A Study on Indoor vs Outdoor Navigational Behaviors

A Project Work

submitted in partial fulfilment of the requirement for the Degree of

Master of Computer Application

of

Jadavpur University

By

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2023

FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY

CERTIFICATE OF RECOMMENDATION

This is to certify that the project entitled "A STUDY ON INDOOR VS OUTDOOR NAVIGATIONAL BEHAVIORS" has been satisfactorily completed under my guidance and supervision by **ANINDITA BARMAN** (University Registration No.: 154251 of 2020- 2021, Examination Roll No.: MCA2360009, Class Roll No.: 002010503043). I hereby recommend that the project be accepted in partial fulfilment of the requirement for the Degree of Master of Computer Application, Department of Computer Science and Engineering in Faculty of Engineering and Technology, Jadavpur University, Kolkata for the academic year 2020-2023.

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FACULTY OF ENGINEERING AND TECHNOLOGY
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CERTIFICATE OF APPROVAL

This is to certify that the project entitled "A STUDY ON INDOOR VS OUTDOOR NAVIGATIONAL BEHAVIORS" is a bona fide record of work carried out by ANINDITA BARMAN(University Registration No.: 154251 of 2020- 2021, Examination Roll No.: MCA2360009, Class Roll No.: 002010503043) in partial fulfilment of the requirements for the award of the degree of Master of Computer Application in the Department of Computer Science and Engineering, Jadavpur University during the period of January 2023 to July 2023. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn there in but approve the project only for the purpose for which it has been submitted.

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Signature of Examiner
Date:

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Signature of Supervisor
Date:

FACULTY OF ENGINEERING AND TECHNOLOGY JADAVPUR UNIVERSITY

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this project entitled "A STUDY ON INDOOR VS OUTDOOR NAVIGATIONAL BEHAVIORS" contains literature survey and original research work by the undersigned candidate, as part of his Degree of Master of Computer Application. All information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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ACKNOWLEDGEMENT

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Abstract

This study is focused on indoor vs outdoor navigational behaviors based on the data collected by the sensors that are commonly available in smartphones such as, accelerometer, gyroscope, magnetometer, along with GPS. Generally, the guide signature of a user signifies interesting characteristics of users' activity. User navigational behavior depends on the surrounding environment. In case of emergency or any phycological discomfort, behavioral changes could be observed.

Surveillance is another application where this kind of behavior study could be useful. So, in this world we have created a dataset of inertial sensors along with GPS and provided the necessary data visualization to extensively study the effect of indoor vs semi-indoor vs outdoor environment on user's navigational behavior.

CONTENTS

CHAPTER 1

1.INTRODUCTION

Navigational behaviour refers to the actions and decisions made by individuals or entities to navigate through a particular environment or to reach a specific destination. It encompasses the strategies, movements, and cognitive processes used to find a route, follow a path, or explore an area. Navigation can also be described as going from point A to point B. Navigation involves determining the position, orientation, velocity and direction of the craft or vehicle, using various methods and techniques, such as maps, compasses, landmarks, celestial bodies, GPS signals and inertial sensors [1].

Outdoor navigation is based on satellite imaging, aerial photography, and GPS signals. These, however, do not include the building's interior. For instance, inside of a building, GPS might not function. The walls or other constructions are easily able to alter it. In that instance, a new service is required to map our venue inside the buildings. Wi-Fi, RFID, Bluetooth, and other technologies-based indoor navigation [1]. However, most technologies offer additional benefits and drawbacks depending on the surrounding circumstances. IPS (Indoor positioning system) steps in to help in this situation by locating the user utilizing radio signals and phone sensors.

More information and landmarks are provided for orientation since outdoor navigation typically covers larger and more complicated areas than interior navigation. Multi-layered locations, such floors or rooms, are frequently involved in indoor navigation and need for many degrees of abstraction and representation. A position precision is desired for indoor positioning, so it is important to consider 3D factors, especially in the inside environment. The same horizontal dimension can include multiple objects with varying vertical dimensions. For each space, proper geocoding (X, Y, and Z) is required. [2] [3]

1.1APLLICATIONS

Recent years have seen a rise in the navigation industry. The market for outdoor, road-based navigation is dominated by well-known navigation services like TomTom, Garmin, MapQuest, and Google Navigation. Additional applications and services, including sport pal, make use of straightforward location determinations. Additionally, GPS navigation systems have become a necessary component of daily life by guiding us to the nearby coffee shop and allowing us to play entertaining games on smartphones. To increase the precision and dependability of the positional data, satellite navigation systems can collaborate with various sensors and technologies including Wi-Fi, RFID, inertial platforms, and magnetometers.

1.2 MOTIVATION

Recent years have seen a rise in interest in the field of environmental navigation. Outdoor navigation is often accomplished using a GPS-based system that uses a satellite navigation system. Even so, it has been noted that GPS signals are flimsy and susceptible to obstruction or attenuation by a variety of objects, including structures, walls, roofs, trees, mountains, and air conditions. Since the signals are weak or cannot reach the device, GPS does not function well within buildings or other enclosed spaces.

The answer is to employ an indoor positioning system (IPS), which is a network of gadgets that locates people or things inside a building without the need of GPS by using other technologies like Wi-Fi, Bluetooth, RFID, or inertial sensors. However, IPS lacks a universal standard and necessitates the installation and upkeep of infrastructure and equipment at each indoor location. Accuracy, reliability, scalability, and interoperability are further difficulties with IPS. [5][6]

Inertial sensor-based navigation systems are commonly known as inertial navigation systems (INS) or inertial measurement units (IMU). The basic IMU components are accelerometer, gyroscope, and magnetometer, which are widely used for many real-world applications. Many sensors are used in the smartphone that consists of numerous sensing sub-devices like, accelerometer, gyroscope, and magnetometers. With the use of these sensors, we can estimate the location of the user either they are at indoor or outdoor. These sensors give different values respected to the location (indoor and outdoor). They consist of a set of three orthogonal accelerometers and three orthogonal gyroscopes, which can measure the specific force and turn rate along three axes. They also include a computer that integrates the sensor measurements and applies error correction algorithms to estimate the navigation states. [4][9]

1.3 CONTRIBUTION

We have designed a mobile application, smartphone sensor-data-collection app which has 3 sensors such as accelerometer, magnetometer, and gyroscope. Which will store the data according to the present environment(indoor-outdoor). Here we also have a GPS system that stores the possible range of the device in meters. After collecting the data, we put all the data in graphs from there we can estimate results of the navigational behavior.

1.4 ORGANIZATION OF THE REPORT

1.4.1 Related Work

In this part we will discuss about what is satellite navigation, its use and Indian satellite navigation system. This part consists the idea of Inertia sensors. How we use these sensors and some descriptions and work related to it.

1.4.2 Roles of smartphone sensors and data collection strategies

This portion of the project consists of a theoretical overview of it and what are the modules. The main module of this project is the roles of smartphone sensors. As we know smartphone consists of numerous sensing sub devices. But in this project, we will discuss about only three sensors that will be the Inertia sensors (accelerometer, gyroscope, and magnetometer). We will have a clear concept about these sensors and about their data in different environment. After visualising the data, we will have the idea of the positioning of the user. We also introduced a current location of the user. Its also store the user's location as well as the possible rang of the user in meters. [5]

1.4.3 Develop a mobile application

In this section, the workflow of the proposed module is displayed, along with the data collection, data labelling, and data strategy of the sensors. The application is developed in Android Studio. Android studio is the official Integrated Development Environment (IDE) for developing Android applications. It is specifically designed for android app development and provides a comprehensive set of tools and features to streamline the development process.

1.4.4 Data visualisation

In this portion of the project, we discuss how these sensors give different types of data patterns for different environment (indoor vs semi-indoor vs outdoor). Some activities could be observed in outdoor spaces which are rare in an indoor space. After plotting the dataset, we can compare the differences between the indoor, semi-indoor, and outside graphs. and the user's behaviour.

1.4.5 Conclusion

In conclusion, the study mainly focused on indoor vs outdoor navigational behaviors. We collect data from different locations and circumstances, including walking, running, and using a vehicle. We can examine the differences between locations that are indoor, outdoor, and semi-indoor after compiling the datasets into graphs. Additionally, the graphs display user activity such as left and right turns. For GPS, outside locations are more accurate than indoor locations, indoor locations are less effective in GPS.

CHAPTER 2

2.Relateted work

2.1 Satellite navigation system:

A satellite navigation system is a system that employs satellites to give autonomous geo positioning, which means it can use time signals broadcast by radio from satellites to identify the location, speed, and direction of a device on the surface of the globe. Global Navigation Satellite System (GNSS) is a global satellite navigation system. System of global positioning, the most widely used worldwide navigation system, GPS, is made up of numerous constellations of satellites circling above the planet. A device's location on the surface of the earth can be found using the satellite-based radio navigation system known as GPS. The United States Space Force manages GPS on behalf of the federal government of the United States.

Navigation with Indian constellation (NavIc)

Navigation with Indian Constellation (NavIC)[8], originally known as Indian Regional Navigation Satellite System (IRNSS), is the name of the satellite navigation system used in India. It is an autonomous regional satellite navigation system that offers India and a region up to 1,500 km (930 mi) from its boundaries accurate real-time positioning and timing services, with plans for further extension. Eight satellites make up the NavIC constellation, three of which are in geostationary orbit and five of which are in an inclined geosynchronous orbit. A network of ground stations manages and keeps an eye on the satellites.

2.2 Inertial sensor-based navigation:

Inertial sensors are based on inertia and relevant measuring principles. An inertial sensor is a device that measures the inertial force, such as acceleration, inclination, and vibration, of an object using electrical signals. Inertial sensors are composed of accelerometers and gyroscopes, which measure linear acceleration and angular rate, respectively. An inertial measurement unit (IMU) is a device that contains three mutually orthogonal accelerometers and three mutually orthogonal gyroscopes, which can measure the specific force and turn rate of an object along three axes. Inertial sensors have many applications in navigation, control, stabilization and monitoring of various vehicles and devices, such as aircraft, missiles, ships, submarines, satellites, landers, robots, smartphones, tablets, cameras, and medical instruments. Inertial sensors can work independently or in combination with other sensors and technologies, such as magnetometers, GPS, Wi-Fi, and RFID, to improve the accuracy and reliability of the positioning and orientation information.[10][11]

Inertial sensor-based navigation is a method of navigation that uses inertial sensors, such as accelerometers and gyroscopes, to measure the acceleration and angular rate of a moving object and compute its position, orientation, and velocity by dead reckoning. Inertial sensor-based navigation does not require any external references, such as GPS signals or landmarks, and is therefore immune to jamming, spoofing or interference. [6]

CHAPTER 3

ROLES OF SMARTPHONE SENSORS AND DATA COLLECTION STRATEGIES

3.1 Accelerometer Sensor: The accelerometer in a smartphone is an electromechanical device that detect orientation and movement of the phone. It measures the force of acceleration cause by any movement or by gravity or by the vibration. The accelerometer sensor is based on micro-electromechanical systems (MEMS) technology, which integrates mechanical structures, sensors, and electronics onto a single silicon chip. The primary function of an accelerometer sensor is to measure the acceleration force along the x, y, and z axes of the phone. These axes correspond to the device's three-dimensional coordinate system. Acceleration forces include linear acceleration (m/s^2 unit) (changes in speed or direction) and gravitational forces. Accelerometer sensors can sense various physical quantities relates to motion and orientation. Here are the main parameters that an accelerometer sensor can detect: linear acceleration, gravitational force, impact and shock, vibration, step count.

