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Indoor Mall Navigator – Smart Way Finding Using Real-Time Positioning

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ABSTRACT: Indoor navigation is essential in large multi-floor shopping malls where traditional static maps are often ineffective. This paper proposes a smart indoor navigation system integrating AutoCAD-based mall layouts with a Flutter mobile application. A graph-based node architecture represents key locations, and the A* algorithm computes the shortest navigation path between user location and destination. Multi-floor routing is enabled through vertical connectors such as lifts and escalators. The system includes OTP-based authentication using Supabase and Brevo, and provides interactive floor maps for efficient wayfinding.

KEYWORDS: Indoor Navigation System, A Pathfinding Algorithm, Graph-Based Routing, Multi-Floor Navigation, Mobile Application, AutoCAD Floor Plan Integration, Supabase Backend

I. INTRODUCTION

With the rapid growth of large shopping malls and commercial complexes, indoor navigation has become a significant challenge for visitors. Modern malls often consist of multiple floors, hundreds of shops, and complex layouts, making it difficult for users to locate specific stores, facilities, or exits quickly. Traditional navigation methods such as static floor maps, information boards, and customer assistance desks are often inefficient and time-consuming, especially for first-time visitors. Unlike outdoor navigation where Global Positioning System (GPS) technology is widely used, indoor environments limit GPS signal availability, creating the need for alternative indoor navigation solutions.

Indoor navigation systems aim to provide accurate and efficient route guidance within buildings by using digital maps and intelligent routing algorithms. Recent advancements in mobile computing and location-based services have enabled the development of smart indoor navigation applications that can assist users in real-time.

These systems convert physical building layouts into structured digital representations that allow efficient route computation.

In this paper, a smart indoor mall navigation system is proposed to assist users in locating stores and navigating efficiently inside shopping malls. The system integrates AutoCAD-based mall layouts into a mobile application developed using the Flutter framework. The mall environment is modeled as a graph structure where important locations such as entrances, corridors, shops, lifts, and escalators are represented as nodes connected through edges. A*

(A-Star) pathfinding algorithm is used to calculate the shortest and most efficient route between the user's location and the selected destination.

The proposed system also supports multi-floor navigation by connecting vertical transition points such as elevators and escalators between different floor levels. In addition, the application provides interactive and zoomable floor maps for better user visualization. Secure user authentication is implemented through OTP-based email verification using Supabase Edge Functions and the Brevo email API. The overall architecture is designed to be scalable and can be extended to support advanced features such as AI-based shop search, heat map analytics, and real-time indoor positioning using BLE beacons.

The implementation demonstrates how graph-based routing and mobile technologies can be effectively combined to build a practical indoor navigation solution for large shopping malls.

II. LITERATURE SURVEY

Indoor navigation has gained significant research attention due to the limitations of traditional GPS systems inside buildings. Various technologies and algorithms have been proposed to provide accurate indoor positioning and navigation solutions. This section reviews some of the existing research works related to indoor navigation systems. Several researchers have explored the use of wireless technologies such as Wi-Fi, Bluetooth Low Energy (BLE), and RFID to determine indoor positions. One widely used approach is Wi-Fi fingerprinting, where signal strength values are collected from different access points to estimate the user's location. Although this method provides reasonable accuracy, it requires extensive calibration and maintenance as signal strengths can vary due to environmental changes. Another important approach is Bluetooth Low Energy beacon-based navigation. BLE beacons are placed at fixed positions inside buildings, and mobile devices detect signals from nearby beacons to estimate the user's location. This method is cost-effective and energy-efficient, but it requires the installation and maintenance of additional hardware throughout the building. Researchers have also investigated the use of computer vision and augmented reality for indoor navigation. These systems use the camera of a mobile device to detect visual markers or recognize indoor environments and provide directional guidance through augmented overlays. While this approach enhances user experience, it may require significant computational resources and good lighting conditions to function effectively.

