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AI-BASED HYBRID NAVIGATION SYSTEM

An Integrated Approach for Seamless Indoor-Outdoor Navigation

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***Abstract**:* Outdoor navigation using GPS is reliable in open environments but fails inside buildings where satellite signals are weak or unavailable. This creates difficulties in large infrastructures such as hospitals, malls, airports, and university campuses. To address this, we propose a hybrid Indoor-Outdoor Navigation System that allows smooth transition between outdoor and indoor navigation. The system uses OpenStreetMap (OSM) for outdoor routing, providing an open-source, cost-effective alternative to proprietary mapping services. For indoor navigation, building floor plans are processed with Optical Character Recognition (OCR) to extract meaningful information such as room names and directions, which are then converted into navigable paths. The system also implements role-based access, where owners can add or update locations, and users can search and navigate to desired destinations. By integrating outdoor GPS navigation with OCR-enabled indoor guidance, the proposed approach offers a scalable, user-friendly, and practical solution for real-world navigation challenges.

Index Terms - Indoor navigation, Outdoor navigation, OpenStreetMap, OCR, Hybrid navigation system, Floor plan processing.

I. INTRODUCTION

Navigation tools have become such a normal part of life that most of us don't even notice how often we use them. Whether we're finding a new shop, checking how much time it will take to reach a place, or just figuring out the shortest route, we mostly depend on GPS and online maps. These systems work really well outdoors because the signals are strong and the maps are very detailed.

But the moment we enter a big building, everything changes. GPS signals drop or get very weak, and the usual apps become almost useless for guiding us inside. On top of that, services like Google Maps depend on paid APIs, which is not always affordable and also limits how much we can customize things. This becomes a problem when we need solutions for places like hospitals or college buildings where indoor guidance is equally important.

Because of these limitations, many indoor navigation techniques have come up over the years such as Wi-Fi based positioning, Bluetooth beacons, different types of sensors, and so on. These methods do work, but they often need extra hardware or setup, which makes them difficult to use on a large scale. Not every place can install special devices just to help people find rooms.

In this project, we have worked on a Hybrid Indoor-Outdoor Navigation System that tries to solve this gap. For outdoor paths, the system uses OpenStreetMap (OSM), which is free and open-source, and gives us the flexibility to build our own features without depending on paid services. For indoor navigation, building owners can upload their floor plans. The system includes two types of users: owners, who manage the building maps and update room information, and normal users, who simply search for the location they want to go to.

One of the important features is the use of Optical Character Recognition (OCR). When owners upload a floor plan, the system automatically reads the text inside the map such as room numbers, labels, directions, and so on. This information is then processed to create a route inside the building.

By combining outdoor OSM navigation with automatic indoor route generation, the system removes the need for expensive hardware and reduces the dependency on commercial APIs. This makes it useful for real-world places like malls, hospitals, airports, and university campuses, where people frequently move from outside areas to indoor spaces and still expect proper guidance.

Some important contributions of this system are: Seamless Hybrid Navigation that combines outdoor navigation using OpenStreetMap (OSM) with indoor floor-plan routing, enabling uninterrupted guidance across both outdoor and indoor environments. Automated Indoor Mapping via OCR that implements Optical Character Recognition (OCR) to extract room names, labels, and directions from uploaded floor plans, reducing manual effort and improving indoor navigation accuracy. Dynamic Role-Based System that introduces distinct Owner and User roles, allowing Owners to add or update locations and floor plans, which ensures a continuously evolving and scalable navigation database. Practical and Cost-Effective Solution that reduces dependency on paid mapping services and extra hardware.

II. LITERATURE REVIEW

[1] Vision-based Localization with LLMs (arXiv, 2025) introduced an advanced system that combines computer vision (ResNet-50) with Large Language Models (LLMs) for floor-plan understanding. The vision model identifies the user's position by analyzing the environment, while the LLM interprets complex floor plans and converts them into human-readable navigation instructions. This approach achieved 96% localization accuracy and 75% instruction accuracy, proving that AI can handle indoor navigation without requiring infrastructure like QR codes or Wi-Fi. Such systems open the door for next-generation AI-driven indoor navigation, where buildings do not need any special modifications.