3.2 Gyroscope Sensor: Gyroscope sensor in a smartphone is a device that measures the orientation and angular velocity(rotation) of the phone in three-dimensional space. The gyroscope sensor complements the accelerometer sensor by adding rotational data to the device's motion sensing capabilities. The gyroscope sensor in a smartphone typically utilizes MEMS technology, similar to the accelerometer sensor. The gyroscope sensor provides main types of data: Angular Velocity and Orientation. The unit of measurement is (degree/ seconds).

1.Angular Velocity: It measures the rate at which the phone is rotating in degrees per second around each of the three axes (X, Y, and Z). This data is useful for tracking the phone's movements and determining its orientation.

2.Orientation: By integrating the angular velocity data over time, the gyroscope sensor can provide information about the phone's current orientation relative to a reference point. This information is crucial for applications that rely on accurate positioning and movement tracking, such as games and navigation systems.

3.3 Magnetometer Sensor: A magnetometer sensor, also known as a magnetic sensor or compass sensor, is a component found in a smartphones and other electronic devices that detects and measures magnetic fields. It enables the device to determine its orientation with respect to the earth's magnetic field and provides information about the surrounding magnetic environment. When exposed to a magnetic field, the sensing element produces an electrical output proportional to the strength and direction of the magnetic field. The key aspects and functionalities of magnetometer sensors in smartphones: Magnetic Field Detection Magnetic Field Sensing, Magnetic Interference Detection. The unit of measurement microteslas (μT).

In chapter 5 we will discuss about these three sensors with results and explanation.

CHAPTER 4

DEVELOP MOBILE APPLICATION

4.1 Data Collection Strategy:

The data collection strategy of accelerometer, gyroscope, and magnetometer sensors can vary depending on the specific application and requirements, but generally, these sensors are used to measure different aspects of an object's motion and orientation.

The data collection strategy for accelerometers involves continuously measuring the forces acting on the sensor, for gyroscopes involves capturing rotational motion data, strategy for magnetometers involves capturing the magnetic field data.

Select an appropriate sampling rate, which determines how frequently the accelerometer records data per second The choice of sampling rate depends on the application, the expected frequency range of the motion, and the required precision. Similar to accelerometers, the gyroscope and magnetometer also requires a sampling rate to determine how often it records data per second. This rate can be the same or different from the accelerometer's sampling rate.

The accelerometer records the acceleration values, gyroscope continuously measures the angular velocity and, magnetometer measures the magnetic field strength along each axis at the selected sampling rate along each axis at the chosen sampling rate over a specific duration. Together, all of these sensors record these values and store them in various locations.[11]

4.2 Data labelling:

Who have sufficient knowledge of the application may determine whether an item is labelled as indoor or outdoor. It is done manually.

4.3 Data collection:

Sensors	X axis	Y axis	Z axis	label	timestamp
Accelerometer (m/s^2)	1.411981	5.468955	8.136695	Outdoor	2.11176E+14
Gyroscope (degree/seconds)	-0.13223	-0.33702	-0.32091	Outdoor	2.11E+14
Magnetometer microteslas(μT)	-20.1938	-33.6563	5.55	Outdoor	2.11E+14

Table 1. Data collection using inertia sensor

GPS_Lat (latitude)	GPS_Long(longitude)	label	Accuracy(metre)
22.49699	88.37255	Indoor	34.757

Table 2. Data collection using GPS

4.4 work flow of the proposed module:

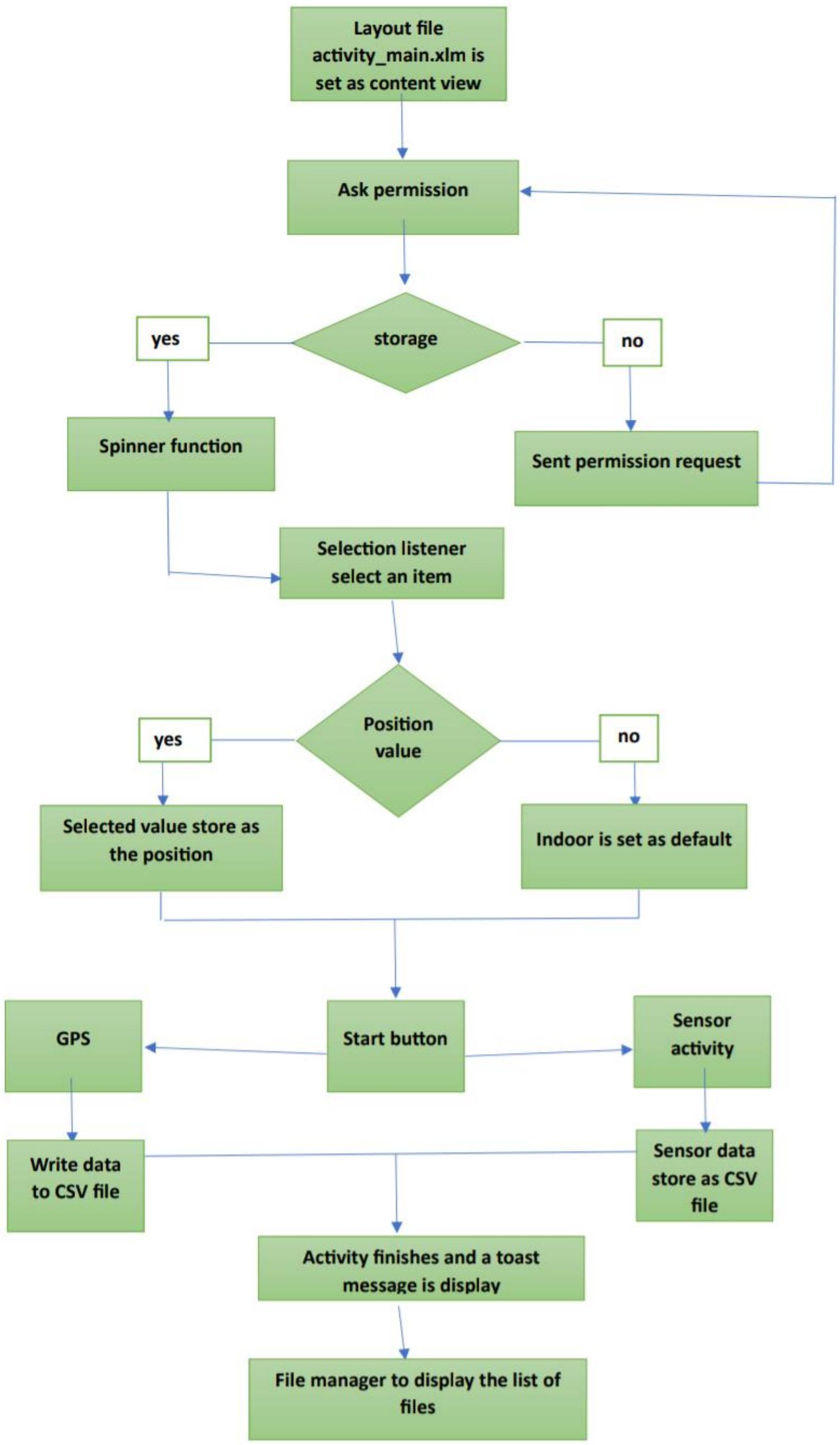

Figure 1. work flow of the proposed module

4.5 Implementation tool of the proposed module:

The app is developed in Android Studio. Android studio is the official Integrated Development Environment (IDE) for developing Android applications. It is specifically designed for android app development and provides a comprehensive set of tools and features to streamline the development process.

Android studio offers a rich visual editor with advanced code editing capabilities. It includes support for Java and Kotlin programming languages. We use Java to create the application.

The layout that we created in the application is shown in Figure 2.

Figure 2. Layout of indoor-outdoor sensor data collection application.

CHAPTER 5
DATA VISUALISATION

5.1 Screenshots

Figure 3. the application in mobile

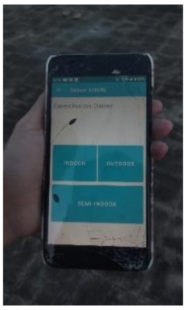

Figure 4. start to collect the data

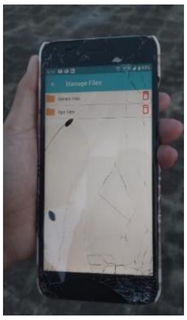

Figure 5. data store in different files

5.2 Results and discussions (graph and explanations)

In this section we will discuss about the difference of indoor data vas semi-indoor vs outdoor data collected from different location. And we will also discuss about the activity of the user.

