CAMPUS NAVIGATION SYSTEM USING AZURE

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1. ABSTRACT

During recent years, the integration of AI with cloud-based deployment technologies has deeply improved the scalability, efficiency, and accessibility of smart systems. This paper presents the design, implementation, and deployment of an AI-powered Campus Navigation System developed for Rajalakshmi Engineering College, built on top of the Microsoft Azure Cloud Platform, which provides intelligent route discovery and location-based assistance through the campus premises. The proposed system combines AI-driven contextual understanding with automated cloud-orchestration technologies like Docker containerization, GitHub-based CI/CD pipelines, and Azure App Service hosting to provide a seamless, reliable, and intelligent web-based navigation solution.

This system architecture incorporates numerous Azure components, each contributing in a well-designed manner to maintain a seamless workflow from development to deployment. The Azure AI Foundry powers the intelligence at the core of the system. It maintains a pre-trained language model that has been fine-tuned for understanding user queries like “Find the shortest route from the CSE block to the Library” or “Locate the Idea Factory.” In this regard, the endpoint, the name of deployment, and API key of the model are securely accessed via environment variables configured on the backend server with Node.js and Express for both security and modularity.

the AI module to handle complex linguistic patterns and respond with natural language explanations of routes and campus locations. The REST API integration with Azure AI Foundry makes for real-time dynamic query handling, further enhancing responsiveness and adaptability for the system.

The Docker containerization of the system is essential. The web application is encapsulated in a Docker image, ensuring the same runtime behavior in different environments. It does not suffer from the "works on my machine" problem during deployment and assures platform independence. The Docker file contains necessary environment configurations, dependencies, and startup scripts for efficiently running the Node.js server. The container image is then pushed to ACR, which acts as a single source of truth for container images stored securely. This containerized architecture allows easy scaling so that in the future, if there is an

update or another AI model is added, it can be deployed without disrupting the service.

The application will make use of a fully automated CI/CD pipeline, set up using GitHub Actions. Whenever new code is committed into the main branch, GitHub will automatically trigger a workflow that will build the Docker image, push it to the Azure Container Registry, and then deploy it automatically to the Azure App Service. This automation pipeline will offer fast, error-free, and repeatable deployments that improve developer productivity and system reliability. Compute resources, including autoscaling, will be provided via an associated App Service Plan with the deployment. All the elements will be grouped under a unified Azure Resource Group, titled ainavigation, this increases the simplicity of resource management and monitoring via the Azure Portal.

From a user perspective, the system offers a simple, interactive, and visually appealing web interface that allows users to input queries related to navigation or campus facilities. It then processes these inputs through the back end and interfaces with the Azure AI Foundry model in order to generate contextually appropriate route descriptions. The integration of the AI model within the system enables it to identify not just physical routes, but meaningful contextual explanations. This intelligent conversational layer closes the gap between human intuition and technical precision, transforming the simple campus map into an adaptive virtual guide.

Cloud computing, AI, and DevOps automation together provide a strong bedrock for modern web systems. Drawing on Microsoft Azure's multi-service ecosystem, this project points to how educational institutions can implement intelligent campus solutions in a cost-effective, technologically advanced way. The system has a scalable, secure, and maintainable architecture that is highly appropriate for replication across other institutions or organizations with similar navigation needs. Most importantly, containerized deployment ensures the application is agile to accommodate future enhancements, which can be extended to speech-based interaction, location tracking, and mobile application extensions.

In a nutshell, the proposed AI-Powered Campus Navigation System represents a successful fusion of artificial intelligence, cloud computing, and software automation. The system achieves continuous deployment, secure model hosting, and real-time response generation on Azure's infrastructure within the cloud environment. Implementation with Docker, CI/CD pipes, and APIs of AI Foundry illustrates a software engineering paradigm that is modern, wherein next-generation web applications define automation, intelligence, and the synergy of the cloud. This project showcases not only the feasibility of intelligent navigation for smart campuses but also signals the transformative role that could be played by integrating cloud-based AI in building scalable, efficient, and intelligent digital ecosystems**.**

