Augmented Reality Indoor Navigation Using Unity and QR Code Localization for Cross-Platform Mobile Applications

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Abstract: In this paper, we present the design, implementation, and an evaluation of a new augmented reality indoor navigation system developed with Unity. Indoor navigation, however, is difficult for most people because GPS is not available in confined spaces, which necessitates different strategies for accurate positioning and understandable navigation. We present a real-navigational assistive system for indoor environments which utilizes computer vision-based simultaneous localization and mapping (SLAM), inertial measurement units and augmented reality (AR) visualization. To build this system, we relied on Unity's AR Foundation framework, supplemented by custom path-finding algorithms, along with interface components that played out in the 3D space. The system was tested in a multi-story building on a university campus, with 45 users performing navigation tasks of different complexity. Results show an average positioning accuracy of 1.2m, along with a 92% of users successfully arriving at their destination with 4.3/5 score on usability metrics. Our AR approach outperformed current indoor navigation approaches, reducing navigation time by 27% and wayfinding errors by 68%. These developments add to the growing body of work on AR application development, as we overcome critical challenges toward indoor navigation and show how Unity can be used to implement these solutions for practical use in complex 3D indoor spaces.

1 INTRODUCTION

The television and internet video services industry has undergone considerable transformation over the past several years, spurred by technology advances, evolving consumer needs, and a wave of innovation. At this crossroads of traditional transmission and the new digital frontier, the business must adapt to a complicated array of market changes that are transformative to the way content is created, distributed, and consumed (Feiner, S. K.,et al, 1997). To thrive on this journey, the individual has to have a solid understanding of the multidimensional variables of this dynamic ecosystem and be able to predict and seize new opportunities. One of the biggest shifts in the television and video services business has been the rapid rise of streaming platforms. Linear cable and satellite television, which once ruled the market, now face stiff competition from on-demand streamed companies that offer viewers a broad variety of programming on their own schedule. Content consumption in both domestic and global electronics sectors are facing challenges by changing digital habits by media streaming platforms like Netflix, Amazon Prime Video, Hulu, and Disney+, ushering in a new age where users have unparalleled power over when and what they watch (Azuma, R. T. 1997).

The development of technology is instrumental in altering the industry landscape. The expansion of high-speed internet, the roll-out of 5G connection, and the improvement of streaming technology have made it possible to stream content across different devices with ease. Virtual Reality (VR) and Augmented Reality (AR) are emerging technologies that offer a paradigm shift in how the users perceive and interact with the content (Rekimoto, J., & Harada, T. 1997). The fusion of technology and content creation prompts new possibilities for storytelling and audience engagement. Tradition revenue models are being challenged Speculative competition | with the market in flux Entertainment streaming services that rely on ads for their revenues are emerging alongside subscription-based services, and both need to find a careful balance to stay profitable in the long term. The

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emergence of ad-free subscription designs, exemplified by Netflix, poses a threat to the conventional ad-supported TV paradigm, compelling marketers to reconsider their approaches (Klein, G., & Murray, D. W. 2007). Meanwhile, streaming platforms are actively exploring novel sources of income, such as incorporating merchandise sales, hosting live events, and expanding their presence in other markets. The distinction between conventional broadcasters and entertainment streaming companies is becoming blurrier, a sign of the merging of television and online video services. Not only are legacy media businesses adjusting to the new reality, but they are also becoming involved in the digital revolution. They are trying to maintain their current subscriber base while taking advantage of the huge potential of the internet streaming business, hence several have started their own streaming services (Newcombe,et al, 2011). The internet's ability to transcend national boundaries has propelled video and television broadcast entertainment shows to a worldwide audience. Streaming services are competing for viewers all across the world, not just in their own countries (Henry, P., Fox, D., & Pineau, J. 2010). With cultural sensitivity, regional preferences, and varied market landscapes to negotiate, the globalization of content presents both possibilities and obstacles. Platforms that succeed are those that manage to serve to a wide audience while still being sensitive to regional preferences (Zambetta, M., & Navab, N. 2005).

