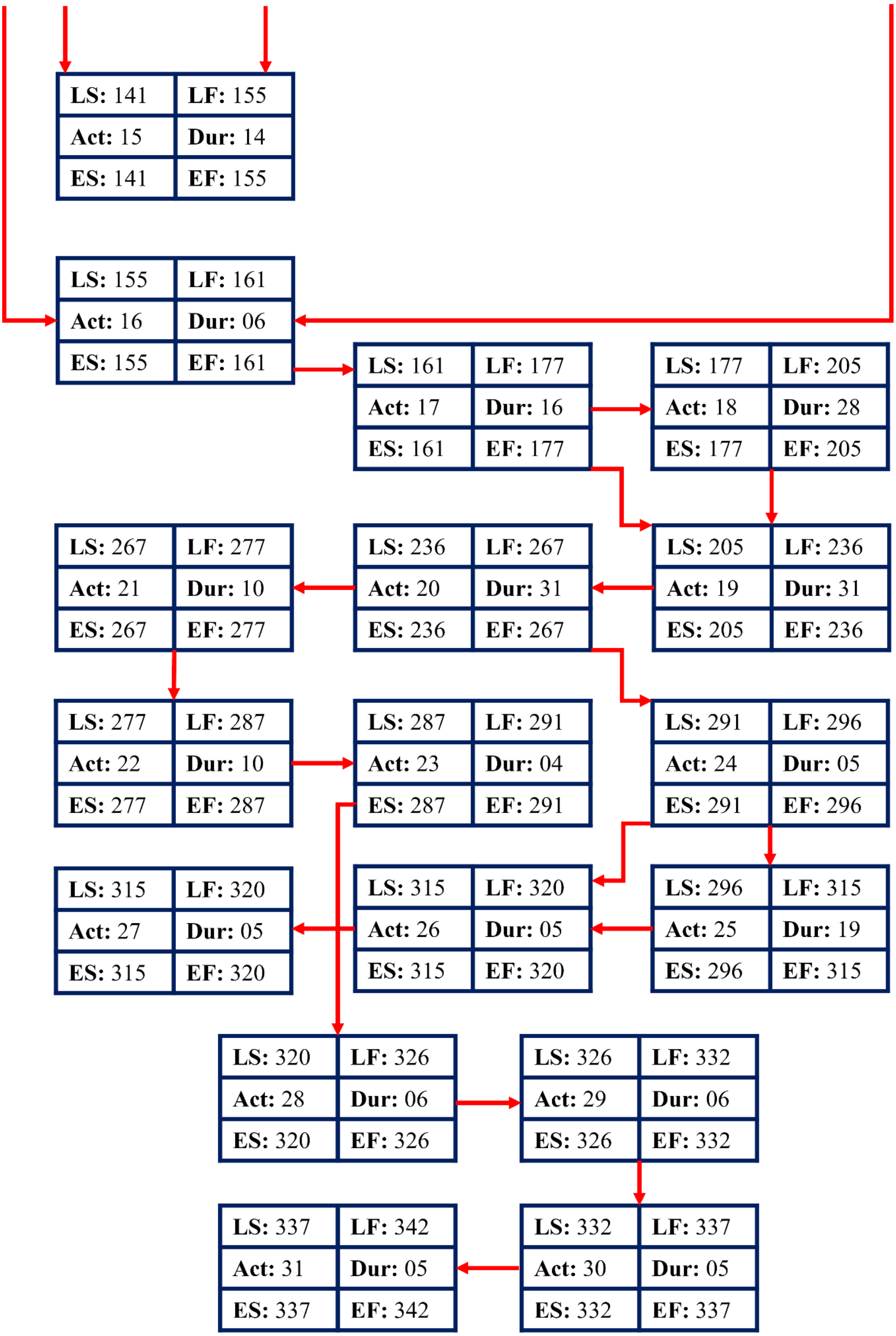
PART-B			
17.	Preliminary Project Design	16	16
18.	Analysis Alternate Solutions	28	17
19.	Design System Circuit	43	17, 18
20.	Preparing Full Prototype Design of the Device	31	19
21.	Preparing Report & Submission	10	20
PART-C			
22.	Find Out the Equipment for the Device	10	21
23.	Purchase Equipment's	4	22
24.	Design Android Mobile App / SMS System	05	20
25.	Implementation	39	24
26.	Analysis the Performance of the Device	15	24, 25
27.	Finalizing the Design According to the Device Performance	15	26
28.	Economic Analysis	07	23
29.	Verification of Complex Engineering Problem	06	28
30.	Report Preparing and Submission	08	29
31.	Preparation for Project Presentation	05	30

Our Critical Path Method (CPM) diagram is now designed. This will help us to determine how much scheduling flexibility we need for our tasks. We can also find the critical path. The critical path indicates the longest path required to complete the project on time.

LS = Late Start, ES = Early Start, LF = Late Finish, EF = Early Finish, Act = Activity Duration, Dur = Duration.

Figure 1.6.1.1: Diagram of CPM




LS: 141 LF: 155
Act: 15 Dur: 14
ES: 141 EF: 155
LS: 155 LF: 161
Act: 16 Dur: 06
ES: 155 EF: 161
LS: 161 LF: 177
Act: 17 Dur: 16
ES: 161 EF: 177
LS: 177 LF: 205
Act: 18 Dur: 28
ES: 177 EF: 205
LS: 267 LF: 277
Act: 21 Dur: 10
ES: 267 EF: 277
LS: 236 LF: 267
Act: 20 Dur: 31
ES: 236 EF: 267
LS: 205 LF: 236
Act: 19 Dur: 31
ES: 205 EF: 236
LS: 277 LF: 287
Act: 22 Dur: 10
ES: 277 EF: 287
LS: 287 LF: 291
Act: 23 Dur: 04
ES: 287 EF: 291
LS: 291 LF: 296
Act: 24 Dur: 05
ES: 291 EF: 296
LS: 315 LF: 320
Act: 27 Dur: 05
ES: 315 EF: 320
LS: 315 LF: 320
Act: 26 Dur: 05
ES: 315 EF: 320
LS: 296 LF: 315
Act: 25 Dur: 19
ES: 296 EF: 315
LS: 320 LF: 326
Act: 28 Dur: 06
ES: 320 EF: 326
LS: 326 LF: 332
Act: 29 Dur: 06
ES: 326 EF: 332
LS: 337 LF: 342
Act: 31 Dur: 05
ES: 337 EF: 342
LS: 332 LF: 337
Act: 30 Dur: 05
ES: 332 EF: 337

CRITICAL PATH:

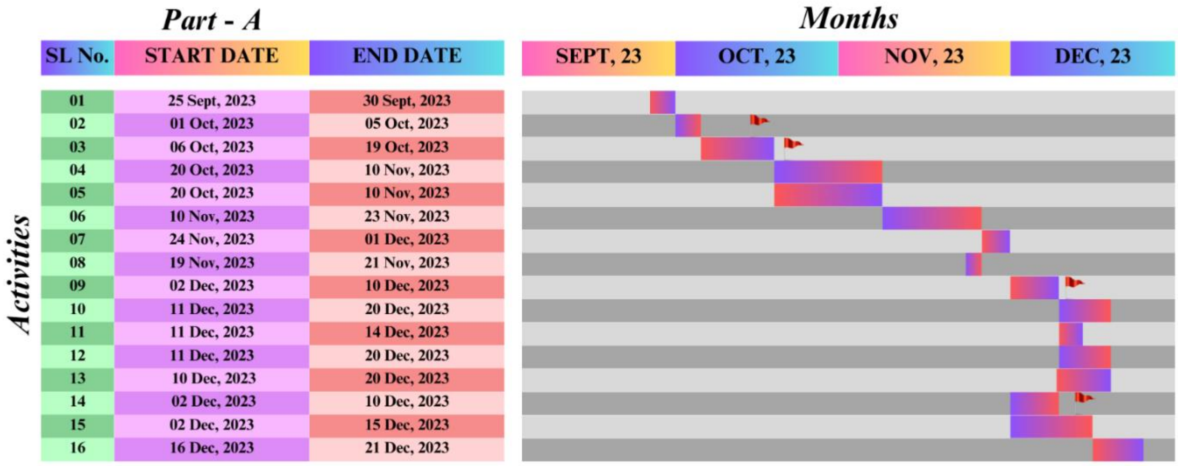
1 > 2 > 3 > 6 > 7 > 8 > 9 > 10 > 11 > 13 > 14 > 17 > 18 > 20 >21 >22 > 27 > 28 > 29 > 30 > 31

GANTT CHART

Table 1.6.1.2: Project Activities (Gantt Chart)

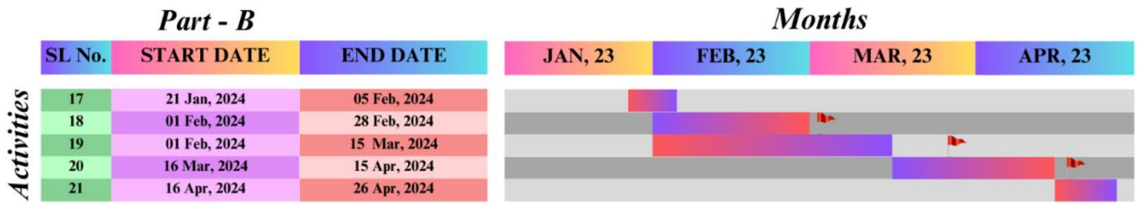
ACTIVITY NO.	ACTIVITIES	DURATION (DAYS)	START DATE	END DATE
PART-A				
01.	Initial Topic Selection	06	25 Sept, 2023	30 Sept, 2023
02.	Discussing with Supervisor and Getting approval from the Supervisor **[Milestone – 01]**	05	01 Oct, 2023	05 Oct, 2023
03.	Getting Approval from the EEE Dept **[Milestone – 02]**	14	06 Oct, 2023	19 Oct, 2023
04.	Literature Review	22	20 Oct, 2023	10 Nov, 2023
05.	Analysis Social Impact	22	20 Oct, 2023	10 Nov, 2023
06.	Identifying Stakeholders & Preparing Questions for Stakeholders	13	11 Nov, 2023	23 Nov, 2023
07.	Taking Feedback from the Stakeholders	08	24 Nov, 2023	01 Dec, 2023
08.	Preparing Project Plan	03	19 Nov, 2023	21 Nov, 2023
09.	Identifying Standard Code of Practice **[Milestone – 03]**	09	02 Dec, 2023	10 Dec, 2023
10.	Project Requirements Finalization	10	11 Dec, 2023	20 Dec, 2023
11.	Project Resource List and Budget Analysis	04	11 Dec, 2023	14 Dec, 2023
12.	Project Specifications and Local Market Analysis	10	11 Dec, 2023	20 Dec, 2023
13.	Product Life Cycle	10	16 Dec, 2023	25 Dec, 2023
14.	Effects on Environment, Sustainability, Health and Safety Issue **[Milestone – 04]**	09	02 Dec, 2023	10 Dec, 2023
15.	Risk Management	14	02 Dec, 2023	15 Dec, 2023

16.	Preparing Report and Submission	06	16 Dec, 2023	21 Dec, 2023
Total Days		87 Days (25 Sept, 2023 – 21 Dec, 2023)		
PART-B				
17.	Preliminary Project Design	16	21 Jan, 2024	05 Feb, 2024
18.	Analysis Alternate Solutions **[Milestone – 05]**	28	01 Feb, 2024	28 Feb, 2024
19.	Design System Circuit **[Milestone – 06]**	43	01 Feb, 2024	15 Mar, 2024
20.	Preparing Full Prototype Design of the Device **[Milestone – 07]**	31	16 Mar, 2024	15 Apr, 2024
21.	Preparing Report & Submission	11	16 Apr, 2024	26 Apr, 2024
Total Days		96 Days (21 Jan, 2024 – 26 Apr, 2024)		
PART-C				
s22.	Find Out the Equipment for the Device	10	13 May, 2024	22 May, 2024
23.	Purchase Equipment’s	04	23 May, 2024	26 May, 2024
24.	Design Android Mobile App / SMS System **[Milestone – 08]**	44	27 May, 2024	09 July, 2024
25.	Implementation **[Milestone – 09]**	44	27 May, 2024	09 July, 2024
26.	Analysis the Performance of the Device	15	10 July, 2024	24 July, 2024
27.	Finalizing the Design According to the Device Performance **[Milestone – 10]**	15	25 July, 2024	08 Aug, 2024
28.	Economic Analysis	07	09 Aug, 2024	15 Aug, 2024
29.	Verification of Complex Engineering Problem **[Milestone – 11]**	06	16 Aug, 2024	20 Aug, 2024
30.	Report Preparing and Submission	05	21 Aug, 2024	24 Aug, 2024
31.	Preparation for Project Presentation	05	21 Aug, 2024	24 Aug, 2024
Total Days		104 Days (13 May, 2024 – 24 Aug, 2024)		



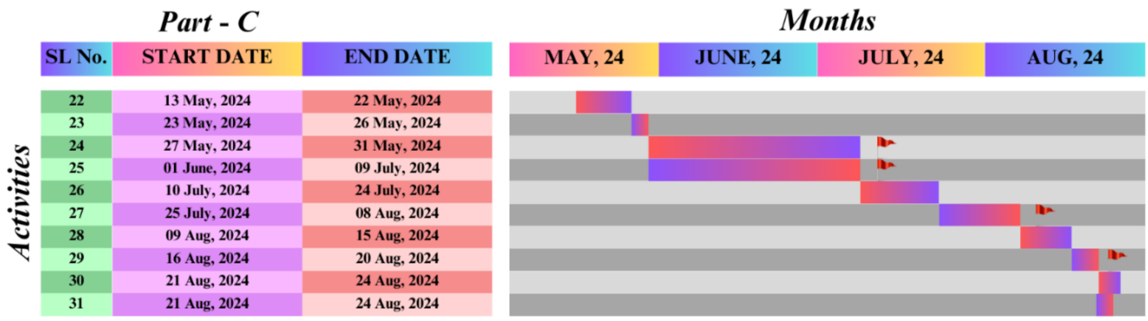
SL No.	START DATE	END DATE
01	25 Sept, 2023	30 Sept, 2023
02	01 Oct, 2023	05 Oct, 2023
03	06 Oct, 2023	19 Oct, 2023
04	20 Oct, 2023	10 Nov, 2023
05	20 Oct, 2023	10 Nov, 2023
06	10 Nov, 2023	23 Nov, 2023
07	24 Nov, 2023	01 Dec, 2023
08	19 Nov, 2023	21 Nov, 2023
09	02 Dec, 2023	10 Dec, 2023
10	11 Dec, 2023	20 Dec, 2023
11	11 Dec, 2023	14 Dec, 2023
12	11 Dec, 2023	20 Dec, 2023
13	10 Dec, 2023	20 Dec, 2023
14	02 Dec, 2023	10 Dec, 2023
15	02 Dec, 2023	15 Dec, 2023
16	16 Dec, 2023	21 Dec, 2023

Figure 1.6.1.2: Gantt Chart of Part A



SL No.	START DATE	END DATE
17	21 Jan, 2024	05 Feb, 2024
18	01 Feb, 2024	28 Feb, 2024
19	01 Feb, 2024	15 Mar, 2024
20	16 Mar, 2024	15 Apr, 2024
21	16 Apr, 2024	26 Apr, 2024

Figure 1.6.1.2: Gantt Chart of Part B



SL No.	START DATE	END DATE
22	13 May, 2024	22 May, 2024
23	23 May, 2024	26 May, 2024
24	27 May, 2024	31 May, 2024
25	01 June, 2024	09 July, 2024
26	10 July, 2024	24 July, 2024
27	25 July, 2024	08 Aug, 2024
28	09 Aug, 2024	15 Aug, 2024
29	16 Aug, 2024	20 Aug, 2024
30	21 Aug, 2024	24 Aug, 2024
31	21 Aug, 2024	24 Aug, 2024

Figure 1.6.1.4: Gantt Chart of Part C

1.6.2 RISK MANAGEMENT

Risk is just an unfavorable circumstance that arises during a project's duration. There is always a chance of risk when working on a project. Risk management is an ongoing process that involves identifying, analyzing, evaluating, and treating potential loss exposures. It also involves keeping an eye on risk control and available funds to lessen the negative effects of loss. Risks associated with a project have the potential to negatively impact both the environment and those involved [9]. The project cannot be properly implemented without assessing the risk. We must determine and establish the risk parameters prior to beginning work on the project. In our capstone project we have determined that there are some risk factors which can affect our project.

COMMUNICATION PROBLEMS: Significant threats to the project's success might arise from communication issues. Collaborating as a team, comprehending the needs of the project, and resolving any unexpected problems all depend on effective communication. Due to various class schedules, we can’t always meet at the same time. Therefore, most of our group sessions are held at night. During this online group session, we encounter various issues such as power outages, internet issues, etc.

EQUIPMENT UNAVAILABILITY: Project-related equipment may be unavailable for a while, which might cause delays in project completion. For various reasons, even the manufacture of some essential items may be halted or reduced.

COST OF EQUIPMENT: The equipment's cost may increase beyond our budget if there is a production delay of any kind. The budget will also be adjusted to account for the cost of any substitute equipment if any is unavailable.

MISUNDERSTANDING AMONG THE MEMBERS: This project is for 1 year. For whatever reason, misunderstandings may occur among the members of the group. As a result, members of the group may not carry out their duties correctly. Due to this, the milestone assigned may not be reached within the time frame, thus delaying the project.

RISK OF UNCERTAINTY**:** Our team members may be dealing with serious health challenges, family issues, or financial crises, which will have an impact on our project timetable. To alleviate the financial issue that arose during the project, the remaining members will divide the remaining funds. And if one of our group members becomes unwell, we will reschedule our project activity list. So, it will waste some time to rearrange everything which can be a problem to finish like project time.

MITIGATION PLAN: In project management, a mitigation plan is a proactive approach to reduce or eliminate a risk. It involves creating and implementing plans to reduce the likelihood of a risk happening or to reduce its potential adverse effects.

It is likely that some devices will become unavailable. In this case, we need to identify other alternative devices that can meet our requirements. Prices of electronic components are rising due to the high rate of the dollar. But if the situation continues to worsen, costs will rise. Then we must deal with the extra volume or find a lower cost alternative device that offers the similar performance. In some cases, some devices may be defective and not give you the expected results. In this case, we will need to find alternative solutions and suitable equipment. Equipment and other necessary costs are required to complete the project. First, we try to manage costs ourselves. If we are not successful, we will look for a sponsor for the project. If there is a misunderstanding between members, we will try to resolve the issue in a short time and get back to work. If we cannot receive the resources we need in a timely manner, engage in resource-independent activities and find alternative resources or where you can access them.

***CONTINGENCY PLAN*:** Contingency plans are an important part of risk management in project management. This involves identifying potential risks and developing strategies to address them when they occur.

The situation may get further critical sometimes. We might need to finish one task before moving on to the next. In such a case, we may have some delays in completing the task and meeting the corner. The design plan may also need to be revised to complete the section or design on schedule. During that time, we can continue working in a logical order, like one member working for a while and the coming member taking over. We will reorganize the work if a group member is unable to participate in the project due to a personal or medical emergency. This will ensure that we meet the project milestone without encountering any obstacles or delays.

1.6.3 REQUIRED RESOURCES AND BUDGET

Several types of hardware, computing resources, external support, etc to achieve our project goals which is given below:

- ***COMPUTATIONAL RESOURCE:***

  - Matlab
  - Proteus
  - AutoCAD
  - TinkerCad
  - Python
  - Arduino IDE 2.2.1

- ***HARDWARE EQUIPMENT'S LIST:***

Table 1.6.3.1: Equipment's Price & Price

SL No.	*Equipment's Name*	*Price (Expected)*
01.	Battery (See Details)	2500 BDT
02.	TP4056-1A Li-ion lithium Battery Charging Module with Current Protection Type-C (See Details)	56 BDT
03.	Arduino Uno R3 (See Details)	1100 BDT
04.	Arduino Android IOS HM-10 BLE Bluetooth 4.0 cc2540 cc2541 serial wireless Module (See Details)	470 BDT
05.	6DOF MPU 6050 3 Axis Gyro (See Details)	200 BDT
06.	ADXL345 Triple Axis Accelerometer Breakout (See Details)	479 BDT
07.	Soldering Kit (See Details)	949 BDT
08.	Double Sided FR-4 PCB Prototype Board 9 x15cm (See Details)	190 BDT
09.	Connection Wires (Male to Male; Male to Female; Female to Female) (See Details)	420 BDT
10.	Airbag Expenses	6000 BDT
11.	Travel Expenses	4000 BDT
12.	Others	4000 BDT
	Total	20,364 BDT

1.7 PROJECTED PRODUCT LIFECYCLE

Our main objective of this project is to build a device that will help old aged people to detect fall and minimize the impact of fall. We must design our device to be user-friendly, inexpensive, and portable as demanded by the product's stakeholders. Next, we must think about how sustainable our business is for our product when we move to large-scale manufacturing by offering several upgrades and enhancements to our product. We know improvement of a device is an important thing in a business. We must consider how we can build this device without any problems going forward. The device's after-sale and customer services must also be taken into account. All of this will help our device to be in demand and our business will continue and grow. market. In order to make the business sustainable, we have planned some updates and features which will keep on bringing new users.

- ***STABILITY OF THE SUPPLY CHAIN:*** To guarantee a smooth production and supply process, it is essential to ensure the timely availability of necessary components and parts. Any disruptions in the supply chain could severely impact the production system, leading to a significant decline in product throughput. A reliable strategy to mitigate supply chain instability involves engaging multiple suppliers for the same product and maintaining backup options.
- ***MARKET DEMAND:*** Market demand for a project is the level of demand or interest shown by potential customers or clients in the product, service, or solution that the project is intended to provide. Market demand analysis is essential for the successful completion of any project. It is essential for us to take this into account if we want to continue growing our business. So, we will continue to analyze the market to know what our customers want and what features we can add to draw them in based on the current social trends. It is important to constantly analyze the market in order to stay in the prominent position of the market.
- ***UPDATES:*** Every potential buyer seeks innovative features when considering a device purchase. To sustain consumer interest, we continually explore avenues to enhance our devices by incorporating new functionalities. This could involve additions like Bluetooth connectivity, comfortability, faster response and other advancements. Regularly designing updates with added comfort mechanisms is crucial to capturing user attention and ensuring the ongoing appeal of our device.

- ***CONTINUED MANUFACTURING:*** It is the continuous process of producing and assembling the parts or components needed for a project. Continuous production is the constant effort to produce the project, meet the demand and maintain a consistent supply. Consumers are more likely to purchase products that have gained broad acceptance because the higher quantity ensures indirect assurance of proper support, repair facilities, and a strong community.
- ***CUSTOMER SERVICE:*** Customer decisions are influenced by the quality of customer service. When customers are confident that their issues will be addressed, and there is a reliable repair service, they are more inclined to make a purchase. To ensure effective customer service, we plan to establish service points staffed by trained professionals who will offer post-sales support. These locations will not only provide repair services but also serve as sales outlets for our products and act as demonstration points for customers to experience our products.
- ***MODULARITY:*** Modularity in project design involves structuring the project so that diverse components or modules can operate independently, enabling straightforward replacement or upgrade without disrupting the entire system. We can improve flexibility, simplify maintenance, and permit the seamless integration of new features or components without causing disturbances to the entire device. So it can contribute to saving time and cost.

1.8 IMPACTS OF THE PROJECT

1.8.1 IMPACTS ON SOCIETY

Falls are a major threat to the health and independence of the old aged people. A wearable device that can detect falls and minimize injury could have a profound impact. Even non-injurious falls undermine seniors' confidence in their mobility. But detecting falls and minimizing injury could help senior citizens maintain active, independent lifestyles for longer. With populations rapidly aging, such technology becomes increasingly important. By mitigating the severity of falls, it would allow seniors to maintain active lifestyles and remain in their homes longer without requiring constant supervision or assistance. If deployed widely, they could substantially reduce healthcare costs associated with falls, benefiting health systems and families financially. Overall, effective fall detection and impact minimization devices would provide physical, mental and financial benefits across society. With further development, these devices could greatly improve the safety, health outcomes and independence of our senior citizens.

1.8.2 EFFECTS ON ENVIRONMENT AND SUSTAINABILITY

The development and widespread adoption of fall detection and impact minimization devices has the potential to impact the environment and sustainability in several ways. Environmental sustainability can be defined as the impact a product has on the environment at each stage of its lifecycle, including during raw material extraction, production, distribution, consumer use, and disposal. Everybody wants their product to be environmentally friendly and sustainable over the long run. We need to understand the product life cycle to do that.

However, the production of the devices themselves would consume raw materials and energy, and potentially generate greenhouse gas emissions depending on manufacturing practices. If the lithium-ion batteries that are frequently used in wearables are not gathered and disposed of ethically, they may have a harmful impact on the environment. The inflatable airbag component would use additional chemicals and materials that need to be managed.

Almost every technological device has both positive and negative impacts on the environment. In this regard, our project which is device or system is not different. Batteries, electronics components, plastic, copper, and silicon are the raw materials required for our device. We will need a Lithium Polymer battery to power our device. Metals such as lithium, cobalt, nickel, and manganese are used in such batteries, and extracting the raw material from these batteries requires a significant amount of energy and resources. Some of these metals, such as cobalt, nickel, and manganese, are toxic when they are released into the environment. If these metals leach out of landfills, they can contaminate water supplies and ecosystems.

We may need to use a small portion of plastics to make it light weight, which has a significant impact on the environment. Plastic takes a long time to decompose and burning is not also a solution as it produces harmful gases like carbon monoxide, nitrogen oxide, sulfur dioxide etc. after burning.

Recycling can be a great way of minimizing environmental stress. But this needs to be done properly by the trained authority. We may provide incentives to return the products to us at the end of the product life cycle so that we can recycle the products and send the products to the appropriate recycling plants.

1.8.3 HEALTH AND SAFETY ISSUES

The development of an effective fall detection and impact minimization device requires extensive evaluation of potential health and safety risks. While the technology aims to improve user safety, diligent design is necessary to ensure it does not introduce unintended hazards. Materials selection requires careful thought, as any inflatable components should be non-toxic, allergen-free and retain integrity over time. Power systems with sufficient capacity need to be made intrinsically safe. Our device will be powered by a lithium-ion battery. Because it is a rechargeable battery, improper charging might cause it to overheat, catch fire, or explode. The battery in our device should live long enough so that users won't need to replace it very frequently. Throwing away these used batteries can cause hazards to the environment and human health. Water exposure can cause electronic devices to malfunction. Therefore, our gadget must be IP rated for reasonable water and dust protection.

PART-B

This part includes the design, analysis and optimization of the project as prepared in EEE400B.

CHAPTER 2 PROJECT DESIGN

2.1 FUNCTIONAL DESIGN

We are working to develop a device capable of detecting elderly people's unwanted falls and minimize the fall impacts.

It is very important to have an idea about the objectives, requirements, applicable standards, safety, comfort, health, and environmental considerations for the project. These discussions are given below,

01. Use of advanced sensors so that fall can detect properly and quickly.
02. By analyzing the data of our sensors, we need to select which sensor gives accurate results for the fall. Integrate data from sensors to improve accuracy and reliability in fall detection. Utilize algorithms to data and distinguish between normal activities and fall events. Develop or utilize sophisticated algorithms to analyze sensor data in real-time. Identify patterns indicative of falls, such as sudden changes in acceleration or orientation.
03. Automatic alarm and notification systems will be implemented, addressing the concern of making the device user-friendly.
04. As this device will be used for medical purposes, it should be safe to use. We will ensure safety with the standard IEC 60601-1-11. IEC 60601-1-11 is a specific international standard that pertains to the safety and essential performance of medical electrical equipment and medical electrical systems used in the home healthcare environment.
05. Lightweight and comfortable to wear is one of the main concerns of this project. We intend that it will be less than 200 grams.
06. It is necessary to protect all electrical equipment from water and dust. IP53 and IP54 standard will be followed.

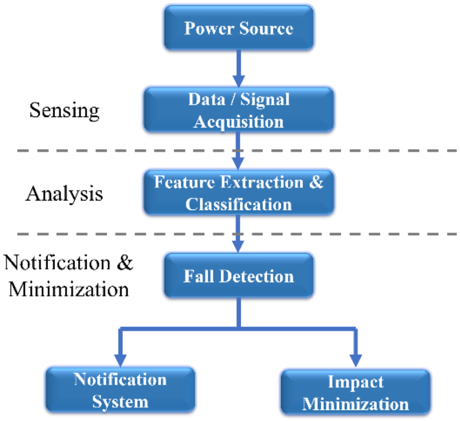


Figure 2.1.1: Fall Detection & Fall Impact Minimization System

- ***POWER SOURCE*:** A power source is needed to run the device. Rechargeable batteries can be used for fall detection devices to ensure long-term operation. The use of battery is determined by factors such as device size, power consumption, and desired operational duration. Lithium-ion batteries can be used as power sources here because of their high energy density, lightweight design and ability to be recharged multiple times.

- ***SENSING*:** Fall detection devices typically use various sensors and algorithms to detect and analyze the movements of a person and determine whether a fall has occurred. The process of sensing involves the following key elements:
  - ***ACCELEROMETER*:** Most fall detection devices are equipped with accelerometers, which are sensors that measure acceleration. Acceleration is the rate of change of velocity with respect to time. In the context of fall detection, accelerometers are used to sense the acceleration and deceleration of the person's body movements.
  - ***GYROSCOPE*:** Some devices also incorporate gyroscopes, which measure the rate of rotation or angular velocity. Gyroscopes provide information about the orientation and angular movements of the device.

- ***DATA ACQUISITION*:** The data or signal acquisition process in a fall detection device involves capturing and collecting information from various sensors to monitor the movements and activities of the user. Fall detection devices incorporate various sensors, commonly accelerometers and gyroscopes, and occasionally magnetometers. These sensors are strategically placed within the device to capture relevant movement data/signals. By collecting these data/signals the system goes to the next process.

FEATURE EXTRACTION AND CLASSIFICATION

- ***FEATURE EXTRACTION*:** Feature extraction involves identifying and extracting relevant characteristics or features from the raw sensor data. These features serve as input for the classification algorithm. Features can be derived from a combination of accelerometer and gyroscope data to capture more comprehensive information about the person's movements.
    - ***ACCELEROMETER FEATURES:*** Common features extracted from accelerometer data include maximum acceleration, minimum acceleration, standard deviation of acceleration.
    - ***GYROSCOPE FEATURES*:** For gyroscope data, features may include maximum angular velocity, minimum angular velocity, standard deviation of angular velocity.

- ***CLASSIFICATION*:** Classification involves categorizing the extracted features into different classes, such as "fall" or "no fall,". Based on the classification result, the fall detection device decides whether a fall has occurred or not. If a fall is detected, the device may trigger alerts or notifications to caregivers, emergency services, or other designated contacts.

  The combination of feature extraction and classification allows fall detection devices to identify potential falls while minimizing false alarms accurately and reliably. The effectiveness of the system often depends on the quality of feature extraction and the choice of an appropriate classification algorithm.

- ***NOTIFICATION SYSTEM*:** This part of the system is designed to notify the user when a fall has been detected by the device. Fall detection devices often come with emergency alert systems which automatically notify caregivers and family members when a fall is detected. These systems use communication technologies like SMS (Short Message Service) system alerts. The rapid response of an emergency alert system provides timely assistance to individuals who have fallen and increases the overall effectiveness of the fall detection device for ensuring the safety of the user.

- ***IMPACT MINIMIZATION*:** This part of the system is designed to reduce the impact of the fall after detecting the fall successfully. Airbag technology can be used in the impact minimization system. When a fall is detected, the airbag system is activated, quickly inflated, and provides a cushioning effect to reduce the impact force on the user's body. This technology aims to reduce the risk of injury during a fall, particularly for elderly people.

2.2 ANALYSIS OF ALTERNATE SOLUTIONS

A major health risk, including injuries, hospitalization, and even death, is posed by falls among the elderly and others with mobility impairments. Fall detection systems have become essential instruments in assisted living and healthcare because they reduce hazards and guarantee prompt aid when needed. But accuracy, dependability, user comfort, and affordability are only a few of the variables that affect how useful these devices are. Through an analysis of a variety of technologies, from wearables to sensor technologies, we explore alternative solutions for fall detection device options in this part. We aim to provide insights on the many strategies for meeting fall detection requirements that consider various user preferences, technology capabilities, and environmental factors by assessing these possibilities. Through this exploration, stakeholders can make informed decisions to select the most suitable fall detection solution for their specific requirements, promoting safety.

2.2.1 SENSOR MODULES

We have three alternative solutions for selecting the sensor modules for this project.

- Accelerometer Sensor Based Fall Detection System.
- Gyroscope Sensor Based Fall Detection System.
- Combine (Accelerometer & Gyroscope) Sensor Based Fall Detection System

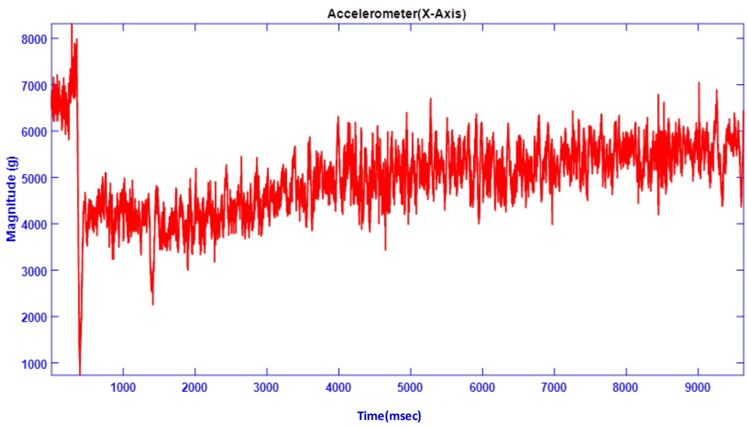
2.2.1.1 ACCELEROMETER SENSOR BASED FALL DETECTION SYSTEM

❖ ***Walking***

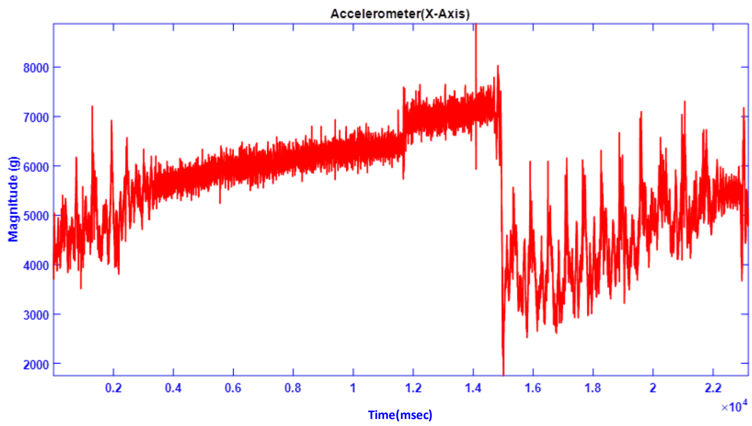
We have taken a set of data from an accelerometer during walking. Each set consists of 3 samples which were taken based on different motions. The data collected from an accelerometer during walking typically shows a distinct pattern characterized by rhythmic peaks and valleys. The peaks define a step taken, while valleys indicate moments of rest or stationary periods. The variation in the pattern differences depends on step length, pace, intensity of movement, and even slight deviations due to factors like terrain, footwear, or fatigue. And, we might observe variations in the rhythm of the steps, such as during moments of acceleration or deceleration.

✓ ***X-Axis***

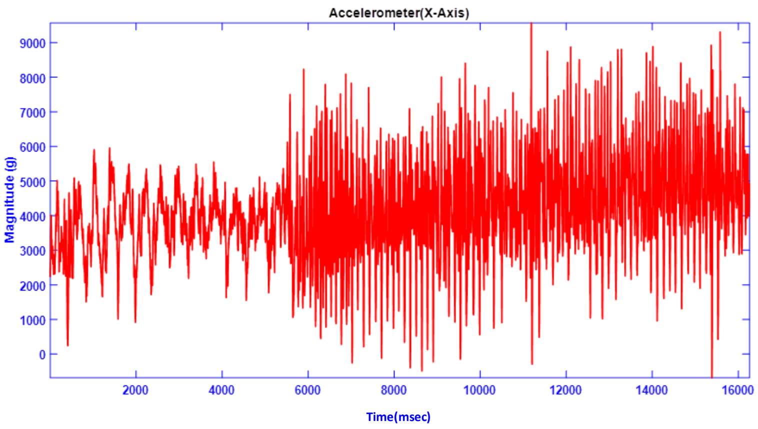
The data of x axis collected from accelerometer indicates horizontal movement(left/right). While walking, the x-axis data shows distinct peaks corresponding to each foot hitting the ground. Each peak defines the start and end of each step anyone takes. Here, every sample is collected in certain period in certain pace of walking.



