SURVEY ON the Transforming Retail With5G: Unlocking Immersive Augmented Reality Shoping Experience

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Abstract— This research harnesses Augmented Reality (AR) to revolutionize the retail experience, merging the tangible supermarket environment with a dynamic, virtual overlay. Leveraging mobile applications, users gain access to interactive product visualizations and optimized aisle navigation, significantly streamlining shopping and reducing temporal expenditure. Employing advanced sensor fusion, the system facilitates seamless indoor positioning, guiding users via efficient pathfinding algorithms to their desired items. A meticulously crafted 3D spatial model of a supermarket, rendered within Unity, forms the foundation. NavMesh technology ensures robust and responsive navigation. Real-time product recognition is achieved through Vuforia's markerless tracking, seamlessly integrated with the smartphone camera. The system's performance is anticipated to be drastically enhanced by the advent of 5G Beyond (6G) communication networks, promising ultra low latency, high-density connectivity, and exceptional throughput, thereby elevating the user-layer Quality of Experience (QoE). This paper investigates the synergistic interplay between 5G Beyond and AR, exploring its transformative potential in the burgeoning field of immersive retail. The research culminates in a functional AR-enabled indoor navigation system, seamlessly fusing Unity and Vuforia to deliver an intuitive and immersive shopping journey. Future iterations may incorporate personalized recommendations, dynamic promotional displays, and interactive shopping lists, further amplifying the system's utility and consumer appeal.

Keywords—5GBeyond, Product location, Augumented Reality, Indore Navigation, AndriodApp, Unity, Vuforia Navemesh

INTRODUCTION

The modern supermarket, while a marvel of consumer accessibility, often presents a labyrinthine challenge to shoppers. Traditional shopping experiences are frequently marred by inefficiencies, leading to frustration and wasted time. Customers grapple with the daunting task of navigating crowded aisles, deciphering complex store layouts, and searching for specific products amidst a sea of options. This inherent difficulty in efficient navigation disrupts the intended convenience of the supermarket, transforming what should be a straightforward errand into a time-consuming and sometimes stressful ordeal. The need for an innovative solution to alleviate these challenges is increasingly evident

Enter Augmented Reality (AR), a transformative technology that promises to bridge the gap between the physical and digital worlds. By overlaying computer-generated images onto the user's real-time view, AR offers a powerful tool for enhancing perception and interaction. In the context of supermarket shopping, AR can provide a seamless and intuitive navigation experience, effectively guiding customers to their desired products. The ubiquitous presence of smartphones, equipped with cameras and screens, makes AR a readily accessible solution for the mass market. The advancement of smartphone technology has brought computational power to our fingertips, making them ideal platforms for sophisticated AR applications.

The core challenge in implementing AR for supermarket navigation lies in providing accurate and reliable real time user location at an affordable cost. However, recent technological advancements and readily available tools are making this goal increasingly attainable. The integration of AR with robust platforms like Unity and Vuforia enables the creation of interactive overlays that display product information and aisle directions directly on the user's smartphone screen.This approach transcends the limitations of traditional navigation methods, such as GPS or beacons, by offering a more personalized and context-aware experience. Furthermore, the development of future network technologies, such as 5G Beyond and 6G, will provide the necessary bandwidth and low latency for seamless AR experiences, even in densely populated and dynamically changing environments.

The primary motivation behind this endeavor is to develop a user-friendly application that simplifies product search and optimizes shopping routes. By allowing users to select the products they need, the application generates a personalized map that guides them through the supermarket. The use of QR codes strategically placed throughout the store ensures accurate location updates, enhancing the precision of the navigation system. Additionally, the ability to scan products for detailed information empowers users to make informed purchasing decisions. This approach not only streamlines the shopping process but also reduces the need for interactions with sales representatives, offering a more efficient and independent shopping experience.

