A

B.TECH PROJECT REPORT ON

"Unity–Based 3D Indoor Navigation System "

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

In

Information Technology

By

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Academic Year 2024 – 25

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CERTIFICATE

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students of B.Tech (Semester VIII) has satisfactorily presented project on **"Unity- Based 3D Indoor Navigation System"** in partial fulfillment of the Bachelor of Technology (B.Tech.) in Information Technology under Dr. Babasaheb Ambedkar Technological University, Lonere during the academic year 2024-2025.

Date:

Place: SVKM's IOT, Dhule

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DECLARATION

We declare that this written submission represents ideas in our own words and where other's ideas or words have been included, we have adequately cited and referenced the sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will cause disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

Outdoor navigation tools like Google Maps have transformed how people find their way to destinations, seamlessly leading them to the exact location of a particular venue not only to the location but also to the entrance of complex venues such as universities, malls, airports, railway stations, and hospitals. Despite that, these solutions cannot offer further guidance when users enter these large spaces or venues. This scarcity of real-time, step-by-step indoor navigation can lead to perplexity, agitation, and wasted efforts while users endeavor to find areas like libraries, classrooms, shops, or departments encased in these wide-ranging interiors. Lacking an integrated, user-friendly solution for indoor navigation, first-timers and others with accessibility needs are greatly affected. Suggest a holistic, real-time indoor navigation system capable of fluid operation in large, complex venues, filling a gap in navigation technology. This shall employ the latest positioning technologies, which will include Wi-Fi triangulation, Bluetooth beacons, and augmented reality to help people navigate indoor spaces from a specific point to a destination with maximum precision in real time. The integration of the system with outdoor navigation platforms already in existence would aim to create a seamless navigation experience from the outdoors into the indoor space. Hence, it encompasses a wide range of applications that make the system more excellent in raising the experience of accessibility and efficiency in many public and private areas.

Keywords— Indoor Navigation, Navigation Efficiency, Positioning Technology, Precision, WI-FI Triangulation.

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Chapter 1

INTRODUCTION

1.1 Introduction to Project

The "Unity-Based 3D Indoor Navigation System" is among developments that have come up in the use of indoor wayfinding technology to meet the high demand for effective navigation in complicated environments. Urbanization and the building of tall buildings create more challenging problems for indoor navigation; therefore, indoor navigation problems increase. GPS-based navigation devices are very effective in open areas, but they fail or are feeble when used indoors. A system with such a capability will more likely be confusing and frustrating for people attempting to locate certain destinations within extensive areas like universities, malls, airports, hospitals, and business houses. In response to this lack, our project is an innovative indoor navigation system applying state-of-the-art technologies to facilitate the smooth navigation of users. This system makes use of state-of-the-art 3D modeling complemented with Wi-Fi-based positioning and real-time pathfinding features to guarantee precise direction as well as complete engagement in their navigation within indoor environments. At a very basic level, it utilizes Unity, which is one of the most well-rounded platforms existing today, famous for the abilities it has in 3D rendering and game development. With Unity, we can create complex and interactive computer simulations of indoor spaces and hence enable users to better visualize their spaces and learn about their spaces in a truly engaging and informative manner. You enter a university campus and notice an interactive map on your tablet or smartphone, not only indicating the building layout but also highlighting libraries, cafeterias, lecture rooms, and restrooms. Navigation technology that saturates the user in his environment and guides him along this with total information enables him to navigate around economically and leaves him with more time for searching. Of key importance in this system is reliance on the fingerprinting method in finding a Wi-Fi-based indoor positioning. It operates on mapping out distinctive signals of Wi-Fi radiating from different access points around the building. By collecting and analyzing such signals, the system can accurately position the user with a high level of precision. Using data from the IMU sensors in most smartphones to track movement and orientation, system is more likely to be precise in tracking locations, particularly where Wi-Fi might be spotty. This two-pronged approach, then, assists in continuing to provide navigations to a user in question despite having had a successful deployment in sometimes less-than-easy conditions. The system might also be capable of providing real-time pathfinding functions. The system would then be capable of providing users with the optimum route to their intended destination; it could be a specific classroom, an administrative office, or even a study zone. Here, the system will record the matters of accessibility and further those of user preference-like not desiring routes with stairs or busy places. This is the degree of personalization which makes the navigation system very usable because it addresses the different needs of its user.

The Unity-Based 3D Indoor Navigation System shall be implemented initially at SVKM's Institute of Technology, a dense and complex educational institution. It will facilitate the easier navigation of students, teachers, and visitors inside the institution using visual handles meant to minimize complexities in finding places within the campus. Where there are many buildings, lecture halls, labs, and recreation centers, it is only logical that people, especially newcomers, have a high chance of getting lost. We hope that with a user-friendly navigation system, navigating around campus would be made easy for people to access the services needed.

Besides direct application within the institute, this has the potential for various industries. As an example, in business districts, the same navigation system might be created at shopping malls to enable customers to find stores, facilities, and special events so that they can offer greater satisfaction. The system can be used in airports for travelers to guide themselves to the gates, lounges, and facilities to help alleviate tensions within them during finding these spaces. A majority of hospitals would be improved by a

navigation system that is tailored to guide visitors to where they want to get, effectively and with reduced anxiety, due to the commonly disorienting spatial organization that may intimidate patients and visitors equally.
The social impact of this project is also extra because the navigation system is dedicated to accessibility. Individuals with mobility disabilities can find paths through large public indoor spaces by building personalized routing that takes into consideration specific needs. The system will also be able to cater to users of diverse ability through voice-guided navigation and other visual aid methods that allow all individuals to move around their indoor spaces with ease. Such a "Unity-Based 3D Indoor Navigation System" can have great potential to revolutionize indoor wayfinding with a consistent, end-user product that generally improves the experience of navigation in numerous environments. The project capitalizes on the versatility of 3D modeling, uses Wi-Fi positioning, and conducts real-time pathfinding in an effort to address one of the key needs for such efficient navigation in complex indoor spaces. It fills us with joy in our hearts to be able to see it progress in its evolution and deployment at SVKM's Institute of Technology so that in the days ahead crossing major museums, stations, and other places will be as easy as navigation in the outdoors.

1.2 Motivation for the project topic

The impetus to develop the Unity-Based 3D Indoor Navigation System comes from the need to overcome the limitations of conventional indoor navigation and improve user convenience and accessibility in complex indoor environments. To begin with, GPS technology is unable to operate indoors due to the fact that the signals are cut off by walls and other structures, so that wayfinding for users proves difficult within large spaces like malls, hospitals, universities, or airports. By utilizing an alternative solution with Wi-Fi RSSI, this system offers reliable indoor positioning during times when GPS is unavailable. Leverage existing Wi-Fi infrastructure already in place diminishes additional setup costs and hardware installation, thus making this solution cost-efficient and scalable for those buildings that would prefer to offer sophisticated navigation without incurring major expenditures.

Alongside these functionalities, the system also uses Unity to project an interactive 3D model of the environment. AI detected Besides these features, the system also utilizes Unity to show an interactive three-dimensional model of the environment. The 3D model facilitates easy navigation of unknown places because users are able to know their precise location along with the structure of the building in real time.The sense of immersion generated by the visual feedback assists the users in getting oriented and experiencing a more natural sense of direction compared to the traditional 2D maps. Furthermore, with the inclusion of machine learning, the system is capable of improving its positioning precision over a long span of time. These models get trained based on data gathered, and thus the system can learn to adapt with changing environments, like shifting furniture or new doorways, thereby giving precise positioning information that dynamically refreshes with building layout. One more strong impetus driving it is convenience and accessibility. The system can be logged into via the web application by scanning a QR code, meaning that users never have to install or download an app.

This allows the system to reach out to anyone who can simply begin using the system without needing technical expertise. This integration of Wi-Fi positioning, machine learning, and Unity's 3D rendering technology brings about a user-focused indoor navigation solution that is groundbreaking yet realistic, solving actual indoor navigation issues. Such an end-to-end solution is not just aiming to deliver accurate real-time guidance but also to optimize the user experience, so that users are assured and oriented in big indoors.

1.3 Objective and purpose of the work:

The central goal of this project is to create a scalable and robust indoor navigation system that can be suitably integrated in a large variety of public areas. This system integrates Wi-Fi positioning with the ability of machine learning and offers navigation in the form of an intuitive 3D visualization interface. The purpose is to make indoor mobility easy for users and offer real-time, precise navigation guidance in areas where GPS does not work.

- To do this, the project aims at the following specific aims:
- To develop a high-resolution Wi-Fi fingerprint database of public places by measuring variations in signal strength at different points.
- To create a real-time 3D navigation and path planning system based on the Unity game engine, with an interactive and immersive visual experience.
- To establish an improved machine learning algorithm that enhances Wi-Fi fingerprint accuracy by learning from signal fluctuations and real indoor dynamics.
- To design an easy-to-use, mobile-compatible app for the user to access the navigation system through QR codes or web interfaces.
- To roll out and pilot the system in real-world sites like airports, schools, and shopping malls, and incrementally refine it using real-world usage data and user feedback. feedback.

1.4 Scope of the project:

The goal of the Unity-Based 3D inside Navigation System is to provide a useful and real-time navigation system designed for expansive inside spaces where GPS is ineffective. This covers locations such as hospitals, shopping centers, airports, corporate offices, and educational institutions. To provide precise indoor location monitoring, the system makes use of Wi-Fi RSSI-based positioning that has been improved with machine learning. The project gives customers an engaging and user-friendly interface by combining this with a 3D environment made using the Unity engine. By eliminating the need to download stand-alone apps, QR code scanning simplifies accessibility and makes it user-friendly and lightweight.

Additionally, the system is built to dynamically adjust to changes in the environment and gradually increase its accuracy by identifying patterns. The project seeks to deliver an inexpensive, scalable, and user-friendly indoor navigation experience by addressing the constraints of GPS in inside settings by combining accuracy, simplicity, and scalability.

1.5 Organization of the project:

- **Introduction**

  In this section, we provide an overview of the project by presenting the background and importance of indoor navigation systems for multi-story buildings. We present the reason for creating an accessible solution to indoor navigation problems, outline the purpose and objective of the project, and state the project scope and report outline. In this section, we create the background for us to have a good understanding of our project's objectives and approach.

- **Summary of the report**

  The report illustrates a revolutionary method of indoor navigation to facilitate users with effective, precise, and interactive navigation of intricate building floor plans. Our Unity-based 3D Indoor Navigation System utilizes the capability of Wi-Fi RSSI data and artificial intelligence to achieve real-time positioning, providing a revolutionary solution that was first put into practice at SVKM's Institute of Technology.

- **Background and Context**

  It might be challenging to navigate a large, multi-story building, especially for novice users or users who are not aware of the building's layout. Inadequate indoor navigation tools generally result in time wastage and user frustration. Having noticed this vacuum, our group started this project with the aim of creating a solid system facilitating adequate indoor positioning and dynamic route computation indoors.

- **Motivation:**

The idea behind this project stems from the need to increase the ease and effectiveness of navigation in institutional and public facilities. Our solution attempts to bridge the gap left by traditional indoor navigation systems, enabling people to navigate with ease, save time, and overcome the difficulties presented by difficult layouts.

layouts.

- **Aim and Objectives**

This project will develop an intuitive and accurate 3D indoor navigation system that assists users to navigate indoors easily. To achieve this goal, the following have been outlined:To design a 3D representation of the SVKM IoT building for a realistic indoor navigation experience.

1. Designing a 3D model of the SVKM IoT building to facilitate a real-world-like indoor navigation experience.
2. Incorporating Wi-Fi RSSI and machine learning algorithms in real-time location determination.
3. Utilizing Dijkstra's algorithm to find an optimized path.
4. Ensuring user-friendly interaction through an easy-to-use web application.
5. To make performance evaluations and tune the system for better accuracy and use.

- **Scope and structure of the report**

The report undertaken here is an exhaustive presentation of the Unity based 3D indoor navigation system, commencing with a literature review of similar technologies and approaches. It proceeds to give an in-depth analysis of system design, including 3D modeling, data collection, and machine learning for positioning. Subsequent chapters briefly discuss the development of pathfinding algorithms, user interface, and testing of the system for precision and functionality. Finally, the report also takes into account probable future development, expansion to more indoor environments and application in numerous other industries, from schools to hospitals.

Chapter 2

LITERATURE SURVEY

These simple environments begin with airports and malls, using Unity's Navmesh to power their navigation system. Here, one of the initial systems received a poor locality because of inaccurate localization as GPS didn't work indoors. Researchers introduced some alternates like QR codes and manual tagging between 2015 and 2016; however, it was narrowly constrained due to its scalability because of manual setup. In 2017-2018, AR technologies like ARCore and ARKit, coupled with SLAM (Simultaneous Localization and Mapping), revolutionized indoor navigation by continuously tracking real-time GPS-free, while Unity's AR capabilities further made it interactive. Still, it was not scalable and efficient for complex environments. By the closing of 2019, pathfinding algorithms like A* implemented by the system to enhance route optimization and also BLE and Wi-Fi-based location with enhanced accuracy at the expense of higher system complexity. During 2020 and 2021, SLAM approaches were integrated with smartphone sensors like accelerometers and gyroscopes to improve the tracking within Unity systems with real-time capabilities, yet still only a way using QR codes to launch the systems. Up to 2022, the application of such systems was deployed into the university setting and hospitals, while object detection in SLAM was enhanced through machine learning. This, though, is an issue for scalability for these systems. Between 2023 and 2024, multi-sensor fusion greatly enhanced the value of use in real-time, though accuracy and user feedback improved. Certain scaling and energy-consumption-related issues must be then resolved in the future.

Paper "Indoor Navigation System Using Augmented Reality": This paper presents a new approach to indoor navigation using SLAM, ARCore, and Unity NavMesh. Overcoming common limitations of GPS in an indoor environment, it really relies on QR-code repositioning and an A* pathfinding algorithm* for precision and excellent user experience. At the same time, there are drawbacks to this system: its dependence on the visibility of QR codes and manual map setup may challenge its scale. This research, however, falls within a body of already extant literature reporting difficult issues in indoor positioning, with SLAM and AR promising but still with gaps regarding scalability and performance evaluation.[17]

The INSUS paper demonstrates good implementation of SLAM, AR, and Unity in terms of indoor navigation, facilitated using 3D mapping and augmented reality to develop an immersive experience. Its reliability has been assured through its high accuracy in QR code detection in addition to showing robust navigation performance despite disturbances. However, the practical implementation may be limited within dynamic or very large environments as it requires special tilt angles, between 90° to 100°, for maximum performance and scanning of the QR code as a prerequisite to initialization of the location. INSUS compares well with a plethora of indoor navigation solutions based on Wi-Fi or Bluetooth as it is specifically designed to counter weaknesses inherent to GPS-based systems but at the same time appears to have scalability problems. This study fills the gap in the literature by using Unity and AR navigation, though further work can be made a lot more flexible to make it even more scalable and deployable. Even so, the paper will prove invaluable in contributions but might allow those to be improved upon when addressing the said gaps.[10]

The paper "A Survey of Smartphone-Based Indoor Positioning System Using RF-Based Wireless Technologies" addresses the provision of an in-depth review of IPS using Wi-Fi and BLE, particularly.