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III. PROPOSED SYSTEM

The proposed system provides a smart indoor navigation solution for large shopping malls. It replaces traditional static directory maps with an interactive mobile-based navigation system that guides users dynamically to their desired destinations. The mall layout is designed using AutoCAD floor plans and converted into digital map layers in PNG format. These maps are integrated into a Flutter-based mobile application that allows users to view and interact with the indoor layout.

In the system, important locations such as entrances, shops, corridors, elevators, and escalators are represented as nodes, while the walkable paths between them are represented as edges in a graph structure. The A* (A-Star) pathfinding algorithm is used to compute the shortest path between the user's current location and the selected destination. The system also supports multi-floor navigation through connectors such as elevators and escalators. Additionally, secure user authentication is implemented using OTP-based email verification.

System Modules

The proposed system consists of the following modules:

1. **User Authentication Module** – Handles user registration and login using OTP-based email verification.
2. **Map Integration Module** – Manages mall floor maps and integrates them into the mobile application.
3. **Graph Construction Module** – Represents the mall layout using nodes and edges.
4. **Pathfinding Module** – Uses the A* algorithm to compute the shortest navigation route.
5. **Navigation Display Module** – Displays the calculated path and guides users to their destination.

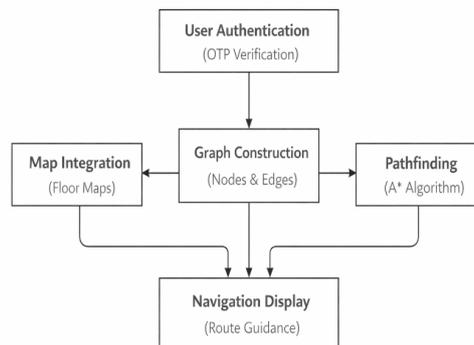


FIG 1: SYSTEM MODULES

IV. SYSTEM ARCHITECTURE

The system architecture of the Indoor Mall Navigator is designed to provide efficient indoor navigation by integrating a mobile application, cloud-based backend services, and intelligent routing algorithms. The architecture follows a modular approach where each component performs a specific function to support the overall navigation system.

Mobile Application Layer

The frontend of the system is developed using the Flutter framework to provide a responsive and user-friendly mobile interface. The application allows users to register and log in using OTP-based authentication. After authentication, users can select their preferred district and mall to access the corresponding digital floor maps. The interface supports zooming and panning features, enabling users to easily explore the mall layout and select their desired destination.

Backend and Authentication Layer

The backend infrastructure is powered by Supabase, which handles user authentication, database management, and serverless edge functions. When a user enters their phone number and email address, the system generates a one-time password (OTP) and stores it securely in the database. The OTP is then delivered to the user through the Brevo Email API. After successful verification of the OTP, the user is granted access to the navigation system.

Graph-Based Navigation Model

The mall environment is modeled using a graph-based structure to support efficient navigation. In this representation, important locations such as entrances, corridors, shops, elevators, and escalators are represented as nodes, while the walkable paths between them are represented as edges. This graph-based model allows the system to efficiently process navigation queries and compute optimal routes.

Pathfinding Algorithm

The system uses the A* (A-Star) pathfinding algorithm to determine the shortest path between the user's current location and the selected destination. The algorithm calculates the optimal path using the cost function:

$$f(n) = g(n) + h(n)$$

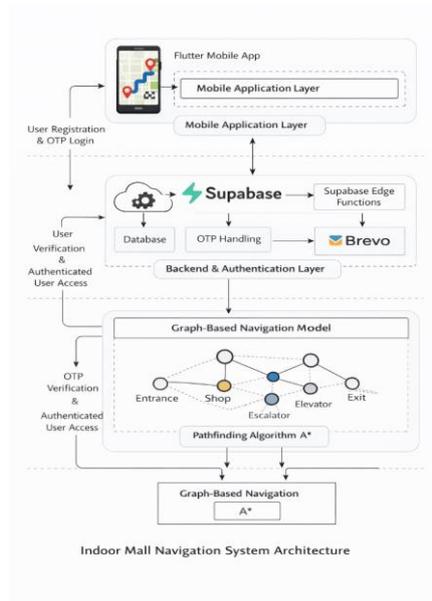


FIG 2 :SYSTEM ARCHITECTURE

where $g(n)$ represents the distance from the starting node, $h(n)$ represents the estimated distance to the destination, and $f(n)$ represents the total cost used for route optimization.

