Blending Social Interaction Realms: Harmonizing Online and Offline Interactions through Augmented Reality

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ABSTRACT

Online social media has revolutionized human interaction by fostering unparalleled cooperation and connectivity, surpassing the bounds of conventional, location-based methods. Despite their inherent limitations—such as physical boundaries, ongoing maintenance expenses, and rigidity—traditional methods impart a vital local context often neglected by digital platforms, potentially overshadowing local environmental engagement in favor of broader online networks. To mitigate this imbalance, it is essential to revitalize the significance of location-specific interactions. Augmented Reality (AR) stands out as a powerful means to enhance the accessibility and allure of such engagements. In this context, our research involved a detailed review and synthesis of existing location-based interactive services, pinpointing prevalent obstacles as well as offering strategic recommendations. Building upon these findings, we innovated ARMessageBoard, a prototype fusing AR with users' immediate surroundings to craft virtual message boards. Our within-subjects study comprised 15 participants with an average age of 21.2 years (SD=5.5), systematically comparing ARMessageBoard with standard location-based mechanisms. Furthermore, we deliberated how blending AR with online social media could positively influence the convergence of virtual and real-world interaction landscapes, potentially enriching the individual's role in shaping socio-digital exchanges.

CCS CONCEPTS

• **Information systems → Collaborative and social computing systems and tools**; • **Human-centered computing → Accessibility systems and tools**.

KEYWORDS

Location-based interaction, Human-computer interaction, Augmented reality, Social media, Human behaviour

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1 INTRODUCTION

When people think about social media, they usually think of its online forms first. The opportunity to connect beyond geographical and social boundaries, along with the benefits of collaborative filtering, has attracted more than two-thirds of internet users worldwide to participate in various online social media sites and applications [27, 36]. The massive number of users gives online social media a strong influence and user stickiness [31], which results in online social media dominance. Social media is usually suited for interacting with different users in a broad community, especially those who are distant from each other in physical location [16]. A peculiar trend is emerging as an increasing number of individuals become part of the 'head-down tribe,' engrossed in their devices, sharing personal anecdotes and daily life experiences with others located across the globe. Although online social media are currently popular in virtual communities [33], there are still many challenges and limitations [1]. In the current market, there are hundreds of online social media platforms, with users dispersed across these varied networks. Consequently, it is challenging to centralize users and efficiently locate the specific information needed due to this fragmentation. Under many circumstances, for

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individuals located in the same place, establishing connections based on geographical proximity is often more direct and effective than using social media, especially when the goal is to rapidly engage with target users who share specific characteristics within a physical public environment.

The pervasive nature of online social interaction has precipitated a concerning shift toward the marginalization of Location-Based Interaction [24]. This disproportionate emphasis on virtual engagement often leads to a diminished awareness of one's immediate environment and the events unfolding within it. Furthermore, there is an observable erosion of offline interpersonal skills among users, an adverse trend that portends potential detriments to overall social development [3]. Location-based interaction centralizes social exchanges around frequently visited sites, enhancing engagement within the same physical community and fostering a sense of connection. Since these locations are stationary and singular, messages can be effectively targeted to those with exclusive access. However, traditional methods like bulletin boards, message boards, and sticky notes—whether physical or digital—are often seen as outdated in today's digital age, diminishing their appeal to users [15].

Consequently, we endeavor to elevate the recognition of location-based interaction's capabilities by engineering an Augmented Reality (AR) application titled ARMessageBoard. This application empowers individuals to deploy their mobile devices in crafting digital message boards as virtual entities tethered to real-world locations. Simultaneously, we aim to integrate this technology with online social media to pioneer novel paradigms for hybrid social interaction frameworks. To this end, we have chosen a university campus as our experimental setting, given the high demand for location-based interactions within such environments. To address Research Question 1 (RQ1): "What is the usability level of the ARMessageBoard system?", participants engaged hands-on with ARMessageBoard, followed by an assessment using the System Usability Scale (SUS). For Research Question 2 (RQ2): "How does the ARMessageBoard system improve user experience compared to traditional location-based interaction methods?", we employed a within-subject experimental design. Participants provided feedback after experiencing both traditional methods and ARMessageBoard, using a questionnaire to evaluate their experiences. Lastly, to explore Research Question 3 (RQ3): "What contributions does ARMessageBoard offer to location-based interaction design, and how does it relate to online social media?", we conducted semi-structured interviews focused on the design of location-centric apps and their integration with virtual social networks. In summary, we made the following contributions:

- We developed the ARMessageBoard prototype, achieving a significant SUS score of 79.167 (85th percentile), indicating its strong potential as a viable product.
- We identified essential design criteria for location-based applications, including user privacy, real-time feedback, user density, and positioning accuracy.
- We proposed integrating AR technology into existing social media platforms to overcome current limitations in location-based interactions, potentially transforming user engagement and communication through ARMessageBoard.

2 BACKGROUND

2.1 Online Social Media

The widespread usage of social media comes with both benefits and detriments. Social media is instrumental in connecting individuals, allowing for collaboration and the formation of wide-reaching virtual communities [21]. Especially for the university community, Pashine et al. (2018) uncovered in his research that a majority of college students prefer to use social media to learn about new people before meeting them in person. Social media acts as a preliminary filter, assisting users in finding others with common interests and backgrounds, which can be quite effectual for friendship formation [11]. However, an overreliance on these platforms might lead to the breakdown of smaller social groups or the creation of polarized communities [13]. While social media has clear upsides such as ease of access and wide connectivity, it is not without its shortcomings, especially when it comes to emulating in-person interactions. As we examine the subtleties of digital communication, it's apparent that convenience and reach provided by online platforms cannot substitute the dynamic of real interactions that physical presence offers [20].

2.2 Location-Based Interaction

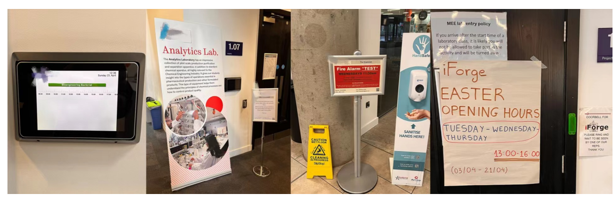

Figure 1: Conventional location-based interaction methods in the campus, and it shows some conventional location-based interaction methods on the campus of the university. From left to right, they are scheduled arrangement panels based on room location, retractable billboard, notification board and hand-painted cardboard.

Location-based technologies use geographic information to provide specialized services, utilizing systems like GPS or other methods for determining location. These technologies have given rise to applications such as location-oriented advertising and social media geotagging, which blend the digital and physical worlds to improve the user's experience [4, 6]. This integration not only bolsters social bonds but also furthers societal progress by instilling a sense of vicinity and closeness that encourages greater engagement in communal activities [32, 35]. Despite a digital inclination, conventional physical bulletin boards maintain their relevance in places such as streets, libraries, and cafés, adding a tangible aspect to location-based experiences and nurturing a sense of community [18, 23].

Although traditional location-based interactions provide genuine face-to-face contact, they are limited by their stationary nature, the need for physical presence, and non-portable setups. Establishing interactions and sending messages to strangers in the same location can be challenging with existing methods. The difficulties include: (1) *Infrequent use*, leading to slower and fewer responses; (2) *Cost*, as developing and implementing traditional methods can be time-consuming and expensive, often only feasible for location owners or administrators; and (3) *Space Dependence*, requiring sufficient physical space for effective functioning. Due to these limitations, many people prefer online social media platforms for making connections, seeking shared virtual communities, which are efficient even when near potential contacts [35]. The advent of AR technology is transforming these aspects by overlaying digital information onto real-world settings, thus redefining conventional location-based experiences. This fusion of digital immediacy with tangible interactions heralds a significant shift towards more engaging and immersive interactive experiences [7].

2.3 Social-Oriented Mobile Applications

Yik Yak, a social media app, aptly reflects the burgeoning interest in location-based interaction systems, notwithstanding their intrinsic shortcomings [12]. It features an exclusive mechanism that facilitates the posting and interaction of localized messages or 'Yaks' within a specific geographical boundary. This design effectively cultivates a sense of community at the local level by allowing individuals to converse about events, pose questions, and share information pertinent to their immediate environment, consequently boosting interactions among users in close vicinities [34]. Yet, the success of Yik Yak is subject to fluctuate based on user density and their level of active engagement within distinct regions. In less populated areas or regions witnessing sparse user involvement, the platform may fail to offer any significant advantage, thus underscoring its dependency on geographic proximity and reflecting a persistent challenge faced by all location-based interactive services [9].

