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Artificial Intelligence Based Navigation System Using Autonomous Robot

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Abstract: Navigating educational institutions can be complex, especially for newcomers. This paper suggests an Artificial Intelligence-based Navigation System employing an Autonomous Robot with the vision of presenting a real-time, efficient, and user-centric navigation system. Using LiDAR technology and artificial intelligence, the robot can detect obstacles and map the environment to provide continuous path directions. The system comes with a graphical user interface developed using Streamlit, supports both traditional and advanced pathfinding algorithms, and applies supervised learning techniques based on pre-trained datasets containing more than 600 A* paths. It is intended to operate within school campuses and promises accessibility, enhances work efficiency, and offers the foundation for larger-scale applications within public spaces.
Keywords: Artificial Intelligence, LiDAR, Navigation System, Autonomous Robot

I. INTRODUCTION

Contemporary college campuses are dynamic, complex ecosystems, thronged with activity as they welcome a diverse range of students, faculty members, staff, and visitors. During the rush periods, including admissions activities, placement campaigns, symposia, and academic conferences, the challenge of getting around an unfamiliar campus can be particularly overwhelming. This is true for the most part for freshmen and first-time visitors who could easily be overwhelmed by the sheer number of structures and trails. These busy settings make the necessity for smart and effective navigation assistance paramount since it not only ends confusion but also conserves precious time, greatly improving overall experience on campus.

A pioneering AI-powered navigation system using Autonomous Robot presents itself as a highly evolved, hardware and software-based solution to meet these needs. Relying on cutting-edge pathfinding algorithms coupled with real-world environmental sensing, such a system navigates users effortlessly through the campus terrain. Using simple web or mobile user interfaces, users simply enter their destination of choice and get real-time, step-by-step navigation guidance customized to their specific needs. The system automatically adjusts constantly to changing conditions like construction areas, blocked routes, or heavily congested areas to give users the best routing possible at all times. In addition to meeting individual navigation requirements, this system operates as a centralized digital information center. It offers instant availability of event calendars, campus notices, and location-based alerts, making a more informed and active campus community. Its inclusive design caters to users with varying levels of technical expertise, and features like voice-guided assistance or accessibility modes can be integrated to support individuals with disabilities, ensuring that everyone can navigate the campus with confidence.

The deployment of such a navigation system fits with the greater vision of a "smart campus"—an ecosystem that integrates digital technologies into the very fabric of learning, security, and operational efficiency. By automating frequent queries and reducing the amount of on-ground directional assistance, institutions can reallocate human resources into more important tasks, especially during peak traffic times. But with the use of AI-based navigation systems also comes the imperative of exercising caution in addressing issues of data privacy, scalability of systems, and limitations of infrastructure. Finding a balance between offering secure, reliable access to a range of services and user confidence is critical in ensuring long-term take-up. This article explores the design, creation, and deployment of an AI-powered campus navigation system, highlighting its technical infrastructure, adaptive routing features, and potential positive effect on accessibility, efficiency, and user satisfaction in educational environments.

The suggested AI based Navigation system using Autonomous Robot is indicative of how artificial intelligence may be leveraged to produce more intelligent, better-organized campus spaces that suit the multifarious requirements of institutions and their diverse constituencies alike, ultimately in the hope of enhancing the campus experience in general.

II. LITERATURE SURVEY

This section reviews existing studies on AI-based navigation, autonomous robotics, LiDAR technology, and real-time obstacle detection. It examines prior research to establish the knowledge gap and justify the study's significance.

A. Development of an Indoor Delivery Mobile Robot for a Multi-Floor Environment. Taejin Kim, Daegyu Lee, Gyuree Kang and D. Hyunchul Shim. IEEE Access, 2024[11]

This research work targets the autonomous navigation problem of intricate indoor spaces where GPS signals are weak or nonexistent. The system outlined contains multiple significant components: map management, localization, path planning, perception, and task planning, all optimized to function well in multi-story buildings. The work identifies significant advancements in indoor localization, particularly from the application of LiDAR odometry, sensor fusion, and 3D point cloud-topography combined navigation maps. Wheeled robots are also subject to special difficulties using elevators. The work addresses this through the perception modules that fuse camera and LiDAR inputs and use semantic segmentation to identify elevators. A 3D route planning module joins points between floors using elevator nodes to enhance floor navigation. Task planning for parcel delivery, which involves driving, use of elevators, delivering parcels, and docking, is also discussed in the study. The performance of the system was evaluated using a month-long field trial. It demonstrated that the system was able to accurately position itself, navigate around obstacles, and finish tasks in an actual building during typical business hours.