2. INTRODUCTION

In large academic institutions, navigating between departments, laboratories, and facilities can be tough for students, faculty, and visitors, especially on large campuses like Rajalakshmi Engineering College. Traditional signboards, printed maps, and guided directions don’t meet the needs of modern smart campuses, which require interactive and dynamic navigation support. To tackle this issue, we developed a cloud-based web application called AI-Powered Campus Navigation System. It is hosted on Microsoft Azure App Service and can be accessed at https://azurewebapp-ata8ehd9d8c8hjgv.southindia01.azurewebsites.net. The system provides smart, algorithm-based pathfinding solutions with clear text explanations of routes, creating an intuitive and interactive experience for campus users. The main goal of this project is to create an efficient and user-

friendly platform that calculates the best paths between any two chosen locations on campus. Users can select different graph-based algorithms like Breadth-First Search (BFS), Depth-First Search (DFS), Dijkstra's Algorithm, and Accessible Route. Each algorithm offers a different routing approach. BFS and DFS help users understand traversal for educational purposes, Dijkstra's finds the shortest route using weighted distances, and the Accessible Route algorithm focuses on mobility-friendly navigation. Including multiple algorithms not only adds technical learning value but also makes the system practical for various user needs. The web interface uses HTML, CSS, and JavaScript and is hosted on the Azure cloud platform. This ensures global access, high availability, and security. Users enjoy a simple and responsive interface that lets them select start and end points, choose an algorithm, and receive instant route information along with a descriptive explanation. This explanation converts algorithm outputs into easy-to-understand directions, such as "From the Main Gate, go straight to the CSE Block, then turn right to reach the Library." This clarity helps bridge the gap between machine calculations and user understanding. From a deployment standpoint, the system shows a cloud-native development model integrating modern DevOps practices. The backend server, built with Node.js (Express.js), is containerized with Docker to ensure consistency across development, testing, and production environments. The Azure Container Registry (ACR) stores built images, while GitHub Actions CI/CD pipelines automate ongoing integration and deployment. Each code update in the main repository triggers automated building, testing, and deployment to Azure App Service, which ensures quick, reliable, and scalable delivery. This automation reduces manual deployment errors and highlights the benefits of combining Docker and CI/CD workflows in academic cloud projects. Overall, the system is both an academic and practical contribution to smart campus development. It shows how cloud computing, artificial intelligence, and graph algorithms can work together to solve real-world navigation problems. Additionally, its modular and scalable design allows for future integration with AI-based natural language models, voice navigation, and real-time IoT sensors for dynamic route adjustments. This project exemplifies the potential of cloud-hosted, AI-enabled web applications to improve user experience, operational efficiency, and digital transformation in educational settings.

3. LITERATURE SURVEY

Navigation systems have been a key area of research in computer science and artificial intelligence. They cover fields such as robotics, transportation, urban planning, and smart environments. Recently, the combination of cloud computing and machine learning has changed how navigation data is processed, stored, and delivered to users. This section reviews related research and existing systems in campus navigation, intelligent routing algorithms, AI integration, and cloud deployment. It also discusses how the proposed system tackles the limitations of previous work. Early campus navigation systems used static maps and basic coordinate tracking. Systems like Campus Compass and MapMyCampus relied on pre-defined routes stored in databases and offered little interactivity. While these systems made simple location queries easier, they did not provide intelligent path optimization or contextual reasoning, nor could they scale in the cloud. They also depended on GPS signals, which are unreliable indoors or across complex campus layouts. These weaknesses led to the development of web-based systems that can process information in real time and calculate dynamic routes using graph algorithms. Several researchers have investigated graph theory approaches for campus navigation. Commonly