In other scholarly pursuits, various studies have integrated AR with location-based interactions to facilitate professional tasks. Yu (2015) [37] developed a mobile application for ecological campus navigation using AR, assisting users in navigation while enriching their knowledge of campus ecology. This initiative exemplifies the potential and strategic approaches for blending location-based interactions with augmented reality, particularly in an educational context. Similarly, the gaming industry has widely adopted location-based concepts [19, 26]. Pokémon GO, which combines location-based paradigms with AR technology, achieved success through social gameplay [28]. Despite a decline in user numbers following the initial craze, the game's popularity has demonstrated the broad appeal of location-based pervasive games to a mainstream audience. It serves as a prime example of integrating location-based and AR technologies, with potential applications in educational and professional settings. Consequently, we aim to explore further applications of location-based interaction using ARMessageBoard as a foundational model for enhancing social interconnectedness.

3 DESIGN AND IMPLEMENTATION

To better understand the specific needs and preferences for location-based interactions among university students, which are crucial for guiding the development of our application, we commenced our research with interviews with 15 students. The purpose of these interviews was to extract in-depth insights regarding the desired features and functionalities for location-based interactions within the university environment. The valuable feedback we gathered played a pivotal role in shaping the development trajectory of our ARMessageBoard prototype, employing visual aids such as storyboards and low-fidelity user interface mockups for iterative comparison and refinement.

The storyboard of the prototype illustrates a typical user journey and the fundamental functionalities of the application. Please refer to Figure 2 for a detailed visualization. Users can deploy ARMessageBoard on their smartphones by arriving at a specific location and tapping the "Add" button on the screen to set up a virtual message board. The location is fixed based on the device's current physical environment and cannot be arbitrarily moved. Upon raising their smartphones and pressing the "Load" button, users will see virtual message boards previously created by others at the physical location, displaying details such as the poster's name and timestamp without additional actions.

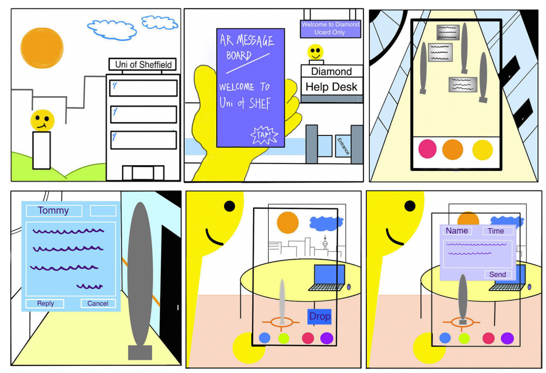

Figure 2: Storyboard Prototype

Finally, the design of our virtual digital message board consists of two distinct elements: the upper section is a semi-transparent digital message board that enables users to achieve the information without losing sight of the real world behind it, as shown in Figure 3. This use of a translucent effect not only preserves the user's connection to their surrounding environment but also enriches the immersive experience by softening the divide between the digital and natural worlds. To simulate the appearance of a floating message board, the lower section features an unidentified UFO shape. This choice addresses the practical issue of ground detection inconsistencies; traditional models that rest on the ground can often appear disjointed due to inaccurate sensing of distance, but a hovering model circumvents these limitations.

We employed ARKit as the Augmented Reality Software Development Kit (SDK) for ARMessageBoard because of its comprehensive features and compatibility with iOS devices. ARKit excels in realistic environmental rendering and tracking, which is crucial for an authentic augmented reality experience. Unity3D complements ARKit by providing robust graphical tools and versatility in AR development, making it the preferred game engine for crafting our virtual elements. CoreLocation [5, 10], a sophisticated iOS framework, was integrated to ensure accurate geolocation and spatial orientation. This framework relies on a trio of techniques, GPS, cellular triangulation, and WiFi positioning,