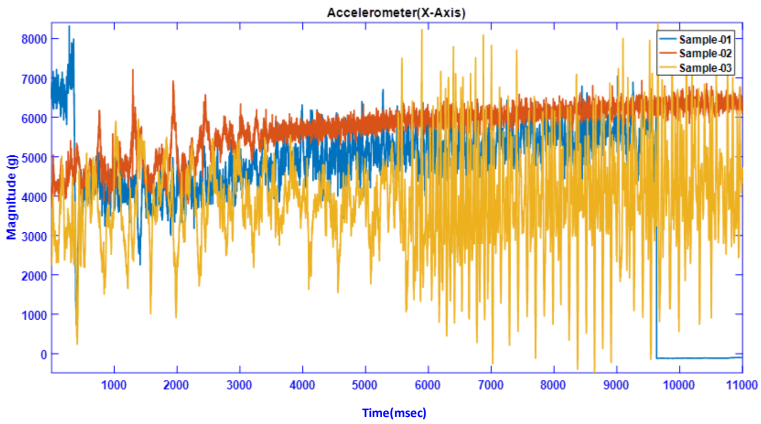
Sample-01



Sample-02



Sample-03



3 Samples Combined

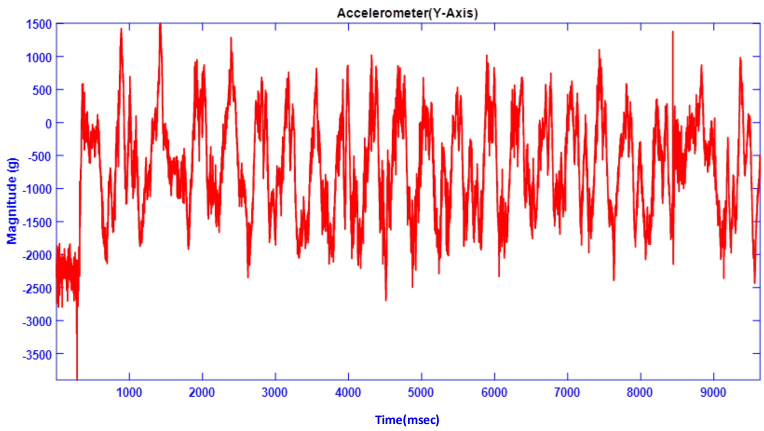
Figure 2.2.1.1.1: Walking Plot using Accelerometer Sensor (x-axis)

In sample-01, the data was taken from the sensor by walking slowly. But in sample-02 and 03 we have taken the data by walking fast. If we observe the plot of sample-01, we see less oscillations than sample-02,03. When the foot hits the ground, we get to a larger peak and turning left or right gives smaller peaks. The frequency of peaks is directly related to the pace of walking. Faster walking generates more frequent peaks in x-axis data. If we observe the three samples we can see these patterns in them.

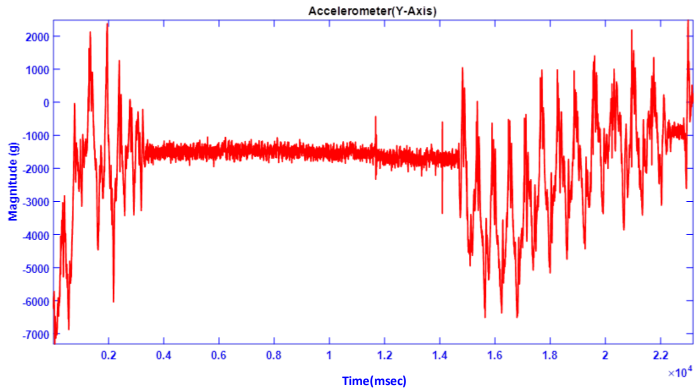
In combined samples plot, we have tried to show all the samples of x axis in one plot to get a good overview comparison among the samples. We clearly see how magnitude and oscillation varies with the pace of walking among the sample we have taken from the sensor.

✓ ***Y-Axis***

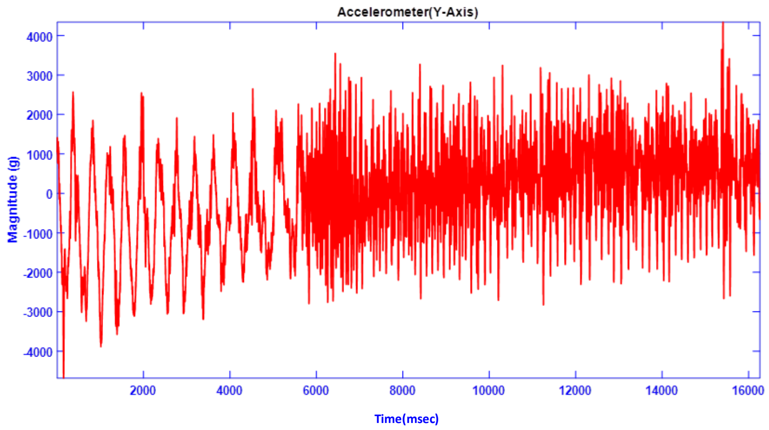
The data of y axis collected from accelerometer indicates forward/backward movement. Every time he/she pushes off with him/her foot, the y-axis data shows a noticeable peak that represents the forward/backward motion of body. The walking pace of the user is directly correlated with the frequency of peaks. In the y-axis data, faster walking induces more frequent peaks. Here, every sample is collected in a certain period at a certain pace of walking.



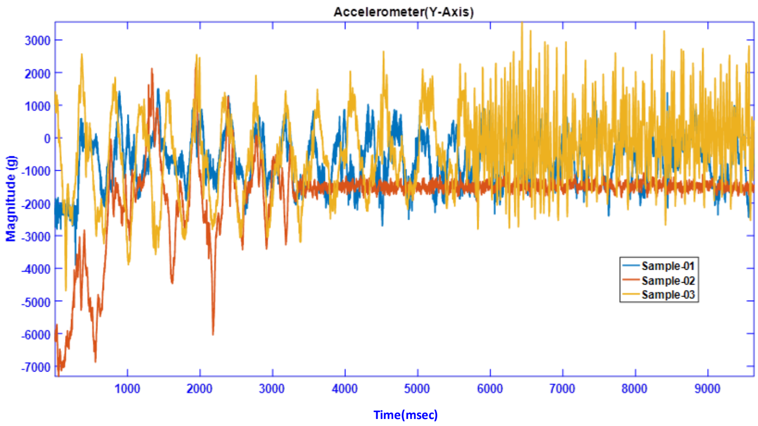
Sample-01



Sample-02



Sample-03



3 Samples Combined

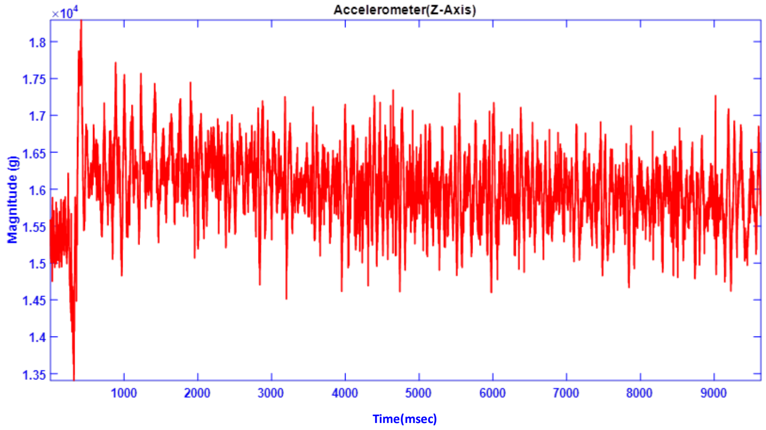
Figure 2.2.1.1.2: Walking Plot using Accelerometer Sensor (y-axis)

In sample-01, the data was collected from the sensor while walking slowly. But in samples-02 and 03, we have collected data by walking quickly. In sample 2, the sudden small amplitude oscillation (0.4 sec to 1.5 sec) occurs because if the accelerometer is not securely attached to the body or device, it may not capture vibrations as effectively. The plot of sample-01 shows fewer oscillations than samples 02 and 03. Faster movement causes more oscillations as we have seen in sample-02,03.

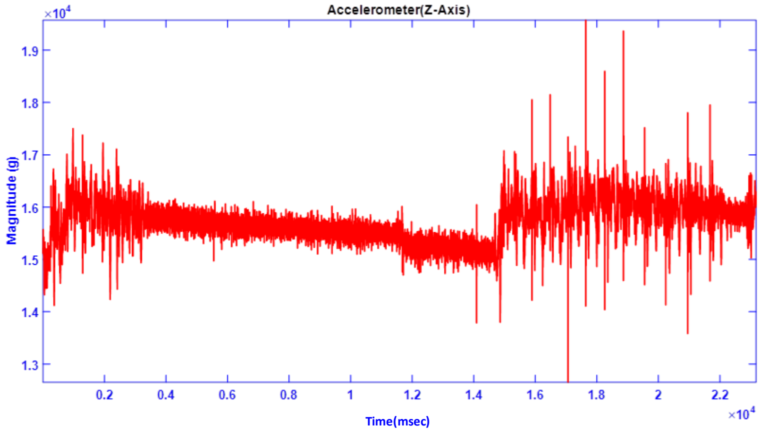
Here, we have tried to show all the samples of y axis in one plot to get a good overview comparison among the samples. We clearly see how magnitude and oscillation varies with the pace of walking among the sample we have taken from the sensor.

✓ ***Z-Axis***

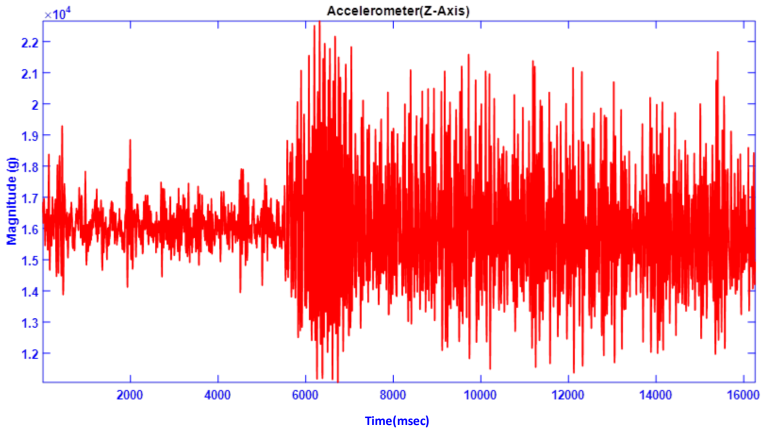
The data of z axis collected from accelerometer generally indicates vertical movement. Generally, the z axis data shows smaller peaks than x and y axis. But unlike x and y axis, z axis data is not directly related to walking pace. Though it shows a pattern. These small peaks represent the slight upward movement of the body during each footstep.



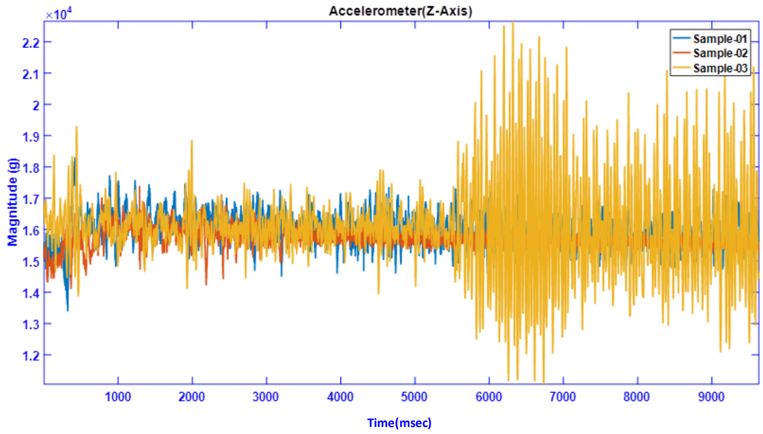
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.1.3: Walking Plot using Accelerometer Sensor (z-axis)

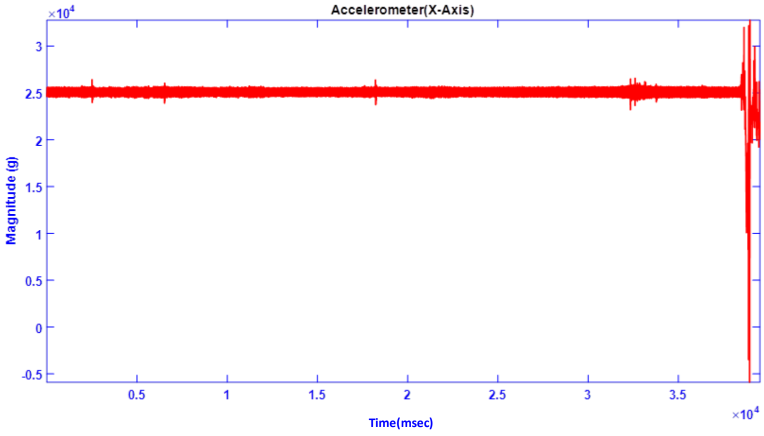
In sample-01, the data was taken from the sensor by walking slowly. But in sample-02 and 03 we have taken the data by walking fast. If we observe the plot of sample-01, we see less oscillations than sample-02,03. Faster walking leads to slightly higher peaks because of increased vertical bounce. The z axis data mainly focuses on capturing the subtle upward movement with each step, instead of walking pace.

❖ ***Lying***

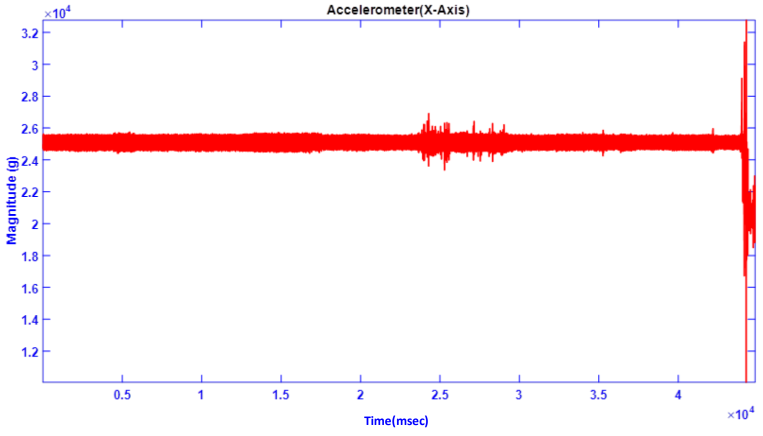
While lying down, the overall accelerations in the x, y, and z axes are much lower in magnitude compared to walking or moving. Because there is minimal movement when lying still. Unlike the walking data which shows repetitive peaks, the lying data does not show any significant pattern of peaks in any axis.

- ***X-Axis***

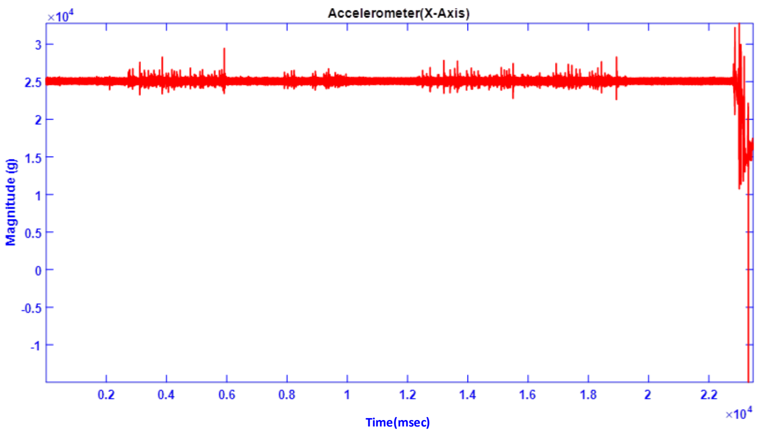
The collected data for the x-axis when someone is lying down shows very little variation, as there is not much motion occurring. During walking x axis shows distinct peaks due to foot strikes but lying down results in minimal to no significant peaks or valleys. While minor body adjustments or breathing may cause slight variations, the constant pull of gravity acting perpendicular to the body has the most influence on the x-axis data (assuming he/she lying flat on his/her back).Shifting positions while lying down, such as changing the side, can cause minor fluctuations in the x-axis data because the accelerometer experiences slight changes in orientation and acceleration or external factors like someone touching him/her or moving of bedsheets can create small, transient spikes in the x-axis data.



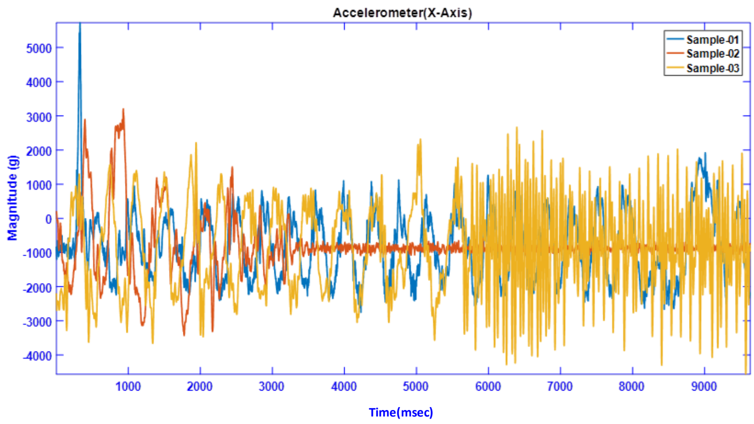
Sample-01



Sample-02



Sample-03



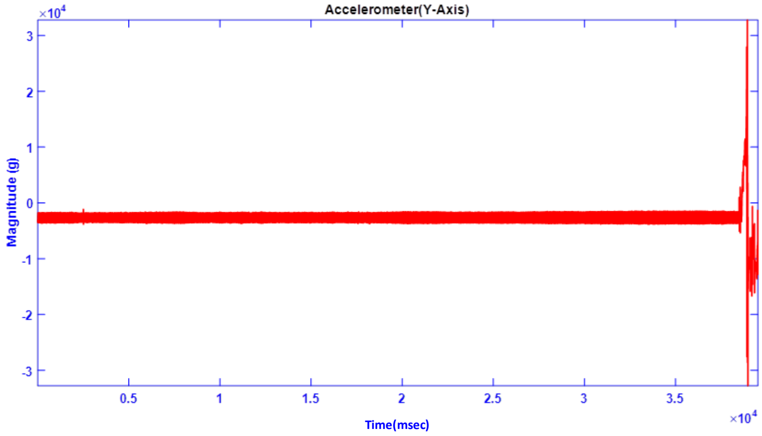
3 Samples Combined

Figure 2.2.1.1.4: Lying Plot Using Accelerometer Sensor (x-axis)

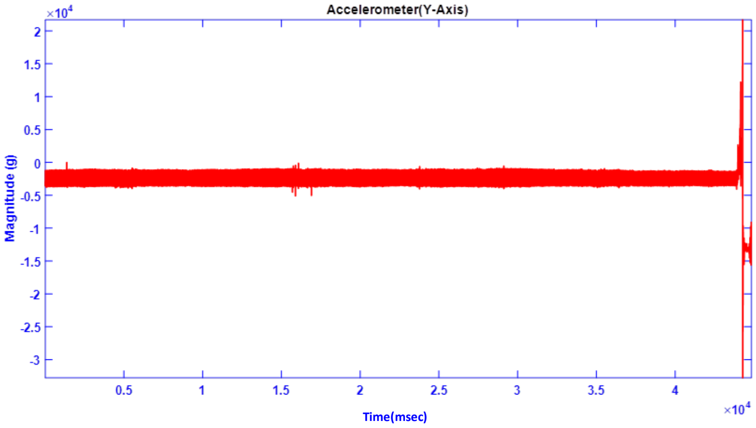
Here, three samples of x axis were taken by lying down on the bed. If we observe three samples closely, we will not find any different pattern in the data because during lying down there is no movement. But sometimes we can get small spikes like sample-01,02,03 which is because of changing sides or little movement of bedsheets. Here,three samples are combined in plot to get a good overview of the comparisons of the samples.But there is no significant pattern found here.

- ✓ ***Y-Axis***

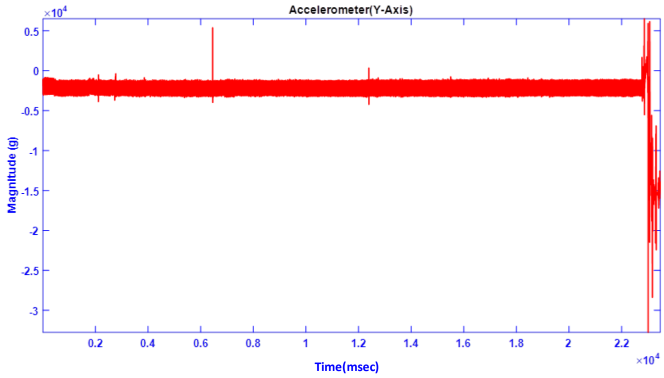
  Y axis data does not shows minimal to no significant peaks or valleys while lying still similar to x axis. Because there is minimal forward/backward movement during lying flat. Shifting positions while lying down, such as changing the side, can cause minor fluctuations in the y-axis data similar to the x axis data because the accelerometer experiences slight changes in orientation and acceleration or external factors like someone touching him/her or moving of bedsheets can create small, transient spikes in the x-axis data. As he/she lay on his/her side, the y-axis data may display a slightly positive or negative value, depending on which side he/she is on and how gravity has changed.



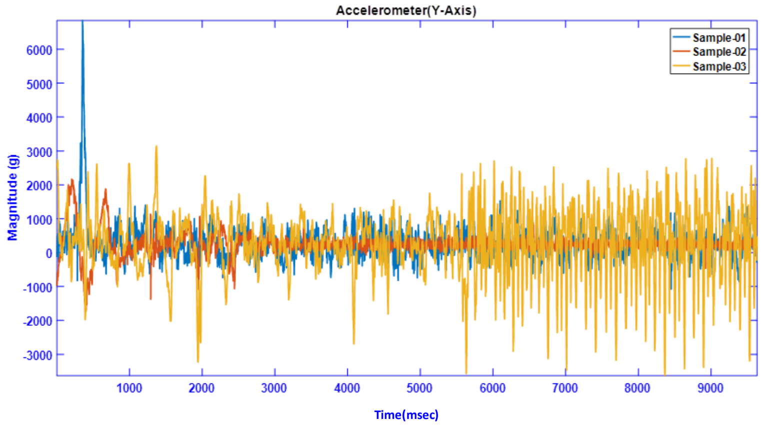
Sample-01



Sample-02



Sample-03



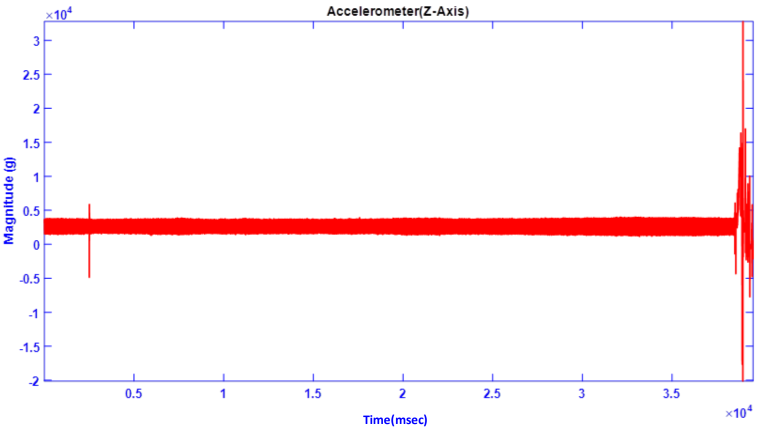
3 Samples Combined

Figure 2.2.1.1.5: Lying Plot Using Accelerometer Sensor (y-axis)

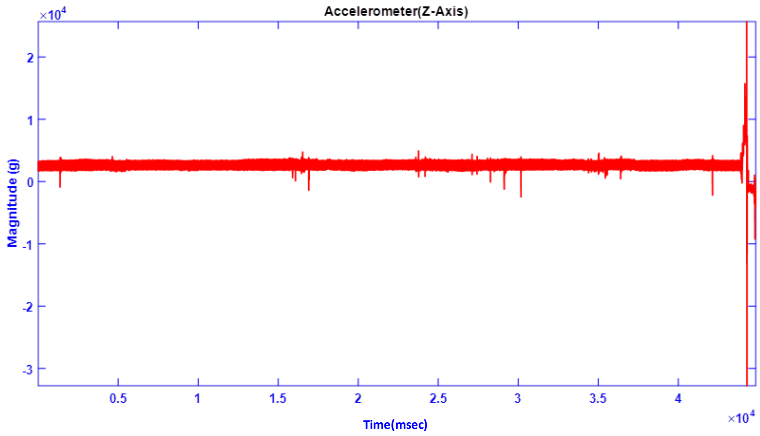
Three y-axis samples were taken while lying on the bed. Because there is no movement while lying down, observing three samples closely shows no different pattern in the data. However, we can sometimes see small spikes similar to samples 01, 02, and 03 as a result of changing sides or minor movement of bedsheets. Here, three samples are combined in plot to get a good overview of the comparisons of the samples. But there is no significant pattern found here.

- ✓ ***Z-Axis***

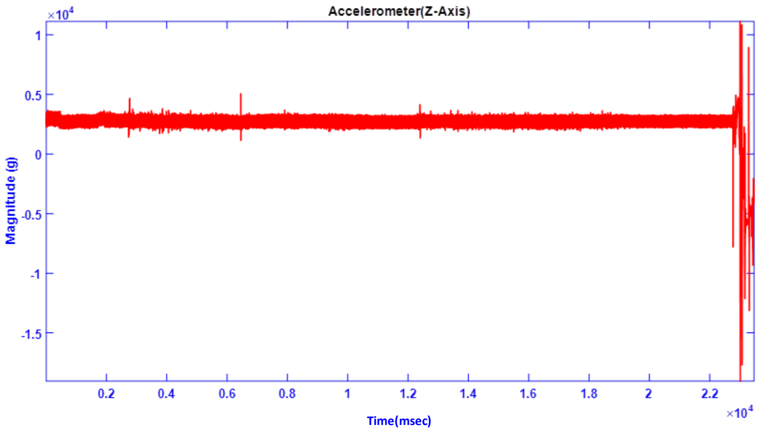
When lying flat, z axis data remain stable similar to both the Y-axis and X-axis data. However, changing positions, such as turning into other side, may lead to slight fluctuations in both z axis data. These fluctuations can occur due to subtle shifts in orientation and acceleration of the accelerometer or external factors like physical contact or movement of bedsheet. The z-axis typically shows a constant negative value with occasional small fluctuations due to the constant pull of gravity while lying flat.



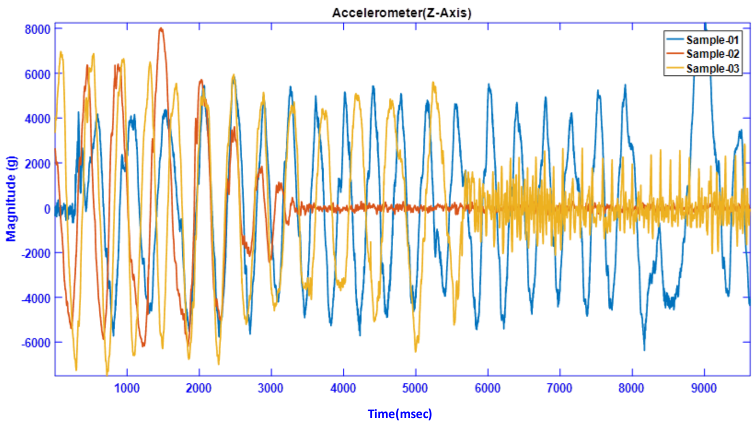
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.1.6: Lying Plot Using Accelerometer Sensor (z-axis)

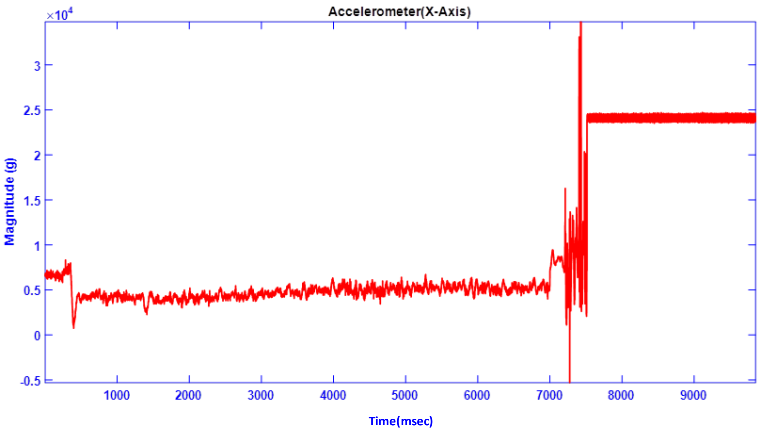
Three z-axis samples were taken by lying on the bed. But we do not find any different pattern in the data if we closely examine three samples because there is no movement while lying down. However, we sometimes observe small spikes like samples-01,02,03 as a result of changing sides or slight movement of the bedsheets. Here, three samples are combined in plot to get a good overview of the comparisons of the samples. But there is no significant pattern found here.

❖ ***Fall Detection***

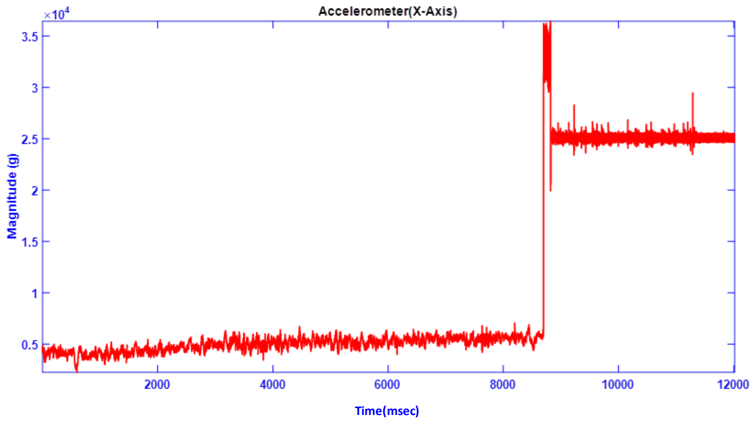
Fall is characterized by a sudden and significant change or increase in the overall magnitude of acceleration across all three axes (x, y, and z). This sharp rise of magnitude reflects the rapid acceleration experienced by the body during the fall. If the person remains lying on the ground after the fall, the data will likely return to a pattern similar to lying down, with minimal fluctuations around a constant value in each axis. But if the person tries to get up or move around, the data will exhibit patterns associated with those activities. We will see smaller peaks in the x and y axes and variations in the z-axis depending on body orientation.

✓ ***X-Axis***

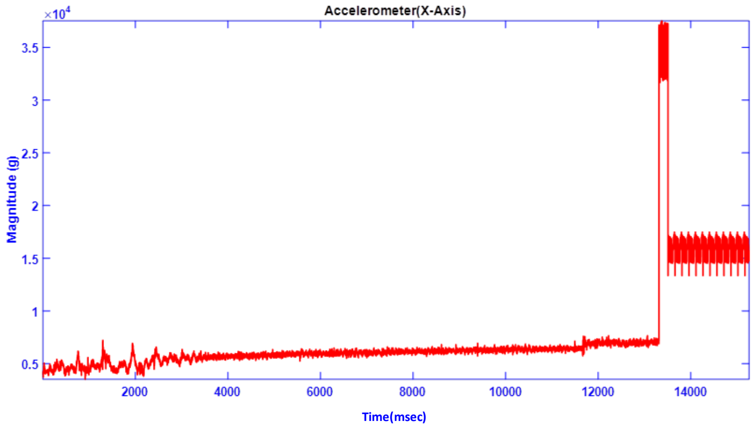
During a fall, the x-axis data will show a sudden and significant increase in magnitude compared to typical lying or walking data patterns. This sharp rise reflects the rapid change in horizontal acceleration experienced by the body as it experienced a fall. Depending on the direction of the fall, the x-axis might show a different peak. This peak represents the moment when the body hit the ground with a horizontal component of force. If the fall is in a forward direction, the x-axis will show a negative peak as the body rapidly decelerates in the forward direction. But a backward fall will result a positive peak on the x-axis due to the sudden acceleration in the backward direction. The x-axis data will return to a constant value close to 0 if the person lie down after the fall.



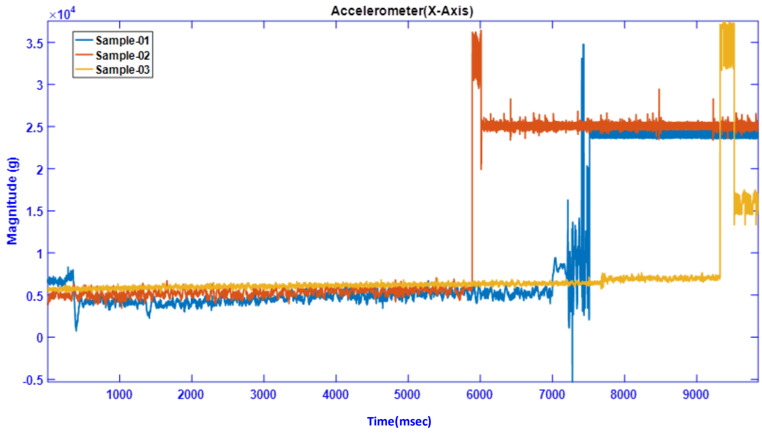
Sample-01



Sample-02



Sample-03



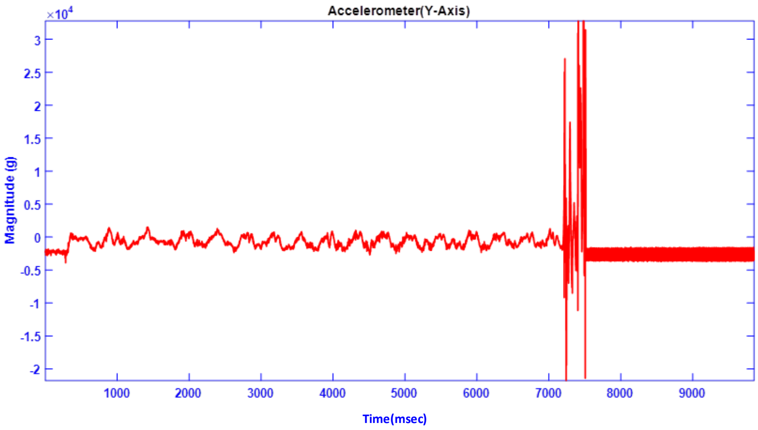
3 Samples Combined

Figure 2.2.1.1.7: Fall Detecting using Accelerometer Sensor (x-axis)

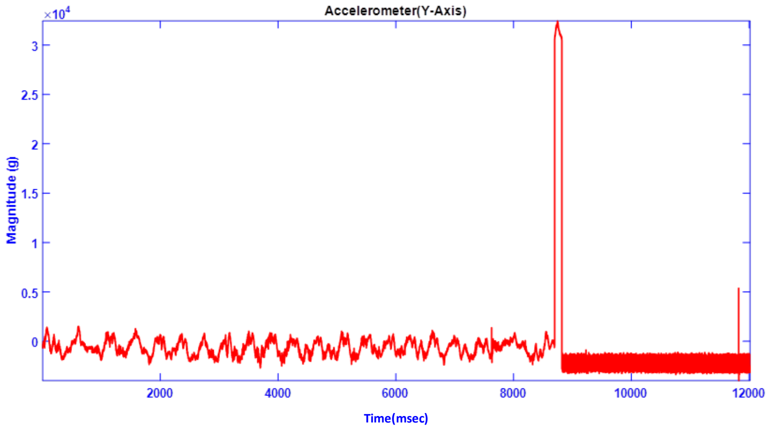
If we closely observe the three samples, we can see sudden increase of magnitude in each sample. Initially the data shows a normal pattern which looks like constant but suddenly it rose too high which is caused by sudden change of acceleration and it stayed for a very short time and going back to normal pattern. The sharp rise of magnitude of certain can be considered as the moment of fall. The combined plot of three samples shows a good overview of the comparison. Here, three samples were taken in three different places in a certain period. And we tried to show how magnitude and time varies with change of pace in three samples.

- ✓ ***Y-Axis***

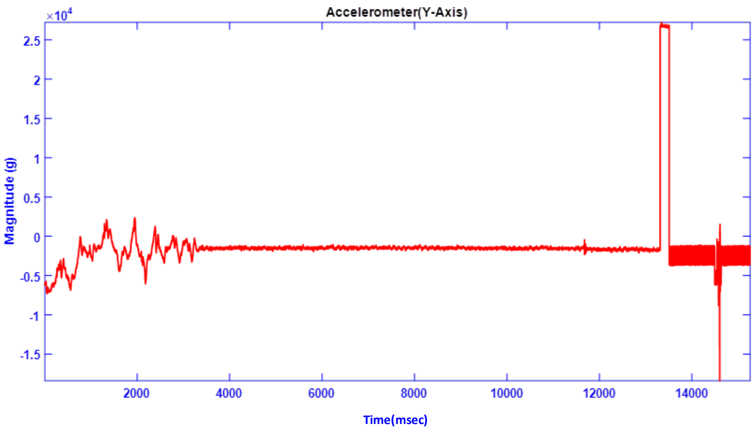
The y-axis data will show a sudden and significant increase in magnitude compared to typical lying or walking data patterns now of fall. This sharp rise reflects the rapid change in forward/backward acceleration experienced by the body now of fall. The y-axis data shows a prominent peak representing the moment of hitting the ground. This peak will be significantly higher than any peak observed during walking or lying down. Depending on the direction of the fall, the x-axis might show a different peak. If the fall is in forward direction, the y-axis data will show a positive peak as the body rapidly accelerates in the forward direction. But a backward fall will result in a negative peak on the y-axis due to the sudden deceleration in the backward direction.