B. Coimbatore Institute of Technology Campus Navigation System (Version 1.0). Sheryl Sharon G, Rohith Vikaas P, Chanduru A, Barathkumar S, Harsha Vardhan P and Dr. M. Mohanapriya. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2023[9]

This paper addressed navigation issues on university campuses using advanced technology. It combines GPS, user-friendly design, and real-time tracking to help people find their way. Data collection involves mapping buildings and paths with GPS to create a GeoJSON dataset, which is used in a web-based map with Leaflet.js and OpenStreetMap. The Leaflet Routing Machine helps users find optimal routes by entering their start and end points. The interface features a search tool and a feedback system, with MongoDB storing user input to improve the navigation tool. It uses HTML, CSS, JavaScript, and React.js for accessibility. Testing and training encourage adoption, while ongoing maintenance and security ensure it meets users' needs.

C. Constructing Metric-Semantic Maps using Floor Plan priors for Long-term Indoor Localization. Nicky Zimmerson, Matteo Sodano, Elias Marks, Jens Behley and Cyrill Stachniss. IEEE/RSJ International Conference on Intelligent Robots and Systems, 2023[6]

This study highlights the essential role of object-based maps in improving our understanding of scenes. These maps merge geometric and semantic information, allowing autonomous robots to navigate and interact with objects more effectively. The main goal is to create metric-semantic maps for long-term object-based localization. The method utilizes 3D object detections from monocular RGB images for two primary tasks: building detailed object-based maps and achieving precise global localization. To adapt to various environments, the study presents a technique for generating 3D annotations that enhances the 3D object detection model. The authors tested their approach in an office building and evaluated long-term localization using challenging sequences over nine months. The results demonstrate the method's effectiveness in creating robust metric-semantic maps and its resilience to long-term environmental changes. Both the mapping algorithm and localization pipeline operate in real-time on an onboard computer. Additionally, the authors plan to provide an open-source implementation of their method using C++ and ROS.

D. Design and Development of Indoor Campus Navigation Application. Rabab Alayham Abbas Helmi, Harini A.P. Ravichandran, Arshad Jamal and M. N. Mohammed. IEEE Conference on Systems, Process & Control (ICSPC), 2022[7]

An easy-to-use app was created to help new students and visitors get directions to specific places within Management and Science University. Management and Science University plans to use smart campus technologies through the "Find 4 Me Application." This app will help users find indoor locations and improve the experience for new students and visitors. Since the campus is large and lacks a navigation tool, newcomers often have trouble locating classrooms and understanding campus resources. Besides navigation, it will include features like 360-degree views of directions, venue bookings within MSU, a live chat option, and a way to provide feedback for future improvements. The study will use the Spiral Model as a research method to meet the project's goals. Findings show that the system is reliable and trustworthy. It provides a personalized experience for students and visitors while engaging them visually.

E. Assistive Delivery Robot Application for Real-world Postal Services. Daegyu Lee, Gyuree Kang, Boseongkim and D. Hyunchul Shim. IEEE Access, 2021[4]

This paper discusses two main ways to determine a robot's location: GPS-based and sensor-based methods. GPS-based methods, like the Kalman filter, can struggle in cities and inside buildings where signals are weak. On the other hand, sensor-based methods, such as Visual Odometry (VO) and LiDAR Odometry and Mapping (LOAM), are effective and accurate, especially when GPS signals are not available. The study also looks at object detection using CNN-based models, like YOLO, which help robots identify objects in real time. It addresses challenges including estimating how far away objects are. This can improve by combining data from LiDAR and cameras and using clustering algorithms to recognize and avoid obstacles in complex settings. Finally, the study highlights motion planning strategies that help robots navigate around obstacles. It mentions algorithms that can plan routes quickly in busy urban and indoor environments, using big data and communication technology to connect vehicles with infrastructure (V2I).