[2] AIGD: AI Guide Dog (arXiv, January 2025) researchers introduced the AI Guide Dog (AIGD), a smartphone-based intelligent navigation assistant specifically designed for visually impaired users. Unlike conventional solutions that focus only on either outdoor or indoor settings, AIGD provides a seamless experience by integrating both environments. For outdoor navigation, the system leverages GPS-based routing, while for indoor spaces it employs a vision-only approach using multi-label classification to recognize obstacles, landmarks, and walking paths without the need for Wi-Fi, beacons, or QR codes. This dual capability makes AIGD the first assistive application to unify outdoor and indoor guidance in a single platform, offering increased accessibility, independence, and safety for users in diverse real-world environments.

[3] Real-Time Wayfinding Assistant (arXiv, April 2025) introduced Path Finder, a map-less navigation assistant for visually impaired users. It integrates Vision-Language Models (VLMs), LLMs, and monocular depth estimation to detect obstacle-free paths using a depth-first search approach. Usability testing showed quick user comprehension (73% in under a minute) and strong balance between accuracy and responsiveness.

[4] Offline QR + PDR Navigation (Springer, 2024) designed a network-independent navigation system using QR codes combined with Pedestrian Dead Reckoning (PDR). In this setup, QR codes were scanned at checkpoints, and between scans, the user's movement was tracked through smartphone sensors (step count, direction, and acceleration). The path was calculated using Dijkstra's algorithm to find the shortest route. A major advantage was that the system worked offline, without depending on GPS, Wi-Fi, or mobile data, making it especially useful in hospitals or emergency environments where network availability is limited.

[5] AR Navigation with Geofencing (Applied Sciences, 2024) developed an Augmented Reality-based navigation system that overlays digital arrows and directions on the smartphone screen in real-time. The system used geofencing and image tracking to improve accuracy and reduce drift (a common issue when cameras lose track of surroundings). By recalibrating position regularly, the app could guide users over

longer distances with higher reliability. This approach showed great potential for public spaces such as museums, universities, and shopping malls, where visual guidance makes navigation more user-friendly.

[6] Literature Survey on QR + OSM (IARJSET, 2024) conducted a survey reviewing different indoor navigation systems that combine QR codes with OpenStreetMap (OSM) data. The paper concluded that QR-based systems are low-cost, easy to deploy, and effective for structured indoor maps, but also highlighted limitations such as scalability for very large facilities. The survey emphasized the growing trend of merging digital mapping tools (OSM) with low-cost localization methods (QR codes) to provide practical indoor navigation solutions.

[7] Liu & Zhang (ISPRS Archives, 2023) proposed an indoor positioning system using QR codes combined with IMU (Inertial Measurement Unit) sensors. QR codes acted as fixed reference points within buildings, while IMU data tracked user motion between them. Together, they created an accurate indoor road network that ensured both local precision (within a room or corridor) and global consistency (across multiple floors or large facilities). This approach was significant because it reduced navigation errors that usually increase when relying only on IMU or Wi-Fi signals.

[8] OCR-Based INSUS (ACM, 2023) improved the INSUS framework by adding Optical Character Recognition (OCR) to detect room numbers, wall signs, and other indoor markers. Unlike traditional QR-only systems, this method reduced the need for dense QR placement everywhere. Even if QR codes were not present, the OCR system could still recognize text-based signs and use them for positioning. This innovation made navigation systems more scalable and practical in buildings like hospitals, where every door or corridor may not have QR codes.

[9] Naser, Lam, Qamar & Zaidan (Electronics, 2023) conducted a systematic literature review on smartphone-based indoor localization systems, emphasizing the increasing use of IMU sensors (accelerometers, gyroscopes) and smartphone capabilities for indoor navigation. The review highlights how Pedestrian Dead Reckoning (PDR) techniques based on motion detection through phone sensors are often combined with other methods like Wi-Fi, BLE, or visual markers to enhance accuracy. This paper underscores the potential of sensor fusion in enabling robust indoor navigation without relying entirely on external infrastructure.

III. PROBLEM STATEMENT

Navigation is something we use almost without thinking about it now, mainly when we're outside and just checking directions on our phones. GPS works fine out there, and most apps give decent routes. But the moment someone walks into a big building like a hospital or an airport or even a college block, everything changes. The signal becomes weak or disappears, and suddenly the same system that felt reliable a minute ago can't guide you at all. So people end up wandering around or asking someone for help.