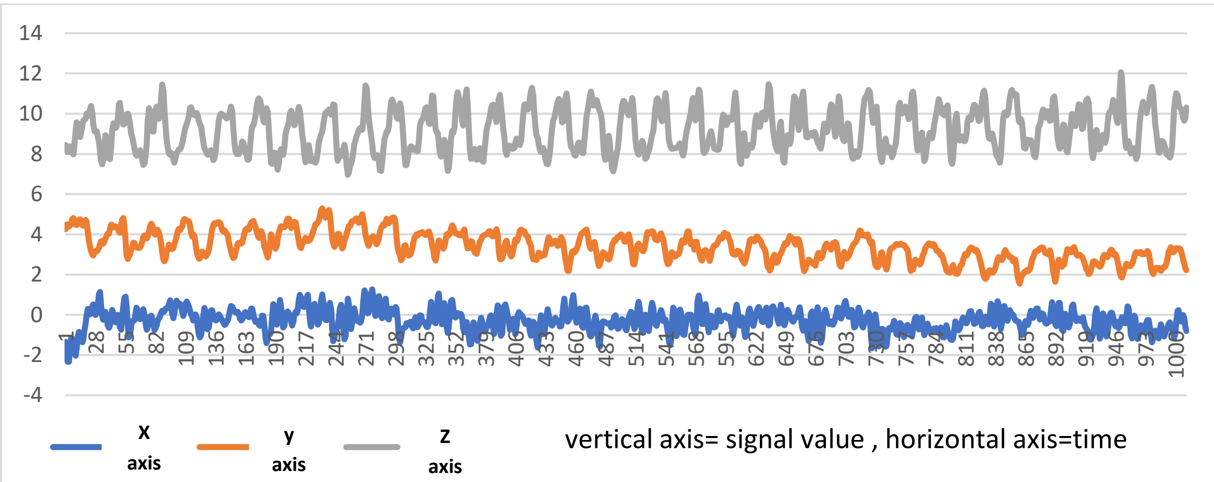

Figure. 6 Outdoor **Accelerometer 3 axis data** near Aurobindo bhavan

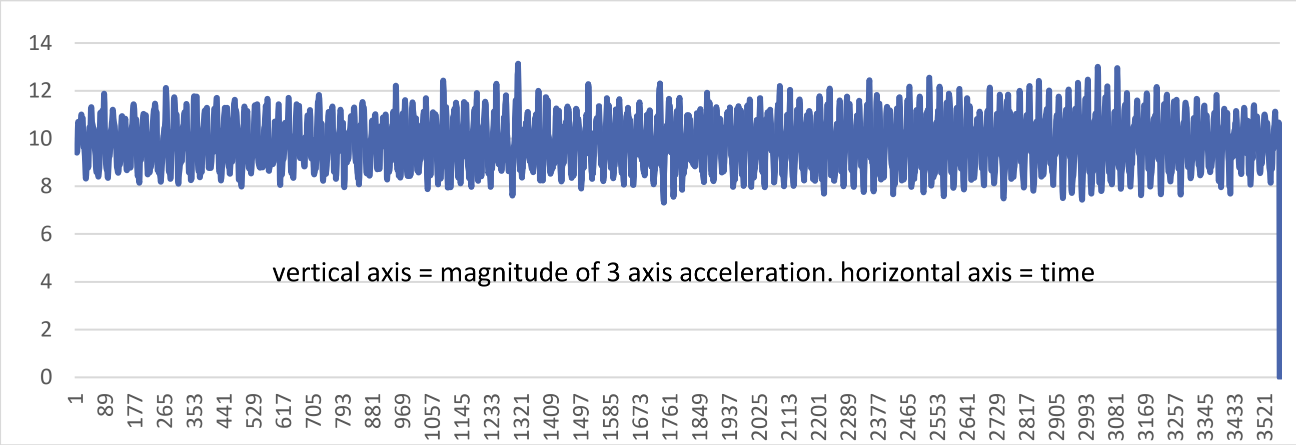

Figure 6.1 magnitude of 3 acceleration from figure 6

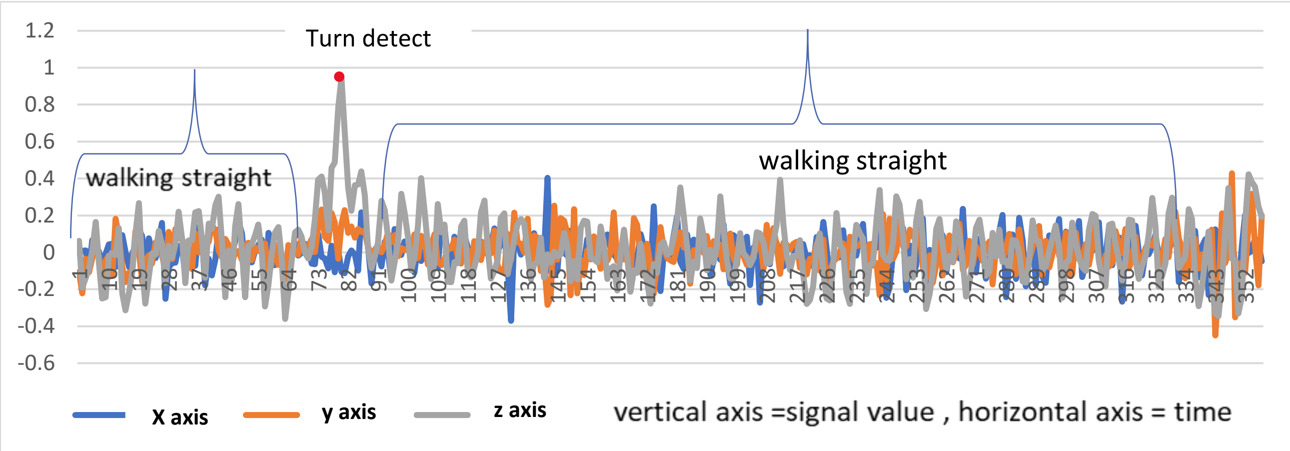

Figure. 7 Outdoor **Gyroscope 3 axis data** near Aurobindo bhavan

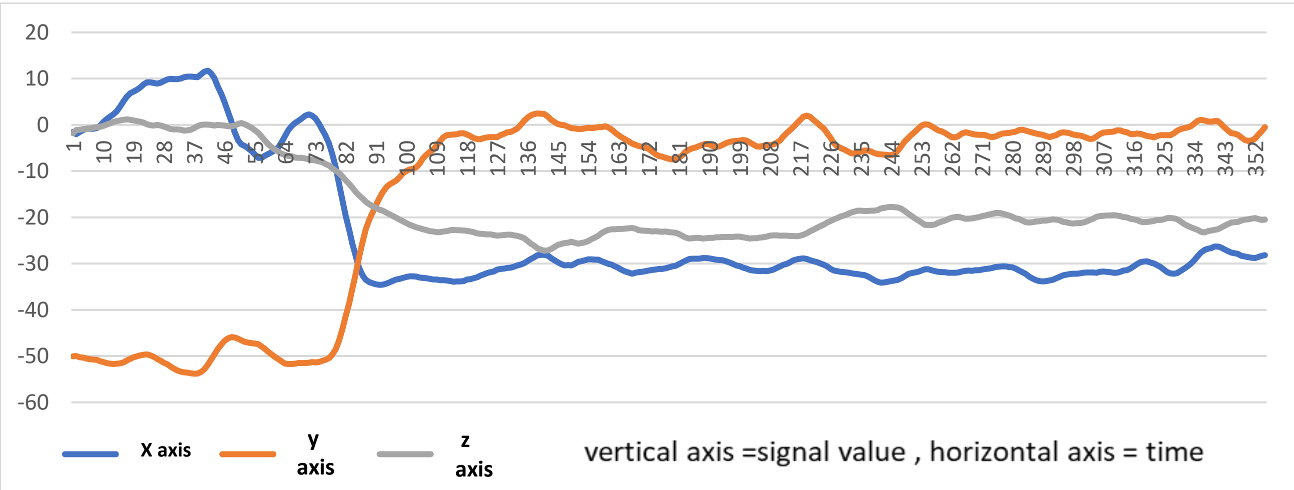

Figure 8 Outdoor **Magnetometer 3 axis data** near Aurobindo bhavan

The above graph of Figure 6, Figure 7, Figure 8 data is collected from outside of Aurobindo bhavan, Jadavpur University. Date:24.04.23, time:4:36 pm, device: MiA1

In Figure 6.1 is the magnitude of 3 acceleration from Figure 6. From that graph Figure 6.1 we can estimate the step count.

The data is collected from the entrance of Aurobindo bhavan then make a left turn and then straight walking. So, while turning left we can see in Figure 6 gyroscope z axis point high to indicate that. And for walking straight there is no other high point like before.
In Figure 7 we can see that after turning left that 3 axes crosse their path to indicate the turning then separated.

Figure 9. Image of collecting data outside of Aurobindo bhavan

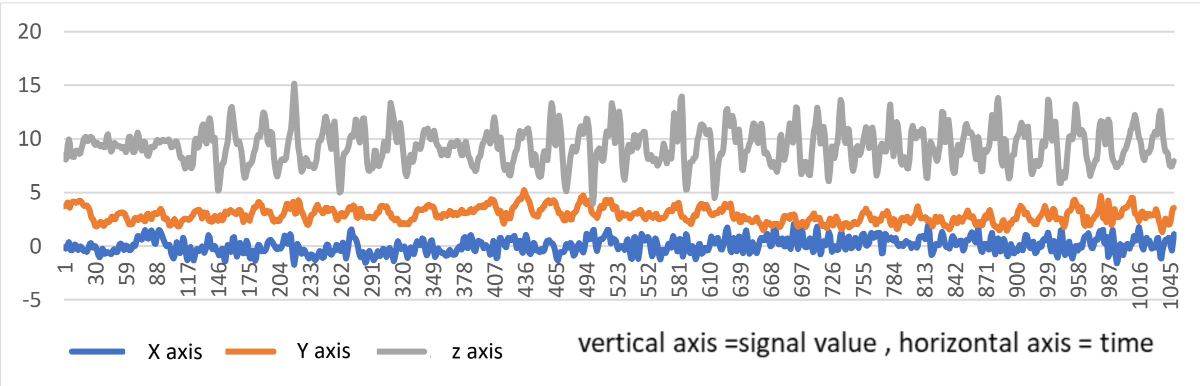

Figure 10. Indoor **Acceleration 3 axis data** inside Aurobindo bhavan stairs downwards.

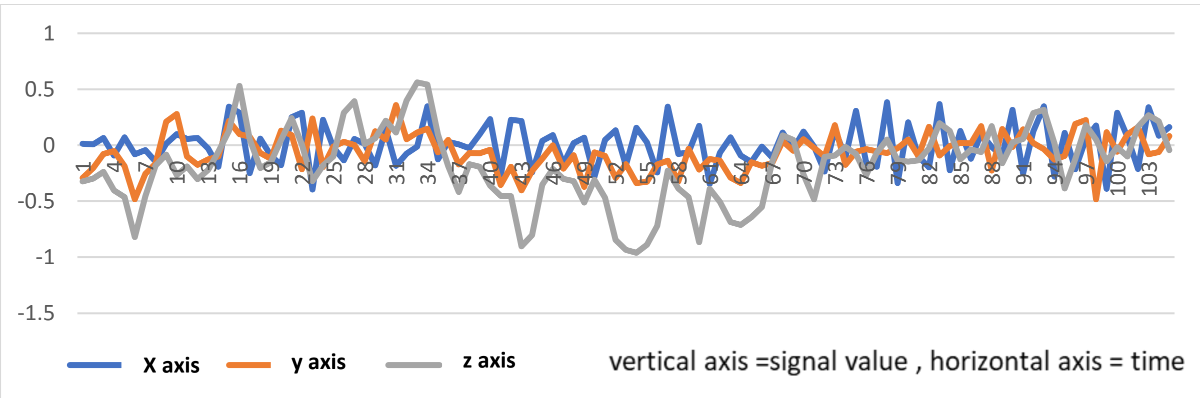

Figure 11. Indoor **Gyroscope 3 axis data** inside Aurobindo bhavan stairs downwards.

