Indoor Wayshowing with Markerless Augmented Reality: Design and Usability Evaluation of a Mobile Navigation Prototype in a University Faculty Building

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ABSTRACT

Newcomers to large institutional buildings often struggle to locate rooms and facilities because signboards and static floor plans provide limited guidance, while satellite positioning is unreliable indoors. This study addresses the problem of indoor wayshowing, the practice of communicating route information to wayfinders, within the Faculty of Information and Communication Technology (FTMK) at Universiti Teknikal Malaysia Melaka (UTeM). The study pursued three objectives: to examine the spatial characteristics of the faculty environment, to design a mobile augmented reality (AR) wayshowing application based on the identified requirements, and to evaluate the application in terms of usability and user acceptance. A markerless indoor positioning approach was adopted using the Vuforia Area Target feature, with the faculty environment captured through LiDAR scanning and the navigation path computed through the NavMesh feature in Unity. The prototype presents route guidance through a ground-rendered path by default, with an arrow indicator available as an alternative. Fifteen participants completed two wayfinding tasks of differing distances while applying the think aloud protocol, after which they answered the Handheld Augmented Reality Usability Scale (HARUS). All participants completed both tasks successfully. The overall HARUS score was 64.27 out of 100, slightly below the commonly cited benchmark of 68, with manipulability scoring 66.67 and comprehensibility scoring 61.88. Qualitative feedback traced the weaker comprehensibility score to insufficient status indicators, the absence of path occlusion at doorways, and a help panel that relied heavily on text. The findings demonstrate that a functional indoor wayshowing application can be produced with modest resources, and they offer practical design guidance for researchers and institutions intending to deploy AR navigation in complex buildings.

Keywords: Indoor Wayshowing, Augmented Reality, Markerless Positioning, Usability Evaluation, Handheld Augmented Reality Usability Scale

INTRODUCTION

Navigation systems have become part of everyday life in large public buildings such as train stations, shopping malls, hospitals, and government complexes (Huang et al., 2020). Navigation itself is a task that involves tracking the position of a user, planning a route, and guiding the user along that route until the destination is reached (Kunhoth et al., 2020). Position localisation sits at the core of this task, because the system cannot guide a person whose location it does not know (Arntz et al., 2020). Outdoors, the Global Positioning System (GPS) handles localisation well and underpins widely used services such as Google Maps. Indoors, the situation is different. Signal attenuation within confined spaces and the difficulty of resolving position across multiple building levels degrade GPS accuracy to the point where it becomes unreliable (Ng & Lim, 2020). High-sensitivity receivers can mitigate the problem, but their implementation cost is a barrier in most real settings (Kunhoth et al., 2020), which has motivated a stream of research into alternative indoor positioning methods.

Universiti Teknikal Malaysia Melaka (UTeM) illustrates the problem at a practical level. The Faculty of Information and Communication Technology (FTMK) occupies nine building blocks that house twelve lecture rooms, seven research laboratories, fourteen categories of teaching laboratories, and various supporting facilities. Wayfinding support in the faculty is currently limited to signboards at stairwells, lists of lecturer rooms at each block, and a legacy mobile application, FTMK Navi, which highlights a searched location on a static floor plan but does not guide the user toward it. New students and visitors consequently report difficulty finding their way to specific rooms. Although several indoor wayfinding methods have been proposed in the literature, each carries trade-offs that depend on the use case and environment, and no solution had been investigated for UTeM faculty buildings prior to this study.

This study therefore set out to answer three research questions. First, what are the requirements for developing a wayshowing application in a university faculty, focusing on FTMK at UTeM? Second, how should the application be built to fulfil those requirements? Third, how does the application affect the user experience during the wayfinding process? Corresponding to these questions, the objectives of the research were: (i) to study the spatial surroundings of the faculty, (ii) to design an application for the wayshowing process in FTMK based on the requirements obtained from the first objective, and (iii) to evaluate the application in terms of its usability and user acceptance. The scope was confined to a selected area on one floor of FTMK, and the prototype was designed for Android devices with ARCore support. Vision-impaired users and iOS users were excluded from the current scope and reserved for future study.