Focusing on the accuracy offered by fingerprinting localization. Such a paper will identify strengths in such systems, for instance, practicality in integrating smartphones, and evaluate different performance metrics against the background of trends in IPS technology. On the other hand, it also reveals the disadvantages of this technique, such as difficulties related to signal interference, a requirement of high-resolution fingerprint databases, and scalability issues. The paper skillfully synthesizes and summarizes existing literature, identifies key debates regarding trade-offs made by accuracy versus resource consumption, and emphasizes the need for improvements in algorithm efficiency and energy use. It constructs a coherent argument whilst critically analyzing the IPS solutions in the absence of direct quotes, making an insightful contribution in terms of the strengths and weaknesses of present technologies.[5]

This paper, "A Survey of Indoor Positioning Systems for Wireless Personal Networks" compares various differing IPSs by grading both commercial solutions and research-based solutions to give the paper a strong critical analysis of the IPS system on security, privacy cost, performance, and user preferences by making it a source of understanding how they compare with each other in personal networks (PNs). The study implies trade-offs with regard to IPS, such as performance with complexity and security with cost. However, the listed limitations were the challenges of integrating IPS into PNs, balancing privacy with functionality, and the commercial feasibility of certain systems. This paper pointed out some fields where related literature is still in deficits, especially the IPS has no user-centric designs, and conducts a synthesis of available literature without direct quotations to present a critical review of the approaches made in location-aware services within personal networks.[1]

In the paper titled "SLAM-based Indoor Navigation in University Buildings," the topic explores the use of SLAM (Simultaneous Localization and Mapping) technology to introduce AR (augmented reality) indoor navigation systems for mobile devices. The advantages are discussed about how point effectiveness within a university setting might be displayed; however, it raises some limitations associated with low levels of accuracy within complex environments. This article remains aware that "there is still much work to be done in SLAM and all the other technologies taken into consideration in this debate, regarding the integration of these technologies and which method is most realistic for SLAM application". In general, it contributes towards a balanced argument on why SLAM is relevant to improving indoor navigation in educational contexts.[11]

This paper, "A Survey of Indoor Localization Systems and Technologies," offers a comprehensive overview of different types of indoor localization techniques based on AoA, ToF, and RSS techniques exploiting techniques such as Wi-Fi, RFID, Ultra Wideband (UWB), and Bluetooth. It effectively synthesizes existing literature on the relative merits of localization systems regarding energy efficiency and cost, reception range, latency, scalability, and tracking accuracy. Its limitation is about incompleteness in solving practical issues relating to the indoor localization user experience as well as the possibility of recent breakthroughs omitted in that fast-paced field. The survey identifies the themes of balancing between accuracy and energy efficiency but accepts that it remains a matter of debate about what performs better, as well as which area of research lags, especially in real-world settings. In developing a coherent argument about the importance of accurate indoor localization for better location-based services, the paper reviews the significant studies with an emphasis on their methodologies. In summary, it values researchers and practitioners by shedding more light on the work that has already been done and opening up further research work in these areas. [13].

2.1 Related Work

Table 2.1. Literature Survey Table

Sr No.	Title	Year	Description	Problem
1.	Indoor navigation through augmented reality	2023	This study creates an affordable, AR-based indoor navigation system with mobile device sensors for improved indoor localization, resolving limitations of GPS in multistory buildings. The system utilizes AR Core to place virtual guidance over real-time, creating an immersive, real-time navigation experience supported by user feedback.	The fundamental issue is that GPS-based navigation is not effective indoors, particularly in intricate buildings. Current indoor systems are expensive, error prone, and have no immersive, user-friendly capabilities..
2.	Comparative Analysis and Review of Indoor Positioning Systems and Technologies	2024	This paper discusses and compares different indoor positioning technologies, including Wi-Fi, Bluetooth Low Energy, RFID, and visual systems. It evaluates their strengths and weaknesses, emerging trends, and considers aspects like cost, power efficiency, and flexibility to indoor spaces.	Indoor positioning systems are troubled by accuracy, energy efficiency, and flexibility, and it becomes challenging to come up with a one-size-fits-all, dependable navigation solution.
3.	Low-Cost UWB-Based Real-Time Locating System: Development, Lab Test, Industrial Implementation, and Economic Assessment	2023	This work introduces the development and lab testing of a low-cost Real-Time Locating System (RTLS) based on Ultra-Wideband (UWB) technology for industrial asset tracking. It utilizes Qorvo MDEK1001 to track objects with RF tags in spaces covered by fixed antennas, validated in lab and industrial environments.	Traditionalasset-tracking solutions tend to be expensive, and thus outside the reach of small and medium-sized businesses. This work is intended to present a low-cost, yet effective solution for real-time industrial assettracking.
4.	Indoor Navigation for the Blind and Vision Impaired: Where are we and Where are we Going?	2012	This paper addresses problems in indoor navigation systems for blind and vision-impaired people, and proposes criteria for evaluating solutions in terms of accuracy, flexibility, and information to users.	Some limitations in position accuracy, integration with the environment, and missing user orientation in existing systems call for a novel solution accommodating the specific requirements of blind and vision-impaired users.

5.	Wi-Fi-Based Indoor Positioning: Fundamentals, Hybrid Algorithms and Open Software Platform	2010	The article presents a hybrid indoor positioning algorithm based on signal strength mapping and a propagation model calibrated from measurements. It facilitates comparative analysis of various indoor positioning methods with the same input data, i.e., signal strength, building layout, and access points.	Outdoor positioning methods such as GNSS are not accurate for indoor and urban environments. It is hard to compare indoor positioning systems due to different methodologies and lack of unified accuracy measures.
6.	INSUS: Indoor Navigation System Using Smartphone and Unity for User Ambulation Support.	2023	INSUS is an AR, SLAM, and Unity-based navigation system for guiding user mobility in complex indoor environments. User position is estimated by a smartphone's camera and gyroscope with visual guidance provided to steer the user. The system was tested in two universities with significant performance and positive user feedback.	Indoor navigation is difficult with complex environments, multiple levels, and obstructions, and existing solutions are inaccurate and unreliable in the absence of costly infrastructure.
7.	A User Experience Study of Locomotion Design for Adults and Children in Virtual Reality	2023	This study contrasts adult and child experiences of locomotion in virtual reality (VR) for different locomotion modalities. The results show movement that mimics action in the real world is disliked most, and adults and children differ in controller-assisted locomotion preferences.	Few VR headsets consider the variability of user experience, particularly in locomotion, between adults and children.

Chapter 3

PROBLEM STATEMENT

Outdoor GPS devices like Google Maps have changed the way people get directions to places, taking them directly to the exact address of a particular venue not only to the building but also to the gate of complex venues like airports, shopping malls, hospitals, universities, railway terminals, and hospitals. However, these solutions cannot give further guidance once the visitors are already in these large spaces or venues. This absence of step-by-step, real-time indoor wayfinding can lead to frustration, disorientation, and wasted effort as users struggle to find spaces like libraries, classrooms, stores, or departments which are located within these vast interiors. In the absence of an accessible, integrated solution for indoor wayfinding, newcomers and others with mobility impairments are disproportionately affected. Suggest an integrated, real-time indoor navigation system that can seamlessly operate in large complex venues, filling a gap in navigation technology. It will leverage the most up-to-date positioning technologies that will include Wi-Fi triangulation, Bluetooth beacons, and augmented reality to guide people through indoor spaces from a starting point to an end point of destination with maximum accuracy in real time. The integration of the system with the current outdoor navigation systems would assist in creating a seamless experience of navigation from outdoor to indoor. Therefore, it encompasses a wide range of applications that make the system even more superior in enhancing the experience of accessibility and efficiency across different public and private domains.

3.1 Project Requirement Specifications:

1. Functional Requirements:

User Interface (UI)::

- Mobile application for both Android and iOS operating systems.
  • Shows an interactive real-time 3D map of the building (rooms, floors, entry/exit points).
  • Offers clear visual (e.g., arrows) and audio directions.
  • Accessibility features such as voice commands and text-to-speech for visually impaired users. visually impaired users.

Indoor Positioning:

- Identifies user location with accuracy using Wi-Fi RSSI, BLE beacons, or UWB technology.
  • Live location updates as the user navigates inside the building.
  •\tHigh precision (order of a few meters) for accurate navigation.
  •\tFeatures an algorithm for pathfinding (such as Dijkstra's or A*) to compute shortest paths.

  •\tImparts support for both automatic and manual override in exceptional situations (like lifts or stairs).

Augmented Reality (AR) Navigation :

- Does AR overlay directional arrows on the view of the real world using the phone camera.
  •\tImproves orientation and user experience in unknown or large areas.spaces.

2. Non-Functional Requirements:

Performance and Efficiency:
- Responds in real-time with low latency (under 2 seconds).
- Optimized for low battery usage and minimal network use.

Scalability:
- Supports navigation in high-rise, multi-story buildings.
- Supports many users at once without impacting performance.

Reliability and Availability:
- Provides uninterrupted operation with little downtime.
- Delivers 99% system availability and contains fallbacks in the event of failures.

3. Usability Requirements:

User Experience (UX):

- Easy to use with a low learning curve.
- Clear instructions with audio and visual feedback.
- Language, voice prompt, and map view customization options.

Accessibility:

- Includes high-contrast mode, screen reader support, etc.
- Made to support visually or cognitively disabled users.

4. System Integration Requirements:

Indoor-Outdoor Integration:

- Smooth transition from outdoor navigation applications (such as Google Maps) to indoor navigation.

Device Compatibility:

- Supports smartphones with GPS, gyroscope, Bluetooth, and camera capability..

Infrastructural:

- Needs to install BLE beacons, Wi-Fi routers, and/or UWB devices within buildings.
- Centralized storage of indoor maps and venue-specific information.

5. Security Requirements:

Data Protection:

- Encrypts all user data during transmission and storage.
- The solution encrypts all user data while in transit and at rest.
- Maintains compliance with privacy legislation such as GDPR and CCPA.

Privacy:

- Users have to opt-in to location tracking.
- invisible privacy policy and data use terms presented.

6. Testing and Validation Requirements:

Accuracy Testing:

- The solution tests location tracking accuracy across different indoor locations (corridors, elevators, stairs, etc.)..

User Feedback Collection:

- Collects feedback for enhancing usability, accessibility, and effectiveness of AR.

Stress and Load Testing:

- Tested under heavy loads to make sure it runs efficiently with several users.

7. Maintenance and Support Requirements:

Ongoing Updates:

- Periodic updates for performance, new features, and fixing bugs.
- Ongoing monitoring of signals, beacons, and server efficiency.

User Support:

- Integrated help section with FAQs and troubleshooting instructions.
- Technical support through live chat or email.
- These will be designed and implemented to provide an end-to-end, user-centered, and efficient indoor navigation system that enables accessibility and offers a trouble-free experience for users in intricate indoor environments.

Chapter 4

PROPOSED SYSTEM ARCHITECTURE

4.1 Data Flow Communication

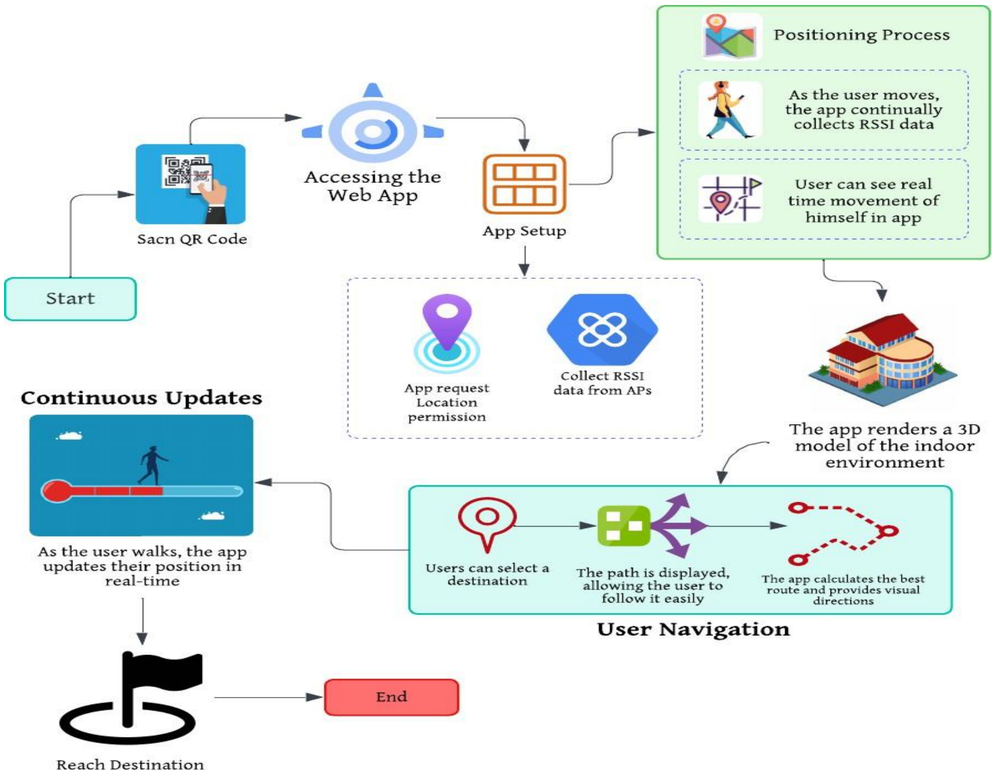

Figure 4.1. Flow Diagram

1. QR Code Scan

Description: The process of navigation is initiated by the user by scanning a QR code which is fixed at a place like the lobby or indoor of a building.

Objective: The user is able to open the web application in a convenient and quick manner without requiring them to look for and download the specific application.

Primary Interactions:

- QR code is scanned via the camera of a mobile phone or any QR scanning app.

2. Accessing the Web App:

Description: Upon scanning the QR, users are redirected to the web app directly. The application is laid out with navigation that is intuitive and provides an excellent experience.

Purpose: This application serves as the primary interface through which the whole navigation system operates.

3. Setup Initialization

Description: Here, it requests permissions or information necessary for location determination.

This initialization is so that it receives necessary permissions to receive location information or Wi-Fi signals to pinpoint its location correctly.

Key Actions:

- Request Permission: The app asks for permission to use the location services.
- Ranging for RSSI: The app begins ranging and collecting data on the received signal strength from the nearby Wi-Fi APs. RSSI is a zero-based metric; its range varies with the different manufacturers. RSSI information are quantified by these values, which will serve as reference points in finding the user's location.
- Fingerprint Map Construction: The RSSI values are mapped to the surroundings to create an initial "fingerprint" map that will be utilized in user location determination.

4. The Positioning Process:

Description: The application browses the real-time RSSI values gathered from nearby APs, and calculates the current position of the user as he traverses the area.

Objective: To get the real location where the user is standing so that he can be provided with proper navigation updates.

Critical Activities:

- Real-Time Data Collection: Records RSSI data from a minimum of three APs while the user is continuously moving.
- Trilateration: For this scenario, the position system makes use of trilateration in the sense that the user's position is determined based on the RSSI values received from multiple APs.
- Machine Learning Models: There has been some usage of machine learning in the sense that the natural patterns a user sees while in motion as well as their past RSSI data can be utilized to increase the accuracy.
- User Location Feed-back: feed back the user's location into the app so that it can be seen by them.

5. Displaying the 3D Model:

Description: The actual location of the user is streamed onto a 3D model rendered of the indoor space using Unity.

Objective: To guide the users by showing them their current location in the indoor space.

Key Actions:

- A 3D representation of the environment is shown on the screen.
- The user's current location is indicated and updated when the user moves.

6. **User Navigation:**

Description: A 3D map of the destination location, e.g., classes, offices, restrooms etc. The system calculates the best route to the destination location.

Objective: To deliver understandable real-time directions to the chosen destination.

Key Actions:

- Destination Selection: The user chooses their destination location in the building either from a list or by clicking a particular point on the map.
- Route Calculation: The system ought to be able to compute the route from the location of the user to the destination
- Visual Directions: The way is shown utilizing the 3D model so it is simple to describe to users how they are able to reach the target

7. **Continuous Updates:**

Description: Keep updating the location and path of the user in motion so the changes in their location are revealed in real-time.

Purpose: Always inform the user about his location and enable him to stay on course even if he changes direction or makes unexpected movements.

Key Actions

- To accurately depict the users location within the 3D world the application continuously recalibrates the user's position using the most recent Wi-Fi RSSI data
- The system constantly recalculates and updates the navigation route in real-time whenever the user changes direction or departs from the recommended path.
- The user can easily follow the navigation since the system graphically tracks the position and refreshes the path within the 3D interface as the user advances.