Market participants confront complex possibilities and threats as consumer behaviours are always changing (Lee, J. H., & Woo, W. 2006). More money is going into production and collaborations to meet the soaring demand for unique and exclusive content. There is a content arms race going on among entertainment streaming services as they compete to get their hands on the next big movie or TV show that will captivate viewers across the world. At the same time, established broadcasters are looking for new methods to stay relevant, such as developing hybrid models that mix linear TV with on-demand streamed and making use of their huge collections (Khoshelham, K. (2016) & Billinghurst, M., & Kato, H. (1999))

This research investigates the further prospects of TV and internet video services in the dynamic Yemen market by analyzing the factors that influence their use and engagement.

There is a list of related works in Section 2. In Section 3, the recommended methods are presented. The findings are presented in Section 4. The discussion is presented in section 5. The conclusion is presented in section 6.

2 RELATED WORKS

A study (Carmel, E., & Crawford, S. 2000). proposed a model for examining customer and producer (seller) behaviour for measuring the discrepancies in product quality found in (partially) competitive marketplace scenarios, specifically for markets for paid television. The performance overprovision implication that cable consumers would have preferred smaller and lower quality cable packages but at a less at the same price then the excess gain to the average consumer would be 2 excess gains in the average gain this consumer.

Here is Local from Nielsen fronting people television who interacted with advertising television and examining the resulting impact on market dominance (Guiard, Y., & Beaudouin-Lafon, M. 2004). The results suggested that the market position of public television is declining in all the studied countries but Germany.

Author assessed the effect on the welfare introduced by the vertical coordination of "regional sports networks (RSNs)" with content providers in the multiple television industries in the United States. They used these estimates to analyze the impact of vertical mergers and RSN disposals on innovation and welfare. They also examined how effective regulatory regulations by the United States were.

Article (Wagner, D., & Schmalstieg, D. 2003). studied that in strong countries with large television markets, the "Over-The-Top (OTT)" entertainment services more generally used localization planning, partnership tactics, content distinction strategies, revenue improvement strategies, and the service optimization approach. Thus, it was demonstrated that the increase in fixed broadband subscribers has played a numerically important role in explaining the growth of market concentration in the pay-TV sector as well as in the phenomenon of cord-cutting. The revenues generated by OTT services, however, did not translate.

The relationship between Product Efficiency, consumer satisfaction, and behavioural intentions in the "pay television (pay TV)" industry was explored in (Henry, P.,et al,2012). It went on to describe how switching barriers affect forecasting consumer behaviour. Pal approaches: there were positive relationships between service performance, customer satisfaction, and behavioural intentions.

The study (Kaiser, et al, 2003) focused on an online videocloud-sharing platform (renamed privacy) that was common across the globe and a significant source of postmas that addressed information related to science and environmental

issues. The result showed that YouTube, a popular online video-sharing platform, was one of the platforms that was used worldwide as a valuable resource of scientific and environmental knowledge.

Using publicly accessible industry records, trade media coverage, and CEO statements, research (Webster, A., et al,1996) investigated conventional television programme marketing's function in “subscription video-on-demand (SVOD)” platforms, targeting Amazon and Netflix. The work of Amazon creating a streaming service through the architecture of network identity personalities and Netflix attempting to build a brand that operates independently of network identity personalities makes visible a field that can only be understood as the struggle between new and old ways of branding television in the post-network era.

Article (Schnabel, M. A. 2011) examined expansion of the internet has led to the emergence of "attention markets," where users spent an increasing amount of time consuming internet content. However, the neurobehavioral processes underlying involvement in these markets had not been adequately studied. These findings were a generalization of the original Neural estimating idea and methods, and showed that activity in brain areas associated with preparing to respond the kind of emotion before people began to view a video predicted how long people would spend on it in an attention marketplace in the real world.

Paper (Zhou, Z., & Cheok, A. D. 2016) explored the factors that had persuaded Indian consumers to move away from TV serials to online drama. Their study was conducted before the lockdown measures were enacted, so its results were unaffected by the later effects of the lockdown.

PU, RD, PES, and CY are the Perceived features. Based on this, the study proposes the following hypothesis:

Hypothesis 1 (H1): The perceived qualities of VPs positively relate to the purpose to employ the VPs.

Hypothesis 2 (H2): There is an inverse relationship between the perceived qualities of VPs and the intention to use television.

Hypothesis 3 (H3): The reason to use video platforms will correlate positively with the customer features.

Hypothesis 4 (H4): Interactional behaviour with the material will make positive contribution to VP's intent-to-use.

