International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 11, pp 444-452, November-2023

https://doi.org/10.47001/IRJIET/2023.711060

Internal Navigation and Crowd Management System for a University

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***Abstract* - Navigating through a campus to access various services provided by its departments, is challenging for visitors and students who are new to the university. It would be beneficial for visitors, students, and staff to get information of all locations that provide a specific service along with availability of each location. People who require services from a university could also benefit from a personalized recommendation service that makes suggestions for any questions they have regarding services provided by the university. This research aims to develop an easily accessible, voice-based internal navigation and crowd management system for universities. The researchers propose to use Bluetooth beacons for accurately identifying the location of a user, using the AR technology for a much more interactive way of navigating users, object detection methodologies for producing crowd density information, and using NLP for making personalized recommendations for any questions the user might have regarding a certain service.**

Keywords: augmented reality, internal navigation, image processing, natural language processing, voice recognition.

I. INTRODUCTION

In recent years, the spotlight has increasingly turned towards indoor navigation systems, acknowledging their potential to enhance user experiences and optimize efficiency across diverse indoor environments. These settings span from bustling shopping malls and busy airports to the intricate layouts of educational institutions like universities [1]. Conventional navigation systems, such as static maps and signs, fall short in delivering the dynamic and user-friendly experiences that contemporary users demand. This inadequacy is particularly pronounced for first-time visitors and individuals facing mobility challenges, amplifying the need for a transformative solution[2].

Augmented Reality (AR) has emerged as a pivotal remedy to these limitations. Its capacity to seamlessly layer digital insights onto the physical world creates an environment where users receive real-time visual cues and navigational directions [3]. The attraction of AR stems from its ability to offer personalized, interactive, and dynamic way finding experiences that transcend the complexities of interior navigation. By overlaying digital maps, routes, and points of interest onto the user's field of view, AR empowers individuals to swiftly identify destinations and make well-informed decisions regarding alternate routes and nearby amenities.

AR when coupled with synergistic technologies like people counting and Natural Language Processing (NLP), transitions universities into intelligent, user-centric domains. Universities stand to gain the capacity to proactively address the challenges posed by navigation and crowd control, thereby fostering a heightened university experience [4].

Furthermore, the amalgamation of NLP and Machine Learning (ML) promises to revolutionize the user experience of indoor navigation systems. NLP introduces an intuitive and user-friendly mode of interaction, enabling users to engage with the system using their natural language[5]. Meanwhile, ML's prowess in refining information delivery by tailoring recommendations based on prior user interactions positions it as an essential tool for enhancing the relevance and accuracy of system outputs[6].

The core of this endeavor lies in crafting an indoor navigation system that not only facilitates effective navigation but also harmoniously integrates crowd management capabilities. The potential applications of such a system encompass voice-based interactions, real-time visual cues, intuitive user engagement, and precise crowd density insights, all contributing to the orchestration of efficient crowd control. This multi-faceted approach ensures that the system remains adaptable to the myriad of scenarios characteristic of universities.

Yet, amidst the expansive landscape of research in indoor navigation systems, a noticeable gap remains. The integration of AR, NLP, Image Processing (IP), and ML into a cohesive system tailored exclusively for universities is an underexplored realm. This lacuna motivates the primary objective of this research: to create an accessible, voice-based internal navigation and crowd management system. The focus

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Volume 7, Issue 11, pp 444-452, November-2023

https://doi.org/10.47001/IRJIET/2023.711060

will be on guiding students, staff, and visitors within the sprawling university premises, facilitating their access to an array of services.

In pursuit of the main objective, the following sub-objectives were identified:

- **Exploration of AR-based indoor navigation**: Investigate the principles and feasibility of integrating Augmented Reality (AR) technology into an internal navigation system for a university, including its potential benefits and challenges.
- **Integration of NLP and ML techniques**: Explore the incorporation of Natural Language Processing (NLP) and Machine Learning (ML) techniques to enhance user interactions and provide personalized recommendations within the navigation system.
- **Design of crowd management strategies**: Develop strategies for efficient crowd management by utilizing the AR-based navigation system's capabilities, including real-time visual cues and crowd density information.
- **User-centered design and usability**: Assess the usability and user experience of the proposed internal navigation and crowd management system, considering factors such as response time, accuracy, and user satisfaction.
- **Performance evaluation in a university setting**: Evaluate the effectiveness and efficiency of the developed system through real-world testing within a university environment, measuring its impact on navigation efficiency and crowd control.