8. **Session End:**

The user only needs to close the program to end the session once they have arrived at their destination. Every piece of information pertaining to navigation is automatically recorded for further review and enhancement.
The goal is to document user movement patterns and feedback in order to enhance the user experience and increase the system's accuracy through machine learning improvements.

to capture user feedback and movement patterns in order to enhance the user experience and improve the system's accuracy through machine learning improvements.
Important Steps:

- When the user reaches their destination, the navigation session is over.
• Important session data, such as user movement pathways, RSSI readings during the session, and any user input, are recorded by the system.
• By using the data gathered, the machine learning model is further trained and improved, increasing the accuracy of indoor positioning for all users in the future.

With constant real-time updates, unambiguous visual instructions, and astute management of deviations, this complete flow guarantees a responsive and seamless user experience. The system offers a very precise and intuitive indoor navigation solution by fusing Wi-Fi RSSI monitoring, 3D visualization, and adaptive machine learning.

4.2 System Design Architecture

Employing a comprehensive method towards solution innovation, the "Unity-Based 3D Indoor Navigation System" has emerged to solve all the issues associated with the navigation of indoor intricate environments. It involves cutting-edge technologies like Wi-Fi-based positioning, machine learning (ML), and 3D modeling using Unity to provide accurate, real-time navigation to the user. Architecture design will enable the system to execute efficiently within settings such as university campuses, shopping malls, airports, and hospital or office buildings. The web or mobile application interface will offer simple navigation direction for the users.

Overview of System

The system is comprised of differential integrated components each of which is in charge of segments of the navigation
process. It begins with using Wi-Fi access points for data collection and goes through a multi
stage that includes location forecasting with machine learning-based trilateration and the generation of a 3D environment using Unity. The components thus integrate to provide real-time updated indoor navigation across the 3D model of the building and enhances the user experience as far as spatial awareness and movement are concerned.

Technology Stack

is a platform where all those new technologies were integrated: It
Unity: A 3D game engine is utilized to address a complete model of the indoor setting. Users can move within the setting, see their position, and get directions to the target in the 3D
Wi-Fi RSSI: It provides an indication of the received signal strength. Wi-Fi access points are dispersed throughout the buildings. With this system, one can obtain real-time position data from the access point. The received signal access point can be utilized to estimate how far the strength from each user is from this point by comparing it with the pre-recorded data.
Machine Learning (ML): Machine Learning (ML): It learns the model from data collected during a fingerprinting phase, where an ML algorithm continues to make progressively better and more realistic predictions
while the user's activity within the with each piece of information it gets to know the environment.
The system features an interactive web application that will be the core of the interacting platform. The 3D model is being accessed through the interface, where customers see their location in real time and set of navigation elements.

System Architecture

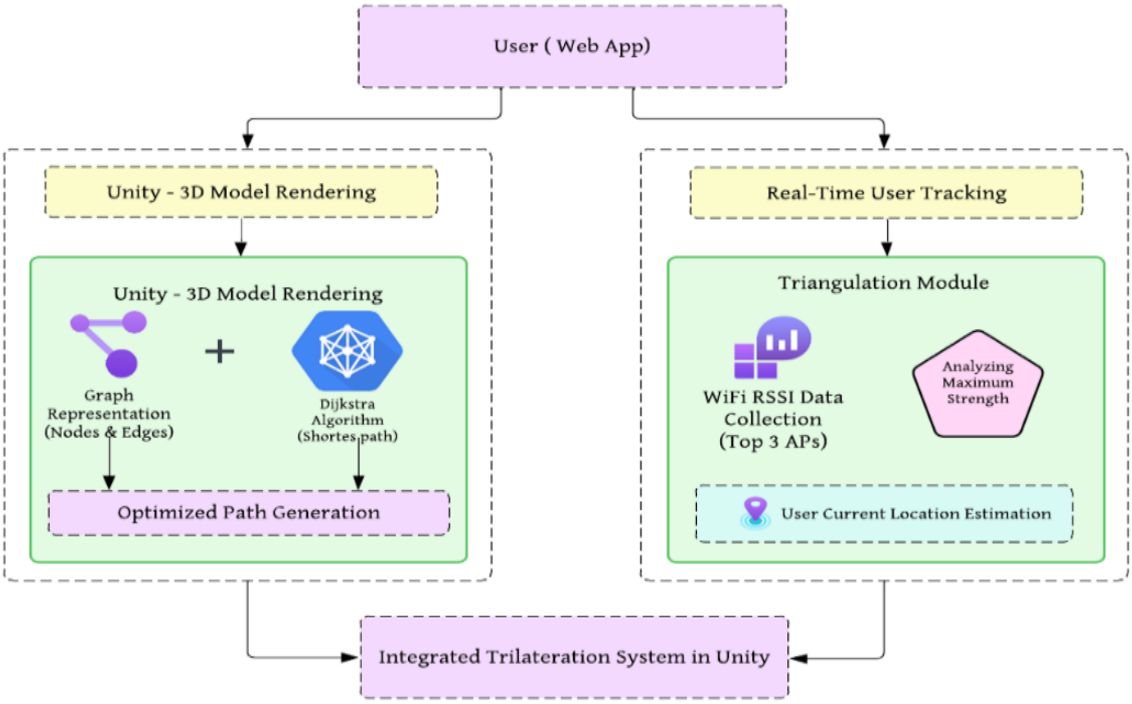

Figure 4.2. System Architecture

The suggested indoor navigation system determines the user's present position and calculates the most effective route to their destination by combining graph-based routing and Wi-Fi-based location detection. A hierarchical graph is used to depict the complete indoor environment, with connecting paths acting as edges and rooms, hallways, and significant landmarks acting as nodes. With the use of sophisticated algorithms, this technique provides accurate pathfinding and improved navigation performance.

1. Graph modeling and infrastructure representation

Unity was used to create a virtual 3D model that faithfully mirrored the actual college layout. Important places like offices, labs, and schools are represented as nodes in a weighted graph. With edge weights denoting the actual lengths, the connecting paths between these places are depicted as edges. All node-to-node relationships are clearly and methodically represented by the adjacency matrix, which is used to geometrically arrange the infrastructure.

$$A_{ij} = f(x) = \begin{cases} d_{ij}, & if\ an\ edge\ exsists\ between\ nodes\ i\ and\ j \\ x, & otherwise \end{cases} \tag{1}$$

where d_{ij} refers to the Euclidean or Manhattan distance between nodes depending on corridor constraints.

For debugging and visualization, Unity's Gizmos.DrawLine() function was employed to indicate the connectivity of the graph.

2. Trie-Based Search for Location Querying

In order to facilitate fast destination lookup, we used a Trie-based search algorithm, which is capable of handling prefix-based queries with a time complexity of O(N).

Each location is represented as a node in the Trie data structure:

$$T_{root} \rightarrow (C) \rightarrow (L) \rightarrow (A) \rightarrow (S) \rightarrow (S) \rightarrow (R) \rightarrow (O) \rightarrow (O) \rightarrow (M) \quad (2)$$

The system, on receiving a user query, searches the Trie to locate the best-matching location name.

3. Log-Distance Path Loss Model Distance Estimation

To find the distance from the user to each of the four selected APs, we applied the Log-Distance Path Loss Model:

$$Distance = 10^{\frac{P\_tx - RSSI}{10 - n}} \quad (3)$$

Where:

D = Distance from access point (AP) in meters
RSSI = Received Signal Strength Indicator (dBm, negative value)
P_tx = Transmit power at 1 meter (usually -30 dBm for Wi-Fi)
n = Path loss exponent (dependent on environment, taken as 3 for indoor navigation)

4. Calculation of User Position via 3D Trilateration

Algorithm: Trilateration Algorithm

Equations:

$$\begin{aligned} (x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 &= d_1^2 \\ (x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 &= d_2^2 \\ (x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 &= d_3^2 \\ (x - x_4)^2 + (y - y_4)^2 + (z - z_4)^2 &= d_4^2 \end{aligned} \quad (4)$$

Here, $(x_1, y_1, z_1), (x_2, y_2, z_2), (x_3, y_3, z_3)$ and (x_4, y_4, z_4) are the known coordinates of four access points, and d_1, d_2, d_3, d_4 are the calculated distances.These equations solved provide the user's coordinates (x, y, z) in real time.

5. Dynamic Pathfinding Using Dijkstra's Algorithm

Once the position of the user is established, the shortest route to the destination is computed via Dijkstra's Algorithm. The algorithm proceeds as follows:

(1) Initialize the distance to all nodes to, except for the source node which is initialized as 0.
(2) Use a priority queue (min-heap) to select the node with the smallest distance.
(3) Relax the distances of its neighbour nodes if a shorter path is found.
(4) Repeat until shortest path to destination node is calculated.

Mathematically, update the shortest path by:

$$D(v) = min(D(v), D(u) + W_{uw}) \quad (5)$$

Where $D(v)$ is the shortest known distance to node v, $D(u)$ is the known shortest distance to node u, and W_{uv} is the edge weight between u and v.

Time complexity of the algorithm is O(E + V log V) using a priority queue-based approach.

6. Dynamic Path Adjustment and Real-Time Tracking

As people move, their RSSI changes, causing them to have updated coordinates constantly.
The system dynamically recalculates the shortest path if a considerable deviation from the optimal path is noticed.

The deviation is determined by:

$$\Delta D = \sqrt{(x_t - x_{t-1})^2 + (y_t - y_{t-1})^2} \qquad (6)$$

If $\Delta D > \tau$, where τ is a threshold, the system makes a new path calculation with Dijkstra's Algorithm. This solution combines Wi-Fi positioning and graph-path finding to produce an effective indoor navigation system. Trilateration and LDPLM offer high accuracy, and Dijkstra's Algorithm calculates the shortest distance dynamically. Trie-based search is utilized to enhance the user experience further by enhancing seamless and efficient navigation.

4.3 Results and Analysis

1. SVKM'S IOT 3D MODEL

Figure 4.3. Outdoor view of 3D Model

A comprehensive 3D model of SVKM's Institute of Technology, Dhule, is depicted in the picture. The model, which was meticulously created, is based on the building's original architectural blueprints and on-site measurements, guaranteeing that it closely resembles the actual structure in terms of both design and proportion.

Genuine-World Accuracy: The 3D model accurately depicts the building's overall structure, layout, and spatial dimensions because it was made using genuine measurements from the SVKM IoT campus.

Multi-Level Detailing: Every floor of the building is represented in the model, and windows and other architectural elements are regularly aligned to preserve structural symmetry and visual harmony.

Useful Application: This digital model is essential to the Unity-based 3D Indoor Navigation System's spatial interaction, environmental simulations, and route planning. Additionally, it facilitates precise Wi-Fi positioning by offering a trustworthy reference for internal and external layouts.

2. 3D Indoor Navigation Path Simulation for SVKM's Institute of Technology

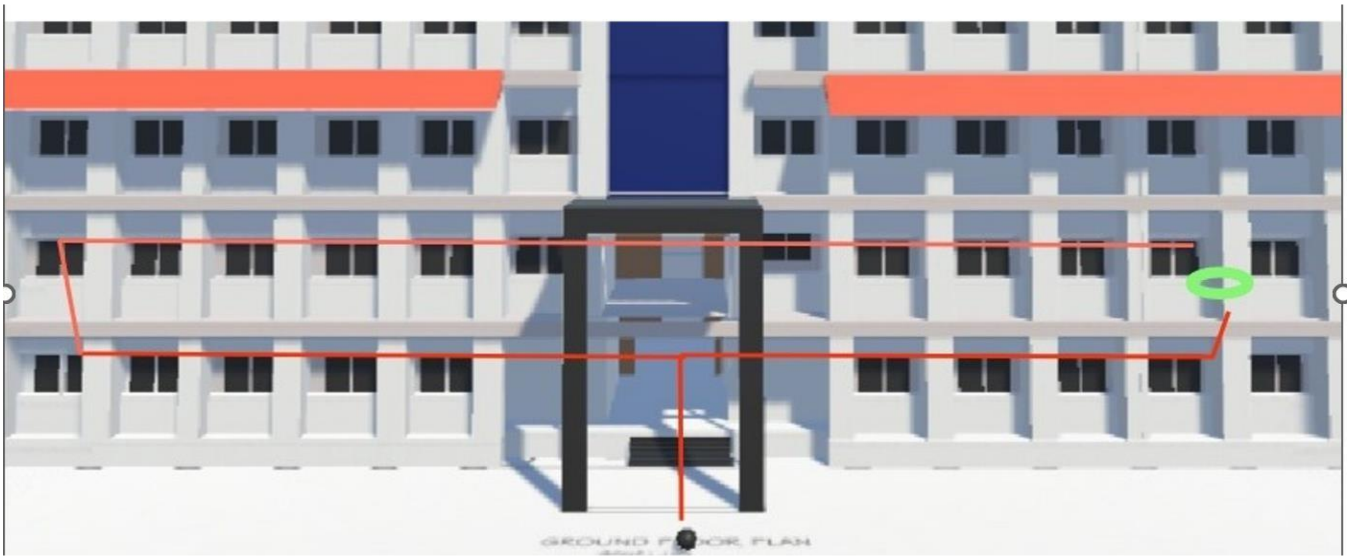

Figure 4.4. 3D Indoor Navigation Path Simulation

The picture displays a very intricate 3D model of SVKM's Institute of Technology, Dhule, which was created using Unity as a component of an interior navigation system. This model, which was constructed using historical architectural drawings and exact physical measurements, remarkably accurately depicts the actual campus structure.

The shortest route from a starting place to the destination is shown by the red line that passes through the building in the picture. This route is computed in real time by combining Dijkstra's method to identify the most efficient path across the modeled infrastructure with Wi-Fi RSSI (Received Signal Strength Indicator) data to ascertain the user's current position.

The user's avatar or position within the system is represented by the black sphere on the path. To replicate real movement through the 3D environment, a more realistic character will take its place in the finished edition.

Key decision points, such as turns, crossroads, or significant pauses, are indicated by a green marker on the route, which illustrates how the system leads users step-by-step.

The main goal of this visualization is to provide a responsive and dynamic pathfinding experience. When a user's location changes, the system instantly adjusts and recalculates routes as necessary. This guarantees consistent and precise direction throughout the structure.

This stage of development shows how the system may integrate immersive 3D mapping with real-time positioning, providing a useful solution for visitors, employees, and students who are not familiar with the campus layout. In the end, it seeks to reduce misunderstandings, save time, and enhance general mobility in big, intricate buildings.

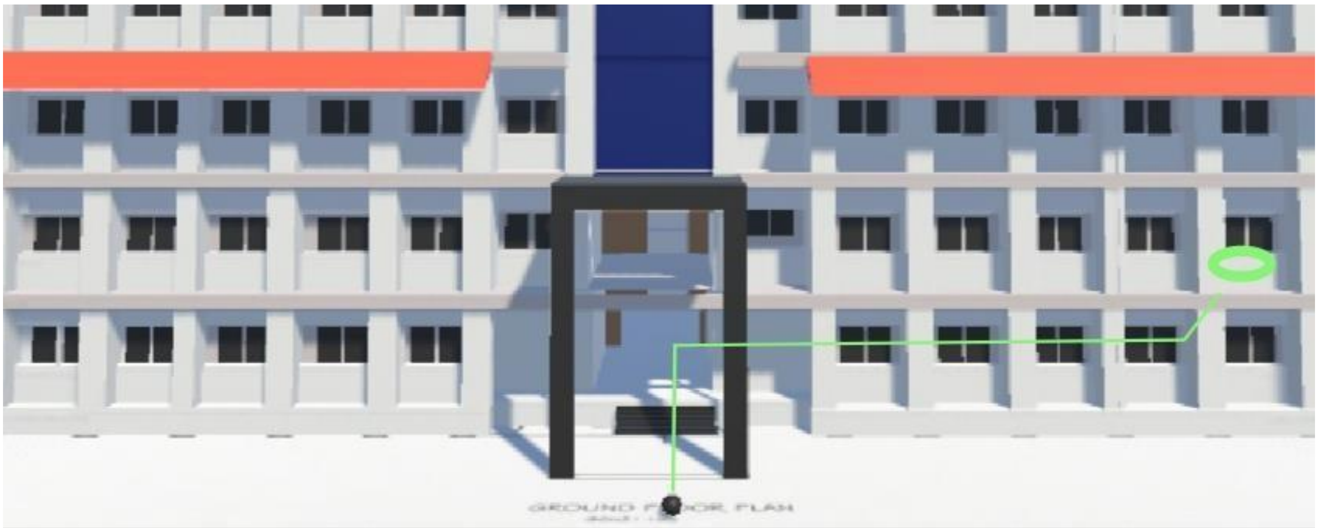

Figure 4.5. Shortest Path Visualization

The display of the shortest path between two points inside the campus building is a crucial component of the Unity-Based 3D Indoor Navigation System created for SVKM's Institute of Technology, Dhule, as seen in the image. The system, which is intended to improve indoor wayfinding, calculates an optimal path from the user's present location to their intended destination using Dijkstra's algorithm. The green circle in this picture represents the goal, and the black sphere represents the beginning position. The shortest path produced by the system's navigation engine is shown by the green path that connects them.