There are indoor navigation systems, but most of them need extra things installed in the building, like Bluetooth beacons or Wi-Fi setups or different kinds of sensors. These things might work, but they also cost money and time. Not every place wants to install hardware just for navigation, especially if the layout changes often. And what makes it worse is that outdoor and indoor navigation usually behave like two different worlds. When you move from outside to inside, the app doesn't smoothly continue the guidance, it basically resets your whole experience.

So the actual problem here is that there isn't a single, simple system that handles both outdoor and indoor movement together. What we really need is something that doesn't depend on expensive devices or complicated installations. One idea that helps is using OCR to pull out room names and labels automatically from floor plans, so nobody has to manually type every detail. If a system can combine that with regular outdoor maps, then people can move around without that sudden "lost" moment at the building entrance. It would make the whole process easier, especially in places where people constantly shift between outdoor paths and indoor corridors.

IV. METHODOLOGY

The idea behind our system is actually pretty simple. We wanted a person to move from outside a building to somewhere inside it without switching apps or getting confused. So we tried to make outdoor and indoor navigation feel like one single thing. For the outdoor part, we just used OpenStreetMap because it's free and reliable enough for GPS routes. We didn't want to depend on paid APIs when OSM already gives what we needed.

The indoor part is a bit more detailed. The building owner uploads their floor plan, and then we run OCR on that image. Whatever text is present such as room names, arrows, numbers gets picked up. Obviously OCR messes up sometimes, so the owner can edit the extracted text. Once everything is corrected, we convert the floor plan into a graph: rooms become nodes, hallways become edges. For finding routes, we mostly used A* or Dijkstra, whichever worked better based on the layout.

To manage all this across different buildings, we added a role-based system. Owners can upload or update maps, and normal users can just use the navigation part. The handover between outdoor GPS and indoor paths happens at the building entrance. We set predefined entry points so that the switch feels natural, not sudden.

Everything runs inside a mobile app. The user types where they want to go, and they get both outdoor and indoor directions together. Owners get a separate dashboard to upload maps and fix OCR mistakes. We tested the system in campuses, airports and railway stations to check whether OCR reads correctly and whether indoor routing makes sense in real scenarios. The transitions were smooth enough, so overall the setup feels practical and scalable without spending too much.

4.1 Outdoor Navigation Module

The user starts by entering a location. Using OSM and GPS, the system finds the best path from the user's location to the entrance of the building. This is basically the first part of the journey.

4.2 Floor-Plan Upload Module

The owner uploads the floor-plan image through the app. The image goes into Firebase Storage, and info like building ID is saved into Firestore. Keeping everything in one place makes future updates easier.

4.3 OCR and Text Cleaning

We used Google ML Kit's text recognition for reading whatever text is on the floor plan. The OCR output is shown to the owner so they can correct mistakes. After the cleaning, we store everything in Firestore.

4.4 Indoor Graph Creation

After the cleanup, the indoor layout is turned into a graph. Rooms become nodes and hallways become edges. A modified A* is used for shortest path calculations. The graph is saved in Firestore so users always see the latest version.

4.5 Outdoor-Indoor Switch

When the user reaches the building edge, the app stops using GPS for routing and switches to the indoor path. This happens through predefined entry nodes.

4.6 Hybrid Routing Engine

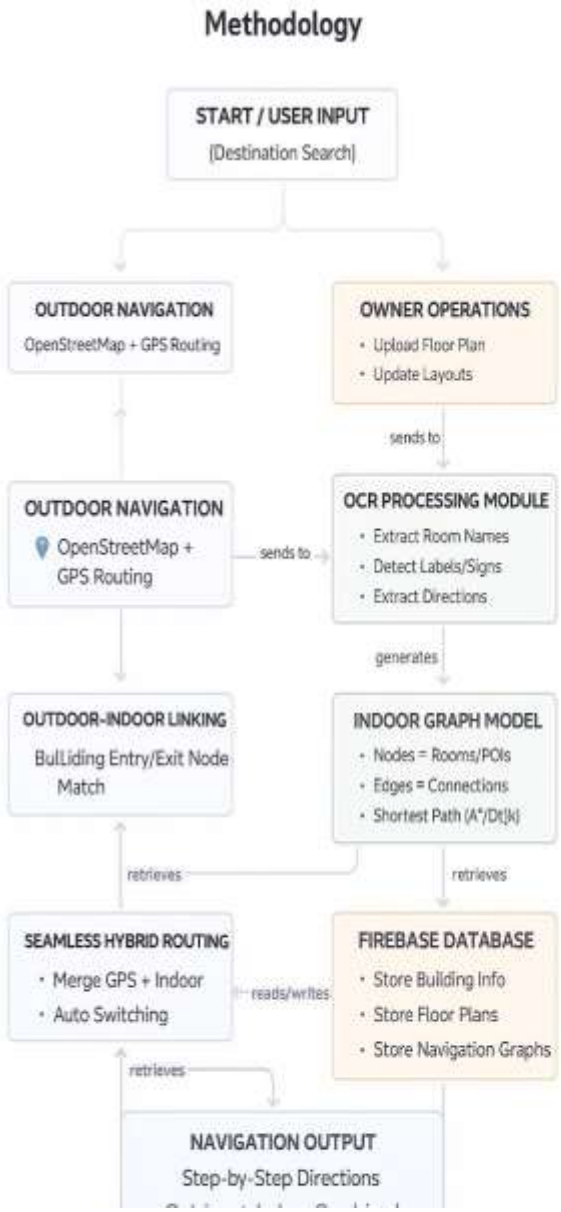
The app blends both outdoor and indoor paths into one complete route. The indoor part comes from the graph algorithm, and the outdoor part comes from OSM. We draw the final route on the screen using Android Canvas, Path, Paint, Bitmap etc.