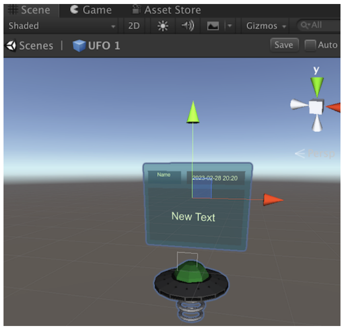

Figure 3: ARMessageBoard's Hierarchy in Unity3D

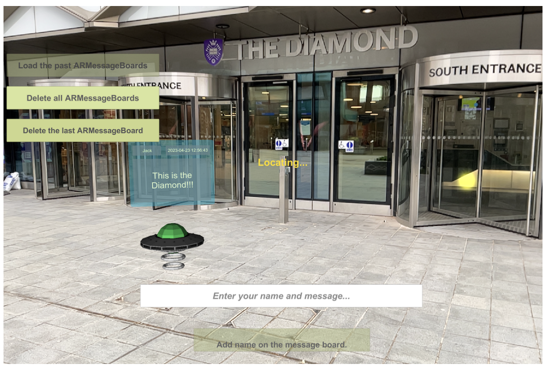

Figure 4: This figure displays a screenshot of the actual device test, running on an iPad Pro.

offering adaptability and precision by exploiting the strengths of each method under varied conditions. These technologies work in tandem within ARMessageBoard to deliver an adaptive augmented reality experience that remains responsive to the user's real-world setting, enhancing the relevance and engagement of geo-tagged interactions.

With the foundational designs from our storyboard and low-fidelity user interface in place, we have finalized the prototype for our upcoming user studies. We have implemented all the planned features except the reply functionality. Figure 4 displays a test run on an iPad Pro, revealing a user interface where control buttons are neatly arrayed along the top left, facilitating easy access to existing virtual boards or the creation of new message spaces. Users are afforded the flexibility to author their digital markings with their name and message content, and the system automatically logs the creation timestamp.

4 USER STUDY

4.1 Within-Subject Study

In this study, a within-subjects design was used to evaluate a consistent group of participants under two interaction settings: traditional location-based interactions and those using ARMessageBoard. We excluded online social media with geographic information, like geotagging, due to its significant differences from ARMessageBoard. Geotagging allows remote location settings with typically imprecise positioning, which does not align with the objectives of our study. This design allows for a direct comparison of user responses, essential for assessing differences in user experience, usability, and engagement. It also mitigates variability from individual differences such as technological aptitude and personal preferences by exposing the same participants to both interaction conditions. This approach helps to limit confounding variables and strengthens the study's validity and credibility. To ensure the comparability of data, the same assessment questionnaire was administered under each condition, maintaining identical questions for all subjects. The Wilcoxon Signed Rank Test was the chosen statistical tool for analyzing differences between these experiences, enabling us to discern if the ARMessageBoard provides a recognizable improvement over traditional approaches. One of the main reasons for choosing it is that we have a small sample of data in a single paired sample (less than 20) and do not require a normal distribution. By calculating the Interquartile Range (IQR), we are further able to evaluate the integrity of our data set and identify any outliers, ensuring greater precision in our data analysis.

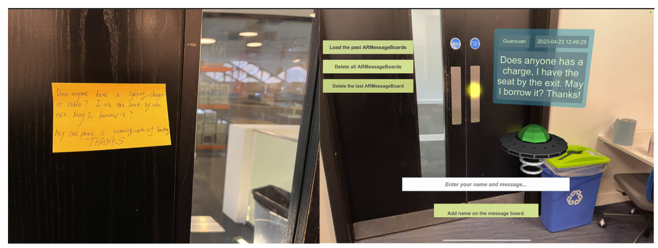

Figure 5: This figure demonstrates an example from the user study, which compares the presentation and formation of traditional location-based interaction methods and the ARMessageBoard in terms of user experience.

4.2 Survey Details

In our user study, participants were actively involved in creating and interpreting information using both traditional location-based interaction methods and the ARMessageBoard.