Dijkstra's algorithm, being both efficient and reliable for graph traversal, has been used as the fundamental pathfinding algorithm. It checks all the possible paths between the source node and the destination node in the 3D space and chooses the shortest one with the least accumulated distance or cost. This makes sure that the user is always taking the most optimal path irrespective of where they are in the building.

The model itself is built with the utmost attention to detail, employing precise construction plans and actual measurements of the institute's infrastructure. This allows for not only the system being technically correct but also practically feasible when implemented in a real-time environment. The simulated object first follows the computed path in order to verify the navigation logic. In the final deployment, the object will be replaced by a human avatar, providing users with an easy-to-use and visually interactive interface as they are led through the building.

This simulation is a significant milestone in presenting the capabilities of the system. By precisely computing and mapping the shortest path in an intricate 3D setting, the project lays a solid foundation for more advanced indoor navigation systems that could be applied to other campuses, hospitals, shopping malls, or smart buildings. The combination of actual architectural designs with smart algorithms showcases the potential of this system in transforming the way individuals navigate in indoor spaces.

3. Room Detection Using Wi-Fi Signal Strength Analysis

```
room_bssid_database = {
    'Room 113 front': {'SVKM NMIMS': '50:0f:80:47:4d:4f:', 'SVKM NMIMS GUEST': '50:0f:80:47:4d:4b:', 'SVKM NMIMS LAB':
    '70:ea:1a:43:74:63:', 'SVKM NMIMS PSK': '50:0f:80:47:4d:4e:', 'SVKM NMIMS SMARTBOARD': '50:0f:80:47:4d:4d:', 'Mru ':
    'ae:cc:7d:a4:8e:7b:', 'Sarthak': '0e:9b:95:51:f5:06:', 'OnePlus Nord CE 2 Lite 5G': '8a:00:16:35:1b:86:', '..': '6e:c8:74:ba:de:af:',
    'vivo Y73': 'be:85:5c:77:31:ba:', 'Baba 504': 'd6:72:dc:09:39:e6:'},
'Room 402': {'SVKM NMIMS': '00:fc:ba:4e:22:40:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:22:44:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:22:42:',
'SVKM NMIMS PSK': '00:fc:ba:4e:22:41:', 'SVKM NMIMS LAB': '70:ea:1a:43:6f:63:'},
'Room 405': {'SVKM NMIMS': '00:fc:ba:4e:25:a0:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:25:a4:', 'SVKM NMIMS PSK': '00:fc:ba:4e:25:a1:', 'SVKM
NMIMS SMARTBOARD': '00:fc:ba:4e:25:a2:', 'SVKM NMIMS LAB': '70:ea:1a:43:73:83:'},
'Room 404': {'SVKM NMIMS': '00:fc:ba:4e:5b:40', 'SVKM NMIMS GUEST': '00:fc:ba:4e:5b:44', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:5b:42',
'SVKM NMIMS PSK': '00:fc:ba:4e:5b:41'},
'Room 405': {'SVKM NMIMS': '00:fc:ba:4e:1c:a0:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:1c:a4:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:1c:a2:',
'SVKM NMIMS PSK': '00:fc:ba:4e:1c:a1:', 'SVKM NMIMS LAB': '70:ea:1a:43:73:83:'},
'Room 407': {'SVKM NMIMS': '00:fc:ba:4e:5b:a0:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:22:44:', 'SVKM NMIMS SMARTBOARD':
'00:fc:ba:4e:5b:a2:',  'SVKM NMIMS LAB': 'd4:c9:3c:42:80:0c:', 'SVKM NMIMS PSK': '00:fc:ba:4e:5b:a1:'},
'Room 409': {'SVKM NMIMS': '00:fc:ba:4e:62:20', 'SVKM NMIMS GUEST': '00:fc:ba:4e:62:24', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:62:22',
'SVKM NMIMS PSK': '00:fc:ba:4e:62:21', 'SVKM NMIMS LAB': '70:ea:1a:43:75:e3'},
'Room 411': {'SVKM NMIMS': '00:fc:ba:4e:24:80', 'SVKM NMIMS GUEST': '00:fc:ba:4e:24:84', 'SVKM NMIMS LAB': '00:ee:ab:2f:ac:e3', 'SVKM
NMIMS PSK': '00:fc:ba:4e:24:81', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:24:82'},
'Room 404': {'SVKM NMIMS': '00:fc:ba:4e:5b:40:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:5b:44:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:5b:42:',
'SVKM NMIMS PSK': '00:fc:ba:4e:5b:41:'},
'Room 409': {'SVKM NMIMS': '00:fc:ba:4e:62:20:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:62:24:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:62:22:',
'SVKM NMIMS PSK': '00:fc:ba:4e:62:21:', 'SVKM NMIMS LAB': '70:ea:1a:43:75:e3:'},
'Room 411': {'SVKM NMIMS': '00:fc:ba:4e:24:80:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:24:84:', 'SVKM NMIMS LAB': '00:ee:ab:2f:ac:e3:', 'SVKM
NMIMS PSK': '00:fc:ba:4e:24:81:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:24:82:',},
'Room 422': {'SVKM NMIMS': '00:fc:ba:4e:3f:20:', 'SVKM NMIMS GUEST': '00:fc:ba:4e:26:8b:', 'SVKM NMIMS SMARTBOARD': '00:fc:ba:4e:3f:22:',
'SVKM NMIMS PSK': '00:fc:ba:4e:3f:21:', 'SVKM NMIMS LAB': '70:ea:1a:43:73:83:'},
```

Figure 4.6. Wi-Fi RSSI Database for Indoor Room Localization

The above image represents a structured Wi-Fi RSSI database, in which rooms are associated with their respective Wi-Fi BSSIDs (Basic Service Set Identifiers) and SSIDs (Service Set Identifiers). The database is needed for running the room detection algorithm in the Unity-based 3D Indoor Navigation System.

Database Details

room_bssid_database is a Python dictionary such that:

- Keys: Room names, such as Room 113 front, Room 402, Room 405, etc.
- Values: Nested dictionaries mapping:
  - SSID (e.g., 'SVKM NMIMS', 'SVKM NMIMS GUEST') to
  - Corresponding BSSID (e.g., '00:fc:ba:4e:22:44', '50:0f:80:47:4d:4b').

Purpose and Functionality

1 Mapping Wi-Fi Signals to Locations:

- Inside each room, there is a distinct set of Wi-Fi access points within view.
- RSSI (signal strength information) is employed to estimate proximity to specific access points in the database.

2 Real-Time Room Detection:

- While scanning for available Wi-Fi signals, the system matches detected BSSIDs and SSIDs with this database to identify the nearest match.
- The room matched is stated as the most probable location of the user at the moment.

3 Dealing with redundancy:

- There are several BSSIDs for a single SSID (e.g., 'SVKM NMIMS') retained, considering where one access point is extended over different areas.

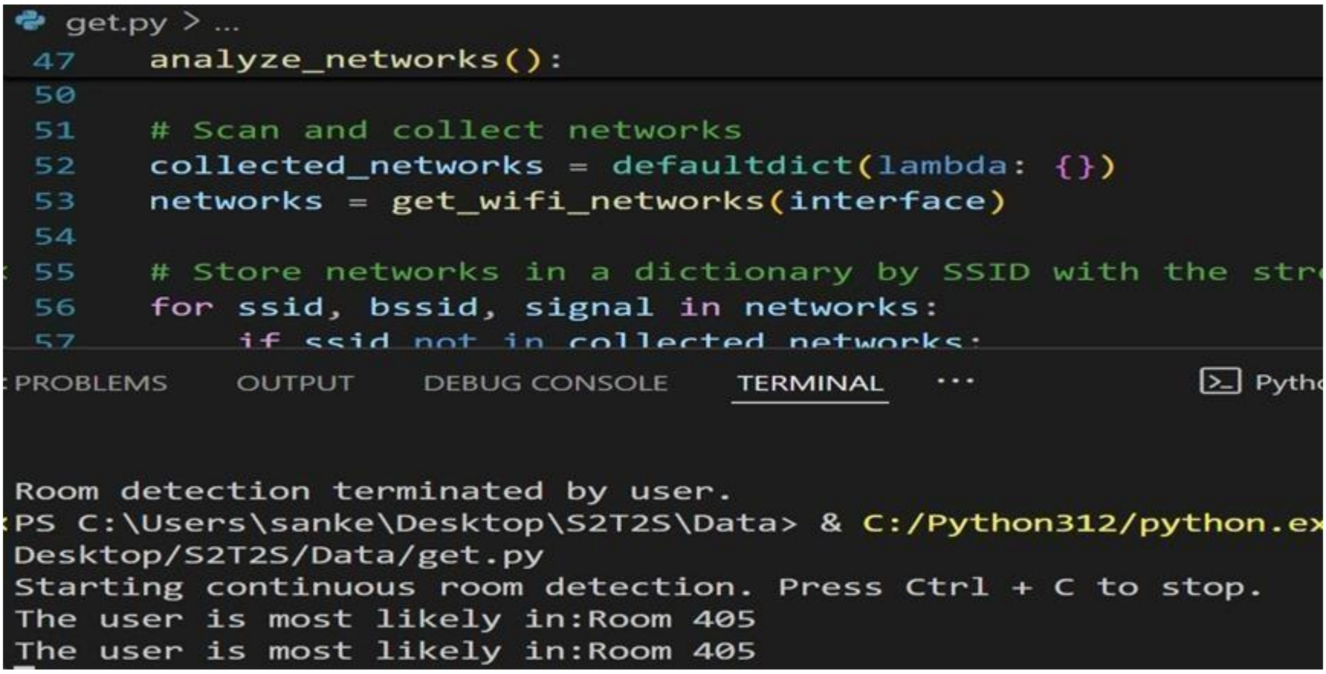

Figure 4.7. Room Detection via Wi-Fi Signal Analysis

The image depicts the real-time room detection capability of the Unity-based 3D Indoor Navigation System. The feature employs Wi-Fi network indications to identify the most probable room where a user is located based on the received signal strength.

Code Functionality

The code snippet, which has been translated using Python, is a critical part of the system's backend. The analyze_networks() function is responsible for:

1. Scanning and Gathering Wi-Fi Networks:

   - It scans Wi-Fi networks available by employing a Python method get_wifi_networks(interface).
   - Detected networks are stored in a dictionary (collected_networks), where the SSID (Service Set Identifier) is the dictionary key, and the corresponding BSSID (Basic Service Set Identifier) and signal strength values are bundled as entries.

2. Signal Strength Comparison:

   - The system ranks networks based on signal strength. By comparing the strongest received signals in different rooms, it determines the user's location.

3. Continuous Monitoring:

   - The software refreshes the detection in real-time continuously, allowing the system to sense room changes dynamically because the user is in motion

.

4. Terminal Output

The terminal output confirms that the system is performing the room detection process:

- The line "Starting continuous room detection." shows the live tracking mode.
- From signal strength data, the system predicts the location of the user as Room 405, and the information is continuously updated as also clear in the regular output: "The user is most likely in: Room 405."
- The process is manually terminated with Ctrl + C whenever the need arises.

System Relevance

This is a critical feature of the navigation system. Using Wi-Fi signal analysis, the system tracks the position of the user in the 3D model of the SVKM IoT building with great accuracy. GPS, when utilized, is supplemented by Wi-Fi RSSI-based localization since GPS is not effective inside. This renders this feature ideal for indoor use.

Comparative Analysis of Unity- Based 3D Indoor Navigation System vs Existing Solutions

Table 4.1. Comparative Analysis

Aspect	Unity-Based 3D Indoor Navigation System	Existing Solutions
Technology Stack	Uses Unity for 3D modeling, Wi-Fi RSSI for location, and ML for path planning.	Strongly depend on Bluetooth beacons, or simple Wi-Fi triangulation without dynamic capabilities.
Positioning Method	Wi-Fi RSSI-based location provides robust r oom-level tracking. Bluetooth or QR code systems typically demand more infrastructure and are less scalable.	Uses Dijkstra's algorithm to compute the shortest and safest route. The majority of systems provide static path plann ing without real-time adjustments or complex algori thms such as Dijkstra's.
Pathfinding Algorithm	Provides auditory, visual, and tactile feedback, guaranteei ng maximum access for all users.	Restricted to visual interfaces or the use of static maps, and frequently not supportin g disabled users.
User Interaction	Modular nature enables expansi on and flexibility for different arra ngements and buildings.	Most current solutions are depende nt on particular hardware, and hence less scalable and expensive to deploy.

Scalability	Modular design can be expanded and tail ored to different layouts and buildings.	Most current solutions necessitate s pecific hardware, therefore being less scalable and more expensive to deploy.
Visualization	Offers real-time, immersive 3D visualization for improved spatial orientation .	Usually restricted to 2D maps or basic navigation arrows without real-time interaction and visualization.
Access Features	Designed for accessibility, mainly caterin g to people with disabilities. Simple solutions tend not to sup port the requirements of people with visual or hearing impairment.	Leverages off existing Wi-Fi infrastructures, minimizing extra hardware expenses.
Infrastructure Requirements	Needs specialized hardware suc h as Bluetooth beacons to be installed, upping installation complexity.	Facilitates seamless integration of future technologies such as AR and AI.
Future Readiness	Has limited flexibility in adapting to new technologies, necessitating full system redesigns for updates.	Cost-effective because it has minimal ext ra hardware and is dependent on current infrastr ucture.
Cost-Effectiveness	More expensive with extra hard ware and maintenance needs.	More expensive with extra hardwar e and maintenance needs.

