Project Report On

AR Based Indoor Navigation System

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering

By

Roshni Joshy (U2003176)
Roze Susan Mathew(U2003178)
Sneha Elsa Mathew(U2003202)
Swathi P (U2003207)

Under the guidance of

Ms. Amitha Mathew

Department of Computer Science and Engineering
Rajagiri School of Engineering & Technology (Autonomous)
(Parent University: APJ Abdul Kalam Technological University)
Rajagiri Valley, Kakkanad, Kochi, 682039
April 2024

CERTIFICATE

This is to certify that the project report entitled ***"AR Based Indoor Navigation System*** *is a bonafide record of the work done by* ***Roshni Joshy (U2003176), Roze Susan Mathew(U2003178), Sneha Elsa Mathew(U2003202), Swathi P(U2003207)****, submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2023-2024.*

Ms. Amitha Mathew
Assistant Professor
Dept. of CSE
RSET

Ms. Anita John
Assistant Professor
Dept. of CSE
RSET

Dr. Preetha K.G.
Professor
Head of Department
Dept. of CSE
RSET

ACKNOWLEDGEMENT

We wish to express our sincere gratitude towards **Prof.(Dr.)P.S.Sreejith**, Principal of RSET, and **Dr.Preetha K.G.**, Head of the Department of Computer science for providing us with the opportunity to undertake our project, "AR Based Indoor Navigation System".

We are highly indebted to our project coordinators, **Ms.Anita John**, Assistant Professor, CS, for their valuable support.

It is indeed our pleasure and a moment of satisfaction for us to express our sincere gratitude to our project guide **Ms.Amitha Mathew** for her patience and all the priceless advice and wisdom she has shared with me.

Last but not the least, we would like to express our sincere gratitude towards all other teachers and friends for their continuous support and constructive ideas.

Roshni Joshy

Roze Susan Mathew

Sneha Elsa Mathew

Swathi P

Abstract

Traditional indoor navigation systems often rely on external infrastructure, such as Wi-Fi access points or beacons, to triangulate a user's location. In areas without these infrastructure elements, the system may not function correctly. Indoor environments can be highly complex with multi-level buildings, multiple rooms, and corridors and existing systems may struggle to provide accurate navigation in such intricate settings.

AR enhances navigation by overlaying digital information onto the real-world environment, making it more intuitive for users. The system initializes a user's location through the scanning of QR codes placed in the indoor environment. Once the user scans the QR code, the smartphone uses visual SLAM technology to track their movement and applies A* algorithm to find the shortest path. Users can follow visual cues and directions overlaid on their smartphone screens, reducing the chances of misinterpretation.

The system can be easily scaled to cover larger indoor spaces or extended to include outdoor navigation, making it highly adaptable.AR based methodology represents a significant advancement in indoor navigation by leveraging the capabilities of modern smartphones and AR technology to provide a more immersive and accurate navigation experience.

Contents

List of Abbreviations

AR-Augmented Reality

SLAM- Simultaneous Localization and Mapping

MR- Mixed Reality

YOLO- You Look Only Once

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

The project provides the implementation of an Indoor Navigation System using Unity and Smartphones. It aims to provide a solution for tracking users' movements within the college using SLAM techniques.

The background of the project underscores the importance of indoor navigation systems in various scenarios, especially in complex environments like university buildings. Traditional GPS systems often struggle to provide accurate positioning indoors, necessitating the development of specialized solutions. The project leverages the capabilities of smartphones, incorporating sensors like the gyroscope and camera to enable precise indoor navigation.

The significance of the project is highlighted by the challenges associated with existing indoor navigation technologies. It emphasizes the need for improved accuracy and user experience in indoor navigation systems. It addresses these challenges by optimizing QR code scanning practices, enhancing navigation accuracy within specific smartphone angles, and conducting user experience evaluations.

Overall, the project responds to the growing demand for reliable indoor navigation solutions, particularly in environments where conventional GPS systems are less effective. It seeks to improve the navigation experience within buildings, providing users with a more accurate and user-friendly solution. [1].

1.2 Problem Definition

Develop an Augmented Reality (AR) based indoor navigation system within the Main Building of RSET which will provide real-time, interactive, and accurate wayfinding.

1.3 Scope and Motivation

The scope of AR-based indoor navigation systems is broad, encompassing applications that enhance user experiences and provide efficient navigation solutions within indoor environments. These systems utilize augmented reality (AR) technologies to overlay digital information onto the physical surroundings, aiding users in wayfinding and orientation[2]. They have extensive potential in various sectors, including retail, healthcare, education, and logistics, where precise indoor navigation is crucial. AR-based indoor navigation can improve accessibility for visually impaired individuals by offering real-time guidance and location-based information. Additionally, these systems contribute to the development of smart buildings and venues, fostering innovative and immersive experiences for users navigating complex indoor spaces

The motivation behind AR-based navigation systems stems from the desire to revolutionize indoor navigation experiences. Traditional navigation tools often fall short in providing seamless guidance within complex indoor spaces. AR navigation systems aim to overcome these limitations by overlaying digital information onto the real-world environment, enhancing users' spatial awareness. The integration of AR technologies seeks to offer more intuitive and interactive navigation, making it easier for users to navigate unfamiliar indoor spaces. Additionally, the motivation includes addressing challenges such as improved accuracy, user-friendly interfaces, and real-time guidance, ultimately enhancing overall navigation efficiency.

1.4 Objectives

1. Map Generation: Develop 3D indoor map of the building including building layouts and room information.

2. QR Code Generation: Generate QR code at different key points.

3. Indoor Navigation: Users can navigate the indoor spaces of the Main Building of RSET using AR technology.

4. Search Functionality: Include a search feature that allows users to input their destination, search for specific rooms or locations, and receive directions using AR.

5. Multi-Platform Compatibility: The system would be available on both iOS and Android devices to cater to a wider audience.

1.5 Challenges

1. Mapping Complexity: Creating accurate and up-to-date maps of indoor spaces can be challenging, especially in dynamic environments where layouts may change frequently.

2. Privacy Concerns: Indoor navigation systems often rely on tracking user movements, raising privacy concerns. Implementing robust privacy measures is essential to address these concerns

3. Device Compatibility: The effectiveness of indoor navigation can be influenced by the devices used by users. Older or less capable devices may not provide accurate results.

4. Dependency on QR Code Scanning: The initial position determination relies on users scanning QR codes on building walls. While this can be effective, it may pose challenges in scenarios where QR codes are not easily accessible or visible.

1.6 Assumptions

1. Availability of AR-capable devices: AR indoor navigation systems typically assume that users have access to AR-capable devices such as smartphones with the necessary sensors and cameras.

2. Connectivity:These systems often assume that users have access to a stable internet connection or, at the very least, a Wi-Fi connection[3] within the indoor environment to download maps and access real-time data.

3. Compatibility with the indoor environment: The system assumes that the indoor space is suitable for AR navigation, including considerations for signal interference, obstructions, and obstacles that may affect the accuracy of positioning and tracking

4. User familiarity with AR technology: Users are expected to have some level of familiarity with AR technology and how to operate AR-capable devices.

1.7 Societal / Industrial Relevance

Indoor navigation using smartphone-based AR and QR code detection has significant societal and industrial implications. In a societal context, the technology has the potential to greatly assist visually impaired people by increasing their mobility and independence. The system can provide real-time navigation guidance by leveraging QR codes and smartphone sensors, allowing users to navigate indoor spaces with greater ease and confidence. An inclusive approach is consistent with the goal of making the environment more accessible to the visually impaired. The applications in an industrial setting are diverse and significant. The seamless integration of inertial navigation systems (INS), global positioning satellite systems (GNSS)[4], and LiDAR technology promises improved navigation accuracy for a variety of applications including logistics, manufacturing, and warehouse management. The ability of the proposed system to integrate with outdoor navigation systems expands its utility for industries that require a seamless transition between indoor and outdoor spaces.

1.8 Organization of the Report

Chapter 1 deals with an overview of what an AR-based indoor navigation system is,its scope and motivation ,objectives,challenges,assumptions and societal relevance.
Chapter 2 deals upon the summary of the various methods and papers that was taken in order to create a literature survey on indoor navigation system with which the current paper was compared to and how it is advantageous over the other.
Chapter 3 deals with hardware and software requirements for the system.
Chapter 4 deals with the system architecture.Includes system overview,module division and work break down.
Chapter 5 deals with the conclusion by comparing AR-based indoor navigation system with existing technologies and drawing their conclusions.