Beyond the immediate benefits for shoppers, this AR-based navigation system has the potential to provide valuable insights for supermarket management. Supervisors can utilize the application to analyze customer behavior and track product interest, enabling them to optimize store layouts and product placement. The focus on developing an indoor navigation system tailored specifically for supermarkets distinguishes this work from existing studies that explore broader applications of AR. By prioritizing efficient and smart shopping experiences, while minimizing social interactions and time spent, this research aims to redefine the supermarket shopping paradigm. As network technologies continue to advance, the potential for AR in retail and other sectors will only continue to expand, promising a future where digital and physical experiences are seamlessly integrated

LITERATURE SURVEY

Early research in AR navigation focused on leveraging the technology for real-time virtual environmental visualization within mobile devices. Studies like [1] demonstrated the feasibility of integrating AR with AI navigation agents using Unity 3D and virtual trackers, eliminating the need for external hardware. Recognizing the limitations of GPS in indoor environments, researchers began exploring alternative indoor positioning methods. For instance, [2] aimed to develop a visual positioning and navigation system for handheld devices using AR. This push for reliable indoor navigation led to methodologies incorporating built in sensors and AR technology, as seen in [3], which utilized IndoorAtlas and ARCore to create a functional indoor navigation mobile application, highlighting the shift towards more accessible and cost-effective solutions.

The application of AR in retail, particularly for enhancing shopping experiences, has been a significant area of focus. Research by [4] showcased the potential of AR to aid individuals with reduced visual senses by developing a HoloLens-based application that provided product information, like expiration dates, directly within the user's view. This project emphasized the importance of modular and adaptable architectures, aiming to port the solution across various mobile platforms. User interface design for AR navigation was also a crucial consideration, with studies like [5] exploring the effectiveness of different visual cues, such as arrows and virtual landmarks, for orientation and spatial learning. These studies underscored the need to address perceptual and cognitive challenges when designing AR navigation systems.

More advanced indoor positioning techniques have been explored to enhance accuracy and reduce hardware dependency. Cankiri Z [6] proposed a marker-based AR navigation system integrating SLAM and IMU technologies within Unity's AR Foundation Framework. This approach focused on mapping indoor environments in 2D and generating visibility graphs for efficient navigation, aiming for high accuracy with minimal hardware requirements. Additionally, the integration of beacon technology for AR-based indoor navigation systems was examined in [7], prioritizing quick and safe guidance while improving spatial learning. The use of AR in conjunction with product recommendation systems, as highlighted in [8], further demonstrates the technology's versatility in creating personalized shopping experiences. Specific applications, such as AR-enabled mobile grocery shopping software that provides personalized health-related suggestions [9] and AR systems for distance based product identification [10], illustrate the sophistication of AR applications in retail.

Beyond traditional GPS and AR-based systems, researchers have explored alternative positioning technologies. Applications like Grook [12] utilize GPS for location-based services, such as booking sports facilities. Magnetic field-based localization [13, 14] has also been considered due to its infrastructure-free nature and immunity to obstacles like walls and roofs, although it faces challenges related to metal interference. Vision-based location methods, including markerless and marker-based tracking [15, 16, 17], have also been investigated. Markerless vision recognition, which relies on natural environmental features, offers the advantage of not requiring additional infrastructure but demands significant computational and memory resources. These diverse approaches highlight the ongoing efforts to develop robust and reliable indoor positioning and navigation systems, each with its own set of advantages and challenges.

PROPOSEDMODEL DESCRIPTION

This research successfully demonstrates a functional Augmented Reality (AR) system for product location search within supermarkets, employing a modular approach that integrates Unity's NavMesh for pathfinding, QR code positioning for accurate localization, Vuforia for image recognition, and AR path visualization. By developing a mobile application that accepts user-defined destinations, the system leverages QR codes strategically placed throughout the supermarket to update the user's location with precision.

Unity's NavMesh then calculates the optimal path, which is dynamically adjusted using the mobile device's motion sensors to reflect the user's movements. Upon each QR code scan, the user's position is refined, ensuring accurate guidance to the desired product's location. This holistic integration of technologies provides a seamless and intuitive navigation experience, effectively bridging the gap between the digital and physical shopping environments.