Digital Map Integration

The floor maps used in the system are created from AutoCAD floor plans and converted into PNG image layers. These map layers are integrated into the mobile application and aligned with coordinate positions that correspond to the navigation nodes within the graph model. This mapping enables accurate visualization of navigation routes on the mall floor plan.

System Integration

The overall architecture integrates the mobile application interface, cloud backend services, and intelligent navigation algorithms to deliver a scalable indoor navigation system. This integrated design ensures efficient route computation, secure user authentication, and seamless interaction with digital mall maps.

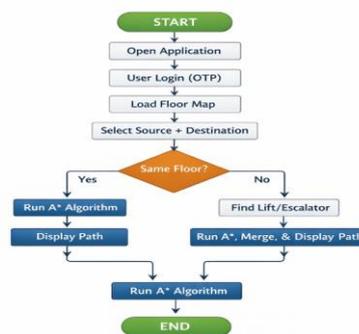


FIG 3: FLOWCHART

V. METHODOLOGY

The methodology of the proposed Indoor Mall Navigator system focuses on designing an efficient indoor navigation framework by integrating digital floor mapping, graph-based modeling, shortest path computation, and secure authentication mechanisms. The complete development process is structured as follows:

Floor Plan Design and Map Conversion

The development process begins with the creation of mall floor layouts using AutoCAD software. These CAD drawings represent the structural layout of the mall, including shops, corridors, entrances, escalators, and elevators. The CAD files are then converted into optimized PNG floor map images. These images are integrated into the mobile application to provide a visual representation of the mall structure. This conversion ensures lightweight rendering and efficient performance within the application.

Graph-Based Environment Modeling

The mall environment is modeled using a graph data structure. In this representation:

- **nodes.** Important locations such as shop entrances, corridor intersections, lifts, and escalators are defined as nodes.
- **edges.** Walkable paths between locations are defined as edges connecting the nodes.
- **coordinates.** Each node is assigned coordinate values corresponding to its position on the floor map image.

This graph-based modeling enables structured representation of indoor space and supports efficient route computation.

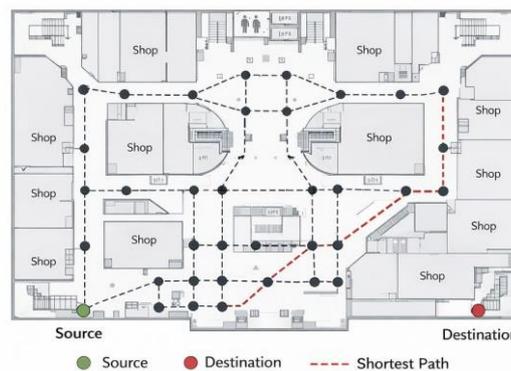


Fig. 4. Graph Representation of Mall Floor Layout

FIG 4: GRAPH-BASED ENVIRONMENT MODELING

Shortest Path Computation Using A* Algorithm

To determine the optimal navigation route, the system implements the A* (A-Star) pathfinding algorithm.

The algorithm calculates the shortest path by:

- Evaluating the movement cost from the starting node (g-cost)
- Estimating the remaining distance to the destination using a heuristic function (h-cost)
- Minimizing the total cost function:

$$f(n) = g(n) + h(n)$$

This approach significantly improves search efficiency compared to traditional routing algorithms by reducing unnecessary node exploration. The A* (A-Star) algorithm is applied to compute the shortest path by evaluating the actual movement cost (g(n)) from the source and estimating the remaining distance (h(n)) to the destination using a heuristic function.