Chapter 2

Literature Survey

2.1 Indoor Navigation System with Unity

Traditional indoor navigation systems often face limitations because they rely on external infrastructure such as Wi-Fi hotspots or beacons to triangulate the user and location. These systems can be overwhelming in areas that lack such infrastructure or have difficulty navigating complex indoor environments with multiple levels, rooms and corridors[5]. Augmented reality (AR) is emerging as an innovative approach for improving navigation by incorporating digital data into the real world, thus promoting a more intuitive user experience[6]. In this system, the user's location is reset by scanning QR codes that are strategically placed in the indoor environment. Visual SLAM technology with the A* algorithm for pathfinding enables precise tracking of the user and movement and identification of the shortest navigation path. AR allows users to receive visual cues and instructions on smart displays, reducing the risk of misinterpretation. This method not only improves accuracy, but also provides a more immersive navigation experience[7]. In addition, thanks to the system and scalability, it can be adapted to larger indoor spaces and expanded for outdoor use. Fundamentally, AR-based methodology represents a significant advance in indoor navigation capabilities. Utilizing the potential of modern smartphones and AR technology, it creates an immersive and accurate navigation solution that can overcome the limitations of traditional systems, especially in difficult indoor environments. [1]

2.2 ARBIN: Augmented Reality Based Indoor Navigation System

ARBIN is an augmented reality based indoor navigation system designed to provide users with navigation instructions in real-world environments. To provide an interactive, personalized experience augmented reality is used. The directions to the user's destination are displayed on smartphones using AR 3D models[5] . The system aims to address the limitations of traditional 2D floor map navigation systems and enhance the user experience in buildings with complex indoor structure such as schools and colleges, hospitals, malls, etc. The system consists of the indoor positioning module, route planning module, motion tracking module and AR 3D model placement module. The user's location can be tracked in a building using the BLE advertisement messages received by the bluetooth beacons[8] and it's associated RSSI. The shortest route to the destination is determined once the user's current location is obtained. When they reach a waypoint (intersection) a 3D arrow model will be displayed on the smartphone. The system aims to address the issues faced during implementation such as the accuracy of indoor positioning, limited range and, coverage area, and the security risks that arise when using beacons to send signals. The system has several potential applications such as it can be used in health care facilities, shopping centers, schools and colleges, etc. [9]

2.3 Designing Mixed Reality-Based Indoor Navigation for User Studies

Indoor navigation involves providing users with real-time information, directions, and location-based services to help them find their way efficiently and effectively in a closed environment. Mixed reality (MR) technology for indoor navigation makes it easier for individuals to find their way within indoor environments. It enhances user experiences by blending digital information with the physical world, creating immersive and interactive environments. MR-based indoor navigation systems encompass four distinct approaches: spatial mapping, spatial localization, path generation, and instruction visualization. These approaches vary based on the use of local or cloud-based spatial anchors and predefined or dynamically generated paths. Using these approaches, it creates a structured and adaptable approach to developing MR-based indoor navigation systems. It simplifies the development process, promotes research in indoor navigation, and enhances the usability of indoor spaces.The advantages of these approaches include flexibility, suitability for different research requirements, and the ability to cater to diverse scenarios and project scales. Thus, MR-based indoor navigation systems have the potential to revolutionize the way people navigate complex indoor environments, enhance user experiences, provide valuable research insights, and offer innovative solutions to address the challenges of indoor navigation.[10]

2.4 CamNav - Indoor Localization using Computer Vision

This system, primarily focuses on the development and precision of an indoor localization system called CamNav. The system utilizes Multiscale Local Binary Pattern features for localization, comparing its performance with existing systems that use Scale-Invariant Feature Transform and Oriented FAST and Rotated BRIEF features. Advantages of this method are improved place-recognition accuracy (97.02%) using MSLBP compared to ORB (96.33%). Combining SIFT features with MSLBP improves accuracy from 88.00% to 94.15%. MSLBP features show high accuracy with both SVM (97.53%) and deep learning (93.85%). Deep learning method consumes significantly more processing resources compared to SVM (87% CPU usage for SVM whereas 12% for Deep Learning). Higher prediction accuracy with MSLBP flat features increases CPU usage in deep learning. Deep Learning model does not perform better when applied to a small set of data.[11]

2.5 AR-based navigation using RGB-D camera and hybrid map

It is a markerless navigation system. The method utilizes an RGB-D camera to capture the surroundings and constructs a point cloud map through SLAM technology. Subsequently, a hybrid map is generated by combining the point cloud map with a floor map. The second step is positioning and third is navigation.These steps are conducted on hybrid map. To seamlessly display enhanced navigation details in the real scene, a method for correcting orientation errors is implemented to improve navigation accuracy. Unlike traditional AR systems relying on predefined markers or beacons, this system doesn't necessitate any additional modifications to the infrastructure.[12]

2.6 Summary and Gaps Identified

Gaps Identified

1. Infrastructure Dependency: Traditional indoor navigation systems depend on external infrastructure (Wi-Fi, beacons), which limits usability in environments where such infrastructure is not available.

2. Accuracy Issues: Solves the limited range, coverage and accuracy issues of traditional 2D base map navigation systems, but does not completely eliminate the location accuracy issues of indoor location.

3. Scalability: Mentions the scalability of AR-based methods INSUS for larger indoor and outdoor applications, but no specific details about the challenges or aspects of such scalability.

4. Resource Cost: Highlights resource consumption challenges in deep learning for location detection, showing the need for more efficient algorithms to balance accuracy and processing resources.

2.6.1 Summary

2.6.2 Conclusion

In conclusion, the investigated indoor navigation systems using technologies such as Augmented Reality (AR), Computer Vision and Mixed Reality (MR) offer promising advances in overcoming traditional limitations[13]. Although these systems solve accuracy problems, there are still problems such as infrastructure dependency and resource costs. The identified gaps highlight the need for continued research to improve scalability, reduce resource consumption and ensure smooth navigation in complex indoor environments. Overall, these innovative approaches provide valuable information for the further development of efficient and user-friendly indoor navigation solutions.

Table 2.1: Advantages and Disadvantages

Methods	**Advantages**	**Disadvantages**
Indoor Navigation System with Unity	Cost-Effective	Limited Data Capacity
ARBIN: Augmented Reality Based Indoor Navigation System	Easy For Navigation	Limited Indoor Coverage
AR Based Navigation System Using RGBD Camera and Hybrid Map	Enhanced Accuracy	Cost and Complexity
Mixed Reality Based Indoor Navigation	Versatility	Simplified Environments
CamNav - Indoor Localization using Computer Vision	Increased Precision	Computationally Expensive

Chapter 3

Requirements

3.1 Software and Hardware Requirements

3.1.1 Software Requirements

- User OS: Android / iOS
- Developer OS: Window 10/11
- Processor: intel i3
- Unity Game Engine(Unity 3D)

3.1.2 Hardware Requirements

- User Device: Smartphone with minimum 6GB RAM
- Windows 10 or 11 with minimum 8GB RAM

Chapter 4

System Architecture

4.1 System Overview

An Indoor Navigation System that would assist the users to navigate within complex environment. It provides an efficient indoor navigation system using smartphones equipped with sensors like a gyroscope and a camera. The system aims to enhance the navigation experience within buildings, especially for scenarios where GPS signals might be weak or unavailable.

4.2 Architectural Design

Proposed model is an Indoor Navigation System that would assist the users to navigate within complex environment. Goal of the project is to enable indoor navigation using smartphones equipped with a gyroscope and a camera. It initializes the user's current location by scanning QR codes placed in the building.The system utilizes Unity, a versatile game development engine, to build a three dimensional model of the indoor map. This 3D model is crucial for implementing Visual SLAM techniques, providing the necessary spatial information for accurate navigation. SLAM technique to navigate movements of the user within the environment[14]. Furthermore, it employs an Internet of Things application server for data storage and visualization, enhancing the overall scalability and accessibility of the navigation solution. It finds the shortest path using A* algorithm and overlays the path using AR arrows.

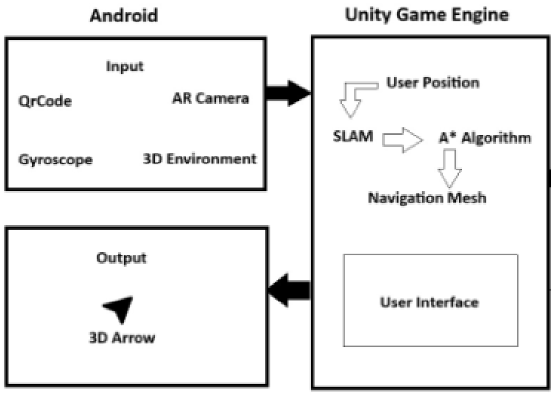


Figure 4.1: Architectural Diagram

4.3 Module Division

4.3.1 QR Code Scanning:

This module focuses on scanning QR codes with smartphone cameras. This optimized scanning technology ensures robust and reliable communication with QR codes, a key component of seamless indoor navigation.Figure 4.2 is the pseudocode for QR Code scanning.

Algorithm 1 Pseudocode for Scanning QR code

```
Ensure: InitCoordinate = 0
  while InitCoordinate = 0 do
     StartScan()
     if Scanned then
        print "n room detected"
        InitCoordinate = 1
     else
        print "unrecognized room label"
  SendInitCoordinateToServer()
  SendInitCoordinateToARScene()
```

Figure 4.2: Pseudocode for QR Code Scanning

4.3.2 Visual SLAM and Gyroscope Data :

This module is about mapping the environment and locating the device at the same time, which uses information such as GPS location and landmark detection to improve navigation accuracy. This approach provides a robust solution that is particularly valuable in challenging indoor environments and lays the foundation for possible integration with outdoor navigation systems.[15]

4.3.3 Unity 3D:

Unity 3D is a popular cross-platform game development engine used to create 3D models or simulations related to indoor navigation. This module increases the versatility of the system by facilitating immersive 3D modeling and visualization. This feature enriches the user experience by providing a more realistic environment and also opens up opportunities for innovative applications in indoor navigation scenarios.