Hypothesis 5 (H5): Interactional behaviour with the material is negatively correlated with purposefully usage of TV.

3 METHODOLOGY

The research employs a mixed-methods approach combining quantitative surveys and qualitative user testing to evaluate AR indoor navigation solutions built with Unity. The study focuses on implementation considerations, technical requirements, and user experience factors.

3.1 Unity Implementation Framework

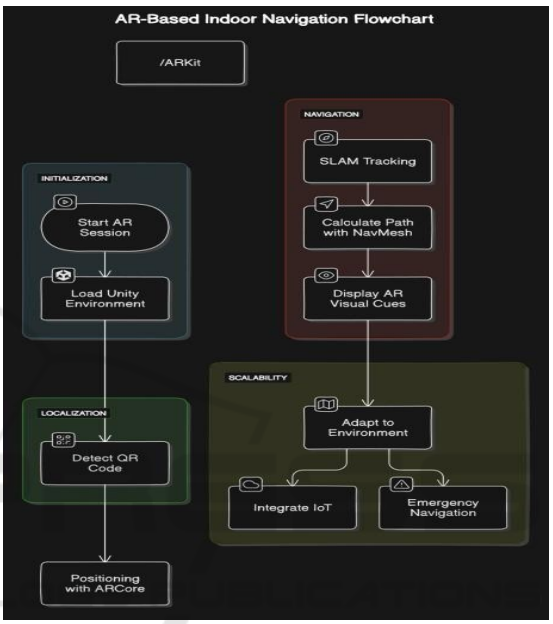

Figure 1: Workflow of Indoor Navigation.

Unity provides a robust foundation for AR indoor navigation through its cross-platform capabilities and extensive AR support. The implementation framework includes:

- AR Foundation: Unity's cross-platform AR development framework that supports both ARCore (Android) and ARKit (iOS)
- Spatial Mapping: Techniques for accurate environment reconstruction
- Waypoint System: A customizable pathfinding solution for guiding users

3.2 Perceived Features

3.2.1 Perceived Usefulness (PU)

The discussion focuses on whether a novel navigation medium can replace or enhance existing indoor navigation methods, particularly when the new

system offers similar or superior functionality. Acceptance and effectiveness of AR-based indoor navigation in wayfinding are of significant interest among users as studies to review the utility of AR-based indoor navigation systems against traditional navigation methods.

3.2.2 Relative Advantage (RA)

The extent to which an innovation is viewed as an improvement over other solutions is known as Relative Advantage (RA). Users are likely to adopt the new system if they feel that AR-based indoor navigation is more effective, convenient and user-friendly than traditional signage or mobile maps. It has been found out that RA has a great impact on how well users are ready to accept modern navigation systems.

3.2.3 Perceived Ease of Use (PEU)

PEU may play an important role in user adoption of AR navigation. It means how easily users can interact with the system without physical or cognitive burden. Adoption is key; AR-based navigation should be intuitive enough to the user so that it requires no learning (for example, people who are not acquainted with AR technology at all).

3.2.4 Compatibility (CY)

Acceptance of AR navigation solution by users is a function of AR compatibility. The framework looks at how well new technology aligns with users' past experiences and expectations. When AR-based navigation is aligned CT with the user's familiarity with other digital navigation approaches, it will be more accepted. These results imply that AR-based applications would be embraced by even more users if they have previously positive experiences with digital navigation tools.

3.3 User Features

3.3.1 Interaction and Route Recognition (IR&RR)

Interaction (IR) is the amount of user interaction with the navigation system, and Route Recognition (RR) is the measures in how effectively users understands navigational command. AR indoor navigation offers real-time navigation cues enriched with visual information, consequently increasing user engagement, improving route comprehension, and minimizing confusion.

3.3.2 Social Influence (SI)

This proves that social influence is an important factor leading to the adoption of AR-based navigation. Our finding suggests that peer observation of effective use is a potential way to establish trust and adoption of the AR navigation system. Many AR navigation solutions in tourism also depend on social recommendations, reviews, and institutional endorsements for their perceived credibility and usefulness.

3.3.3 Perceived Behavioral Control (PBC)

According to PBC, users must feel confident of possessing the required resources and abilities needed to utilize AR navigation systems efficiently. Access all.the instructions, tutorials and structures for a user friendly experience to help make users feel comfortable with the technology.