1.If the source and destination are on different floors, the algorithm first computes the path to the nearest vertical connector (lift/escalator), switches floors, and then computes the remaining path. Finally, the computed optimal path is visually drawn on the digital floor map for user navigation.

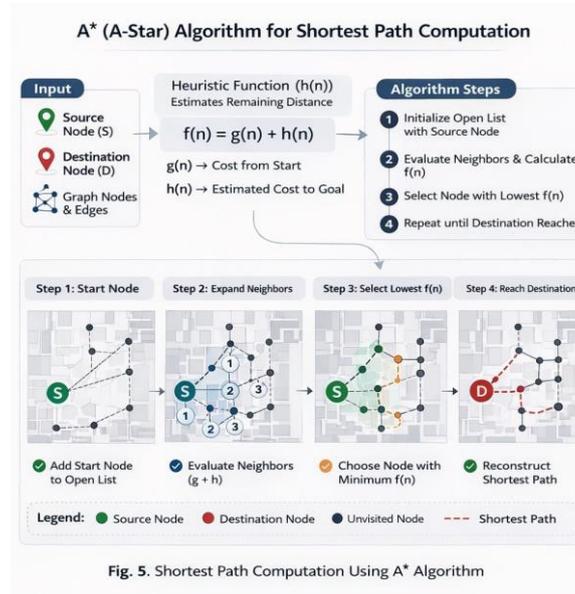


Fig. 5. Shortest Path Computation Using A* Algorithm

FIG 5: SHORTEST PATH COMPUTATION

Mobile Application Development

The mobile application is developed using the Flutter framework, which provides a cross-platform environment for building responsive and interactive user interfaces.

The application allows users to:

- Select districts
- Choose malls
- Interact with digital floor maps
- Select source and destination locations

Interactive features such as zooming and panning enhance usability and improve the overall navigation experience.

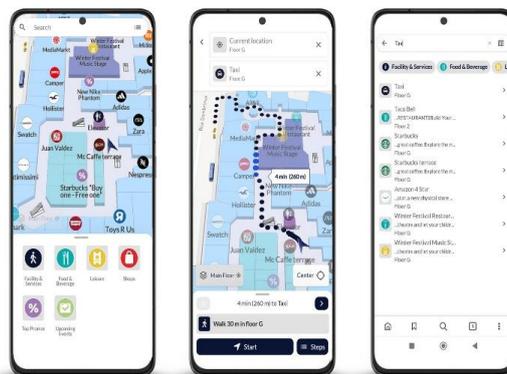


FIG 6 : MOBILE NAVIGATOR

OTP-Based User Authentication

User authentication is implemented using an OTP-based verification mechanism.

When a user enters their phone number and email address:

1. An OTP is generated using Supabase Edge Functions.
2. The OTP is securely stored in the Supabase database.

3. The OTP is delivered to the user via the Brevo Email API.
4. Upon successful verification, access to the navigation system is granted.
This mechanism ensures secure and reliable user authentication.

System Integration and Scalability

The overall methodology integrates structured floor mapping, graph-based routing, shortest path algorithms, mobile application development, and secure backend authentication services.

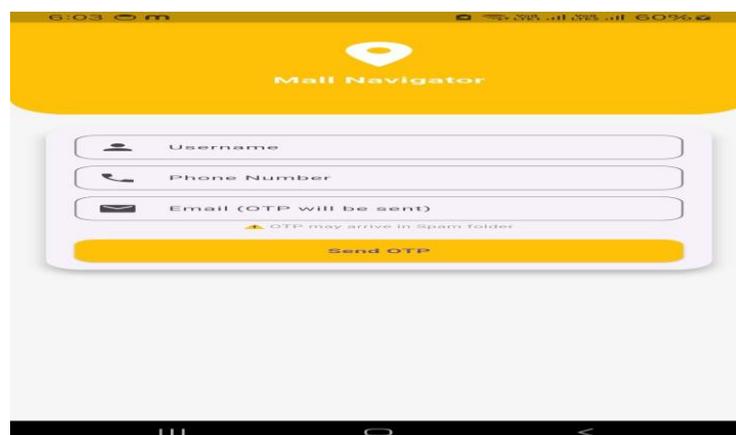
This integrated approach ensures accurate indoor navigation while providing a scalable framework that can be extended to support advanced indoor positioning technologies in future implementations.