4.3.4 AR Camera:

By overlaying digital content over the real world, a camera can detect surfaces and planes while also tracking real-world objects. ARIN uses the AR camera to detect the floor, scan the QR code and determine the user's location using SLAM technology (SIM). SLAM estimates the user's state and environment map based on sensor data and control functions. The camera's ability to detect horizontal planes enables it to position navigation elements, while computer vision algorithms enable it decode QR codes with precision[16]. It integrates visual data from the camera and inertial data from the sensors to estimate the position and orientation of the user. AR scene uses the Unity game engine and ARCore SDK to display virtual elements in a real environment, enhancing the user experience. ARCore features include target tracking, surface detection and real-time environmental monitoring via SLAM. This combination of technologies enables ARIN to seamlessly integrate digital content into the physical environment for intuitive navigation and interaction.[17]

4.3.5 Indoor navigation:

Determines the most efficient navigation route by considering user input, current location, and the 3D model. This component may employ pathfinding algorithms like A* to identify the shortest path within the 3D environment.

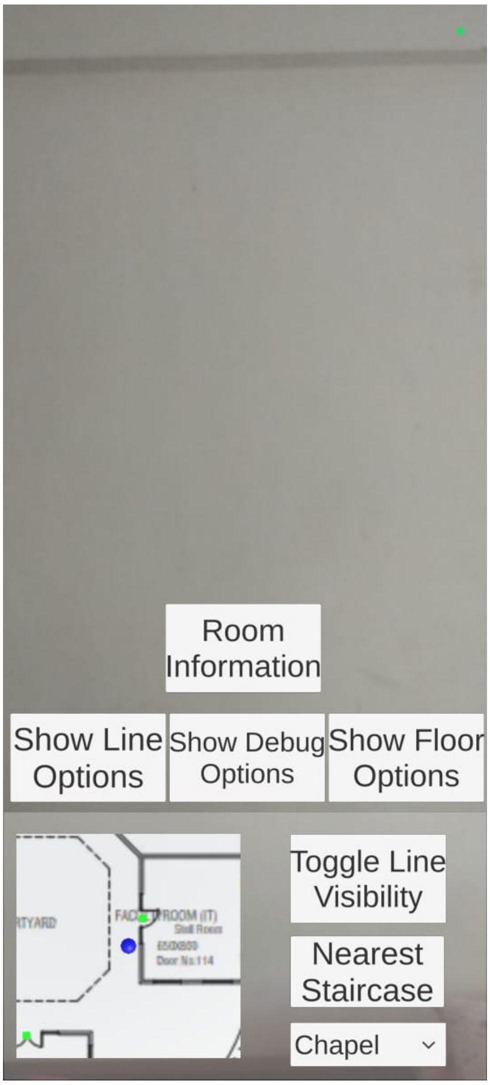


Figure 4.3: User Interface

4.3.6 User Interface :

A user interface plays a vital role in a computer system, allowing user interaction through graphical elements, texts, and feedback.There are 4 main butons - Show Line Options , Show Debug Options , Show Floor Options Toggle Line Visibility. Other buttons visible on the user's mobile screen are Room information Nearest Staircase. The initial position scene requires users to scan QR codes on building walls to determine their location. In the navigation scene, users input target rooms, and a shortest path is calculated using the A* algorithm, guiding users with a 3D arrow on a mini-map.

4.4 Work Schedule

4.4.1 Work Breakdown

1. Roshni Joshy

   - Collect blueprint for each floor and generate 3D model for first floor.
   - QR code generation recenter

2. Roze Susan Mathew

   - Generate 3D model for ground floor
   - Floor To floor navigation for all floors

3. Sneha Elsa Mathew

   - Generate 3D model for second floor
   - Any Source to any destination ground and first floor

4. Swathi P

   - Generate 3D model for third floor
   - Any Source to any destination second and third floor

4.4.2 Gantt Chart

1. Phase 1 of Project

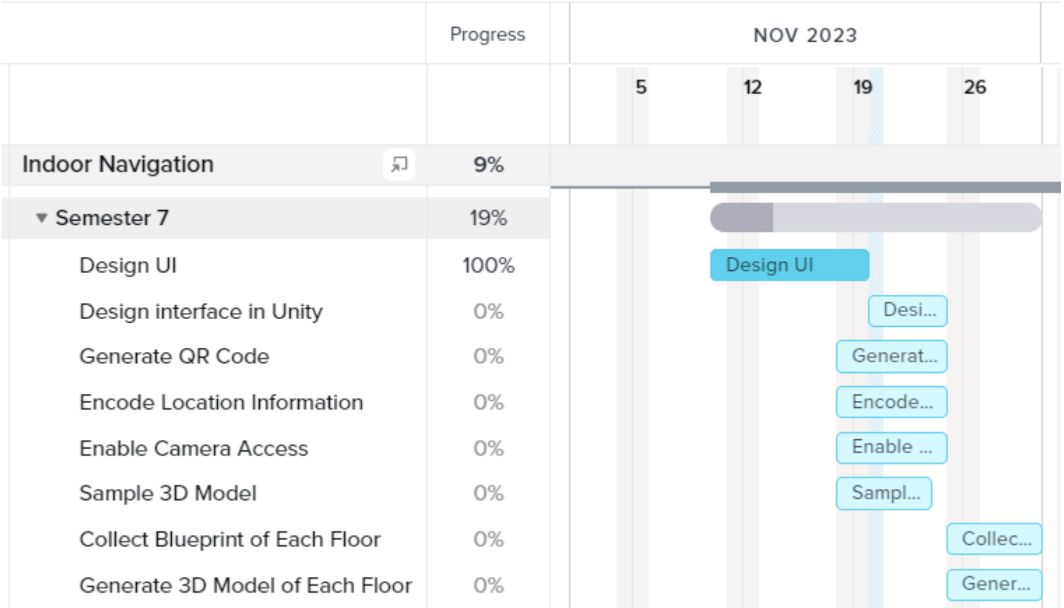


Figure 4.4: Phase 1

2. Phase 2 of Project

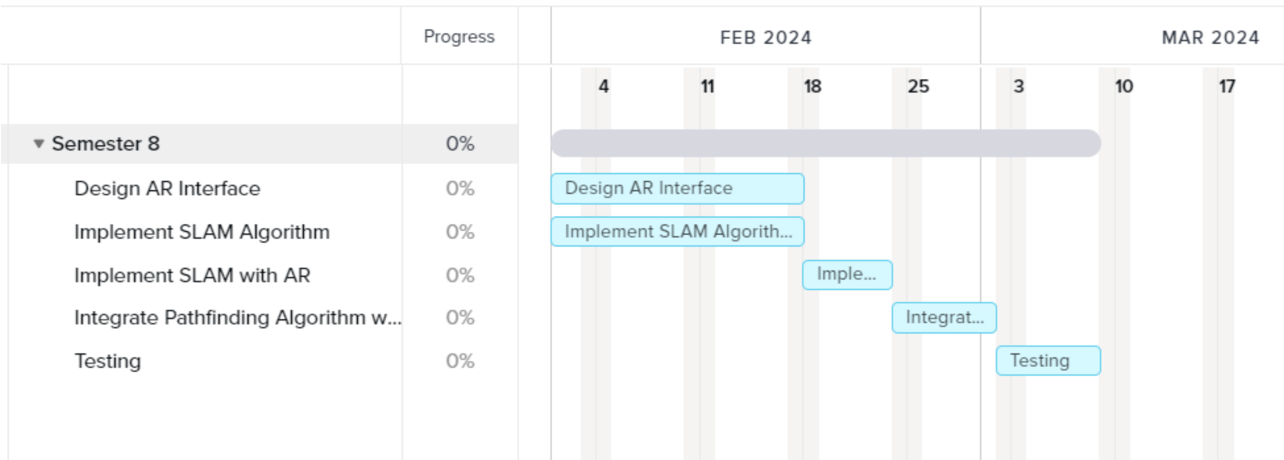


Figure 4.5: Phase 2

Chapter 5

System Implementation

The implementation of the Indoor Navigation System using Unity and Smartphone represents a cutting-edge solution for addressing the challenges associated with indoor navigation.

5.1 Datasets Identified

1. **Floor Maps:** The floor maps contain information about the layout, dimensions, and structural details of the indoor environment where the navigation system is implemented.

2. **QR Codes at All Locations:** This dataset likely includes the QR codes positioned throughout the indoor space. Each QR code has a unique identifier associated with a specific location.

3. **User's Initial Position and Target Location:** The initial position of the user and the target destination are used for initiating the navigation process.

4. **SLAM Dataset:** Dataset includes sensor data from the smartphone's gyroscope and camera, used in conjunction with SLAM techniques for real-time mapping and localization.