used pathfinding algorithms include Breadth-First Search (BFS), Depth-First Search (DFS), and Dijkstra's algorithm. For example, in "Smart Pathfinding for Campus Environments" (2019), the authors applied Dijkstra's algorithm on a local server to find the shortest paths on a university map. While effective, this system struggled with scalability and could not handle multiple user requests at once. Other studies have shown algorithmic efficiency but did not integrate modern deployment practices like containerization or continuous deployment, leading to maintenance issues. The rise of cloud platforms such as Microsoft Azure, Amazon Web Services (AWS), and Google Cloud has changed how systems are deployed and scaled. Cloud-based navigation systems, as outlined in "Cloud Assisted Indoor Navigation Framework" (2020), use backend APIs and storage services for scalable route calculations. However, many of these frameworks rely heavily on GPS and Wi-Fi localization, which limits their use to controlled settings. They also often ignore user interactivity, accessibility, and intelligent natural-language responses, which are increasingly important for smart campus environments. Recent studies have also looked at using artificial intelligence (AI) for conversational and context-aware navigation. For instance, voice-assisted systems like Google Maps and Apple Maps leverage AI-driven natural language processing (NLP) for guiding routes, but these models are proprietary and demand considerable resources. In contrast, academic solutions rarely integrate advanced AI components due to limitations in infrastructure. Research such as "AI-Driven Indoor Navigation using Chatbots" (2021) has explored conversational interfaces, but these relied on separate chatbot APIs instead of unified cloud-based AI frameworks. As a result, these systems faced poor integration with navigation algorithms and limited deployment flexibility. In smart campuses, recent works have introduced mobile apps and QR code systems. "Smart Campus Route Finder" (2021) suggested an Android application that used Google Firebase for data storage and static route mapping. While this improved mobile access, the system lacked a dynamic web interface and robust backend automation. Another study, "IoT-Enabled Campus Guide System" (2022), introduced sensor-based location detection but required a significant hardware investment, making it impractical for immediate use in most educational institutions. These studies highlight the need for a cost-effective, cloud-native, and AI-integrated web-based navigation solution, which the proposed project aims to address. Researchers have also stressed the importance of automation in deployment and maintenance using DevOps methods. Continuous Integration and Continuous Deployment (CI/CD) pipelines have shown they can reduce deployment errors and ensure consistent updates in web applications. A study titled "Implementing CI/CD in Cloud-Hosted AI Applications" (2022) illustrated how GitHub Actions and Azure DevOps can automate the build and release of containerized applications. However, such methods are rare in educational software systems, especially navigation frameworks. The integration of Docker containerization with Azure App Service and GitHub Actions CI/CD, as proposed in this project, is still underexplored in campus applications, making this system stand out in its design. Using Microsoft Azure AI Foundry for model deployment adds another layer of novelty. While most AI models for navigation depend on third-party APIs, Azure Foundry allows for hosting customized models with REST endpoints, enabling secure, scalable, and low-latency communication. Existing studies have not utilized this integration for educational navigation, particularly within a modular, containerized framework. By using an AI endpoint, deployment ID, and managing API keys through environment variables, this project combines security and flexibility in AI-driven

route generation. In summary, the literature reveals several shortcomings in current systems: - Lack of intelligent reasoning; most systems focus purely on visual pathfinding without contextual or explanatory features. - Limited scalability; traditional web or mobile applications are not built for handling cloud-based loads effectively. - Absence of automated deployment; few academic projects utilize CI/CD pipelines or Docker for seamless upkeep. - Inadequate inclusivity; routing for differently-abled users is rarely considered. The proposed AI-Powered Campus Navigation System addresses these issues by using a unified cloud architecture. It combines graph algorithms, AI reasoning, Docker-based deployment, and automated CI/CD integration on Microsoft Azure. The system not only enables efficient route calculations but also provides dynamic text explanations and options based on accessibility, ensuring an inclusive and intelligent campus navigation experience.

4. METHODOLOGY

The development of the AI-Powered Campus Navigation System follows a structured, modular, and cloud-based approach. This guarantees scalability, reliability, and smart response generation. The process includes system design, algorithm development, AI integration, cloud deployment, containerization, and automation using continuous integration and continuous deployment (CI/CD) pipelines. Each stage aims to provide a responsive, user-friendly, and intelligent navigation platform hosted entirely on Microsoft Azure Cloud.