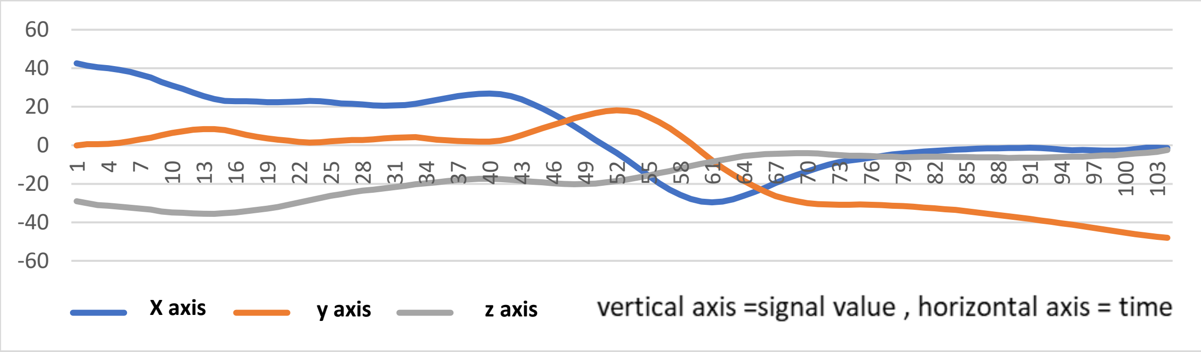

Figure 12. Indoor **Magnetometer 3 axis data** inside Aurobindo bhavan stairs downwards.

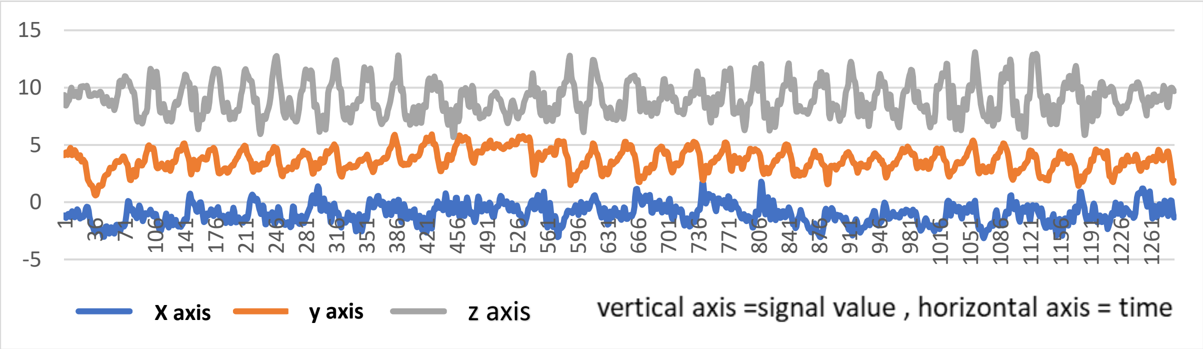

Figure 13. Indoor **Acceleration 3 axis data** inside Aurobindo bhavan stairs upwards.

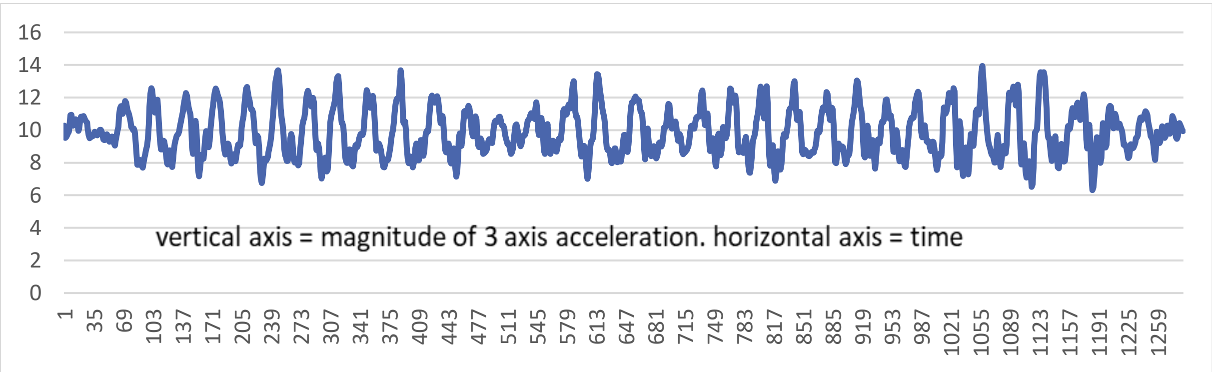

Figure 13.1 magnitude of 3 acceleration from figure 13

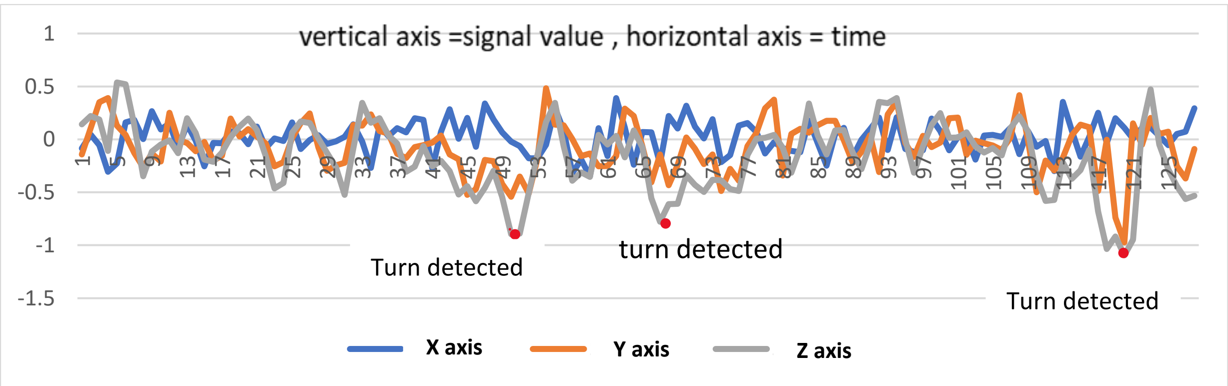

Figure 14. Indoor **Gyroscope 3 axis data** inside Aurobindo bhavan stairs upwards.

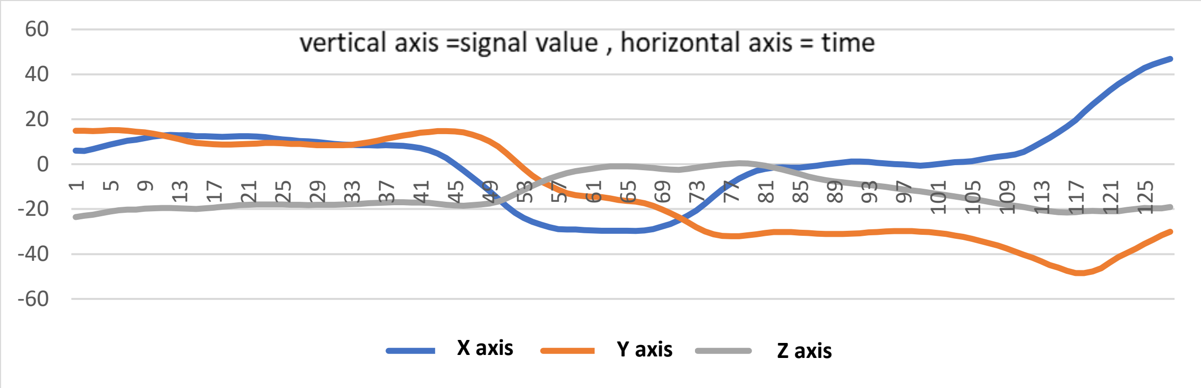

Figure 15. Indoor **Magnetometer 3 axis data** inside Aurobindo bhavan stairs upwards.

The above graph of Figure 10, Figure 11, Figure 12, Figure 13, Figure 14, Figure 15 data is collected from inside of Aurobindo bhavan, Jadavpur University. Date:24.04.23, time:4:36 pm, device: MiA1

Figure 13, Figure 14, Figure 15 data is collected from the starting of the ground floor to the 1st floor of Aurobindo bhavan. In figure 13.1 is the graph of magnitude of 3 acceleration of the graph Figure 13. From that we can estimate the step count of the user.

In that root we make 3 turns that can detect from Figure 14 gyroscope graph. and in Figure 15 we can see that after turning left that 3 axes crosse their path to indicate the turning also in compare to the Figure 8 graph which is outdoor magnetometer graph we can see some difference.

Figure 16. Image of collecting data inside of Aurobindo bhavan

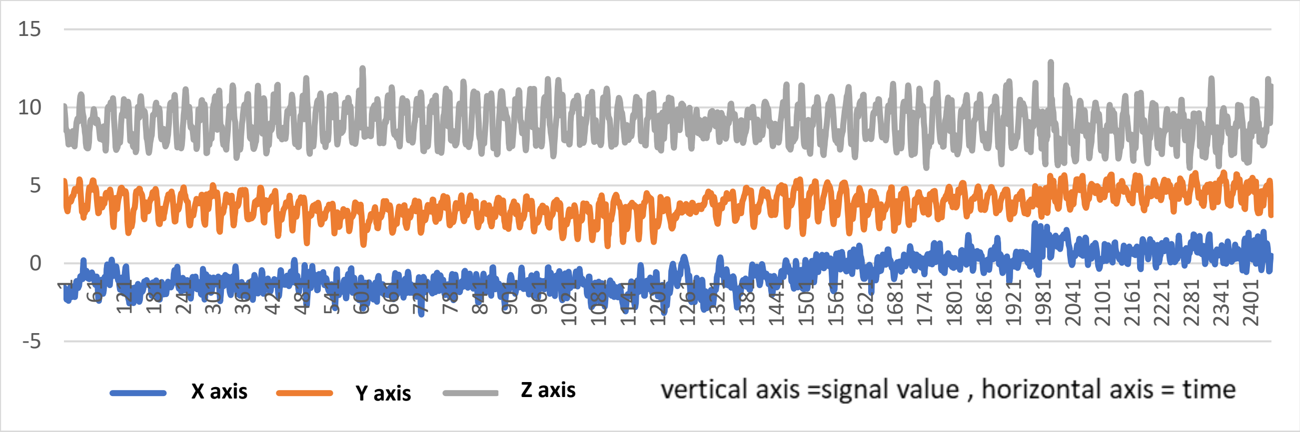

Figure 17. Semi-Indoor **Acceleration data 3 axis** inside Aurobindo bhavan corridor.