5.2 Proposed Methodology/Algorithms

5.2.1 QR Code Initialization Algorithm

Algorithm 1: Pseudocode for Scanning QR code

Ensure: InitCoordinate = 0

while InitCoordinate = 0 do

StartScan()

if Scanned **then**

  print "n room detected"

  InitCoordinate = 1

else

  print "unrecognized room label"

  SendInitCoordinateToServer()

  SendInitCoordinateToARScene()

5.2.2 Pathfinding - A* Algorithm

Algorithm 2: A* Algorithm for Pathfinding

Input: Graph G, Start node *start*, Goal node *goal*

Output: Optimal path from *start* to *goal*

1. Initialize open set with *start* and closed set as empty

2. **while** open set is not empty **do**

    (a) CurrentNode ← node in open set with lowest f value

    (b) **if** CurrentNode is *goal* **then return** reconstruct path

    (c) Move CurrentNode from open set to closed set

    (d) **for each** neighbor of CurrentNode **do**

        i. **if** neighbor is in closed set **then continue**

        ii. Calculate tentative g value

        iii. **if** neighbor is not in open set or tentative g is lower **then**

            A. Set g value of neighbor

            B. Set f value of neighbor

            C. Set parent of neighbor to CurrentNode

            D. **if** neighbor is not in open set **then** add it

3. **return** failure (no path found)

5.3 User Interface Design

Users are required to scan QR codes on building walls to pinpoint their location. Through the user interface, they can select their destination room from a dropdown menu, accessing room information via a designated button. Utilizing the A* algorithm, the shortest route is determined, with a 3D arrow guiding users on a mini-map displayed through the device's camera. The UI features three buttons: "Show Line Options," "Show Debug Options," and "Show Floor Options."

In "Show Line Options" (Figure 5.1), users can toggle line visibility to display the path from the source to the destination in both the AR Camera and the mini-map. Additionally, a dropdown list facilitates the selection of destinations.

The "Show Debug Options" panel (Figure 5.2) includes a "Toggle QR Code" button for initializing the current location by scanning a QR code. A line scale allows users to adjust the height of the path in the AR scene.

The "Show Floor Options" button (Figure 5.3) presents four floor buttons, enabling users to view target locations available on the desired floor.

The mini-map features a blue indicator denoting the current location, the path from the source to the destination, and green cubes indicating target locations.

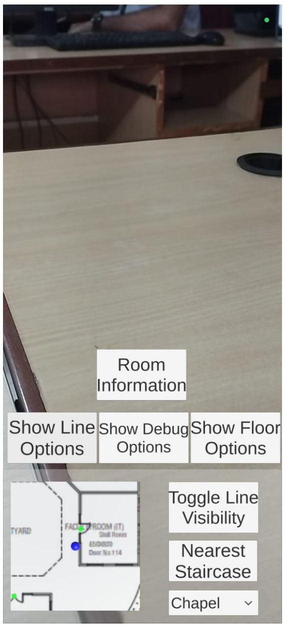


Figure 5.1: Show Line Options Button

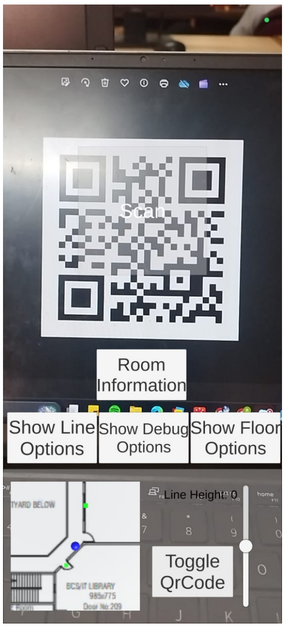


Figure 5.2: Show Debug Options

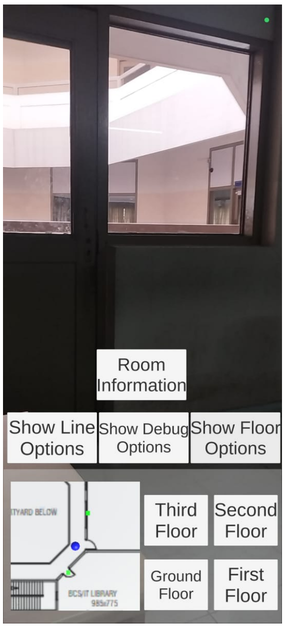


Figure 5.3: Show Floor Options

5.4 Description of Implementation Strategies

5.4.1 Design Implementaion Stratergies

1. QR Code Scanning:

   The QR code scanning module integrates QR code decoding logic to retrieve relevant information. This strategy includes real-time processing to quickly recognize QR codes, which promotes efficient navigation.

2. Visual SLAM and Gyroscope data:

   Visual SLAM algorithms process camera data and create a real-time map of the environment. Integration of data from gyroscopes provides orientation information. The goal of this strategy is to create a reliable indoor positioning system using Visual SLAM and gyroscopic data that provides accurate user localization and mapping.

3. Unity 3D :

   The Unity 3D modeling module uses Unity tools to create a virtual representation of the indoor environment. This involves integrating 3D models with mapping data generated by SLAM. Augmented reality (AR) components are integrated to provide users with real-time navigation tips. This strategy aims to improve the user experience by presenting a visually intuitive and contextual 3D environment.

4. User Interface(UI): Users scan QR codes for location can choose destination from dropdown menu, and can see floor on which the target location is present on UI. A* algorithm calculates shortest path, guiding with 3D arrow on mini-map through device camera. UI includes 3 buttons Debug options,Floor options Line Options. It also includes the minimap, dropdown for destination, and toggle button for path display in AR.

5. Indoor Navigation:

   Indoor Navigation will implement pathfinding algorithms for optimal route determination. It involves integrating sensor data from QR codes, Visual SLAM, and gyroscope for precise navigation. The strategy focuses on creating a comprehensive navigation system that adapts to diverse indoor environments.

6. AR Camera:

   AR camera is used to detect surfaces, QR codes, and user location via SLAM. It integrates camera and sensor data for precise positioning. Unity and ARCore display virtual elements in real space, enhancing user experience with target tracking and surface detection for seamless navigation and interaction.

Chapter 6

Results and Discussions

6.1 Overview

AR based indoor Navigation System demonstrated notable success in both QR code detection accuracy and indoor navigation. Across various smartphone viewing angles, the system achieved optimal QR code detection accuracy between 60° and 100°, exceeding 80% for tested smartphones. Navigation experiments using SLAM showed the highest success rates, exceeding 80%, when smartphones were held upright within the 60° to 100° angle range. User experience feedback from participants in different buildings was largely positive, with users expressing agreement on the system's accuracy, usefulness, and ease of use. However, a subset of participants disagreed with the system's usefulness. Quantitative data presented in tables indicated specific accuracy percentages for QR code detection and navigation across different scenarios. Overall, the results suggest that the system has promising potential for effective indoor navigation, with room for refinement based on user input and further technological advancements.

6.2 Testing

Unit testing for indoor navigation typically was conducted which involves testing each floor of the main building of RSET. The unit testing conducted for each floor in an indoor navigation system consisted of:

Test Navigation : Covered various scenarios such as navigating from one room to another and moving between floors.

Test Route Calculation: Using route calculation algorithm to ensure it accurately determines the shortest path between two locations on the floor. Test different combinations of start and end points to verify that the algorithm behaves as expected in various scenarios.

Test Navigation Instructions: Validate that the system provides clear and accurate navigation instructions to guide users from their current location to the desired destination.

Test Error Handling: Verify that the system handles errors and exceptions that may occur during navigation, such as signal loss, invalid inputs, or system failures. Ensure that appropriate error messages are displayed to the user and that the system can recover from errors.

6.3 Quantitative Results

ARIN provides a structured and intuitive approach for users to navigate within the main building of RSET, including seamless floor-to-floor navigation capabilities. ARIN, allows users to effortlessly transition between different floors within the building, with the help of mapping and route planning features.

Additionally, ARIN enables users to navigate from any source location to any destination within the building. Users can input their current location or scan QR codes placed strategically throughout the building to determine their starting point. From there, they can specify their desired destination within the building. ARIN then calculates the most efficient route based on real-time data and provides step-by-step guidance to help users reach their destination accurately and efficiently.

The break down of the process step by step is as follows:

1. Read Information Button: This button allows users to access information about the floor where their desired target location is situated. By clicking on this button, users can view details such as the floor plan, room numbers, and other relevant information to aid in navigation(Figure 6.1 a).

2. Show Floor Options: Users must select the current floor from the floor option presented in the user interface. This allows users to spot the nearest staircase from the user's current position thus, enabling the system to provide shortest path navigation guidance.

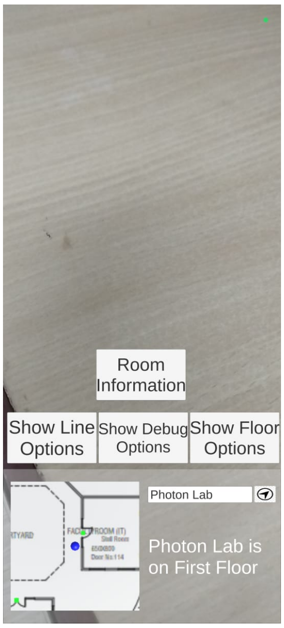
3. Toggle QRCode Button: To initialize their current location within the building, users scan a QR code using this button. Scanning the QR code provides the system

with the necessary information to pinpoint the user's location accurately, ensuring precise navigation guidance.