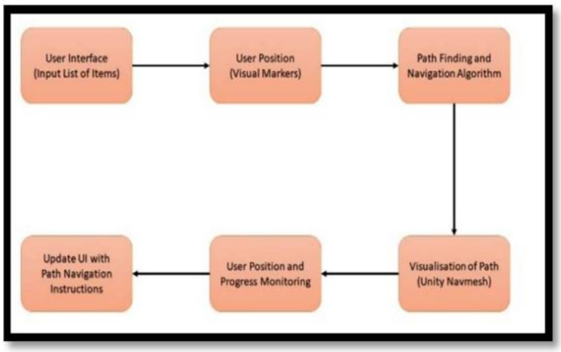

FIG 1; Proposed system of AR Mobile Application

A. *Unity NavMesh Navigation*

Unity's NavMesh system, a cornerstone of its robust game engine, provides an efficient and intuitive solution for indoor navigation through the utilization of the A* pathfinding algorithm. This system, integral to the creation of both 2D and 3D mobile applications, empowers developers to design virtual environments where characters and objects can intelligently traverse obstacles and follow optimized routes. The CalculatePath() function, a key component, enables the computation of paths between designated points on the navigation mesh, taking into account the scene's geometry and navigation data. By leveraging NavMesh, developers can create realistic and seamless navigation experiences, crucial for applications aiming to guide users through complex indoor spaces like supermarkets. Unity's NavMesh system typically employs a variant of the A* (A- star) pathfinding algorithm to compute paths.

B. *Vuforia*

Vuforia, a powerful Augmented Reality Software Development Kit (SDK), simplifies the development of AR applications by providing robust image and object recognition capabilities. Integrated seamlessly with Unity, Vuforia enables real-time tracking of 3D objects, images, and physical environments through advanced computer vision technology. Originally developed by Qualcomm and later acquired by PTC, Vuforia supports a wide array of targets, including images, objects, and surfaces, facilitating the creation of immersive AR experiences. Its ability to accurately recognize and track these targets makes it an essential tool for applications that require precise overlaying of digital information onto the real world, such as the supermarket navigation system described earlier.

C .*QR Code positioning*

QR codes serve as crucial navigational beacons in indoor environments, enabling precise and continuous location updates for users. In the context of supermarket navigation, strategically placed QR codes act as checkpoints, allowing users to accurately pinpoint their position and track their progress towards a designated destination. By scanning these codes, users provide real-time location data, which the system uses to refine pathfinding and provide accurate directions. The ZXing (Zebra Crossing) library, an open-source, multi-format barcode processing tool, plays a pivotal role in this process. Its robust implementation in Java and other languages, including C#, makes it a highly reliable and versatile solution for QR code scanning. This widely adopted library ensures that users can seamlessly interact with the QR codes, facilitating a smooth and efficient indoor navigation experience.

D. AR Path Showing

In this AR-driven navigation system, visual pathfinding is achieved through the use of a dynamic line indicator that guides the user directly to their desired product destination. This line, rendered using Unity's Line Renderer component, provides a clear and intuitive visual cue, effectively bridging the gap between digital instructions and physical movement. As the user progresses through the supermarket, the system dynamically updates the line, removing the old path and generating a new one based on the user's current position and the destination. The Line Renderer, a versatile tool for rendering lines in 3D space, is particularly valuable in AR applications for visualizing paths and trajectories. By leveraging the path data generated by Unity's NavMesh CalculatePath() function, the system converts an array of corner waypoints into a continuous line, which is then rendered in the user's AR view. This seamless integration of pathfinding data and visual rendering ensures that users can easily follow the optimal route, enhancing their overall shopping experience

E. Designing a 3D model of the supermarket

A meticulously crafted 3D model of a supermarket, built within Unity, serves as the foundational virtual environment for this indoor navigation system. This model, encompassing aisles, shelves, and essential features, ensures a realistic and usable space for users to virtually explore, locate products, and plan shopping routes. Leveraging Unity's powerful 3D modeling tools, the creation of this detailed supermarket representation is crucial for providing an immersive and effective AR navigation experience.