Initially, each participant individually spent eight minutes engaging with traditional location-based interaction tools—such as bulletin boards, sticky notes, and portable cards—in a predefined space by the researchers. They were instructed to freely explore, create, and absorb the information provided by the reserachers, enabling a nuanced understanding of standard interaction systems' effectiveness within a managed setting. After this interactive phase, they proceeded to fill out the first section of the survey, directed specifically at their interaction with traditional methods. The survey used a 5-point Likert scale with six questions, the details of which are depicted in Figure 5.

Following the traditional interaction phase, participants were handed devices (an iPad Pro 2020 or an iPhone 14) featuring the ARMessageBoard app. Over a similar eight-minute duration, they were asked to experiment with setting up virtual message boards and to assimilate content from existing virtual boards provided by the researchers. At the end of this session, participants completed the second part of the survey—the System Usability

Scale (SUS) questionnaire, consisting of ten standardized queries [8]—to evaluate the ARMessageBoard's usability. Subsequently, they tackled the third segment of the survey, which included questions paralleling those from prior research on location-based interactions to maintain result comparability. The final step of the study was a semi-structured interview conducted in a calm environment, aimed at collecting more profound feedback on their experience with the ARMessageBoard.

4.3 Participants

We enlisted 15 undergraduate students of both genders from a university in England as volunteers for our comprehensive user research project. These individuals actively agreed to participate in the study, bringing with them a habitual engagement with social media as a routine part of their daily information-sharing practices. As outlined in Table 1, the majority of the participants reported using social media "Several times a day," with many of them posting content regularly, either several times a month or once a year. Based on their digital media usage habits, we inferred that the participants were proficient in navigating digital communication platforms. Consequently, we anticipated that any potential negative feedback arising from the within-subjects study was unlikely to stem from an inherent discomfort or adverse disposition toward social media. The university's ethical committee approved the experiment.

Table 1: Social Media Usage Frequency Response Table of the Participants

	Several times a day	Several times a week	Several times a month	Several times a year	Less than several times a year
How often do you use social media?	9	5	1	0	0
How often do you post on social media?	1	2	7	5	0

Table 2: System Usability Survey Results

Participant ID	SUS Score	Participant ID	SUS Score
P1	67.5	P2	70
P3	82.5	P4	85
P5	77.5	P6	75
P7	77.5	P8	77.5
P9	82.5	P10	82.5
P11	85	P12	77.5
P13	80	P14	87.5
P15	80		
Average Score:	79.167	Grade:	A-

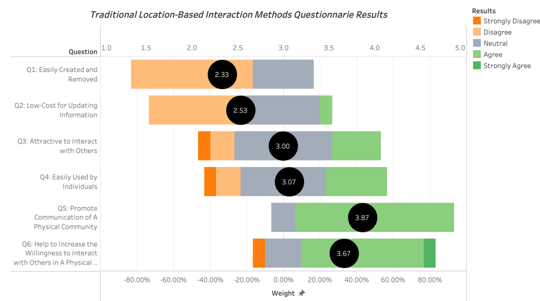

Figure 6: Traditional Location-Based Interaction Methods Questionnaire Results

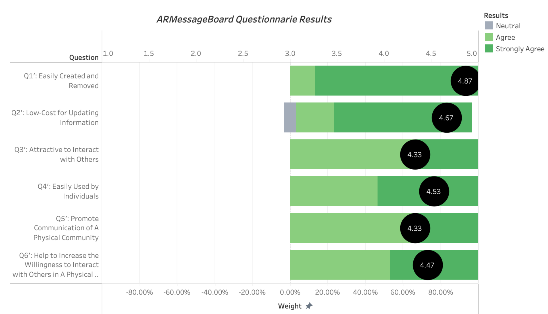

Figure 7: ARMessageBoard Questionnaire Results

5 RESULT

5.1 ARMessageBoard Usability

We transferred the numerical outcomes for each participant in the system usability survey questionnaire, enabling us to determine a score for each survey. Subsequently, we calculated the average score and compared it to a reference table to evaluate the general usability performance of ARMessageBoard.

Table 2 indicates that ARMessageBoard has achieved outstanding system usability, min:67.5, max: 87.5, mean: 79.167, and sd: 29.90. Based on the comparison result with the standard table [8], we have assigned a rating of A- to ARMessageBoard. At the same time, the initial prototype application successfully fulfils the user functional requirements identified in the formative study.