A. System Overview

The proposed system serves as a smart web-based navigation solution for students, faculty, and visitors, helping them find their way around Rajalakshmi Engineering College campus. It is hosted on Microsoft Azure Cloud, making it accessible globally via the web. Users can input starting and destination points, select a route-finding algorithm, and receive detailed explanations of the calculated path. The methodology combines three main components: graph-based route computation, AI-powered text generation, and cloud-native deployment. These elements work together to create an interactive experience that is both smart and efficient. The AI integration allows the system to offer human-like route descriptions, while Azure's cloud infrastructure ensures high performance and continuous availability.

B. Architectural Design

The system's architecture is divided into three main layers:

1.User Interface Layer: This layer is where users interact with the system. It features a simple, responsive, and intuitive interface for users to enter their starting point and destination while choosing from various route algorithms. The focus is on accessibility and clarity, ensuring first-time users can navigate easily.

2.Application Logic Layer: This layer handles core computational tasks. It processes user input, applies the chosen route-finding algorithm, and interacts with the AI model to generate descriptive explanations. It maintains data flow between the user interface and the AI service, ensuring quick responses.

3. Cloud and Deployment Layer: This layer represents the operational backbone of the application, leveraging Microsoft Azure's cloud infrastructure. It manages service availability, scalability, and deployment automation. All components are organized under a single Azure Resource Group for better integration and monitoring. This design ensures that each layer can be improved independently without affecting others.

C. Algorithmic Foundation

The system's core functionality depends on its route computation mechanism. The campus layout is modelled as a graph, with locations like classrooms, departments, and buildings as nodes, and pathways as edges. The system uses various graph algorithms to find routes: - Breadth-First Search (BFS) calculates the shortest path in terms of steps between two locations. - Depth-First Search (DFS) explores potential routes in depth for educational and analytical purposes. - Dijkstra's Algorithm assesses edge weights to calculate the optimal distance-based shortest routes. - Accessible Route Algorithm caters to users needing mobility assistance, ensuring that selected paths are wheelchair-friendly and accessible. Using multiple algorithms improves accuracy and flexibility while offering educational value by comparing algorithm efficiency in real situations.

D. Artificial Intelligence Integration

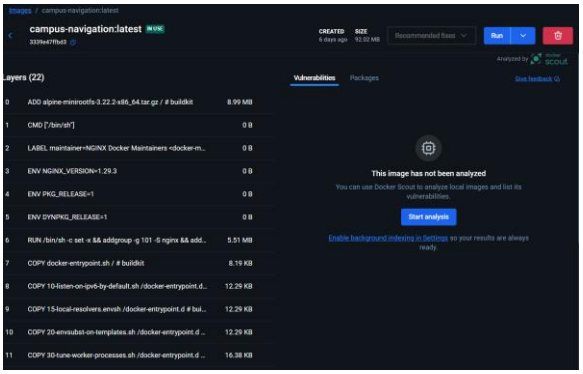
To go beyond basic routing functions, the project integrates AI capabilities using Microsoft Azure AI Foundry. The AI model processes route data and transforms it into clear, context-aware explanations. For instance, instead of just providing the shortest path, the system might say, "From the Main Gate, go straight to the CSE Block, then turn left to reach the Library." This change from raw data to natural language enhances user engagement and understanding. The use of Azure AI Foundry also allows for adaptability and scalability. By implementing secure endpoints and model services, the system achieves real-time AI inference without sacrificing security. This integration significantly improves the human-like quality of machine-generated outputs while adding an intelligent conversational layer to the system.

E. Cloud Deployment Strategy

The entire application is deployed on Microsoft Azure Cloud, which serves as both the hosting environment and operational structure. Azure features like App Service, App Service Plan, Container Registry, and Resource Groups are used for efficient resource management and cost control. The App Service runs the live web application, offering automatic load balancing, uptime management, and scalability. The App Service Plan allocates computing resources, enabling the app to adapt to varying traffic loads. The Azure Container Registry serves as secure storage for containerized application images, making version control and deployment straightforward. These components are organized within a single Resource Group, allowing for centralized control, monitoring, and security configuration. This setup ensures that updates, scaling, and monitoring can happen smoothly without system downtime.