II. LITERATURE SURVEY

Several studies have investigated the challenges and opportunities of indoor navigation systems in the context of universities[7][8]. For instance, Kaisler et al. [1]identified the need for personalized and context-aware navigation systems that can consider the user's preferences, goals, and location. Lee et al.[9] proposed an indoor navigation system using Bluetooth Low Energy (BLE) beacons and evaluated its performance in a university building.

The implementation of voice-based interaction systems in various domains has gained significant attention in recent years. In the context of university environments, such systems hold the potential to revolutionize internal navigation and improve the overall university experience.

Studies conducted by Chen et al.[10] highlight the effectiveness of voice user interfaces in navigation systems. They report that Voice User Interfaces (VUIs) provide intuitive and hands-free navigation, addressing the limitations of traditional visual interfaces, especially in complex indoor environments such as universities.

Research by Wang et al. [11]demonstrate advancements in Automatic Speech Recognition (ASR) technologies, including deep learning-based models and transformer architectures. These studies emphasize the importance of accurate speech recognition in ensuring seamless voice-based interactions.

NLP plays a crucial role in interpreting user intent from voice commands. Chen et al.[10] and Yang et al. [11]explore various NLP techniques, such as named entity recognition and intent classification, to extract and process user queries in navigation applications. These studies underscore the significance of NLP in enhancing system understanding and context-aware responses.

Research by Jung et al.[12] focuses on evaluating the user experience and usability of voice-based interaction systems. They identify factors like response time, accuracy, and conversational flow as critical aspects impacting user satisfaction. These studies emphasize the need for user-centered design and iterative testing to optimize system performance.

People counting technology has evolved as a critical component in the advancement of integrated internal navigation and crowd management systems. Universities can maximize space use, reduce congestion, and ensure smooth crowd flow during diverse events by employing sensor-based technologies and data-driven insights [13]. Chen et al. underline the critical importance of people counting in such systems, allowing for real-time crowd density monitoring and informed decision-making [10]. People counting, in conjunction with other technologies like as AR navigation and NLP, creates a complete ecosystem that improves the entire university experience by providing timely information and assuring efficient movement [14][15].

The use of AR navigation within the framework of an internal navigation and crowd management system is a viable option for transforming how universities manage complicated landscapes. AR technology superimposes digital information on the actual environment, providing users with real-time visual assistance and contextual information as they navigate complicated paths and buildings. Garcia and Johnson evaluated the viability of AR navigation, proving its usefulness in increasing navigation experiences within educational environments [16].

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III.PROBLEM DEFINITION

The contemporary landscape of university campuses presents multifaceted challenges in terms of user navigation and crowd management. With a diverse community of students, faculty, and staff, coupled with dynamic infrastructure changes, there exists a compelling need for an integrated solution. Existing research predominantly focuses on isolated technologies, lacking a comprehensive system tailored to the unique requirements of universities. This research aims to bridge this gap by developing a unified internal navigation and crowd management system, which amalgamates AR navigation, precise people counting, NLP, voice-based interaction, and real-time crowd management. The primary objective is to create a system that enhances user safety, convenience, and experience while ensuring that it is adaptable to the diverse and ever-evolving campus environments. This research responds to the growing demand for a system that prioritizes user-centric solutions in campus management.

IV. METHODOLOGY

A) Voice-based Interaction System

The methodology for developing and evaluating the voice-based interaction system for the Internal Navigation System in the university involves several key steps as shown in Figure 1. The approach encompasses data collection, system design, implementation, and evaluation to ensure a robust and effective solution.