5.2 Performance Comparisons

ARMessageBoard offers notable advantages when compared to traditional location-based interactive methods. ARMessageBoard provides a **user-friendly**, **cost-effective**, and **less restrictive** approach to location-based interactions, thereby enhancing location-based interactions within the physical community. Furthermore, ARMessageBoard **fosters communication among community members** and encourages increased interaction among individuals in a physical environment.

Figure 6 and Figure 7 demonstrate the questionnaire results for the traditional location-based interaction methods questionnaire and ARMessageBoard questionnaire, and they present the proportion of each question result and the mean of the results for each question. In the bar chart, we can distinctly observe that ARMessageBoard indicates higher scores.

Table 3 present the statistical results of the traditional location-based interaction questionnaire. It includes valid cases, invalid cases, median and interquartile range of each question. The data from all 15 survey questionnaires are valid, and the

Table 3: Traditional Location-Based Interaction Questionnaire Statistical Results

Traditional Location-Based Interaction	Q1	Q2	Q3	Q4	Q5	Q6
Valid Cases	15	15	15	15	15	15
Invalid Cases	0	0	0	0	0	0
Median	2.00	2.00	3.00	3.00	4.00	4.00
Quartile 25	2.00	2.00	3.00	3.00	4.00	3.00
Quartile 50	2.00	2.00	3.00	3.00	4.00	4.00
Quartile 75	3.00	3.00	4.00	4.00	4.00	4.00
Interquartile Range	1.00	1.00	1.00	1.00	0.00	1.00

Table 4: ARMessageBoard Statistical Questionnaire Results

ARMessageBoard	Q1	Q2	Q3	Q4	Q5	Q6
Valid Cases	15	15	15	15	15	15
Invalid Cases	0	0	0	0	0	0
Median	5.00	5.00	4.00	5.00	4.00	4.00
Quartile 25	5.00	4.00	4.00	4.00	4.00	4.00
Quartile 50	5.00	5.00	4.00	5.00	4.00	4.00
Quartile 75	5.00	5.00	5.00	5.00	5.00	5.00
Interquartile Range	0.00	1.00	1.00	1.00	1.00	1.00

Interquartile range for each item is either 1 or 0, which suggests that the data distribution may be very concentrated or exhibit minimal variation in certain aspects. Therefore, the collected data are robust and statistically significant. We observed that the median values for Q1 and Q2 are only 2, indicating that participants are dissatisfied with traditional location-based interaction methods in these two aspects.

Table 4 present the statistical results of the ARMessageBoard questionnaire. It includes valid cases, invalid cases, median and interquartile range of each question. The data from all 15 survey questionnaires are valid, and the Interquartile range for each item is either 1 or 0, which suggests that the data distribution may be very concentrated or exhibit minimal variation in certain aspects. Therefore, the collected data are robust and statistically significant. The median values for Q1, Q2, Q3, Q4, Q5 and Q6 being greater than or equal to 4 indicates that a majority of the participants were satisfied with ARMessageBoard.

For the Asymp. Sig. (Two-tailed P-value), the result is displayed as .000 when the value is less than .001. Due to the relatively small sample size, we did not calculate the Z-value as a reference, choosing to use the p-value, which is more statistically significant and precise. The significance level in this work was set to .05. Therefore, the Wilcoxon Signed-Rank Test results found significant differences in the following questions:

(1) Q1 ($p < .01$): Participants felt that the ARMessageBoard(Md = 5, IQR = 0) is easier to create and remove than traditional location-based interaction methods (Md = 2, IQR = 1).
(2) Q2 ($p < .01$): Participants thought that ARMessgaeBoard (Md = 5, IQR = 1) is low-cost for updating information approach than traditional location-based interaction methods (Md = 2, IQR = 2).
(3) Q3 ($p < .01$): Participants felt ARMessageBoard (Md = 4, IQR = 1) is more attractive to interact with others than traditional location-based interaction methods (Md = 3, IQR = 1).
(4) Q4 ($p < .01$): Participants felt ARMessageBoard (Md = 5, IQR = 1) is more easily used by individuals than traditional location-based interaction methods (Md = 3, IQR = 1).
(5) Q5 ($p = .02$): Participants felt ARMessageBoard (Md = 5, IQR = 1) promotes communication of a physical community more than traditional location-based interaction methods (Md = 4, IQR = 1).
(6) Q6 ($p < .01$): Participants felt ARMessageBoard (Md = 4, IQR = 1) helps to increase willingness to interact with others in a physical environment than traditional location-based interaction methods (Md = 4, IQR = 1).