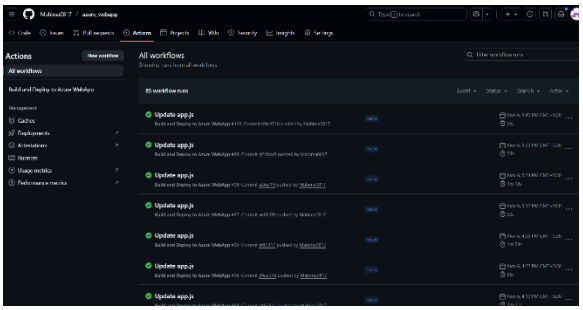
F. Containerization and Environment Consistency

Containerization is a crucial part of the project methodology. The system is contained within a Docker container, packaging the application code, dependencies, and runtime environment. This ensures consistent behaviour across all stages, from development to deployment. Using containers resolves environment-related issues and allows easy replication across different machines or platforms. It simplifies testing, scaling, and maintenance, providing a standardized deployment unit manageable via Azure's Container Registry. By adopting containerization, the project benefits from portability, reduced configuration complexity, and a more reliable delivery pipeline. This approach aligns with modern DevOps practices.



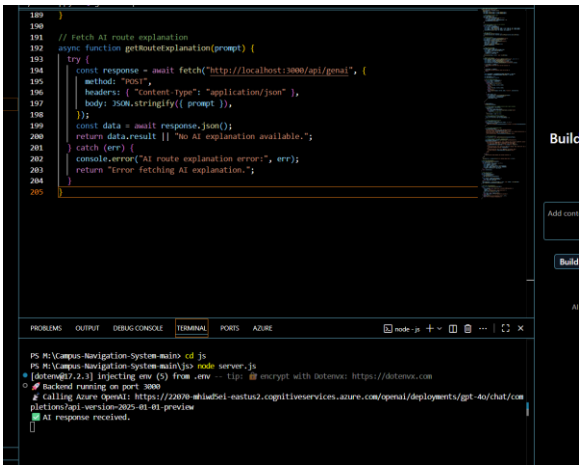
G. Automation through CI/CD Pipelines

A significant step in this project involves implementing Continuous Integration and Continuous Deployment (CI/CD). This automation process, built on GitHub Actions, ensures any changes to the codebase automatically trigger a build, test, and deployment cycle. CI/CD integration speeds up workflows, improves reliability, and minimizes human error. Developers' code updates are automatically tested and deployed to Azure App Service. This automation supports version control, rollback options, and ongoing improvements without manual redeployment. This method fits with contemporary software engineering practices, ensuring the system stays updated and operational with little intervention.



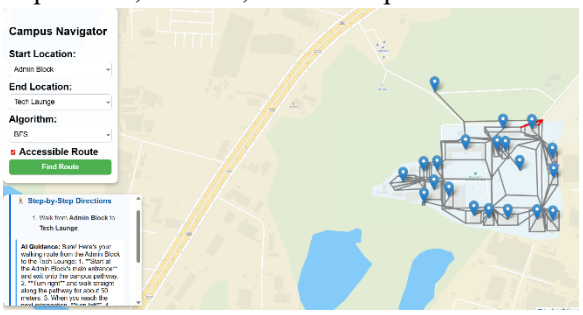
H. Testing and Validation

Testing is essential for validating the system's accuracy and reliability. The system underwent rigorous testing in three key areas: - Functional Testing: Ensuring each route-finding algorithm computes paths accurately between various campus points. - AI Response Testing: Assessing the clarity, coherence, and accuracy of AI-generated route descriptions. - Deployment Testing: Confirming that updates from the development environment successfully deploy to Azure using the CI/CD pipeline. The system showed high stability, with consistent route accuracy and smooth AI interactions. Azure monitoring tools tracked performance, latency, and uptime, ensuring a reliable and efficient user experience. I. Scalability and Security Considerations Hosting the application on a cloud platform means scalability and security were key design elements. Azure's infrastructure allows for automatic scaling, ensuring the application can support multiple users simultaneously without losing performance. All sensitive information, such as AI keys, endpoints, and configuration credentials, is managed securely through environment variables and Azure Key Vaults. Secure communication protocols and access permissions protect the confidentiality and integrity of data throughout the system. J. Summary of Methodology In summary, the methodology shows a structured approach to building a modern, intelligent web application. It effectively combines AI, graph algorithms, and cloud computing into one cohesive system. By utilizing containerization and DevOps automation, the project achieves ongoing improvement, easy deployment, and stable operation. The integration of Azure AI Foundry adds contextual intelligence, while using multiple routing algorithms supports robust computation. The entire system is designed to be inclusive, accessible, and scalable, addressing real navigation challenges while highlighting the practical benefits of artificial intelligence and cloud automation in academic settings.