Chapter 5

HIGH-LEVEL DESIGN OF THE PROJECT

5.1 Use Case Diagram

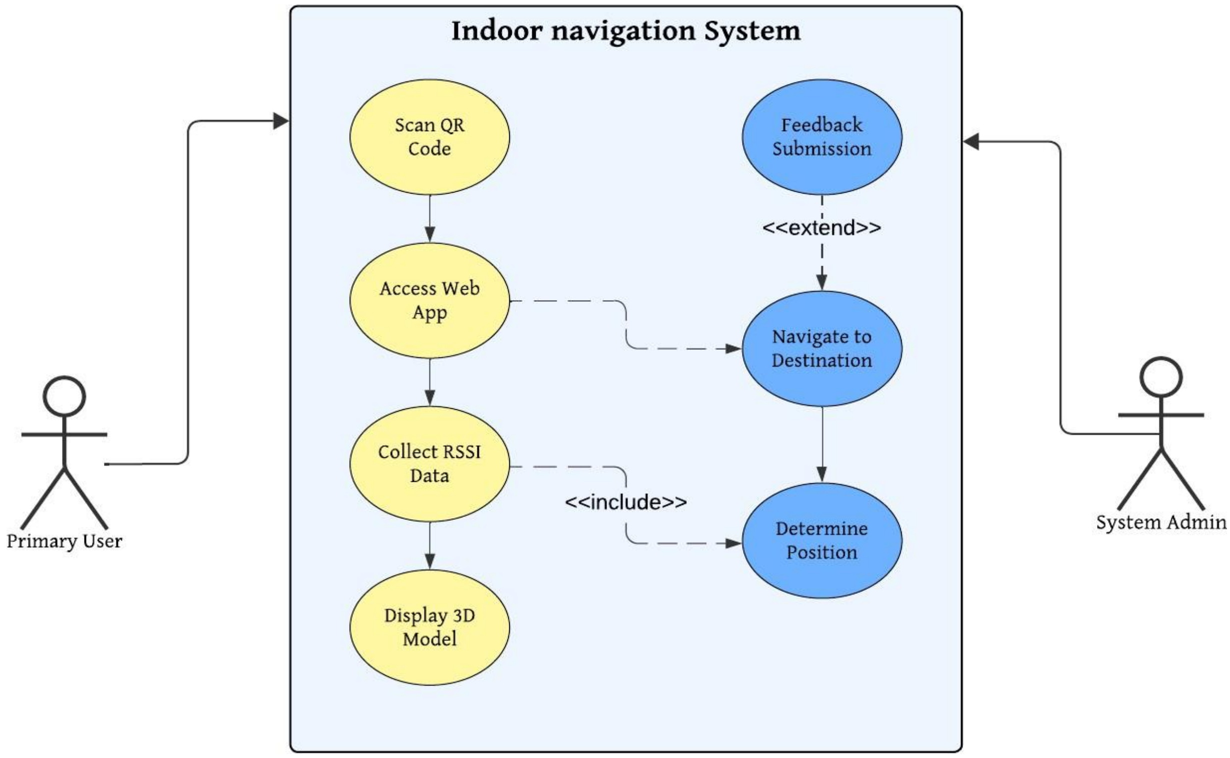

Figure 5.1 Use Case Diagram

This Use Case Diagram depicts the functionality and interaction in the Indoor Navigation System, where the Primary User and System Admin interact with the system components. Each of the components is explained in detail as follows.

Actors in the System

1. Primary User:

- The user who interacts with the system for the purposes of navigation. The typical user in this case might be a visitor, student, or employee in the indoor setting (e.g., a building or campus).
- Their objective is to travel effectively and precisely to a destination via the application of the system tools.

2. System Admin:

- The system administrator in charge of administrating and maintaining the system.
- Maintain the accuracy and effectiveness of the indoor navigation system and responds to user comments along with optimizing the experience

The system is aimed at delivering an easy-to-use and user-friendly navigation experience. The ensuing use cases outline its main functionalities.

1. Scan QR Code:

The navigation process is initiated by the user scanning a strategically positioned QR code at entry points or Salient location in the building.

How it Works:

QR code contain unique codes that relate to particular positions within the indoor space.

QR code scanning enables the system to identify the user's entry point.

The user is redirected to a web application for extended interaction.

2. Access Web App:

The web app is the primary interface to access the navigation system.

How it Works:

When scanning the QR code, the user opens the web app, which offers options of choosing a destination, looking at the 3D model, and starting navigation.

Users are able to enter their destination and look at further navigation information via the application.

3. Gather RSSI Data:

The user's precise location within the building is determined by collecting RSSI (Received Signal Strength Indicator) data.

How it Operates:

Data on signal strength is continuously transmitted by Wi-Fi routers positioned throughout the building. After receiving this information, the system use signal triangulation techniques to precisely ascertain the user's present location within the building. Once found, the system updates the user's location on the 3D map based on the optimal navigation route determined by this real-time position.

4. Display 3D Model:

To provide users with an interactive and accurate representation of the building's plan, which will facilitate understanding and navigating inside areas.

How It Operates:

The system builds a comprehensive virtual model of the building, complete with rooms, hallways, and important common areas, using Unity 3D. The 3D model displays the users' current location as they navigate the building. Additionally, the navigation path to the chosen location is dynamically shown by the system.

The whole navigation experience is greatly enhanced by this interactive 3D display, which makes it easier for users to follow directions and comprehend their surroundings.

5. **Navigate to Destination**
To employ the quickest, most effective route to direct people to the destination they have selected within the building.
How it Operates:
• The system uses algorithms such as Dijkstra's to determine the best route when the user chooses a location.

• The online interface generates and displays step-by-step instructions; at the same time, the 3D environment graphically represents the path, making it easier for users to comprehend and follow instructions.
• This guarantees that consumers get where they're going quickly and without needless confusion or diversions.

6. **Establish Position (Incorporate RSSI Data Gathering)**
to instantly determine the user's precise location within the structure.
How it Operates:

• Nearby Wi-Fi routers send RSSI (Received Signal Strength Indicator) information to the system.
• Triangulation techniques are used to estimate the user's present location based on these signal strengths.
• By mapping the predicted position onto the Unity-based 3D model, the system is able to dynamically update navigation directions and track user progress over time.

7. **Submission of Feedback**
to gather user feedback and make system improvements based on practical experience.
How it Operates:

• Following navigation, users have the option to provide feedback through the online application, where they can rate the system's usability, point out any problems, or make suggestions for enhancements. Administrators examine this input, which gradually improves the system's performance, accuracy, and usability.

System Relationship

• **<<include>> Relationship:** One crucial element of Determine Position is RSSI Data Collection.

• **<<extend>> Relationship**: Navigate to Destination is extended by feedback submission. Only once the navigation procedure is finished does it become active, and it is optional.

Process Flow

• **QR Code Scan:** To access the navigation web application, the user scans a QR code at the building.

• **Destination Selection:** Using the UI, the user chooses the desired room or location.
• **Position Determination:** To determine the current position, the system starts gathering RSSI data.
• **3D Model Display:** The user's current position and chosen destination are displayed in a 3D model built on Unity.
• **Step-by-Step Guidance:** Using pathfinding algorithms, the system calculates the shortest route and offers both visual and textual guidance.
• **Optional Feedback Submission:** Users have the opportunity to submit feedback once they arrive at their destination.
• **Admin Review:** Administrators examine user feedback to identify areas where the system could be

improved.

This indoor navigation system combines machine learning, 3D modeling with Unity, and Wi-Fi-based location monitoring into a single integrated platform. It is intended to make navigating in expansive or strange areas—such as offices, hospitals, and college campuses—easier. It is both technically efficient and user-centric, with administrators overseeing backend operations and system enhancement while users enjoy real-time, clear navigation.

5.2 Class Diagram

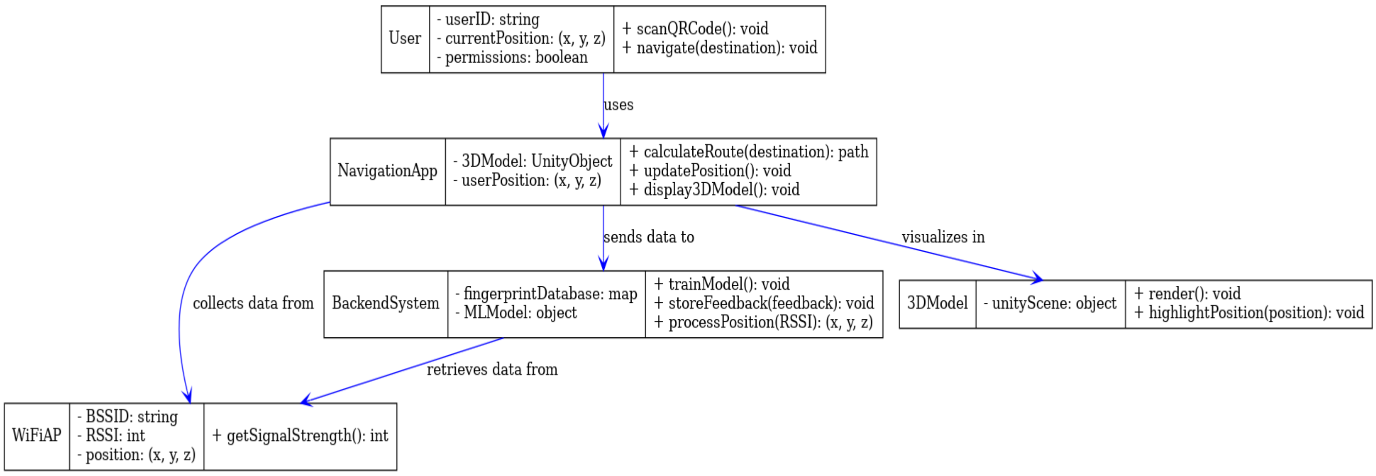

Figure 5.2. Class Diagram

The class diagram indicates how the various components of the indoor navigation system interact with each other and what functions each component fulfills. Here is a simplified and thorough explanation of the system's structure and interactions:

User:

Attributes:

- userID: A special identifier for every user so that the system can identify different users.
  • currentPosition (x, y, z): Actual coordinates of the user in the 3D environment, which get updated continuously.
  • permissions: Access level for the user, e.g., standard user or admin..

Methods:

scanQRCode(): Allows the user to scan a QR code at their location to open the navigation interface.
• navigate(destination): Starts the navigation process once the user chooses a destination point.

1. Navigation App:

Attributes:

- 3DModel (UnityObject): Unity-generated digital model of building structure for immersive navigation.

- userPosition (x, y, z): Monitors the user's current location in 3D space of the building.

Methods:

- calculateRoute(destination): Calculates the optimal path from the current position to the destination via algorithms such as Dijkstra's.
- updatePosition(): Modifies the coordinates of the user based on received Wi-Fi signal data (RSSI).
- display3DModel(): Displays the 3D model in the user interface with indications of current location and navigation.

2. Backend System:

Attributes:

- fingerprintDatabase (map): A map of Wi-Fi RSSI values to physical coordinates within the building.
- MLModel (object): A machine learning model to improve location prediction accuracy by training with signal data.

Methods:

- fingerprintDatabase (map): A map of Wi-Fi RSSI values to physical coordinates within the building.

- MLModel (object): Machine learning model employed to increase location prediction accuracy via training on signal data.

3. WiFi AP (Access Point)

Attributes:

- BSSID (string): Access point identifier that is unique for each access point, employed to distinguish signal sources.
- RSSI (int): The strength of signal received from the access point, utilized to estimate distance from the user.
- position (x, y, z): The physical position of the Wi-Fi access point in the building's 3D space.

Methods:

- getSignalStrength(): Returns the latest RSSI value broadcast by the access point, which is helpful in user localization.

4. 3Dmodel:

Attributes:

- unityScene (object): The entire Unity-rendered scene of the building with the rooms, corridors, and significant navigation points.

Methods:

- render(): Shows the interactive 3D layout to users.
- highlightPosition(position): Makes a specific coordinate (user's position or destination) highlighted for clear visibility in the 3D model.

5.3 Sequence Diagram

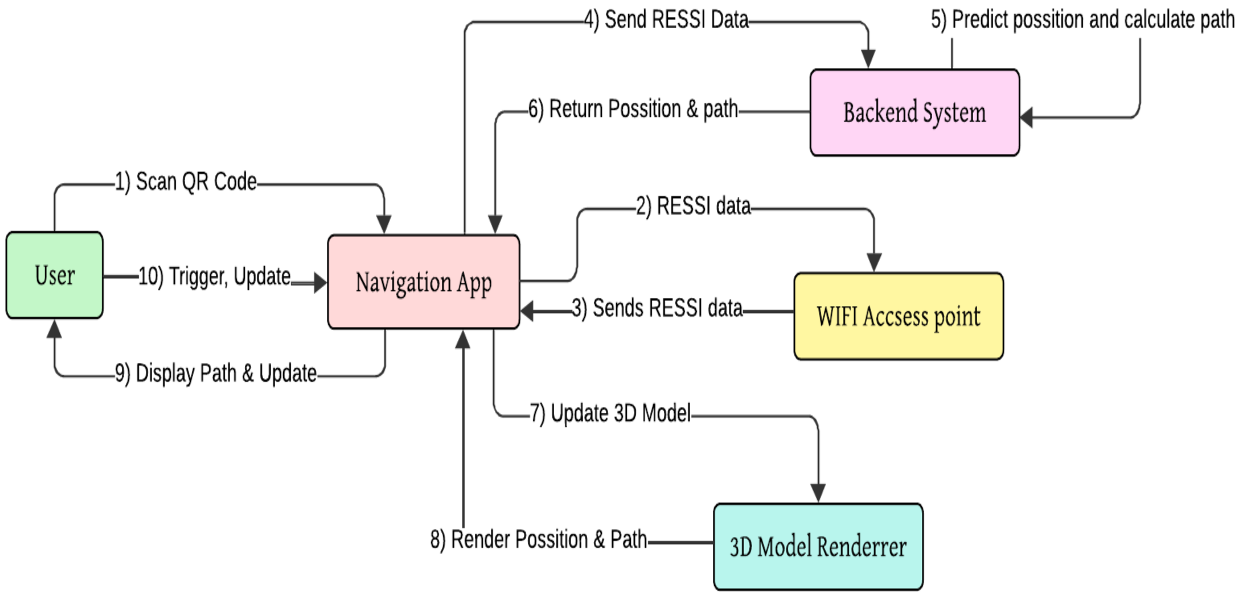

Figure 5.3. Sequence Diagram

User Interaction:

Step 1: Scan the QR Code

The user scans a QR code to begin navigation.

• This guarantees a safe and customized user experience.

• The QR code may include access-level information or the user's current location.

Step 2: Signal Data Request
• Nearby Wi-Fi Access Points (APs) receive a request from the navigation app.
• As a result, RSSI (signal strength) values are gathered.

Step 3:Getting RSSI Values in Step Three
• In response, WiFi access points provide RSSI (Received Signal Strength Indicator) readings.
• These numbers show the strength of each AP's signal.

Step 4: Sending Data to the Backend

- The app sends the backend server the signal data it has gathered.
- Analysis and processing are handled by the backend.

Step 5: Estimating Position and Calculating the Route

- The backend estimates the user's position based on signal data:
- It determines the best route to the selected destination using techniques like Dijkstra's or A*, either by triangulation or a trained machine learning model.

Step 6: Return Results to App

- The Navigation App receives the estimated position and calculated route from the backend.

Step 7: Revise the 3D model

The app updates the Unity-based 3D environment using new data.

- The user's current location and route are shown in real time;
- The program uses fresh data to refresh the Unity-based 3D environment.

Step 8: Produce a 3D model and render an updated view

- The renderer displays the path and current location in an easy-to-understand manner.
- The environment and navigational cues are interactively visible to users.

Step 9: The user is shown the revised 3D itinerary

- which they can follow to get to their destination quickly.

Step 10: Interaction/Rerouting:

- The app permits rerouting and promptly recalculates the route if the user deviates from the path or changes destination.

Important System Elements and Their Functions

User: Scan a QR code to begin navigation, then follow the app's visual instructions.

• Navigation App: Connects all other components of the system and controls real-time updates, functioning as a central controller.
• Wi-Fi access points: Gather and transmit signal information that aids in determining the user's location.
Backend System: The system's central nervous system. It determines the shortest path, anticipates the user's position, and processes signal data.
• 3D Model Renderer: Provides a visual representation of all the data, enabling the user to comprehend their environment more easily.

This system provides an effective indoor navigation solution by combining machine learning, Wi-Fi-based localization, and Unity 3D visualization. By fusing accuracy, interactivity, and automation, it provides a smooth user experience whether in corporate buildings, hospitals, or campuses.

Chapter 6

FEASIBILITY STUDY

6.1Introduction: Pioneering the Future of Indoor Navigation for Accessibility

In The Unity-based 3D Indoor Navigation System is a system that combines accessibility with contemporary tools in an era of technological innovation and human-centered design. This technology enables users, particularly those with impairments, to confidently and easily navigate complicated indoor surroundings by focusing on the needs of people with limited indoor mobility. It transforms the way people perceive indoor environments by fusing machine learning, pathfinding algorithms, and real-time 3D graphics. It offers a dependable, engaging, and easy-to-use platform that helps people navigate complex layouts on their own.

The method was created with a thorough awareness of the anxiety people experience when navigating complicated or unknown indoor spaces. It can be challenging to get to a certain place safely due to issues like unclear hallways, poor signs, or visual impairments.

By directly addressing these issues, this navigation system gives users a sense of dignity and independence. Users may move about easily without outside help thanks to its user-friendly interface, which is improved by multisensory feedback and precise placement.