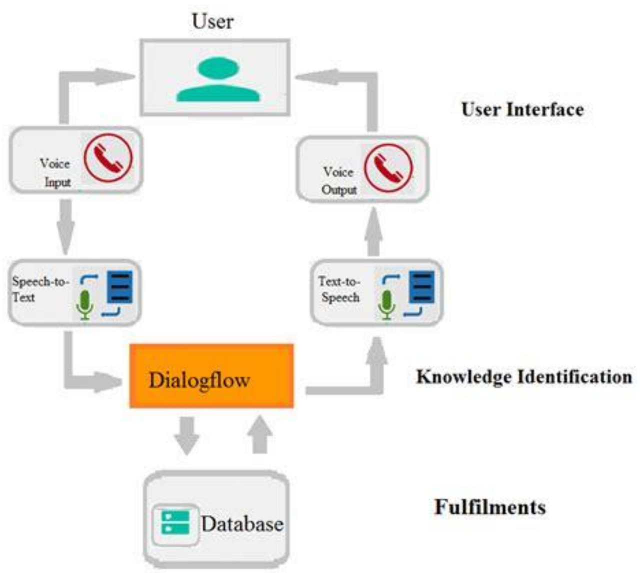

Figure 1: Architecture of a voice-based interaction system

i) Requirements Gathering

Conduct interviews and surveys with university stakeholders, including students, faculty, and staff, to identify their navigation needs and pain points. Gather feedback on existing navigation systems and preferences for voice-based interaction. Determine the specific functionalities and information users expect from the voice-based interaction system.

ii) Data Collection

Gather and curate a diverse dataset of voice samples reflecting the university's user demographics. This dataset will be used to train the speech recognition model to accurately interpret user voice commands.

iii) Backend Development

Implement the backend infrastructure to support the voice-based interaction system. This includes setting up databases for storing event information, operating hours, building layouts, and other relevant data. Develop APIs for communication between the voice interface and the Internal Navigation System.

iv) Voice Interaction System Integration

Implement the voice-based interaction capabilities to facilitate natural, human-like conversations between users and the system.

v) User Testing and Evaluation

Conduct extensive user testing to evaluate the usability and effectiveness of the voice-based interaction system. Invite a diverse group of users, including students, faculty, and visitors, to participate in real-world scenarios and use cases. Collect feedback through questionnaires, interviews, and observation of user interactions.

B) Personalized Recommendations

In this research project, NLP is being used to analyze user feedback on canteens in the university, as shown in Figure 2. NLP is a subfield of artificial intelligence that enables computers to interact with humans through natural language. The goal of this project is to use NLP to identify key features or aspects of food items mentioned in user feedback, such as taste, price, quality, etc. These feedbacks will then be used to recommend the best canteen for a specific food item.

NLP is essential in this project as it enables the analysis of unstructured text data, which is the most common type of feedback provided by users. By utilizing NLP techniques, it is possible to extract meaningful information from this data, including identifying frequently mentioned food item features or aspects. This data can then be used to make more informed recommendations for the best canteen for a specific food item.

The SQL Lite database was used for maintaining data required for making recommendations for desired food items.

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The TF-IDF vectorizer was used for encoding textual data into numerical format, after considering how its capabilities can be effectively used for the development of this component. Moreover, restaurant data, IMDB, and Amazon datasets were used for training the model. When preprocessing the datasets emojis were identified and disregarded, and regular expression patterns were compiled to return a pattern object.

The Collaborative filtering algorithm is then utilized to recommend canteens based on users' preferences. This algorithm identifies similar users based on their feedback history and suggests canteens that have received high ratings from those users. This helps to provide personalized recommendations based on the user's feedback history.

The Content-based filtering algorithm is also employed to recommend canteens based on the specific food item the user is looking for. The algorithm analyzes the keywords in the user's voice command and matches them with the feedback collected for that particular food item. This algorithm considers the features of the item and recommends canteens based on the similarity of the food item's features and user preferences.

Linear Support Vector Classifier (Linear SVC), a specific type of Support Vector Machines (SVM), was used as the classifier. Main reason for using Linear SVC was its capability of effectively separating by hyperplane.