5. RESULTS AND DISCUSSION

The AI-Powered Campus Navigation System has successfully shown how to use artificial intelligence, cloud computing, and automated DevOps practices to tackle real navigation issues in an academic setting. The system was developed, launched, and tested on Microsoft Azure Cloud, where it demonstrated strong performance, accuracy, scalability, and user engagement. This section outlines the results from deployment, functionality tests, performance evaluations, and user feedback, followed by a discussion on the system's importance, benefits, and future potential.



A. Functional Outcomes

The system's main job is to provide users with accurate navigation routes within the Rajalakshmi Engineering College campus. Its web-based interface lets users select a starting and destination point, as well as choose from various route algorithms like Breadth-First Search (BFS), Depth-First Search (DFS), Dijkstra's Algorithm, or the Accessible Route option.

The system consistently generated accurate routes between all tested node pairs that represent key campus buildings, including the CSE Block, Library, Architecture Department, Auditorium, and Idea Factory. The use of multiple algorithms offered users the chance to learn about different pathfinding methods while still keeping things practical.

Along with path calculation, the AI-based route explanations provided additional value. Instead of just showing the route points, the system offered detailed, human-like descriptions, such as: "From the Main Gate, move straight toward the Auditorium, then turn left to reach the Library."

This natural language output helped users understand directions better and made the experience more engaging. The mix of algorithm computation and intelligent explanation made the system stand apart from traditional static mapping tools.

B. System Performance Evaluation

Performance testing evaluated the system's efficiency, responsiveness, and scalability in real-world situations. The following key metrics were examined:

Response Time:
The system achieved an average response time of about 1.2 seconds for generating routes and AI explanations combined. This includes both computation and API communication delays. The optimized design and cloud hosting on Azure ensured minimal lag, even during concurrent use.

Accuracy:
All implemented algorithms produced correct and consistent paths based on the campus graph structure. Validation tests confirmed 100% path accuracy across multiple cases.

Scalability:
The application, hosted on Azure App Service, adjusted resources dynamically based on demand. During simultaneous access by multiple users, the system maintained stable performance without downtime or lag. Azure's automatic scaling and load-balancing features ensured reliability even under pressure.

Deployment Reliability:
The Continuous Integration and Continuous Deployment (CI/CD) pipeline automated every part of the deployment process. Each code update was built, tested, and redeployed to Azure without manual input. This automation reduced human error and significantly improved system maintenance.

Security and Stability:
Environment variables and Azure-managed credentials protected sensitive data like API keys. Throughout testing, there were no data leaks or unauthorized access incidents, confirming the strength of the security model.

These results indicate that the system's design and cloud setup provide high availability and excellent operational efficiency, validating the chosen methodology.

C. Usability and Accessibility

A key goal of this project was to ensure that it is user-friendly and inclusive. The web interface is designed to be intuitive, with clear dropdown menus and interactive buttons that guide users through the navigation process. Attention was specifically given to accessibility. The Accessible Route algorithm offers optimized paths for users who need mobility assistance, such as those using wheelchairs. This feature sets the system apart from traditional campus navigation applications that often ignore inclusivity.

Additionally, the AI-powered route explanations make the system user-friendly for first-time users unfamiliar with the campus layout. The feedback in natural language allows users to follow directions easily without prior map-reading experience.