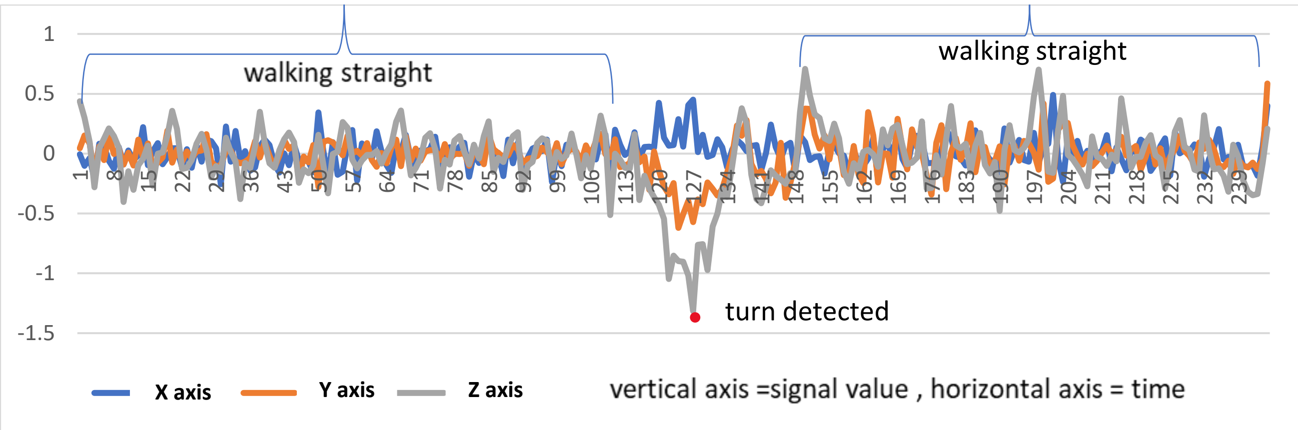

Figure 18. Semi-Indoor **Gyroscope 3 axis data** inside Aurobindo bhavan corridor.

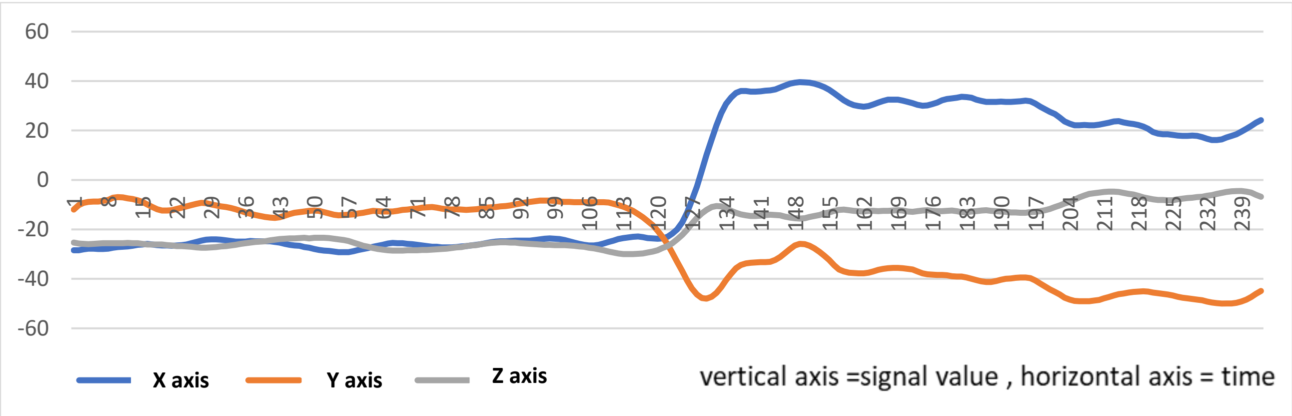

Figure 19. Semi-Indoor **Magnetometer 3 axis data** inside Aurobindo bhavan corridor.

The above graph of Figure 17, Figure 18, Figure 19 data is collected from inside of Aurobindo bhavan corridor, Jadavpur University. Date:24.04.23, time:4:45 pm, device: MiA1

Here data is collected from the corridor, which is a semi-indoor position. Walking straight to the end of the corridor then turning back and go back to the starting position.

In Figure 18 we can see the turning is detected by the gyroscope sensor. And in Figure 19 the magnetometer 3 axes crossing their path and then separated. Figure 18 somewhere behaves like Figure 8, which is outside of Aurobindo bhavan magnetometer graph. Here magnetometer graph reading is also very stable.so we can say that semi-indoor can somewhere also behave like outdoor.

Figure 20. Image of collecting data inside of Aurobindo bhavan

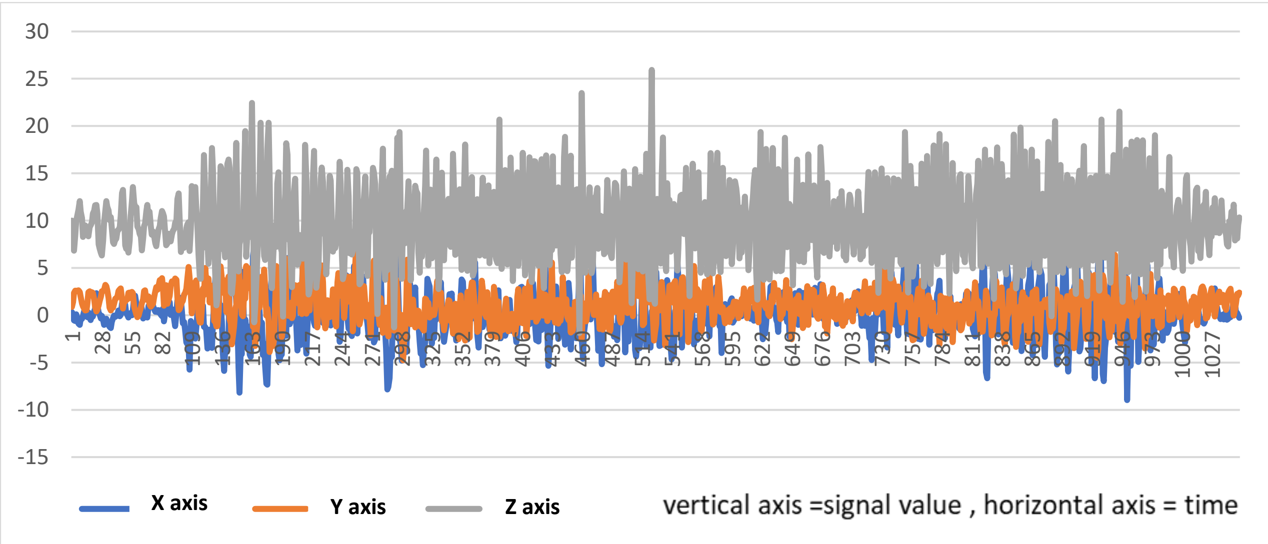

Figure 21. Outdoor **Acceleration 3 axis data** from Central Library to impact centre running

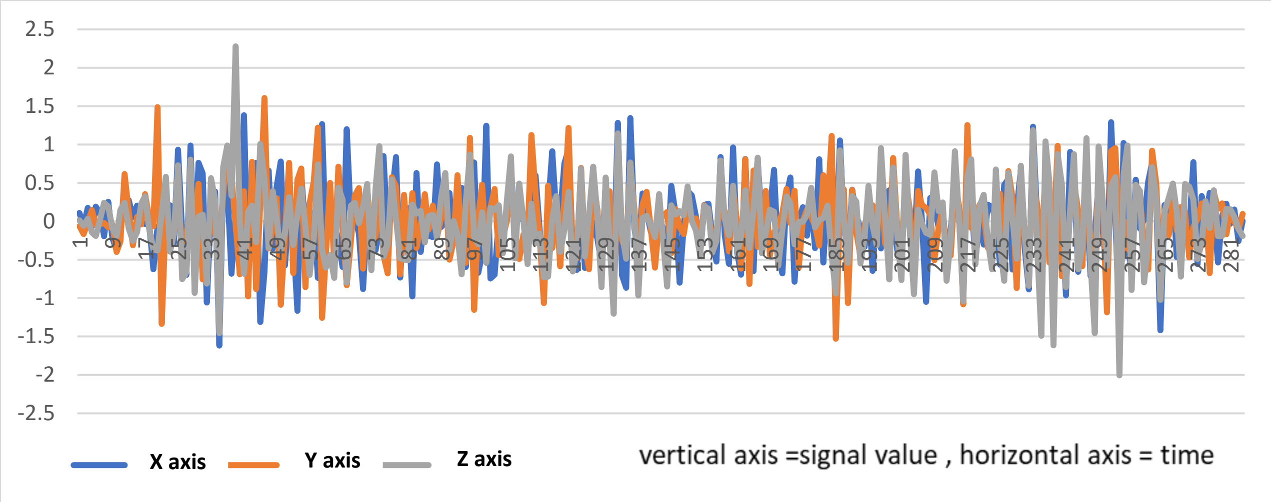

Figure 22. Outdoor **Gyroscope 3 axis data** from Central Library to impact centre running

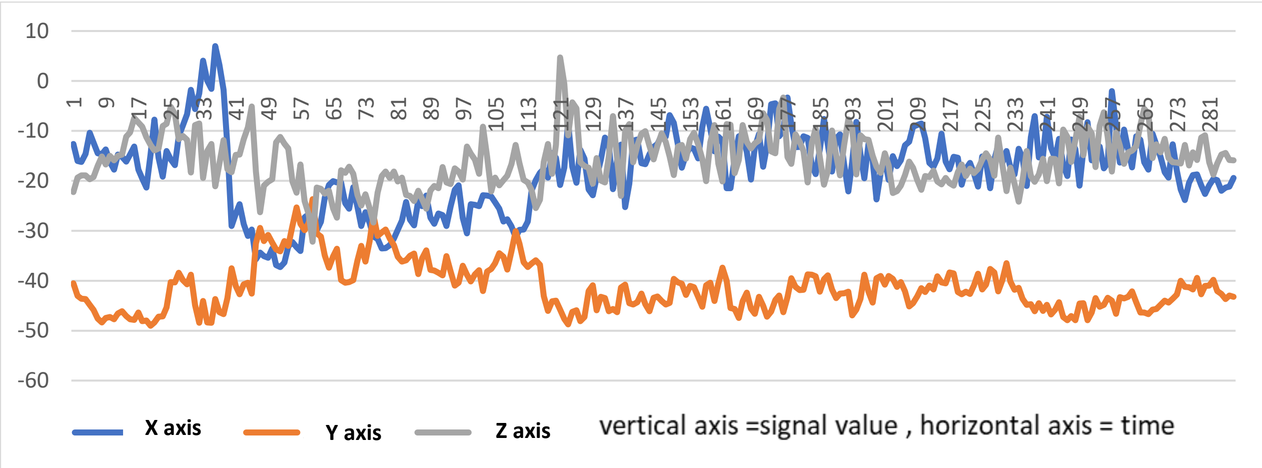

Figure 23. Outdoor **Magnetometer 3 axis data** from Central Library to impact centre running

The above graph of Figure 21, Figure 22, Figure 23 data is collected while running straight from Central Library to impact centre, Jadavpur University. Date:24.04.23, time:5:00pm, device: MiA1

Here data is collected while running straight. That is why we can see the difference from the graph where data is collected by walking in Figure 6, Figure 7, and Figure 8.