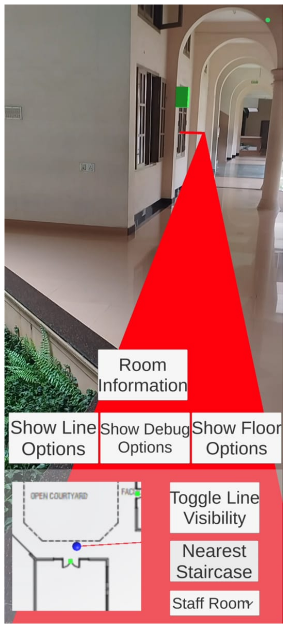
5. Show Line Options: Users can select their desired destination from a dropdown list after scanning the qr code of the nearest staircase. This allows users to specify where they want to navigate within the building.(Figure 6.1 b c)

6. Toggle Line Visibility: Upon selecting the destination, users activate this button to display the path from their current staircase location to the desired destination in the augmented reality (AR) scene. The path visualization aids users in following the recommended route to reach their destination efficiently.(Figure 6.1 d)

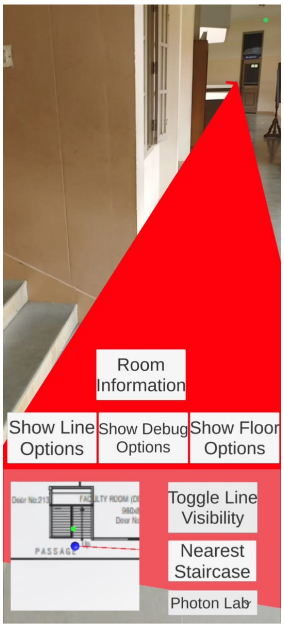
By following this structured process, users can navigate within the building effectively using the indoor navigation system.



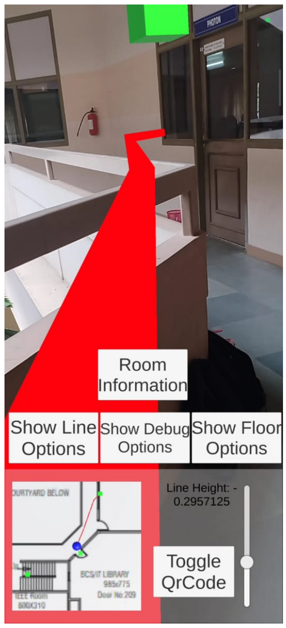
(a) Get information of required target room



(b) Navigation path to nearest staircase



(c) Navigation path from the nearest staircase to target room



(d) Target Room

Figure 6.1: Steps for floor to floor navigation

6.4 Discussion

Users can efficiently navigate through the main building of RSET using the indoor navigation system(ARIN). The user interface offers straightforward and user-friendly controls, guaranteeing a smooth navigation journey while making use of cutting-edge technologies like QR code scanning and AR. Moreover, the system's capability to furnish comprehensive floor details and accurate route guidance significantly boosts user trust and contentment with the navigation process. By offering floor-to-floor navigation and the flexibility to navigate from any source to any destination, ARIN enhances user convenience and efficiency within the main building of RSET.

6.5 Conclusion

The experiments were conducted in the main building of RSET to determine the implementation of the indoor navigation system (ARIN) at RSET's main building represents a remarkable advancement in user experience and convenience. By seamlessly integrating QR code scanning and augmented reality technologies, coupled with intuitive user interface design, ARIN ensures a smooth and efficient navigation journey for users. The provision of comprehensive floor details and precise route guidance further enhances user trust and satisfaction.

Chapter 7

Conclusions & Future Scope

The presented AR-based indoor navigation system shows significant success in overcoming the limitations associated with traditional navigation methods. Using the technology of modern smartphones and augmented reality, the system offers users an intuitive and immersive navigation experience. The use of QR codes to initialize the location along with visual SLAM and A* algorithm for wayfinding improves accuracy and ensures reliable navigation even in complex indoor environments. Cross-system adaptability, scalability and possible extension to outdoor navigation highlight its versatility and effectiveness in dealing with the complexities of various spatial settings.

Positive user feedback from survey responses emphasizes the system and user-friendly design. As the technology evolves, future improvements may include seamless integration with outdoor navigation systems, expanding the applicability of this AR-based method to various environments.Overall, this lays the groundwork for future advancements in advanced navigation solutions, which is an important step toward improving user experience and spatial awareness in both indoor and outdoor settings.

The future scope of this project is the continuous development and expansion of an AR-based indoor navigation system. Integration with new technologies such as GPS and landmark detection promises better accuracy. Further development may include adding real-time environmental information and collaborative features to promote a dynamic and contextual navigation experience. As the system evolves, possible extensions to outdoor navigation systems and integration to smart infrastructure can make it a complete space management solution for various environments. Continuous user feedback and iterative improvements are critical to staying abreast of cutting-edge navigation technologies.

References

[1] S. S. Y. Y. F. P. K. D. F. S. Evianita Dewi Fajrianti, Nobuo Funabiki and A. A. S. Pradhana, "Insus: Indoor navigation system using unity and smartphone for user ambulation assistance." MDPI, 2023, pp. 1–20.

[2] F. Sato, "Indoor navigation system based on augmented reality markers," in *Proceedings of the International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing*, Torino, Italy, July 10–12 2017.

[3] T. Vaupel, J. Seitz, F. Kiefer, S. Haimerl, and J. Thielecke, "Wi-fi positioning: System considerations and device calibration," in *Proceedings of the 2010 International Conference on Indoor Positioning and Indoor Navigation*, Zurich, Switzerland, September 15–17 2010.

[4] L. Hsu, Y. Gu, Y. Huang, and S. Kamijo, "Urban pedestrian navigation using smartphone-based dead reckoning and 3-d map-aided gnss," *IEEE Sens. J.*, vol. 5, pp. 1281–1293, 2016.

[5] E.-H. Chu, S. Wang, J. Liu, J. Hsu, and H. Wu, "Wpin: A waypoint-based indoor navigation system," in *Proceedings of the IEEE 10th International Conference on Indoor Positioning and Indoor Navigation*, Pisa, Italy, September 30–October 3 2019.

[6] S. Kasprzak, A. Komninos, and P. Barrie, "Feature-based indoor navigation using augmented reality," in *Proceedings of the 9th International Conference on Intelligent Environments*, Athens, Greece, July 18–19 2013, pp. 100–107.

[7] B. Liu, L. Ding, and L. Meng, "Spatial knowledge acquisition with virtual semantic landmarks in mixed reality-based indoor navigation," *Cartography and Geographic Information Science*, vol. 48, pp. 305–319, 2021.

[8] R. Faragher and R. Harle, "An analysis of the accuracy of bluetooth low energy for indoor positioning applications," in *Proceedings of the 27th International Technical*

Meeting of The Satellite Division of the Institute of Navigation, Tampa, FL, USA, September 8–12 2014.

[9] Y. Xu, J. Zhang, Q. Zhang, and D. Tao, "Augmented reality based indoor navigation system," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2023.

[10] S. W. L. M. Bing Liu1, Linfang Ding2, "Designing mixed reality-based indoor navigation for user studies," *Journal of Cartography and Geographic Information*, 2022.

[11] J. K. . A. B. Abdel Ghani Karkar, Somaya Al-Maadeed, "Camnav - computer vision based indoor navigation system," *The Journal of Supercomputing*, 2021.

[12] Y. G.-I. Chidsin, W.; Gu, "Ar-based navigation using rgb-d camera and hybrid map." *Sustainability*, 2021,13,5585.

[13] C. Bauer, M. Ullmann, and B. Ludwig, "Displaying landmarks and the user's surroundings in indoor pedestrian navigation systems," *Journal of Ambient Intelligence and Smart Environments*, 2015.

[14] E. Aksoy, D. Aydin, and G. İskifoglu, "Analysis of the correlation between layout and wayfinding decisions in hospitals," *Megaron*, vol. 4, pp. 509–520, 2020.

[15] I. Koc, T. Serif, S. Gören, and G. Ghinea, "Indoor mapping and positioning using augmented reality," in *Proceedings of the 7th International Conference on Future Internet of Things and Cloud (FiCloud)*, Istanbul, Turkey, August 26–28 2019, pp. 335–342.

[16] Y. Wang, Y. Wu, C. Chen, B. Wu, S. Ma, D. Wang, H. Li, and Z. Yang, "Inattentional blindness in augmented reality head-up display assisted driving," *International Journal of Human-Computer Interaction*, 2021.

[17] A. Mulloni, D. Wagner, I. Barakonyi, and D. Schmalstieg, "Indoor positioning and navigation with camera phones," *IEEE Pervasive Computing*, vol. 8, pp. 22–31, 2009.

