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A* Algorithm and Unity for Augmented Reality-based Indoor Navigation

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***Abstract*— Indoor navigation systems play a crucial role in enhancing user experience and efficiency within complex indoor environments. This paper presents an innovative Augmented Reality (AR) based indoor navigation system that leverages the Unity framework and Wi-Fi positioning (Fusion of Wi-Fi signals and Geomagnetic Fields) to provide accurate and immersive navigation for users. The proposed system combines the power of AR technology with positioning techniques to offer real-time navigation assistance within indoor spaces such as shopping malls, airports, and large buildings. Unity, a widely used game development engine, is employed to create an intuitive and visually appealing AR interface, overlaying relevant information onto the user's view of the physical environment.**

***Index Terms*— Indoor Navigation, Augmented Reality (AR), AR-based Tourism, Wi-Fi, Indoor Positioning, Unity, AR Mapping, A* algorithm, Real-time Navigation, Artificial Intelligence**

I. Introduction

Navigation techniques have been through a great evolution in history, continuously changing and improving the way people traverse from one destination to another. In the contemporary era, navigation is simplified to a great extent with the advent of technologies such as Google Maps, it provides visible pathways and guidance in routes to its users. A cornerstone of modern-day navigation systems is the widespread use of the Global Positioning System (GPS), i.e. satellite-based GPS. It offers precise tracking ability to guide people to their concerned locations. However, even as GPS remains ubiquitous, it is not without its own limitations.

Augmented Reality (AR) represents the integration of real-world technology and virtual elements, it thus can be aptly described as a mixture of virtual and real-world content, interacted with in real-time and registered in 3-dimensional space. AR, along with its ability to seamlessly blend digital information with the physical world, provides a transformative way to different domains. This includes tourism as well. One such application is the real-time visualization of navigation information which is within the physical environment, which makes directions and different pathways intuitively comprehensible.

There are several methods for visualization of virtual and augmented reality-based applications. The mode of projection and visualization must be considered before developing an AR application.[1]

The implementation and development of this technology is facilitated through the 3D engine of unity. It is a versatile and renowned platform for experiences in mixed reality, rendering graphical interfaces, and diverse applications, which also includes educational virtual reality systems. Unity 3D acts as a foundation tool for creating an immersive and interactive experience, it ensures that the capabilities of AR in tourism are realized completely. AR-based systems used in navigation stand out for their cost effectiveness and accessibility, mostly because they

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don’t rely on high-end hardware or not also on inertial sensors. The objective can be achieved by using simple devices such as mobile phones with cameras which can be able to scan the environment.

This paper proposes an efficient method to provide real-time indoor navigation using augmented reality (AR) and built-in sensors of mobile devices. This method uses markerless vision recognition technology. The proposed technology uses the mobile device’s camera, Unity’s NAVMESH technology and the A* algorithm in ideal lighting conditions. Although this method provides relatively accurate positioning, it might fail in low-lighting conditions. To combat this specific scenario, magnetic fields and Wi-Fi signals are used for localization. AR technology is used to replace the traditional two-dimensional map with a real-time immersive navigation system.

II. RELATED WORK

Umashankar et. al discussed the growing possibility of Augmented Reality in tourism and tools to build an application. The paper explains the processing happening from the client’s and server’s side. It aims to provide an interactive experience for the tourists by providing heritage information at any time. The application works by focusing the camera of the device on the monument. Then the frames from the scan are compared with the location-tagged images stored in the database. Once matched, the information is overlayed on the real world on the screen. [2]

Sebastian et. al created a prototype for indoor navigation using Augmented Reality inside a mall. The user is presented with a list of shops in the mall and can choose one of them as their destination. They used features of the environments as position markers, instead of requiring special markers or other infrastructure. They implemented feature-based indoor navigation. [3]

Ravinder et. al proposed an interactive indoor navigation system that makes use of image processing and augmented reality. The camera searches for a trained marker in the environment to determine the user’s position. After detection, the detected maker location becomes input to the route planner module. [4]