VI. IMPLEMENTATION

The Indoor Mall Navigator system was implemented using a combination of mobile application development frameworks, backend services, and navigation algorithms. The frontend of the application was developed using the Flutter framework, which enables cross-platform mobile application development with a responsive and interactive user interface. The application interface includes user authentication, district and mall selection, interactive floor maps, and navigation features. User authentication is implemented using an OTP-based verification system. When a user enters their phone number and email address, an OTP is generated using Supabase Edge Functions and stored in the Supabase database along with a request ID and expiration time. The OTP is delivered to the user's email through the Brevo Email API. Once the user enters the correct OTP within the allowed time, the system verifies the request and grants access to the navigation features of the application. The floor maps used in the system were initially designed using AutoCAD to represent the layout of the shopping mall. These CAD floor plans were then converted into PNG image formats and integrated into the mobile application as map layers. Each floor image is displayed within the application using interactive viewing components that allow users to zoom, pan, and explore the layout. A graph-based navigation model was implemented to represent the internal structure of the mall.

Important locations such as entrances, corridor intersections, shops, escalators, and elevators are represented as nodes, while walkable paths are represented as edges connecting these nodes. Each node is mapped to specific coordinates on the floor map to ensure accurate path visualization. To calculate the shortest path between two locations, the A* (A-Star) pathfinding algorithm was implemented. The algorithm evaluates possible routes by combining the distance already traveled with a heuristic estimation of the remaining distance to the destination. This approach efficiently identifies the optimal navigation route and reduces computation time.

The application also supports multi-floor navigation by connecting nodes across different floors through vertical connectors such as elevators and escalators. When the destination is located on another floor, the navigation algorithm automatically includes these transition points and updates the route accordingly. The implemented system demonstrates how modern mobile development frameworks, cloud backend services, and intelligent pathfinding algorithms can be integrated to create an efficient indoor navigation solution for large shopping malls.