Appendix A: Presentation

AR based Indoor Navigation System

100% OUTPUT PRESENTATION

Roshni Joshy (U2003176)
Roze Susan Mathew (U2003178)
Sneha Elsa Mathew (U2003202)
Swathi P (U2003207)

Rajagiri School of Engineering and Technology, Kakkanad
Department of CSE

April 4, 2024

Guided by: Ms. Amitha Mathew
Assistant Professor , Department of CSE

Contents

Problem Definition

Develop and implement an Augmented Reality (AR) based indoor navigation system within the Main Building of RSET. By leveraging AR technology, it will provide real-time, interactive, and personalized wayfinding.

Problem Objectives

- Map Generation: Develop 3D indoor map of the building including building layouts and room information
- QR Code Generation: Generate QR code at different key points
- Indoor Navigation: Develop a system that allows users to navigate the indoor spaces of the Main Building of RSET using AR technology.
- Search Functionality: Include a search feature that allows users search for specific rooms or locations, and receive directions using AR.
- Platform Compatibility: The system would be available on Android devices to cater to a wider audience

Novelty of Idea

- An innovative and practical solution for enhancing navigation within the college premises.
- Address the specific challenges associated with indoor navigation, where traditional GPS-based systems may be less effective.
- Enables students, faculty, and visitors to navigate the college building efficiently, reducing time spent searching for rooms, offices, or facilities.

Scope of Implementation

- The scope encompasses diverse sectors/spaces like mall,airports,etc. promising improved efficiency, enriched user engagement, and heightened accessibility in indoor spaces.
- It can enhance user experiences by overlaying digital information onto the physical environment, guiding users seamlessly.
- This technology aids in real-time wayfinding and providing interactive maps.

Work Done During 30% Evaluation

- **Creation of user interface**
- **QR code scanning**
- **Creating 3D walls for each floor**

Work Progress (60% Evaluation)

- **Navigation mesh(Navmesh) for all Floors**

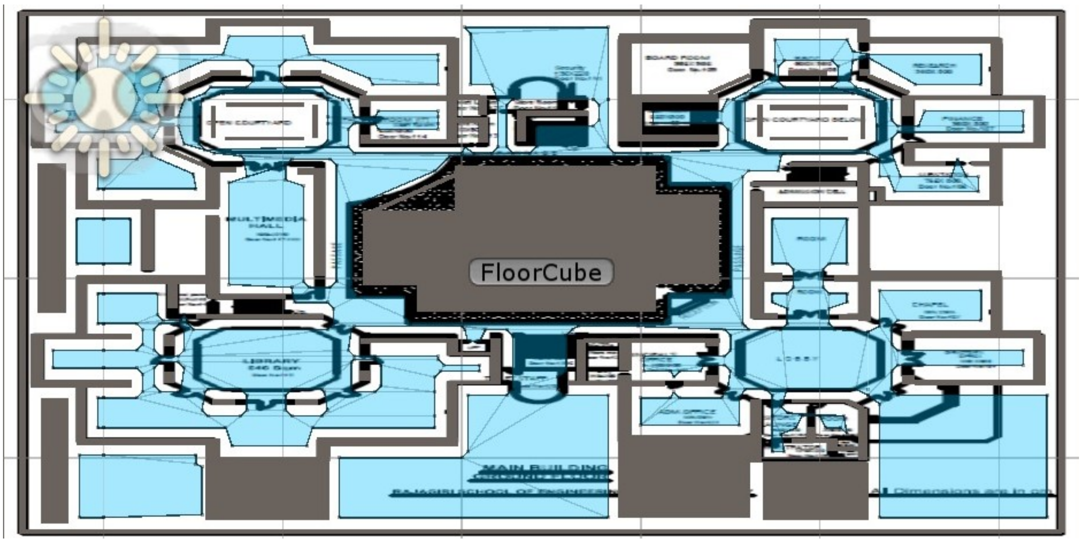


Figure: Navmesh of GroundFloor

Work Progress (60% Evaluation)

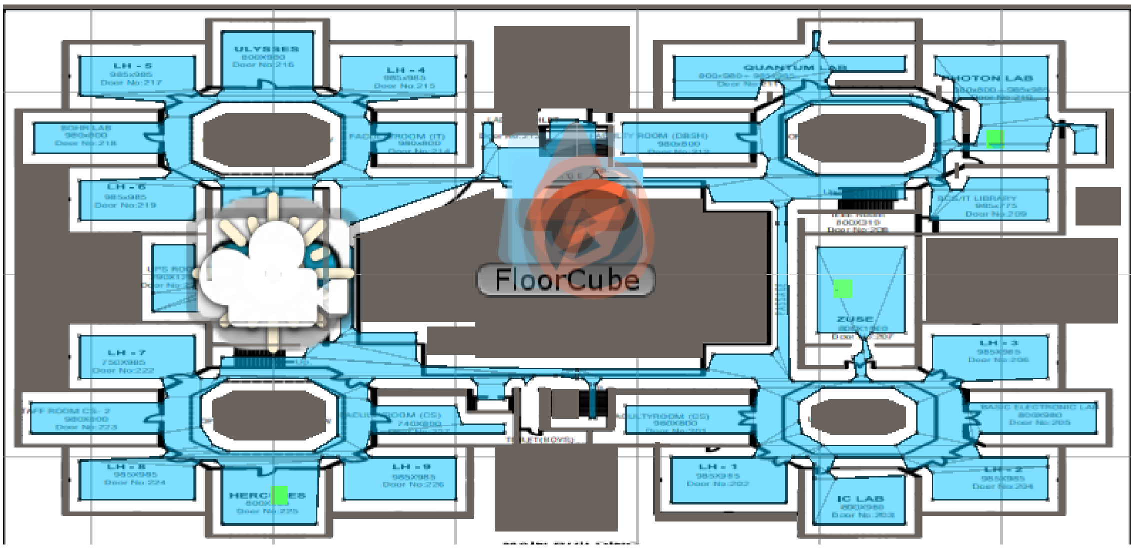


Figure: Navmesh of Floor1

Work Progress (60% Evaluation)

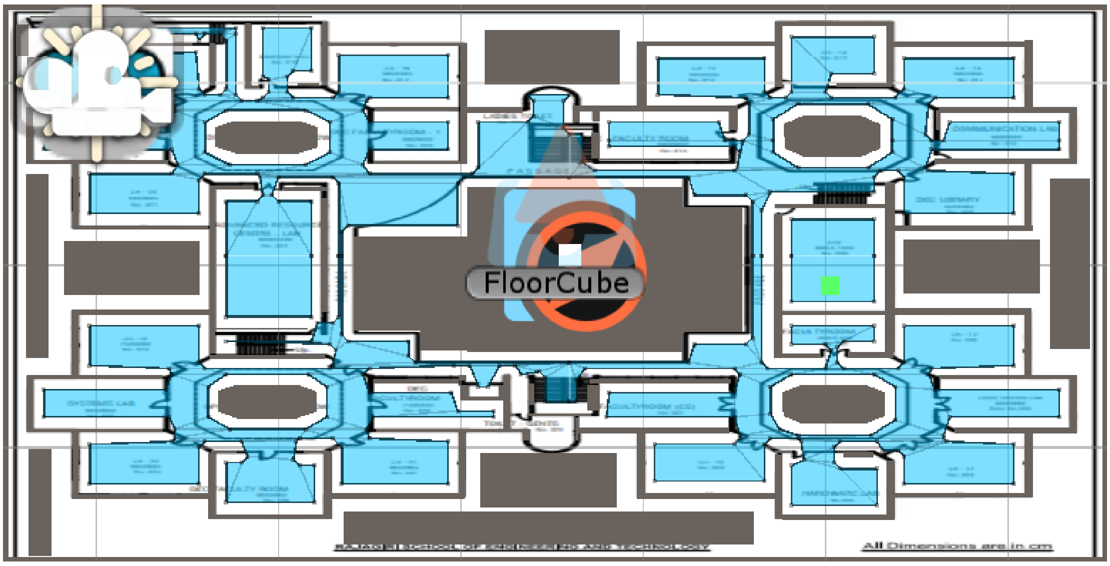


Figure: Navmesh of Floor2

Work Progress (60% Evaluation)