Here accelerometer graph Figure 21. Encounter more vibration and motion due to running.

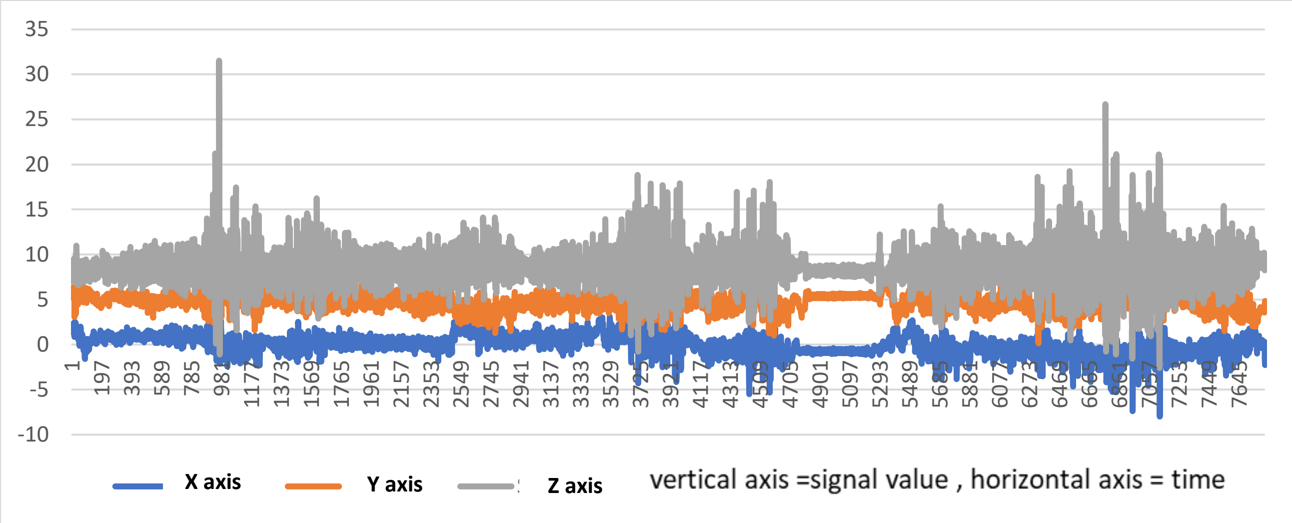

Figure 24. Outdoor **Accelerometer 3 axis graph** from university to home via auto

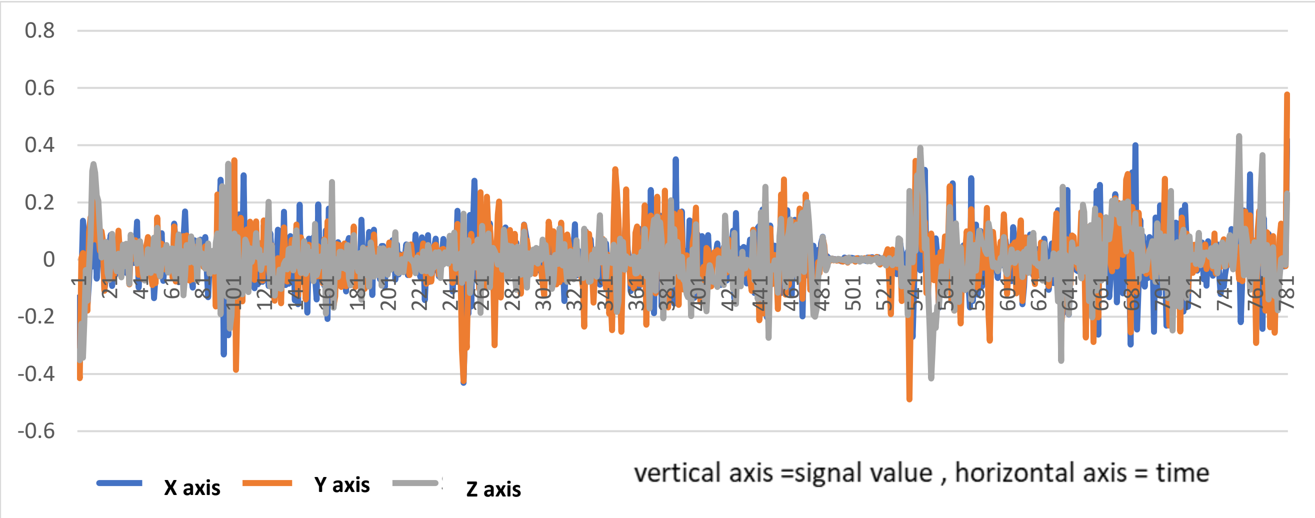

Figure 25. Outdoor **Gyroscope 3 axis graph** from university to home via auto

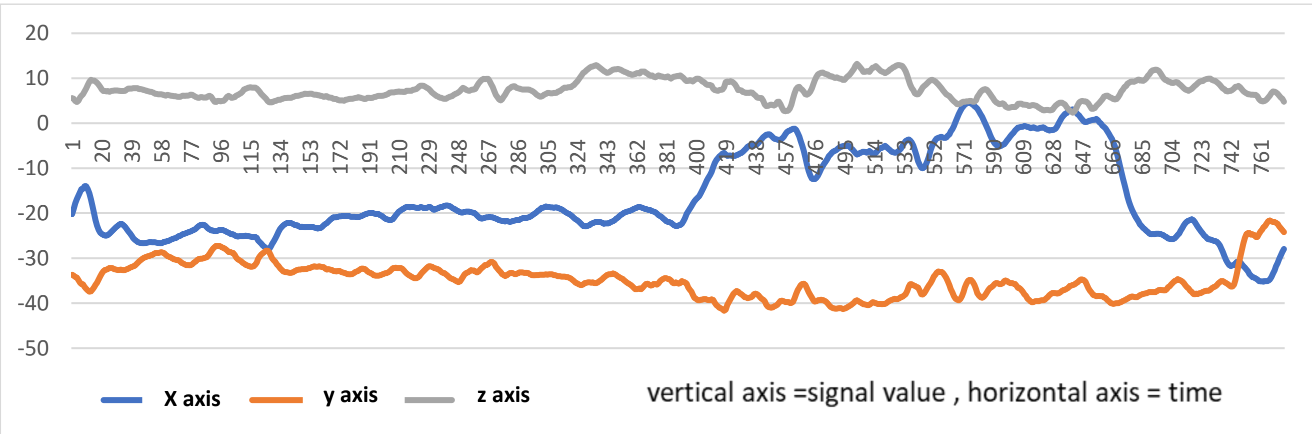

Figure 26. Outdoor **Magnetometer 3 axis graph** from university to home via auto

The above graph of Figure 24, Figure 25, and Figure 26 data is collected while going home from Jadavpur University via auto. Date:24.04.23, time:5:30pm, device: MiA1

Here in Figure 24, Figure 25, and Figure 26 we collect data while travelling university to home in the auto. This graph gets more value than other graphs. Gyroscope detect more than one rotation. And magnetometer also detect magnetic field but the change of value is low compare to Figure 23, which is Outdoor Magnetometer data from Central Library to impact centre running.

We can now predict that the sensors will detect increased noise and vibration on the road and outside.

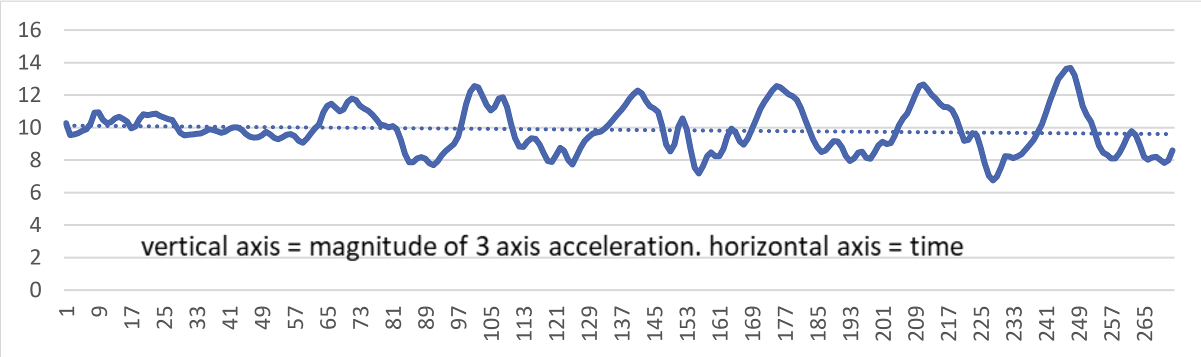

Figure 27. indoor magnitude of accelerometer data walking

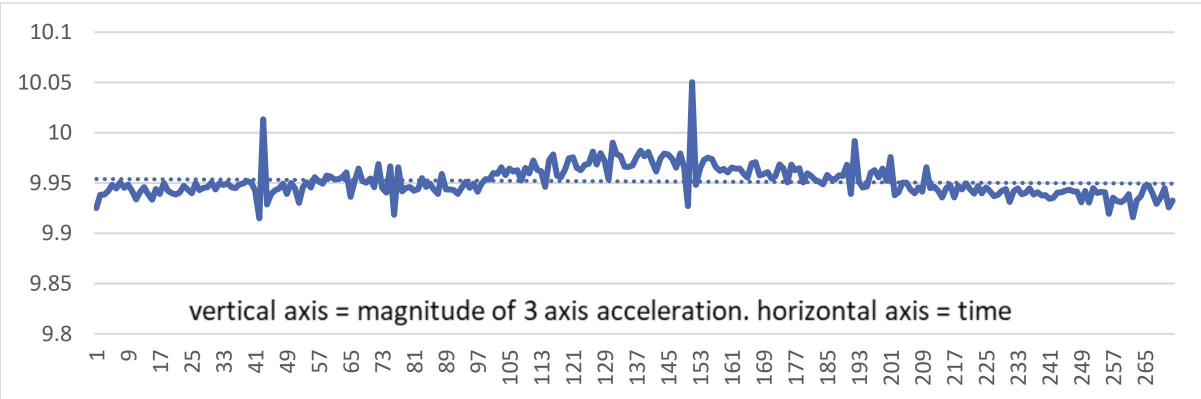

Figure 28. indoor magnitude of accelerometer data standing position.