4.7 Cloud Sync

User roles are handled by Firebase Authentication. Firestore syncs all the building data, OCR text, graphs, etc. When the owner updates something, users immediately get the updated map.

4.8 Final Output

The user gets step-by-step navigation. The indoor part can be zoomed or moved around using Sub sampling Scale Image View so that every detail is clear.



V. RESULS AND DISCUSSION

5.1 Home Screen

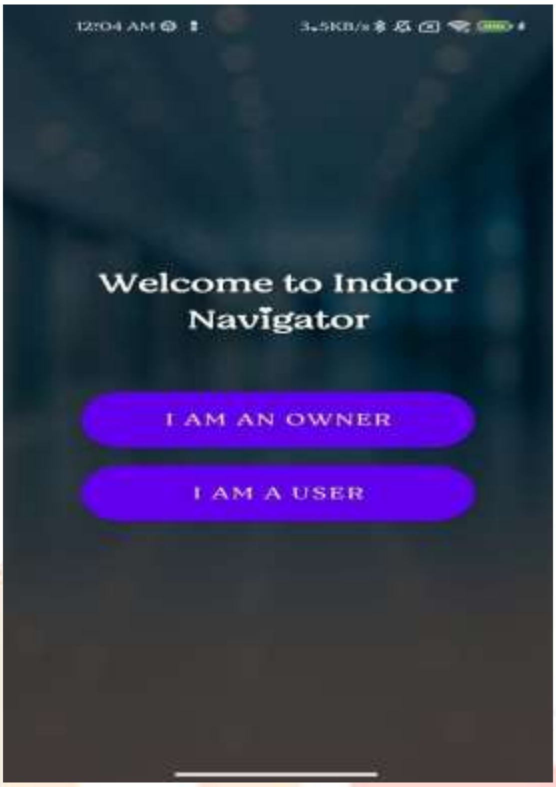


Fig 1: Home Screen

The first screen of the application displays a simple interface where the user can choose between Owner mode and User mode. This serves as the entry point to the navigation system. The buttons are clearly highlighted, and the system remains idle until a selection is made.

5.2 Login Screen

Fig 2: Owner Login Screen

The login screen of the Indoor Navigation Admin app shows fields for email, password, and buttons for Login and Register.