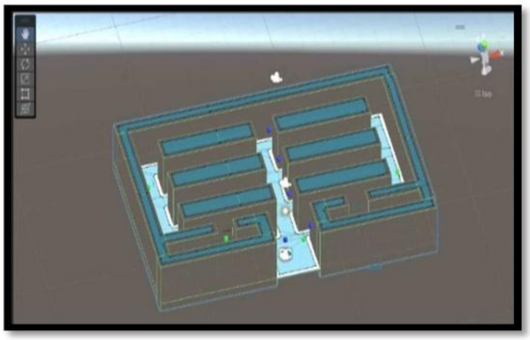

Fig: 2 A 3D model design of a supermarket developed in Unity

F. Overall Navigation Workflow

The indoor navigation system's workflow, as depicted in Fig. 3, centers on integrating critical modules to facilitate efficient product location within supermarkets. This system prioritizes network availability and leverages key components like Unity's NavMesh algorithm, Vuforia for image recognition, QR code positioning for accurate localization, and pathfinding algorithms for optimal route calculation. Initially, mobile sensors track the user's movement upon entering the supermarket, initiating the product search. Once a QR code is scanned, the application updates the user's position and calculates the shortest path to the desired product using pathfinding algorithms in conjunction with Unity's NavMesh. This dynamic process ensures real-time path visualization, guiding the user through the supermarket.

Simultaneous to path visualization, the system relies on continuous user location updates via QR code scanning, ensuring precise navigation to the destination product. This iterative process refines the user's position, correcting any deviations from the calculated route. Furthermore, the system incorporates a product description module, providing customers with detailed information about the products they encounter. This feature allows users to view product descriptions for future reference, enhancing their shopping experience and enabling informed purchasing decisions. The combination of accurate navigation and comprehensive product information creates a seamless and user-friendly shopping Environment

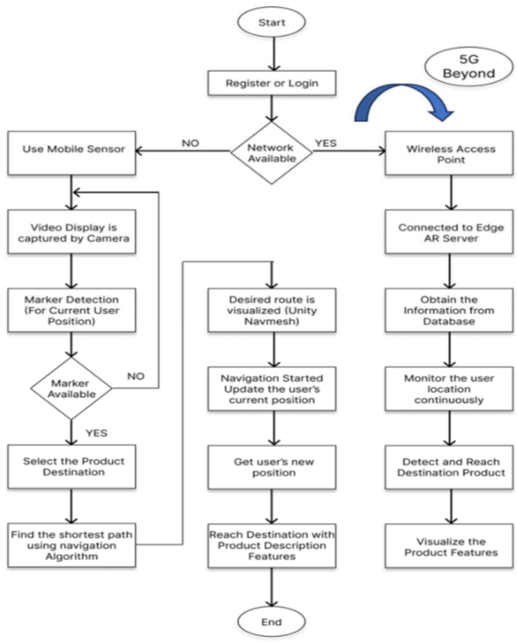

Fig 3 Workflow of AR Navigation System

G. Opportunities and Challenges in AR

Augmented Reality (AR) indoor navigation presents significant opportunities, yet faces notable challenges, primarily due to the limitations of current network technologies. While AR offers an intuitive way to guide users within indoor spaces, traditional GPS tracking struggles with signal attenuation, necessitating alternative solutions. Real-time AR applications grapple with issues like network bandwidth, latency, connectivity, and security, hindering the seamless integration of virtual information with the real world. Moreover, privacy concerns arise from the use of cameras, potentially causing discomfort among individuals. However, the advent of 5G Beyond technologies holds the promise of overcoming these limitations by delivering the necessary low latency and high network quality crucial for high-potential AR applications.