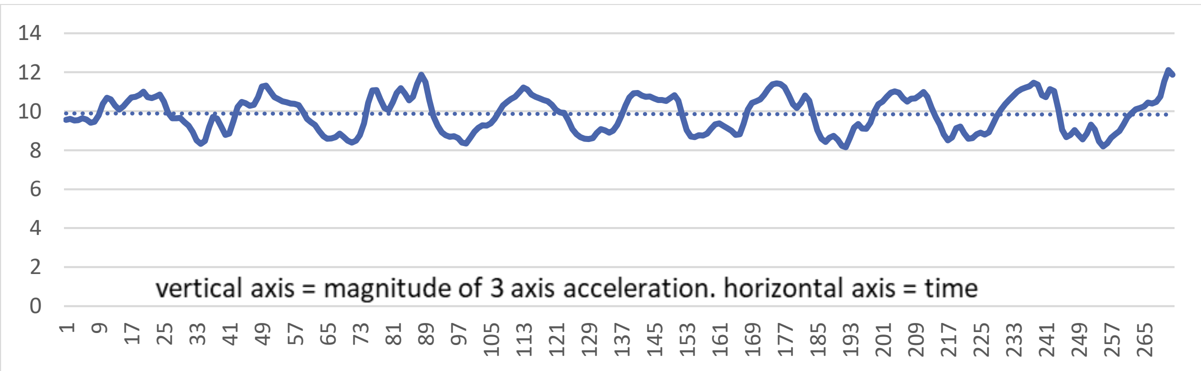

Figure 29. outdoor magnitude of accelerometer walking

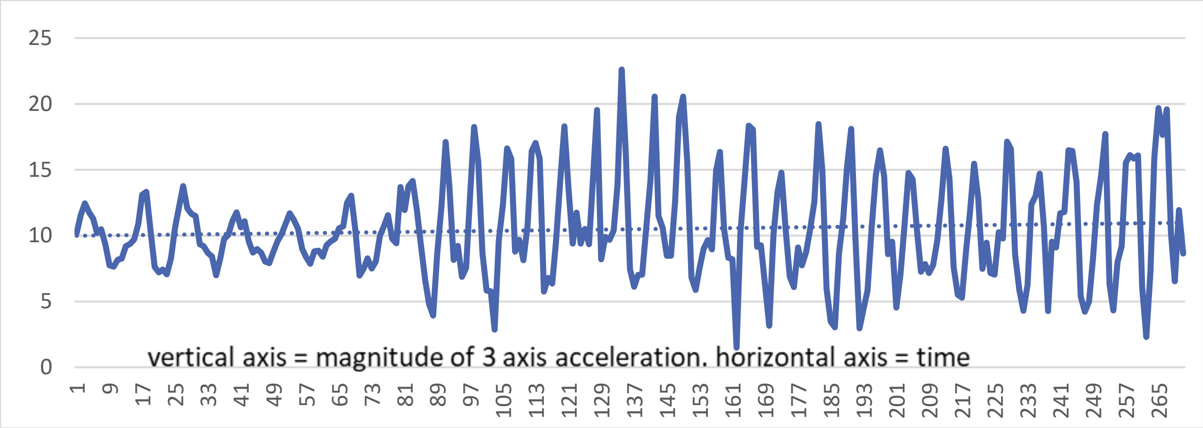

Figure 30. outdoor magnitude of accelerometer running

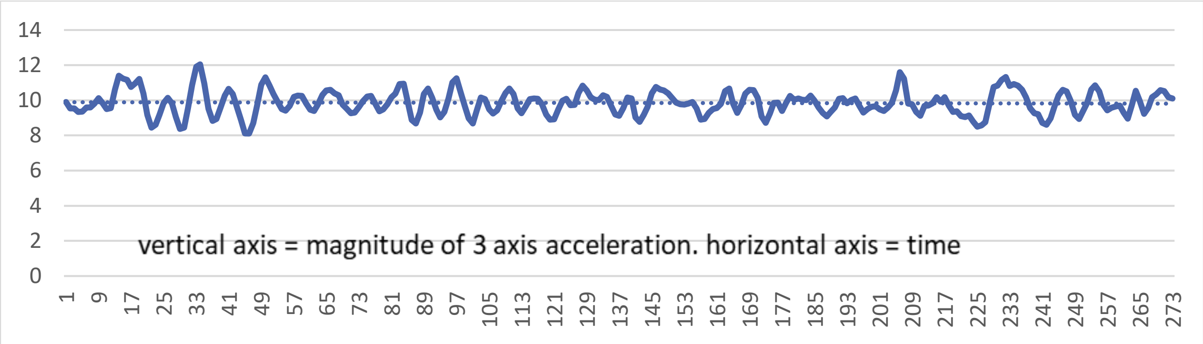

Figure 31. outdoor magnitude of accelerometer travelling via auto

The data collected while walking indoors in Figure 27 is more steady than the data collected while walking outside in Figure 29. Figure 28, on the other hand, was taken while standing inside and is also more stable. Figure 30's data is more erratic than any other graph because it was collected while the subject was running. In Figure 32 is taken while travelling and the data is stable.

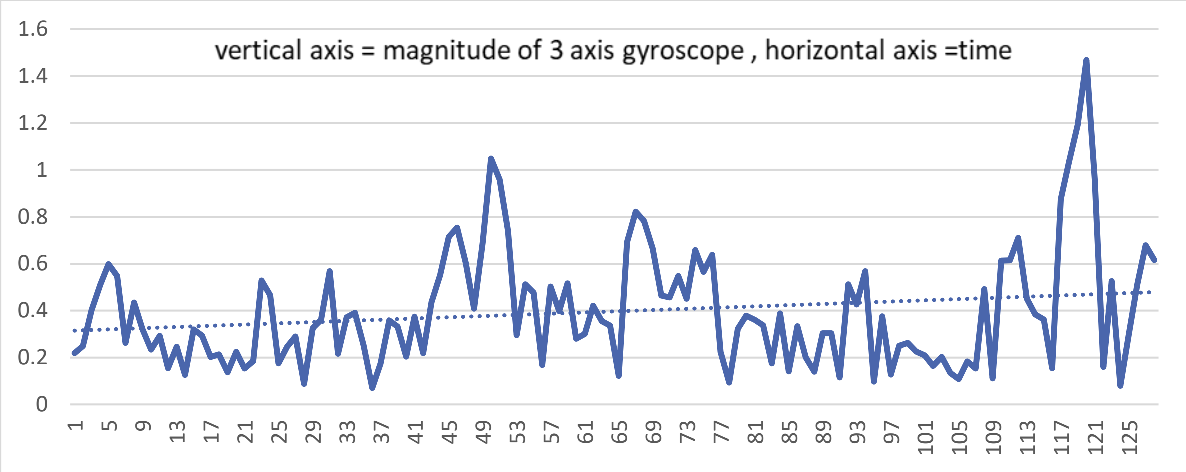

Figure 32. indoor gyroscope data while walking

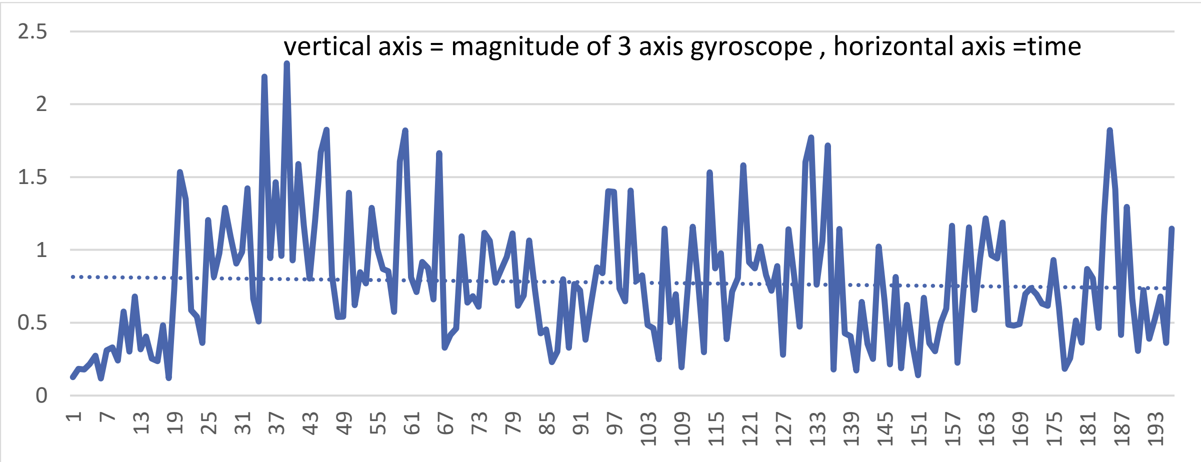

Figure 33. outdoor gyroscope data while running

Data acquired when running outdoors fluctuates more frequently than data collected while walking indoors, as shown in Figure 33 and Figure 34.

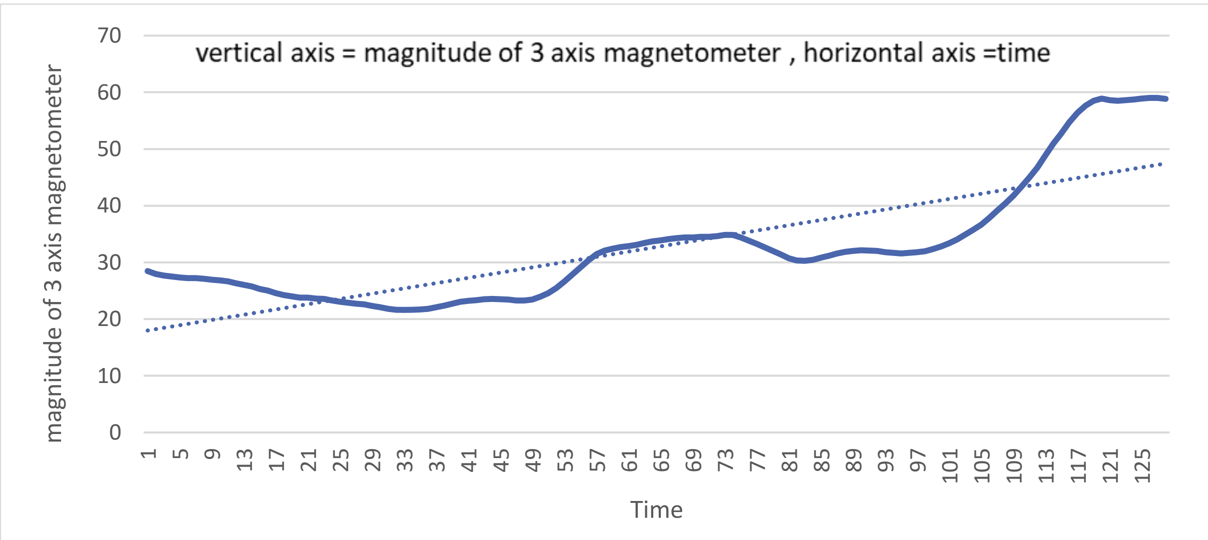

Figure 34. Indoor magnetometer while walking.