5.3 Signup Screen

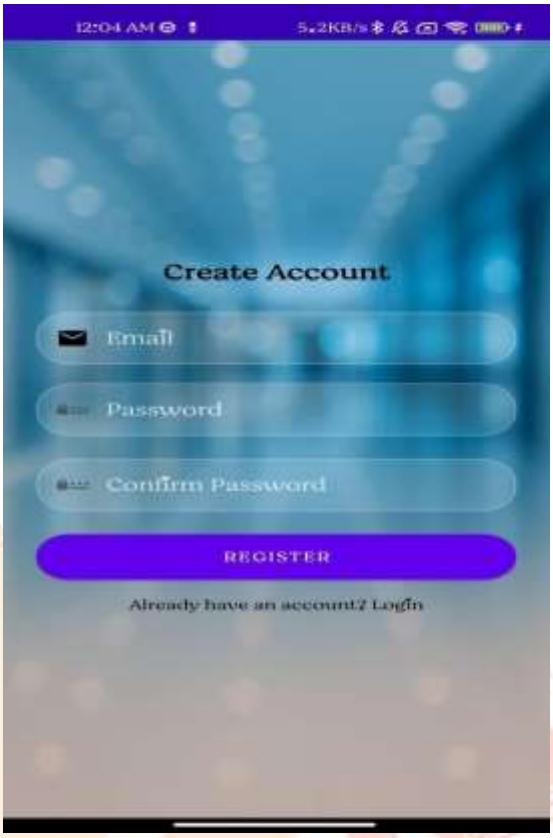


Fig 3: Owner Registration Screen

The registration screen of the app displays fields for email, password, confirm password, and a Register button with a link to return to login.

5.4 Owner - Search Location on Map

Fig 4: Owner – Search Location on Map

The Owner interface for searching a location on the map is displayed. After selecting Owner mode, the map is displayed with zoom controls to help the user find the correct geographical point. The system waits for user input, displaying the map without any markers unless a location is selected.

5.5 Location Handling Interface

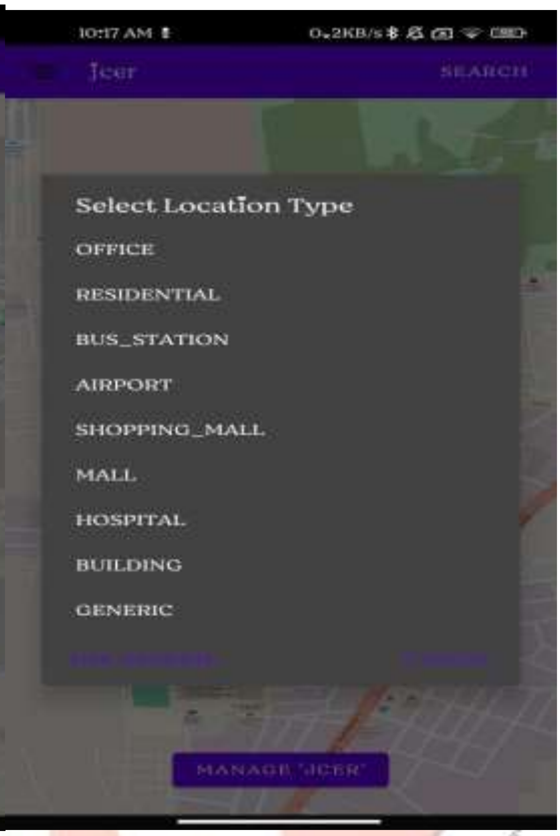


Fig 5: Location Not Found Popup

Fig 5.1: Select Location Type Menu

This shows the popup that appears when a searched place is not found online. It allows the user to manually add a new location by entering its name, latitude, and longitude. This displays the menu where the user selects the type of location, such as office, mall, hospital, or generic, before proceeding with map management.

5.6 Owner - Location Details & Upload Floor Map

Fig 6: Owner – Location Details

Fig 6.1: Uploaded floor map

The screen where the owner can view location details such as latitude, longitude, type, and name is shown. This interface provides an option to upload the floor map image. Until the image is uploaded, the display area remains blank, awaiting user action.

5.7 Owner - Floor Map Upload with OCR Extraction

Fig 7: Owner – Floor Map Upload with OCR Extraction

The system displays a Work Summary containing all registered places and their corresponding floor maps uploaded by the owner. This screen helps the owner track existing data, ensuring that previously entered locations and maps are visible and accessible for future edits. Once the owner uploads a floor map image, the system processes it using OCR to extract room names and labels. The extracted labels appear as editable fields. The user can add, delete, or modify labels. This allows accurate preparation of the indoor map for navigation.

5.8 User - Viewing Current Location

Fig 8: User – Viewing Current Location

When a User enters the navigation mode, the system immediately displays the current location on the map with a tooltip stating "You are here". The map zoom controls allow the user to adjust the view. The system stays ready for destination input.