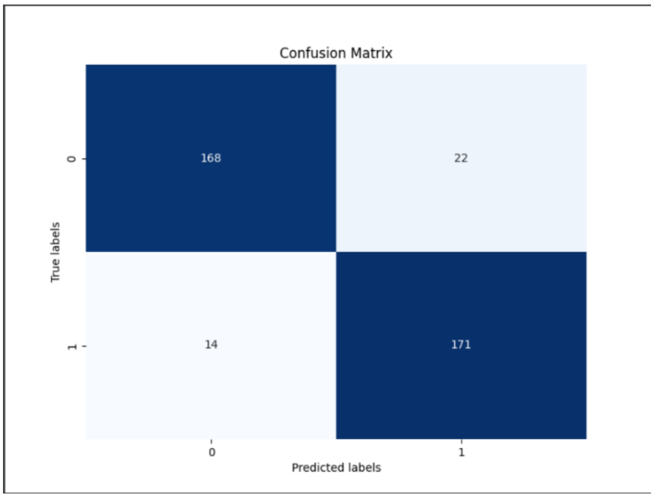

Figure 2: Confusion Matrix of Feedback Analysis

C) Crowd Management

The component that is responsible for getting the real-time count of people in a specific place, will use image processing techniques and then use the pre-processed footage as input for getting accurate head count through the applications of Object Identification and People Counting. The component uses video footage taken from a camera as the input and uses it to detect human heads and thereby identify humans.

Figure 3: Example of identifying humans by their heads

As shown in Figure 3, the component follows image processing techniques such as smoothing, filtering, and color correction to enhance the quality of the image and reduce noise. Then, it uses an object detection algorithm such as YOLO (You Only Look Once), to detect human heads in the video. The Open Images Dataset will be used to train the model to identify humans by their heads.

The component then tracks the detected human heads for ensuring that each person is counted only once and get the total count of tracked human heads in the video footage. The accuracy of the count of people is dependent on the quality of the input video footage, and the tracking algorithm used.

This component also uses a database for storing real-time people count information of selected places of the university. By using a database and a proper hierarchy for storing people count information, communication of captured information will be done more efficiently. The crowd density information will be updated real-time and will be used to provide a status of either "Available" or "Crowded".

D) AR Navigation

a) Mapbox

Mapbox is a mapping and location data platform that offers developers tools for creating customized maps and integrating location-based features. It provides APIs and SDKs for incorporating interactive maps, geocoding, routing, and spatial analysis into applications. Developers can customize map styles, markers, and overlays, and access extensive global map data. Mapbox supports data visualization, navigation, geocoding, and reverse geocoding services. It is a flexible and popular choice for developers

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looking to incorporate location-based functionalities into their applications.

Mapbox is used for developing the functionality of navigating the user to a selected location through a selected route. AR GPS plugin is used with Mapbox to implement the system's capability of displaying visual cues to the user.

b) Unity Hub and AR Core

Unity Hub is a software management tool developed by Unity Technologies. It serves as a centralized hub for managing Unity installations, projects, and versions. With Unity Hub, developers can easily install and switch between different versions of the Unity engine, access project templates, and manage add-ons and extensions. It simplifies the process of managing multiple Unity projects and ensures compatibility between Unity versions and project dependencies.

Google built the augmented reality platform known as AR Core. It gives programmers the resources and APIs they need to make AR experiences for Android smartphones. Virtual objects may interact with the actual world in a realistic way because to AR Core's characteristics, which include motion tracking, environmental comprehension, and light estimation. It gives developers access to the device's sensors and cameras, laying the groundwork for creating AR applications that allow for immersive and interactive experiences.

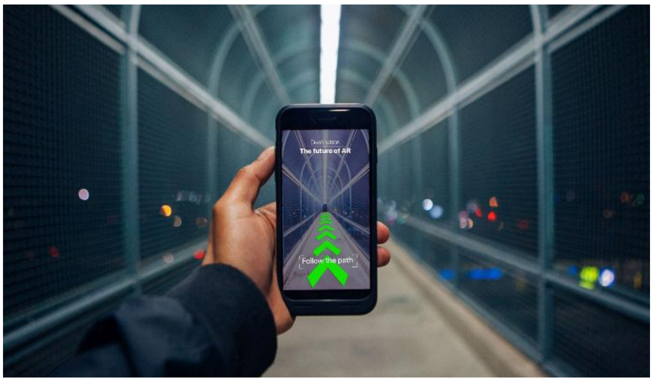

Figure 4: Example of AR navigation system implemented using Unity Hub and AR Core