Ramesh et. al suggests the use of QR codes as markers that provide a simple solution to the indoor navigation problem. In their project, the system asks the user to register and log in with the credentials. Once logged in, the camera on the smartphone is enabled. Guidance to the desired location is provided in the form of arrows augmented on the screen. [5]

Bakhmut et al. used augmented reality to create a web application for their research which allowed users a virtual tour of the campus. They overlaid 3D constructions of buildings on campus and landmarks onto actual photographs taken with the help of a smartphone camera, by using image recognition technology and also tracking technology. The application had more detailed information about the historical and cultural importance of each location. Moreover, solely being dependent on AR web applications may have limitations on breadth and depth of information as directly compared with real-life guide tours. The virtual tours may lack a unique individual touch and also the ease of asking questions in real-time, which can be significant to some visitors or individuals wanting to know specific insights. Additionally, technical glitches like compatibility issues, connectivity problems, or application inconsistencies may also arise, which can affect the overall experience of the user [6].

III. EXISTING SYSTEMS

Inertial measurement units (IMU) and Wi-Fi/Bluetooth-based methods are the widely used indoor positioning techniques utilized for local navigation. An inertial measurement unit typically comprises components like an accelerometer, gyroscope, and compass recorder. However, it is observed that the accuracy of navigation using these sensors often falls short of anticipated levels. Researchers in the field have previously explored technologies such as Simultaneous Localization and Mapping (SLAM), Radio frequency identification (RFID), Unity, and Vuforia as means of tracking indoor locations. While these technologies offer promising capabilities, they all have their own respective drawbacks in terms of accuracy and cost-effectiveness. They also tend to be resource-intensive, particularly in terms of battery consumption on mobile devices. This excessive power drain can result in premature device shutdowns, significantly impacting user experience.

Wi-Fi fingerprinting has become popular recently due to its non-requirement of line-of-sight measurement of access points (APs) and is highly applicable in indoor spaces which are complex. Wi-Fi-based positioning has low hardware installation costs and high availability because Wi-Fi is commonly deployed inside buildings nowadays [7]. The process is time-consuming since it uses Wi-Fi signals by fingerprinting technique as well as associating the signals with location. Obstacles inside buildings may also produce multipath effects, resulting in inconsistent accuracy.

Simultaneous localization and mapping (SLAM) uses both Mapping and Localization and Pose Estimation algorithms to build a map and localize the user in that map at the same time. [8] The primary sensor used in this technology is the device’s camera. Also, the device uses a gyroscope and accelerometer. SLAM technology showed its benefits and drawbacks throughout application testing. The location is established quite accurately, up to centimetres, in well-lit areas and with the smooth movement of the smartphone. In dim lighting or when the smartphone is moving swiftly (blur appears in the image). Camera problems are the most common: the device's rotation is not read, therefore further navigation is impossible. [9]

Radio frequency identification (RFID) is composed of two components: tags and readers. It is a wireless system. The primary approach of RFID positioning is to use the tag as the object's unique identifier and measure the spatial position based on the received signal strength indication (RSSI) of the radio communication between the reader and the tag put on the object. [10]

Furthermore, it's important to highlight the role of augmented reality (AR) technology in modern navigation solutions. AR has gained prominence for its ability to enhance navigation experiences by overlaying digital information onto the physical world. However, the effective implementation of AR often hinges on the presence of specific hardware components that may not be universally available in smartphones. Notable examples include devices like Google Glass and Google Cardboard, which offer augmented reality functionalities but are not standard features on all mobile devices. In general, AR navigation works in the following manner.

TABLE I. COMPARISON OF INDOOR POSITIONING TECHNIQUES

Sr. No.	**Positioning Technology**	**Accuracy**
1.	Wi-Fi signals	80%
2.	Radio frequency identification (RFID)	87%
3.	Simultaneous Localization and Mapping (SLAM)	90%
4.	AR Mapping	93.3%

1. Capture real-world surroundings from the user’s point of view.
2. Obtain the user tracking location.
3. Generate virtual data based on real-world views.
4. Register the physical information provided by the real-world view and display the user information, resulting in augmented reality.[11]

According to [12], AR Mapping provides the maximum accuracy as compared to other indoor positioning techniques as shown in Table I.