F. A Comprehensive Survey of Indoor Localization Methods. Anca Morar, Alin Moldoveanu, Irina Mocanu, Florica Moldoveanu, Ion Emilian Radoi, Victor Asavei, Alexandru Gradinaru and Alex Butean. National Library of Medicine, Sensors (Basel), 2020 [1]

This survey provided an overview of indoor localization techniques that use computer vision to track mobile entities like people or robots in indoor spaces. These techniques fall into two main groups: those that use a network of fixed cameras and those that use cameras on the moving entities themselves. The study covers different aspects of indoor localization, including application areas, commercial tools, existing benchmarks, and related reviews. It also examines research solutions in this field and introduces a new classification system based on various factors, such as the use of known environmental data, the types of sensing devices, the elements detected, and the localization method used. The authors categorize and discuss 70 recent image-based indoor localization methods according to this new system. They emphasize methods that provide orientation information, which is important for many applications, such as augmented reality.

G. Campus Guide: A Lidar based Mobile Robot. Minghao Liu, Zhixing Hou, Zezhou Sun, Ning Yin, Hang Yang, Ying Wang, Zhiqiang Chu and Hui Kong. European Conference on Mobile Robots (ECMR), 2019 [5]

This paper demonstrated how robots can navigate urban areas with multi-line LiDAR systems, although extensive sensor calibration is needed. Other methods, like using QR codes for indoor navigation, need prior setup, limiting flexibility. It introduces "teach and repeat," where robots learn and retrace routes from human guidance. LiDAR techniques, such as LOAM (LiDAR Odometry and Mapping), are essential for real-time mapping and help robots detect moving objects in busy environments. The research emphasizes the need for cost-effective and scalable navigation solutions, especially in complex areas like campuses, where robots navigate around pedestrians and obstacles with minimal sensors.

H. Navigation Algorithms with LIDAR for Mobile Robots. Cristian MOLDER, Daniel TOMA and Andrei ȚIGĂU. Journal of Military Technology, 2019[3]

This paper discusses human-following algorithms that use proximity data from LIDAR, which is also useful in robot navigation. By combining depth cameras and active infrared markers, researchers have improved the accuracy of controlling indoor environments through sensor fusion. Using data from Kinect and LIDAR highlights the need for different technologies to achieve reliable and accurate autonomous navigation. Processing speed is still a limitation, but new algorithms, like the "Follow Me" navigation strategy, show promise in human-robot interaction. These methods allow robots to track moving targets while keeping a safe distance, showcasing advancements in control systems. In addition, using graphical visualization and dynamic target tracking provides an easy way to watch and improve navigation algorithms.

I. Indoor Navigation for Shopping Robot. Sithara Jeyaraj and Jincy Jose. International Journal for Research in Engineering Application & Management (IJREAM), 2018[9]

This paper examines the ways of enhancing positioning precision. Zhao's method fuses inertial sensors, magnetometers, and ultrasonic sensors to minimize drift errors [12]. Wi-Fi signal strength indoor navigation is also suitable for generating maps. Position and orientation accuracy enhancement techniques such as Kalman filters and sensor fusion are crucial. A* (A Star) algorithm effectively determines optimal routes and operates with vision systems or sonar for detecting obstacles. Accelerometer and magnetometer readings support real-time mapping, while photoelectric encoders are used to correct errors. The problem of real-time map construction is pointed out in Chen Qiu's automatic mobile sensing work [13].

The combination of A* algorithms for path planning and ARM Cortex M3 control processors reflects a balance of efficiency and application, consistent with trends in indoor navigation and service robots.

J. Autonomous Navigation of a Mobile Robot in Indoor Environments. Bimal Paneru, Niraj Basnet, Sagar Shrestha, Rabin Giri and Dinesh Baniya Kshatri. Zerone Scholar, 2016 [2]

This study demonstrated how probabilistic algorithms assist differential drive robots in navigating autonomously. It focuses on mapping, localization, and path planning. One key area is sensor fusion. Kalman filters combine data from gyroscopes and digital compasses for accurate pose estimation. To improve localization, the study uses Adaptive Monte Carlo Localization (AMCL). For mapping, the authors use occupancy grid mapping with LiDAR, creating a two-dimensional map that shows areas as free, occupied, or unexplored.