LITERATURE REVIEW

Wayfinding and Wayshowing

Wayfinding is a goal-directed process through which people find their way to a defined destination (Dong et al., 2021). Wayfinders receive cues from the environment, make movement decisions based on those cues, and continuously update their sense of where they are (Farr et al., 2012; Hegarty et al., 2023). Several factors shape the decisions made during this process, including familiarity with the surroundings, physical constraints such as mobility and energy, and the capacity to break large volumes of information into manageable pieces (Hegarty et al., 2023; Mollerup, 2017). Under normal conditions, people seek the shortest and most efficient route and tend to prefer straight, visible paths because these reduce the number of turns that must be held in memory (Farr et al., 2012; Jeffrey, 2017). Wayfinding becomes considerably harder inside complicated buildings, where the whole environment cannot be perceived from a single vantage point (Zhang et al., 2021).

Wayshowing is the complementary activity. Mollerup (2005) describes the relationship by analogy: wayshowing relates to wayfinding as writing relates to reading. Where wayfinding is the cognitive and physical task of moving through space, wayshowing provides the cues, such as signs and maps, that support it (Wilding, 2019). Traditional wayshowing relies on static elements, including directional signs, kiosks, painted guidelines, and site maps (Jeffrey, 2017; Khaled, 2017). Signs serve several jobs at once: identifying buildings and rooms, giving directions to places out of sight, stating rules, announcing opening hours, and providing you-are-here information (Mollerup, 2009). A sign must be noticeable and readable while the wayfinder is walking, yet environments with too many signs, or with overly complicated signs, force people to stop and read, which adds mental workload (Mollerup, 2017). Interactive wayshowing, delivered through portable devices and digital kiosks, adapts to the position of the wayfinder and offers personalisation, but it introduces its own risks, among them dependence on network connectivity, battery life, and equitable access to digital devices (Jeffrey, 2017; Khaled, 2017). For these reasons, interactive systems are generally seen as complements to, rather than replacements for, traditional signage.

Augmented Reality in Indoor Navigation

Augmented reality (AR) combines virtual content with the real environment while running interactively and in real time (Muthalif et al., 2022; Van Krevelen & Poelman, 2010). Because AR overlays navigational information directly onto the camera view of the surroundings, users are spared the additional workload of mentally

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connecting instructions to the physical world (Zhang et al., 2021; Huang et al., 2020). AR navigation is also attractive from an infrastructure standpoint, since the only hardware required at the point of use is a smartphone (Ng & Lim, 2020). A recent systematic review of sixty-five studies confirms that users generally prefer AR guidance over traditional maps because of the immediacy and clarity of visual cues, and reports evidence that AR can reduce cognitive load and support cognitive map development, while noting persistent challenges around device ergonomics, lighting sensitivity, and information overload (Qiu et al., 2025). Designers of indoor AR wayfinding systems face two challenges that outdoor systems largely avoid: the vertical movement of users between floors, and the indoor positioning problem itself (Ockerse & Mollerup, 2017). Navigation aids can lower the cognitive load of wayfinders, yet they must be designed carefully because poorly considered features can degrade the overall experience, and applications should accommodate both novice and experienced users (Tahir & Krogstie, 2023).

Indoor Positioning Methods

A human indoor navigation system comprises three modules: indoor positioning, navigation, and human-machine interaction (Kunhoth et al., 2020). The positioning module has attracted the most attention because no single method determines indoor position with the accuracy that GPS achieves outdoors (Cibilic et al., 2020). Four families of methods dominate the literature. Wi-Fi based positioning exploits existing wireless access points and therefore requires little additional infrastructure, but it suffers from low accuracy because networks are designed for coverage rather than localisation, and the fingerprinting process is time consuming (Luschi et al., 2022; El-Sheimy & Li, 2021). Bluetooth Low Energy beacons consume little power and are easy to set up, yet their positional accuracy is weaker still (Ng & Lim, 2020). Marker-based techniques use QR codes or similar markers placed in the environment; accuracy improves with the number of markers, but users must repeatedly find and scan markers, dense marker sets slow database searching, and installation and maintenance carry costs (Cibilic et al., 2020; Luschi et al., 2022). Markerless approaches based on Simultaneous Localization and Mapping (SLAM) recognise natural features of the environment, such as corners and surface textures, from prior scans, with LiDAR variants offering high accuracy that is unaffected by lighting conditions (Gehring & Mosler, 2022). Their weaknesses are the memory and processing demands placed on the device and the risk of failure when the environment changes or when different areas look alike (El-Sheimy & Li, 2021; Ng & Lim, 2020). Table 1 summarises these trade-offs.