As the example shown in Figure 4, Unity Hub, and AR Core can work together to create complex augmented reality apps. Unity Hub streamlines the management of Unity installations and projects, whereas AR Core enables developers to build AR experiences on Android devices, leveraging features such as motion tracking and environmental understanding to create compelling and immersive augmented reality applications.

c) Development of AR Experience

The AR platform Vuforia allows developers to create AR experiences on devices such as smartphones and smart glasses. Vuforia, with capabilities such as marker-based tracking and object identification, enables virtual material to be put and interacted with in the real environment. It has an SDK and APIs for simple integration and supports common programming languages like as C++, Java, and Unity. Overall, Vuforia is a widely used and capable platform for developing immersive AR apps.

Virtual navigation cues, directional arrows, and annotations may be layered onto the user's vision via the device's camera using Vuforia. Vuforia constantly detects and tracks the marks as users walk across the campus, updating the AR overlay in real-time to assist them along the best path. This dynamic display of navigation directions aids in intuitive navigation, allowing users to get at their destinations more quickly.

E) Native Mobile Platform

The selection of the Android platform is critical in the creation of the Integrated Internal Navigation and Crowd Management System for institutions. Android's diverse features and wide capabilities contribute considerably to the effective deployment of numerous components inside the system, delivering a seamless and user-friendly experience.

Users may easily interact with the system using speech and text instructions because to Android's sophisticated voice recognition and Natural Language Processing capabilities. Users can ask for directions, find out about upcoming events, or get information about crowd density using natural language. The incorporation of Google's speech-to-text technology into Android increases accessibility and inclusivity by accurately interpreting voice input.

It's important to mention that this mobile application is part of the AR Navigation System, a larger project aimed at providing a seamless and interactive way finding experience within the university campus. The AR Navigation System employs computer vision and ML algorithms to recognize the user's surroundings and offer visual directions through an augmented reality interface. The mobile application will also provide users with food recommendations within the university.

The mobile application will function alongside the university's Wi-Fi infrastructure to determine the user's location on the campus. When a user requests a recommendation, the app will utilize natural language processing algorithms to comprehend the user's request from

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their voice input. The application will then access the database of previous user feedback to identify the ideal canteen for the requested food item. The app will show the recommended canteen and provide directions to reach it.

a) Voice and Text Input

Users may easily interact with the system using speech and text instructions because to Android's sophisticated voice recognition and NLP capabilities1. Users can ask for directions, find out about upcoming events, or get information about crowd density using natural language. The incorporation of Google's speech-to-text technology into Android increases accessibility and inclusivity by accurately interpreting voice input.

b) Recommendation Output

Android's powerful text rendering and display capabilities help the system's capacity to offer advice and instructions in textual format. Android makes sure the output text is readable, understandable, and consistent with user preferences. Users are able to make educated decisions based on the system's recommendations thanks to the platform's sophisticated typography and layout features.

c) AR Navigation

The implementation of the system's AR navigation component depends on Android's support for AR technologies like AR Core. AR Core makes it possible to superimpose digital navigational signals onto the physical environment, improving users' awareness of their surroundings and streamlining tricky navigational paths. Users receive precise, real-time assistance thanks to Android's seamless integration of AR features, which promotes effective navigation throughout the campus.

d) User-Friendly Experience

A user-friendly interface for the navigation and crowd control system is made possible by Android's user-centric design principles and readily available developer tools. The platform enables simple interactions, seamless transitions, and attractive interfaces. Consistent design principles for Android's user interface promote familiarity and lower the learning curve, which speeds up adoption and guarantees users have a favorable overall experience.

A reliable framework that is capable of seamlessly integrating voice and text input, delivering suggestion outputs, enabling AR navigation, and presenting a user-friendly interface are all ensured by using Android as the system's base. These features work together to improve and streamline navigation on college campuses, encouraging user interaction, accessibility, and efficient crowd control.