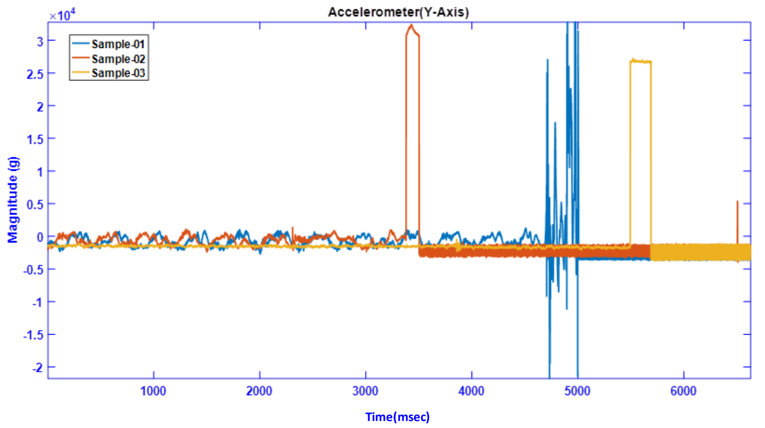
Sample-01



Sample-02



Sample-03



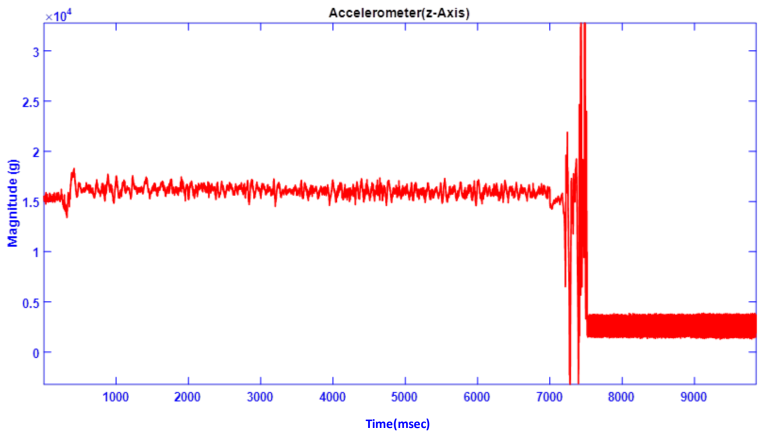
3 Samples Combined

Figure 2.2.1.1.8: Fall Detecting using Accelerometer Sensor (y-axis)

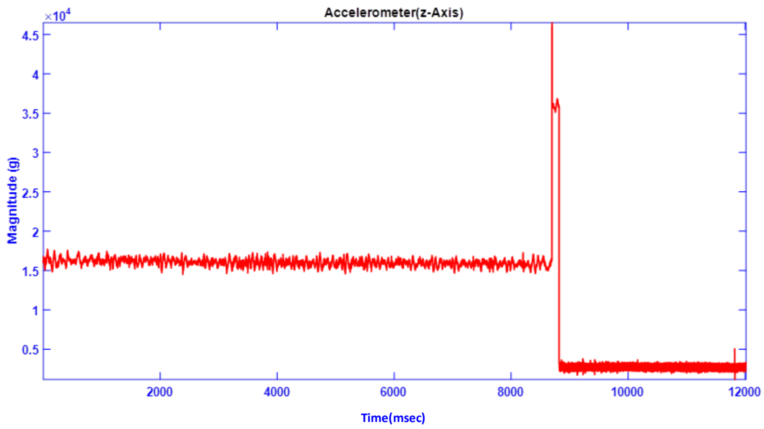
After analyzing the three samples, we can see sudden increase of magnitude in each sample. Initially the data shows a normal pattern which looks like constant but suddenly it rose too high which is caused by sudden change of acceleration and it stayed for a very short time and going back to normal pattern. The y-axis data returned to constant value close to 0 as the person lying down after the fall. The sharp rise of magnitude of certain can be considered as the moment of fall. The combined plot of three samples shows a good overview of the comparison. Here, three samples were taken in three different places in a certain period of time. And we tried to show how magnitude and time varies with change of pace in three samples.

✓ ***Z-Axis***

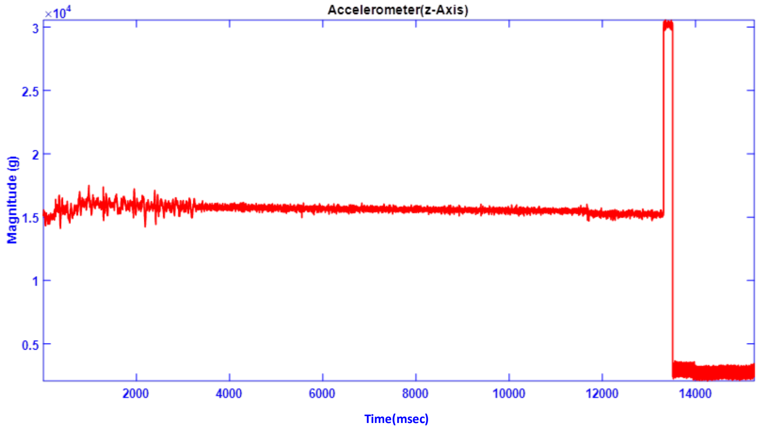
The z-axis data will show a sudden and significant decrease in magnitude compared to typical lying or walking data patterns at the moment of fall. This decrease occurs because of the primary acceleration experienced during a fall in the direction of gravity, which aligns with the z-axis. The z-axis may show a transient positive peak at the moment of hitting the ground. This peak reflects the moment when the body experiences an upward acceleration force just before coming to a complete stop. After the initial decrease and potential peak, the z-axis data pattern might return to a constant negative value close to -1g, similar pattern of lying down. This signifies that the body is again at rest due to gravity.



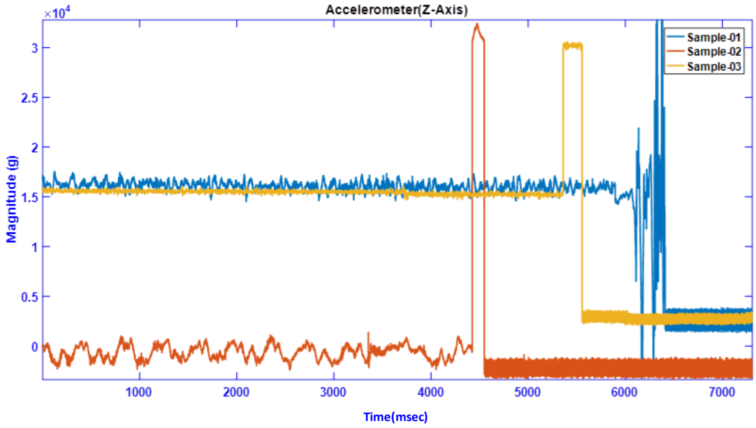
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.1.9: Fall Detecting using Accelerometer Sensor (z-axis)

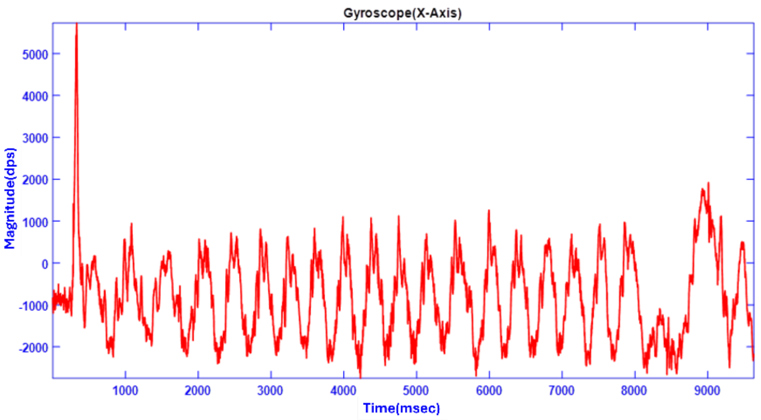
If we take a good look over three samples, we can see sudden increase and decrease of magnitude in each sample. Initially the data shows a normal pattern which looks like constant but suddenly it rose too high which is caused by sudden change of acceleration and it stayed for a very short time. The z-axis data returned to constant value close to 0 as the person lying down after the fall. The sharp rise of magnitude of certain can be considered as the moment of fall. The combined plot of three samples shows a good overview of the comparison. Here, three samples were taken in three different places in a certain period. And we tried to show how magnitude and time varies with change of pace in three samples.

2.2.1.2 GYROSCOPE SENSOR BASED FALL DETECTION SYSTEM

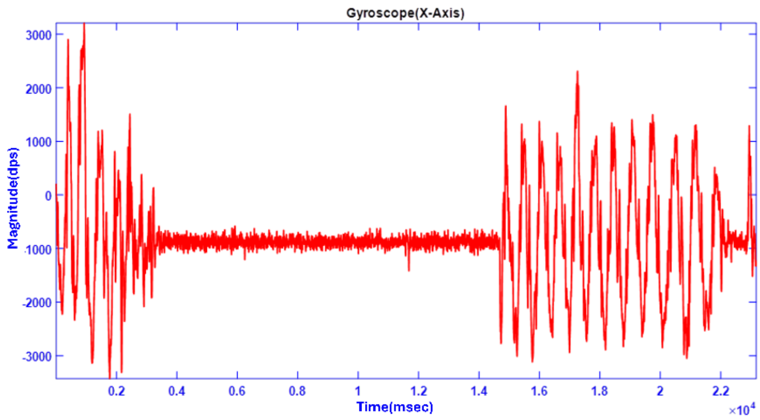
In a gyroscope, detecting a fall typically involves monitoring sudden changes in orientation or angular velocity that indicate a rapid descent or impact. The gyroscope comprises four proof masses (It serves as the movable element within the device, whose displacement or movement is measured to determine changes in orientation or acceleration) that undergo continuous oscillating motion. When subjected to angular motion, the Coriolis Effect alters the capacitance between the masses along the relevant axis (X, Y, Z). This capacitance change is detected and translated into a measurable output. Gyroscope sensors measure angular velocity along three axes: x, y, and z. Each axis corresponds to a specific direction in three-dimensional space. We can collect data from the 3 axes (X, Y, Z) of the gyroscope to know about the information of activity like walking or lying and if there is any fall or not.

- ***Walking***
  - ***X-Axis***

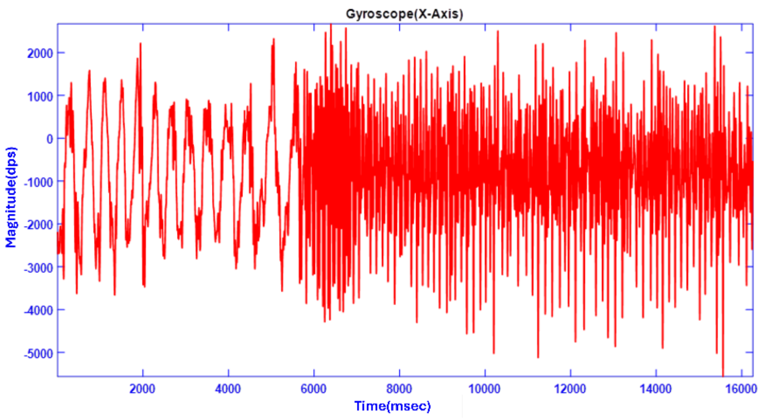
When walking, the X-axis of the gyroscope can detect the subtle tilting motion of the device as our body moves forward with each step. Our body swings slightly forward and backward while we walk. These pitch revolutions are measured by the gyroscope; forward movement is indicated by positive values, while backward movement is indicated by negative values.



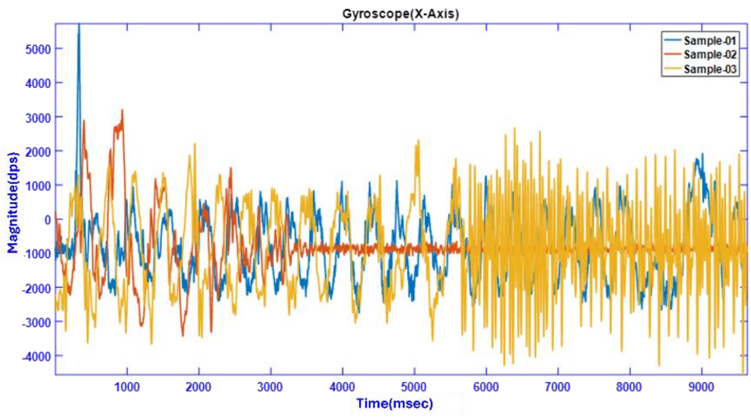
Sample-01



Sample-02



Sample-03



3 Samples Combined

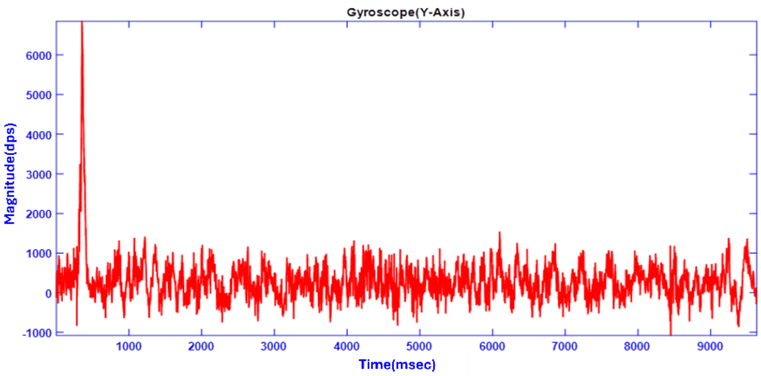
Figure 2.2.1.2.1: Walking Plot using Gyroscope Sensor (x-axis)

Sample-01, the data was taken by walking slowly. We can see from the plot that there is a large spike at the start of sample 1 when the foot hits the ground. In the X axis, positive value indicates forward movement and negative value indicates backward movement. In sample 2, there are sudden small oscillations because if the person walking becomes fatigued, their movements might become more controlled and less jerky, resulting in smaller rotational amplitudes. The gyroscope sensor may register slight fluctuations in angular velocity as each foot alternately makes contact with the ground. In sample 1, slow walking would show relatively low and smooth fluctuations. Here sample 2 for normal walking and sample 3 for faster walking. In sample 2, these modifications are seen by the gyroscope sensor as larger oscillations in angular velocity along the X-axis, which correspond to the body's rhythmic motion as it advances with each stride. But in sample 3 when running, the gyroscope sensor detects sharp and quick changes in angular velocity along the X-axis, which indicates the increased force and effect of running on the body's orientation. By looking at the samples, we can understand the activity during walking by looking at the plot.

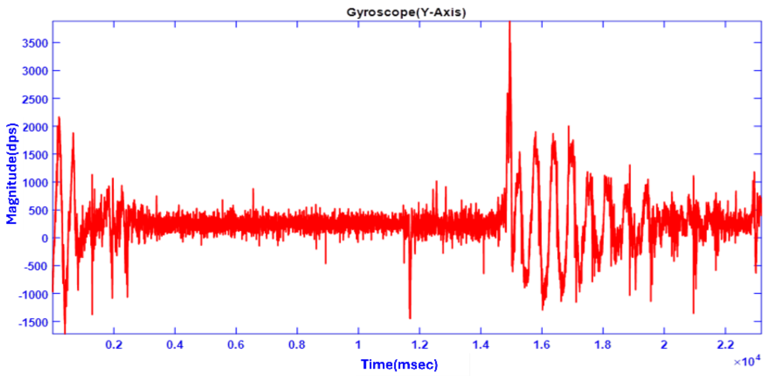
In order to provide a clear overview and comparison of the samples, we have attempted to display all of the x axis samples in a single plot. In the all plot, we'd see fluctuations in angular velocity over time for each activity. Slow walking would show relatively low and smooth fluctuations, normal walking would display moderate fluctuations, and running would exhibit rapid and pronounced fluctuations. This plot shows how the X-axis angular velocity changes over different activities, giving insight into the rotational motion of the body while walking slowly, walking normally, and running.

- ***Y-Axis***

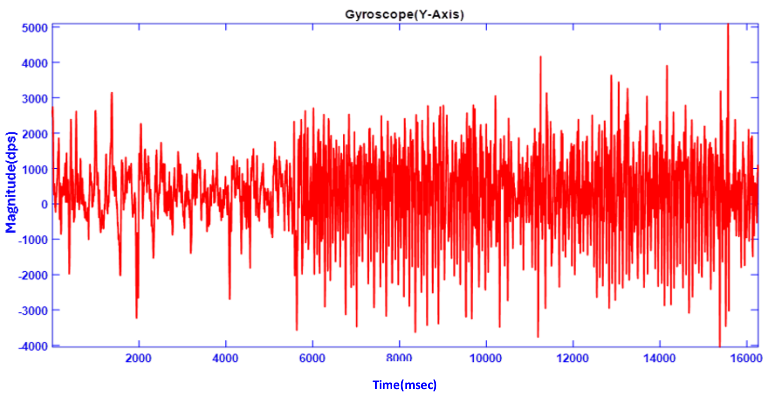
The Y-axis of the gyroscope can detect changes in direction as we turn while walking. The gyroscope detects the rate of rotation around the Y-axis as we change directions while walking, such as turning left or right, and provides information on the turn's direction.



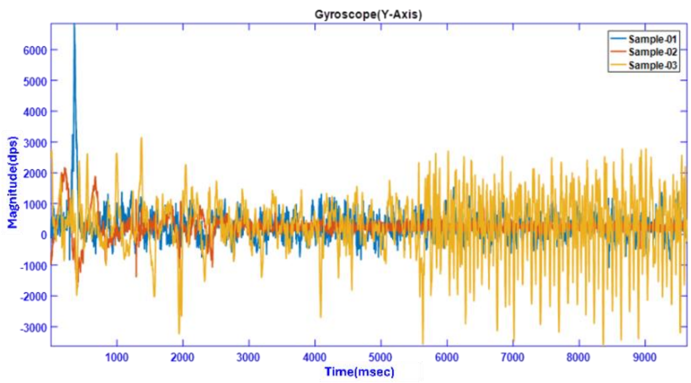
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.2.2: Walking Plot using Gyroscope Sensor (y-axis) **17**

Sample-01, we walked slowly to get the data. From the plot, we can see that there is a big peak at the beginning of Sample 1 when the foot touches the ground. In the Y-axis, we change directions while walking, such as turning left or right, and provide information on the turn's direction. Here positive and negative values indicate.

Turn the body in the left and right directions. In sample 1, it registers small fluctuations in angular velocity as each foot contacts the ground, but these changes are not as pronounced as during faster activities. Here sample 2 for normal walking and sample 3 for faster walking. In sample 2, as speed increases body movements become more dynamic, resulting in greater weight and momentum changes in the vertical plane. The gyro sensor detects these changes as more significant oscillations in angular velocity along the Y axis. But in sample 3, running involves a more forceful propulsion phase, resulting in larger accelerations and decelerations in the vertical plane. The gyroscope sensor registers rapid and substantial fluctuations in angular velocity along the Y-axis during running. By looking at the samples, we can understand the activity during walking by looking at the plot.

To provide a clear overview and sample comparison, we tried to show all Y-axis samples on a single plot. In all samples plot, we would see the changes in angular velocity of each function over time. It detects the rate of rotation around the Y-axis as we change directions while walking, such as turning left or right, and provides information on the turn's direction. We can clearly see how the magnitudes and oscillation of the sensor varies with walking speed.

- ***Z-Axis***

While walking, the Z-axis of the gyroscope may not provide significant data since walking typically involves minimal side-to-side tilting motion. On the other hand, the gyroscope can pick up on any lateral motions or faint swaying motions that occur while wandering around the Z-axis.

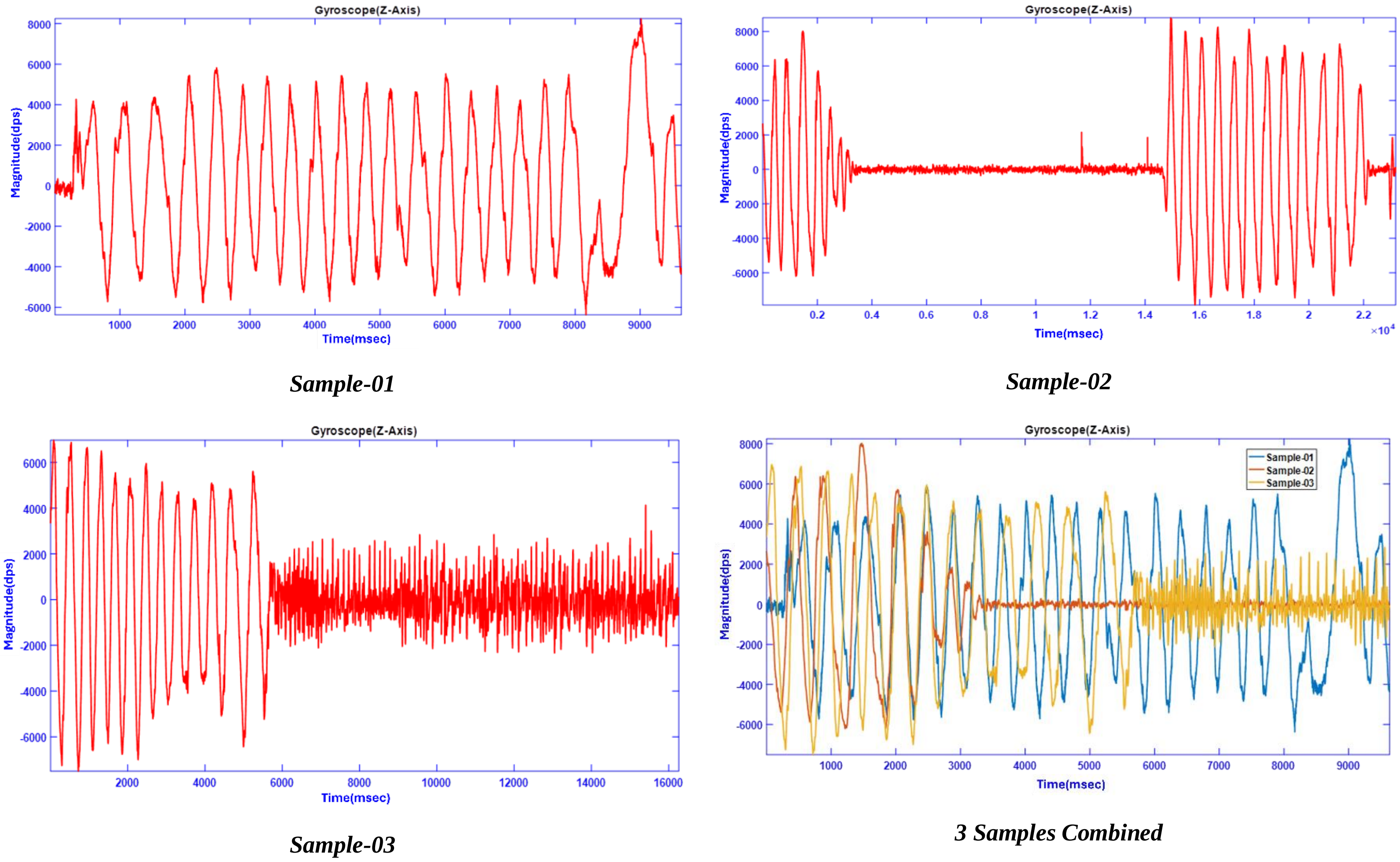


Figure 2.2.1.2.3: Walking Plot using Gyroscope Sensor (z-axis)

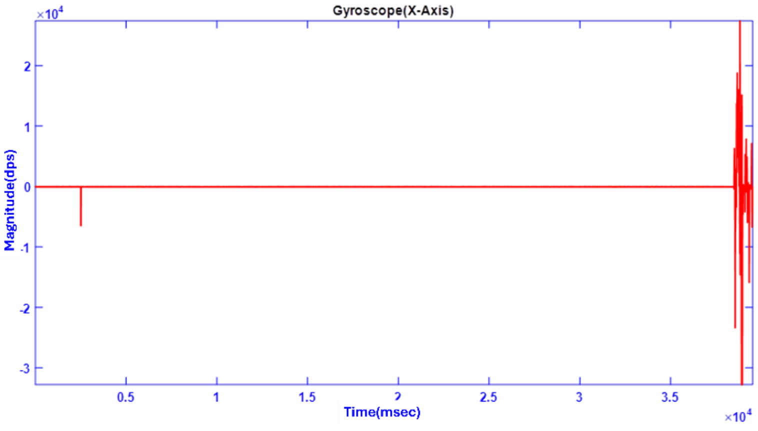
Here Sample-01, we walked slowly to get the data. And in sample 2 for normal walking and sample 3 for faster walking. In gyroscope can pick up on any lateral motions or faint swaying motions that occur while wandering around the Z-axis. In sample 1, we can see that during slow walking the gyroscope sensor usually registers relatively small and gradual changes in the Z axis. This is because slow walking requires minimal vertical movement, keeping the body in a relatively stable position. The gyroscope can detect the small fluctuations caused by the natural oscillation of the body with each step. Then in sample 2 and 3 we can see the greater variations of these 2 samples because of normal walking and running. Because the gyroscope sensor would detect more pronounced changes in the Z-axis compared to slow walking. Also, in running condition it involves significant vertical movement with each stride, resulting in rapid and relatively large changes in the Z-axis as the body bounces up and down. So, we can understand the walking activities of Z axis in this way.

To provide a clear overview and sample comparison, we tried to show all Z-axis samples on a single plot. In all samples plot, we would see the changes in angular velocity of each function over time in Z-axis. We can see that sample 1 shows relatively small and gradual changes in the angular velocity of the Z axis, indicating a slight swaying of the body with each step during slow walking. But in samples 2 and 3 we can see that there are more oscillations. The plot will show some highest peaks and troughs, with sharp and abrupt changes in angular velocity along the Z-axis due to the intense bouncing motion during running. This can help in understanding how the gyroscope sensor responds to variations in movement intensity and identifying characteristic signatures for each activity.

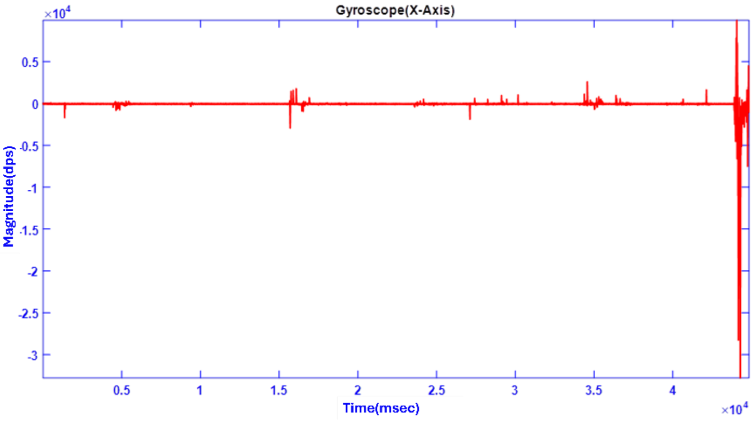
❖ *Lying*

- ***X-Axis***

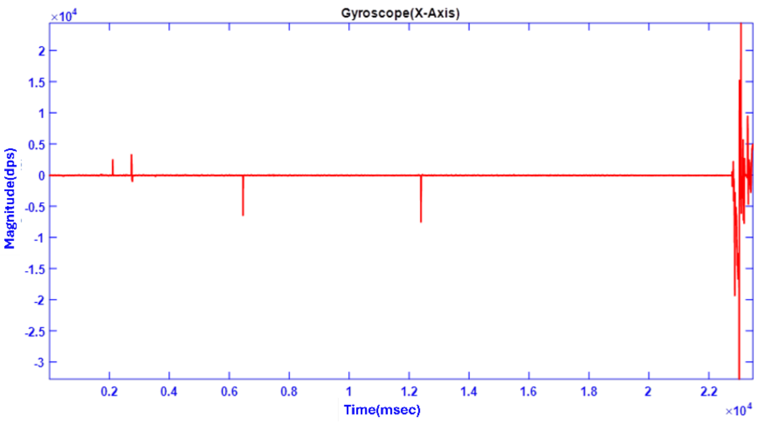
When a person is lying down, the gyroscope sensor detects changes especially in the X-axis (horizontal axis) when the body orientation changes from vertical to horizontal. In the lying position, the gyroscope sensor stabilizes and records a uniform direction along the X-axis. In this position, the direction of the X-axis remains relatively unchanged unless the person makes further movements or adjustments.



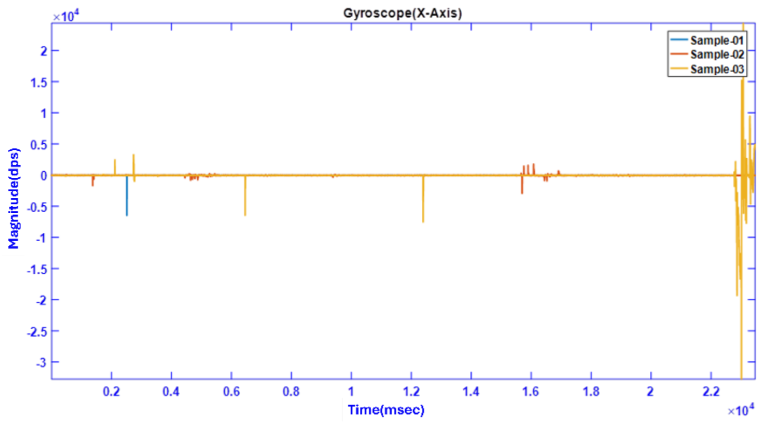
Sample-01



Sample-02



Sample-03



3 Samples Combined

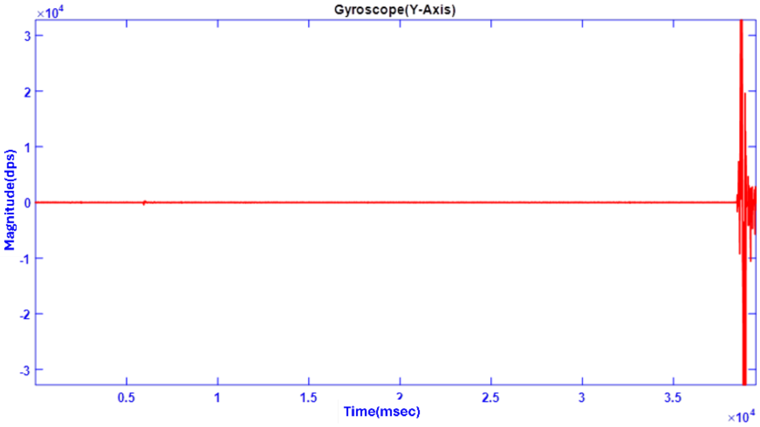
Figure 2.2.1.2.4: Lying Plot using Gyroscope Sensor (x-axis)

In sample 1,2 and 3, we can see that from 3 sample plots that no change is detected by the gyroscope sensor when the human is lying down. In sample 2, the light spikes may have been caused by the sensor trembling. In a gyroscope sensor, the X axis can detect orientation from vertical to horizontal. But we can see from the plots that there is a spike towards the last part in 3 samples plots because of body movement or adjustment.

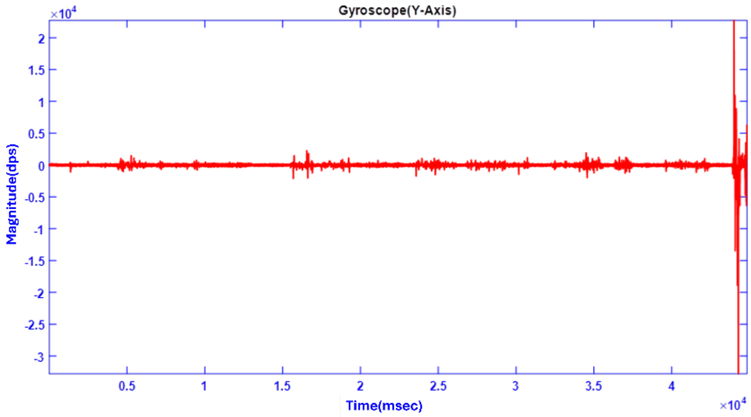
By plotting the data from the gyroscope sensor on the same plot, it can show a better view of every sample. We can see that the data of the 3 samples are similar in this plot. In all samples, when lying down the plot will initially display rather consistent data points that represent the baseline X-axis orientation. If there's movement while lying down (such as rolling over), the plot may show variations and spikes.

- ***Y-Axis***

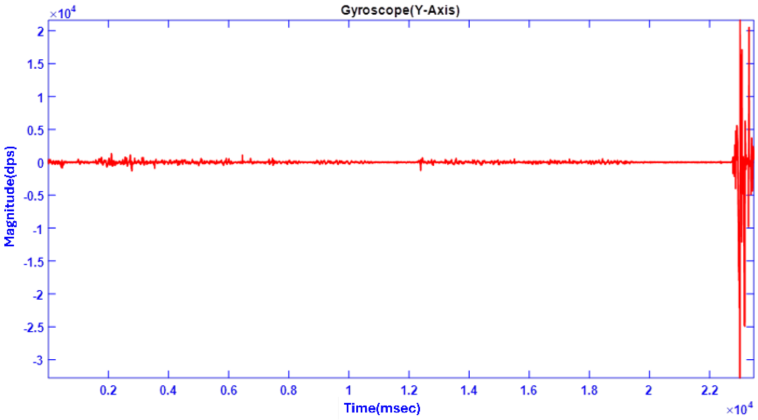
In the laying down position, the gyroscope sensor typically registers minimal changes along the Y-axis. Because the Y-axis orientation of the body remains relatively constant during this operation. When a person is lying down, the main changes detected by the gyro sensor are usually in the X-axis (horizontal) and Z-axis (vertical), reflecting the transition from vertical to horizontal. However, the direction of the y-axis, which represents lateral movement, remains relatively stable while lying down.



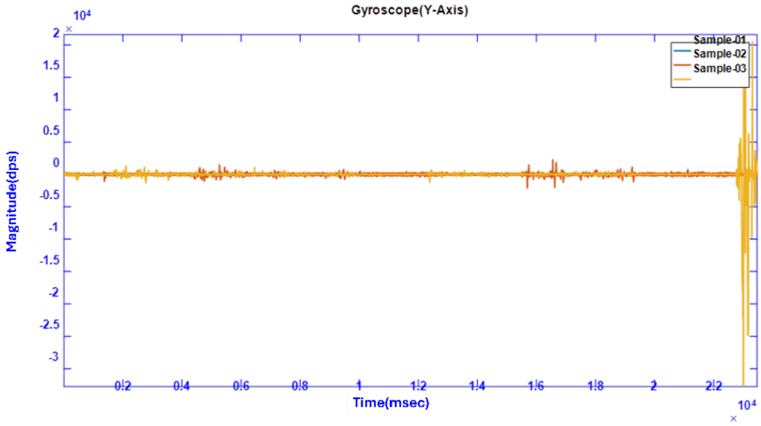
Sample-01



Sample-02



Sample-03



3 Samples Combined

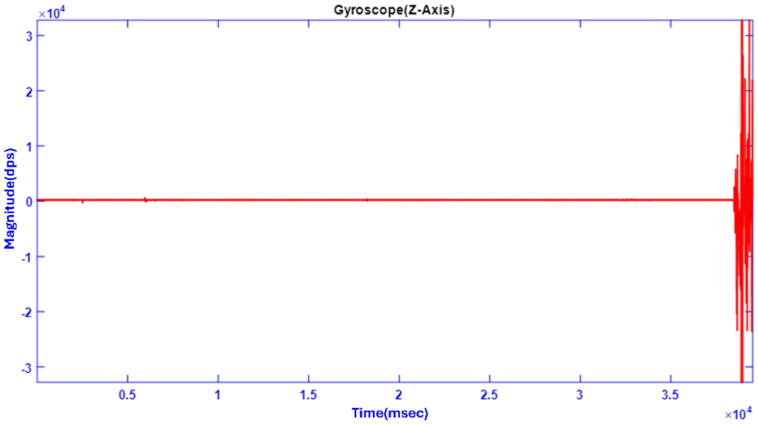
Figure 2.2.1.2.5: Lying Plot using Gyroscope Sensor (y-axis)

In samples 1,2 and 3 we can see that from 3 sample plots that no alteration is recognized by the gyroscope sensor when the human is lying down. In its default position, the gyroscope sensor's Y-axis is ordinarily adjusted with vertical movement, meaning it identifies changes within the device's vertical orientation. When the Y-axis lies down, it implies the sensor is situated on an orientation plane relative to the ground. In sample 2 and 3, we can see there is little oscillation. But we can see from the plots that there is a spike towards the last part in 3 samples plots because of body movement or adjustment.

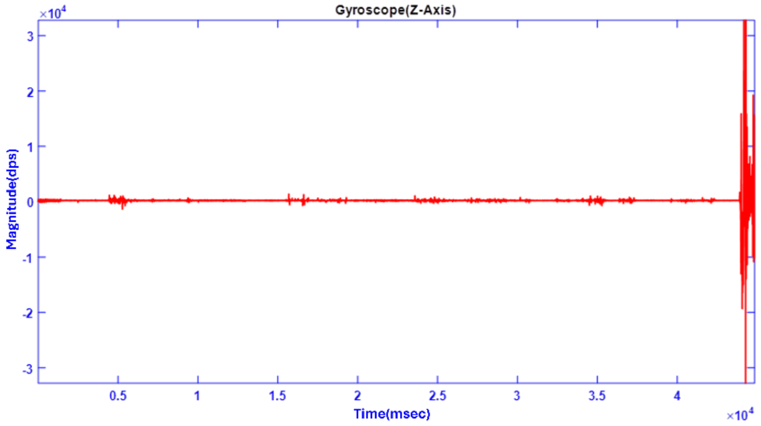
By plotting the data from the gyroscope sensor on the same plot, it can show a better view of every sample. We can see that the data of the 3 samples are similar in this plot. In all samples, when lying down the plot will initially display rather consistent data points that represent the baseline Y-axis orientation. If there's movement while lying down (such as rolling over), the plot may show variations and spikes which occur at the last part of the plot.

- ***Z-Axis***

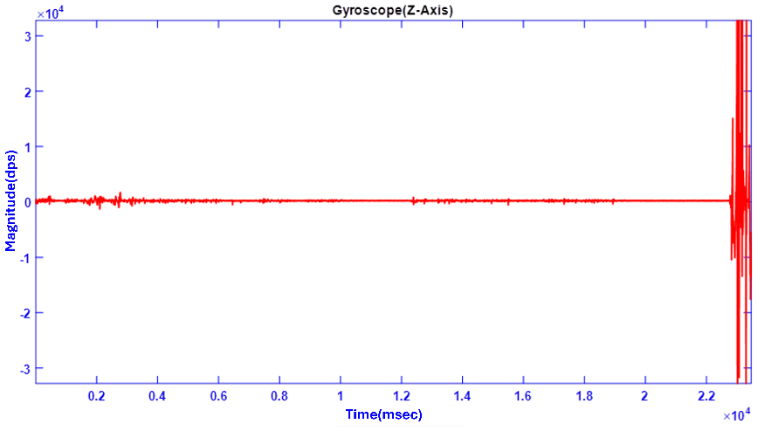
When a person is lying down, the gyro sensor can detect changes mainly in the Z axis (vertical axis) when the orientation of the body changes from vertical to horizontal. When the person is completely lying down, the gyro sensor stabilizes and registers a constant direction along the Z axis. In this position, the direction of the Z-axis remains relatively unchanged unless the person makes further movements or adjustments.