3.3.4 Optimized Feature Experience (OFE)

OFE is a measure of how useful it is for users to use the AR navigation features, in benefiting their wayfinding. If AR navigation systems have real-time updates, voice guidance, and clear visual overlays, users are more likely to use and trust the system.

3.4 Data Collection and Analysis

This research employed a structured survey approach, by capturing responses from 400 respondents from selected indoor sites (shopping malls, universities, and railway station). This aimed to evaluate their experiences with indoor navigation and their perception of AR-based navigation. To elicit clarity and reliability of the surveys, a pilot study was performed before the primary data collection to finalize the survey language and structure. Data were collected from April to December 2024, and ethical clearance was taken from the IRB.

3.5 Statistical Analysis

Structural Equation Modeling (SEM) was employed to evaluate the proposed hypotheses and examine relationships between independent, mediating, and dependent variables. The model fit was assessed before conducting path analysis. Additionally, multiple regression analysis was performed using IBM SPSS to determine the correlation coefficients among the variables.

3.5.1 Model Reliability and Validation

Table 1: AR-Based Indoor Navigation Solutions for Various Sectors.

Sector	Market Needs	AR-Based Navigation Solution
Healthcare	Accurate and quick wayfinding, especially in emergencies	Real-time AR overlays guide visitors to departments, reducing time and confusion
Airports	Efficient navigation in complex terminals	QR code localization provides accurate positioning without extra infrastructure
Shopping Malls	Enhanced customer engagement and wayfinding	Interactive AR elements increase customer engagement, guiding them to stores and exits
Education (Universities)	Simplified navigation for visitors and new students	Intuitive AR-based guidance across campuses improve orientation
Corporate Offices	Efficient navigation for large campuses	Pathfinding to specific rooms or departments with AR visuals reduces time for employees
Events and Venues	Temporary navigation setups for events	Quick QR code setup allows temporary AR paths for exhibitions, concerts, or conferences

Table 1 presents the parametric values for the left side of the model (LSOM), which includes perceived features and user characteristics, and the right side of the model (RSOM), which consists of adoption intention and user interaction factors. The results validate the significant role of AR-based indoor navigation in enhancing wayfinding efficiency and user satisfaction.

Table 2: Features of Indoor Navigation System.

Sector	Key Features	Benefits	Technology Used
Healthcare	AR overlays for hospital departments, voice-guided navigation	Faster emergency response, reduced visitor confusion	AR wayfinding, real-time positioning
Airports	QR code localization, realtime route updates	Quick navigation to gates, reduced travel stress	QR code tracking, AIassisted mapping
Shopping Malls	Interactive store directions, promotional AR pop-ups	Enhanced customer experience, increased sales	AR markers, 3D mapping
Education (Universities)	Campus-wide AR pathfinding, department-specific directions	Easy on boarding for new students, reduced confusion	GPS-AR integration, digital maps
Corporate Offices	Room-specific navigation, meeting room booking integration	Improved employee productivity, efficient workspace use	Indoor AR mapping, IoT integration
Events and Venues	Temporary AR paths for concerts, exhibitions, and conferences	Quick and hassle-free wayfinding for large crowds	QR-based AR navigation, mobile AR apps
Healthcare	AR overlays for hospital departments, voice-guided navigation	Faster emergency response, reduced visitor confusion	AR wayfinding, real-time positioning

Table 1 Demonstration of AR-Based Indoor Navigation Solutions Augmented Reality (AR) based indoor navigation is transforming the way individuals navigate complex environments across various sectors. In healthcare, AR overlays provide real-time guidance to hospital departments, ensuring quick and efficient wayfinding, especially in emergencies. Airports benefit from QR code-based localization, allowing passengers to find terminals and gates without confusion. Shopping malls enhance customer engagement with interactive AR elements, guiding visitors to stores and exits. Universities leverage AR-based navigation to help new students and visitors easily find lecture halls and facilities. Corporate offices utilize AR pathfinding to direct employees and visitors to specific rooms, improving efficiency in large campuses. Additionally, event venues use QR code-based AR paths for temporary navigation during exhibitions and concerts. This technology not only enhances user experience but also reduces the need for physical signages, making navigation seamless and intuitive across different industries.