An AR navigation application was developed for the Sunway University campus information and plans about the floors and university were gathered. [13] They built a system using the Wi-Fi positioning technology along with utilizing the earth’s geomagnetic field to locate the user’s position using an SDK. The authors proposed that the fusion of Wi-Fi signal and magnetic strength provided a better accuracy range. In order to gather location data, including Wi-Fi signals and magnetic fields inside the building, the fingerprinting process requires both physically going about the Sunway University campus and calibrating the device's sensors Fig.1.

The Mobile Campus Navigation Application makes use of AR Mapping for indoor positioning using the Unity engine. A model of the campus is created in Unity and with the help of ARCore, the user’s position as well as pathfinding is done. [12]

IV. PROPOSED SYSTEM

Using the above-mentioned technologies, we propose to build an Augmented Reality based Indoor Navigation system that allows users to navigate in indoor spaces with directions to the desired location in the environment. The application asks the user to select the destination which is already fed into the database. After the camera scans the surroundings in perfect lighting conditions, the algorithm calculates the distance to the destination and shows directions on the screen in the form of trackers.

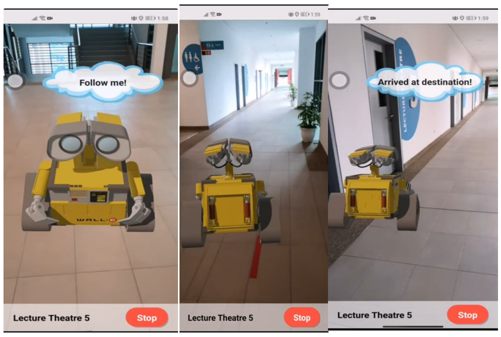

Figure 1. Sun-U app - AR Navigation

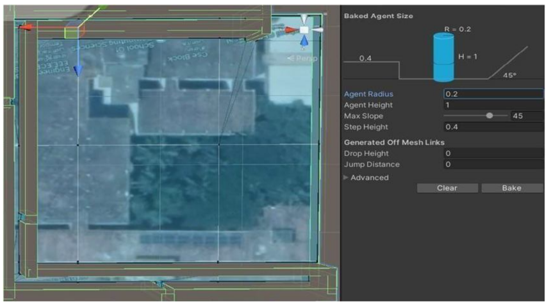

Figure 2. AR mapping using Unity

A. Flowchart

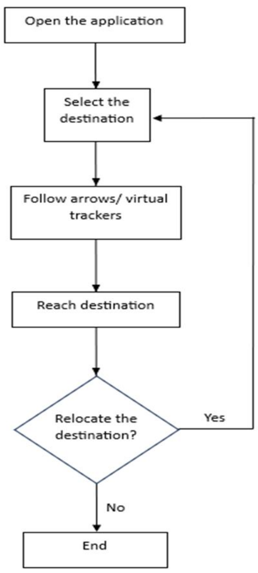

Figure 3. Flowchart of the AR application

The overall functioning of the app can be simplified using the flowchart shown in Fig. 3. It involves two parts- positioning of the user and the pathfinding technique.

B. Architecture design

The system consists of two parts: positioning and pathfinding. Positioning or localization ensures the accurate location of the user in the indoor space whereas pathfinding provides route guidance techniques in order to calculate the distance and direction to the desired location.

Fig. 4 explains the workflow and architecture of the application. The system combines two indoor positioning techniques- AR mapping and Fusion of WiFi signals and Geomagnetic fields. The proposed system uses signals from routers to detect the user's position in a low-visibility environment. It makes use of Wi-Fi signals, magnetic field and inertial sensor to provide indoor positioning, whereas the AR guidance is provided by ARCore SDK. Once the user initiates navigation, sensor data from the device is collected and delivered to the server. The positioning and wayfinding information are computed and fed back to the devices.