H. *Potential of 5G Beyond (6G) in AR*

5G Beyond (6G) emerges as a pivotal technology for fulfilling the escalating demands of AR/VR applications, particularly in terms of throughput and Quality of Service (QoS). The deployment of 6G networks promises to revolutionize user interfaces by delivering exceptional real-time interaction through robust signal strength across diverse AR/VR scenarios. It facilitates ultra-low latency, crucial for immersive AR/VR experiences, and provides high peak data rates with enhanced reliability, as illustrated in Fig. 3, which outlines the key features of 6G in AR/VR. This advancement addresses the fundamental need for seamless and responsive AR/VR interactions, paving the way for more sophisticated and engaging applications.

AR/VR technologies necessitate internet connectivity with extremely low latency and the ability to transport substantial data volumes via smartphones. 6G networks, with their higher frequencies and bandwidths, are poised to meet these stringent requirements. The capabilities of 6G, including reduced latency, increased throughput, enhanced connectivity, speed, and security, will enable the realization of numerous potential AR use cases. In industrial settings, private 6G networks will offer heightened security and leverage increased bandwidth and reduced latency, significantly benefiting AR/VR applications. Moreover, 6G is expected to mitigate thecurrent drawbacks of AR/VRconcerningQoS, security, and userprivacy over public networks. While 5G has already reduced latency for 3D models compared to earlier generations, 6G aims to further decrease latency to less than 100 microseconds, a critical improvement for demanding AR applications.

A comparative analysis of technologies, including real-time multimedia streams, 4G,5G Beyond, and 6G, presented in TABLE I and illustrated in Fig. highlights the significant performance advantages of 6G. The results demonstrate that 6G technology offers greater data rates, increased bandwidth, enhanced security, and reduced latency, while also supporting a larger number of connected devices with greater speed. This advancement underscores 6G's potential to transform AR/VR experiences by providing the necessary network infrastructure to support complex and demanding applications. The enhanced capabilities of 6G will enable the development of more immersive, responsive, and secure AR/VR environments, driving innovation and expanding the scope of these technologies.

TABLE 1 COMPARISION OF TECHNOLOGIES IN TERMS OF NETWORK PARAMETERS

Networks	Model	Latency	Data Rate	Bandwidth	Security
Real-Time Multimedia stream	2D Camera model flow	<120-150 ms	<10 Mbps	Depends on the stream of Multimedia used	80–90 %
	3D Camera model flow	<120-150 ms	137 Mbps – 1.6 Gbps		90%
3G,4G	3D model	<100 ms	1 – 10 Gbps	100MHz	99%
5G Beyond	3D model	<10 ms	> 20 Gbps	Sub 6 GHz, mm-wave (24GHz – 100GHz)	99.99 %
6G	3D model	<0.1 ms	1Tbps	Higher frequency of THz (>300 GHz)	99.999 %

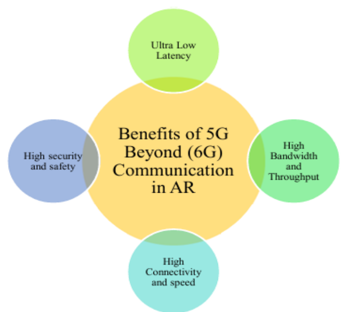

Fig. 4. Key Features of 5G Beyond in AR

RESULTS AND DISCUSSION

The development and testing of this AR-based indoor navigation application at the ALMART supermarket in VIT, Vellore, have demonstrated its effectiveness in achieving its core objectives, providing a seamless user experience. All functionalities performed as intended, validating the system's viability in real-world supermarket environments. Notably, this research also explored the potential integration of 5G Beyond technology to further enhance the system's capabilities. By leveraging the increased data transmission speeds and reduced latency of Ultra Low Latency High security and safety Benefits of 5G Beyond (6G) Communication in AR High Ba h ndwidt and Thr put ough High Connectivity and speed 5G Beyond, the application could support more responsive real-time updates and interactions within the AR environment, leading to a more fluid and efficient user experience. This consideration highlights the system's adaptability and its readiness to incorporate future technological advancements for Continious improvement