V. RESULTS AND DISCUSSION

A) Voice-based Interaction System

The Voice-based Interaction component of the Internal Navigation and Crowd Management System demonstrated significant success in enhancing user experiences within the university campus. Through rigorous testing and user feedback, several key outcomes were observed:

1) Context-Aware Guidance:

The Virtual Assistant effectively provided context-aware guidance to users, offering precise directions and recommendations based on their current location and preferences. This feature greatly contributed to improved navigation experiences.

2) Real-Time Data Integration:

The integration of real-time data sources, including indoor navigation and crowd density updates, allowed the Virtual Assistant to offer up-to-the-minute information to users. This ensured accurate and timely responses to user queries.

3) Personalization and Continuous Learning:

The machine learning algorithms implemented in the Virtual Assistant enabled it to continuously learn from user interactions. As a result, the system adapted to individual preferences, providing personalized recommendations and responses over time.

4) Multimodal Interaction Support:

The Virtual Assistant successfully supported both text and voice inputs, accommodating various user preferences and accessibility needs. This flexibility enhanced the overall usability of the system.

5) User Feedback and Improvement:

The incorporation of a feedback mechanism facilitated valuable insights from users. This feedback loop proved instrumental in identifying areas for improvement and implementing enhancements to the Virtual Assistant's functionality.

6) Security and Privacy Measures:

Robust security measures, including data encryption and authentication mechanisms, ensured the protection of user data

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and interactions. This instilled confidence in users regarding the privacy of their information.

The success of the Virtual Assistant component can be attributed to its seamless integration with the overall system architecture. By combining natural language processing, real-time data integration, and machine learning, the Virtual Assistant delivered on its promise of providing intelligent, context-aware assistance.

The continuous learning capabilities of the Virtual Assistant were particularly noteworthy, as they contributed to an increasingly personalized user experience. As users interacted with the system, it adapted to their preferences and behavior, enhancing the quality of recommendations and guidance offered.

	precision	recall	f1-score	support
0	0.92	0.88	0.90	190
1	0.89	0.92	0.90	185
accuracy			0.90	375
macro avg	0.90	0.90	0.90	375
weighted avg	0.90	0.90	0.90	375

Figure 4: Classification Report

B) Personalized Recommendations

The precision, recall, and F1-score are considered crucial metrics for assessing the model's overall performance. As shown in Figure 5, for the macro-average, which computes these metrics across classes and then averages them, the model achieved a precision, recall, and F1-score of 0.9 for each. This indicates that the model maintains a high level of accuracy, balance between precision and recall, and an overall strong F1-score when considering both classes. For the weighted average, which considers class imbalances, the results are consistent with those of the macro-average, with precision, recall, and F1-score all achieving 0.9. This suggests that the classifier performs exceptionally well even when accounting for differences in class sizes. The results of the Linear SVC classifier are highly promising. The high precision, recall, and F1-scores for both macro and weighted averages indicate that the model can effectively distinguish between the two classes. The model excels in correctly identifying both "True" and "False" instances, as reflected in the high true positive and true negative counts. Furthermore, the low false positive and false negative counts highlight the model's ability to minimize misclassifications. It is worth noting that the balanced performance metrics for both macro and weighted averages demonstrate the classifier's robustness in the face of “True” and “False” class imbalances.

C) Crowd Management

The crowd management component of the internal navigation and crowd management system is fundamental to ensuring the safety and user experience on university campuses. In this section, we present the results and engage in a discussion of the crowd management component, emphasizing the process of collecting video feed, image processing techniques using OpenCV, and real-time availability information retrieval by the Android application.

1) Video Feed Processing

The video feed captured by surveillance cameras is sent to the backend at regular 30-second intervals, each frame represented as image files. The backend's ability to process these image files in near real-time is essential for accurate people counting and crowd density assessment. Through this process, the system continuously collects data on the movement and distribution of individuals across various campus locations.

2) Image Processing with OpenCV

Image processing techniques, particularly those implemented with OpenCV, play a pivotal role in detecting and counting the presence of humans in each frame. The application of OpenCV provides a robust and efficient means of performing object detection and image analysis. This results in accurate crowd counting, even in scenarios with varying lighting conditions and occlusions.