The foundation of this system is the smooth integration of technology. It determines the user's present location within a building using Wi-Fi RSSI triangulation. Dijkstra's algorithm aids in determining the most effective path to the intended destination, while Unity's real-time 3D modeling allows the surroundings to be visualized. In order to optimize routes and adjust to user preferences, machine learning is also utilized to analyze user behavior over time. With the help of these technologies, the system is transformed from a simple navigation tool into a smart assistant that can comprehend user demands and offer seamless, guided experiences in indoor system.

Enabling Accessibility by Means of Personalization: Another around the block of personalized assistive technology is the 3D Indoor Navigation System developed in Unity. With machine-learning algorithms that learn to adjust themselves to individual users, the system is not a map anymore; now it is more akin to a guide personalized for particular individuals: it recognizes travel patterns, optimizes routes most used, and considers user preferences. It is this self-adaptability that makes navigation a great experience, giving suggestions and presenting routes that are optimal, dynamic, and ever-changing on parameters of past routes used and patterns of user behavior. By converting the navigation process to a personalized and dynamic experience, the system invokes an empowerment feeling wherein the users are directed and not dictated to. Through the multi-sensory feedback by way of the system that includes visual, auditory, and haptic feedback, themselves are assuring inclusion catering to all users with various requirements, thereby enhancing usability for all. The Unity-based 3D Indoor Navigation System is an example of a technology being used for a bigger cause, making indoor navigation an inclusive experience for all people.

This project is a manifestation of the strength of invention, with the technological design focused on accessibility, autonomy, and human advancement. By combining high technology with inclusivity, the Unity-based 3D Indoor Navigation System aims not only to cater to but also to create an inclusive world where anybody can move around their environment with confidence and autonomy with regard to their level of capacity.

6.2Economic Feasibility:

The Unity-based 3D Indoor Navigation System is an instance where new technology can create huge transformations in the economy and society. Standing on the brink of disrupting indoor navigation, the system has the potential to generate economic value for the long term in addition to providing accessibility. Serving interests of users in learning establishments, medical facilities, corporate premises, and shopping complexes, the system can deliver large-scale adoption and disruptive innovation into industries. A close analysis of its economic feasibility proves its potential to anchor economic growth, create employment opportunities, and enable local economies.

Market Demand and Growth Potential: The indoor-navigation market is experiencing growth on the back of the increased need for assistive technology and the swelling emphasis on accessibility across public and private spheres. The Unity-based 3D Indoor Navigation System is a new rising star in this field; it sees an unmet demand cast to serve differently abled people, senior citizens, and tourists who face difficulties amid more complicated buildings and complicated indoor-layout considerations. The advancement will continue to escalate for new indoor navigation solutions as companies, universities, and other players in the healthcare arena try to better a user's experience while also making accessibility laws compliant. The system real-time locating and dynamic pathfinding representation offer is still very rare in this underserved vertical and will grow fast.

Cost-effectiveness and Affordability: From the perspective of the development of the Unity-based 3D Indoor Navigation System, cost efficiency is stressed without compromising on the functionality of the system. The system is built on open source software and existing hardware (Wi-Fi routers for RSSI data) to avoid major investments in expensive hardware and proprietary technology development. Through Unity, which is both inexpensive and one of the widely used game engines, we have been able to develop and execute navigation systems comparatively faster and at less cost than regular navigation systems. This option has the potential to enable indoor navigation in deliberate settings, from small businesses to big organizations, making these advanced navigation technologies more accessible. Focused on ensuring affordability, yet possessing a good level of user experience and features, the Unity-based 3D Indoor Navigation System should gain fast popularity.

Employment avenues and skill development: Once operational, the Unity-based 3D Indoor Navigation System will provide a few job opportunities in the area of software development, data science, and IT infrastructure. In designing the system, a wide variety of skills will be required in the software development, ranging from Unity development skills to machine learning (ML) skills in implementing path finding algorithms. Other skills will relate more to data collection, such as triangulation of Wi-Fi data. Following the extended roll-out of the system implementation across a wide array of post-secondary institutions, further public institutions, and public spaces, systems installers will be required, technicians will be needed to maintain the system, and customer support roles will come into demand. Therefore, it further develops a technology-skilled workforce in emerging technologies of AR, ML, and real-time data processing, which would enhance the technology ecosystem and nurture sustained innovation.

Local Communities Empowerment: Exercising essentially presents an array of options in strengthening the body with cardiovascular conditioning and having the ability to lower the possibility of diseases implicated in magnificently. A Lifecourse project by Nystoriak et al. (2018) stated that physical activities inversely relate to mortality rate from cardiovascular causes and, hence, they are also inversely related to cardiovascular diseases. The exercise manages or modifies a good number of the risk factors for heart disease: high blood pressure and cholesterol. Moreover, it has been shown that both aerobic-type exercise and muscle-strengthening-type exercise have physiological effects beneficial to vascular metabolic activities in terms of preventing diseases.

Scalability and Sustainability: The uniqueness of the Unity 3D Indoor Navigation System comes with the advantage or scalability. The system can be scaled easily, say for a bigger facility or a new location, without any increase in costs. The modules are easy to update, and they fit into existing infrastructure, which ensures the deployment of the 3D Indoor Navigation into almost any kind of building. The use of ubiquitous technologies such as Wi-Fi for location services could result in the belief that the system will remain relevant as technology continues to evolve. However, even in the face of new options, modular development through strategic innovative partnering is what will take the project beyond the current parameters put forth for its development and into newer markets for adoption.

Society and Economy: The far-reaching societal implications of the Unity-based 3D Indoor Navigation System are vast and go beyond the mere utility of the system at present. It can limit to enhance the mobility and accessibility of disabled and elderly persons while giving them a more inclusive opportunity to interact with the world fully. This, in turn, will foster broader community participation and result in a thriving community full of diversity, where an individual, irrespective of their physical attributes that may act as a handicap, can freely walk about in public and private places. New scope areas for accessibility-oriented products and services will, therefore, spur economic growth. Should more establishments find rescue in making their premises more welcoming to clientele using this technology, such conversions will accrue a win for inclusivity that fairly factors to increased loyalty and customer satisfaction. Similarly, more opportunities for mobility will enable persons with disabilities to enter the workforce and post-secondary education avenues, hence gearing them toward self-reliance and societal integration.

6.3 Technical Feasibility

The "Unity-based 3D Indoor Navigation System" is considered a very advanced system in assistive technology, where emphasis must be placed on very advanced technologies without compromising the simplicity from the user's end. From a technical point of view, the solution found is technically feasible, mainly because of the use of tried and tested methods and tools combined with innovative elements to achieve the solution." Presented below are some technical factors that in conjunction provide a solid foundation on which the Unity-based 3D Indoor Navigation System can be considered a credible and transformative product for indoor navigation in institutional and public spaces.

High-Level Positioning Technology (Wi-Fi RSSI & Triangulation): The three-dimensional indoor navigation system positioning space evolves into Wi-Fi Received Signal Strength Indicator data from its technology. Triangulating the signal positions of RSSI data taken from BSSIDs on APs allows for services to account for an extremely precise indoor location of the user. This enables maximizing the use of existing Wi-Fi infrastructure rather than using conventional GPS location. The triangulated information is fully applicable in mixed-use areas or buildings that do not have GPS coverage or can be taken as a supportive and/or secondary resource. This method is as practical and effective as it is because of several issues: such as the triangulation by RSSI signal can use required adjunct hardware at minimum cost. As shown in the figures above, this positioning system would satisfactorily operate based on the resources inherently available in the Wi-Fi infrastructure.

To describe our system in 3D modeling and real-time visualization sense, it basically integrates Unity: A very important technical consideration. The engine is powerful and flexible, hence capable of creating alluring interactive environments in 3D. Due to the diverse opportunities for experiences within the 3D environment, Unity becomes a fitting platform for indoor navigation applications. We model building interiors in Unity to simulate navigation paths. The system offers the user an intuitive visualization of the building layout with real-time positioning and dynamic pathfinding. Moreover, since Unity is cross-platform, the system can also be implemented across many devices allowing for flexibility, resilience, people reaching out, and trialability. Also, from a rendering perspective, Unity really helps keep the user interface feeling very smooth throughout the experiences, something that comes in handy when you are dealing with elaborately set-up scenarios.

Dynamic Pathfinding with Machine Learning: The Unity-based 3D Indoor Navigation System utilizes machine learning algorithms in order to provide more accurate pathfinding. It optimizes the paths of the users based on the data gathered from the environment, their present state, and their position. Having learned from the previous user data, the system can give better recommendations to the user. In their adaptation to various room sizes, layouts, user preferences, or hindrances, this machine learning actively provides real-time feedback and route adjustment. This flexibility and adaptability render the system a little more than a navigation application, for it is a highly intelligent and always evolving dynamic helper that will continue to increase the user's ease and productivity as time goes on.

Integration of Dijkstra's Algorithm for Optimal Pathfinding: Dijkstra's algorithm plays a central role within the 3D Indoor Navigation System, organizing the shortest and most efficient path throughout a building. This classical algorithm excels in the use of Dijkstra's algorithm for indoor navigation where the environment is highly constrained and pathfinding accuracy is paramount. Users will be able to receive the fastest and safest route to their destination by using Dijkstra's algorithm along with the real-time inputs of Wi-Fi RSSI and learning-based models. The fusion of static algorithms with dynamic real-time pathfinding will allow accurate results, maximizing efficiency in a dynamic environment.

User Interface and Experience Design: A primary technical aspect of the Unity-based 3D indoor navigation system is its focus on user-centered design. All aspects of the interface were developed to allow users to interact with the system easily and intuitively, and in both automatic or manual movement mode. The system gives the user both audio and tactile feedback for navigational pointers. Considerations for accessibility are paramount; therefore, design features were optimised so that people with disabilities, including people who are blind or partially-sighted, could use the system. All these variations of design features rely upon multiple sensory modes of feedback (visual, auditory, and tactile), making accessibility for different types of technological users and physical limitations a priority.

Scalability and Adaptability of the System: The technical feasibility of the Unity-based 3D Indoor Navigation System is also found in its scalability and adaptability. Intended to grow alongside users' needs, the system allows easy addition of sensors and incorporation of new technology as continuous improvement and enhancements for users of the system. The system can also accommodate advancements in sensor technologies (e.g., ultra-wideband [UWB], Bluetooth Low Energy [BLE]) in order to achieve higher precision as technology advances. The modularity of the system allows users to update hardware and software in order to keep pace with innovation in indoor navigation.

Integration with Existing Building Infrastructure: The 3D Indoor Navigation System has been developed to work seamlessly with existing building infrastructure. This technical consideration minimizes the cost of implementation by relying on existing building infrastructure that includes Wi-Fi networks and other basic hardware systems. Another key feature is that the system is able to function with little setup, allowing faster and easier deployment in a variety of spaces, from small office space to large institutional campus. Significantly, there is an uncomplicated interface for administrators to use in order to update building layouts and other existing rooms or areas; allowing for flexibility for years to come.

Data Privacy and Security: In a world today dominated by facts and figures, the attention to user data privacy and security within the Unity-based 3D Indoor Navigation System is first and foremost. All user data, including location information, is comprehensively encrypted either in transit or at rest. The way

Unity stores data is the best way to store data securely, reducing and/or eliminating the risk of disclosure of the user's personal information to unauthorized parties. The system complies with privacy regulations around the world, making available information regarding how the user’s data is used, and what happens to the data after a user has fully enrolled. With cloud storage options that are secure, the system provides the opportunity for safe data backup and retrieval. Everything is designed to be reliable and secure.

Future Enhancements and Upgrades: The 3D Indoor Navigation System using Unity is future-proof. The system's technical architecture is modular, and hence it's easy to update and implement new features as technology advances. Future enhancements may be Advanced real-time object detection using computer vision, augmented reality (AR) feature for richer navigation experience, and AI-driven prediction and suggestion of optimal routes based on user behavior. With its flexible and scalable architecture, the system will be able to evolve with the emerging technologies and continue to be the optimal solution for indoor navigation in the future years.

6.4 Behavioral Feasibility

The “Unity-Based 3D Indoor Navigation System” being a technically feasible solution as well as a very practical and viable tool from the behavioral point of view, with emphasis on the end user’s requirements, habits and end to end user experience is described in this section .The behavioral feature of the system that make it an efficient, responsive and user-friendly solution for indoor navigation, especially in institutional and public environment are mentioned here.

User-Centric Design and Accessibility: User-Centric Design and Accessibility: One of the central ideas of the 3D Indoor Navigation System is user-centered design to ensure usability and accessibility to users with diverse levels of technological expertise. The system must be smooth and intuitive to a broad group of users, including people who are disabled. The system must be simple to use, easy to understand, and simple to navigate, with auditory and touch feedback incorporated to enhance the usability of the system. The accessibility ensures even visually impaired users or nontechnical users can use the system with confidence. The focus on inclusive design enables the system to meet the needs of a large user group, ensuring equal opportunity to indoor navigation.

Freedom and Confidence in Navigation: The 3D Indoor Navigation System liberates users through an increased level of independence in movement within complex indoor spaces. Users can move confidently within unknown environments, such as university campuses, shopping malls, or office complexes, without any support. The system delivers real-time directions, guiding users to the shortest and safest route to the destination. This independence of travel produces a feeling of independence and confidence, with users being able to control their travel, less dependent on others and free from uncertainty that usually comes with unknown indoor areas.

Personalization and Adaptive Behavior: The 3D Indoor Navigation System allows the user to be more independent when moving within complex indoor areas. The users can navigate in unfamiliar environments, such as college campuses, shopping malls, or office buildings, without assistance. The system provides feedback in real-time, guiding users on the safest and shortest path to the destination. The ability to move unaided instills a sense of independence and feeling of autonomy, as users are enabled to control their movement, reducing reliance on others and removing the uncertainty that is normally present in unknown indoor environments.

Social Inclusion and Engagement: 3D Indoor Navigation System facilitates social inclusion by ensuring that individuals, particularly those mobility impaired or visually impaired, can engage more actively with the world around them. Independent navigation powered by the system removes obstacles that otherwise would limit participation in social, educational, or vocational pursuits. Increased mobility through such navigation enables the users to communicate with their environment and with other individuals more freely, and to become less isolated and more integrated into Activities. Moreover, the system encourages the change of society's attitude towards the disabled, so that they can be more accepted and esteemed.

Adaptability to Individual Needs and Preferences: As a manifestation of user diversity and their different needs, the system also proves to be highly customizable in many different ways. From changing the sensing feedback (visual, tactile, or auditory) to selecting among different modes of motion (manual or automatic), users can customize the system to meet their needs in the best possible manner. The ability to customize the system makes the experience more comfortable and intuitive for all. By providing the ability to choose the use of the system, the 3D Indoor Navigation System provides users the ability to utilize the technology in the most appropriate manner based on their individual needs, allowing them a sense of power and control.

User Training and Support: To render the system behaviorally feasible, user training and support rank high on the priority list. The user introduction process is made simple and informative, and the users are offered an instructional tutorial in the usage of the system. Instructions and tutorials are also given to aid users in achieving the maximum utilization of the system, whether the user is a novice user or a seasoned traveler. Since the system collects user feedback, it can be updated with continuous enhancements that include better usability and better navigation aids, and users will be assisted and confident to use the technology.

Community Support and Outreach: The behavioral feasibility of the system is also ensured through interaction with advocacy groups, disability groups, rehabilitation centers, and local communities. Integration with educational organizations, rehabilitation organizations, and disability groups creates a support framework for users, with the added advantage of resource supply, training, and counseling. Community connection facilitates the promotion of the widespread use of the system and its use as an effective means to users over the long term. These collaborations also create a feeling of sense of responsibility, with technology providers and the rest of society coming together in order to make it possible for people to be able to interact more with their world.