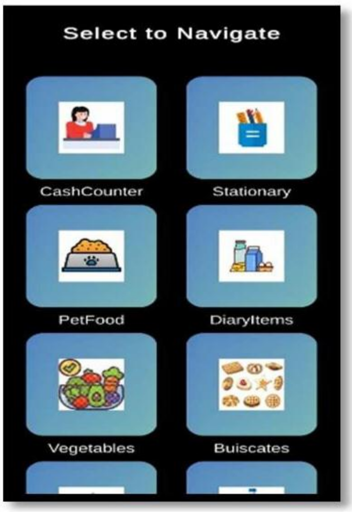

Fig.5. Navigation Page of the App

shown in Fig.5. This app provides an intuitive indoor navigation experience, specifically designed for locating products within a large space. Upon launching the application, users are presented with a straightforward choice: register or log in. Once authenticated, users can browse and select the item they wish to find. This selection triggers the core navigation process, which relies on QR code scanning for precise location tracking.

The user is then prompted to scan a strategically placed QR code. This initial scan establishes the user's starting point within the environment. Subsequently, as the user moves, scanning additional QR codes dynamically updates their location, As ensuring accurate navigation. After selecting the desired product, an augmented reality (AR) pathway is overlaid on the user's device screen, visually guiding them to their destination. This AR pathway manifests as a clear, directional line, effectively turning the user's physical surroundings into an interactive navigation map, simplifying the process of finding specific items within complex indoor spaces

Fig.6. Path displaying in the supermarket for navigation

From Fig.6 After a user's location is updated via QR code scan, the app displays an augmented reality navigation path to their selected destination. This path dynamically adjusts as the user moves, utilizing the mobile device's sensors to track movement and update the displayed route. This continuous, sensor-driven feedback loop ensures real-time path corrections, providing an accurate and responsive indoor navigation experience that guides the user efficiently to their desired location

Fig.7. Labelling of the items after arriving at the destination

After reaching the destination the item labeling will be displayed and further movement of the user will take place using QR code scanning which is illustrated in Fig.7.

Fig. 8. Product Description of Item-1, soap

Fig.8. Illustrates the snapshot of the product description testing conducted within our app, utilizing Vuforia's augmented reality capabilities. This immersive approach to product description testing enhances user engagement and facilitates informed decision-making during the shopping process.

TABLE II. COMPARISION OF INDOOR POSITIONING TECHNOLOGIES

Technology	No. of AR devices/ Km^2	End – to – end Latency	Data Capacity	Requirements
4G	< 1 million devices	< 50 – 100 ms	1 – 10 Gbps	Mobility support at higher user speeds
5G Beyond	1 million devices	< 1 – 10 ms	> 20 Gbps	Mobility support at > 500 Km/hr user speeds
6G	> 1 – 10 million devices	< 0.1 – 1 ms	≥ 1 Tbps	Mobility support at ≥ 1000 Km/hr user speeds

TABLE III. This analysis delves into the technical underpinnings of 4G, 5G Beyond, and 6G networks, specifically focusing on their suitability for Augmented Reality (AR) real-time communications. It meticulously compares these technologies based on critical specifications, including the number of AR devices supported per base station, a key metric for scalability. Expected end-to-end latency is another crucial factor examined, as it directly impacts the fluidity and responsiveness of AR experiences. Data capacity, vital for handling the bandwidth-intensive nature of AR, is also rigorously analyzed.

CONCLUSION

This ar-powered supermarket navigation application demonstrably enhances the shopping experience by significantly reducing time spent searching for products. The integrated product scanning feature further empowers users with detailed information, fostering informed purchasing decisions. As the landscape of augmented, virtual, and mixed reality continues to evolve, applications like this will become increasingly indispensable for streamlining everyday tasks. Looking ahead, the advent of 6g beyond promises to unlock even greater potential for ar/vr applications, offering unparalleled performance across diverse scenarios. Future iterations of ar navigation will prioritize an improved user interface, coupled with robust seecurity and safety measures, solidifying its role as a transformative tool in retail and beyond

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