5.9 User - Enter Destination and Route Display

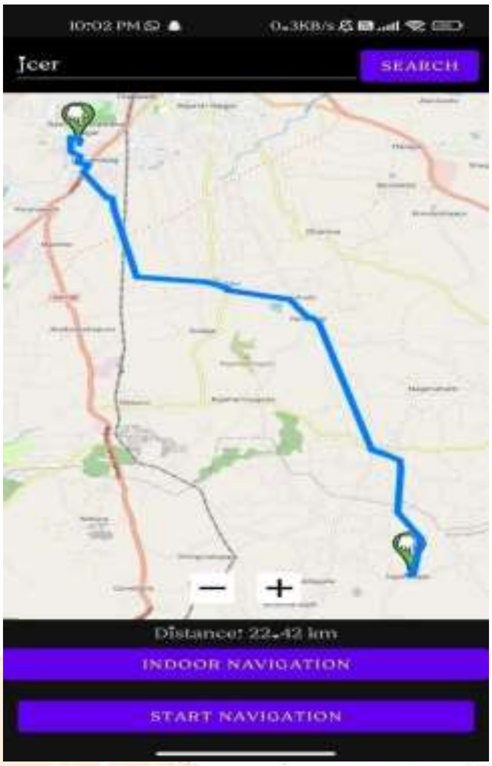


Fig 9: User – Enter Destination and Route Display

This demonstrates the interface where the user enters a destination in the search bar. Once the search is completed, the system calculates and displays the optimized route from the current location to the target point. The path is highlighted in blue to ensure clarity. The system shows the computed distance to the destination and provides two navigation options: Indoor Navigation (if a floor map is available for the selected location) and Start Navigation (for outdoor route guidance). This screen marks the transition point from route calculation to actual guided navigation.

5.10 Indoor Navigation - Path Selection Interface

Fig 10: Indoor Navigation-Path Selection Interface

Fig 10.1: Path Search Screen

This shows the dropdown menu used to select the starting and destination rooms inside a building. Users can choose from available room labels such as Chem Lab, Mech Lab, Office 2, and Seminar Hall. This displays the interface after selecting the source and destination rooms. The user can click the "Search Path" button to generate the indoor navigation route on the displayed floor map.

5.11 Indoor Navigation - Generated Path Visualization

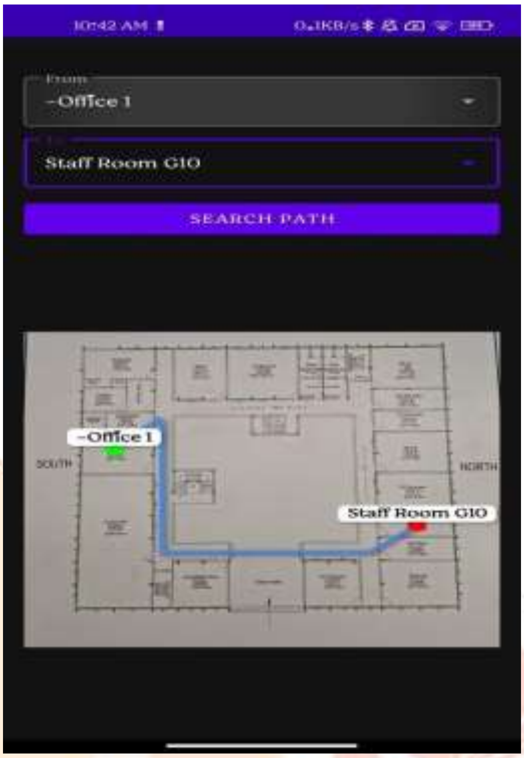


Fig 11: Displaying the Navigation Path Between Selected Rooms

This shows the generated indoor navigation route from "Office 1" to "Staff Room G10". The path is highlighted on the floor map, clearly marking the start and end locations for easy visual guidance.

VI. CONCLUSION

Navigation in both indoor and outdoor environments remains a critical challenge, particularly in areas where GPS signals are weak or unavailable. Traditional solutions, relying on specialized hardware such as Bluetooth beacons, Wi-Fi triangulation, or LiDAR sensors, are often costly and difficult to scale. Moreover, existing systems typically treat indoor and outdoor navigation separately, limiting user convenience and accessibility.

This research emphasizes the need for a hybrid navigation system that integrates indoor and outdoor guidance into a single, cost-effective platform. By utilizing techniques such as Optical Character Recognition (OCR) for automated indoor map generation, the proposed approach simplifies navigation in complex environments while reducing dependency on expensive hardware. Implementing such a system can significantly enhance user experience, improve accessibility, and increase efficiency in real-world scenarios. Future work can focus on further improving accuracy, incorporating real-time updates, and expanding adaptability to different infrastructures, ensuring seamless and reliable navigation across all environments.

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