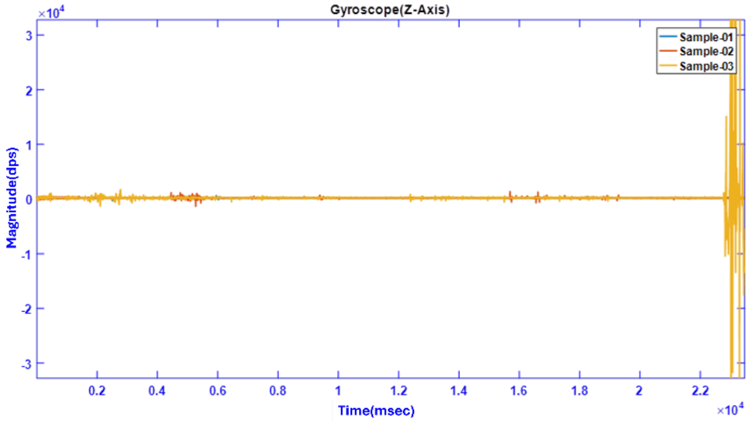
Sample-01



Sample-02



Sample-03



3 Samples Combined

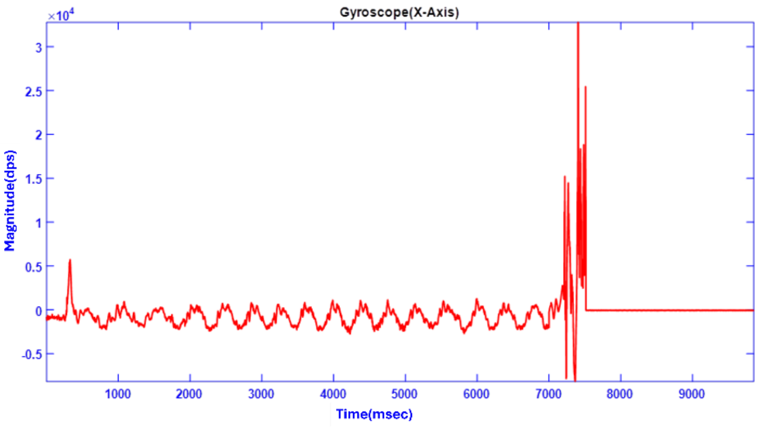
Figure 2.2.1.2.6: Lying Plot using Gyroscope Sensor (z-axis)

If the Z-axis of the gyroscope sensor is horizontal, it indicates that the sensor is horizontal to the ground and its Z-axis is parallel to the base plate. In samples 1, 2 and 3, we see that 3 of the sample curves do not detect a change in the gyroscope sensor when the person is lying down. In samples 2 and 3 we can see that there is little vibration. However, we can see from the graphs that the three samples' graphs are sharp spike towards the last part due to body movement or adjustment.

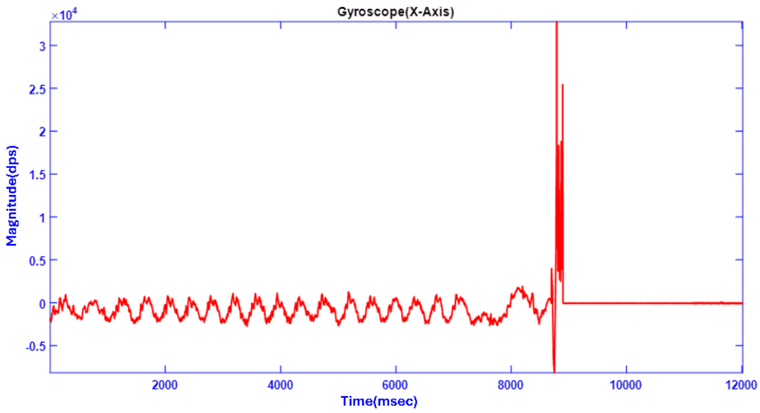
By plotting the gyro sensor data on the same graph, it can show a better picture of each sample. We can see that the data for the three samples are similar in this plot. For all samples in the lying down position, the plot initially shows consistent data points representing the Z-axis orientation of the baseline. If there is movement while lying down, the curve may show fluctuations and spikes that occur in the latter part of the plot.

- ***Fall Detection***
  - ***X-Axis***

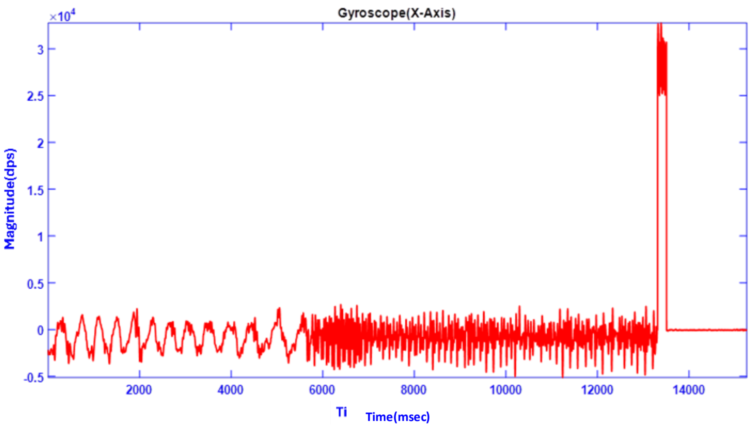
When falling, the gyro sensor can be a valuable sensor for detecting sudden changes in direction, including changes in the X-axis (horizontal axis). Initially, when a person walks, the gyroscope sensor records a relatively stable change along the X axis. When a person begins to fall, the direction of the X-axis changes rapidly and sudden spikes occur in the plot. This change represents the transition from a walking position to a falling position, where the body moves from an upright position to a horizontal or inclined position.



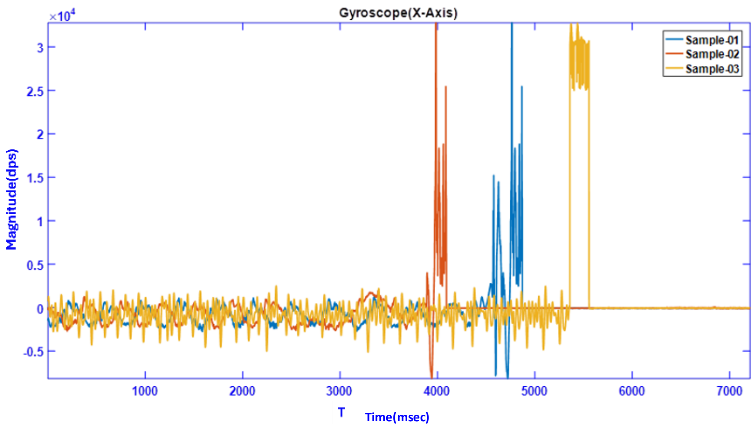
Sample-01



Sample-02



Sample-03



3 Samples Combined

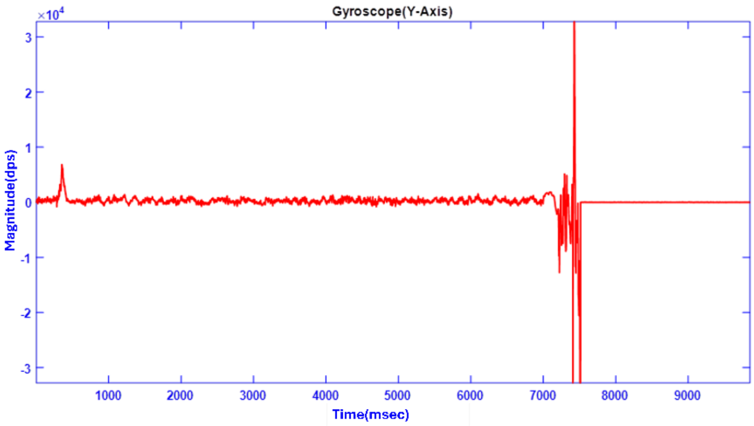
Figure 2.2.1.2.7: Fall Detecting using Gyroscope Sensor (x-axis)

Sample-01, the data was taken by walking slowly to fall. Here sample 2 for normal walking to fall and sample 3 for faster walking to fall. Forward motion is indicated by positive values on the X axis, while reverse movement is shown by negative values. We can see from the 3 samples; The baseline X-axis orientation of the walking subject will be represented by rather steady data points. For walking, no sudden changes or sudden spikes are seen here. When falls occur, in sample 1, 2 and 3 the graph shows a sudden spike or drop in the values of the angular velocity, indicating the moment when the person starts to fall. This dramatic change indicates a transition from walking to falling motion when the person's orientation changes from vertical to horizontal or inclined. So, we can understand when the person is falling by looking at these changes in the samples.

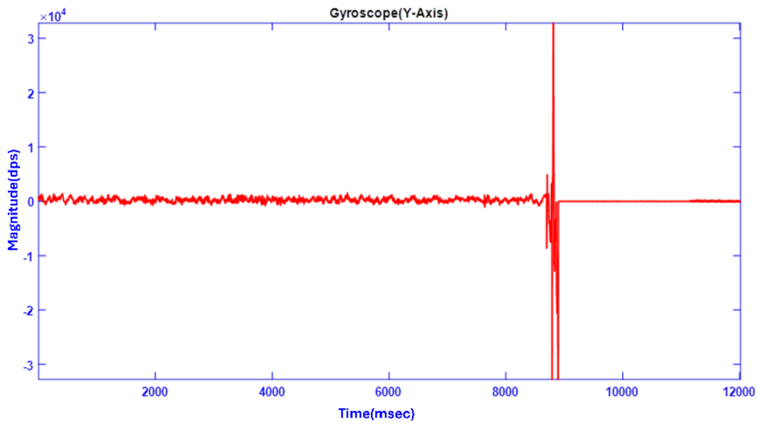
In a combined plot illustrating the transition from walking to falling using gyroscope sensor data along the X-axis. In the plot, when we are walking angular velocity values will remain consistent as the person maintains their upright position and forward movement. In the combined plot, since each of the 3 samples fell at different timings, the spikes appear at different timings. Here we see that there is no value on the negative side in sample 3, it means that it is a forward fall.

- ***Y-Axis***

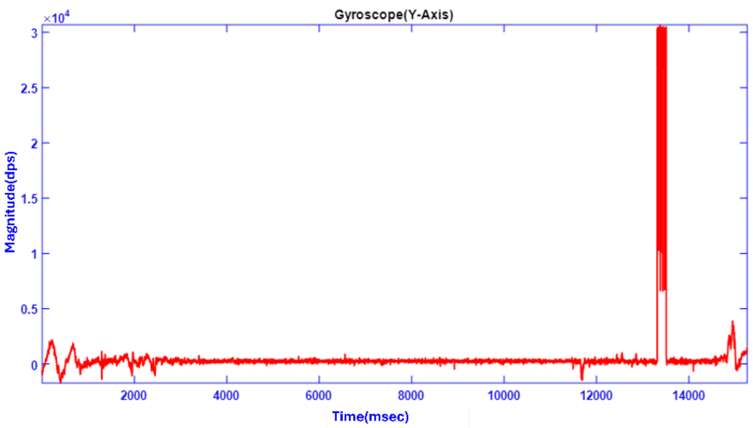
As a person moves from walking to falling to lying down, the gyroscope sensor can detect changes in direction along the Y axis (the horizontal axis perpendicular to the X axis), noting that change in motion. Initially, when a person walks, the gyroscope sensor records a relatively stable direction along the Y axis, which indicates the horizontal position of the body during movement. When the person is in the process of falling, there will be a rapid and significant change in orientation along the Y-axis. This change represents the transition from a walking stance to a falling position.



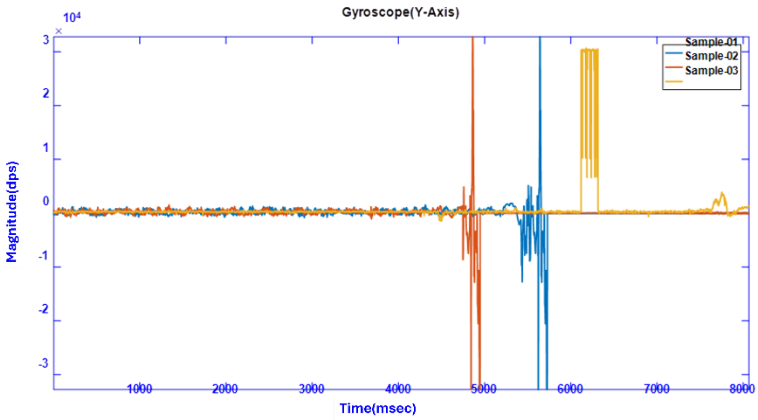
Sample-01



Sample-02



Sample-03



3 Samples Combined

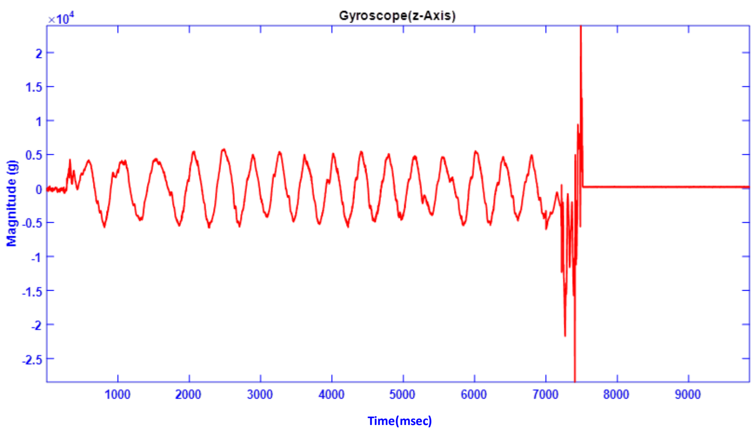
Figure 2.2.1.2.8: Fall Detecting using Gyroscope Sensor (y-axis)

On the y-axis, we change direction while walking, for example turn left or right, and provide information about the direction of the turn. Here, positive and negative values indicate turning the body left and right. In Sample 1, it registers small changes in angular speed when each foot touches the ground, but these changes are not as strong as for faster actions. Here is sample 2 for normal walking and sample 3 for faster walking. When a person begins to fall, there is a sudden and significant change and sudden spike in all samples in the direction along the Y axis. This change represents the transition from a horizontal walking position to a horizontal or prone position when a person falls. By monitoring changes in orientation along the Y-axis during the transition from walking to falling, the gyroscope sensor can provide valuable data for fall detection systems.

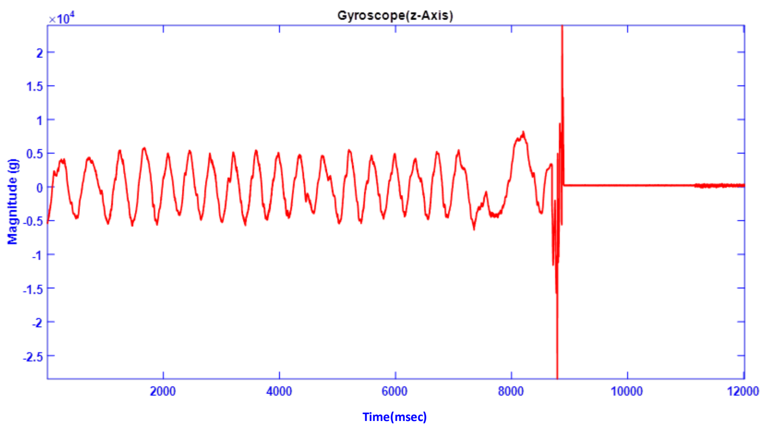
Combined graph illustrating the transition from walking to falling using data from the gyroscope sensor along the Y-axis. On the plot, the angular velocity values remain constant during walking, if the person maintains a left and right direction. Since all three samples fell at different times on the combined graph, spikes appear at different times. Here we see that there is no value on the negative side of sample 3, which means it indicates movement or rotation in the one direction on the forward side.

- ***Z-Axis***

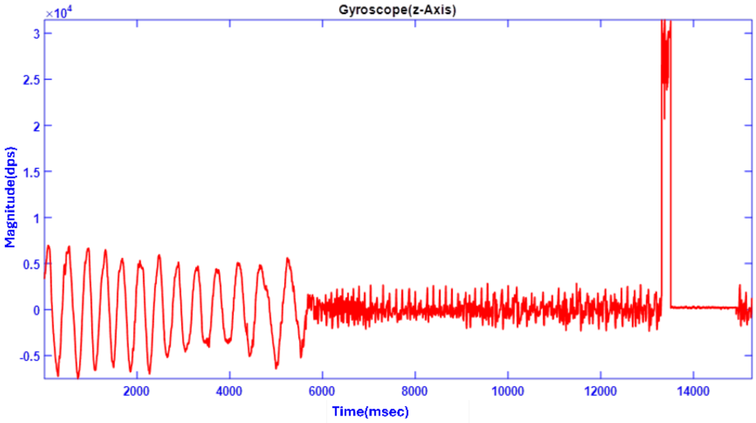
The gyroscope sensor can detect changes in orientation along the Z-axis (vertical axis) that signify this shift in movement. Initially, while the person is walking, the gyroscope sensor registers a relatively stable orientation along the Z-axis, indicating the vertical position of the body as they move. When a person begins to fall, there is a rapid and significant change in direction along the Z axis. This change represents the transition from a walking position to a falling position, where the body moves from an upright position to a horizontal or inclined position.



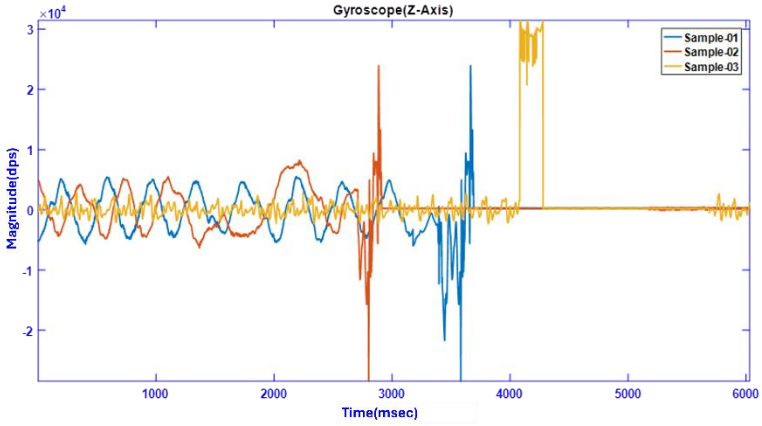
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.2.9: Fall Detecting using Gyroscope Sensor (z-axis)

In a gyroscope, it can detect any lateral movements or weak oscillatory movements caused by wandering around the Z axis. Sample 1 shows that during slow walking, the gyroscope sensor typically registers relatively small and gradual changes in the Z axis. This is because slow walking requires minimal vertical movement, which keeps the body in a relatively stable position. The gyroscope can detect small fluctuations due to the body's natural vibrations with each step. Then in samples 2 and 3 we see the larger variations of these two samples due to normal walking and running. Here in all plots, we see from 3 samples when walking to fall condition it shows a very large spike. And when the person was falling to lying down it shows there are no changes or no oscillations in the plot. So mainly this spike here represents that fall occurs.

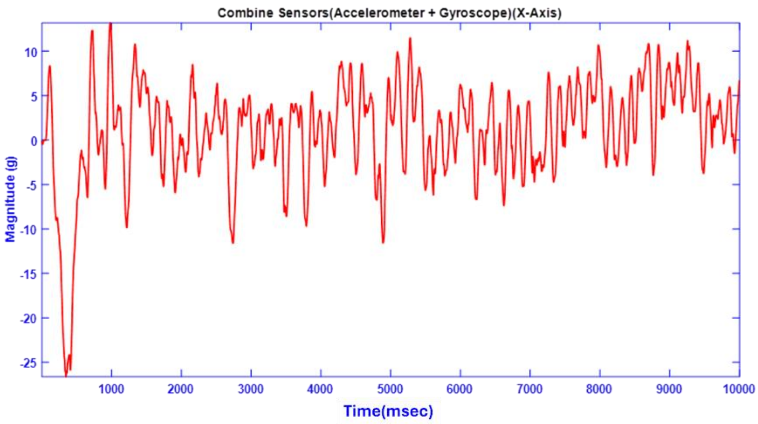
In a combined plot illustrating the transition from walking to falling using gyroscope sensor data along the Z-axis. While walking, the Z-axis is believed to have a uniform vibration pattern. This is because when he walks, his body naturally rocks back and forth to maintain balance. In the plot, when we are walking angular velocity values will remain consistent. In the combined plot, since each of the 3 samples fell at different timings, the spikes appear at different timings. As the person falls forward, the positive Z-axis rotation rate can rapidly increase, indicating a forward fall. Here we see that there is no value on the negative side in sample 3, it means that it is a forward fall.

2.2.1.3 Combined Sensor Based Fall Detection System

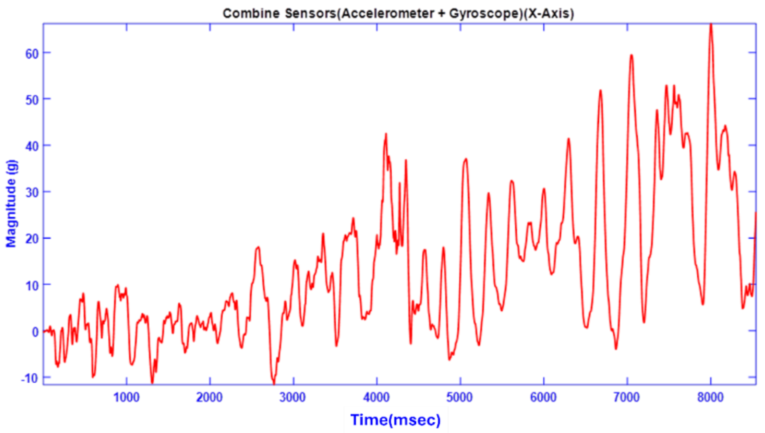
Combining accelerometer and gyroscope data using a complementary filter for a fall detection algorithm involves leveraging the strengths of both sensors to achieve accurate orientation and motion analysis. The accelerometer provides reliable low-frequency information, capturing static tilt due to gravity, while the gyroscope offers high-frequency data, detailing rapid rotational movements. The complementary filter fuses these signals by applying a low-pass filter to the accelerometer data and a high-pass filter to the gyroscope data, blending them in a way that minimizes their individual weaknesses. This fusion enhances the detection of falls by ensuring precise monitoring of abrupt changes in orientation and acceleration, typical characteristics of a fall event, thereby improving the reliability and responsiveness of the algorithm in distinguishing falls from normal activities.[22]

- ***Walking***
  - ***X-Axis***

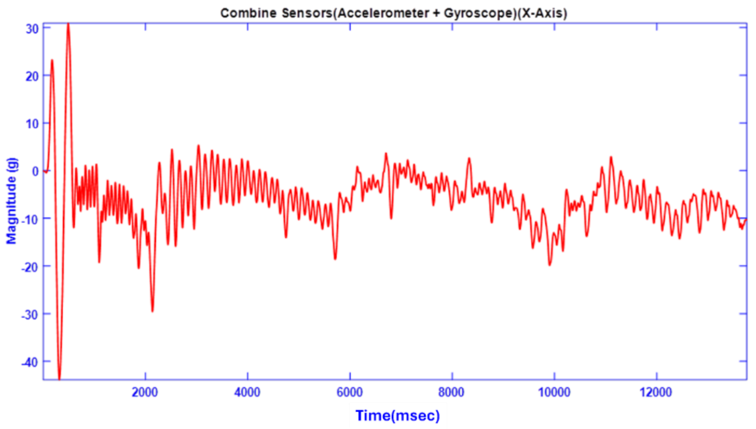
Three axes (x, y and z) are used by accelerometers to quantify linear acceleration. We will mainly use the x-axis acceleration data for walking detection along the x-axis. Pitch, roll, and yaw angular velocity are measured using a gyroscope. The direction and abrupt changes in movement may be recognized with the aid of the x-axis angular velocity.



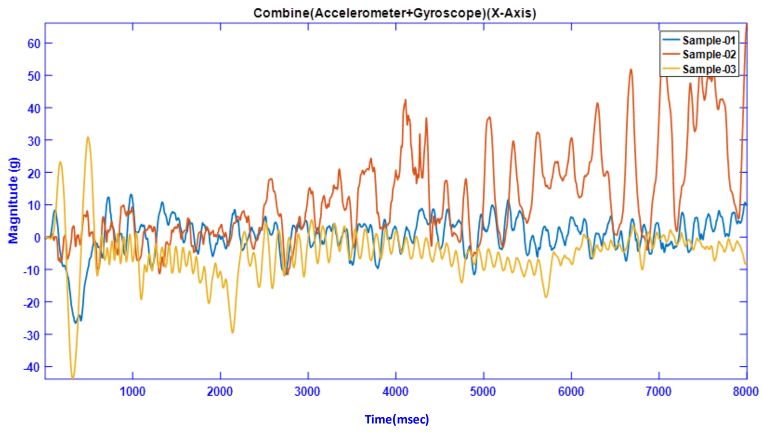
Sample-01



Sample-02



Sample-03



3 Samples Combined

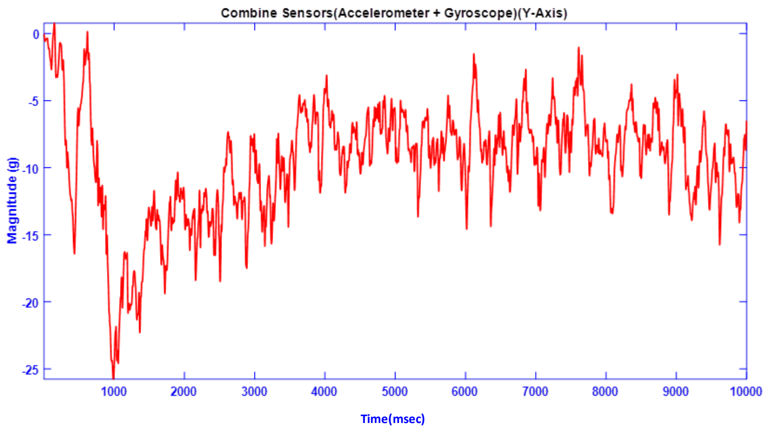
Figure 2.2.1.3.1: Walking Plot using Combine Sensors (x-axis)

Sample-01 was collected by walking slowly. The plot indicates a large spike at the start of sample 3 when the foot strikes the ground. In the X-axis, positive values indicate forward movement, sample 1, there is a sudden spike on the negative side, captured by the combined accelerometer and gyroscope sensors, likely indicating the impact of the foot hitting the ground. The combined sensor might register slight fluctuations in angular velocity and horizontal movement as each foot alternately makes contact with the ground. For slow walking in sample 1 and 2, the fluctuations are relatively high and not smooth. Sample 2 represents normal walking, and sample 3 represents faster walking. In sample 2, the combined sensor detects low to larger oscillations along the X-axis, corresponding to the body's rhythmic motion advancing with each stride. In sample 3, while running, the sensor identifies a sharp spike when it hits the ground and changes the oscillation along the X-axis.

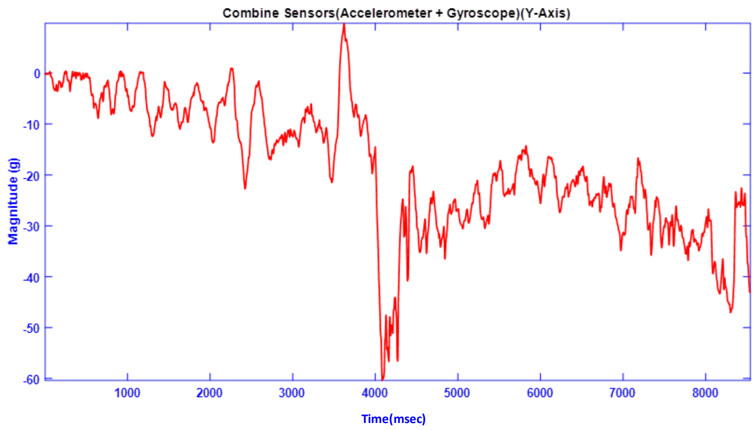
In this plot, we've combined all the samples of the X-axis to provide a comprehensive comparison. This allows us to clearly observe how the magnitude and oscillation vary with movement, which does not directly correlate with the walking pace.

- ***Y-Axis***

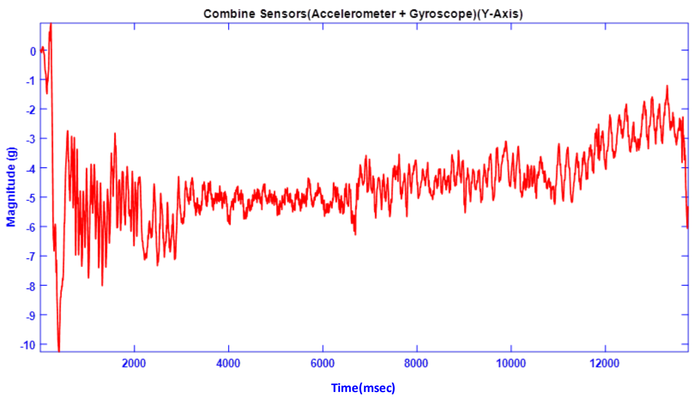
The accelerometer measures the gravitational force acting on the sensor in the y-axis direction. The gyroscope measures the rate of rotation around each axis. Combining accelerometer and gyroscope data allows for detection of walking motion along the y-axis. By analyzing specific characteristics of both sensor outputs, such as periodic peaks in acceleration and accompanying changes in angular velocity, it's possible to accurately identify walking behavior.



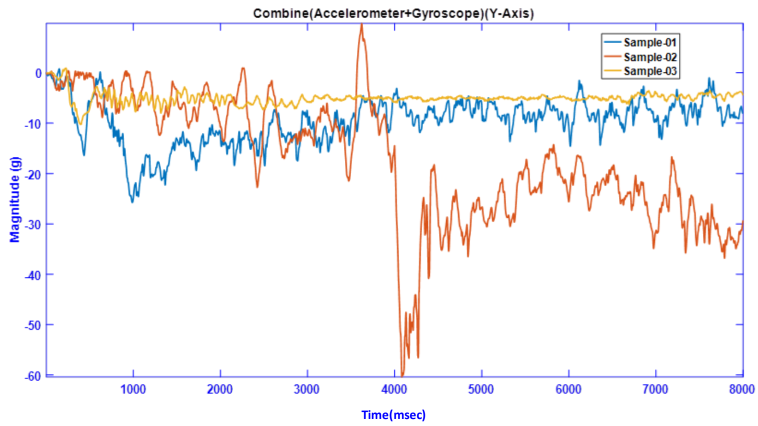
Sample-01



Sample-02



Sample-03



3 Samples Combined

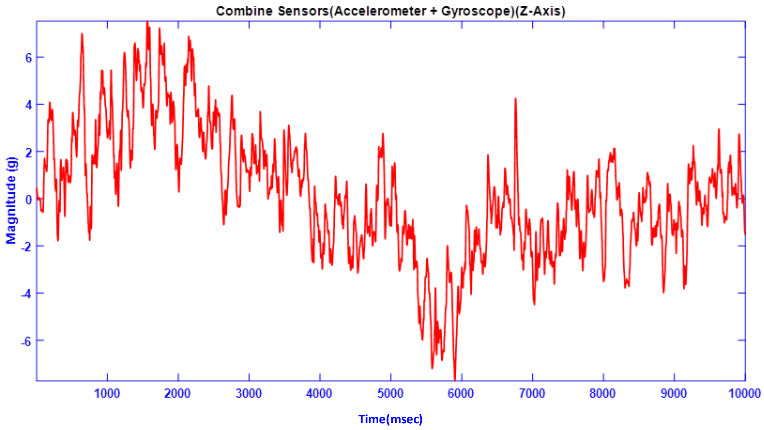
Figure 2.2.1.3.2: Walking Plot using Combine Sensors (y-axis)

In sample-01, the data was collected from the sensor while walking slowly. In contrast, samples 02 and 03 were collected while walking quickly. In sample 1, the sudden small amplitude oscillations observed may occur if the sensor is not securely attached to the body or device, leading to less effective capture of vibrations. The plot of sample-01 shows fewer oscillations compared to samples 02 and 03. Faster movement results in more oscillations, as seen in samples 02 and 03.

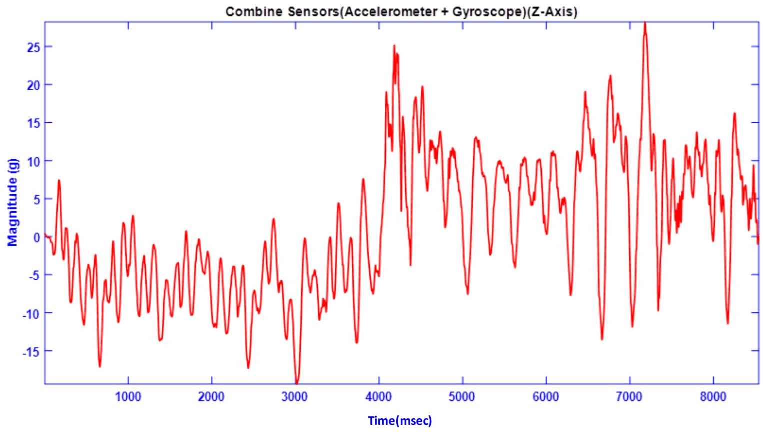
In this plot, we have combined all the Y-axis samples to offer a comprehensive comparison. This clearly illustrates how the magnitude and oscillation vary with the walking pace across the different samples collected from the sensor.

- ***Z-Axis***

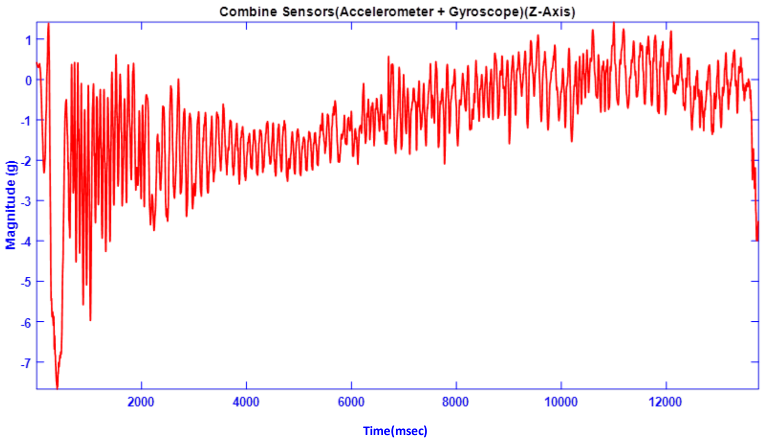
Combining accelerometer and gyroscope data for detecting walking along the z-axis involves analyzing specific characteristics of both sensor outputs. While walking, there may be minimal rotation around the z-axis, which can be detected as slight changes in angular velocity. It is possible to identify walking motion along the z-axis easily by combining accelerometer and gyroscope data. Walking behavior may be reliably identified by examining features of both sensor outputs, such as periodic acceleration peaks and corresponding variations in angular velocity.



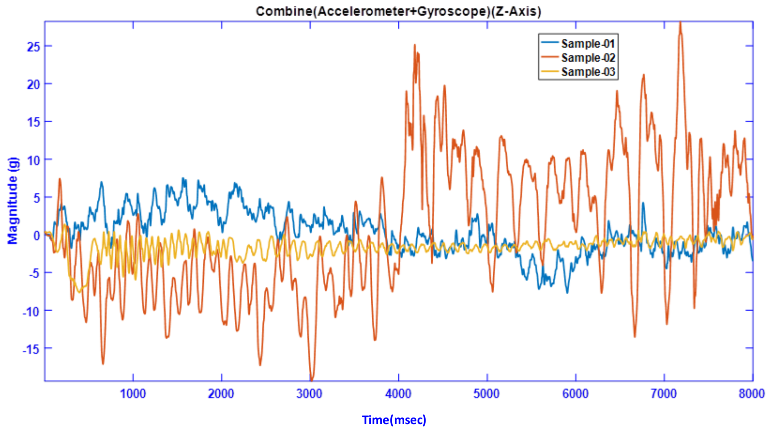
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.3.3: Walking Plot using Combine Sensors (z-axis)

In sample-01, the data was collected from the sensor while walking slowly. In contrast, samples 02 and 03 were taken while normal walking and walking like running. Observing the plot of sample-02, we see fewer oscillations compared to samples 02 and 03. Faster walking results in slightly higher peaks due to increased vertical bounce. The Z-axis data primarily captures the subtle upward movement with each step, rather than the walking pace.

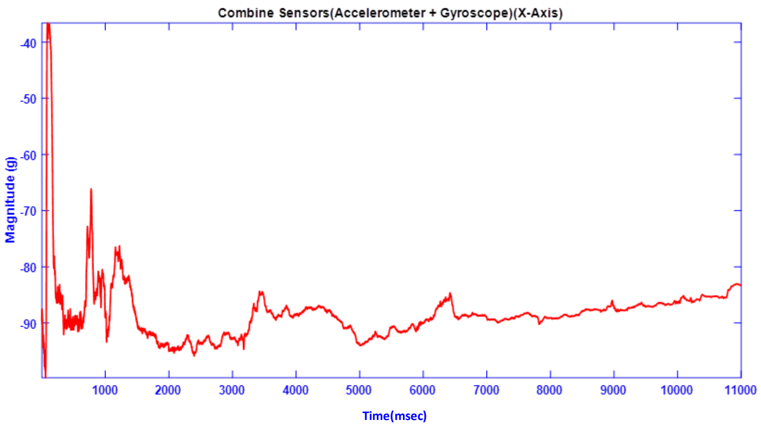
We tried to show all Z-axis samples on a single plot to provide a clear overview and sample comparison. In the all-sample plot, we would see the changes in the angular velocity of each function over time in the Z-axis. We can see that sample 1 shows moderate variability in the angular velocity over time. No extreme spikes are observed here. Sample 2 shows higher fluctuations compared to other samples. This suggests more dynamic motion. In sample 3, we see a relatively stable magnitude over time. These plots provide an idea of the motion pattern of the combined sensor.