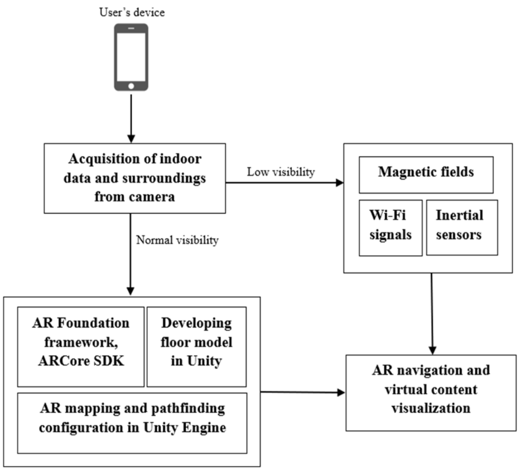

Figure 4. Architecture design

The AR Foundation framework offers a cross-platform SDK for creating augmented reality experiences. AR-Core is one of the main elements of the AR Foundation framework. It performs AR mapping as an indoor positioning technique in perfect visibility conditions. A model of the environment is created using Unity assets and is used for AI-based navigation-mesh baking. It performs vision recognition to scan the environment and identify the user's location. NAVMESH agent is used for path-finding. NAVMESH agent allows users to create characters that can intelligently move around the scene, using navigation meshes that are created automatically from our Scene geometry. The AR line is drawn in the given model based on the NAVMESH data. By identifying accessible and inaccessible regions and determining the quickest route to the intended destination, line renderers employed as tracking lines will penetrate utilizing NAVMESH data.

C. User Interface

This proposed system aims at building an indoor navigation system with an AR tracking element that overlays directions in real-time space to guide users to the destination. The Unity 3D Platform and AR Foundation are responsible for the project's AR component, in which an app is developed to recognise the real-time plane target using a mobile phone camera. The user can select their destination from the available categories of the environment. Once selected, the route is calculated and the virtual trackers are shown on the screen that interact with a real-time environment that shows directions to the destination. It also provides rerouting if the user does not follow the given guidance and performs re-localization of the user.

D. Pathfinding Techniques

A Algorithm*: The A* algorithm is a popular choice for AR-based applications. It finds the shortest path between points of interest while considering obstacles efficiently. A* combines the benefits of Dijkstra's algorithm and heuristic search, making it suitable for real-time navigation with interactive AR overlays. The shortest path is produced by both algorithms, however, the A* produces a quicker and more effective solution. Because Dijkstra's method keeps trying to improve an initial approximation (cost) of each node, it runs slower than A*. It takes longer to get to the target node as a result. Unity finds a path between two points using the A* algorithm. [14]

By changing the heuristic functions, the A* method might be considered an improvement over Dijkstra's algorithm. When using Dijkstra's algorithm, the overall trajectory value will be decreased by using A*. At the ideal moment, A* will provide the best answer. When searching for a path without any obstacles on the map, the A* method performs just as fast and effectively as the Dijkstra algorithm. When a map encounters an obstacle, it is able to find a way around the obstruction rather than becoming stuck in it.[15]

E. Route Guidance Techniques

In the realm of indoor navigation, digital two-dimensional maps have conventionally served as the go-to tool for offering guidance. Nonetheless, research findings have underscored the limitations of computer graphics in adequately representing the real world. Consequently, users often encounter challenges when attempting to reconcile the map's depiction with their physical surroundings, leading to potential confusion as they must continuously cross-reference actual landmarks and directions with those presented on the map. To enhance the user experience, Augmented Reality (AR) technology has emerged as a more immersive guiding solution. AR seamlessly overlays virtual images onto the real-world camera view, departing from the conventional digital two-dimensional map approach, which provides a third-person perspective of the environment. With AR, users are presented with a first-person view of their intended direction, promoting natural interaction with the device. Notably, AR has been demonstrated to reduce the time and cognitive workload associated with human wayfinding behaviors.

V. Result And Discussion

The proposed system combines two indoor positioning techniques – AR mapping and Signal Fusion(Wifi signals and Geomagnetic fields). Unity is used for AR mapping and Indoor Atlas SDK is used for Signal Fusion. We've tested both the systems individually and demonstrated the use of both these techniques.