Table 1. Comparison of indoor positioning methods

Method	Advantages	Disadvantages
Wi-Fi	Uses existing infrastructure at almost no additional cost; unaffected by lighting conditions	Low accuracy; fingerprinting is time consuming
BLE beacon	Low power consumption; easy to set up; unaffected by lighting conditions	Accuracy lower than Wi-Fi; fingerprinting is time consuming
Marker-based	Accuracy scales with the number of markers placed	Added cognitive load from repeated scanning; dense markers slow database search; affected by lighting; installation required
Markerless (SLAM/LiDAR)	Less installation work; good accuracy; LiDAR scanning is independent of lighting	Environmental similarity or change can cause failure; high memory and processing demands

Related AR Wayfinding Systems

A number of AR wayfinding prototypes have been reported over the past few years. Al Rabbaa et al. (2019) built MRsive, a museum wayfinding application that used Placenote SDK on an iPhone to localise users against a scanned 3D model and displayed a mini-map alongside the AR view. Cibilic et al. (2020) developed GeofAR for a university campus, where users scanned posters to obtain their location and an arrow then indicated the way. Ng and Lim (2020) took a different route on their campus, combining Wi-Fi, inertial sensors, and magnetic fields, with positioning computed on a cloud server. Dinna et al. (2021) proposed a QR-triggered AR application for student halls of residence that paired an arrow indicator with a floor map. Zhang et al. (2021) compared guidepost-style and you-are-here AR navigation on HoloLens devices supported by wall-mounted QR markers, and found that immersive AR navigation can enhance cognitive map development. Gehring and Mosler (2022) applied marker-based AR on a construction site, deliberately avoiding SLAM because the environment changed too quickly for pre-scanned data to remain valid. Rokesh et al. (2023) used image tracking and the NavMesh agent in Unity for campus wayfinding. Google Maps offers indoor AR navigation for partnered venues, though its markerless localisation degrades when the environment changes and it requires users to rescan their surroundings after changing floors.

More recent work has broadened the design space. Ahn et al. (2024) integrated building information modelling with AR for indoor emergency evacuation, and Qiu et al. (2024) demonstrated with NavMarkAR that landmark-anchored AR cues can improve spatial learning among older adults. Ramirez-Galvan et al. (2025) presented an infrastructure-free campus navigation system that recognises existing signage through lightweight neural networks, reporting that 85.2 percent of participants reached their destinations. A systematic review of campus-based deployments similarly concluded that AR indoor mapping improves navigation accuracy, engagement, and accessibility, while identifying infrastructure cost and usability as recurring barriers (Nordin et al., 2025). Across this body of work, two gaps remain visible: usability evaluations frequently rely on generic instruments that were not designed for handheld AR, and few studies document the design reasoning that connects positioning choices, guidance visualisation, and user comprehension in a single account. The present study responds to both gaps in the setting of a Malaysian public university faculty.

METHODOLOGY

Research Design

The study followed a five-phase research design aligned with three broad goals: investigation, development, and evaluation. The conceptual phase and the design and planning phase addressed the first research objective through observation of the faculty environment and a review of the literature, producing a list of requirements for the application. The empirical phase covered the development of the prototype and the collection of data from participants, the analytic phase covered the analysis and interpretation of that data, and the dissemination phase covered the reporting of the research. A qualitative design was selected, combining a system test, usability testing, and the think aloud protocol, because this combination is capable of identifying the majority of problems in an application prior to further development (Thyvalikakath et al., 2009).

Instrument

Usability was measured with the Handheld Augmented Reality Usability Scale (HARUS) developed by Santos et al. (2014). Generic instruments such as the System Usability Scale (SUS) do not account for issues specific to handheld AR, and project-specific questionnaires devised by individual researchers tend to lack validity and comparability across studies. HARUS was constructed to fill this gap by integrating usability with the ergonomic concerns of handheld AR, including screen visibility, latency, interaction workload, and physical fatigue. The instrument contains sixteen Likert-scale statements arranged in a two-factor structure: the first eight items measure manipulability, which concerns the ease of physically handling and controlling the device, and the remaining eight measure comprehensibility, which concerns the ease of understanding the information presented on screen. Scoring follows the SUS convention: responses to positively worded items are reduced by one, responses to negatively worded items are subtracted from five, the converted responses are summed, and the sum is multiplied by 1.5625 to yield a score between 0 and 100. Because HARUS correlates strongly with SUS, the SUS benchmarks reported by Lewis and Sauro (2018) were adopted, with 68 taken as the average score. The two factors correlate only moderately, so they can also be analysed separately (Santos et al., 2014).