❖ ***Lying***

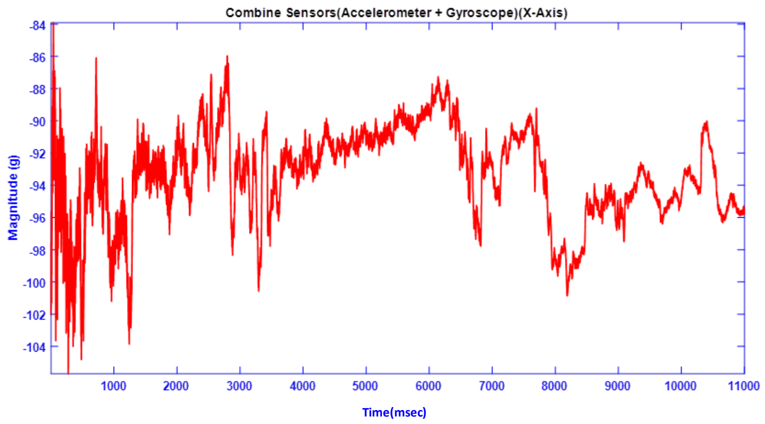
While lying down, the overall accelerations and rotation around the x, y, and z axes are much lower in magnitude compared to walking or moving. Because there is minimal movement when lying still. Here data is collected by combination of two sensors. Unlike the walking data which shows repetitive peaks, the lying data does not show any significant pattern of peaks in any axis.

- ***X-Axis***

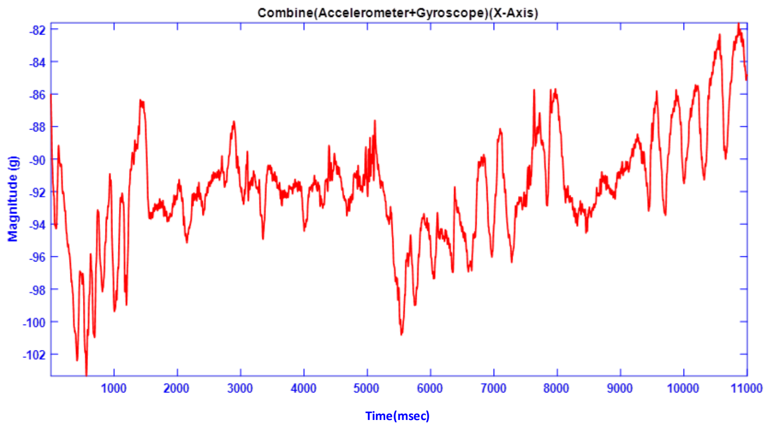
The collected data from combination of two sensors for the x-axis during lying down, it shows very little variation, as there is not much motion happening. During walking x axis shows distinct peaks due to movement and foot strikes but lying down results in minimal to no significant peaks or valleys. While minor body adjustments or breathing may cause slight variations in data, the constant pull of gravity acting perpendicular to the body has the most influence on the x-axis data (assuming he/she lying flat on his/her back).But shifting positions while lying down, such as changing the side, can cause minor fluctuations in the x-axis data because sensors experience slight changes in orientation and acceleration or external factors like someone touching him/her or moving of bedsheets can create small, transient spikes in the x-axis data.



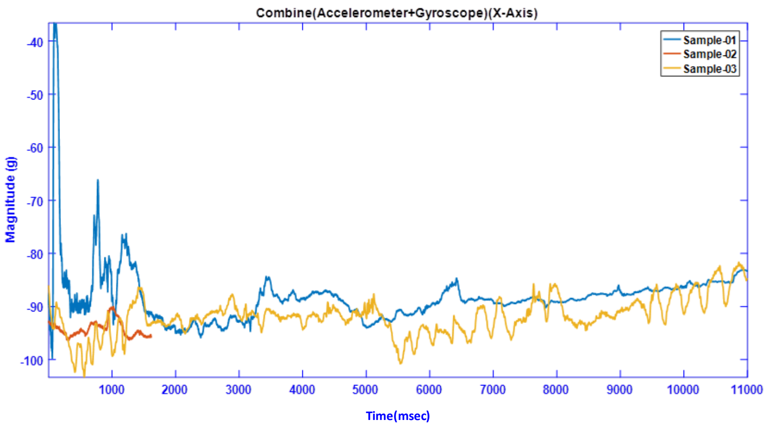
Sample-01



Sample-02



Sample-03



3 Samples Combined

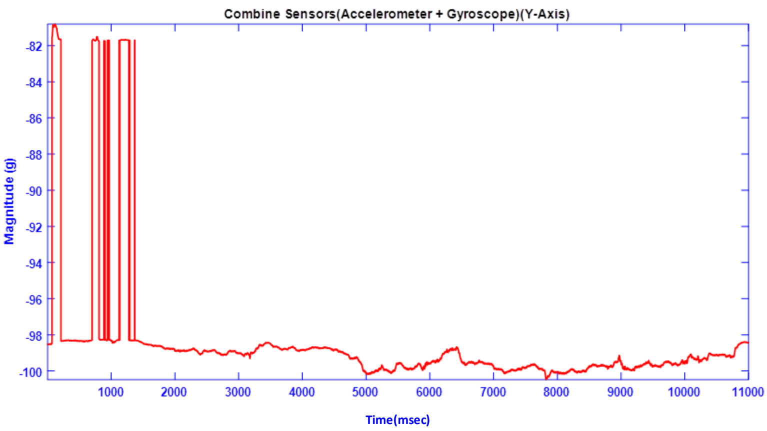
Figure 2.2.1.3.4: Lying Plot using Combine Sensors (x-axis)

Here, three samples of the x axis were taken by lying down on the bed. The horizontal axis represents time, and the vertical axis represents the magnitude. If we observe three samples closely, we will not find any relative pattern in the data because during lying down there is no movement or slight movement. But sometimes we can get small spikes like sample-01,02,03 which is because of changing sides, little movement of bedsheets or involuntary movement of muscles.

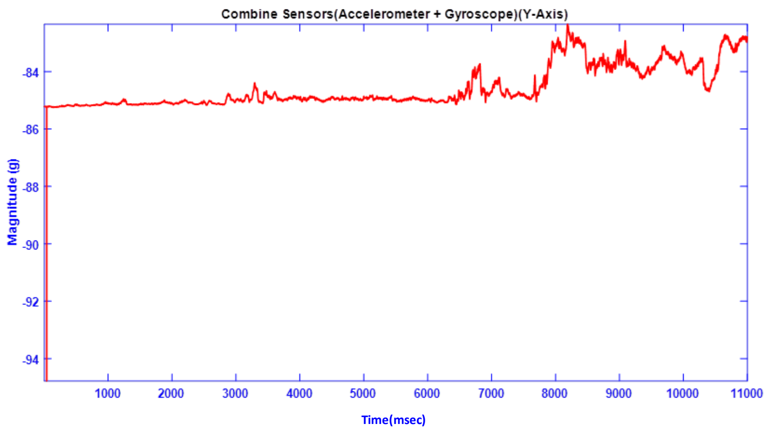
Here, three samples are combined in plot to get a good overview of the comparisons of the samples. There is no significant pattern to follow when the samples are combined. But it gives a good overview of the state of lying along the x axis.

- ***Y-Axis***

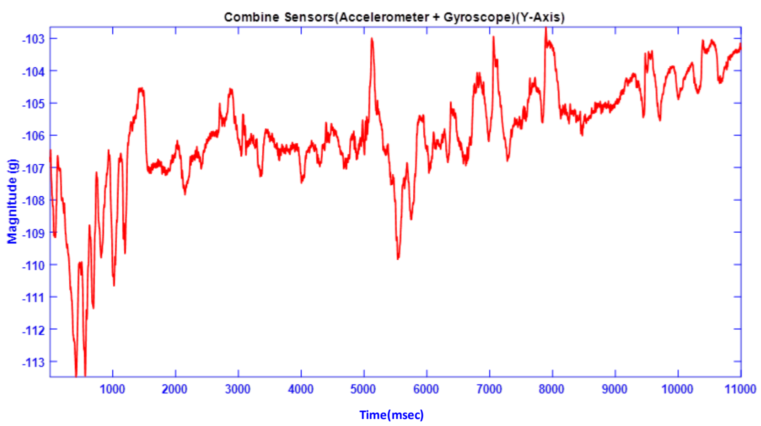
Y axis data does not show minimal to no significant peaks or valleys while lying still similar to x axis. Because there is minimal movement while lying flat. Shifting positions while lying down, such as changing the side, can cause minor fluctuations in the y-axis data similar to the x axis data because sensors experience slight changes in orientation and acceleration or external factors like someone touching him/her or moving of bedsheets can create small, transient spikes in the y-axis data.



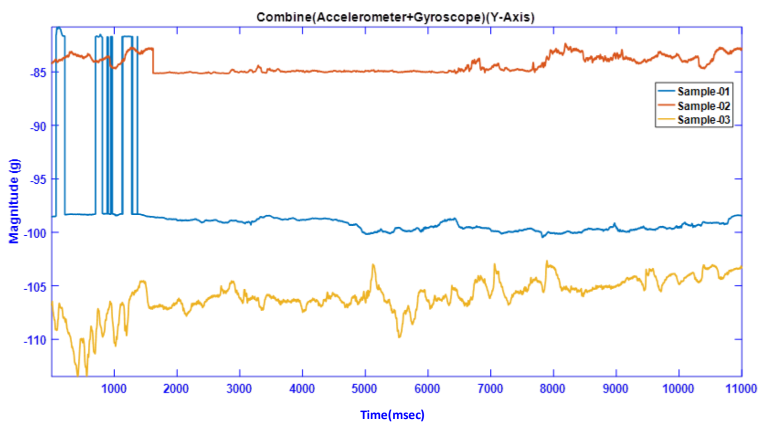
Sample-01



Sample-02



Sample-03



3 Samples Combined

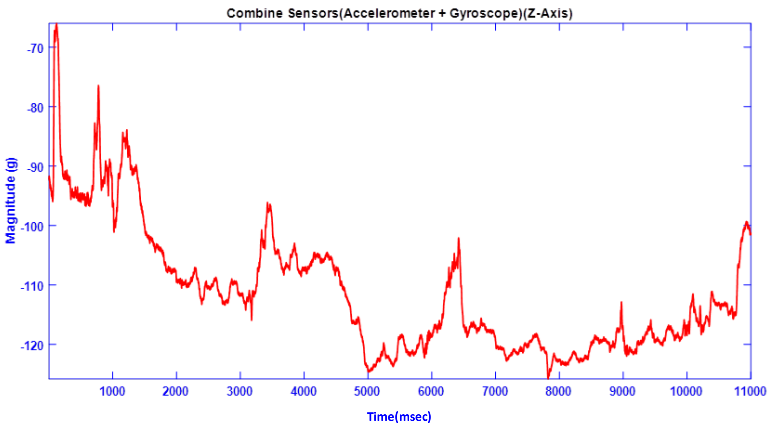
Figure 2.2.1.3.5: Lying Plot using Combine Sensors (y-axis)

Three y-axis samples were taken while lying on the bed. Because there is no movement while lying down, observing three samples closely shows no different pattern in the data. But in sample 1, there are spikes at the beginning because of the initial adjustment. However, we can sometimes see small spikes similar to samples 01, 02, and 03 as a result of changing sides or minor movement of bedsheets.

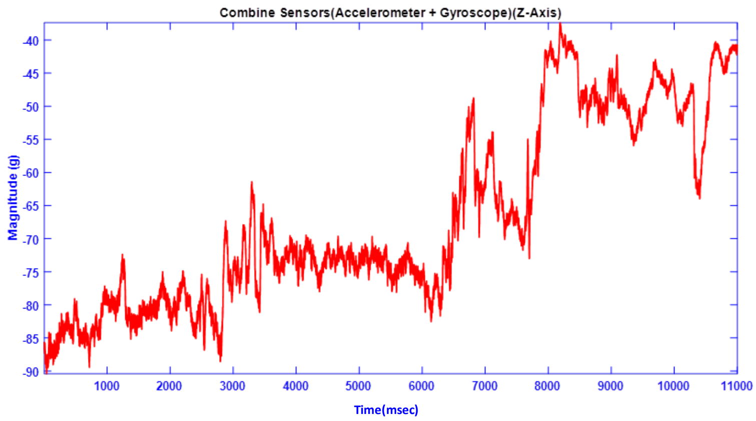
Here, three samples are combined in plot to get a good overview of the comparisons of the samples. There is no significant pattern to follow when the samples are combined. But it gives a good overview of the state of lying along the y axis.

- ***Z-Axis***

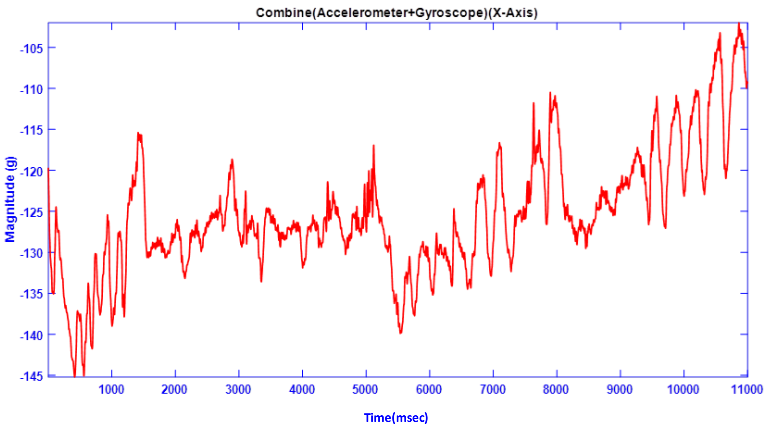
While lying flat, z axis data remain stable like both the Y-axis and X-axis data. However, changing positions, such as turning into the other side, may lead to slight fluctuations in both z axis data. These fluctuations can occur due to subtle shifts in orientation and acceleration of the sensors or external factors like physical contact or movement of bedsheet.



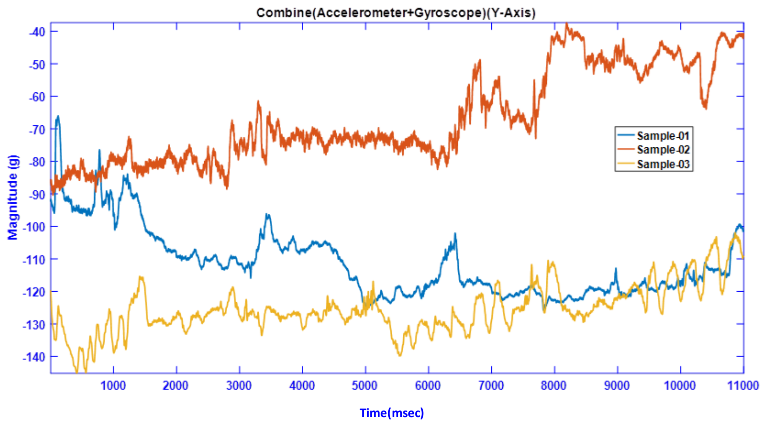
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.3.6: Lying Plot using Combine Sensors (z-axis)

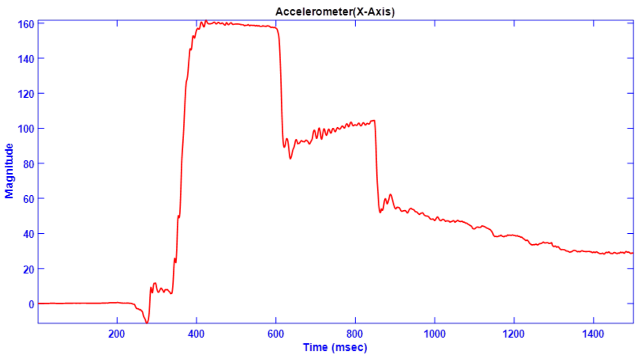
Three z-axis samples were taken by lying on the bed. But we do not find any different pattern in the data if we closely examine three samples because there is no such movement while lying down. However, we sometimes observe small spikes like samples-01,02,03 as a result of changing sides or slight movement of the bedsheets.

Here, three samples are combined in plot to get a good overview of the comparisons of the samples. There is no significant pattern to follow when the samples are combined. But it gives a good overview of the state of lying along the z axis.

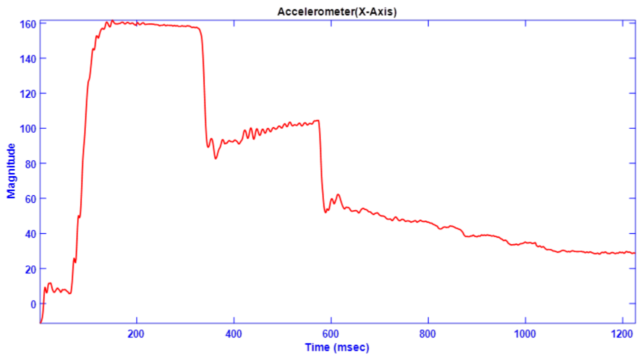
❖ *Fall Detecting*

- ***X-Axis***

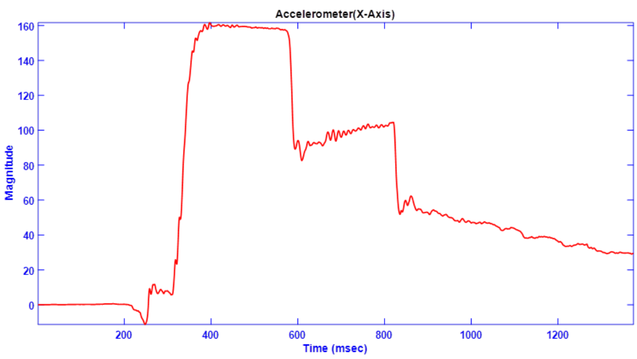
Fall detection using combined x-axis data from an accelerometer and a gyroscope involves analyzing specific patterns in the sensor readings that typically occur during a fall. Collect continuous data from both the accelerometer and gyroscope on the x-axis. Sudden increases in acceleration indicate rapid movement. Suddenly higher values followed by low activity, indicating the impact with the ground. When a person begins to fall, the X-axis direction changes rapidly, resulting in sudden spikes in the plot. This transition reflects the shift from a walking or upright position to a falling position, where the body moves from being vertical to becoming horizontal or inclined.



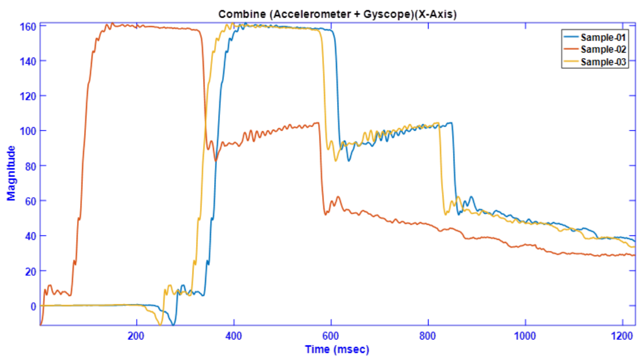
Sample-01



Sample-02



Sample-03



3 Samples Combined

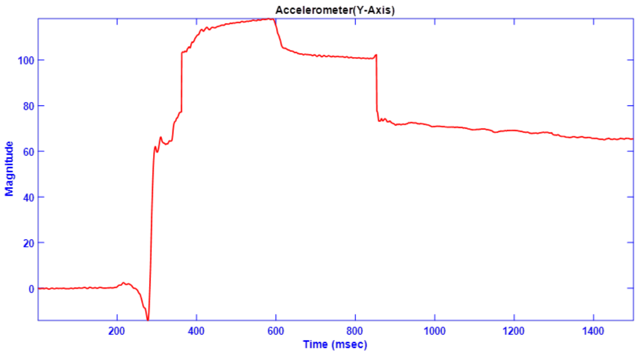
Figure 2.2.1.3.7: Fall Detecting using Combined Sensor (Accelerometer + Gyroscope) (x-axis)

In Sample-01, the data was collected by walking slowly and then falling. Sample-02 captures data from normal walking followed by a fall, and Sample-03 records faster walking before a fall. Forward motion is indicated by positive values on the X-axis. Examining the three samples, falls occur at different times: 300-900 milliseconds for Sample-01, 100-800 milliseconds for Sample-02, and 200-800 milliseconds for Sample-03. During walking, the data does not show sudden changes or spikes. However, when a fall occurs, all three samples display a sudden change or drop in angular velocity values, indicating the moment the person starts to fall. This dramatic change signals the transition from walking to falling, as the person's orientation shifts from vertical to horizontal or inclined. By observing these changes in the data, we can determine when a person is falling.

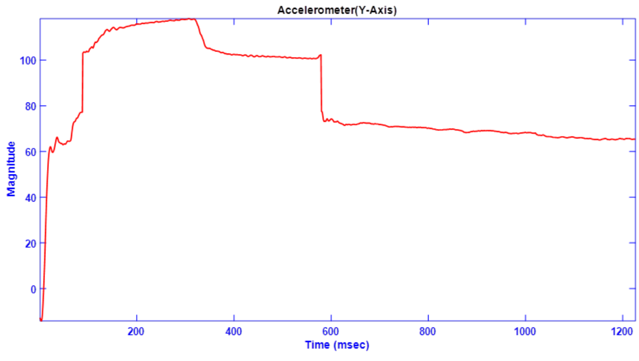
In a combined plot illustrating the transition from walking to falling using combined sensor data (accelerometer and gyroscope) along the X-axis, we observe specific patterns that help identify falls. When a person is walking, the angular velocity values remain consistent, indicating an upright position and forward movement. However, when a fall occurs, sudden changes in the data are observed at different times for each sample.

- ***Y-Axis***

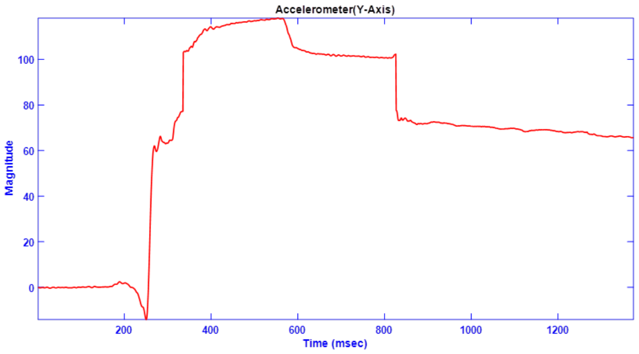
Detecting falls using combined accelerometer and gyroscope data along the Y-axis involves analyzing patterns in the sensor readings that indicate a transition from walking to falling. The Y-axis values are relatively stable, showing slight variations due to normal body movements. A sudden spike or drop indicates rapid movement. If the fall is to the side, a significant change in the Y-axis is expected.



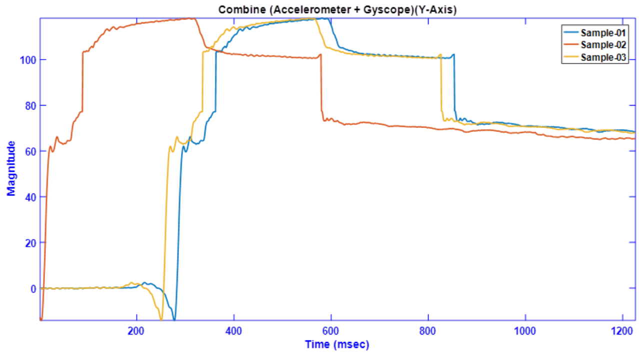
Sample-01



Sample-02



Sample-03



3 Samples Combined

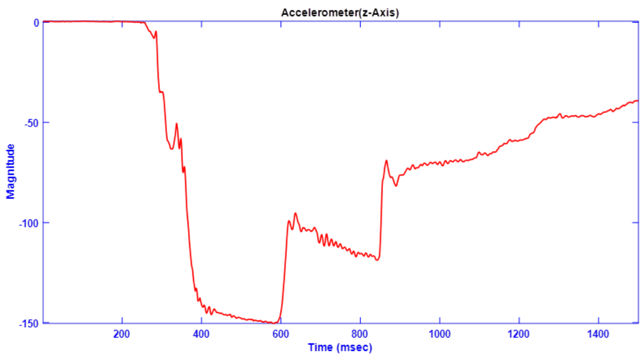
Figure 2.2.1.3.8: Fall Detecting using Combined Sensor (Accelerometer + Gyroscope) (y-axis)

In Sample-01, the data was collected while the person was walking slowly before falling. Sample-02 captured data from regular walking followed by a fall, and Sample-03 recorded data from faster walking preceding a fall. Positive values on the Y-axis denote forward motion and direction. Falls occurred at varying times: 300-850 milliseconds for Sample-01, 20-600 milliseconds for Sample-02, and 300-800 milliseconds for Sample-03. Throughout the walking phases, the data remained stable without sudden changes or spikes. However, during a fall, all three samples exhibited sudden changes or drops in angular velocity values and directional shifts, indicating the onset of the fall. This abrupt alteration signals the transition from walking to falling. By monitoring these changes in the data, we can effectively detect when a person is falling.

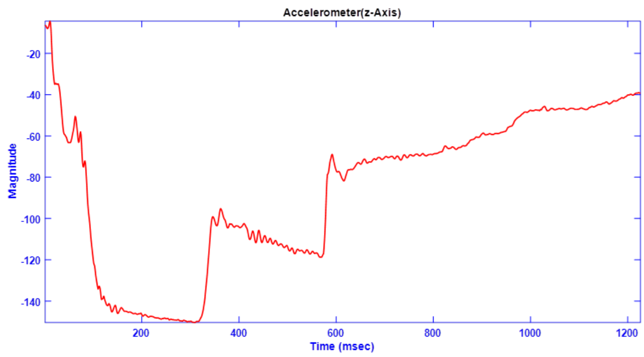
Creating a combined plot to illustrate the transition from walking to falling using data from a combined sensor along the Y-axis reveals constant values during walking to falling, indicative of a consistent left or right direction. As all three samples experienced falls at different times, changes manifest at distinct points on the combined graph. Notably, the absence of negative values in three samples suggests movement or rotation in a forward direction.

- ***Z-Axis***

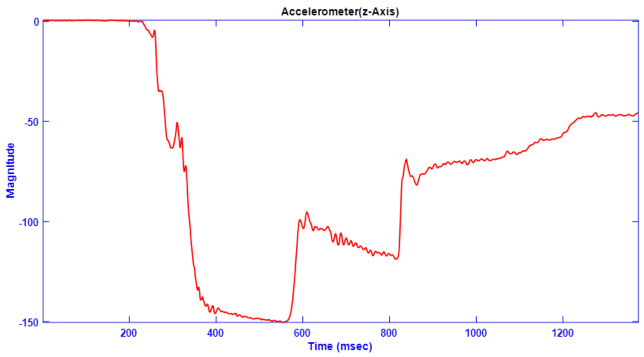
Combining data from both the accelerometer and gyroscope can provide more robust fall detection. Algorithms such as Kalman filters or complementary filters can be used to fuse accelerometer and gyroscope data to improve accuracy in detecting falls. When a fall occurs, there will be a rapid change in acceleration along the Z-axis. This change can be detected to indicate the start of a fall. When a fall occurs, there may be sudden changes or spikes in the angular velocity data due to the rapid change in orientation as the person falls.



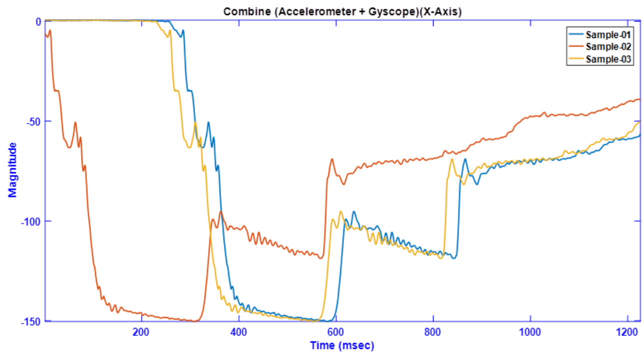
Sample-01



Sample-02



Sample-03



3 Samples Combined

Figure 2.2.1.3.9: Fall Detecting using Combined Sensor (Accelerometer + Gyroscope) (z-axis)

In a combined sensor, Sample 1 shows that during walking to fall, the combined sensor typically registers noticeable and gradual changes in the negative sides in the Z axis. This is because walking requires vertical movement, which keeps the body in a relatively stable position. Falls occurred at varying times: 200-850 milliseconds for Sample-01, 80-600 milliseconds for Sample-02, and 300-850 milliseconds for Sample-03. The combined sensor can detect fluctuations due to the body's natural vibrations with each step. Here in all plots, we see from 3 samples when walking to fall condition it shows a very large negative side changes the values. And when the person was falling to lying down it shows there are no changes or small oscillations in the plot. So mainly these changes here represent that fall occurs.

In a combined plot illustrating the transition from walking to falling using combined sensor data along the Z-axis. During walking, the Z-axis is believed to have a stable vibration pattern. This is because when he walks, his body naturally rocks back and forth to maintain balance. In the plot, when we are walking values will remain consistent. In the combined plot, since each of the 3 samples fell at different timings, the changes appear at different timings. Here we see that there is value on the negative side in all samples, it means that it is a backward fall.

2.2.2 AIRBAG

The airbag system in fall detection system is an innovative approach to minimizing injuries from falls, particularly for elderly individuals or those with mobility impairments. We have two alternative solutions for airbag systems to reduce the injuries from falls.

→ Chemical Based Airbags
→ Air Compressor Based Airbags

- ***Chemical Based Airbags:*** Chemical-based airbag systems for fall detection typically involve the use of gas-generating chemicals that rapidly inflate an airbag when a fall is detected. These systems often utilize sensors, such as accelerometers or gyroscopes, to detect sudden changes in motion or orientation indicative of a fall. Once a fall is detected, the system triggers the release of the gas-generating chemicals, which rapidly produce gas to inflate the airbag and cushion the impact of the fall.

  The chemicals used in these systems are typically stored in a locked compartment until needed. When a fall is detected, an electrical signal is sent to activate a mechanism that ruptures the compartment or cartridge, allowing the chemicals to mix and react, producing gas that inflates the airbag.[19]

- ***Air Compressor Based Airbag:*** Air compressor-based airbag systems for fall detection offer a versatile and effective solution for mitigating the impact of falls in various settings. These systems utilize compact and lightweight air compressors to rapidly inflate airbags upon detecting a fall through sensors such as accelerometers or gyroscopes. The portability of the air compressor allows for easy integration into wearable devices or safety equipment, making them suitable for applications such as elderly care, industrial safety, and sports protection. By quickly deploying an airbag to cushion the impact of a fall, these systems can help reduce the risk of injury and provide added peace of mind to users, family members and caregivers.[20]

2.3 Refined Design

2.3.1 Finalization

2.3.1.1 Sensor Module

Accelerometer based fall detection systems offer an acceptable solution because of their low cost, small size, and ease of use. It requires less power and functions for a large period on a single battery charge. But it can detect a fall from other rapid movements like bending over or tripping. This can lead to false alerts and impact on the device’s accuracy.

Gyroscope based fall detection systems are also very popular and reliable. Gyroscope is another sensor technology that brings a unique solution to fall detection systems after the accelerometer sensor. Gyroscopes measure angular velocity and provide insights of a person's body orientation during movement. It is major factor for differentiating falls from other activities where the body's axis remains relatively stable. Using gyroscopes in fall detection system adds another layer of complexity to the system. Ans it also requires more power for processing and which potentially impacts on battery life. And also using gyroscopes in fall detection system makes the system more expensive compared to accelerometer.

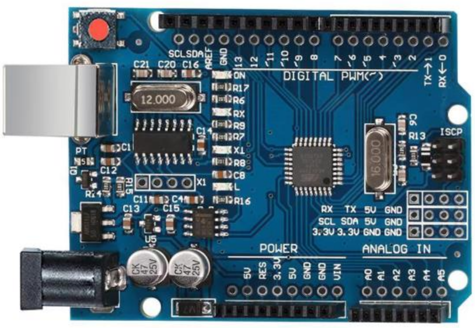
Combined (Accelerometer + Gyroscope) based method is proposed to achieve better performance from the system yet single sensor-based systems have limitations. This method works by combining the data from two sensors at a time. Combined data achieved from accelerometer and gyroscope creates a more comprehensive pattern of body movement. It allows the system to not only detect a sudden change in pace of the body but also identify the body's orientation during the movement. The combined data helps to filter out false alerts triggered by activities that might appear similar to a fall on an accelerometer or gyroscope alone. But accurate calibration should be maintained to get optimal performance from the system. [23]

Though it has some limitations like increased complexity, cost, and calibration which must be considered, focusing on the system's accuracy and performance we are choosing this method among those three methods.

2.3.1.2 MICROCONTROLLER

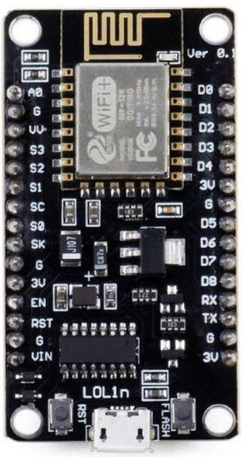
The decision between using the Arduino Uno R3 and the ESP8266 for fall detection hinges on a variety of factors, such as project-specific needs, preferred functionalities, and limitations such as power usage and connectivity choices.

➢ ***Arduino Uno R3***



- Versatile & easy to use with a wide range of compatible sensors and shields available.
- Suitable for interfacing with various sensors, including accelerometers and gyroscopes commonly used in fall detection systems.
- Offers analog and digital input/output pins, making it easy to connect and communicate with sensors.
- Typically used for standalone applications where connectivity to Wi-Fi networks or cloud services is not required.

➢ ***ESP8266***

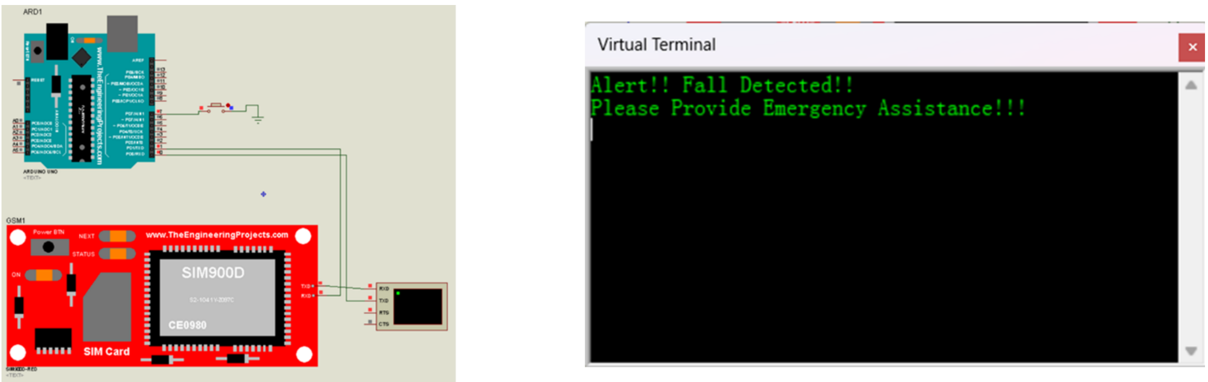


- Built-in Wi-Fi connectivity enables real-time data transmission and remote monitoring capabilities, which can be valuable for fall detection systems deployed in IoT or networked environments.
- Offers more processing power and memory compared to the Arduino Uno R3, allowing for more complex algorithms and data processing.
- Higher power consumption compared to the Arduino Uno R3, which may be a concern for battery-powered applications unless power-saving techniques are implemented.

In short, our fall detection system needs basic functionality and does not require internet connection so can use Arduino Uno R3. Our fall detection system doesn't need internet connection because when our device detects the fall and then SMS will reach family members and caregivers through the GSM module system. Arduino Uno r3 has lower power consumption than ESP8266, so battery charge will last longer. In terms of raw processing speed, the Arduino Uno R3 generally offers faster response times for sending signals compared to the ESP8266. The Arduino Uno R3 microcontroller has a higher clock speed and more processing power, allowing it to handle tasks more quickly. So, we will use Arduino uno r3 as a microcontroller.

2.3.1.3 MESSAGE ALERT SYSTEM

The GSM SIM800L is a compact and versatile module designed for mobile communication. With its small form factor and low power consumption. Equipped with features like quad-band connectivity, integrated TCP/IP stack, and support for SIM card functionalities, it enables seamless communication over GSM networks.



(a) (b)

Figure 2.3.3.1: (a) Circuit Diagram of GSM Module; **(b)** Sent Message

To connect a SIM800L GSM module to an Arduino Uno R3, we'll need to connect several pins between the two devices. Below is a typical pinout and explanation:

SIM800l	Arduino Uno R3
VCC	3.3V
GND	GND
TXD	Pin (D3)
RXD	Pin(D2)
ANT	GSM Antenna

The simulation in the above figure is done in proteus. As shown in the figure above, a push button is used. When the push button is pressed i.e. Arduino uno r 3 will detect "low" then the message will show on the virtual screen as shown in figure.

When this subsystem is added with a fall detection system, if fall is detected, the microcontroller will detect it as "low" and send SMS immediately.[17]

2.3.1.4 BATTERY

Selecting the appropriate battery for a fall detection system, which involves sending SMS alerts and activating an airbag, relies on various factors including power needs, space limitations, and safety concerns. It's crucial to consider the total power consumption of the system, ensure compatibility with component voltage requirements, prioritize rechargeability for prolonged use, and prioritize safety features like protection against overcharging. Additionally, factors such as size, weight, operating environment, and cost-effectiveness should be considered when choosing the ideal battery solution.