For path planning, the study combines both global and local strategies. The A* algorithm finds the best global routes, while the Dynamic Window Approach handles local navigation more responsively. The study also integrates depth sensing with Kinect to enhance LiDAR's abilities. This helps detect non-planar obstacles and improve obstacle avoidance. Overall, this study demonstrates how these methods work well together in both simulations and real-world situations, achieving accurate navigation with minimal positional error.

K. An Event-driven University Campus Navigation System on Android Platform. Susovan Jana and Matangiri Chattopadhya. Applications and Innovations in Mobile Computing (AIMoC), 2015 [10]

This paper discusses an Android application made with the Android Software Development Kit (SDK). The app is designed to help users navigate the Jadavpur University campus and stay updated on events. It was tested thoroughly at both the main campus and the Salt Lake campus. Feedback from users showed that the app improves campus navigation and helps them learn about different activities.

The application integrates Google Maps, which allows users to track their location in real-time, find the best routes, and get details about ongoing events. This study highlights a practical solution that aims to make it easier for students and visitors at Jadavpur University to navigate the campus and engage with campus events.

These researches confirm the growing need and utility of advanced indoor navigation systems, but they show a lack of integration of artificial intelligence-based prediction with real-time user support in a spatial autonomous robot system.

III.METHODOLOGY

The two sections that make up this work's methodology are the software description and the hardware description. The user interface, also known as Streamlit, serves as a link between the software and hardware components of the project.

A. Software Description

Figure 1 shows a detailed workflow that combines classic graph theory with algorithmic analysis and modern AI techniques. This structured pipeline is meant for AI-driven pathfinding within a mapped environment. The process starts with map preprocessing and walkability extraction, using image processing methods to find areas that can be traversed.

Next, the data undergoes transformation through graph construction, which involves creating nodes and edges that represent possible paths in the environment. A path visualization layer is then applied, overlaying the computed paths onto the map to make it easier to understand.

After that, coordinate extraction is performed to get the spatial positions of the nodes, which are then used to create an adjacency list that defines the relationships between the nodes. With the graph data ready, various pathfinding algorithms, such as Dijkstra, A*, Breadth-First Search (BFS), and Depth-First Search (DFS), are run to find the best routes.

The performance of these algorithms is assessed through different metrics, comparing factors like speed, path cost, and overall efficiency. Finally, the insights gained from this analysis help in developing AI models, where machine learning methods are used to predict the most effective pathfinding strategies for specific environments or conditions. Data from 600 pre-computed A-star paths is used to train a supervised learning model for future path prediction based on environment metrics. The best route is visualized over the map in real-time.

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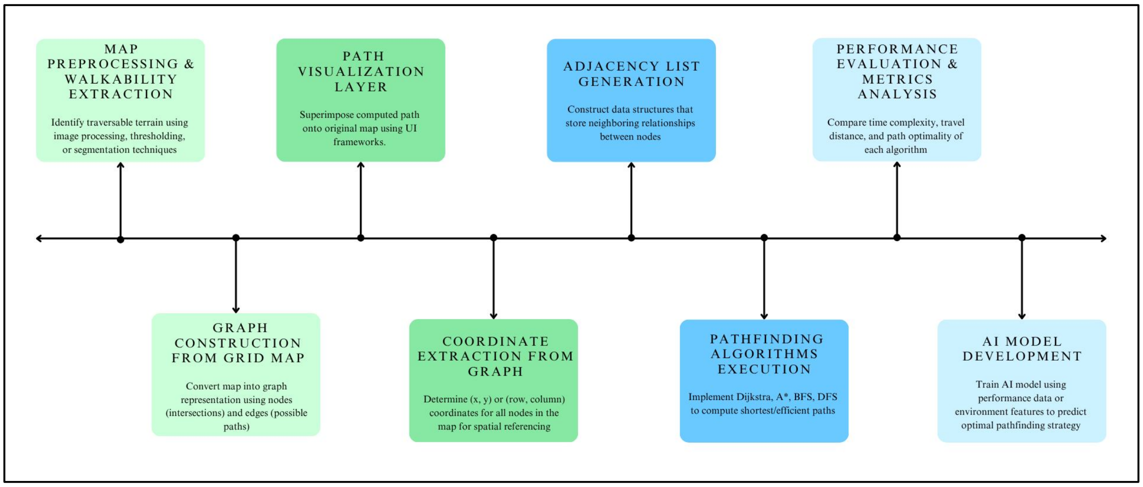