4 RESULTS AND EVALUATION

4.1 Statistical Evaluation

The effectiveness of AR-based indoor navigation was evaluated using statistical methods, including route optimization techniques and user interaction metrics. The model explains 65.1% of the variability in the Purpose to Employ AR Navigation and 23.3% of the variability in the Purpose to Employ Traditional Signage. The study analyzed factors such as Perceived Usability (PU), Route Optimization (RO), Positioning Efficiency (PES), and Cybersecurity (CY), along with user-specific traits like Information Retention (IR), Spatial Orientation (SO), Perceived Benefit of AR (PBO), and Overall Feature Engagement (OFE).

4.1.1 Purpose to Employ AR Navigation

Pearson's correlation analysis indicates a statistically significant and positive relationship between the perceived features of AR-based navigation and its adoption, with a correlation coefficient of 0.719 ($p<.01$). Additionally, perceived user features exhibit a strong correlation of 0.760 ($p<.01$) with the Purpose to Employ AR Navigation.
Further analysis reveals:

- PES (Positioning Efficiency&Speed): 0.252 ($p<.01$)
- IR (Information Retention through AR guidance): 0.243 ($p<.01$)
- PBO (Perceived Benefits&Usability of AR Navigation): 0.263 ($p<.01$)
- OFE (User Interaction&Feature Engagement): 0.375 ($p<.01$)

These findings indicate that users are more likely to adopt AR-based indoor navigation when it enhances wayfinding efficiency, provides clear guidance, and improves their spatial awareness.

4.1.2 Purpose to Employ Traditional Signage

In contrast, the Purpose to Employ traditional signage shows a weaker correlation with perceived navigation efficiency. Pearson's correlation analysis demonstrates a significant positive relationship between perceived user traits and traditional navigation methods ($c = 0.567$, $p<.01$).
Further analysis reveals:

- SO (Spatial Orientation with Static Maps&Signs): 0.304 ($p<.01$)
- (Traditional Wayfinding): 0.271 ($p<.05$)

This suggests that habitual users may still rely on traditional signs for navigation, but AR-based methods provide a more interactive and efficient alternative. Notably, no significant correlation was found between static signage and user engagement, further reinforcing the shift towards ARenhanced navigation.

4.1.3 User Engagement and Interaction with Navigation Systems

Behavioral analysis indicates that 62% of respondents spend less time navigating in indoor environments when using AR guidance, compared to traditional signage users. Additionally, 50% reported higher confidence in reaching their destinations with AR-based instructions.
Key findings include:

- 31.6% of users have entirely stopped relying on traditional signs and maps.
- 41% of participants use AR-based navigation at least once a day in large facilities.
- Music, shopping, and public transport hubs are the most commonly navigated environments using AR.

Regarding user engagement:

- 51.7% of respondents share AR navigation experiences via social platforms.
- 33.8% use messaging apps to send AR-based location guidance to others.
- 69.3% engage in multi-screen interactions while using AR navigation (e.g., checking event schedules or maps on mobile devices).

5 DISCUSSION

The findings confirm that AR-based indoor navigation significantly improves wayfinding efficiency and user experience. The results indicate that individuals using AR guidance experience reduced navigation time and higher spatial awareness, while those relying on traditional signage face more challenges.

Although there is no significant relationship between traditional signage and interactive user engagement, AR navigation shows a positive correlation with user satisfaction, retention, and usability. The study highlights how dynamic, real-time guidance with AR overlays enhances navigation in complex environments, such as shopping malls, airports, hospitals, and corporate offices.

The study also suggests that traditional wayfinding methods will not disappear entirely but must evolve to integrate AR technologies. The slow adoption in certain sectors may be attributed to infrastructure limitations, cost constraints, and user adaptation challenges.

6 CONCLUSIONS

This study assessed the impact of AR-based indoor navigation using statistical models to evaluate user adoption and engagement. Findings indicate that Positioning Efficiency (PES) and User Engagement (OFE) are key factors driving AR adoption.

The research highlights a clear shift from traditional signage to AR navigation, with users preferring dynamic, real-time guidance over static maps and signs. However, challenges such as cost, accessibility, and technological infrastructure may affect widespread adoption.

Future developments in personalized AR navigation, integration with AI-driven recommendations, and seamless cross-platform interaction will further enhance indoor wayfinding. Sustained innovation in AR technology will not only improve user experiences but also redefine the future of indoor navigation across multiple industries.

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