- ***Capacity*: The battery will have sufficient capacity to power all components of the system, including the microcontroller, sensors, GSM module for sending SMS, and any actuators such as an airbag.
- ***Voltage***: We will ensure that the battery voltage matches the requirements of the components in our system. The microcontroller and sensors operate at lower voltages (3.3V or 5V), while GSM modules and Airbag may require higher voltages.
- ***Rechargeability***: A rechargeable battery is typically preferred to allow for easy recharging and extended battery life. Lithium-ion (Li-ion) or lithium-polymer (LiPo) batteries are common choices for rechargeable applications due to their high energy density and long cycle life.
- ***Safety***: Safety is paramount, especially when dealing with batteries in wearable devices. We'll choose a battery with built-in protection circuitry to prevent overcharging, over-discharging, and short circuits. Additionally, we'll consider the battery's certification (UL, CE) to ensure compliance with safety standards.
- ***Size and Weight***: For wearable devices, the size and weight of the battery are critical factors. We'll look for compact and lightweight battery options that can be

comfortably integrated into the device without causing discomfort or hindering mobility.

A 5000mAh battery is a suitable choice for powering a fall detection system, including components for detecting falls, sending SMS notifications, and activating an airbag. Its capacity allows for extended operation, depending on component power consumption and frequency of use. It's crucial to assess component power requirements and conduct testing to confirm that the selected battery capacity aligns with the system's needs, while still prioritizing portability and usability.

The charge duration of a 5000mAh battery relies on factors such as charging current, initial state of charge, and charging efficiency. With a typical 1 ampere (A) charging current, it may take around 5 hours to fully charge the battery. However, actual duration can vary due to factors like charging method and battery condition. For the remaining duration of a fall detection system powered by a 5000mAh battery, factors such as component power consumption and event frequency influence operation. Moderate consumption and efficient use could yield several hours to days of continuous operation. Monitoring battery level and performance is crucial for reliable system functionality.[18]

2.3.1.5 AIRBAG

Both chemical-based airbags and air compressor-based airbags have their own advantages for reducing the impact of falls, and the choice between them depends on various factors. Chemical-based airbags offer rapid inflation times and can be compact and lightweight, making them suitable for wearable devices or situations where space and weight are critical. They typically rely on gas-generating chemicals that react when triggered, rapidly inflating the airbag to cushion the impact of a fall. However, they may require periodic maintenance to replace depleted chemicals and can be prone to false activations or accidental deployments. Chemical-based airbag systems use gas-generating chemicals that can potentially pose risks to human health if not handled properly. These chemicals, such as sodium azide or potassium nitrate, undergo rapid chemical reactions to generate gas and inflate the airbag when triggered.

One concern with chemical-based airbags is the potential for exposure to toxic or harmful by-products produced during the gas generation process. For example, sodium azide can release toxic nitrogen oxides when it decomposes, which can pose risks if inhaled or absorbed through the skin in high concentrations. [21]

On the other hand, air compressor-based airbags utilize compressed air to inflate the airbag upon detecting a fall. They offer greater control over the inflation process and may have longer-lasting functionality compared to chemical-based systems. Additionally, they can be more easily integrated into existing infrastructure or safety equipment, making them suitable for a wider range of applications. However, they may require more power and can be bulkier and heavier than chemical-based systems.

The optimal selection between chemical-based airbags and air compressor-based airbags hinges on health issues and limitations of the particular application at hand because we're mainly focusing on old aged people. Both chemical-based airbags and portable air compressor-based airbags have their advantages and limitations, making it difficult to determine which one is definitively "best" for reducing the impact of falls. However, portable air compressor-based airbags offer certain advantages such as versatility, ease of maintenance, and potentially faster inflation times compared to chemical-based systems. Therefore, portable air compressor-based airbags may be considered more suitable for certain applications where rapid deployment, reliability, and ease of use are priorities.

2.3.2 CIRCUIT DIAGRAM

This is the circuit diagram of our full system which we will implement in EEE400C.

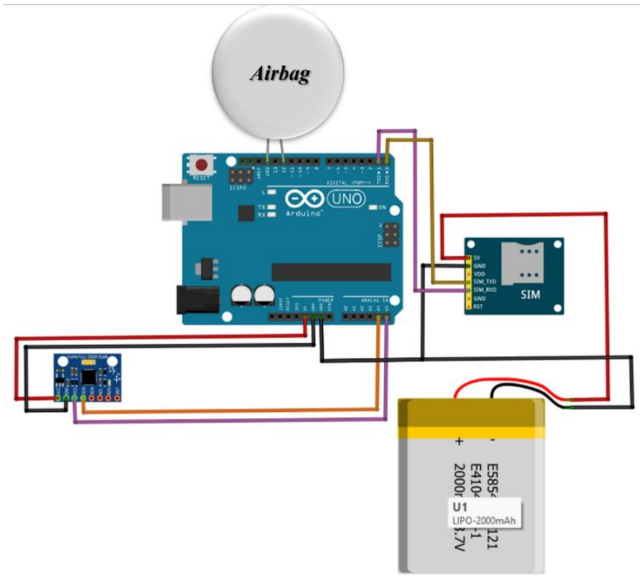


Figure 2.3.1.1: Circuit Diagram of Fall Detection System and Fall Impact Minimization System

2.3.3 Final Outlook

The outfit of our final device will look like the below image,

(a) The Wearable Jacket

(b) The Wearable Jacket when Airbag ON

Figure 2.3.3.1: The Final Outfit of Fall Detection System

2.3.4 Box Dimension

This is the box dimension of our system that we will try to keep around the waist.

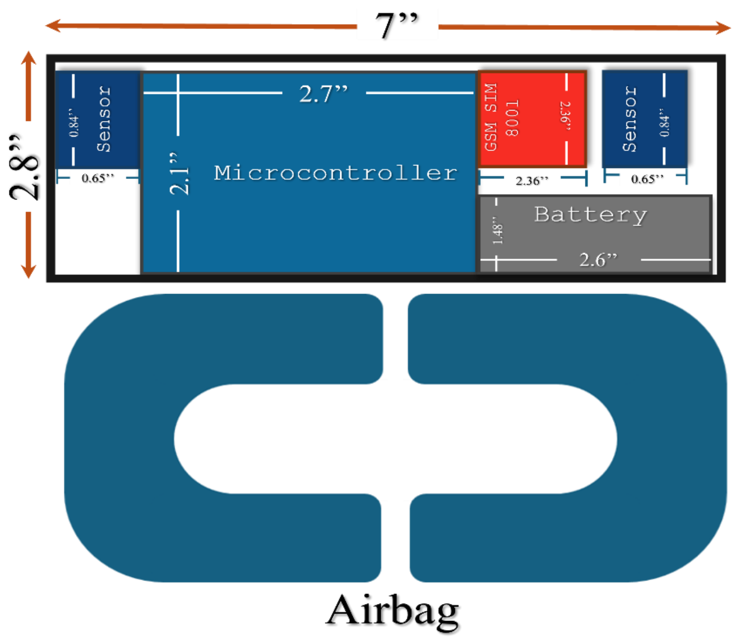


Figure 2.3.4.1: The Box Dimension of the Fall Detection System

PART-C

This part includes the implementation, finalized design, and analysis of economic viability of the project.

CHAPTER 3 DEMONSTRATION OF IMPLEMENTED SOLUTION AND FINALIZATION OF DESIGN

3.1 DEVELOPMENT OF THE PROTOTYPE

We have divided our device into three subsystems. Fall detection system, fall impact minimization system (Activate Air bag) and SMS based notification system. We have developed this device mainly focusing on elderly people and they usually have walking problems due to old age. Because most of them usually have trouble walking independently, they are prone to falls. When an elderly person wearing this device is likely to fall while walking, our device will first detect the fall and immediately activate the airbag. Then the message will be sent to the mobile of the family member & caregivers through SMS. This device can be divided into three sub sections. These are:

- ❖ Fall detection
- ❖ Alert system (SMS)
- ❖ Fall impact minimization

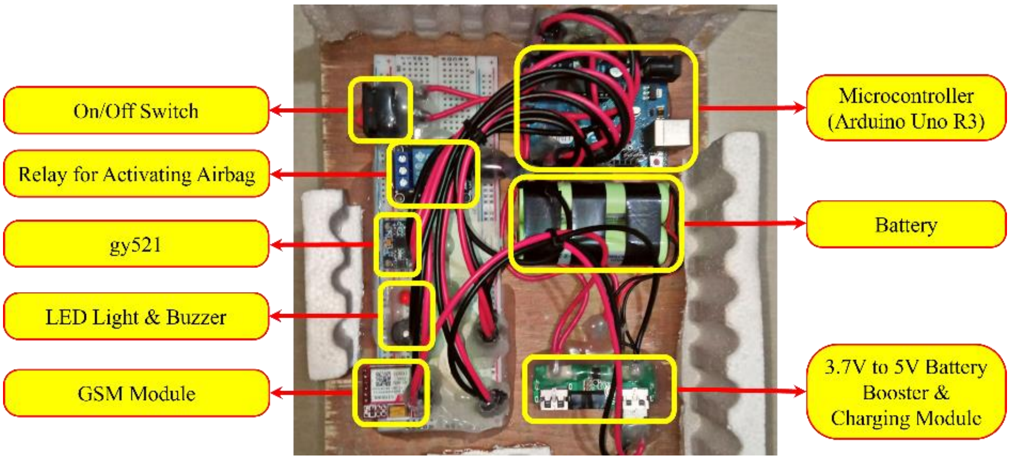


Figure 3.1.1: Circuit diagram of Fall Detection and minimization system without the connection to airbag

Firstly, we talk about the connection from Arduino Uno R3 to 3.7V to 5V Booster Module (USB), GY-521, GSM800l, LED, Relay & Buzzer. Here's the connection table,

Table 3.1.1: Connection Overview for Arduino Uno R3 with GY-521, LED, Buzzer, Relay, Booster Module, and GSM SIM800L

Arduino Uno R3		***gy521***	***LED***	***Buzzer***	***Relay***	***3.7V to 5V Booster Module (USB)***	***GSM sim800l***
5V		VCC (+)					
GND		GND	GND	GND	GND	GND	GND
SDA		A4					
SCL		A5					
D2	***To***		VCC (+) + 150 ohm				
D3				VCC (+)			
D4					signal		
3.7v							VCC
D9							TX
D10							RX

To connect all these components to the microcontroller (Arduino Uno R3), connect the GY-521 (MPU6050) module's VCC to the 5V pin on the microcontroller (Arduino Uno R3), GND to GND, SDA to A4 and SCL to A5. For the LED, connect its positive terminal to D2 on the Arduino through a 150-ohm resistor and its negative terminal to GND. The buzzer's positive terminal goes to D3, and it's GND connects to the microcontroller's (Arduino Uno R3) GND. For the connection of the relay, connect the relay's signal pin to D4, VCC to 5V, and GND to GND. The GSM SIM800L module's VCC connects to the 5V output from a 3.7V to 5V booster module, TX to D9, RX to D10, and GND to microcontroller's (Arduino Uno R3). The 3.7V to 5V booster module's input terminal connects to a 3.7V battery, and its output provides 5V for the SIM800L and relay.

Table 3.1.2: Connection Overview for Battery, 3.7V to 5V Booster Module, Switch, and GSM SIM800L

Battery		***3.7V to 5V Booster Module (USB)***	***Switch***	***GSM sim800l***
Red		B+		
Black		B-		
Terminal 1	To		(+)ve Terminal 1	
Terminal 2			(−)ve Terminal 2	
GND				GND

To connect the battery, 3.7V to 5V booster module, switch and GSM sim800l module connect the battery's red (B+) wire to the positive terminal of the booster module and the black (B-) wire to the negative terminal. The positive 5V output from the booster module goes to terminal 1 of the switch and the negative output (GND) connects directly to the GSM sim800l's GND. Terminal 2 of the switch is connected to the VCC of the GSM sim800l module. This setup allows the switch to control the 5V power supply from the booster module to the GSM sim800l.

(a) **(b)**

Figure 3.1.2: (a) Before Fall Detected & the airbag position and (b) After Fall Detected & the airbag inflated

Figure 3.1.3: After Detecting Fall send alert notification through SMS system

3.1.1 FALL DETECTION

This section of the device consists of a microcontroller (Arduino Uno R3) and sensor module (GY521) which are connected through the breadboard. Data is collected from the sensor and sent to the processing unit (microcontroller) where an algorithm is already set to take the decision of a falling situation. If the processing unit (microcontroller) concludes detecting fall from the pattern of the data collected from the sensor, it sends a signal to the rest of the two sections.

3.1.2 FALL IMPACT MINIMIZATION SYSTEM

This section of the device consists of a relay, an air compressor, an airbag (neck pillow), where the air compressor is not directly connected to the microcontroller (Arduino Uno R3). Rather it is connected through a relay. And the tube of the air compressor is connected to the airbag (neck pillow). When a fall is detected, the microcontroller (Arduino Uno R3) sends the signal to the relay and then it reaches the air compressor. When the microcontroller (Arduino

Uno R3) sends signal to the relay it turns on instantly but when signal reaches the air compressor it takes 2-3 seconds to turn on the air compressor for its' default function. Then the air compressor starts to pump the airbag (neck pillow) and it takes almost 20 seconds to pump completely.

3.1.3 ALERT SYSTEM (SMS)

This part of the device includes an Arduino Uno R3 microcontroller and a GSM sim800l module, both are connected directly. A buzzer and an LED are also connected. A small computing unit (such as Arduino Uno R3) processes data from the sensors and detects a fall has occurred and sends a signal to the GSM module, buzzer and LED. A GSM sim800l sensor module allows the system to send SMS alerts to predefined phone numbers when a fall is detected. It uses a SIM card for cellular connectivity.

3.1.4 POWER CONSUMPTION

All power consumption calculations are shown below:

- ***BATTERY CAPACITY & VOLTAGE CALCULATION***

  Battery capacity (Power), P = 4400 mAh= 4.4Ah
  Battery Voltage = 5V

  We know,
  $E = PV$
  $= (4.45)$ Wh $=$ 22 Wh

So, this is the total energy the battery can supply before being fully drained.

- ***CURRENT DRAW BY INDIVIDUAL COMPONENTS***

  Each component in the system draws a specific current(I). Here are a approximate values for the current draw of the major components:

Table 3.1.4.1: Approximate Current Consumption of All Components

Component's Name	***Approximate Value of Current (mA)***
Arduino Uno R3[28]	100
GY-521[29]	5
LED [30]	15
Buzzer [31]	3
Relay [32]	175
GSM 800l Module[33]	7
3.7V to 5V Booster module [34]	200

Total current(I)= 100+5+15+3+175+7+200 = 505 mA

➢ *CALCULATING TOTAL POWER CONSUMPTION*

Voltage, V = 5V

Total current, I = 505 mA = 0.505 A

We know,

$P = V \times I$

For the system:

P= (5 × 0.505) W = 2.525 W

➢ *BATTERY RUNTIME CALCULATION*

For calculating how long the battery stays charged, we can divide the battery's energy capacity by the total power consumption:

$$Total\ Runtime = {Energy\ (Wh)}/{Power\ (W)}$$

$$= \frac{22\ Wh}{2.252W} = 8.71hr \approx 9\ hours$$

By calculating,

- ✓ **Total Current Draw:** 505 mA
- ✓ **Power Consumption:** 2.525 W
- ✓ **Battery Runtime:** 9 hours

3.2 Performance Evaluation of Implemented Solution Against Design Requirements

The table shows the time in seconds for multiple functions like Fall Detection, Relay, Air Compressor, and SMS across multiple attempts by different users.

Table 3.2.1: Performance Timing Data for Fall Detection System, Relay System, Air Compressor System & SMS System Across Multiple Users and Attempts

USER - 01											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of Functions	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***
Fall Detect	0.81	***Fall Detect***	0.6	***Fall Detect***	0.3	***Fall Detect***	0.78	***Fall Detect***	0.81	***Fall Detect***	0.5
Relay	0.81	***Relay***	0.6	***Relay***	0.3	***Relay***	0.78	***Relay***	0.81	***Relay***	0.5
Air Compressor	3.31	***Air Compressor***	3.1	***Air Compressor***	2.8	***Air Compressor***	3.28	***Air Compressor***	3.31	***Air Compressor***	3
SMS	23.31	***SMS***	23.1	***SMS***	22.8	***SMS***	23.28	***SMS***	23.31	***SMS***	23
USER - 02											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of Functions	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***
Fall Detect	0.53	***Fall Detect***	0.38	***Fall Detect***	0.56	***Fall Detect***	0.42	***Fall Detect***	0.65	***Fall Detect***	0.54
Relay	0.53	***Relay***	0.38	***Relay***	0.56	***Relay***	0.42	***Relay***	0.65	***Relay***	0.54
Air Compressor	3.03	***Air Compressor***	2.88	***Air Compressor***	3.06	***Air Compressor***	2.92	***Air Compressor***	3.15	***Air Compressor***	3.04
SMS	23.03	***SMS***	22.88	***SMS***	23.06	***SMS***	22.92	***SMS***	23.15	***SMS***	23.04
USER - 03											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***

Functions	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***
Fall Detect	0.48	***Fall Detect***	0.61	***Fall Detect***	0.33	***Fall Detect***	0.59	***Fall Detect***	0.47	***Fall Detect***	0.62
Relay	0.48	***Relay***	0.61	***Relay***	0.33	***Relay***	0.59	***Relay***	0.47	***Relay***	0.62
Air Compressor	2.98	***Air Compressor***	3.11	***Air Compressor***	2.83	***Air Compressor***	3.09	***Air Compressor***	2.97	***Air Compressor***	3.12
SMS	22.98	***SMS***	23.11	***SMS***	22.83	***SMS***	23.09	***SMS***	22.97	***SMS***	23.12
USER - 04											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of Functions	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***
Fall Detect	0.35	***Fall Detect***	0.57	***Fall Detect***	0.45	***Fall Detect***	0.68	***Fall Detect***	0.52	***Fall Detect***	0.39
Relay	0.35	***Relay***	0.57	***Relay***	0.45	***Relay***	0.68	***Relay***	0.52	***Relay***	0.39
Air Compressor	2.85	***Air Compressor***	3.07	***Air Compressor***	2.95	***Air Compressor***	3.18	***Air Compressor***	3.02	***Air Compressor***	2.89
SMS	22.85	***SMS***	23.07	***SMS***	22.95	***SMS***	23.18	***SMS***	23.02	***SMS***	22.89
USER - 05											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of Functions	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***	***Name of Functions***	***Time (sec)***
Fall Detect	0.34	***Fall Detect***	0.51	***Fall Detect***	0.32	***Fall Detect***	0.48	***Fall Detect***	0.64	***Fall Detect***	0.44
Relay	0.34	***Relay***	0.51	***Relay***	0.32	***Relay***	0.48	***Relay***	0.64	***Relay***	0.44
Air Compressor	2.84	***Air Compressor***	3.01	***Air Compressor***	2.82	***Air Compressor***	2.98	***Air Compressor***	3.14	***Air Compressor***	2.94
SMS	22.84	***SMS***	23.01	***SMS***	22.82	***SMS***	22.98	***SMS***	23.14	***SMS***	22.94
USER - 06											
ATTEMPT - 01		***ATTEMPT - 02***		***ATTEMPT - 03***		***ATTEMPT - 04***		***ATTEMPT - 05***		***ATTEMPT - 06***	
Name of	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***	***Name of***	***Time***

Functions	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***	***Functions***	***(sec)***
Fall Detect	0.4	***Fall Detect***	0.23	***Fall Detect***	0.49	***Fall Detect***	0.52	***Fall Detect***	0.33	***Fall Detect***	0.72
Relay	0.4	***Relay***	0.23	***Relay***	0.49	***Relay***	0.52	***Relay***	0.33	***Relay***	0.72
Air Compressor	2.9	***Air Compressor***	2.73	***Air Compressor***	2.99	***Air Compressor***	3.02	***Air Compressor***	2.83	***Air Compressor***	3.22
SMS	22.9	***SMS***	22.73	***SMS***	22.99	***SMS***	23.02	***SMS***	22.83	***SMS***	23.22

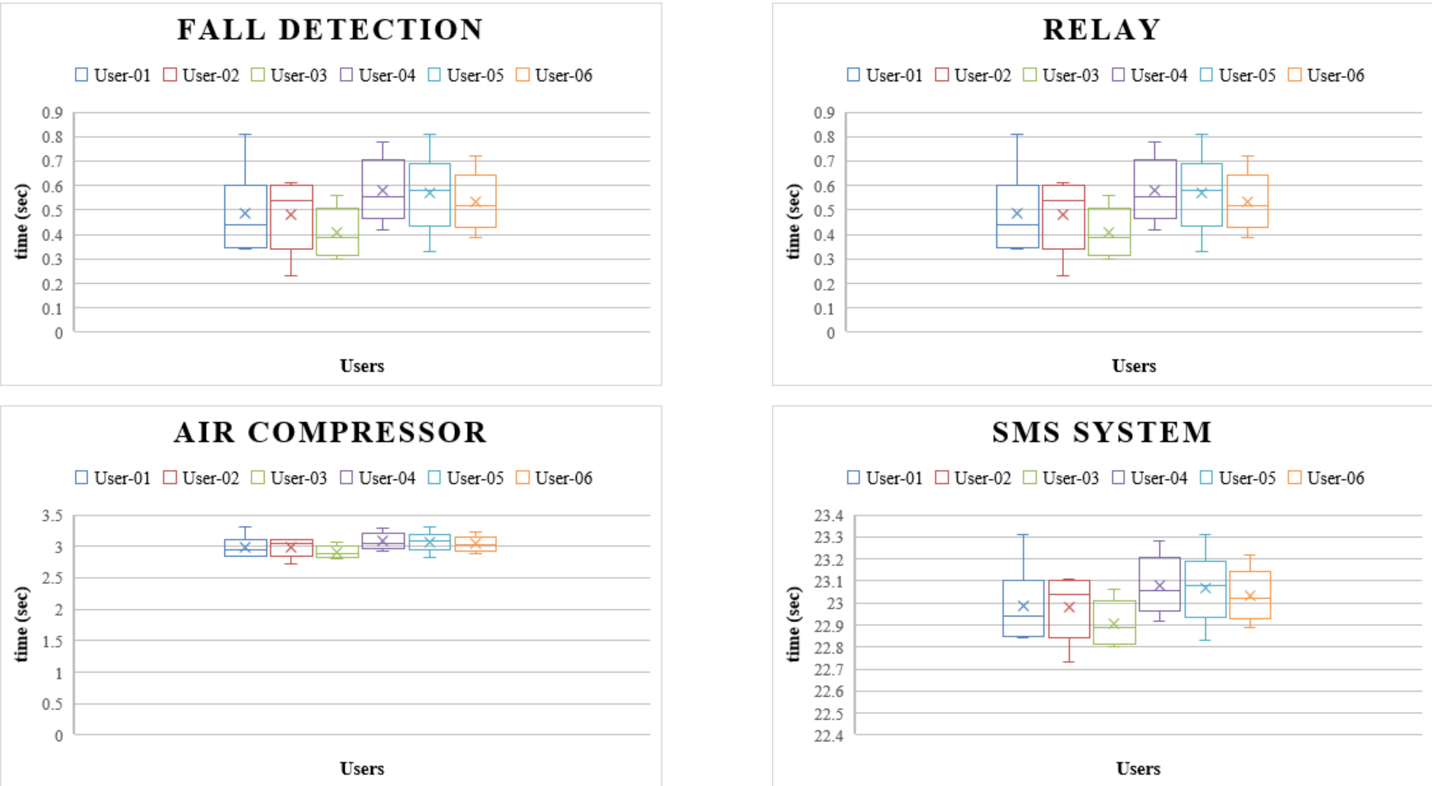


Figure 3.2.1: Fall detection, Relay, Air Compressor, Sending SMS with times (sec) for six users

Boxplot representing fall detection times (in seconds) for six different users. The 'X' marks the mean fall detection time for each user, while the box and whiskers show the interquartile range and variability in detection times.

The collected data reveals that the execution times for fall detection, LED activation, buzzer activation, and relay functions are consistent, ranging from 0.23 to 0.81 seconds, with minimal variation among users. In contrast, the air compressor operation is significantly slower, ranging from 2.73 to 3.31 seconds, primarily due to air compressor's default delay of approximately 2.5 seconds before turning on after receiving a signal from the relay. SMS sending times are the longest, consistently between 22.73 and 23.31 seconds, as the Arduino Uno R3 processes one task at a time. Overall, while fall detection and related functions perform consistently, the delays in air compressor and SMS functions suggest areas for potential optimization to enhance system efficiency.

There are two companies available on the market who are selling devices like our prototype device. Features, technology and mechanism of these devices are also quite like our prototype device. These companies are SKYVEST[11], S-Airbag Official online Store[12]. Among these two companies only S-Airbag Official Online Store[12] works for elderly people but SKYVEST[11] works only industrial workers. But some dissimilarities are also observed between our prototype device and the devices available on the market.

1. ***PRICING:*** We have priced our final device at 25,000 BDT for sale. On the other hand, at the S-Airbag Official Online Store[12], they are selling their product at $999 (in Bdt 119,193.53). Considering the price, our device is becoming very affordable in this market.
2. ***WEIGHT:*** Through the internet, we have known that people over the age of 65 can carry 7 - 10% of their body weight. Our prototype device weighs 1.2183 kg. We have used a separate air compressor in our prototype device which weighs about .516kg, but we won't use an air compressor in our final device to inflate the airbag so that its weight is likely to be reduced further. On the other hand, S-Airbag Official Online Store's[12] product weight is between 1.5-1.9 kg. In terms of weight, our final device is expected to be relatively light due to which it will be comfortable for old aged people to wear.
3. ***ALERT SYSTEM:*** Alert system of our prototype device is SMS (Short Message Service) after detecting fall where S-Airbag Official Online Store[12] provides app-based notification. Our prototype device takes approximately 20 seconds to send a text message or SMS after detecting a fall in our prototype device but the S-Airbag Official Online Store[12] is not mentioned this about.
4. ***FALL DETECTION:*** Our prototype device detects fall in between 0.3-0.5 seconds where the product from S-Airbag Official Online Store[12] detects the fall in 0.1 second. So,

this device detects the fall 0.2-0.4 seconds earlier than our prototype device. In future, we'll work on this more so that our final device can detect fall in less time.

5. ***Weight:*** According to the internet, we have come to know that people over the age of 65 can carry 7 - 10% of their body weight. Our prototype device weighs 1.2183 kg. We have used a separate air compressor in our prototype device which weighs about 0.516kg, but we won't use an air compressor in our final product to inflate the airbag so that its weight is likely to be reduced further. On the other hand, S-Airbag Official Online Store's[12] product weight is between 1.5-1.9 kg. In terms of weight, our final device is expected to be relatively light and it will be more comfortable for old aged people to wear.
6. ***Airbag Activation:*** Our prototype device turns on the relay for activating the airbag after the fall is detected in between 0.3 - 0.5 seconds. S-Airbag Official Online Store[12] declares that their airbag system deploys only in 0.08 seconds.

3.3 Finalization of Design

- ***Weight:*** The table lists the approximate weights of components used in the device, including the Arduino Uno R3, GY-521, GSM SIM800L, LED, buzzer, breadboard, relay, container, air compressor, airbag, Li-ion battery, resistor, booster module, switch, and board.

Table 3.3.1: Component Weight Breakdown for Fall Detection and Impact Minimization Device

No.	*Component's Name*	*Approx. Weight (gm)*
01.	Arduino Uno R3	25
02.	Gy-521	2
03.	GSM SIM800L	3
04.	LED	0.2
05.	Buzzer	2
06	Breadboard	80
07.	Relay	15

08.	Container	100
09.	Air Compressor	516
10.	Airbag (neck pillow)	200
11.	18650 44000mAh Li-ion Battery	60
12.	150-ohm Resistor	0.1
13.	3.7V to 5V Booster & Charging Module	10
14.	Switch	5
15.	Board	200
	Total Weight	**1218.3**

In the finalization of our device, we are transitioning from a breadboard to a custom PCB board to enhance durability and reliability. The airbag inflation mechanism will utilize CO_2 cartridges or pyrotechnic inflation mechanism for instant deployment, replacing the air compressor to reduce the device's weight and improve portability. These updates aim to provide a more efficient, user-friendly, and affordable solution for minimizing the impact of falls, ensuring the device remains accessible to normal individuals.

- ***Safety:*** Since we have used a breadboard in our prototype device, the connection wires are exposed. So, our prototype device is not safe.
- ***Fall Detection Sensor:*** The Raspberry Pi Pico is defined as a versatile microcontroller board equipped with a dual-core ARM Cortex-M0+ processor, making it suitable for various embedded applications, including fall detection systems. The article highlights that the fall detection time using the Raspberry Pi Pico is approximately 20 milliseconds. This rapid detection capability allows for quick data processing from sensors to accurately identify falls. In comparison, the Arduino Uno R3 typically experiences a fall detection time ranging from 50 to 100 milliseconds. Although the Arduino Uno R3 offers a simpler setup and lower power consumption, its slower response time makes the Raspberry Pi Pico a more effective choice for applications where immediate intervention is critical, such as monitoring the elderly or individuals with mobility challenges[42].
- ***Airbag:*** Although our prototype detects falls within seconds and the airbag activation mechanism responds swiftly, there is a delay in the rapid inflation of the airbag. To pump

the airbag (neck pillow) instantly into our device, we will need a more efficient inflation mechanism. Here are a few mechanisms,

- ***CO_2 CARTRIDGES FOR INSTANT INFLATION*:** Adding a CO2 cartridge could help reduce the weight of our system. Using a CO2 cartridge as a replacement for the air compressor could be a great way to make the system lighter and more portable. Just make sure to consider how the CO2 will be controlled and released to ensure it functions effectively for the fall detection and impact minimization. CO2 cartridges release gas at high pressure, which might be difficult to control precisely. Depending on the size of the airbag we plan to inflate, CO2 cartridges might not provide enough gas or pressure for adequate cushioning. Alternatively, too much pressure could make the inflation too rapid and uncomfortable. If our system requires precise inflation, managing this pressure can be challenging [38]. CO2 cartridges can be relatively expensive compared to other inflation methods, especially if our system needs frequent refills or replacements [39].
- ***PYROTECHNIC INFLATION MECHANISM***: Similar to how airbags in cars work, a pyrotechnic gas generator could be used to rapidly inflate the airbag upon detecting a fall. This method would require careful testing but could be quite effective for fast inflation. Generally, pyrotechnic inflation mechanisms are much lighter than air compressors. The pyrotechnic device itself is compact, and the amount of material needed for inflation is minimal. This lightweight characteristic allows for easier integration into portable or wearable systems where space and weight are crucial. Pyrotechnic mechanisms can inflate airbags extremely quickly, which is crucial in preventing injuries during sudden impacts[40].

  Pyrotechnic devices involve explosive materials, which can pose significant safety risks if not handled or deployed correctly. There are strict regulations and standards governing the use of pyrotechnic devices, which can complicate development and approval processes. Achieving certification for safety and compliance can be more challenging and costly[41].

This is why we do not use these methods in our prototype device, in future research we will use one of them to reduce the weight of our device which is convenient for elderly people to wear and the airbag is triggered immediately. We will decide to use one of these two by experimenting in the future.

3.4 USE OF MODERN ENGINEERING TOOLS

We have used several hardware and software tools for experimentation, computation, and design. The tools' applications and limitations are written here.

- ***MICROSOFT EXCEL*:** We have stored the output data from Arduino IDE in Microsoft Excel. We also plot pie charts on stakeholders' reviews using Microsoft excel. Here are some limitations of this platform:
  - ✓ We wanted to plot through Microsoft Excel but for complex functions we plotted in MATLAB instead of plotting here.
- ***ARDUINO IDE*:** We have used the Arduino Integrated Development Environment (Arduino IDE) software which is used for writing algorithms and uploading code to the Arduino board. Arduino IDE 1.8.19 version is used, which is stable and reliable.
  Here are some limitations of this platform:
  - ✓ The Arduino IDE software doesn't allow handling multiple tasks at the same time, which limits the ability to manage different events or processes simultaneously in the "Fall Detection" project.
- ***FRITZING*:** This software is used for designing electronic projects. We design the connections for the battery and GY-521 module using Fritzing.
  Here are some limitations of this platform:
  - ✓ Using fritzing software we designed the connection of gy-521 and Arduino Uno R3. We wanted to do the same connection with the GY-87 component on fritzing software but this component is missing in fritzing.
  - ✓ Fritzing's focus is on circuit design rather than simulation, so it doesn't support circuit behavior testing.

- ***MATLAB***: A very flexible and popular software platform in complex engineering. It is very effective in function plotting, algorithm development, and numerical computation. In our work, we use it for output plotting of Arduino. We use MATLAB to plot graphs based on the data obtained from the Arduino IDE software.

Limitations Of This Tool

- ✓ The latest versions require high space and high configuration to run MATLAB.
- ✓ MATLAB's startup time can be slow, especially on systems with limited resources like 8 GB of RAM. When opening a large MATLAB file, MATLAB can take additional time to initialize.

- ❖ ***PROTEUS*:** We use Proteus software to design and simulate circuits involving the GSM SIM800L module.

Here are some limitations of this tool

- ✓ We designed the SMS alert system part in Proteus using the GSM SIM900D, but we are working with the GSM SIM800L module. We didn't get GSM sim800L in proteus to design in EEE 400B so we used GSM sim900D.
- ✓ We converted our Arduino code to HEX file for the Arduino of proteus to run GSM sim 900D with Arduino uno R3 on proteus which we faced a little problem

CHAPTER 4 REVIEW OF MILESTONE ACHIEVEMENTS AND REVISION OF SCHEDULE

❖ ***PART-B***

Our planned period of “Spring 2024” for EEE400B was a total of 96 days (21 Jan, 2024 – 26 Apr, 2024). But on our authorities' decision, the “Spring 2024” semester started on January 28 and ended on May 22. We had 124 days to complete our 400B. That's why we revised our project plan for “Spring 2024” according to our semester duration.

Table 4.1: Revised Project Plan of Part–B

Activity No	*Activities*	*Predecessor*	*Duration (Days)*	*Start Date*	*Finish Date*
17.	Preliminary Project Design	16	20	28 Jan, 2024	16 Feb, 2024
18.	Analysis Alternate Solutions **[Milestone – 05]**	17	32	17 Feb, 2024	20 March, 2024
19.	Design System Circuit **[Milestone – 06]**	17, 18	44	21 Mar, 2024	2 May, 2024
20.	Preparing Full Prototype Design of the Device **[Milestone – 07]**	19	18	3 May, 2024	20 May, 2024
21.	Preparing Report & Submission	20	2	21 May, 2024	22 May, 2024
		Total Days	116 Days (28 January, 2024 – 22 May, 2024)		

❖ ***PART-C***

Our planned period of “Summer 2024” for EEE400C was a total of 104 days (13 May, 2024 – 24 Aug, 2024). But on our authorities' decision, the “Summer 2024” semester turned into “Short Semester”. Thats why we got only two months (30 Jun, 2024 – 19 Aug, 2024) to complete EEE400C. We started our work according to this schedule. But because of the unstable situation in our country, our authority announced the decision to close our university. So our university was closed for one month and reopened on 18

Aug, 2024. As result our schedule changes and our work is postponed. That's why we revised our project plan for “Summer 2024” according to our semester duration.

Table 4.2: Revised Project Plan of Part–C

Activity No	*Activities*	*Predecessor*	*Duration (Days)*	*Start Date*	*Finish Date*
22.	Find Out the Equipment for the Device	21	17	30 Jun, 2024	16 Jun, 2024
23.	Purchase Equipment’s	22	04	19 Aug, 2024	22 Aug, 2024
24.	Design Android Mobile App / SMS System **[Milestone – 08]**	20	03	23 Aug, 2024	25 Aug, 2024
25.	Implementation **[Milestone – 09]**	24	08	26 Aug, 2024	2 Sept, 2024
26.	Analysis the Performance of the Device	24, 25	03	03 Sept, 2024	05 Sept, 2024
27.	Finalizing the Design According to the Device Performance **[Milestone – 10]**	26	07	06 Sept, 2024	12 Sept, 2024
28.	Economic Analysis	23	02	13 Sept, 2024	14 Sept, 2024
29.	Verification of Complex Engineering Problem **[Milestone – 11]**	28	02	15 Sept, 2024	16 Sept, 2024
30.	Report Preparing and Submission	29	02	22 Sept, 2024	23 Sept, 2024
31.	Preparation for Project Presentation	30	14	24 Sept, 2024	07 Oct, 2024
	Total Days	62 Days (30 June, 2024 – 07 October, 2024)			

We have identified 11 milestones in part A of our project and assigned a time frame for each activity. While some milestones were completed on schedule, others were delayed due to various reasons.

The table below shows the number of milestones achieved on time and those that were delayed.