Participants and Procedure

Fifteen potential users participated in the evaluation. Twelve were Year 1 students from faculties other than FTMK, two were Year 1 FTMK students, and one was a Year 3 FTMK student, meaning most participants were unfamiliar with the testing environment. A system test preceded the usability sessions; every interface element, AR element, and system function on a prepared checklist was exercised, and no abnormality was found. Each participant was then briefed on the think aloud protocol and the overall procedure, but deliberately not on how to operate the application, since learning to use the application was itself part of the experience under study. Each participant completed the session individually to prevent learning through observation of others.

The sample size of 15 participants was determined with reference to established guidance for formative usability testing. Nielsen and Landauer (1993) reported that small samples uncover the large majority of usability problems, and Faulkner (2003) found that 15 users detect at least 90 percent of the problems in an interface, with an average of 97 percent. This also exceeds the 10±2 participants recommended by Hwang and Salvendy (2010) for usability evaluation. Because the study pursued a formative aim of identifying and diagnosing usability issues in the prototype rather than generalising scores to a wider population, and because the think aloud protocol generates rich qualitative data from each participant, the sample was considered sufficient to yield valid and actionable usability findings (Lazar et al., 2017). Sample sizes in this range are also typical of published handheld AR evaluations that employ the HARUS instrument (Santos et al., 2014).

Every participant performed two navigation tasks, a short-distance task followed by a long-distance task, drawn from four designed destinations: the student common room, the office, the lobby, and the parking area. The starting point was not fixed, and destinations were assigned relative to it so that the two tasks differed meaningfully in distance. Participants voiced their thoughts throughout, and the researcher intervened only under the conditions recommended for the protocol, such as technical failure or an action with wider negative consequences. Observed behaviours were recorded through contextual inquiry, with questions posed when participants performed notable actions. After both tasks, a short interview captured final impressions, and participants completed the HARUS questionnaire through Google Forms. Descriptive statistics, specifically the mean and the standard deviation of each item, were used to examine the dispersion of responses, following the practical validation approach for Likert-scale questionnaires described by Othman et al. (2011). The main limitation of this methodology is its purely qualitative nature and small sample, which constrains the generalisability of the findings; this is addressed further in the concluding section.

Development Of the Prototype

Design Decisions

The prototype, named NavigARte FTMK, was designed with four defining characteristics. It is an AR application developed in Unity; it adopts a markerless indoor positioning solution; its pathfinding is built on the NavMesh feature of Unity; and its default guidance visualisation is a path rendered on the floor, with an arrow indicator available as a user-selectable alternative. Unity was chosen because its free plan is sufficient for an application of this scale, its community and documentation are extensive (Hussain et al., 2020), and features relevant to navigation, notably the Vuforia Software Development Kit (SDK) and NavMesh, integrate directly into the platform (Teli et al., 2022). During design, the AR usability heuristics proposed by Guimaraes and Martins (2014), which extend Nielsen's heuristics with the ergonomic concepts of ISO 9241-11, were consulted as a checklist covering system status visibility, match with the real world, error prevention, minimalist design, and related criteria.

Markerless Positioning with Vuforia Area Targets

The markerless choice was grounded in the character of the environment and in experimental evidence from an earlier build. The room and laboratory locations in FTMK are fixed, so the principal weakness of markerless positioning, sensitivity to environmental change, is greatly reduced. Marker-based positioning was trialled first: a 3D map was generated from the building plan and QR markers were configured so that scanning would relocate the user. Two problems proved unavoidable. Increasing accuracy demanded more markers, which forced users to chase markers rather than attend to their actual task, and positional offset accumulated during movement, which could only be corrected by scanning yet another code, creating a frustrating loop. Wi-Fi and BLE approaches were ruled out on accuracy grounds. The Vuforia Area Target feature was therefore adopted. The faculty environment was scanned with a LiDAR-equipped handheld device (an iPhone 14 Pro), and the scan data were imported into Unity, where the integration with Vuforia allowed virtual objects to be placed and aligned with the physical world. One constraint emerged during development: the corridors of the upper floor offered too few visual feature points, especially near corners, for the positioning to remain stable there. The prototype was consequently limited to a single floor, a limitation acknowledged for future work.