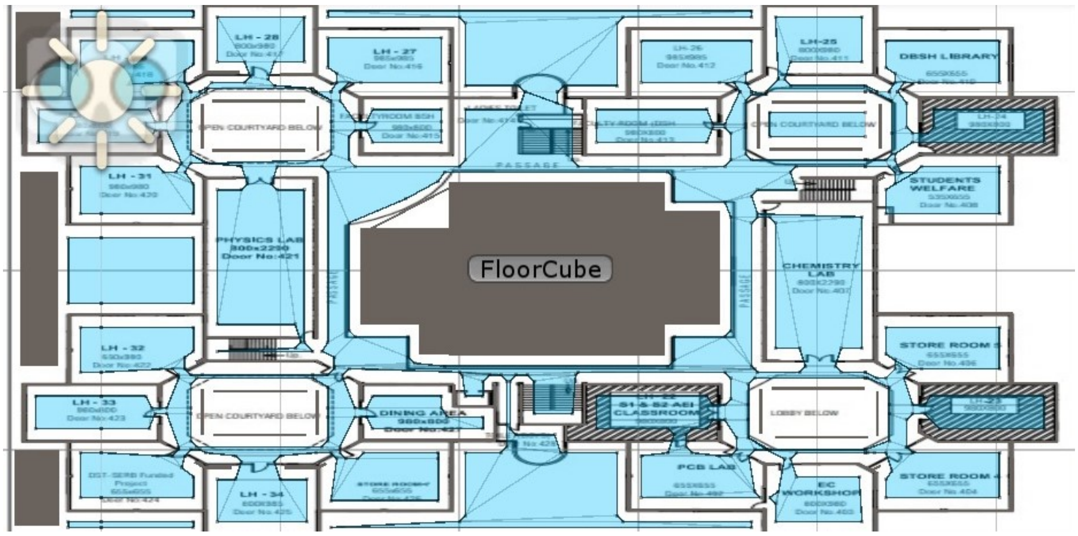


Figure: Navmesh of Floor3

Work Progress (60% Evaluation)

- **One Source To One Destination for Floor1**

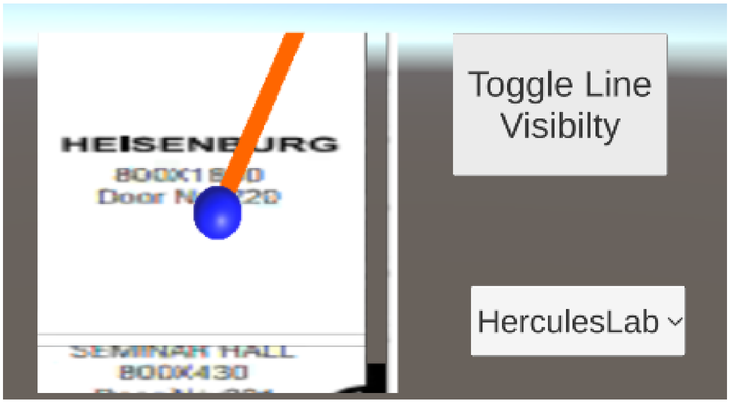


Figure: Setting the source

Work Progress (60% Evaluation)

- **One Source To One Destination for Floor1**

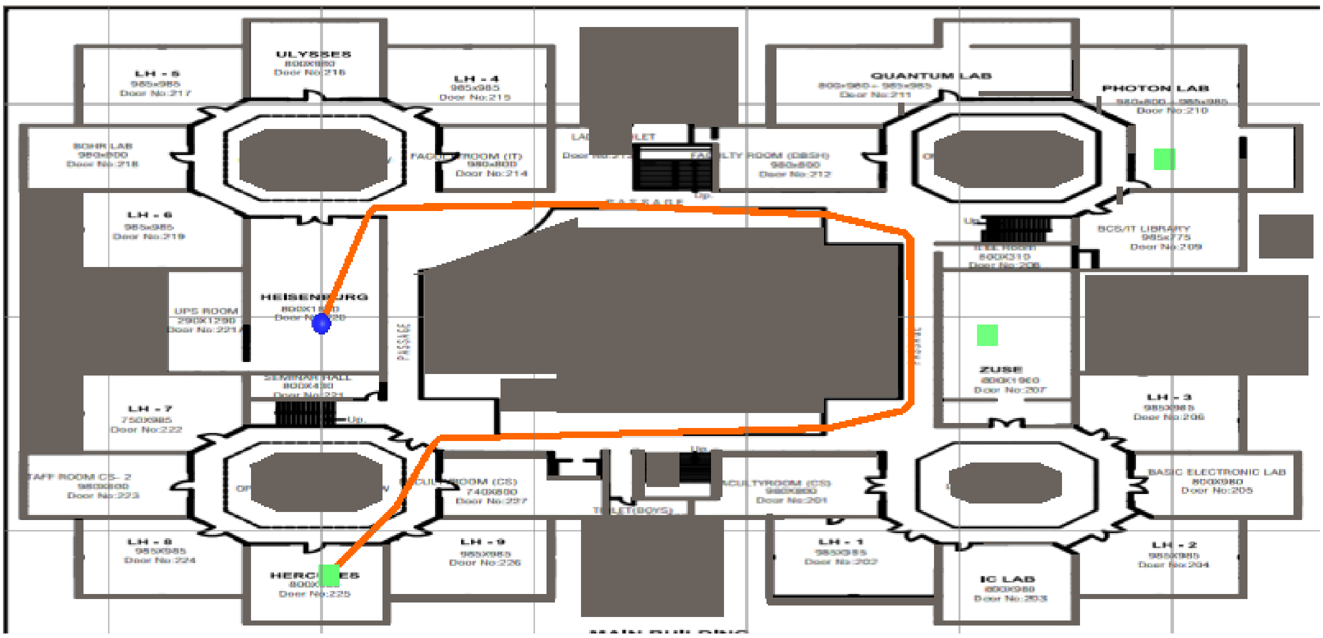


Figure: Navigation Path to required Path

Work Progress (60% Evaluation)

- **One Source To one Destination for Floor2**

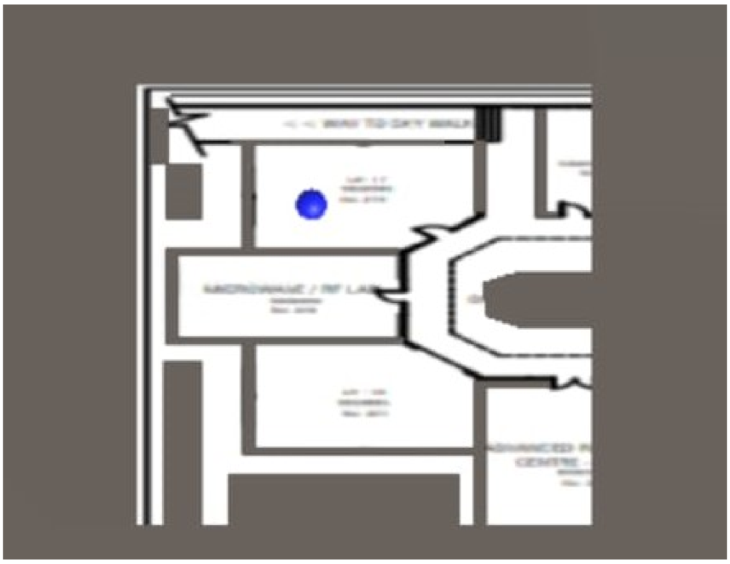


Figure: MiniMap

Work Progress (60% Evaluation)

Figure: Navigation Path From the source

Results (100% Evaluation)

- Detecting Source Via QR Code

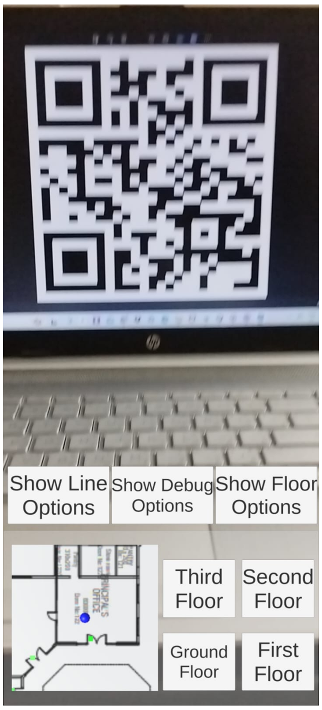


Figure: Scanning QR Code

Results (100% Evaluation)

- Implementing A* algorithm

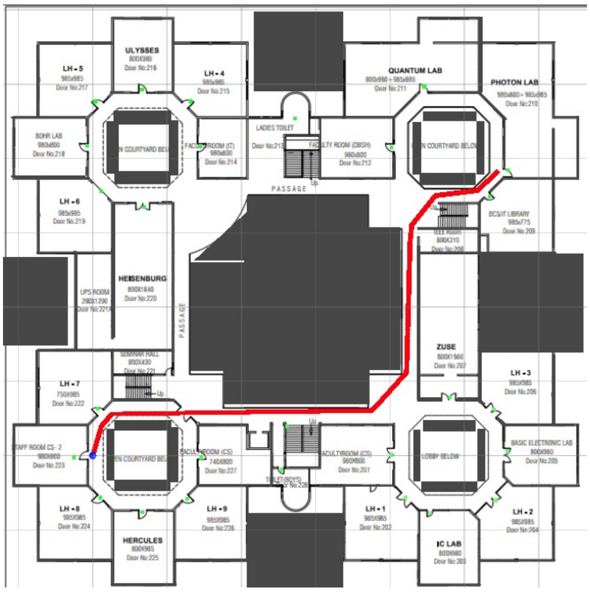
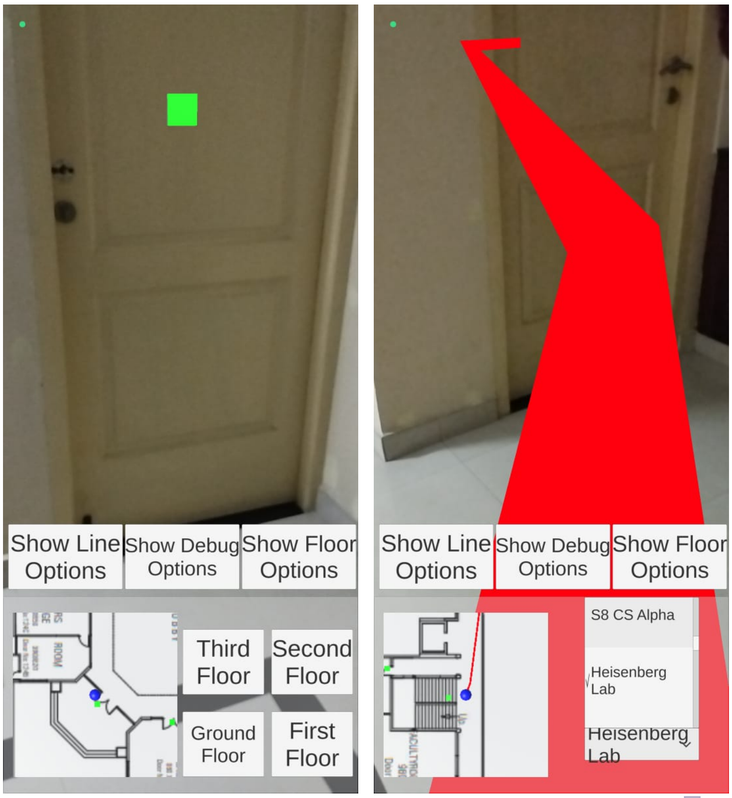