3) Real-Time Availability Information Retrieval

The Android application is the primary user interface for accessing crowd density and availability information. It calls a specific API endpoint on the backend, which in turn retrieves and provides real-time availability data for various campus locations. This information allows users to make informed decisions about their routes, such as selecting less crowded pathways or venues.

D) AR Navigation

Implementation of AR navigation demonstrated promising results. User testing revealed that the system accurately overlaid virtual navigation instructions onto the real-world view, simplifying navigation within the university campus. Feedback from users highlighted the system's accuracy, with most participants praising its ability to guide them to their destinations with minimal errors.

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1) Visual Cues and Animations

The integration of visual cues and animations within the system significantly enhanced the navigation experience. User feedback confirmed that the addition of visual elements, such as directional arrows and contextual animations, not only improved navigation accuracy but also made the process engaging and enjoyable. Users reported that the system effectively bridged the gap between real and virtual environments, making navigation more intuitive and user-friendly.

2) Personalized Navigation Routes

The implementation of machine learning algorithms to suggest personalized navigation routes was met with favorable responses. User preferences and real-time factors, such as crowd levels, were considered to generate efficient and customized routes. User testing confirmed that the system provided efficient route recommendations, saving users time, and contributing to effective crowd management.

VI. CONCLUSION

AR navigation, enabled by systems such as AR Core and Vuforia, provides dynamic and interactive wayfinding experiences. Users may overlay digital information on their real-world perspective, receive contextual assistance, and interact with virtual features, transforming how people move and engage on campus. The use of people counting technology guarantees data-driven crowd control, maximizing space usage, and boosting the entire campus experience during events and peak periods. NLP and voice-based interaction bring natural and intelligent communication, allowing users to engage with the system in a smooth manner and acquire contextually relevant information.

As universities continue to expand as varied and dynamic ecosystems, the system proposed by this literature solves the issues associated with navigation and crowd control, encouraging a user-centric and technologically sophisticated campus environment. However, issues such as technological implementation problems, user uptake, and ethical implications must be carefully considered.

VII. FUTURE SCOPE

This research paves the way for further exploration and improvement of the Internal Navigation and Crowd Management System in the future. The following are potential research directions that could be explored in this area:

i) Enhanced Personalization

Future work based on this research may concentrate on improving the customization of AR navigation by incorporating user preferences, historical data, and real-time contextual information. This might lead to customized navigation experiences that adapt to individual requirements.

ii) Real-Time Decision Support

Increasing the system's capability to give real-time decision assistance during emergencies or unforeseen situations will help to improve campus safety. Crowd management in dynamic circumstances might be improved by using predictive analytics and adaptive navigation techniques.

iii) Intelligent Spatial Design

Investigating the incorporation of AR navigation and crowd management factors into campus spatial design and infrastructure planning might result in improved physical layouts that favor efficient mobility and user experience.

iv) Multi-Campus Integration

Expanding the system's scope to serve multi-campus or bigger university settings might entail dealing with scalability issues, various user demands, and interaction with current campus administration systems.

v) User Experience and Accessibility

Doing user-centric research to assess the system's usability, accessibility, and user satisfaction might result in iterative changes and a better knowledge of user preferences.

By focusing on these possible improvements, the Internal Navigation and Crowd Management System's potential to provide a more efficient, and user-centered university campus experience can be realized, contributing to the advancement of smart campus environments.

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NOMENCLATURE

Abbreviation	**Definition**
AR	Augmented Reality
ASR	Automatic Speech Recognition
BLE	Bluetooth Low Energy
IP	Image Processing
ML	Machine Learning
Linear SVC	Linear Support Vector Classifier
NLP	Natural Language Processing
SVM	Support Vector Machines
VUI	Voice User Interface
YOLO	You Only Look Once

Citation of this Article:

Piyumantha H. P. A. H., Prabhash D. V. S., Weerasinghe T. K., Weerasiri R. T. K., D. I. De Silva, “Internal Navigation and Crowd Management System for a University” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET,* Volume 7, Issue 11, pp 444-452, November 2023. Article DOI https://doi.org/10.47001/IRJIET/2023.711060

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