Path Computation and Guidance Visualisation

Pathfinding uses the NavMesh feature, which bakes a walkable surface mesh from the imported model and computes routes corner to corner until the destination is reached (Teli et al., 2022). Walkable areas missed by the scan were bridged with invisible virtual surfaces, and a NavMesh Modifier Volume excluded hazardous areas, inconsistent surfaces created by furniture, and areas outside the prototype scope. The two guidance visualisations implemented in the prototype are shown in Figure 1. In the path mode, a continuous line is rendered on the floor surface from the user's current position to the destination, so the direction of travel is always visible on the ground plane. In the arrow mode, a directional arrow is placed on the floor ahead of the user and reorients as the user moves. The choice of the ground-rendered path as the default follows the comparison by Arntz et al. (2020), who found that although the two designs did not differ in navigation time, the path design outperformed the arrow design in ease of use and support for task completion because it renders a clear direction on the ground. Li et al. (2014) similarly reported low user preference for arrow-only guidance, attributing it to a sense of lost control when no information is provided in advance. The arrow mode in Figure 1 addresses that criticism by projecting the arrow ahead of the user, so an upcoming turn is visible before the junction is reached, and users may switch between the two modes at any time.

Figure 1. Path design (left) and arrow design (right) of the guidance visualisation in the prototype

Destination selection is handled through a dropdown bar positioned at the top of the interface, shown in Figure 2. The bar lists the four destinations designed for the prototype, with the first entry serving as the default. This control was adequate at the current scale, although the design analysis recognised that a dropdown would not scale to a full building directory; a search-based selection interface is identified as the replacement once the destination set grows.

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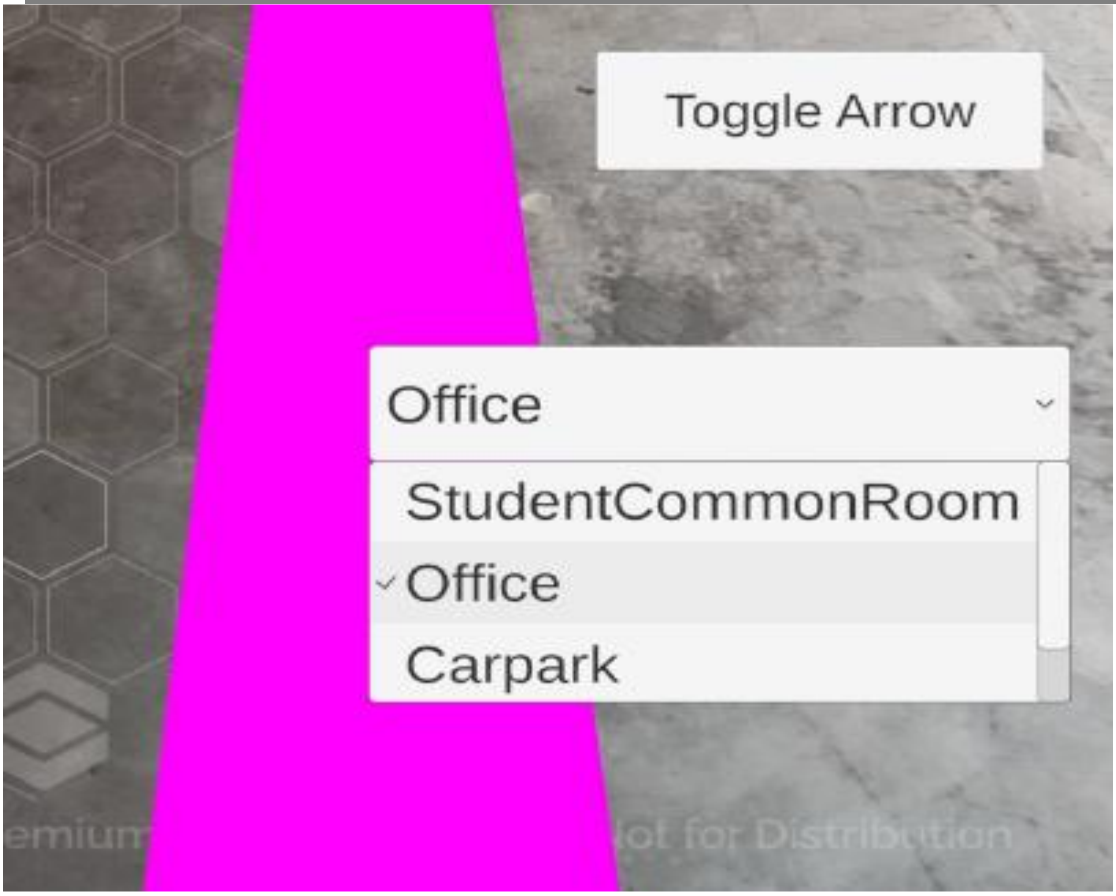

Figure 2. Dropdown bar for destination selection

Once a destination is selected, a pinpoint marker is placed at that location, as illustrated in Figure 3. The pinpoint serves two purposes. It anchors the endpoint of the path calculation, and it remains visible to the user even when the destination lies behind walls, providing a persistent through-wall cue to the general direction and distance of the goal. When the user selects a new destination from the dropdown bar, the pinpoint relocates and the route is recomputed accordingly. As reported in the results, this through-wall visibility proved particularly valuable to participants who were already familiar with the building.