IndoorAtlas SDK uses magnetic field, Wi-Fi signals and inertial sensor to provide indoor positioning and path-finding services. We've tested the IndoorAtlas SDK in a small area of a college. A room plan for the area was created and it was mapped using IndoorAtlas SDK. Various waypoints were established over the area, and their locations were recorded using the fingerprinting of multiple signals. The SDK uses Wi-Fi Signals, Geomagnetic fields and inertial sensors for fingerprinting. The accuracy of waypoints' position can be improved by recording the movement of the user over the area multiple times. The mapping quality of the Geomagnetic fields and the mapping coverage of Wi-Fi signals can be understood through the Fig 4 & 5 respectively. We've created a 3D model of the same area in Unity using NavMesh agent. It is demonstrated in the Fig 6.

Thus our demonstration proves that these two technologies can be implemented individually and we propose the use of those technologies alternatively to increase their efficiency and accuracy as a whole. When combined together, the cons of these two technologies (AR mapping: Fails in bad lighting conditions; Signal Fusion: Overall less accuracy compared to AR mapping, but accuracy is independent of the lighting conditions) can be eliminated.

Figure 5. Geomagnetic mapping quality (IndoorAtlas SDK)

Figure 6. Wi-Fi mapping coverage (IndoorAtlas SDK)

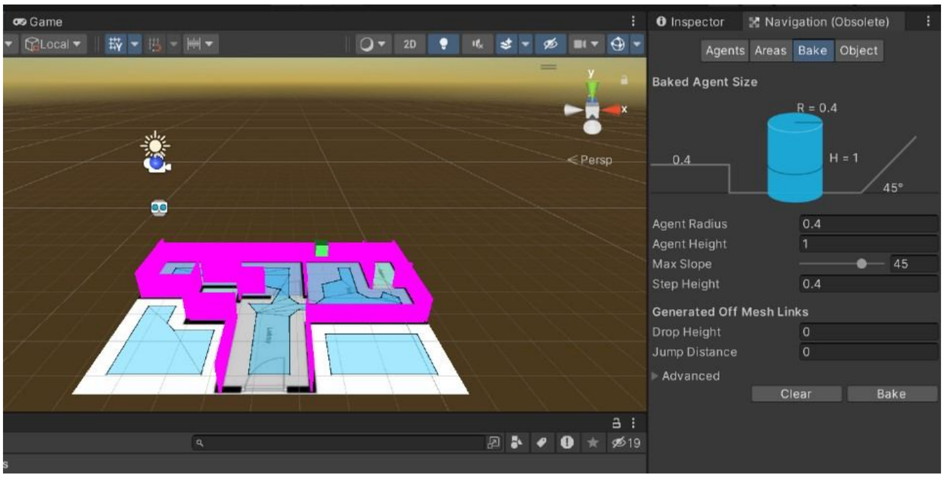

Figure 7. 3D model of a room using NavMesh agent in Unity

VI. LIMITATIONS

There can be limitations of the application and these difficulties can arise due to different smartphone hardware quality and different configurations. The versions of the operating system can be different as well. Furthermore supporting required hardware like minimal RAM required and processors complying with it are important to obtain support of augmented reality. There is also concern about the difference between operating systems like iOS and Android being used. [16]

Moreover, our system makes use of existing sensors (from Wi-Fi routers) for positioning, and not all buildings may be equipped with all area-covered routers. Additionally, there can be black spots in places even where routers are used, these can be places of weak signals, thus this can negatively affect the accuracy of the application.

For a moving user, AR systems need to constantly determine the position of a user surrounding the virtual object within the environment because the identical object generated by the computer needs to appear to be stationary. Managing the visualization of available content within AR view to maintain the readability of the information is also a challenge, especially on a mobile device with small displays. [17]

VII. CONCLUSION

Our proposed next-generation indoor navigation system seeks to transcend the limitations of current indoor positioning technologies. By offering users a precise, energy-efficient, and universally accessible indoor navigation experience, we aim to redefine indoor navigation across various sectors such as tourism, retail stores, airports, shopping malls, etc. This system has the potential to enhance user experiences in indoor spaces, providing a reliable and intuitive means of navigation. What makes our proposed system different from the existing systems is the use of two technologies for indoor positioning in different circumstances that increase the accuracy and avoid downtime of the application.

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