Table 4.3: Review of Milestones

Milestone No.	*Expected Date*			*Actuated Date*			*On Time / Delay*
	Start Date	*End Date*	*Duration*	*Start Date*	*End Date*	*Duration*	
PART - A							
01	01 Oct, 23	05 Oct, 23	05	01 Oct, 23	05 Oct, 23	05	On Time
02	06 Oct, 23	19 Oct, 23	14	06 Oct, 23	19 Oct, 23	14	On Time
03	02 Dec, 23	10 Dec, 23	09	02 Dec, 23	10 Dec, 23	09	On Time
04	02 Dec, 23	10 Dec, 23	09	02 Dec, 23	10 Dec, 23	09	On Time
PART - B							
05	01 Feb, 24	28 Feb, 24	28	17 Feb, 24	20 Mar, 24	32	Delay
06	01 Feb, 24	15 Mar, 24	43	21 Mar, 24	02 May, 24	44	Delay
07	16 Mar, 2024	15 Apr, 24	31	03 May, 24	20 May, 24	18	Delay
PART - C							
08	27 May, 24	09 Jul, 24	44	23 Aug, 24	25 Aug, 24	03	Delay
09	27 May, 24	09 Jul, 24	44	26 Aug, 24	02 Sept, 24	08	Delay
10	25 Jul, 24	08 Aug, 24	15	06 Sept, 24	12 Sept, 24	07	Delay
11	16 Aug, 24	20 Aug, 24	06	15 Sept, 24	16 Sept, 24	01	Delay

CHAPTER 5 COST OF SOLUTION AND ECONOMIC ANALYSIS

5.1 BILL OF MATERIALS COST OF SOLUTION

The cost of the prototype is outlined below:

Table 5.1.1: Prototype Equipment Cost

SL No.	*Equipment's Name*	*Amount (BDT)*
01.	Breadboard	110
02.	Jumper MTOMF	140
03.	GSM Sim 800L	380
04.	MPU-6050 module	250
05.	Raspberry Pi Pico	870
06.	Neck Rest Pillow (Airbag)	238
07.	PVC Copper Wire	350
08.	Soldering Wire	180
09.	Glue Gun Stick	200
10.	Dupont Connector	400
11.	Foam	200
12.	18650 44000mAh Li-ion Battery	700
13.	Buzzer	30
14.	Switch	30
15.	5V Relay	90
16.	3.7V to 5V Booster & Charging Module	600
17.	Red LED	5
18.	150-ohm Resistor	5
19.	Black PVC Tape	15
20.	Cable Ties	60
21.	Male USB A Module	90
22.	Mini Air Compressor	3600
23.	Jacket	130
24.	Belt	160
23.	Container	120
24.	Travel & Other Expenses	3200
	Total	12,153

Form the source,[24]

Retail price × 0.6 = Wholesale price

Wholesale price of the prototype is, 12,153 × 0.6 = 7,291.8 BDT

NPV is a financial metric used to evaluate the profitability of a project. It represents the difference between the present value of cash inflows and the present value of cash outflows over a period. To bring our product to market and establish the business in the market, a detailed economic analysis is essential. We have conducted a calculation to determine the Net Present Value (NPV) of our device.

5.2 ECONOMIC ANALYSIS

Here is the estimated monthly cost for operating and maintaining our system:

- ***OPERATIONAL COST***

Table 5.2.1: Employee Salaries Overview

DESIGNATION OF EMPLOYEES	SALARY PER MONTH (BDT)	NUMBER OF EMPLOYEES	AMOUNT (BDT)
Manager	25,000	1	25,000
Engineers	20,000	2	40,000
Technician	8,000	2	16,000
Salesman	8,000	4	32,000
Advertisement	2,000	---	2,000
		TOTAL	115,000

- ***MAINTENANCE COST***

Table 5.2.2: Monthly Costs Overview

DESCRIPTIONS	RENT PER MONTH (BDT)
Office Rent	25,000
Security	6,000
Utility Bills	10,000
Others	5,000
TOTAL	**46,000**

➢ ***TAX FEES***

Table 5.2.3: Yearly Fees Overview

DESCRIPTIONS	FEES PER YEAR (BDT)
Trade License Fee	2,000
License Fee	60,000
TOTAL	62,000

Our production cost for each device is 7,291.8 BDT per unit.

Bangladesh has approximately 5,816 hospitals. A large household survey covering a population of approximately 1.16 million people in 51 unions of Bangladesh to assess the burden of all injuries, including falls. The South-East Asia region has the highest injury mortality rate (80 per 100,000) of elderly people dying from falls. Falls are the second leading cause of unintentional injury deaths, and the 13th leading cause of global years lived with disability[25]. As falling is a serious problem in Bangladesh. So, we started to produce this device. In the beginning of this project, we are planning to produce 1,000 units annually. Then slowly we will increase production according to the demand.

Total annual expenditure = (161,000 × 12) + (7,219.8 × 1000) + 62,000

= 9,285,800 BDT/year

Product selling price = 15,000 BDT

Per year sell = 15,000 × 1000 = 15,000,000BDT

Present Value Function (PVF):

$$PVF(d,n) = \frac{(1+d)^n - 1}{d(1+d)^n}$$

Discount rate[26], d = 5.5%

Interest rate[26], i = 8.50%

Inflation rate[27], r = 9.20%

n= 10 years

Now,

$$PVF(d,n) = \frac{(1+d)^n - 1}{d(1+d)^n}$$

$$= \frac{(1+0.055)^{10}-1}{0.04(1+0.055)^{10}} = 7.537 \text{ years}$$

Capital Recovery Factor (CRF):

$$CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n-1}$$

$$CRF(8.50\%, 10) = \frac{0.085(1+0.085)^n}{(1+0.085)^n-1} = 0.152$$

Annual loan Payment, A= P*CRF (i, n)

Here, P =annual expense or capital cost = 9,285,800 BDT/year

A = 9,285,800*0.152 = 1,4,11,441.6 BDT/year

Annual saving, ΔA= 15,000,000 – 1,4,11,441.6 – 9,285,800

= 4,302,758.4 BDT/year

Initial first cost, ΔP = 9,285,800 BDT/year

Simple payback period $= \frac{\Delta P}{\Delta A} = \frac{9,285,800}{4,302,758.4} = 2.158$ years

Table 5.2.4 Chart to estimate the Internal Rate Return

Life (years)	9%	11%	13%	15%	17%	19%	21%	23%	25%	27%	29%	31%	33%	35%	37%	39%
1	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.81	0.80	0.79	0.78	0.76	0.75	0.74	0.73	0.72
2	1.76	1.71	1.67	1.63	1.59	1.55	1.51	1.47	1.44	1.41	1.38	1.35	1.32	1.29	1.26	1.24
3	2.53	2.44	2.36	2.28	2.21	2.14	2.07	2.01	1.95	1.90	1.84	1.79	1.74	1.70	1.65	1.61
4	3.24	3.10	2.97	2.85	2.74	2.64	2.54	2.45	2.36	2.28	2.20	2.13	2.06	2.00	1.94	1.88
5	3.89	3.70	3.52	3.35	3.20	3.06	2.93	2.80	2.69	2.58	2.48	2.39	2.30	2.22	2.14	2.07
6	4.49	4.23	4.00	3.78	3.59	3.41	3.24	3.09	2.95	2.82	2.70	2.59	2.48	2.39	2.29	2.21
7	5.03	4.71	4.42	4.16	3.92	3.71	3.51	3.33	3.16	3.01	2.87	2.74	2.62	2.51	2.40	2.31
8	5.53	5.15	4.80	4.49	4.21	3.95	3.73	3.52	3.33	3.16	3.00	2.85	2.72	2.60	2.48	2.38
9	6.00	5.54	5.13	4.77	4.45	4.16	3.91	3.67	3.46	3.27	3.10	2.94	2.80	2.67	2.54	2.43
10	6.42	5.89	5.43	5.02	4.66	4.34	4.05	3.80	3.57	3.36	3.18	3.01	2.86	2.72	2.59	2.47
15	8.06	7.19	6.46	5.85	5.32	4.88	4.49	4.15	3.86	3.60	3.37	3.17	2.99	2.83	2.68	2.55
20	9.13	7.96	7.02	6.26	5.63	5.10	4.66	4.28	3.95	3.67	3.43	3.21	3.02	2.85	2.70	2.56
25	9.82	8.42	7.33	6.46	5.77	5.20	4.72	4.32	3.98	3.69	3.44	3.22	3.03	2.86	2.70	2.56
30	10.27	8.69	7.50	6.57	5.83	5.23	4.75	4.34	4.00	3.70	3.45	3.22	3.03	2.86	2.70	2.56

[a]Enter the row corresponding to project life, and move across until values close to the simple payback period, $\Delta P/\Delta A$, are reached. IRR is the interest rate in that column. For example, a 10-year project with a 5-year payback has an internal rate of return of just over 15%.

Here, the simple payback period is 2.158 which is nearly 2.14. So, according to the chart we get

IRR = 19% for n = 10 years.

Now, Our Net present Value (NPV), NPV = $\Delta A \times PVF\ (d, n) - \Delta P$

$$= 4,302,758 \times 8.11 - 9,285,800$$

$$= 25,609,570.624 \text{ BDT}$$

Here, the Net Present Value of this business is positive. So, we can say that the business is profitable.

The NPV of **25,609,570.624 BDT** indicates the project is profitable. Because a positive NPV means that the present value of expected future cash inflows exceeds the initial investment or costs. In this case, our NPV of **25,609,570.624 BDT** means that the project or investment will generate **25,609,570.624 BDT** more in value than it costs. When NPV > 0, it suggests that the investment will create additional value and is expected to improve wealth. NPV of **25,609,570.624 BDT** indicates the total expected profit in present value terms after covering all costs and considering the discount rate. So, we understand from this analysis that our device is perfect as pricing and for starting the business plan.

CHAPTER 6 CONCLUSION

6.1 VERIFICATION OF COMPLEX ENGINEERING PROBLEM

Our project has fulfilled 3 complex engineering problems,

- ***P1: DEPTH OF KNOWLEDGE REQUIRED***
  - ✓ ***K3(KNOWLEDGE OF ENGINEERING FUNDAMENTAL)*:** For our project, we had to integrate several areas of engineering. The fall detection component required us to have a strong grasp of sensor technology and signal processing to accurately identify potential falls. We utilized basic circuit analysis and numerical methods to design and optimize the detection system. Additionally, understanding control systems was crucial for developing the response mechanism that activates during a fall. On the impact minimization side, knowledge of materials science and biomechanics was essential to design protective measures that effectively reduce injury risks. This project demanded a multidisciplinary approach, combining electronics, mechanics, and control systems to create a comprehensive solution.
  - ✓ ***K4(ENGINEERING SPECIALIST KNOWLEDGE)*:** For our project, we have a small processing unit for providing logical decisions to detect fall and to send signal to impact minimization unit. For this we have to solve power issues and need a risk free, efficient, durable and light weight power source as this device will be attached to the human body, so we need better knowledge of power electronics.
  - ✓ ***K6(KNOWLEDGE OF ENGINEERING TOOLS)*:** For our Project, we used ISIS 7 Professional (Proteus), Fritzing, Gimp 2.10.36, Arduino IDE and MATLAB in the different parts of our project. We used Gimp 2.10.36 for our final product design, Professional (Proteus) & Fritzing used for circuit design and for plotting graphs we used MATLAB.
  - ✓ ***K8(ENGINEERING RESEARCH KNOWLEDGE)*:** To determine the feasibility of our method for developing this our project, we extensively reviewed journals and research papers. The literature review helped us identify three potential alternatives based on existing research. This research was essential not only for analyzing the solutions but also for designing and constructing the system effectively.

- ***P3: Depth of Analysis Required*:** We have analyzed the accuracy and reliability of sensors. We have considered the design and placement of airbags to protect sensitive areas. We have ensured that the system reliably sends notifications to caregivers. We have analyzed the battery backup and power usage of our system. Finally, the most important analysis is the market demand for this type of device.
- ***P7: Interdependence*:** We have divided our project into three subsystems: "Fall Detection System", "Fall Impact Minimization System" and "SMS System". Our device will detect the fall when an elderly person is going to fall on the ground and immediately activate the airbag and send SMS to the caregiver and family members.

6.2 Meeting the Project Objectives

Our project has demonstrated the potential for creating a reliable solution to mitigate the risks associated with falls. Our focus for the development of this project is to help older people walk independently, not be dependent. When our prototype device detects a possibility of fall, it will immediately activate the relay of the airbag and send an alert message to family members and caregivers through SMS. A limitation of our device is that we used a mini air compressor to pump the airbag in the prototype. Since we used it due to budget constraints, the airbag takes 20 sec to pump but the airbag relay activates as soon as it detects a fall. Another limitation we have is the weight of the device. Because our focus is on old aged people, the weight must be low so that they can easily wear this device and walk around. Since our device is a prototype, its weight is relatively high. Later we must manage to reduce it. We have considered the impact on society, the environment & health and safety. We must improve our device and be more careful about the airbag because in real life if the airbag is not activated on time, it can cause major problems.

APPENDIX

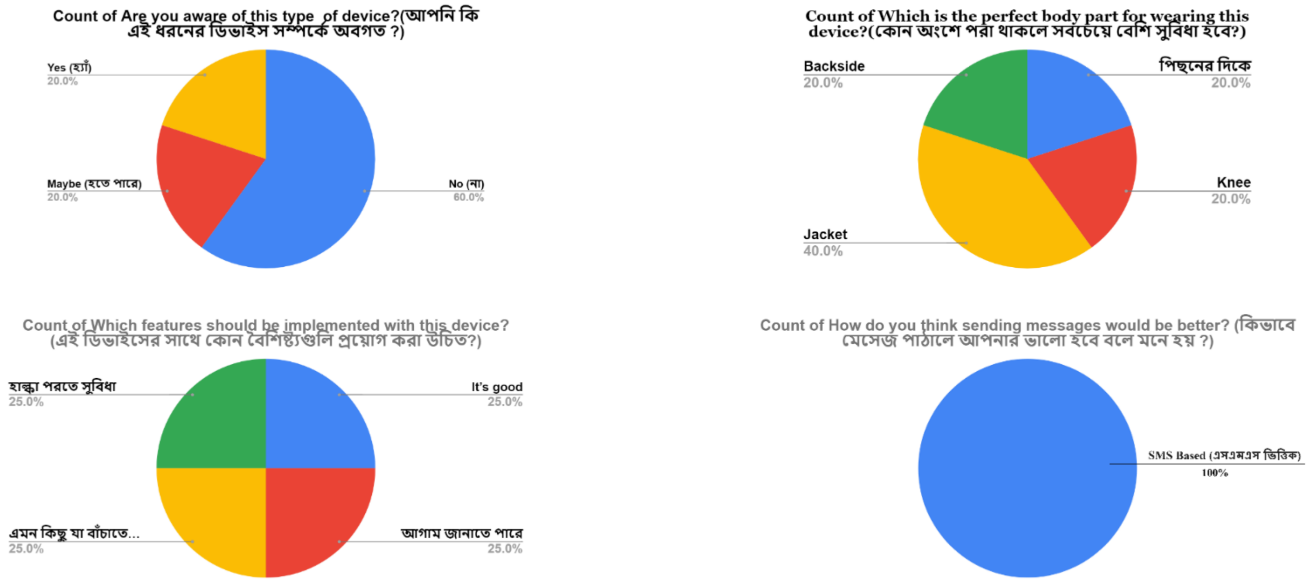
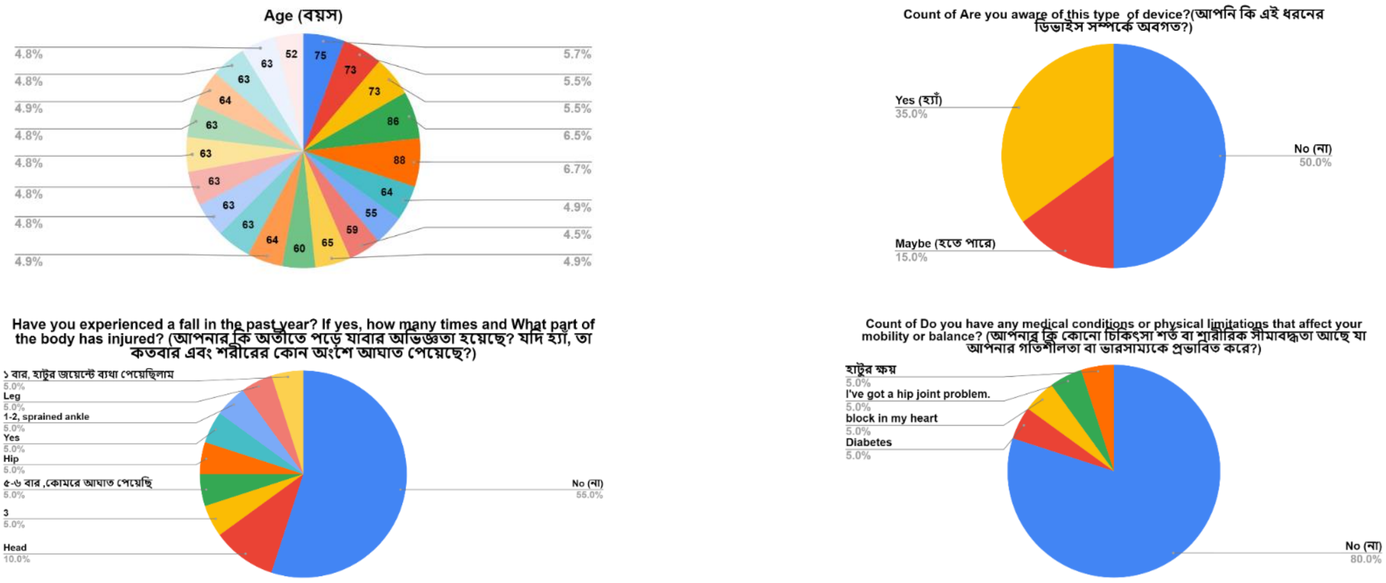


Figure App. 01: Responses of Stakeholders (Specialists)



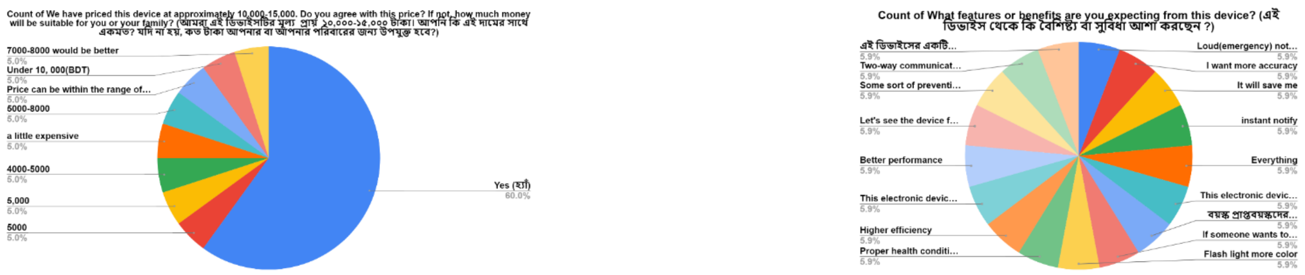


Figure App. 02: Responses of Stakeholders (Old Aged People)

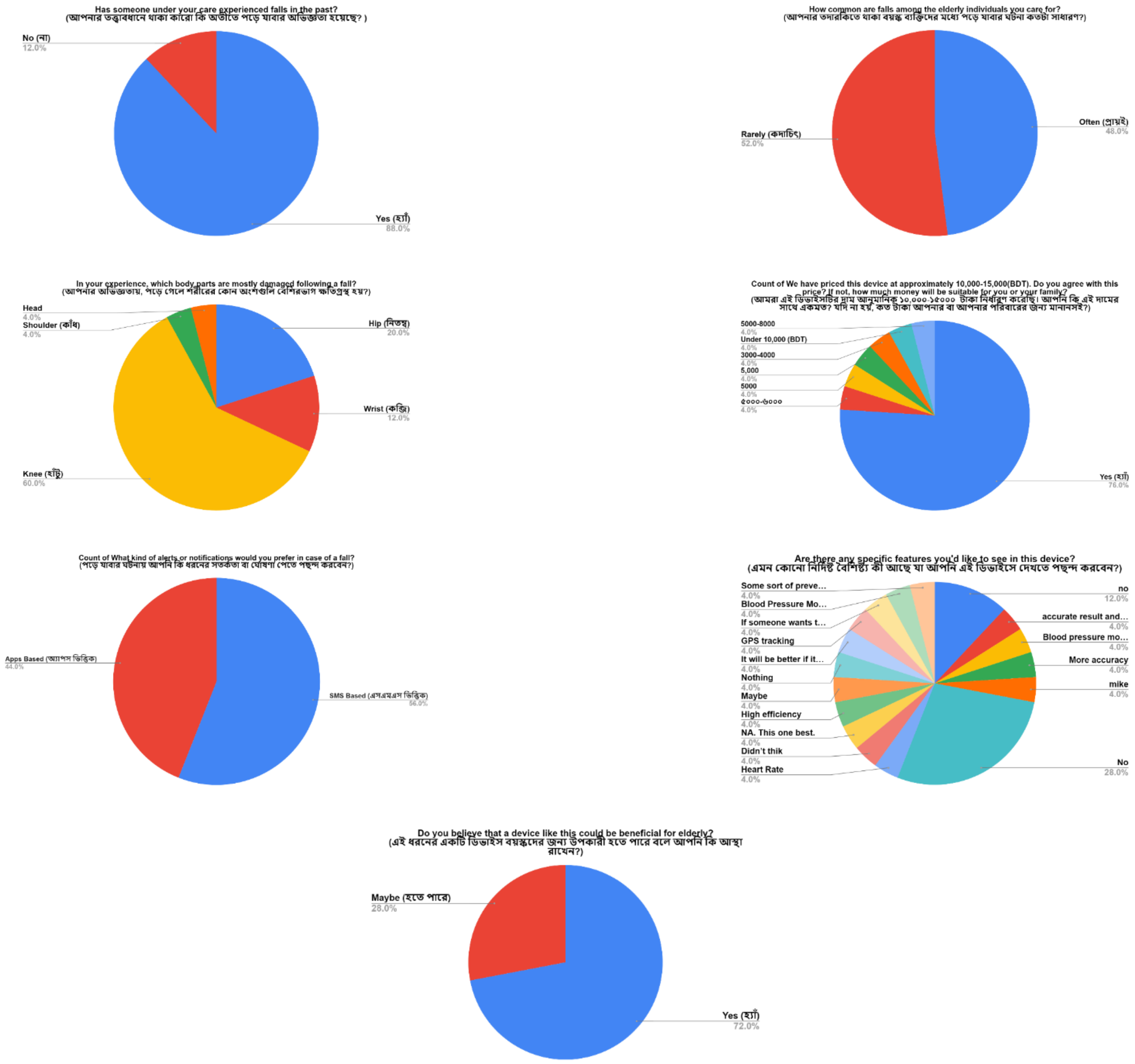


Figure App. 03: Responses of Stakeholders (Caregivers)

APPENDIX A. ACTIVITY CHART

PART – A

Table App. A. 01: Project Timeline and Activity Log of Part–A

DATE	PARTICIPANTS	ACTIVITY DESCRIPTION	APPROX. HRS. SPENT
25 September, 2023	Everyone	Topic Selection & Initial Research	3
26 September, 2023	Everyone	Topic Selection & Initial Research	3
27 September, 2023	Everyone	Topic Selection & Initial Research	3
28 September, 2023	Everyone	Topic Selection & Initial Research	3
29 September, 2023	Everyone	Topic Selection & Initial Research	3
30 September, 2023	Everyone	Topic Selection & Initial Research	3
01 October, 2023	Everyone	Discussing with Supervisor & Getting Approval from the Supervisor	0.5
02 October, 2023	Everyone	Discussing with Supervisor & Getting Approval from the Supervisor	0.5
03 October, 2023	Everyone	Discussing with Supervisor & Getting Approval from the Supervisor	0.5
04 October, 2023	Everyone	Discussing with Supervisor & Getting Approval from the Supervisor	0.5
05 October, 2023	Everyone	Discussing with Supervisor & Getting Approval from the Supervisor	0.5
19 October, 2023	Everyone	Getting Approval from the Dept. EEE	0.5
20 October, 2023	Ifty, Asif	Literature Review	02
21 October, 2023	Ifty, Asif	Literature Review	02
22 October, 2023	Ifty, Asif	Literature Review	02
23 October, 2023	Ifty, Asif	Literature Review	02
24 October, 2023	Ifty, Asif	Literature Review	02
25 October, 2023	Rohit	Analysis Social Impact	01
26 October, 2023	Rohit	Analysis Social Impact	01
28 October, 2023	Everyone	Identifying Stakeholders & Preparing Questions for Stakeholder	01

29 October, 2023	Everyone	Identifying Stakeholders & Preparing Questions for Stakeholder	01
30 October, 2023	Everyone	Identifying Stakeholders & Preparing Questions for Stakeholder	01
31 October, 2023	Everyone	Identifying Stakeholders & Preparing Questions for Stakeholder	01
10 November, 2023	Everyone	Taking Feedback from the Stakeholders	02
11 November, 2023	Everyone	Taking Feedback from the Stakeholders	02
12 November, 2023	Everyone	Taking Feedback from the Stakeholders	02
13 November, 2023	Everyone	Taking Feedback from the Stakeholders	02
14 November, 2023	Everyone	Taking Feedback from the Stakeholders	02
21 November, 2023	Rohit	Preparing Project Plan	02
22 November, 2023	Rohit	Preparing Project Plan	02
02 December, 2023	Rohit	Identifying Standard Code of Practice	02
03 December, 2023	Rohit	Identifying Standard Code of Practice	02
06 December, 2023	Ifty	Effects on Environment, Sustainability, Health & Safety Issue	02
07 December, 2023	Ifty	Effects on Environment, Sustainability, Health & Safety Issue	02
08 December, 2023	Ifty	Effects on Environment, Sustainability, Health & Safety Issue	02
09 December, 2023	Arpon	Risk Management	02
016December, 2023	Arpon	Risk Management	02
11 December, 2023	Rohit	Project Requirements Finalizations	01
12 December, 2023	Rohit	Project Requirements Finalizations	01
13 December, 2023	Rohit	Project Resource List & Budget Analysis	01
14 December, 2023	Rohit	Project Resource List & Budget Analysis	01
17 December, 2023	Rohit	Project Specification & Local Market Analysis	01
18 December, 2023	Rohit	Project Specification & Local Market Analysis	01
20 December, 2023	Arpon	Product Life Cycle	02
21 December, 2023	Arpon	Product Life Cycle	02
09 January, 2024	Rohit	Report Preparing	01
10 January, 2024	Rohit	Report Preparing	01
11 January, 2024	Rohit	Report Preparing & Report Submission	01

PART – B

Table App. A. 02: Project Timeline and Activity Log of Part–B

Date	Participants	Activity Description	Approx. hrs. spent
16 January, 2024	Arpon, Rohit	Discussed about EEE400B with supervisor	0.5
20 January, 2024	Everyone	Functional Design	01
21 January, 2024	Everyone	Functional Design	01
22 January, 2024	Everyone	Functional Design	02
23 January, 2024	Everyone	Functional Design	01
09 February, 2024	Rohit	Design Final Device Design	01
10 February, 2024	Rohit	Design Final Device Design	01
20 February, 2024	Everyone	Go to Market	03
08 March, 2024	Rohit	GSM Message System (Simulation)	02
10 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
11 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
12 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
13 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
14 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
15 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
16 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
17 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
18 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
19 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
20 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
21 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
22 March, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
04 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
05 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
06 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
07 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
08 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01

09 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
10 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
11 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
12 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
13 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
24 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
25 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
26 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
27 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
28 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
29 April, 2024	Rohit, Ifty, Arpon	Analysis of Alternate Solutions	01
18 May, 2024	Rohit	Refined Design	01
19 May, 2024	Rohit	Refined Design	01
20 May, 2024	Rohit	Refined Design	01
21 May, 2024	Rohit	Refined Design	01
22 May, 2024	Rohit	Refined Design	01
27 May, 2024	Rohit	Preparing Report	02
28 May, 2024	Rohit	Preparing Report & Report Submission	0.5

PART – C

Table App. A. 03: Project Timeline and Activity Log of Part–C

Date	Participants	Activity Description	Approx. hrs. spent
11 June, 2024	Everyone	Go to Market	04
21 June, 2024	Everyone	Make Device (Only Fall Detection)	03
22 June, 2024	Everyone	Make Device (Only Fall Detection)	03
23 June, 2024	Everyone	Make Device (Only Fall Detection)	03
24 June, 2024	Everyone	Make Device (Only Fall Detection)	03
25 June, 2024	Everyone	Make Device (Only Fall Detection)	03
26 June, 2024	Everyone	Make Device (Only Fall Detection)	03
27 June, 2024	Everyone	Make Device (Only Fall Detection)	03
13 July, 2024	Everyone	Make Device (GSM System)	03
14 July, 2024	Everyone	Make Device (Relay)	03
15 July, 2024	Everyone	Make Device (Relay)	03
16 July, 2024	Everyone	Make Device (Relay)	03
23 August, 2024	Everyone	Go to Market	02
28 August, 2024	Everyone	Go to Market	04
27 August, 2024	Everyone	Go to Market	02
29 August, 2024	Arpon, Rohit, Asif	Go to Market	05
30 August, 2024	Everyone	Make Device (Airbag)	02
31 August, 2024	Everyone	Make Device (Airbag)	02
01 September, 2024	Everyone	Make Device (Airbag)	02
04 September, 2024	Rohit	Go to Market	01
05 September, 2024	Everyone	Fix Full Device	04
06 September, 2024	Rohit	Fix Full Device	02
07 September, 2024	Rohit, Ifty	Development of Prototype (Fall Detection + Fall Impact Minimization System)	02
08 September, 2024	Rohit, Ifty	Development of Prototype (Fall Impact Minimization System + Alert System)	04
09 September, 2024	Rohit, Arpon	Development of Prototype (Power Consumption)	02

10 September, 2024	Rohit	Finalization of Design	03
11 September, 2024	Rohit	Finalization of Design	01
	Rohit, Ifty	Verification of Complex Engineering Problem	02
12 September, 2024	Rohit	Use of Modern Engineering Tools	01
	Rohit	Meeting Project Objectives	02
13 September, 2024	Arpon, Rohit	Cost of Solution and Economic Analysis	01
14 September, 2024	Arpon	Cost of Solution and Economic Analysis	03
	Rohit	Review of Milestone Achievements and Revision of Schedule	02
15 September, 2024	Rohit	Use of Modern Engineering Tools	01
	Everyone	Performance Evaluation of Implemented Solution Against Design Requirement	03
16 September, 2024	Arpon	Economic Analysis	02
	Rohit	Performance Evaluation of Implemented Solution Against Design Requirement (writing)	02
17 September, 2024	Rohit	Performance Evaluation of Implemented Solution Against Design Requirement (writing)	01
		Use of Modern Engineering Tools	01
		Executive Summary	01
19 September, 2024	Rohit	Corrections & Executive Summary	02
20 September, 2024	Ifty	Executive Summary	01
21 September, 2024	Rohit	Preparing Report	02
22 September, 2024	Rohit	Performance Evaluation of Implemented Solution (Plot)	03
23 September, 2024	Ifty, Rohit	Performance Evaluation of Implemented Solution	04
		Finalization of Design	
24 September, 2024	Rohit	Preparing Report & Submit Final Report	0.5

APPENDIX B. OTHER TECHNICAL DETAILS

APPENDIX B .1 QUESTIONNAIRE FOR OLD AGED PEOPLE

1. Age (বয়স)__________________
2. Are you aware of this type of device? (আপনি কি এই ধরনের ডিভাইস সম্পর্কে অবগত?)
   - Yes (হ্যাঁ)
   - No (না)
   - Maybe (হতে পারে)

3. Have you experienced a fall in the past year? If yes, how many times and What part of the body has injured? (আপনার কি অতীতে পড়ে যাবার অভিজ্ঞতা হয়েছে? যদি হ্যাঁ, তা কতবার এবং শরীরের কোন অংশে আঘাত পেয়েছে?)
   - No (না)
   - (other) ____
4. Do you have any medical conditions or physical limitations that affect your mobility or balance? (আপনার কি কোনো চিকিৎসা শর্ত বা শারীরিক সীমাবদ্ধতা আছে যা আপনার গতিশীলতা বা ভারসাম্যকে প্রভাবিত করে?)
   - No (না)
   - (other) ____
5. How comfortable are you with technology and devices like wearable technology? (পরিধানযোগ্য প্রযুক্তির মতো প্রযুক্তি এবং ডিভাইসগুলির সাথে আপনি কতটা স্বচ্ছন্দ?) ____
6. We have priced this device at approximately 10,000-15,000. Do you agree with this price? If not, how much money will be suitable for you or your family? (আমরা এই ডিভাইসটির মূল্য প্রায় ১০,০০০-১৫,০০০ টাকা। আপনি কি এই দামের সাথে একমত? যদি না হয়, কত টাকা আপনার বা আপনার পরিবারের জন্য উপযুক্ত হবে?)
   - a. Yes (হ্যাঁ)
   - (other) ____
7. What features or benefits are you expecting from this device? (এই ডিভাইস থেকে কি বৈশিষ্ট্য বা সুবিধা আশা করছেন ?) ____

APPENDIX B .2 QUESTIONNAIRE FOR CAREGIVERS

1. Has someone under your care experienced falls in the past? (আপনার তত্ত্বাবধানে থাকা কারো কি অতীতে পড়ে যাবার অভিজ্ঞতা হয়েছে?)
    - Yes (হ্যাঁ)
    - No (না)
2. How common are falls among the elderly individuals you care for? (আপনার তদারকিতে থাকা বয়স্ক ব্যক্তিদের মধ্যে পড়ে যাবার ঘটনা কতটা সাধারণ?)
    - Rarely (কদাচিৎ)
    - Often (প্রায়ই)
3. In your experience, which body parts are mostly damaged following a fall? (আপনার অভিজ্ঞতায়, পড়ে গেলে শরীরের কোন অংশগুলি বেশিরভাগ ক্ষতিগ্রস্থ হয়?)
    - Hip (নিতম্ব)
    - Knee (হাঁটু)
    - Elbow(কনুই)
    - Wrist (কব্জি)
    - Shoulder (কাঁধ)
    - (others)______________
4. We have priced this device at approximately 10,000-15,000(BDT). Do you agree with this price? If not, how much money will be suitable for you or your family? (আমরা এই ডিভাইসটির দাম আনুমানিক ১০,০০০-১৫০০০ টাকা নির্ধারণ করেছি। আপনি কি এই দামের সাথে একমত? যদি না হয়, কত টাকা আপনার বা আপনার পরিবারের জন্য মানানসই?)
    - a. Yes (হ্যাঁ)
    - (other) _______________________________________
5. What kind of alerts or notifications would you prefer in case of a fall? (পড়ে যাবার ঘটনায় আপনি কি ধরনের সতর্কতা বা ঘোষণা পেতে পছন্দ করবেন?)
    - SMS Based (এসএমএস ভিত্তিক)
    - Apps Based (অ্যাপস ভিত্তিক)
6. Are there any specific features you'd like to see in this device? (এমন কোনো নির্দিষ্ট বৈশিষ্ট্য কী আছে যা আপনি এই ডিভাইসে দেখতে পছন্দ করবেন?)