Fig. 1 Operational Workflow of AI-based pathfinding system

B. Hardware Description

The figure 2 shows how power is distributed and how components connect in a robotics system. This robotic system is powered via a centralized power supply. The power first goes to a power distributor, which sends electricity to two main subsystems: the L293 motor driver module and the Raspberry Pi 4. The motor driver module powers the robot chassis, allowing it to move and perform mechanical functions. Meanwhile, the Raspberry Pi 4 acts as the master controller and connects with two important sensor modules: the MPU 6050 module, which provides inertial measurements like acceleration and gyroscope data, and the VL53L0X TOF-Based LIDAR laser distance sensor, which measures distance using time-of-flight technology to detect obstacles and map the environment. This organized setup makes sure that both the mechanical and sensor components get the right power and control, creating a unified robotic system that can navigate and interact on its own.

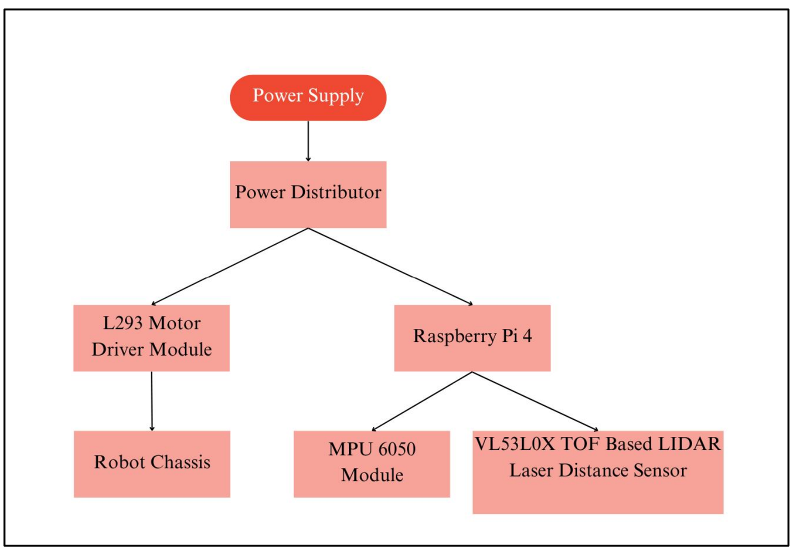

Fig. 2 Block diagram of Autonomous robot

IV. IMPLEMENTATION

The entire system consists of a hardware configuration with the software component stored on the SD card of the Raspberry Pi. The physical device and the experimental configuration depicted in Fig. 3 need to be connected through a shared network. Accessing the setup is done with administrator privileges. All control commands are issued through the command prompt. The user interface utilized is Streamlit.