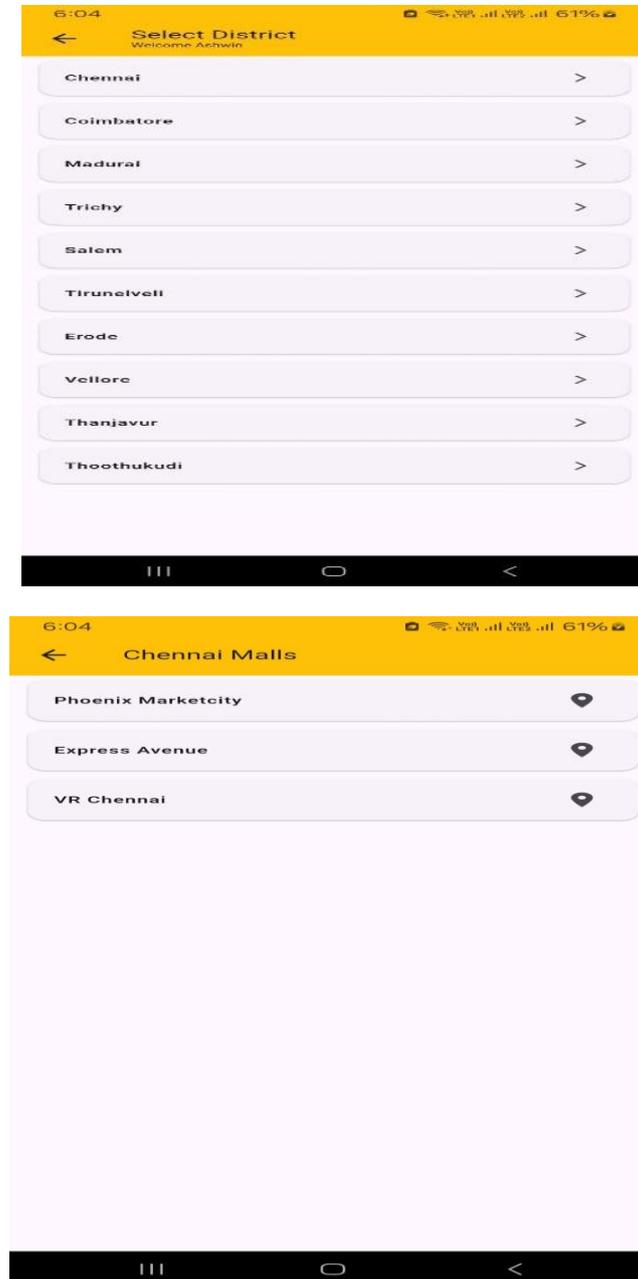


FIG 7: MOBILE APPLICATION UI SCREENS

VII. RESULTS

The Indoor Mall Navigator system was successfully developed and tested as a mobile application to demonstrate efficient indoor navigation within a shopping mall environment. The implemented system integrates digital floor maps, graph-based routing, and the A* pathfinding algorithm to guide users from the entrance to any selected shop or facility inside the mall.

The application interface allows users to log in securely using OTP-based authentication and access the navigation features after successful verification. Users can select the desired district and mall, view the floor layout, and interact

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with zoomable and scrollable floor maps. The system accurately displays floor layouts converted from AutoCAD drawings, ensuring realistic representation of the mall structure.

The graph-based navigation model effectively represents the mall layout using nodes and edges. Each important location such as entrances, shops, escalators, and corridors is mapped as a node, while the walkable paths are represented as edges connecting the nodes. The A* pathfinding algorithm successfully calculates the shortest route between the user's current position and the selected destination.

During testing, the algorithm demonstrated efficient route computation and successfully generated navigation paths within a short processing time. The system also supports multi-floor navigation by connecting vertical transition points such as escalators and elevators, allowing the algorithm to guide users across different floors seamlessly.

The integration of interactive map visualization improves the user experience by allowing smooth zooming and panning of the floor layout. The overall results indicate that the proposed system provides an effective solution for indoor navigation in large commercial environments. The system can be further enhanced by integrating real-time indoor positioning technologies such as Bluetooth Low Energy (BLE) beacons and advanced analytics features like crowd heat map visualization.

VIII. CONCLUSION

This paper presented the design and implementation of a smart indoor navigation system for shopping malls using graph-based routing and the A* pathfinding algorithm. The proposed system addresses the limitations of traditional static mall directories by providing an interactive mobile-based navigation platform that helps users efficiently locate shops, facilities, and exits within large multi-floor malls. By integrating AutoCAD-based floor layouts with a Flutter mobile application, the system provides realistic digital maps with zoomable and interactive features. The graph-based node architecture models the mall structure effectively, enabling efficient path computation between different locations. The implementation of the A* algorithm ensures optimal route calculation and improved navigation performance. Multi-floor navigation is handled through interconnected vertical nodes such as escalators and elevators, allowing seamless movement between floors. Secure user authentication using OTP verification through Supabase Edge Functions and Brevo email integration enhances system security. The developed prototype demonstrates the feasibility of implementing practical indoor navigation solutions using modern mobile development technologies and intelligent routing algorithms. In the future, the system can be extended by integrating real-time indoor positioning technologies such as Bluetooth Low Energy (BLE) beacons, AI-based shop recommendation systems, and crowd heat map analytics to further enhance user experience and mall management capabilities.

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