Drawing from the findings of the aforementioned data analysis, we can deduce the answer to **RQ2**. The ARMessageBoard displays notable or marginally significant differences when compared to traditional location-based interaction methods concerning the aforementioned issues. This platform offers several advantages, such as enhanced user-friendliness, decreased costs, and increased engagement. Moreover, users of ARMessageBoard are considerably more encouraged to engage actively in frequent location-based interactions.

5.3 Design Considerations

Following the analysis of the responses from the semi-structured interviews, we have identified several essential elements that need to be taken into account during the design of a location-based interaction application: the user density in the intended usage scenarios, the privacy concerns of the users, and the provision for easy feedback.

Can you describe how you experienced location-based interactions in the past and how it feels to use them? The most words that answered this question are "*Not attractive enough*", "*Outdated*" and "*Less response from others*". P13 mentioned "*It's been a long time since I've paid attention to location-based interaction methods.*" Besides, P6 said "*I couldn't find a suitable location to create a traditional location-based interaction, and I may be blacklisted by the administrators if I create a location-based interaction method at the wrong place.*" This feedback underscores a trend: traditional location-based interaction methods are steadily being edged out of daily use and growing less frequent due to inherent limitations. A primary challenge is the difficulty of implementing personalized location-based interactions that do not disrupt the existing physical environment, a common constraint.

Can you describe your experience with ARMessageBoard? P2 described that "*I love it.*", and "*The first time I felt that AR technology is so close to me.*" As P7 said, "*Discovered more opportunities to interact with people around me based on location.*" P5 mentioned "*Easy to use and looks cool.*" P1 mentioned "*I'm a little worried about my privacy.*" The collective feedback we gathered points to ARMessageBoard as a tool that enhances users' focus on the possibilities of location-based engagement and brings a high level of user satisfaction and interaction. Nonetheless, it is crucial to adequately address the privacy apprehensions highlighted by the participants, as such interactions necessitate access to the user's device location which could compromise user privacy. It is noteworthy that during testing, the devices provided by the researchers had geolocation permissions pre-enabled. Therefore, users must carefully manage these permissions according to their personal preferences when installing this application on their own devices.

Table 5: Wilcoxon Signed-Rank Test

	Q1	Q2	Q3	Q4	Q5	Q6
Wilcoxon Signed-Rank Test Statistic (W Statistic)	0.0	1.5	0.0	0.0	0.0	0.0
Asymp. Sig. (Two-tailed P-value)	<.01	<.01	<.01	<.01	.020	<0.1

Q1: Easily Created and Removed. Q2: Low-Cost for Updating Information. Q3: Attractive to Interact with Others. Q4: Easily Used by Individuals. Q5: Promote Communication of A Physical Community. Q6: Help to Increase the Willingness to Interact with Others in A Physical Environment. **Given the relatively small sample size, a p-value $p < .05$ should be considered significant, while a p-value $.05 \leq p < .10$ should be considered marginally significant according to the statistical convention [17].**

Could you specify improvements in ARMessageBoard that would lead you to use it more often? "*Add like and reply functions, and devices can receive real-time alerts.*" (P8). This functional suggestion significantly increases the variety of interactions and gives the publisher more information, which may boost the frequency of use. "*When there are other virtual message boards created in the vicinity, users should receive the corresponding reminders.*" Some participants felt that more reminders are needed to monitor the dynamics of the users around them. It is a constructive suggestion, and message reception is a passive process. It is inaccessible for users to sustain using their mobile devices to scan their surroundings to determine if there is a new virtual message board. P14 said, "*Setting a fixed location in a large physical space to create a fixed digital message board can concentrate more users to interact.*" A combination of a marker-based augmented reality system and a markerless augmented reality system is a better supplement. Although markerless AR systems offer better freedom and fewer limitations, setting up partially marker-based interactions depending on the usage scenario would increase the application's usability. For example, setting up a fixed QR code on a specific location provides a relatively centralized location for interaction when users are dispersed. "*No doubt, more accurate positioning.*" P10 mentioned. It is critical for location-based interaction. However, the cost required for more accurate technology is extremely high. P1 said, "*More users to interact or communicate.*" It is significant for ARMessageBoard to have a sufficient amount of user-generated content to be truly effective. Limited user engagement could diminish the overall experience due to a lack of interaction and feedback.