Figure: Shortest Path

Results (100% Evaluation)

- Floor To Floor Navigation



Future Scope

- Providing login & register feature
- Extending Navigation to KE Block

Task Distribution

- **Roshni Joshy**
  - QR code generation recenter
  - Worked on Research Paper
- **Roze Susan Mathew**
  - Generate 3D model for ground floor
  - Floor To floor navigation for all floors
- **Sneha Elsa Mathew**
  - Generate 3D model for first and second floor
  - Any Source to any destination ground and first floor
- **Swathi P**
  - Generate 3D model for third floor
  - Any Source to any destination second and third floor

Conclusion

- The AR-based Indoor Navigation System is intended to make indoor navigation easier.
- QR codes are currently used to initialize location, which provides valuable insights into the development of indoor navigation technologies and systems.
- The technology employs the SLAM technique gyroscope feature, which tracks users' movements within a building.
- Uses A* algorithm to provides the shortest path from any given source to a destination.

Status of Paper Publication

- Type: Conference
- Name : Augmented Reality Based Indoor Navigation(ARIN)
- Status: Draft Completed
- Paper Submission Date: 31/March/2024

Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

Engineering Graduates will be able to:

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills
The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills
The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills
The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes (CO)

Course Outcome 1: Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).

Course Outcome 2: Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).

Course Outcome 3: Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: Apply).

Course Outcome 4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

Course Outcome 5: Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: Analyze).

Course Outcome 6: Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: Apply).

Appendix C: CO-PO-PSO Mapping

CO-PO AND CO-PSO MAPPING

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO 1	2	2	2	1	2	2	2	1	1	1	1	2	3		
CO 2	2	2	2		1	3	3	1	1		1	1		2	
CO 3									3	2	2	1			3
CO 4					2			3	2	2	3	2			3
CO 5	2	3	3	1	2							1	3		
CO 6					2			2	2	3	1	1			3

3/2/1: high/medium/low

JUSTIFICATIONS FOR CO-PO MAPPING

MAPPING	LOW/MEDIUM/ HIGH	JUSTIFICATION
100003/ CS722U.1-PO1	M	Knowledge in the area of technology for project development using various tools results in better modeling.
100003/ CS722U.1-PO2	M	Knowledge acquired in the selected area of project development can be used to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions.

100003/ CS722U.1-PO3	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO4	M	Can use the acquired knowledge in designing solutions to complex problems.
100003/ CS722U.1-PO5	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.1-PO6	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.1-PO7	M	Project development based on societal and environmental context solution identification is the need for sustainable development.
100003/ CS722U.1-PO8	L	Project development should be based on professional ethics and responsibilities.
100003/ CS722U.1-PO9	L	Project development using a systematic approach based on well defined principles will result in teamwork.
100003/ CS722U.1-PO10	M	Project brings technological changes in society.

100003/ CS722U.1-PO11	H	Acquiring knowledge for project development gathers skills in design, analysis, development and implementation of algorithms.
100003/ CS722U.1-PO12	H	Knowledge for project development contributes engineering skills in computing & information gatherings.
100003/ CS722U.2-PO1	H	Knowledge acquired for project development will also include systematic planning, developing, testing and implementation in computer science solutions in various domains.
100003/ CS722U.2-PO2	H	Project design and development using a systematic approach brings knowledge in mathematics and engineering fundamentals.
100003/ CS722U.2-PO3	H	Identifying, formulating and analyzing the project results in a systematic approach.
100003/ CS722U.2-PO5	H	Systematic approach is the tip for solving complex problems in various domains.
100003/ CS722U.2-PO6	H	Systematic approach in the technical and design aspects provide valid conclusions.
100003/ CS722U.2-PO7	H	Systematic approach in the technical and design aspects demonstrate the knowledge of sustainable development.

100003/ CS722U.2-PO8	M	Identification and justification of technical aspects of project development demonstrates the need for sustainable development.
100003/ CS722U.2-PO9	H	Apply professional ethics and responsibilities in engineering practice of development.
100003/ CS722U.2-PO11	H	Systematic approach also includes effective reporting and documentation which gives clear instructions.
100003/ CS722U.2-PO12	M	Project development using a systematic approach based on well defined principles will result in better teamwork.
100003/ CS722U.3-PO9	H	Project development as a team brings the ability to engage in independent and lifelong learning.
100003/ CS722U.3-PO10	H	Identification, formulation and justification in technical aspects will be based on acquiring skills in design and development of algorithms.
100003/ CS722U.3-PO11	H	Identification, formulation and justification in technical aspects provides the betterment of life in various domains.
100003/ CS722U.3-PO12	H	Students are able to interpret, improve and redefine technical aspects with mathematics, science and

		engineering fundamentals for the solutions of complex problems.
100003/ CS722U.4-PO5	H	Students are able to interpret, improve and redefine technical aspects with identification formulation and analysis of complex problems.
100003/ CS722U.4-PO8	H	Students are able to interpret, improve and redefine technical aspects to meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
100003/ CS722U.4-PO9	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
100003/ CS722U.4-PO10	H	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools for better products.
100003/ CS722U.4-PO11	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
100003/ CS722U.4-PO12	H	Students are able to interpret, improve and redefine technical aspects for demonstrating the knowledge of, and need for sustainable development.

100003/ CS722U.5-PO1	H	Students are able to interpret, improve and redefine technical aspects, apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.5-PO2	M	Students are able to interpret, improve and redefine technical aspects, communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
100003/ CS722U.5-PO3	H	Students are able to interpret, improve and redefine technical aspects to demonstrate knowledge and understanding of the engineering and management principle in multidisciplinary environments.
100003/ CS722U.5-PO4	H	Students are able to interpret, improve and redefine technical aspects, recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
100003/ CS722U.5-PO5	M	Students are able to interpret, improve and redefine technical aspects in acquiring skills to design, analyze and develop algorithms and implement those using high-level programming languages.
100003/ CS722U.5-PO12	M	Students are able to interpret, improve and redefine technical aspects and contribute their engineering skills

		in computing and information engineering domains like network design and administration, database design and knowledge engineering.
100003/ CS722U.6-PO5	M	Students are able to interpret, improve and redefine technical aspects and develop strong skills in systematic planning, developing, testing, implementing and providing IT solutions for different domains which helps in the betterment of life.
100003/ CS722U.6-PO8	H	Students will be able to associate with a team as an effective team player for the development of technical projects by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
100003/ CS722U.6-PO9	H	Students will be able to associate with a team as an effective team player to Identify, formulate, review research literature, and analyze complex engineering problems
100003/ CS722U.6-PO10	M	Students will be able to associate with a team as an effective team player for designing solutions to complex engineering problems and design system components.
100003/ CS722U.6-PO11	M	Students will be able to associate with a team as an effective team player, use research-based knowledge and research methods including design of experiments, analysis and interpretation of data.

100003/ CS722U.6-PO12	H	Students will be able to associate with a team as an effective team player, applying ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
100003/ CS722U.1-PSO1	H	Students are able to develop Computer Science Specific Skills by modeling and solving problems.
100003/ CS722U.2-PSO2	M	Developing products, processes or technologies for sustainable and socially relevant applications can promote Programming and Software Development Skills.
100003/ CS722U.3-PSO3	H	Working in a team can result in the effective development of Professional Skills.
100003/ CS722U.4-PSO3	H	Planning and scheduling can result in the effective development of Professional Skills.
100003/ CS722U.5-PSO1	H	Students are able to develop Computer Science Specific Skills by creating innovative solutions to problems.
100003/ CS722U.6-PSO3	H	Organizing and communicating technical and scientific findings can help in the effective development of Professional Skills.