Figure 3. Pinpoint marking the selected destination

Assistance and system feedback are provided through two further elements. A help button opens the panel shown in Figure 4, which explains the function of each control and lists recovery steps for situations where the virtual overlay drifts out of alignment with the real environment. The panel text sits on a semi-transparent black background, a compromise that improves legibility without fully obscuring the camera view behind it, and the same button closes the panel. Finally, a status text at the top of the screen communicates the localisation state, reading Scanning while the application searches for a positional match against the scanned environment and changing to Location Found once localisation succeeds; the meaning of each status message is documented within the help panel.

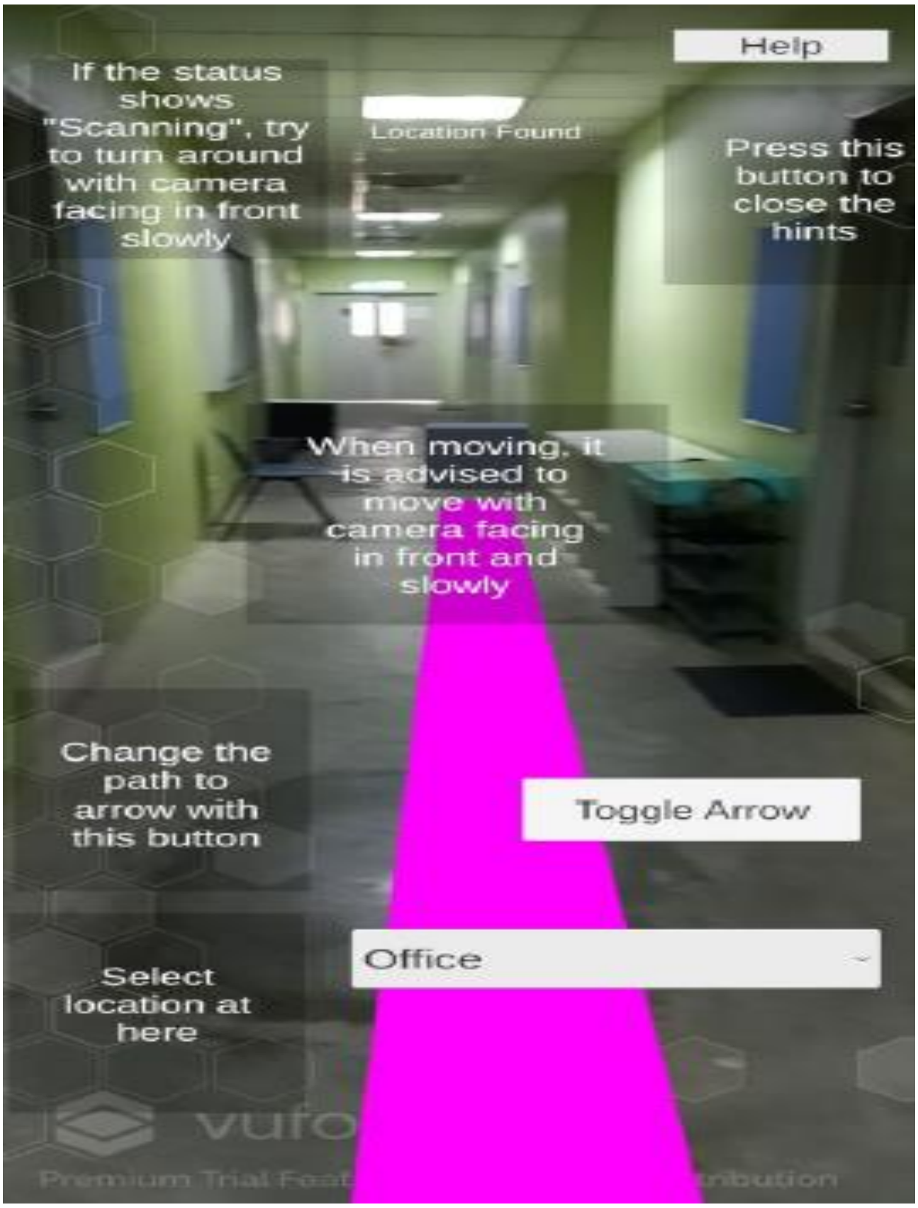

Figure 4. Help panel of the prototype

RESULTS AND DISCUSSION

Task Completion and HARUS Scores

All fifteen participants completed both wayfinding tasks with the prototype. HARUS responses were pre-processed according to the scoring procedure, and the mean and standard deviation of each item were computed. Table 2 presents these values. Items 9, 11, 13, 14, and 16 showed noticeably higher standard deviations than the rest, and all five belong to the comprehensibility factor, indicating that participants diverged most in their judgements of how understandable the on-screen information was. The ratio of the largest to the smallest item standard deviation was 2.03 overall, essentially at the 2:1 rule-of-thumb threshold described by Othman et al. (2011), so no single item was judged to distort the overall score. Within each factor the ratios were 1.60 for manipulability and 1.46 for comprehensibility, indicating internally consistent responses.

Table 2. Mean and standard deviation for each HARUS item (converted scale 0 to 4)

HARUS Item	Mean	Standard Deviation
Item 1	2.800	1.082
Item 2	2.533	0.743
Item 3	2.533	1.187
Item 4	2.733	1.100
Item 5	2.333	1.113
Item 6	2.733	0.884
Item 7	2.333	1.047
Item 8	3.333	0.816
Item 9	2.800	1.207
Item 10	2.800	1.082
Item 11	2.000	1.512
Item 12	2.667	1.047
Item 13	1.933	1.486
Item 14	2.067	1.280
Item 15	2.933	1.033
Item 16	2.600	1.242

The summed score across the fifteen respondents was 617, giving a mean of 41.13 out of 64 on the raw scale, or 64.27 out of 100 after conversion. Against the benchmark of 68 proposed by Lewis and Sauro (2018), the prototype falls slightly below average usability. Decomposing the score by factor, manipulability totalled 320 points for a converted mean of 66.67, while comprehensibility totalled 297 points for a converted mean of 61.88, with standard deviations of 1.02 and 1.27 respectively on the 0 to 4 scale. Table 3 tabulates these results. Neither factor reached the benchmark, but the gap was clearly wider for comprehensibility, which directed the subsequent analysis toward perceptual and informational issues rather than physical handling.