6 DISCUSSION

This work is to address the limitations of conventional location-based interaction modes with AR. We are putting forward a progressive model of social interaction that intertwines the location-based model with AR innovation within the sphere of online social media. This new paradigm marries the advantages of both realms, heightened by AR's immersive experience. Melding AR with location-based interactions on social media platforms would revitalize the way users engage, offering instantaneous responses and a richer interactive experience. The fusion of these technologies draws upon the unique features of each, fostering interactions that are both more vibrant and attuned to user responses.

Previous investigations into AR technology combined with location-based interaction have predominantly concentrated on areas such as gaming, education, and navigational systems [2, 25]. Javornik et al. 2022 also examines the enhancing effects of AR within the realm of social media platforms. Yet, the integration of location-based interaction with AR for social media purposes remains relatively unexplored. This study seeks to bridge this void by providing a prototype application tailored to social media. As such, we developed the ARMessageBoard prototype, leveraging AR technology to rectify the deficits inherent in traditional location-based interaction methods, with an emphasis on refining social interaction apps. Our within-subject investigation demonstrates that ARMessageBoard outshines traditional approaches, thus corroborating the potential of merging location-based interaction with AR in social media.

In addition, our study outlines crucial elements to be contemplated when devising a location-based interaction application, thereby contributing to the future design of related products. We have augmented the extant design guidelines, offering a richer compendium of factors for consideration than prior research [14]. Compared with the foundational principles governing conventional location-based interaction apps [29], our conclusions provide deeper insight and guidance for the development of AR-enhanced location-based interaction platforms.

Despite being positively evaluated, ARMessageBoard remains not perfect and deserves improvement. A primary concern highlighted by users is the lack of real-time feedback. At present, the platform requires users to be at the physical location to interact with digital message boards, a limitation that poses inconvenience and may deter user engagement. This calls for an improvement to allow remote access to updates and feedback. Additionally, the platform faces challenges with user dispersion in expansive environments with minimal visitor traffic. Users' tendency to create message boards across wide areas leads to scattered interactions. Introducing a visible cue, such as a QR code in a central location, could guide users to a collective message board, streamlining communication even in less trafficked venues.

Moreover, the size of the user base profoundly affects the interactive experience. With a limited number of participants, the platform struggles to serve with satisfied interaction. Integrating ARMessageBoard with prevalent social media platforms would harness their extensive user networks, enhancing ARMessageBoard's functionality as an adjunct rather than a stand-alone service. This could offer users augmented location-based social interaction while still using their existing social media channels. However, this integration poses privacy concerns that must be meticulously addressed to ensure user trust.

7 CONCLUSION

The integration of AR technology with location-based interactions has been thoroughly investigated within educational, gaming, and navigational contexts. Nevertheless, there is a discernable need for a deeper exploration of social media. Highlighting this necessity, our study ventures into the underexplored terrain of incorporating AR into social applications through location-based interactions. To embody this initiative, we developed the ARMessageBoard prototype and implemented user research to assess its merits over conventional location-based techniques. The data gleaned from this research unequivocally support the viability of ARMessageBoard, which demonstrated notable benefits over the traditional approaches.

Further enriching our study, semi-structured interviews unveiled key considerations that are essential when developing location-based interactions. By addressing these aspects, our study makes a substantial contribution to the body of research where AR meets social interaction, filling an existing research void. Alongside shaping future inquiry, the ARMessageBoard prototype emerges as a valuable asset for future developments in this domain. The design insights we accumulated for location-based interaction applications are set to be instrumental for subsequent AR application development. Additionally, our study lays out a framework for fusing AR-driven location-based interactions within the fabric of online social media platforms, paving the way for a more interconnected digital experience.

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