Continuous Improvement through Feedback: Perhaps the most crucial behavioral characteristic of the system is that it can collect feedback from users and adapt itself based on it. When the users operate the system, the feedback they provide is utilized in a way that makes the technology improve continuously such that it continues to satisfy the evolving needs of the users. The ongoing improvement process makes the system more effective and guarantees that it is an efficient, usable, and user-friendly solution in the long term. With a robust feedback loop, the system can rectify any usability problems and adapt to new issues as and when they arise.

6.5 Time Feasibility:

A timeline that guarantees the development and implementation of the Unity-based 3D Indoor Navigation System can be finished in a reasonable amount of time has been meticulously designed. The objective is to meet reasonable timelines while producing an effective, superior solution.

Phases of Development and Implementation: The development of the system is separated into logical stages. In the first phase, Wi-Fi RSSI data integration and the creation of 3D models of the building are done. These activities are simple and may be finished quickly. Later phases deal with the basic system features, such as path planning, real-time location tracking, and machine learning integration. Multiple development teams can operate in parallel because to the modular architecture, which cuts down on overall time.

versatile and Scalable Timeline: The system can be implemented progressively because it is modular and versatile. It could begin with just one building or campus block before spreading to other areas. In addition to minimizing disturbance, this phased rollout strategy enables frequent testing and enhancement in response to customer input. Each stage ensures a balance between quality and progress by providing engineers with the opportunity to improve the system before scaling it further.

Technological Readiness: The system makes use of well-known technologies such as Dijkstra's algorithm for pathfinding, Wi-Fi RSSI-based position recognition, and Unity for 3D visualization. These are tried-and-true tools that cut down on development time considerably and are widely utilized in industry. Furthermore, existing frameworks are used to integrate machine learning, obviating the requirement to create components from the ground up. Because the system is built on dependable platforms and tools, integration and customization—rather than pure development—remain the key priorities.

Testing and Optimization: To guarantee both technical correctness and user happiness, testing is carefully designed. Various sites will be used for real-environment testing, with time allotted for feedback-driven enhancements at each stage. At regular intervals, performance tuning will be done, including enhancing path accuracy and honing the ML models. This guarantees that the system will continue to be effective and user-focused.

Resource Allocation: The development team and resources that are available were taken into consideration when scheduling the timeline. Modules including 3D modeling, system integration, UI/UX design, and machine learning are handled by different teams. Each team's assigned tasks and due dates aid in maintaining the project's overall direction. Coordination and careful preparation guarantee that the system is finished quickly and effectively.

rollout Strategy: Pilot testing at specific sites is the first step in the system's phased rollout plan. Initially, hardware such as sensors and Wi-Fi routers are installed, and software is made interoperable with a variety of devices. Because the system is modular, it is possible to install essential functions initially, then increase them gradually.

Post-Deployment Support: Following launch, the system will be updated often in response to user input and new requirements. Its architecture allows for updates without interfering with ongoing services, guaranteeing that it adapts to changing user demands and emerging technology.

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6.6 Resource Feasibility:

The 3D Indoor Navigation System may be developed, implemented, and maintained with the use of current infrastructure, software tools, and human experience. The project is set up to make effective use of the resources at hand, reducing expenses and guaranteeing sustainability.

Human Capital and Proficiency: Professionals from a variety of fields make up the project team, including UI/UX specialists, network specialists with experience in Wi-Fi RSSI data, machine learning engineers, Unity and C# developers, and 3D designers. The system may be developed to high standards without significant external hiring or training efforts thanks to the abundance of expertise.

Software Tools and Platforms: The main development tool for 3D modeling and interaction is Unity, which is feature-rich and available for free non-commercial use. Development expenses are greatly decreased by publicly available pathfinding methods like Dijkstra's and open-source machine learning libraries like PyTorch or TensorFlow. Standard networking protocols and APIs are used for Wi-Fi data, negating the requirement for pricey licensed software.

Hardware and Infrastructure: To detect location, the system makes use of buildings' pre-existing Wi-

Fi infrastructure. These networks are already present in the majority of establishments, including offices and colleges, which makes the system economical. All you need for initial testing is a PC, a Wi-Fi router, and a tablet or smartphone. If necessary, optional improvements like UWB sensors can be installed later.

Time and Project Management: The project is broken up into phases with specific objectives in order to effectively manage progress. Jira and Trello are two tools that can be used for team communication and task tracking. The distribution of tasks prevents any one team from being overworked, guaranteeing timely completion without sacrificing quality.

Training and Support Materials: Because of the system's intuitive design, little user training is required. It is accessible to all users due to its tactile, auditory, and visual input. Admin users, such as college employees, could need little assistance in managing user settings or updating building maps. When necessary, the development team will offer technical support and help documents. It is simple to train support personnel for widespread deployment.

Technically, resource-wise, and in terms of time management, the Unity-based 3D Indoor Navigation System is completely doable. It incorporates tried-and-true technologies like machine learning for adaptive navigation, Unity for realistic 3D settings, and Wi-Fi RSSI for interior position monitoring. Accessibility is guaranteed even for those with disabilities thanks to the user-friendly interface and multisensory support.

Low cost and great efficiency are guaranteed by the phased timeframe, use of pre-existing technology, and reliance on open-source tools. The system is scalable and future-ready due to its modular architecture, which makes expansion and updates simple. All things considered, the idea offers a thoughtful, creative, and practical answer to the contemporary problem of indoor navigation in big or complicated structures.

Chapter 7
RESULTS

7.1. Accuracy Graph (User Positioning)

We have utilized a trilateration method for the user's exact location as it is more accurate than the conventional Wi-Fi fingerprinting. The significant drawback of conventional Wi-Fi fingerprinting is that it relies on environmental factors, e.g., open doors within a classroom. If the doors are open, BSSID-based location estimation is okay, but real conditions may vary, and there would be 1-3 meter displacements. By contrast, the triangulation technique selects three access points (APs) in an area and determines the best signal strength AP. The user is then estimated to be closest to the best signal AP.

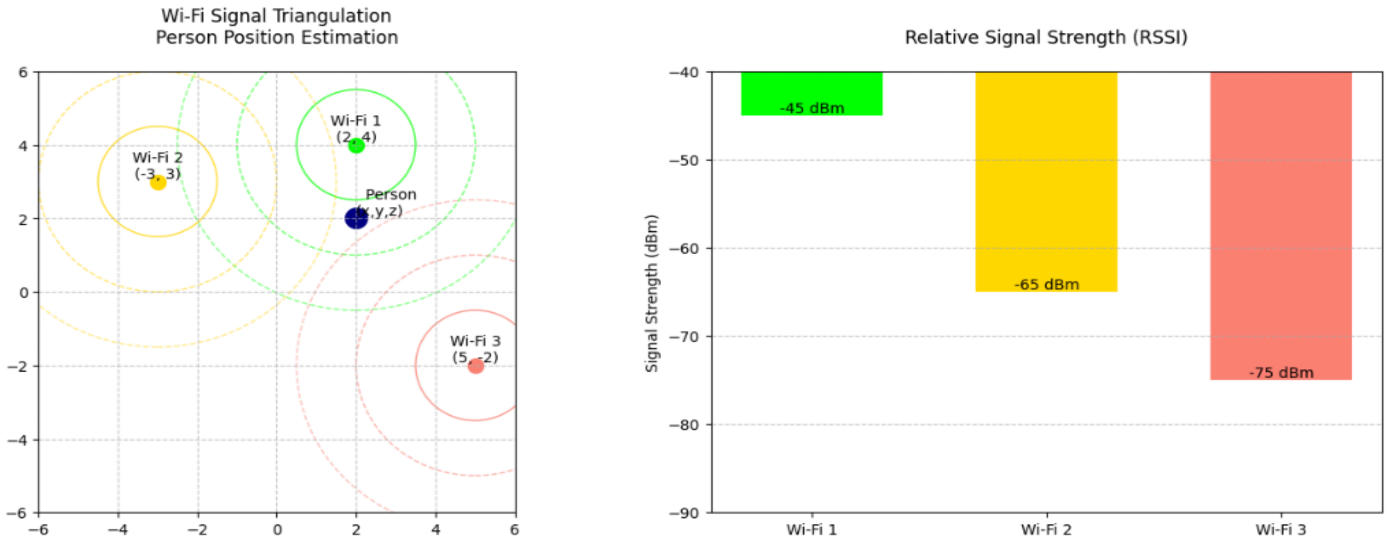

Fig 7.1 Accuracy Analysis Graph

From the graph, we observe that there are RSSI values of three APs. We selected three APs from three classes and collected RSSI values for each. When validating, since the user moves, the signal strength of one AP becomes stronger and weaker for others, allowing real-time location prediction inside the building. Since RSSI values are negative, the lesser the numeric value, the stronger the signal. For example, if Wi-Fi-1 = -45 in RSSI, it is the highest signal, confirming the closeness of the user to Wi-Fi-1.

2. RSSI Data and BSSID Analysis

In order to develop an accurate indoor positioning system, we collected over 150 routers in our college campus. Data collection was done by remaining in front of each router for two minutes to record its Received Signal Strength Indicator (RSSI) and Basic Service Set Identifier (BSSID) values. RSSI fluctuation at different points was one of the key challenges encountered, affecting data consistency. In order to address this, we gathered data in three rounds in order to conduct difference studies. We compared results and observed that the two groups shared the same values in order to ensure credibility of the collected data. These very same values were agreed to so that there is accuracy in our positioning model.

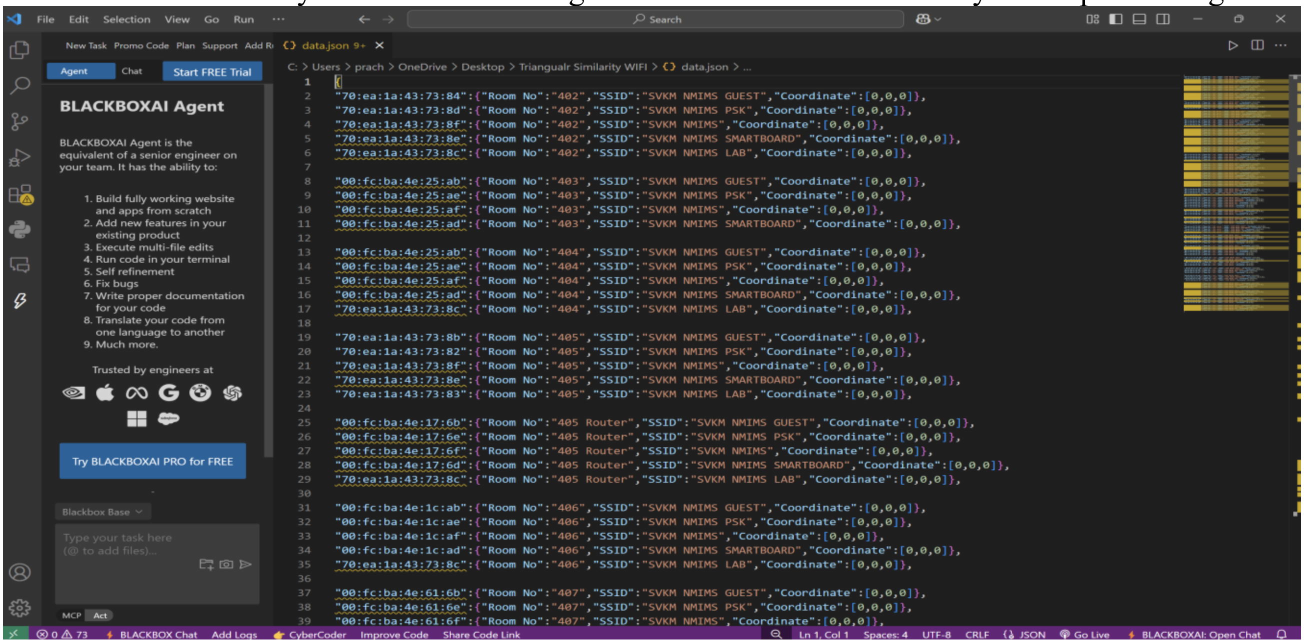

Fig 7.2 Data Collection

For further precision, we also excluded public networks from the picture. Our college campus contains a variety of Wi-Fi networks like SVKM NMIMS, SVKM NMIMS GUEST, SVKM NMIMS PSK, SVKM NMIMS SMARTBOARD, and SVKM NMIMS LAB. Since SVKM NMIMS is overused by students and instructors, dense user traffic can cause signal interference, leading to tracking errors. To prevent this, we ignored the SVKM NMIMS network and prioritized the unused SVKM NMIMS GUEST higher. This approach enhances positioning accuracy by minimizing external signal interference.

3. Validation of Positioning Accuracy Using RSSI vs Distance

The given graph depicts the relationship between RSSI and distance from an Access Point (AP) within an indoor scenario. Using the Log-Distance Path Loss Model.

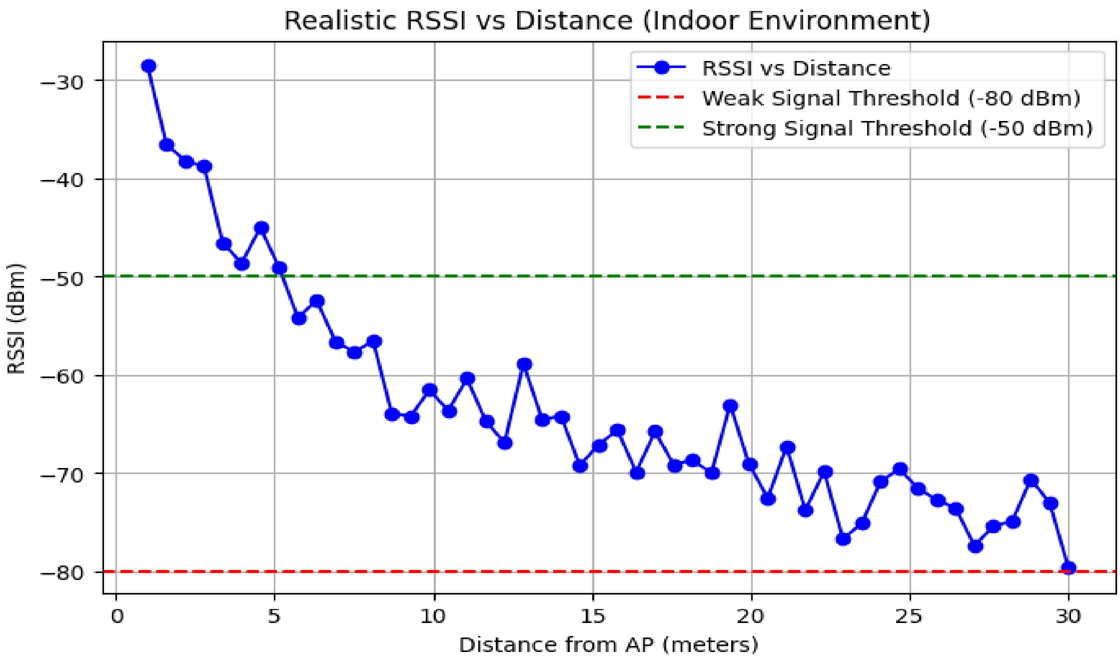

Fig 7.3 RSSI vs Distance Graph

The provided graph illustrates the correlation of RSSI with distance from an Access Point (AP) in an indoor environment. From the Log-Distance Path Loss Model, we are able to
From the graph, we observe that RSSI decreases with larger distance from the AP, indicating that signal weakens over distance. The green dash line (-50 dBm) shows the strong signal threshold, i.e., the user is very close to the AP. The red dash line (-80 dBm) shows the weak signal threshold, i.e., the user is far away from the AP. Fluctuations in RSSI beyond 10 meters show real-time environmental conditions like obstacles, interference, and multipath effects. By comparing measured positions with estimated positions from the AP using RSSI values, we can verify the indoor positioning system's accuracy. Consistency in trend between estimated positions and actual positions confirms the method's reliability, which helps to develop positioning algorithms for improved real-time tracking.