Table 3. HARUS results by factor

Aspect	Total Score	Mean (0 to 4)	Std. Dev.	Mean (0 to 100)
Manipulability	320	2.670	1.02	66.67
Comprehensibility	297	2.475	1.27	61.88
Overall	617	2.570	1.15	64.27

Comprehensibility Issues from the Think Aloud Protocol

Comprehensibility problems in handheld AR are closely tied to perceptual issues, since handheld devices still trail dedicated AR hardware in visibility and latency (Santos et al., 2014). Depth perception distortion is a recognised problem in AR, and mutual occlusion between real and virtual objects, together with the avoidance of physicality conflicts, is important for removing perceptual confusion (Kim et al., 2022). Shadows cast on virtual objects assist judgements of size, height, and distance (Adams et al., 2022), and camera capabilities can be extended or limited to shape user perception (Nijholt, 2022). The think aloud data mapped onto this literature in concrete ways. Six of the fifteen participants asked for stronger status indication; after the application announced that scanning was complete, comments such as What is next? revealed that no further cue told them what to do, particularly when the rendered path lay outside their field of view. Four participants reported that the absence of occlusion on the path caused genuine confusion: when the path passed through a closed door, they could not tell whether they were meant to enter the room or whether the display was in error, and one participant hesitated for some time at exactly that point. Interestingly, these participants preferred the arrow indicator (Figure 1, right), which avoided the ambiguity, a preference running counter to the general finding of Arntz et al. (2020) and suggesting that the advantage of path designs depends on proper occlusion handling. Two participants found the arrow mode weak for a different reason: the arrow sometimes rendered too far ahead and lay flat on the floor, making it hard to read, in contrast to the upright arrow style used by Google. All three FTMK participants, who knew the building, reported that the through-wall pinpoint alone (Figure 3) allowed them to navigate by forming a rough idea of the destination and route, which is consistent with the role of environmental familiarity in wayfinding strategy (Hegarty et al., 2023).