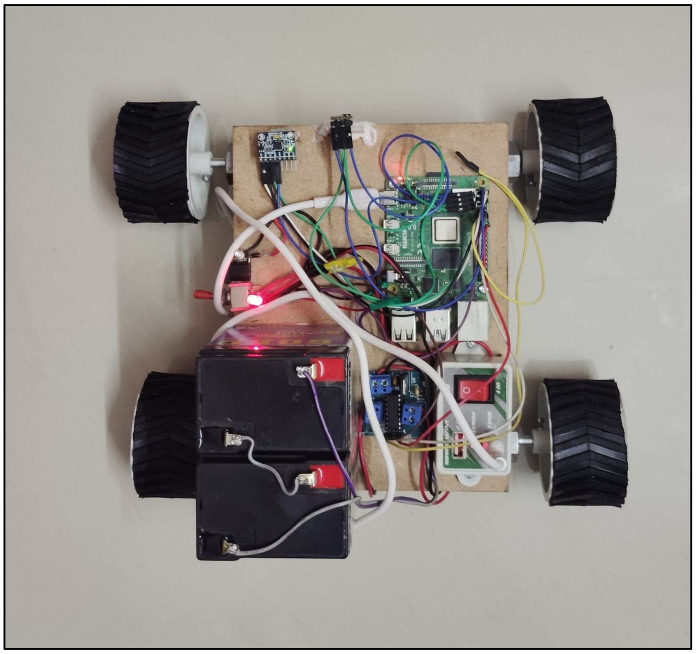

Fig. 3 Experimental Setup of AI- based Navigation System using Autonomous Robot

Once the user specifies the source and target locations, the route is determined using supervised learning based on pre-trained data. This dataset comprises 600 paths generated using the A* algorithm for each source-target pair. The selected route is illustrated in Fig. 4, and the robot guides the user to the chosen destination. The MPU 6050, which is a 6-axis gyro-accelerometer module, controls the robot's speed, while the VL53L0x time-of-flight (TOF) lidar sensor is responsible for detecting and avoiding obstacles. Preliminary test conducted within the NITTTR campus shows successful navigation of various source-target pairs. The robot successfully navigated pre-trained A* paths with minor environmental modifications. The Streamlit interface successfully supported user interaction. The key performance measures were 2.3 seconds average response time, over 90% route accuracy, and an 85% success rate in obstacle avoidance. Further testing in real-world scenarios is recommended to assess scalability and performance in varying conditions.S

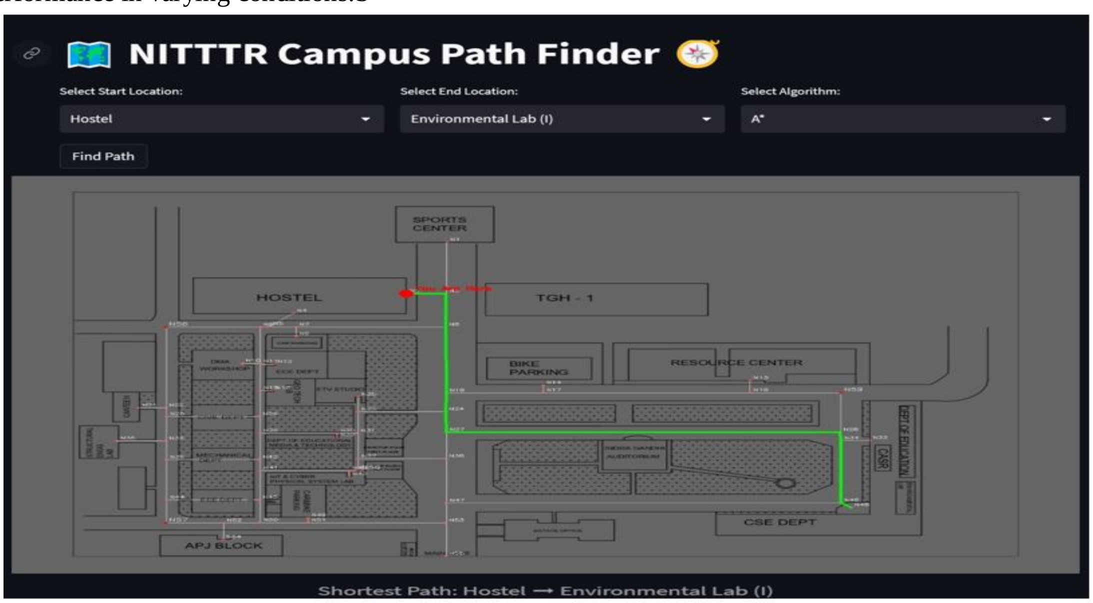

Fig. 4 Displayed route of AI- based pathfinding system

V. CONCLUSIONS AND FUTURE SCOPE

Artificial Intelligence based Navigation System Using Autonomous Robot are becoming valuable tools for improving navigation, accessibility, and the overall user experience on university campuses. These robots use advanced technologies such as LiDAR and Inertial Measurement Units (IMUs) to provide efficient, real-time guidance, which is essential for navigating complex environments. One of their main roles is to assist visitors, students, faculty, and guests by offering reliable navigation support. Additionally, they can streamline campus operations by handling routine navigation-related tasks. With ongoing advancements in robotics and artificial intelligence, the future of Artificial Intelligence based Navigation System Using Autonomous Robot looks promising, indicating potential improvements in educational environments and other public spaces.

The ensuing AI-driven navigation system is an efficient solution to navigation issues on a campus. Its hardware and cognitive software integration offers real-time autonomous navigation. Areas of future work are: Multilingual speech guidance integration, real-time rerouting feature, extension to areas such as airports, hospitals, and museums and scalability through cloud-based path training.

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