    ____
7. Do you believe that a device like this could be beneficial for elderly? (এই ধরনের একটি ডিভাইস বয়স্কদের জন্য উপকারী হতে পারে বলে আপনি কি আস্থা রাখেন?)
    - Yes (হ্যাঁ)
    - No (না)
    - Maybe (হতে পারে)

APPENDIX B .3 QUESTIONNAIRE FOR SPECIALISTS

1. Age (বয়স)__________________
2. Profession (পেশা)
    - Doctor (ডাক্তার)
    - Therapist (থেরাপিস্ট)
3. Write the name of your workplace. (আপনার কর্মস্থলের নাম লিখুন।)
   ____
4. Are you aware of this type of device? (আপনি কি এই ধরনের ডিভাইস সম্পর্কে অবগত?)
    - Yes (হ্যাঁ)
    - No (না)
    - Maybe (হতে পারে)
5. Which injuries or fractures are common due to falls? (পড়ে যাওয়ার কারণে সাধারণত কোন ধরণের আঘাত বা ফ্র্যাকচার হয়ে থাকে?) ____
6. Which is the perfect body part for wearing this device? (কোন অংশে পরা থাকলে সবচেয়ে বেশি সুবিধা হবে?) ____
7. Which features should be implemented with this device? (এই ডিভাইসের সাথে কোন বৈশিষ্ট্যগুলি প্রয়োগ করা উচিত?) ____
8. How do you think sending messages would be better? (কিভাবে মেসেজ পাঠালে আপনার ভালো হবে বলে মনে হয়?)
    - SMS Based (এসএমএস ভিত্তিক)
    - Apps Based (অ্যাপস ভিত্তিক)

APPENDIX B .4 CODE OF ACCELEROMETER SENSOR & GYROSCOPE SENSOR

```
#include <Wire.h>
#include <SoftwareSerial.h>
SoftwareSerial mySerial(9, 10);// SIM800L TXD and RXD pin to arduino pin 9 and 10

const int MPU_addr = 0x68;  // I2C address of the MPU-6050
int16_t AcX, AcY, AcZ, Tmp, GyX, GyY, GyZ;
float ax = 0, ay = 0, az = 0, gx = 0, gy = 0, gz = 0;
boolean fall = false; //stores if a fall has occurred
boolean trigger1 = false; //stores if first trigger (lower threshold) has occurred
boolean trigger2 = false; //stores if second trigger (upper threshold) has occurred
boolean trigger3 = false; //stores if third trigger (orientation change) has occurred
byte trigger1count = 0; //stores the counts past since trigger 1 was set true
byte trigger2count = 0; //stores the counts past since trigger 2 was set true
byte trigger3count = 0; //stores the counts past since trigger 3 was set true
int angleChange = 0;

const int LED = 2;
const int Buzzer = 3;
const int Airbag = 4;
void setup()
{
  mySerial.begin(9600);
  Serial.begin(9600);
  Wire.begin();
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x6B);  // PWR_MGMT_1 register
  Wire.write(0);     // set to zero (wakes up the MPU-6050)
  Wire.endTransmission(true);
  Serial.println("Wrote to IMU");

  pinMode(LED, OUTPUT);
  pinMode(Buzzer, OUTPUT);
  pinMode(Airbag, OUTPUT);
  }
void loop()
{
  mpu_read();
```

```
ax = (AcX - 2050) / 16384.00;
ay = (AcY - 77) / 16384.00;
az = (AcZ - 1947) / 16384.00;
gx = (GyX + 270) / 131.07;
gy = (GyY - 351) / 131.07;
gz = (GyZ + 136) / 131.07;

// calculating Amplitude vector for 3 axes
float Raw_Amp = pow(pow(ax, 2) + pow(ay, 2) + pow(az, 2), 0.5);
int Amp = Raw_Amp * 10;  // Multiplied by 10 because values are between 0 to 1
Serial.println(Amp);

angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
Serial.println(angleChange);
if (Amp >= 11 && (angleChange >= 150) && (angleChange <= 400))
{ // if orientation changes remain between 0-10 degrees
  Serial.println(angleChange);

  digitalWrite(LED, HIGH);
  tone(Buzzer, 4000);
  digitalWrite(Airbag, HIGH);
  delay(1500);
  digitalWrite(Airbag, LOW);
  delay(2000);
  digitalWrite(Airbag, HIGH);
  delay(100);
  digitalWrite(Airbag, LOW);
  delay(20000);
  digitalWrite(Airbag, HIGH);
  delay(1500);
  digitalWrite(Airbag, LOW);

  mySerial.println("AT+CMGF=1");    //To send SMS in Text Mode
  delay(100);
  mySerial.println("AT+CMGS=\"+8801736666420\"\r");  // the phone number you are using
  delay(100);
  mySerial.println("ALERT!! Fall Detected!! Please Provide Emergency Assistance");//the content of the
message
```

```
  delay(100);
  mySerial.println((char)26);//the stopping character
  delay(100);

  digitalWrite(LED, LOW);
  noTone(Buzzer);
}

if (Amp <= 2 && trigger2 == false)
{ // if AM breaks lower threshold (0.4g)
  trigger1 = true;
  Serial.println("TRIGGER 1 ACTIVATED");
}

if (trigger1 == true)
{
  trigger1count++;
  if (Amp >= 12)
  { // if AM breaks upper threshold (3g)
    trigger2 = true;
    Serial.println("TRIGGER 2 ACTIVATED");
    trigger1 = false;
    trigger1count = 0;
  }
}

if (trigger2 == true)
{
  trigger2count++;
  angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
  Serial.println(angleChange);
  if (angleChange >= 30 && angleChange <= 400)
  { // if orientation changes by between 80-100 degrees
    trigger3 = true;
    trigger2 = false;
    trigger2count = 0;
    Serial.println(angleChange);
    Serial.println("TRIGGER 3 ACTIVATED");
```

```
  }
}

if (trigger3 == true)
{
  trigger3count++;
  if (trigger3count >= 10)
  {
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
    Serial.println(angleChange);
    if ((angleChange >= 0) && (angleChange <= 10))
    { // if orientation changes remain between 0-10 degrees
      fall = true;
      trigger3 = false;
      trigger3count = 0;
      Serial.println(angleChange);
    }
    else
    { // user regained normal orientation
      trigger3 = false;
      trigger3count = 0;
      Serial.println("TRIGGER 3 DEACTIVATED");
    }
  }
}

if (fall == true)
{ // in event of a fall detection
  Serial.println("FALL DETECTED");
  fall = false;
}

if (trigger2count >= 6)
{ // allow 0.5s for orientation change
  trigger2 = false;
  trigger2count = 0;
  Serial.println("TRIGGER 2 DEACTIVATED");
}
```

```
  if (trigger1count >= 6)
  { // allow 0.5s for AM to break upper threshold
    trigger1 = false;
    trigger1count = 0;
    Serial.println("TRIGGER 1 DEACTIVATED");
  }

  delay(100);
}

void mpu_read()
{
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x3B);  // starting with register 0x3B (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_addr, 14, true);  // request a total of 14 registers
  AcX = Wire.read() << 8 | Wire.read();  // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
  AcY = Wire.read() << 8 | Wire.read();  // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
  AcZ = Wire.read() << 8 | Wire.read();  // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
  Tmp = Wire.read() << 8 | Wire.read();  // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
  GyX = Wire.read() << 8 | Wire.read();  // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
  GyY = Wire.read() << 8 | Wire.read();  // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
  GyZ = Wire.read() << 8 | Wire.read();  // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
}
```

APPENDIX B .5 CODE OF COMBINED SENSORS

```
#include <Wire.h>
#include <SoftwareSerial.h>
SoftwareSerial mySerial(9, 10);// SIM800L TXD and RXD pin to arduino pin 9 and 10

const int MPU_addr = 0x68;  // I2C address of the MPU-6050
int16_t AcX, AcY, AcZ, Tmp, GyX, GyY, GyZ;
float ax = 0, ay = 0, az = 0, gx = 0, gy = 0, gz = 0;
boolean fall = false; //stores if a fall has occurred
boolean trigger1 = false; //stores if first trigger (lower threshold) has occurred
boolean trigger2 = false; //stores if second trigger (upper threshold) has occurred
boolean trigger3 = false; //stores if third trigger (orientation change) has occurred
byte trigger1count = 0; //stores the counts past since trigger 1 was set true
byte trigger2count = 0; //stores the counts past since trigger 2 was set true
byte trigger3count = 0; //stores the counts past since trigger 3 was set true
int angleChange = 0;

const int LED = 2;
const int Buzzer = 3;
const int Airbag = 4;

void setup()
{
  mySerial.begin(9600);
  Serial.begin(9600);
  Wire.begin();
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x6B);  // PWR_MGMT_1 register
  Wire.write(0);     // set to zero (wakes up the MPU-6050)
  Wire.endTransmission(true);
  Serial.println("Wrote to IMU");

  pinMode(LED, OUTPUT);
  pinMode(Buzzer, OUTPUT);
  pinMode(Airbag, OUTPUT);
  }
void loop()
{
```

```
mpu_read();
ax = (AcX - 2050) / 16384.00;
ay = (AcY - 77) / 16384.00;
az = (AcZ - 1947) / 16384.00;
gx = (GyX + 270) / 131.07;
gy = (GyY - 351) / 131.07;
gz = (GyZ + 136) / 131.07;

// calculating Amplitude vector for 3 axes
float Raw_Amp = pow(pow(ax, 2) + pow(ay, 2) + pow(az, 2), 0.5);
int Amp = Raw_Amp * 10;  // Multiplied by 10 because values are between 0 to 1
Serial.println(Amp);

angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
Serial.println(angleChange);
if (Amp >= 11 && (angleChange >= 150) && (angleChange <= 400))
{ // if orientation changes remain between 0-10 degrees
  Serial.println(angleChange);

  digitalWrite(LED, HIGH);
  tone(Buzzer, 4000);
  digitalWrite(Airbag, HIGH);
  delay(1500);
  digitalWrite(Airbag, LOW);
  delay(2000);
  digitalWrite(Airbag, HIGH);
  delay(100);
  digitalWrite(Airbag, LOW);
  delay(20000);
  digitalWrite(Airbag, HIGH);
  delay(1500);
  digitalWrite(Airbag, LOW);

  mySerial.println("AT+CMGF=1");    //To send SMS in Text Mode
  delay(100);
  mySerial.println("AT+CMGS=\"+8801736666420\"\r");  // the phone number you are using
  delay(100);
```

```
    mySerial.println("ALERT!! Fall Detected!! Please Provide Emergency Assistance");//the content of the message
    delay(100);
    mySerial.println((char)26);//the stopping character
    delay(100);

    digitalWrite(LED, LOW);
    noTone(Buzzer);

  }

  if (Amp <= 2 && trigger2 == false)
  { // if AM breaks lower threshold (0.4g)
    trigger1 = true;
    Serial.println("TRIGGER 1 ACTIVATED");
  }

  if (trigger1 == true)
  {
    trigger1count++;
    if (Amp >= 12)
    { // if AM breaks upper threshold (3g)
      trigger2 = true;
      Serial.println("TRIGGER 2 ACTIVATED");
      trigger1 = false;
      trigger1count = 0;
    }
  }

  if (trigger2 == true)
  {
    trigger2count++;
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
    Serial.println(angleChange);
    if (angleChange >= 30 && angleChange <= 400)
    { // if orientation changes by between 80-100 degrees
      trigger3 = true;
      trigger2 = false;
```

```
    trigger2count = 0;
    Serial.println(angleChange);
    Serial.println("TRIGGER 3 ACTIVATED");
  }
}

if (trigger3 == true)
{
  trigger3count++;
  if (trigger3count >= 10)
  {
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
    Serial.println(angleChange);
    if ((angleChange >= 0) && (angleChange <= 10))
    { // if orientation changes remain between 0-10 degrees
      fall = true;
      trigger3 = false;
      trigger3count = 0;
      Serial.println(angleChange);
    }
    else
    { // user regained normal orientation
      trigger3 = false;
      trigger3count = 0;
      Serial.println("TRIGGER 3 DEACTIVATED");
    }
  }
}

if (fall == true)
{ // in event of a fall detection
  Serial.println("FALL DETECTED");
  fall = false;
}

if (trigger2count >= 6)
{ // allow 0.5s for orientation change
  trigger2 = false;
```

```
    trigger2count = 0;
    Serial.println("TRIGGER 2 DEACTIVATED");
  }

  if (trigger1count >= 6)
  { // allow 0.5s for AM to break upper threshold
    trigger1 = false;
    trigger1count = 0;
    Serial.println("TRIGGER 1 DEACTIVATED");
  }

  delay(100);
}

void mpu_read()
{
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x3B);  // starting with register 0x3B (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_addr, 14, true);  // request a total of 14 registers
  AcX = Wire.read() << 8 | Wire.read();  // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
  AcY = Wire.read() << 8 | Wire.read();  // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
  AcZ = Wire.read() << 8 | Wire.read();  // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
  Tmp = Wire.read() << 8 | Wire.read();  // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
  GyX = Wire.read() << 8 | Wire.read();  // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
  GyY = Wire.read() << 8 | Wire.read();  // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
  GyZ = Wire.read() << 8 | Wire.read();  // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
}
```

APPENDIX B .6 CODE OF GSM SIM800L

```
#include <SoftwareSerial.h>
SoftwareSerial sim800l(0, 1);
#define button1 7
bool button_State; //Button state
void setup()
{
   pinMode(button1, INPUT_PULLUP); //The button is always on HIGH level, when pressed it goes LOW
  sim800l.begin(9600);   //Module baude rate, this is on max, it depends on the version
  Serial.begin(9600);
  delay(100);
}
 void loop()
{
   button_State = digitalRead(button1);

  if (button_State == LOW) {            //And if it's pressed
    Serial.println("Alert!! Fall Detected!!");   //Shows this message on the serial monitor
    delay(20);
        SendSMS();
 }

  if (sim800l.available()){
    Serial.write(sim800l.read());
  }
}

void SendSMS()
{
  Serial.println("Please Provide Emergency Assistance!!!");
  sim800l.print("AT+CMGF=1\r");
  delay(10);
  sim800l.print("AT+CMGS=\"+8801736666420\"\r");
  delay(50);
  sim800l.print("SIM800l is working");
  delay(50);
  sim800l.print((char)26);
  delay(50);
```

```
  sim800l.println();
}
```

APPENDIX B .7 CODE OF OVERALL SYSTEM

```
#include <Wire.h>
#include <SoftwareSerial.h>
SoftwareSerial mySerial(9, 10);// SIM800L TXD and RXD pin to arduino pin 9 and 10

const int MPU_addr = 0x68;  // I2C address of the MPU-6050
int16_t AcX, AcY, AcZ, Tmp, GyX, GyY, GyZ;
float ax = 0, ay = 0, az = 0, gx = 0, gy = 0, gz = 0;
boolean fall = false; //stores if a fall has occurred
boolean trigger1 = false; //stores if first trigger (lower threshold) has occurred
boolean trigger2 = false; //stores if second trigger (upper threshold) has occurred
boolean trigger3 = false; //stores if third trigger (orientation change) has occurred
byte trigger1count = 0; //stores the counts past since trigger 1 was set true
byte trigger2count = 0; //stores the counts past since trigger 2 was set true
byte trigger3count = 0; //stores the counts past since trigger 3 was set true
int angleChange = 0;

const int LED = 2;
const int Buzzer = 3;
const int Airbag = 4;

void setup()
{
  mySerial.begin(9600);
  Serial.begin(9600);
  Wire.begin();
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x6B);  // PWR_MGMT_1 register
  Wire.write(0);     // set to zero (wakes up the MPU-6050)
  Wire.endTransmission(true);
  Serial.println("Wrote to IMU");

  pinMode(LED, OUTPUT);
  pinMode(Buzzer, OUTPUT);
  pinMode(Airbag, OUTPUT);

}
```

```
void loop()
{
  mpu_read();
  ax = (AcX - 2050) / 16384.00;
  ay = (AcY - 77) / 16384.00;
  az = (AcZ - 1947) / 16384.00;
  gx = (GyX + 270) / 131.07;
  gy = (GyY - 351) / 131.07;
  gz = (GyZ + 136) / 131.07;

  // calculating Amplitude vector for 3 axes
  float Raw_Amp = pow(pow(ax, 2) + pow(ay, 2) + pow(az, 2), 0.5);
  int Amp = Raw_Amp * 10;  // Multiplied by 10 because values are between 0 to 1
  Serial.println(Amp);



  angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
  Serial.println(angleChange);
  if (Amp >= 11 && (angleChange >= 150) && (angleChange <= 400))
  { // if orientation changes remain between 0-10 degrees
    Serial.println(angleChange);

    digitalWrite(LED, HIGH);
    tone(Buzzer, 4000);
    digitalWrite(Airbag, HIGH);
    delay(1500);
    digitalWrite(Airbag, LOW);
    delay(2000);
    digitalWrite(Airbag, HIGH);
    delay(100);
    digitalWrite(Airbag, LOW);
    delay(20000);
    digitalWrite(Airbag, HIGH);
    delay(1500);
    digitalWrite(Airbag, LOW);

    mySerial.println("AT+CMGF=1");    //To send SMS in Text Mode
```

```
    delay(100);
    mySerial.println("AT+CMGS=\"+8801736666420\"\r");  // the phone number you are using
    delay(100);
    mySerial.println("ALERT!! Fall Detected!! Please Provide Emergency Assistance");//the content of the message
    delay(100);
    mySerial.println((char)26);//the stopping character
    delay(100);

    digitalWrite(LED, LOW);
    noTone(Buzzer);

  }



  if (Amp <= 2 && trigger2 == false)
  { // if AM breaks lower threshold (0.4g)
    trigger1 = true;
    Serial.println("TRIGGER 1 ACTIVATED");
  }

  if (trigger1 == true)
  {
    trigger1count++;
    if (Amp >= 12)
    { // if AM breaks upper threshold (3g)
      trigger2 = true;
      Serial.println("TRIGGER 2 ACTIVATED");
      trigger1 = false;
      trigger1count = 0;
    }
  }

  if (trigger2 == true)
  {
    trigger2count++;
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
```

```
  Serial.println(angleChange);
  if (angleChange >= 30 && angleChange <= 400)
  { // if orientation changes by between 80-100 degrees
    trigger3 = true;
    trigger2 = false;
    trigger2count = 0;
    Serial.println(angleChange);
    Serial.println("TRIGGER 3 ACTIVATED");
  }
}

if (trigger3 == true)
{
  trigger3count++;
  if (trigger3count >= 10)
  {
    angleChange = pow(pow(gx, 2) + pow(gy, 2) + pow(gz, 2), 0.5);
    Serial.println(angleChange);
    if ((angleChange >= 0) && (angleChange <= 10))
    { // if orientation changes remain between 0-10 degrees
      fall = true;
      trigger3 = false;
      trigger3count = 0;
      Serial.println(angleChange);
    }
    else
    { // user regained normal orientation
      trigger3 = false;
      trigger3count = 0;
      Serial.println("TRIGGER 3 DEACTIVATED");
    }
  }
}

if (fall == true)
{ // in event of a fall detection
  Serial.println("FALL DETECTED");
  fall = false;
```

```
  }

  if (trigger2count >= 6)
  { // allow 0.5s for orientation change
    trigger2 = false;
    trigger2count = 0;
    Serial.println("TRIGGER 2 DEACTIVATED");
  }

  if (trigger1count >= 6)
  { // allow 0.5s for AM to break upper threshold
    trigger1 = false;
    trigger1count = 0;
    Serial.println("TRIGGER 1 DEACTIVATED");
  }

  delay(100);
}

void mpu_read()
{
  Wire.beginTransmission(MPU_addr);
  Wire.write(0x3B);  // starting with register 0x3B (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(MPU_addr, 14, true);  // request a total of 14 registers
  AcX = Wire.read() << 8 | Wire.read();  // 0x3B (ACCEL_XOUT_H) & 0x3C (ACCEL_XOUT_L)
  AcY = Wire.read() << 8 | Wire.read();  // 0x3D (ACCEL_YOUT_H) & 0x3E (ACCEL_YOUT_L)
  AcZ = Wire.read() << 8 | Wire.read();  // 0x3F (ACCEL_ZOUT_H) & 0x40 (ACCEL_ZOUT_L)
  Tmp = Wire.read() << 8 | Wire.read();  // 0x41 (TEMP_OUT_H) & 0x42 (TEMP_OUT_L)
  GyX = Wire.read() << 8 | Wire.read();  // 0x43 (GYRO_XOUT_H) & 0x44 (GYRO_XOUT_L)
  GyY = Wire.read() << 8 | Wire.read();  // 0x45 (GYRO_YOUT_H) & 0x46 (GYRO_YOUT_L)
  GyZ = Wire.read() << 8 | Wire.read();  // 0x47 (GYRO_ZOUT_H) & 0x48 (GYRO_ZOUT_L)
}
```

APPENDIX C. JUSTIFICATION OF COMPLEX ENGINEERING PROBLEM

This table prepared in EEE400A justifies the proposed project as a complex engineering problem

Table App. C. 01: Complex Engineering Problems Analysis

Attribute	**Complex Engineering Problems** have characteristic P1 and some or all P2 to P7:	Covered in the project? (Y/N)	Explain / Justify
Depth of knowledge required	P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamental based, first principles analytical approach	Y	➢ ***K3: Knowledge of Engineering Fundamental*** ✓ Circuit Knowledge ✓ Logic Circuit Knowledge ➢ ***K4: Engineering Specialist Knowledge*** ✓ Sensor System ➢ ***K6: Knowledge of Engineering Tools*** ✓ Arduino Uno R3 ✓ Matlab ✓ Proteus ✓ Fritzing ➢ ***K8: Engineering Research Knowledge*** ✓ Literature Review
Range of conflicting requirements	P2: Involves wide-ranging or conflicting technical, engineering and other issues	N	N/A
Depth of analysis required	P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models	Y	***This project has three alternative solutions*** ➢ Accelerometer Based Fall Detection ➢ Gyroscope Based Fall Detection ➢ Combined (Accelerometer + Gyroscope) Based Fall Detection
Familiarity of issues	P4: Involves infrequently encountered issues	N	N/A
Extent of applicable codes	P5: Are outside problems encompassed by standards and codes of practice for professional engineering	N	N/A

Extent of stakeholder involvement and conflicting requirements	P6: Involves diverse groups of stakeholders with widely varying needs	N	N/A
Interdependence	P7: High level problems including many component parts or sub-problems	Y	➢ Fall Detection System ➢ Fall Impact Minimization System ➢ Alert Message System

APPENDIX D. JUSTIFICATION OF COMPLEX ENGINEERING ACTIVITIES

This table prepared in EEE400C describes the complex engineering activities in the project

Table App. D. 01: Analysis of Complex Activities in Engineering Projects

Attribute	**Complex activities mean (engineering) activities or projects that have some or all the following characteristics:**	**Covered in the project? (Y/N)**	**Explain**
Range of resources	A1: Involves the use of diverse resources (for this purpose, resources include people, money, equipment, materials, information and technologies)	Y	We utilized various resources throughout our project and divided the tasks among group members to ensure timely completion. We invested financially to develop the prototype, utilizing tools like a multimeter, soldering iron, and glue gun for assembly and testing, as well as software such as MATLAB, Arduino Uno R3, Fritzing, Canva, GIMP, Microsoft Excel, and Proteus for various purposes. Additionally, research insights referenced in our literature review supported our design. For the hardware, we incorporated components such as an Arduino Uno R3, GY-521 module, GSM SIM800L module, LED, buzzer, relay, and an air compressor to inflate an airbag (neck pillow used as an airbag).
Level of interaction	A2: Requires resolution of significant problems arising from interactions among wide-ranging or conflicting technical, engineering, or other issues	Y	The development of our system, which incorporates an Arduino Uno R3, a 3.7V to 5V booster module, a GY-521 module, LED, buzzer, GSM SIM800L, a 4400mAh battery, and a relay, presents several significant technical and engineering challenges. Key issues include ensuring stable voltage regulation from the booster module, seamless integration of the relay with the Arduino, precise synchronization for accurate fall detection and response, and efficient power management to prolong battery life.

Innovation	A3: Involves creative use of engineering principles and research-based knowledge in novel ways		We have used the air compressor in our device to inflate the air bag. Since using it increases the weight of our device, we will not use this method while finalizing our device. We read the research paper and found two methods such as CO_2 Cartridges for Instant Inflation & Pyrotechnic Inflation Mechanism. If we use one of them then it'll reduce the weight of our device and inflate the airbag faster. Later we will see through more testing which of these two is better and more comfortable for users. We will also pay attention to the price so that it is affordable.
Consequences for society and the environment	A4: Has significant consequences in a range of contexts; characterized by difficulty of prediction and mitigation	N	N/A
Familiarity	A5: Can extend beyond previous experiences by applying principles-based approaches	N	N/A

APPENDIX E. RUBRICS

Rubrics for EEE400

Table 1: Rubrics for Assessment of PO9 (Individual Work & Teamwork)

Performance indicators	***Outstanding (9-10)***	***Good (7-8)***	***Satisfactory (6)***	***Unsatisfactory (0-5)***
Individual Skills	Actively participates in group discussions and decision making, contributes useful ideas, completes assigned responsibilities thoroughly on time	Participates in group discussions and decision making, contributes ideas, completes assigned responsibilities mostly on time	Somewhat participates in group discussions and decision making, sometimes contributes ideas, completes some of the assigned responsibilities on time	Does not participate in group discussions and decision making, does not contribute relevant ideas, does not complete assigned responsibilities on time
Team Skills	Always collaborates with others, always promotes constructive team atmosphere, always identifies and responds to conflicts promptly and positively	Usually collaborates with others, usually promotes constructive team atmosphere, usually identifies and responds to conflicts positively	Sometimes collaborates with others, sometimes promotes constructive team atmosphere, sometimes identifies and responds to conflicts positively	Does not collaborate with others, does not promote constructive team atmosphere, does not identify and respond to conflicts
Leadership Skills	Always provides direction to achieve goals, always respects and listens to other members, always plans for improvement, always motivates others	Usually provides direction to achieve goals, usually respects and listens to other members, usually plans for improvement, usually motivates others	Sometimes provides direction to achieve goals, sometimes respects and listens to other members, sometimes plans for improvement, sometimes motivates others	Does not provide direction to achieve goals, does not respect and listen to other members, does not plan for improvement, does not motivate others
Multidiscipline Activities	Fully understands and appreciates the multidisciplinary nature of the project activities, shows interests and participates in activities in	Mostly understands and appreciates the multidisciplinary nature of the project activities, participates in activities in disciplines outside of own	Somewhat understands and appreciates the multidisciplinary nature of the project activities, participates in some activities in disciplines outside of	Does not understand or appreciate the multidisciplinary nature of the project activities, does not participate in activities in disciplines outside of

	disciplines outside of own		own	own

Table 2: Rubrics for Assessment of PO8 (Ethics)

Performance indicators	***Outstanding (9-10)***	***Good (7-8)***	***Satisfactory (6)***	***Unsatisfactory (0-5)***
Equity	Always approaches situations with consideration of equity, always behaves inclusively	Mostly approaches situations with consideration of equity, mostly behaves inclusively	Sometimes approaches situations with consideration of equity, Sometimes behaves inclusively	Does not approach situations with consideration of equity, does not behave inclusively
Accountability	Always understands about accountability and personal responsibility, always assumes responsibility of own actions	Mostly understands about accountability and personal responsibility, mostly assumes responsibility of own actions	Sometimes understands about accountability and personal responsibility, sometimes assumes responsibility of own actions	Does not understand about accountability and personal responsibility, does not assume responsibility of own actions
Proper use of others' works	Always recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and acts accordingly	Mostly recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and mostly acts accordingly	Sometimes recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and sometimes acts accordingly	Does not recognize the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and does not act accordingly
Professionalism	Fully understands the role of the engineer in protecting public interests, fully understands and is aware of relevant codes of ethics	Mostly understands the role of the engineer in protecting public interests, mostly understands and is mostly aware of relevant codes of ethics	Somewhat understands the role of the engineer in protecting public interests, somewhat understands and is somewhat aware of relevant codes of ethics	Does not understand the role of the engineer in protecting public interests, does not understand or is not aware of relevant codes of ethics

Rubrics for EEE400A

Table EEE400A: Rubrics for Assessment of the Project Concept and proposal

Performance indicators	***Outstanding (9-10)***	***Good (7-8)***	***Satisfactory (6)***	***Unsatisfactory (0-5)***
PCP_PI1: Able to identify a suitable complex engineering design problem (1a) [sec-1.1, Appendix C] (CO1/PO12, P1)	Demonstrates an ability to explore a topic thoroughly, and to identify a suitable complex engineering problem	Demonstrates an ability to explore a topic, and to identify a reasonably suitable complex engineering problem	Demonstrates an ability to somewhat explore a topic, and to identify a somewhat suitable complex engineering problem	Demonstrates minimal or no ability to explore a topic, or to identify a suitable complex engineering problem
PCP_PI2: Engages to stay up to date on the relevant topic (2b) [sec-1.2] (CO1/PO12, P1)	Demonstrates thorough engagement to stay up to date on the relevant topic	Demonstrates engagement to stay up to date on the relevant topic	Demonstrates some engagement to stay up to date on the relevant topic	Demonstrates minimal or no engagement to stay up to date on the relevant topic
PCP_PI3: Identifies the regulatory requirements, standards, and codes of practice (2a) [sec1.3] (CO2/PO3, P5)	Identifies all the relevant regulatory requirements, standards, and codes of practice	Identifies most of the relevant regulatory requirements, standards, and codes of practice	Identifies some of the relevant regulatory requirements, standards, and codes of practice	Does not identify any of the relevant regulatory requirements, standards, and codes of practice
PCP_PI4: Explains the objectives, project requirements and constraints of the solution considering the expectations of the stakeholders (2c) [sec-1.4, 1.5] (CO2/PO3, P2, P6)	Clearly explains the objectives, project requirements and constraints considering all the expectations of the stakeholders	Explains the objectives, project requirements and constraints taking into account most of the expectations of the stakeholders	Somewhat explains the objectives, project requirements and constraints fully taking into account some the expectations of the stakeholders	Does not explain the objectives, project requirements and constraints and/or does not take into account any expectation of the stakeholders
PCP_PI5: Prepares project management plan, setting up milestones and considering risks and contingencies (2d) [sec-1.6.1, 1.6.2] (CO3/PO11)	Prepares a comprehensive project management plan, clearly sets up milestones, thoroughly considers risks and contingencies	Prepares a project management plan, sets up milestones, considers risks and contingencies	Prepares a project management plan, sets up a few milestones, attempts to considers risks and contingencies	Prepares an unclear / incomplete project management plan, does not set up milestones, does not consider risks and contingencies
PCP_PI6: Identifies required resources and prepares a realistic budget (2e,	Identifies all resources and prepares budget that covers all applicable	Identifies most resources and prepares budget that covers most	Identifies some resources and prepares budget that covers some	Cannot identify resources and cannot prepare a budget addressing major

2g) [sec-1.6.3] (CO3/PO11)	areas of the project including room for contingency	applicable areas of the project including room for contingency	applicable areas of the project	applicable areas of the project
PCP_PI7: Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized. (2h) [sec-1.7]	Clearly explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Somewhat explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Does not explain how to sustain and maintain the product/service in business if the solution is successfully commercialized.
PCP_PI8: Considers the impact of the solution on society including health, safety, cultural, and legal issues (2f) [sec1.8.1, 1.8.3] (CO4/PO6)	Considers all the impacts on society including health, safety, cultural and legal issues	Considers most of the impacts on society including health, safety, cultural and legal issues	Considers some of the impacts on society including health, safety, cultural and legal issues	Does not consider any impact on society including health, safety, cultural and legal issues
PCP_PI9: Considers the impact of the solution on environment and sustainability over the entire product life cycle. Proposes mitigating solution if needed. (2f) [sec1.8.2] (CO5/PO7)	Considers all the impacts on environment and sustainability. If necessary, proposes solutions to mitigate negative impact	Considers most of the impacts on environment and sustainability. If necessary, identifies impacts which need mitigation	Considers some of the impacts on environment and sustainability	Minimal or no consideration of impacts on environment and sustainability

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach

P2: Involves wide-ranging or conflicting technical, engineering and other issues

P4: Involves infrequently encountered issues

P6: Involves diverse groups of stakeholders with widely varying needs

Rubrics for EEE400B

Table EEE400B: Rubrics for Assessment of the Design Report

Performance indicators	***Outstanding (9 – 10)***	***Good (7 – 8)***	***Satisfactory (6)***	***Unsatisfactory (0 – 5)***
DR_PI1: Develops a functional design considering applicable standards, codes of practice, health, safety, and environmental considerations. (1a) [sec-**Error! Reference source not found.**] **(CO2/PO3, P2, P7)**	Appropriately partitions the problem into sub-problems, considers all relevant engineering standards and codes where applicable, involves all health, safety, and environmental issues in design	Partitions the problem into sub-problems, considers most relevant engineering standards and codes where applicable, involves major health, safety, and environmental issues in design	Partitions the problem into sub-problems to some extent, considers some relevant engineering standards and codes where applicable, involves some health, safety, and environmental issues in design	Does not usefully partition the problem into sub-problems, does not consider relevant engineering standards and codes, health, safety, and environmental issues not involved in design
DR_PI2: Formulates and evaluates alternate solutions (1b) [sec-**Error! Reference source not found.**] **(CO1/PO2, P1, P3)**	Effectively formulates multiple solutions that functionally meet most requirements, compares and evaluates alternate solutions, extracts valid conclusions	Formulates multiple solutions that functionally meet most requirements, partially compares and evaluates alternate solutions, conclusions in line with analysis	Formulates multiple solutions that functionally meet some requirements, attempts to compare and evaluate alternate solutions, conclusions somewhat in line with analysis	Does not formulate multiple solutions, no attempt to compare and evaluate alternate solutions, conclusions not based on analysis
DR_PI3: Prepares and refines design with analysis and/or simulation of the system for implementation (1c, 1d) [sec-**Error! Reference source not found.**] **(CO2/PO3, P1)**	Performs all design calculations, produces detailed design, analyzes and/or simulates to verify that the design satisfies all requirements. Design is skillfully refined to facilitate implementation.	Performs most design calculations, produces design with some details, analyzes/simulates to verify that the design satisfies most requirements. Design is refined to facilitate implementation.	Performs some design calculations, produces design with a few details, attempts to analyze/simulate the design to verify satisfaction of requirements. Design is somewhat refined to facilitate implementation.	Does not perform design calculations, detailed design not produced, analysis/simulation not done to verify satisfaction of requirements. Design is not refined to facilitate implementation.

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach

P2: Involves wide-ranging or conflicting technical, engineering and other issues

P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models

P7: High level problems including many component parts or sub-problems

Rubrics for EEE400C

Table EEE400C: Rubrics for Final Report of EEE400C

Performance indicators	***Outstanding (9 – 10)***	***Good (7 – 8)***	***Satisfactory (6)***	***Unsatisfactory (0 – 5)***
FR_PI1: Discusses how the prototype of the solution is developed. [sec **Error! Reference source not found.**]	Comprehensively discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Somewhat discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Poorly discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams
FR_PI2: Evaluates performance of the developed system as per requirements. Finalizes design based on performance evaluation (1a and 1b) [sec **Error! Reference source not found.**, sec 3.3] **(CO1/PO4, CO3/PO3)**	System meets all requirements or the students can identify and explain clearly when deviation from requirements occurs. Revises design with appropriate technical analysis if necessary to achieve compliance with all specification and requirements	System meets major requirements. Students can identify and explain most deviations from requirements. Revises design with technical analysis if necessary to achieve compliance with most specification and requirements	System meets some requirements. Students can identify and explain some deviations from requirements. Revises design with some technical analysis if necessary to achieve compliance with some specification and requirements	System does not meet most requirements. Students cannot identify and explain most deviations from requirements. Design not revised to achieve compliance.
FR_PI3: Finalizes design based on performance evaluation (1c) [sec **Error! Reference source not found.**] **(CO3/PO3)**	Revises design with appropriate technical analysis to achieve compliance with all requirements finalized in 400B	Revises design with technical analysis to achieve compliance with most requirements finalized in 400B	Revises design with some technical analysis to achieve compliance with some requirements finalized in 400B	Does not revise design with technical analysis to achieve compliance with any requirement finalized in 400B
FR_PI4: Selects and uses appropriate	Carefully selects and skillfully uses	Selects and uses modern engineering	Selects and uses modern	Selected and used modern engineering

modern engineering tools for modeling, simulation and/or performance evaluation throughout the project (EEE400 A, B, C) [sec **Error! Reference source not found.**] **(CO2/PO5)**	modern engineering tools knowing all the relevant limitations of the tools	tools with some degree of care and skill knowing major relevant limitations of the tools	engineering tools knowing some relevant limitations of the tools	tools are mostly not appropriate. No knowledge of relevant limitations of the tools
FR_PI5: Achieve the milestones set in the project proposal or revises the schedule appropriately to complete the project within the deadline (EEE400 A, B, C) [**Error! Reference source not found.**] **(CO4/PO11)**	All milestones are reached on time or corrective measures are appropriately taken to revise the schedule to complete the project within deadline	Most milestones are reached on time or corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are somewhat reached on time or some corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are mostly not reached on time. Corrective measures are not taken to revise the schedule to complete the project within deadline
FR_PI6: Prepares the bill of materials and estimates the cost of the system [sec **Error! Reference source not found.**] **(CO5/PO11)**	Prepares bill of materials considering all the project components and/or parts and the cost is accurately estimated	Prepares bill of materials considering most the project components and/or parts and the cost is estimated	Prepares bill of materials considering major project components and/or parts and the cost is reasonably estimated	Prepares bill of materials ignoring important project components and/or parts and the cost is not reasonable
FR_PI7: Performs economic analysis to calculate suitable economic parameter(s) to evaluate the economic prospect of the proposed project [sec **Error! Reference source not found.**] **(CO5/PO11)**	Evaluates the financial prospect of the project through detailed and thorough analysis. Interpretation is clear	Evaluates the financial prospect of the project through analysis. Provides interpretation	Evaluates the financial prospect of the project through analysis.	Does not evaluate the financial prospect of the project through analysis

Table EEE400(a): Overall Rubrics on Report Writing

Communicates the main ideas in written form [Overall] **(CO8/PO10)**	Communicates the main ideas clearly and to the point	Communicates the main ideas	Communicates the main ideas to some extent	Does not communicate the main ideas
Uses illustrations (graphs, tables, diagrams) to support ideas, analysis and interpretation [Overall] **(CO8/PO10)**	Skillfully uses illustrations to support ideas. Illustrations enhance comprehension of analysis and interpretation	Uses illustrations to support ideas. Illustrations somewhat enhance comprehension of analysis and interpretation	Uses illustrations which are related to analysis and interpretation	Either does not use illustrations or illustrations used are not relevant to ideas, analysis and interpretation
Uses citations and references [Overall] **(CO8/PO10)**	Citations and references are effectively used to duly acknowledge prior art and other people’s works	Citations and references are used to acknowledge prior art and other people’s works	Citations and references are used to somewhat acknowledge prior art and other people’s works	Citations and references are not used or prior art and other people’s works are not acknowledged
Uses a language which is mechanically (punctuation, spelling and grammar) correct [Overall] **(CO8/PO10)**	The report is free from mechanical errors	The report contains a few mechanical errors	The report contains some mechanical errors	The report contains several mechanical errors

Table EEE400(b): Rubrics for Oral Presentation

Performance indicators	***Outstanding (9 – 10)***	***Good (7 – 8)***	***Satisfactory (6)***	***Unsatisfactory (0 – 5)***
Communicates appropriately targeting the society at large **(CO8/PO10)**	Communication is skillfully tailored to appropriately suit the level of target audience	Communication is tailored to suit the level of target audience	Communication is somewhat tailored to suit the level of target audience	Communication is not tailored to suit the level of target audience
Focusses on the creative aspects of the solution with clarity **(CO8/PO10)**	Creative aspects are clearly articulated and emphasized. Presentation is logically and skillfully structured	Creative aspects are articulated and emphasized. Presentation structure is logical	Creative aspects are somewhat articulated and emphasized. Presentation structure is somewhat logical	Creative aspects are not articulated or emphasized. Presentation structure is not logical
Above two PIs will assess the sales pitch part of the presentation. Following PIs are for the technical part				
Designs and integrates visual aids (illustrations, demonstrations, props, etc) to support and focus presentation **(CO8/PO10)**	Visual aids are creatively designed, skillfully used and seamlessly integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation to some extent	Visual aids are not designed, used or integrated to enhance and focus presentation
Completes presentation within the allotted time **(CO8/PO10)**	Finishes the presentation as prepared within time without rushing or skipping content	Finishes the presentation as prepared within time with rushing or skipping content occasionally	Finishes the presentation as prepared within time with rushing or skipping content a few times	Does not finish the as prepared presentation within time or skips major contents to finish within time
Listens to the questions and answers appropriately **(CO8/PO10)**	Carefully listens to the questions, answers concisely transitioning skillfully between presentation and Q/A	Listens to the questions, answers to the point transitioning well between presentation and Q/A	Listens to the questions, answers somewhat to the point transitioning between presentation and Q/A in an acceptable manner	Does not listen to the questions, answers not to the point transitioning between presentation and Q/A not in an acceptable manner

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