Other Usability Issues

Several further issues surfaced across participants. Ten of the fifteen were unaware of the help panel (Figure 4) at the start and resorted to trial and error once their location had been found; four suggested the help panel should appear automatically at launch, and five were confused by the wording inside it, recommending clearer verbs or graphical instructions in place of text. Three participants raised a safety concern, noting that attention to the screen reduced awareness of slopes and stairs, and one proposed that the application require the phone to be raised only when necessary, with vibration cues signalling upcoming decisions; two others independently linked the sustained raised-arm posture to hand fatigue. Two participants asked for route recalculation that respects the direction the user is facing rather than always presenting the shortest path. One participant noticed device heating during use, an observation not shared by others and left for further investigation. Taken together, the evaluation indicates that the technical core of markerless positioning and path computation performed reliably, while the communication layer, covering onboarding, status feedback, and occlusion, is where design effort should now be concentrated. This echoes the broader pattern in recent reviews, where usability and comprehension, rather than raw positioning capability, are identified as the persistent barriers to adoption of AR indoor navigation (Qiu et al., 2025; Nordin et al., 2025).

CONCLUSION AND RECOMMENDATIONS

This study set out to examine the spatial surroundings of FTMK, to design a wayshowing application based on the identified requirements, and to evaluate that application for usability and user acceptance. An effective indoor wayshowing application must determine the user's location, compute the path to a destination, present that path clearly, update continuously as the user moves, and maintain accuracy throughout. Markerless AR met these requirements in the FTMK setting because the environment is stable, and the prototype built on Unity, Vuforia Area Targets, and NavMesh demonstrated that a working system can be produced with modest resources, including scans captured on a consumer handheld device. The evaluation with fifteen participants produced a HARUS score of 64.27, slightly below the average benchmark, with comprehensibility identified as the factor most in need of improvement.

The contributions of the study are twofold. For practice, it shows building operators in universities, hospitals, malls, and similar complex environments that indoor wayshowing is achievable without dedicated positioning infrastructure, and that resources currently absorbed by wayfinding assistance could be redirected once such a system is in place; the visual layer can even carry institutional branding, such as a mascot guiding visitors. For research, it documents the design reasoning connecting positioning method, guidance visualisation, and user comprehension, and it demonstrates the value of HARUS as an evaluation instrument tailored to handheld AR.

Several limitations qualify the findings. The prototype covered a single floor because the upper-floor corridors lacked sufficient visual feature points for stable markerless positioning. The evaluation was purely qualitative with fifteen participants, most of whom were first-year students, so the sample does not represent the full user population, and the prior AR experience of participants was not recorded. The sample was nevertheless appropriate for the formative purpose of the study, since fifteen users exceed the 10±2 participants recommended for usability evaluation and can be expected to reveal well over 90 percent of the usability problems present in an interface (Faulkner, 2003; Hwang & Salvendy, 2010). The think aloud protocol captured rich first-hand impressions but no objective behavioural measures, and the study did not compare wayfinding with and without the prototype.

Future work should proceed along three lines. First, the positioning limits can be tackled by hybridising markerless and marker-based methods, for example by placing a small number of QR codes that identify the floor level so that the system restricts its point cloud search accordingly, or by capturing scans with industrial-grade scanners rather than handheld LiDAR. Second, the prototype should be revised in line with participant feedback: graphical rather than textual instructions, a tutorial shown at first launch, occlusion of the path behind walls and doors with an option to toggle the full path view, upright arrows with advance notice of turns, and multimodal cues such as vibration so that the device need not be held raised continuously. Third, evaluation should be broadened to a summative, mixed-method design with a larger and more demographically diverse sample that includes first-time visitors and users with varying levels of AR familiarity, enabling inferential analysis of HARUS scores and comparison across user groups, supplemented by objective instruments such as eye tracking, and extended to include wayfinders with motor or cognitive impairments. With these refinements, AR wayshowing can make the wayfinding process in complex buildings more engaging and accessible for everyone.

Ethical Considerations

The study involved human participants in a low-risk usability evaluation conducted in accordance with the research ethics guidelines of Universiti Teknikal Malaysia Melaka. All participants were briefed on the purpose and procedure of the study and took part voluntarily, with informed consent obtained prior to the sessions. No personally identifiable information was collected, and all responses were anonymised before analysis.

Conflict Of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data Availability

The data supporting the findings of this study, comprising anonymised HARUS questionnaire responses and think aloud session notes, are available from the corresponding author upon reasonable request. The data are not publicly deposited in order to preserve the confidentiality of participant records.

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