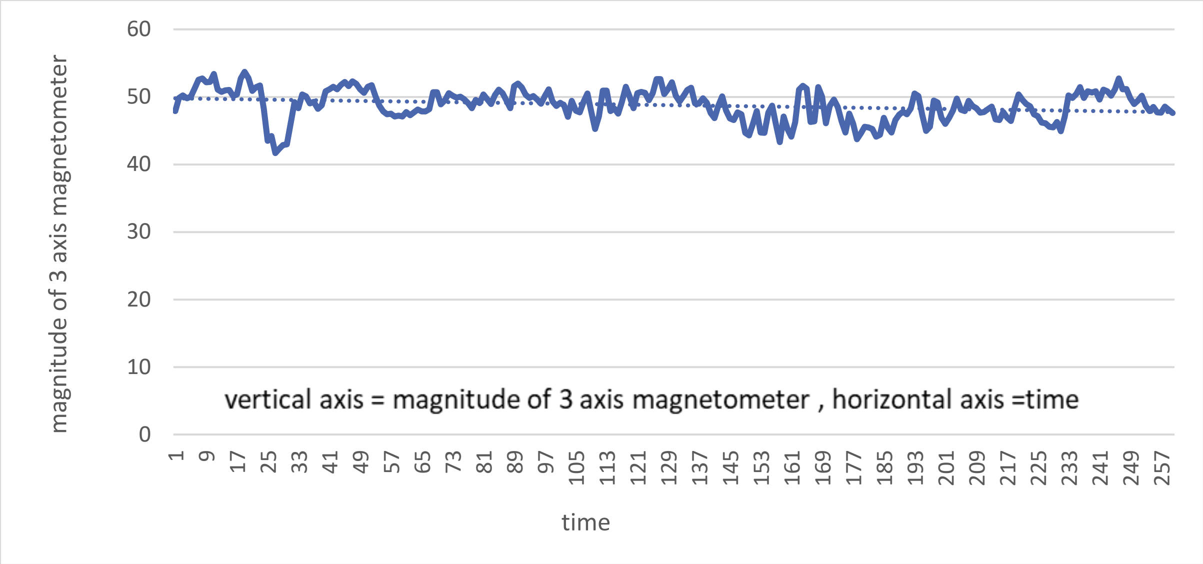

Figure 35. Outdoor magnetometer while running.

Magnetometer average values in Figures 34 and Figure 35 are 20 and 50, respectively. Figures 34 and Figure 35 show values obtained when walking indoors and while jogging outside, respectively. And it is clear from looking at these two graphs how they different.

Global positioning system (GPS):

- In this part data collected from outdoor to indoor. Figure 36 is collected from Playground of the Jadavpur university main campus to Impact Centre. The experiment involves Real me 8 and Samsung Galaxy smartphones.Date-28/4/2023.Time-6.30pm

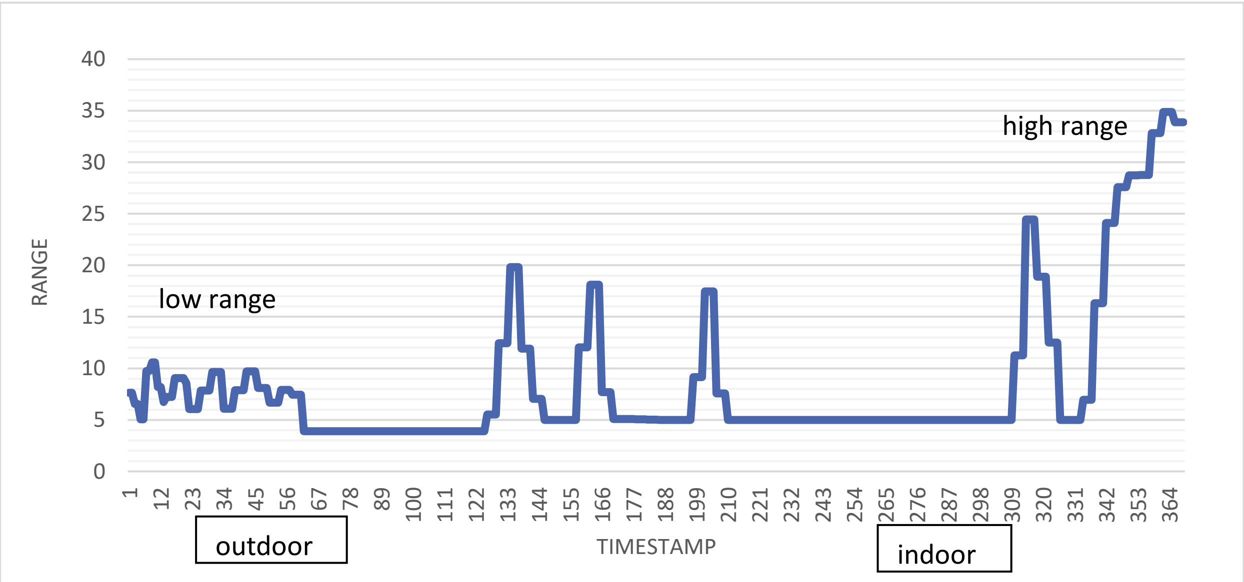

Figure 36. outdoor to indoor data from playground of Jadavpur university to impact centre.

- Figure 37 is collected from outside of my house to Inside of my house. The experiment involves Real me 8.Date-16/5/2023.Time-4.56pm.

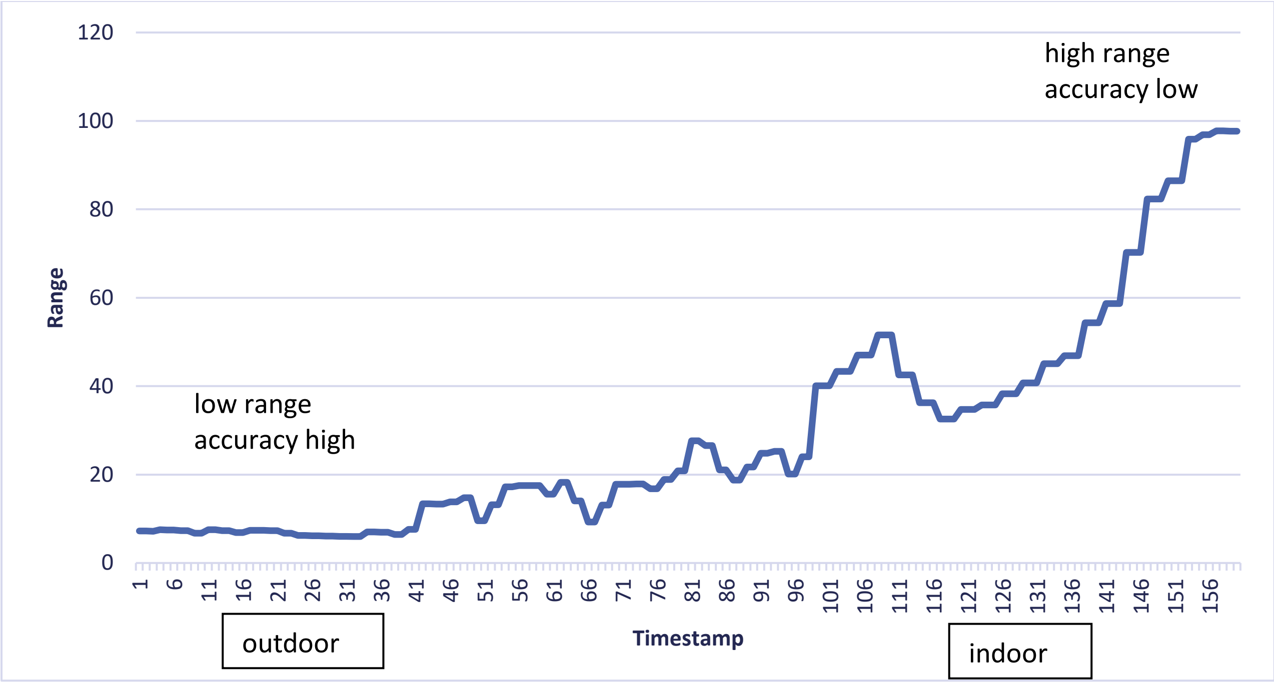

Figure 37. outdoor to indoor data from my house.

Explanation:

The GPS (Global Positioning System) accuracy is typically expressed in terms of a circular error probable (CEP) value, which represents the radius of a circle within which the true position is likely to fall with a certain level of confidence. For example, if a GPS device has an accuracy of 10 meters CEP, it means that there is a 50% probability that the true position is within a circle of 10 meters radius centered on the reported GPS position.

Also, in Figure 36 and Figure 37 the graph range is getting higher as we enter to the inside of the building or to my house. But initially when we are at the outdoor, we can see that the range is quiet low compare to the indoor.

The actual accuracy of GPS can vary in different scenarios. In ideal conditions with a clear view of the sky and a high-quality GPS receiver, accuracies within a few meters or even centimeters can be achieved. However, in urban environments with tall buildings, dense forests, or other obstacles that block or reflect satellite signals, the accuracy may be reduced, and errors in positioning can occur.

In Figure 36, the data is collected from the Jadavpur university which belongs to urban environment with tall buildings, so we see that the graph is not very smooth it has some ups and downs. Now in Figure 37, the data is collected from my hometown, which do not have any tall buildings around, so we can see that the graph is very smooth compare to Figure 36.

CHAPTER 6
Conclusion

The study largely examined navigational habits indoors vs outdoors. We gather information from a variety of locations and situations, including driving, running, and strolling. The inertial sensors data from commonly available smartphones have been collected along with GPS for different activities. Extensive data visualisation has been performed to develop insight about human behavior for indoor vs semi-indoor vs outdoor setting.

The semi-indoor location data behaves much like outside location data. The main distinction among the inertial sensors' 3 axis magnitude in indoor and outdoor settings and for various activities different patterns are visible. For GPS the location is important factor, such as data collection from city area (university campus in Kolkata) vs rural area (in hometown Cooch Behar).

Some activities could be observed in outdoor spaces which are rare in an indoor space. For instance, the average walking speed of the user is more in outdoor spaces. Even the turns could also be detected through the inertial sensing patterns. Thus, inertial sensing could supplement GPS when GPS accuracy is low. In future we plane to apply deep learning/machine learning technique for extensive data analysis. We also plan to explore the change in navigational behavior for urban vs rural context for indoor vs semi-indoor vs outdoor setting.

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