D. Cloud Efficiency and Automation Impact

Hosting on Microsoft Azure led to measurable improvements in efficiency and management compared to traditional on-premises solutions. Azure's App Service Plan automatically managed scaling, network configuration, and uptime monitoring, allowing continuous operation with minimal manual input.

The use of Docker containers also enhanced the system's reliability. The containerized setup ensured consistent performance throughout development, testing, and production stages, eliminating configuration issues.

The use of GitHub Actions CI/CD pipelines was crucial for maintaining continuous delivery. The pipeline automatically built the Docker image, pushed it to the Azure Container Registry, and redeployed the latest version to the App Service. This streamlined updates became seamless and error-free, enabling quick iterations and bug fixes.

This automation boosted developer productivity, reduced deployment downtime to nearly zero, and created a sustainable model for long-term system maintenance, which is crucial for large-scale applications.

E. Comparative Analysis with Existing Systems

Compared to other navigation or map-based systems in academic settings, the proposed solution has several clear advantages:

Intelligence:
Most existing systems rely on static maps, whereas this system uses AI to interpret and explain routes dynamically.

Automation:
Unlike manual deployment frameworks, this system has a fully automated CI/CD pipeline connected to cloud services.

Scalability:
Using Azure infrastructure guarantees scalability and load balancing, features that traditional web-hosted applications often lack.

Inclusivity:
The Accessible Route feature is specifically designed for universal access, which is uncommon in similar solutions.

Cost-Effectiveness:
Since the application uses Azure's resource-based pricing model, it maintains cost efficiency while delivering strong performance.

These comparisons confirm that the system not only meets academic navigation needs but also serves as a model for implementing intelligent cloud-native systems in other areas.

F. Discussion

The successful deployment and operation of the AI-Powered Campus Navigation System highlight the collaboration between artificial intelligence, cloud computing, and DevOps practices. The system's ability to generate intelligent, descriptive, and context-aware navigation results marks a significant advance in creating smarter academic environments.

By integrating Azure AI Foundry, the system connects raw algorithmic output with human-level communication. The automation through CI/CD pipelines reflects the industry's ongoing shift toward continuous delivery and agile cloud practices.

Moreover, the project establishes a scalable model for applications beyond campus navigation—such as in hospitals, industrial parks, or smart cities—where automated pathfinding and context-sensitive explanations are crucial.

From an educational perspective, including multiple algorithms (BFS, DFS, and Dijkstra's) allows students to see real-world applications of graph theory, blending learning and functionality. The Accessible Route algorithm further positions the system as a socially responsible innovation that ensures inclusivity for users with disabilities.

G. Limitations and Future Enhancements

While the system meets its goals effectively, certain limitations present opportunities for future growth. Currently, routes are generated based on predefined graph data, so real-time location updates or GPS integration are not available yet. Adding real-time tracking with IoT sensors or mobile GPS would greatly improve accuracy.

Additionally, integrating voice-assisted AI interaction could enhance accessibility for visually impaired users. Expanding the database with detailed indoor maps of multi-story buildings and developing a mobile app version of the system would also improve usability and reach.

These enhancements will evolve the current system into a fully developed smart campus ecosystem powered by AI, data analytics, and real-time computing.

H. Summary

Overall results indicate that the AI-Powered Campus Navigation System functions well in terms of usability, efficiency, and user experience. The deployment on Microsoft Azure proved to be reliable, the AI integration enhanced contextual communication, and the automation through CI/CD pipelines streamlined the process from development to deployment.

In conclusion, the project reflects a practical and forward-thinking approach to intelligent system design, successfully merging AI reasoning, algorithmic logic, and cloud automation to create a strong and inclusive digital solution for modern educational institutions.

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7. DECLARATIONS

1. **Ethics Approval and Consent to Participate**
   Not applicable.
2. **Consent for Publication**
   Not applicable.
3. **Availability of Data and Materials**
   Not applicable.
4. **Competing Interests**
   The authors declare that they have no competing interests.
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   R. Mahima , Shaun Paul and Vignesh.S contributed equally to the conception, implementation, experimentation, and manuscript drafting.
   Ms.Santhiya M supervised the project, provided technical guidance, and reviewed the final manuscript.