4. 3D Model of the College

The college campus was also modelled in 3D virtual form to mimic its actual structure, consisting of corridors, staircases, doors, and windows. It was built in Unity 3D with spatial precision and structural realism. Every element—walls, floor, classrooms, labs, and offices—was so modeled that it consisted of actual dimensions, and the intention was to stick to the actual structure.
Textures were applied to mimic brick, concrete, and glass to provide realism. Meshing tools in Unity developed the geometry of the model to enable correct positioning of objects like furniture and signage. The main routes and room adjacencies were allocated to indicate actual paths within campus. This 3D model is the foundation of user interaction and navigation within the indoor system.

Fig 7.4 3D Model of College Building in Unity

5. Graphical User Interface (GUI) for Navigation

To facilitate easy interaction between the users and the navigation system, a Graphical User Interface (GUI) was added to the Unity platform. The interface enables users to search for their preferred destination in the 3D model directly, thus making navigation easy. The GUI features a search panel with an input field and a dropdown list of all nodes that are available, including rooms, staircases, and entrances, enabling fast and accurate destination choice. The GUI design, as can be seen from the screenshot, organizes such elements as the search panel, canvas, and dropdown list hierarchically, being user-friendly by masking the system's complexity and presenting it in an easily understandable manner to a large majority of users.

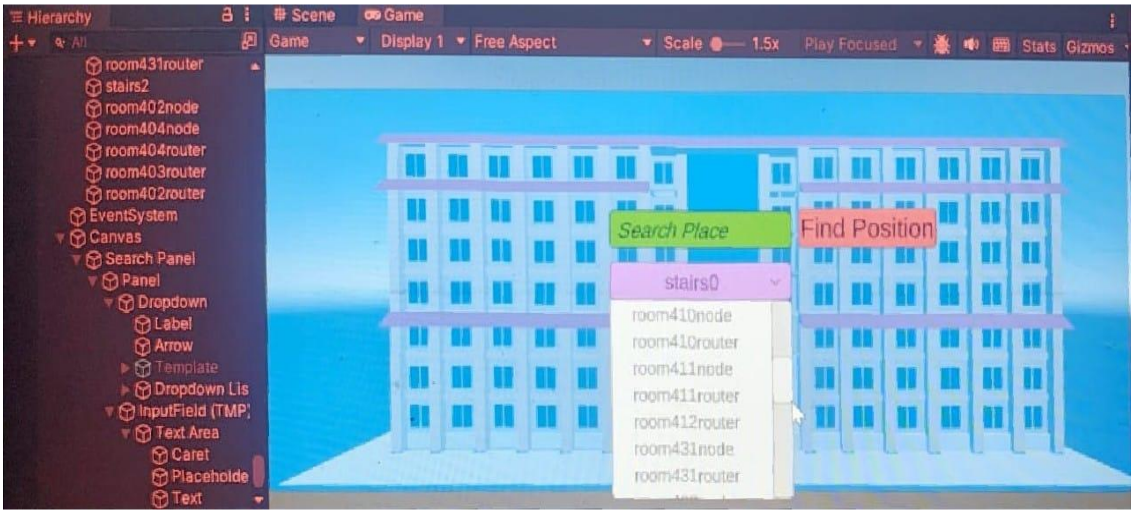

Fig 7.5 Graphical User Interface

6. Graph-Based Pathfinding System

In 3D projection, a graph-based strategy was used to perform effective destination pathfinding. Each room in the campus infrastructure was given a specially designated node, and the nodes were connected with edges to form an entire graph. The graph includes all the paths on the campus such that the system will be able to determine the shortest path between the location of the user and the location of their desired destination. For instance, nodes like room40/node, stairs0, and entrance node were established and linked to replicatethe actual routes. The systematic strategy allows the system to generate dynamic optimum routes.

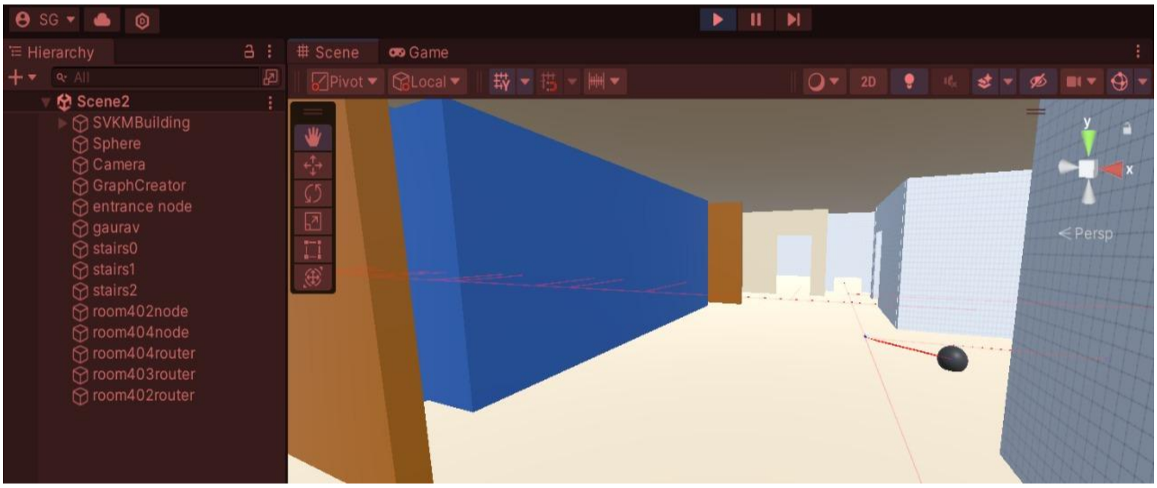

Fig 7.6 Graph Generation

7. Trilateral-Based Positioning System

The trilateration method was utilized to precisely estimate the user's location based on gathered RSSI (Received Signal Strength Indicator) and BSSID (Basic Service Set Identifier) information. The information was fed into the trilateration algorithm, which estimates the coordinates of the user based on the strengths of multiple Wi-Fi nodes. As shown in the snapshot, the system accurately pinpointed the user's location on the 2D map of the college campus. For example, the user was pinpointed to be in Room 404, showing the capability of the system to give accurate real-time positioning. Using RSSI values and the given coordinates of the access points, the trilateration system offers precise and reliable location tracking even for difficult indoor locations. This feature is the basis for easy navigation, allowing users to get real-time guidance based on their precise location within the campus.

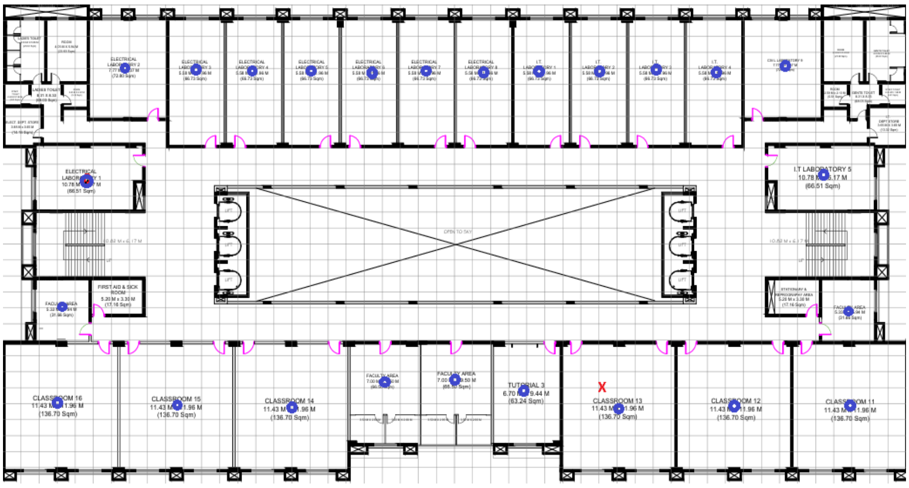

Fig 7.7 User's Current Location in 2D Map

8. Dijkstra Algorithm-Based Pathfinding

Smooth navigation within the 3D campus model was implemented using a Dijkstra algorithm-based pathfinding system. The virtual world was represented as a graph with the main locations as nodes and the paths that can be traversed as edges. Once a destination is selected, the algorithm calculates paths to get the shortest distance path.

Color-coded lines provide visual feedback:

• Red lines show potential routes and detours.

• Green lines show the best route from the algorithm.

This two-level visualization allows the user to compare routes and follow the shortest path. It provides dynamic updating of the object path in real time as it moves within 3D space. Ease of use and effectiveness are given high priority in implementation to provide for effortless navigation without sacrificing spatial accuracy and usability.

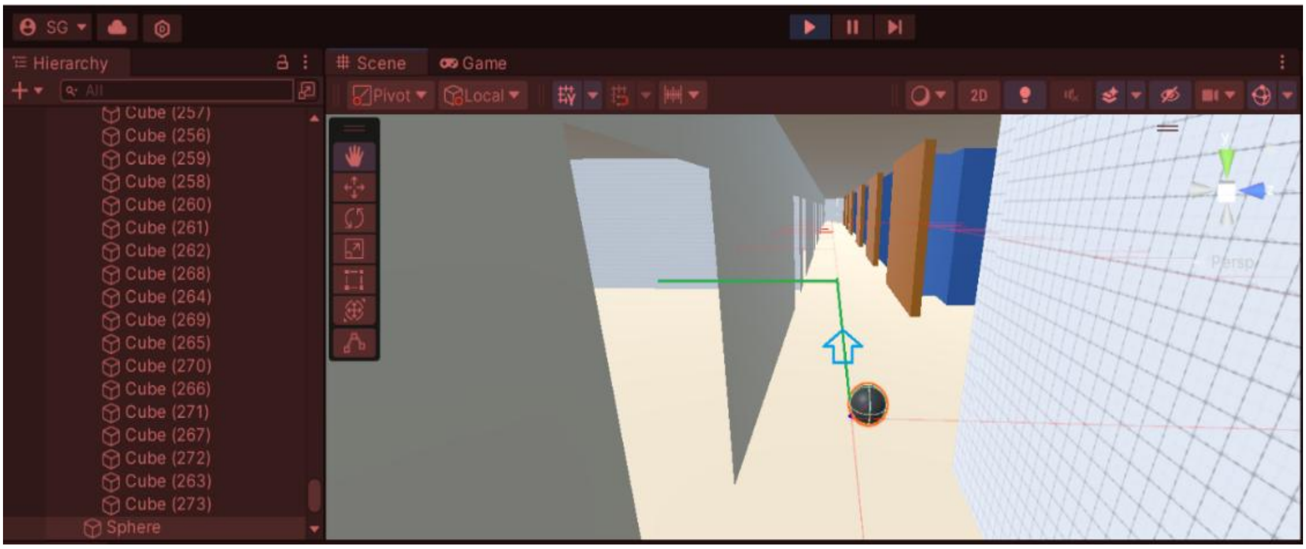

Fig 7.8. Shortest Pathfinding

9. Comparative Analysis

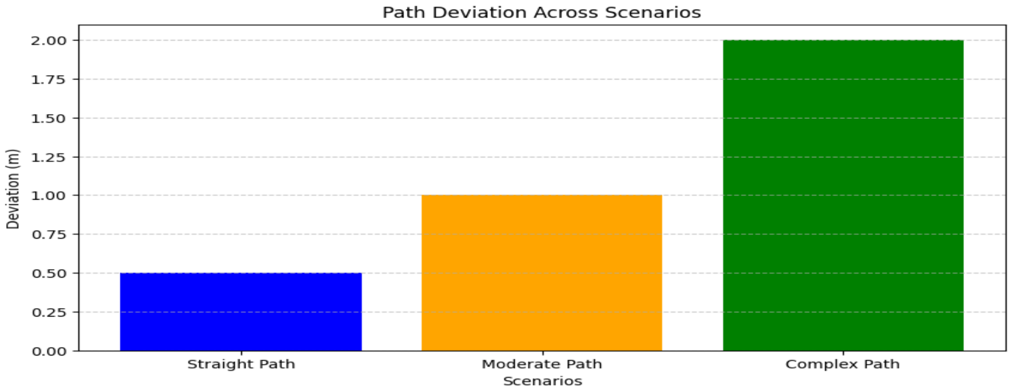

Fig 7.9 Deviation Across Different Path Scenarios

Path deviation is an important measure to determine navigation precision. Figure 6 shows the deviation for three path types: Straight Paths have Minimal deviation because they have unobstructed movement. Moderate Paths have Slightly higher deviation induced by random bends. Complex Paths have Maximum deviation, with frequent turns and high-density obstacles being the reasons.

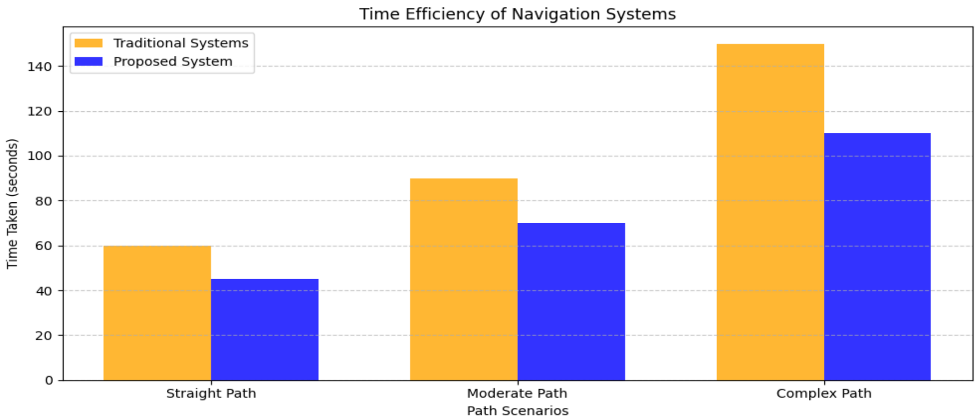

Fig 7.10 Time Efficiency of Navigation

Time efficiency is an important metric to measure the feasibility of indoor navigation systems. Figure 6 illustrates the navigation time under various conditions. The system proposed is 20–30% more efficient than the conventional methods, showing that it saves users' time while ensuring accuracy. Time efficiency has been enhanced in cases with improved pathfinding algorithms and strong localization features.

Table 7.1. Navigation Approach Success Rate

Navigation Approach	**Success Rate (%)**
Proposed Unity-Based and Wi-Fi Triangulation Approach	95%
Traditional Beacon-Based	85%
Basic Directional System	75%
Vision-Based Navigation	90%(varies)
Hybrid Approach (Wi-fi + Beacons + Vision)	97%(potentially)

Indoor navigation systems use various technologies for routing and user position. The Unity-Based 3D Indoor Navigation System with Wi-Fi Triangulation has a 95% success rate through Wi-Fi signal strength position estimation and offers an interactive 3D environment. Beacon-based systems have 85% accuracy with numerous beacons and are plagued by signal interference, while Wi-Fi triangulation does not require specialized hardware and is extremely accurate. Basic Directional Systems have a 75% success rate but are unsuccessful in complex environments because of low accuracy. Vision-based navigation is 90% accurate in open areas but necessitates good lighting and camera-capable devices. The Hybrid Approach (Wi-Fi + Beacons + Vision) is 97% accurate but is more complex and costly. Generally, Unity-Based 3D Indoor Navigation with Wi-Fi Tri-Tri-angulation is a good balance between simplicity and accuracy and is a suitable option for indoor navigation.

CONCLUSION

The 3D Indoor Navigation System based on Unity is an innovative solution for navigating indoors that integrates Wi-Fi RSSI-based localization, Unity as the 3D modeling and real-time visualizer, and machine learning for dynamic pathing. These technologies guarantee precise location tracking and optimized route guidance, and Dijkstra's algorithm adds reliability through the computation of shortest and safest routes. The accessibility features of the system, such as auditory and haptic feedback, render it useful to various groups of users, including those with disabilities, to ensure utility in public and commercial environments. Its scalability and modularity enable the system to adapt to various environments and layouts, facilitating future capabilities such as augmented reality enhancements and AI-based optimizations. Feasibility studies affirm its technical and behavioral feasibility, leveraging the installed Wi-Fi infrastructure and user-focused methodology for fulfilling various needs. By solving instant navigation problems and laying the groundwork for future development, the project helps build inclusive, intuitive, and effective indoor navigation experiences.

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