Increasing Socio-Spatial Connectedness Among Students: A Location-Based AR Social Media Network Approach

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(a) (b) (c)

Fig. 1. Creating and sharing AR social media content on our app: a) creation, b) location anchoring, c) shared AR social media.

Augmented Reality (AR) applications embedding user-generated social media content into the physical environment have the potential to increase users' socio-spatial connectedness but are under-researched. Therefore, we built a location-based AR social network app, including geotagged AR social media photos. We explore our app in a research probe of senior university students (n = 6), providing activity-related information to first-year university students at the campus (n = 11). We could identify how AR content is created at a location, what type of pictures are shared with whom, how the sharing increased the attachment to local places and the socio-spatial connectedness for first-year students. Finally, we discuss other application scenarios and outline challenges and opportunities for location-based AR social media networks.

CCS Concepts: • **Human-centered computing** → **Ubiquitous and mobile computing**.

Additional Key Words and Phrases: AR social media, location-based, socio-spatial connectedness, place attachment, AR

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1 INTRODUCTION

In higher education, students' feeling of belonging has been strongly challenged due to COVID-restrictions [29]. It caused a lack of social interaction and peer exchange among students leading to increasing demotivation toward their studies and mental health issues [9], particularly for students who started during the pandemic [22]. Locative mobile social networks (LMSN) support building a sense of belonging by supporting socio-spatial connectedness [39] and community building [42, 44] through exploration of local areas (see e.g. *Spotted by Locals*[1], or *Google Maps*[2]). They use location-based, shared social media content, similarly to, e.g., geo-tagged content on Instagram [35]). Location-based augmented reality (AR) applications, where digital content is overlayed onto the physical environment promote the creation of meaningful connections to one's physical surrounding and community even stronger through spatial content integration [14, 25, 28]. The technology increasingly allows to share user-generated content as in, e.g., *Mapstar*[3] or the social media app *Skrite*[4]. However, these developments are still in their beginnings, and location-based AR social networks have been little researched, considering their potential to strengthen users' socio-spatial connectedness and content sharing behavior.

In our work, we developed a prototype of a location-based AR social network. Users can upload and share their pictures and retrieve those shared by others within their physical environment. We combined the concept of geo-tagged social media content and location-based AR and introduce WIMS, *Walk in My Shoes*, a location-based AR social network to foster socio-spatial connectedness among higher education students (see Figure 1). To inform the implementation of the application, this work aims to create a better understanding regarding interactions patterns, the content shared as well as the ties it makes to the surroundings, which lead to the following research questions:

RQ1 What type of information do users share in location-based AR social networks?
RQ2 How does the shared content influence the socio-spatial connectedness and user-place relationship?

To approach these questions in initial development, we decided to target higher education students as a research probe. The goal was to support first-semester students who had moved to the city in getting to know study- and student life-relevant areas to foster their sense of connectedness and community. We tested our application in a two-phase qualitative field study with university students (n = 17) around the university campus in the city center. In the first phase, six higher education students functioned as experts creating content and sharing their favorite locations around campus using WIMS in a walking&talking method [37]. In the second phase, we conducted user testings with eleven first-semester students who explored the content of experts onsite while creating and sharing their own.

Our results show that users like to share content on WIMS across social circles (e.g., friends or strangers). Therefore, WIMS could additionally increase the socio-spatial connectedness to other students while learning about their personal experiences and activities at the respective places. It means that location-based AR social networks can increase the place attachment and deepen the user-place relationship by social means. We relate our findings to potential alternative application scenarios for location-based AR social networks that highlight their benefits and challenges, such as clutter, movement risks, and content management.

2 RELATED WORK

In the following, we present current work on LMSN and location-based AR applications that frame our work.

[1] https://play.google.com/store/apps/details?id=com.spottedbylocals.guide, last accessed January 2022
[2] https://www.google.com/maps, last accessed January 2022
[3] https://www.mapstar.io/, last accessed January 2022
[4] https://www.facebook.com/skriteapp/, last accessed January 2022

2.1 Locative Mobile Social Networking and Content

Online social networks enable users to establish and keep occasional contact and relationships [8, 40], and to share important, personal life events [36]. LMSNs additionally allow sharing and exchanging information about places and local knowledge on the go. This generates a shared understanding and connectedness among users, which, in turn, contributes to a sense of community and familiarity [21]. For example, geotagged content is used by others to identify points of interest for their next excursions or vacations [35]. Photographs are thereby one of the main utilized media types [23] that represent and appeal to users' emotions [24]. Users may know each other and share personal details, such as their location and address of residence, or communicate indirectly or anonymously [39]. Thus, LMSN can disclose private information, which increases the social connectedness but challenges user's privacy at the same time. Besides photos, other content types such as written anecdotes about the place, support the creation of meaningful user-place relationship [18, 30]. For example, Nisi et al. [30] embedded visual, digital markers and stories (called "*breadcrumbs*") that represented personal memories and stories from app users. It allowed users to explore and discover a physical space while connecting socio-spatially to others but did not provide the social network to continue these connections. Bilandzic et al. [2] supported community building with their mobile app *Cityflock* that provided new residents with crowd-sourced local knowledge and insights. Comparing direct and indirect communication channels, their work revealed that users preferred indirect, asynchronous channels, such as location-based notes or images [2].

2.2 Location-Based AR Applications

Mobile social media content stays mainly detached from the physical environment leading to a feeling of disconnect between users and their their surroundings. Latest developments in AR may allow tackling this challenge by embedding digital content into the user's physical surroundings [14, 28, 44]. Gamified approaches similar to *Pokémon Go* [14] or *Can You See Me Now?* [1] show to reshape the user-place relationship and sense of place [13] by changing the spatial affordance and deepening user's connection to the physical space and sense of community [14]. Other approaches embedded AR content into a narrative linked to the physical place, which facilitated users' spatial immersion [38], emotional attachment and contextual understanding [18, 20]. Location-based AR applications also foster the exploration of new areas and increase users' willingness to be physically active outdoors [12, 26]. They also foster collaboration and social interaction more than purely 2D digital social networks through the shared spatial experience [44].

However, there is still little knowledge about users' content creation, sharing, and retrieving of personalized location-based AR as part of a LMSN. Approaching the gap, we present our location-based AR social network, WIMS, and its initial exploration regarding its effect on community building and users' socio-spatial connectedness.

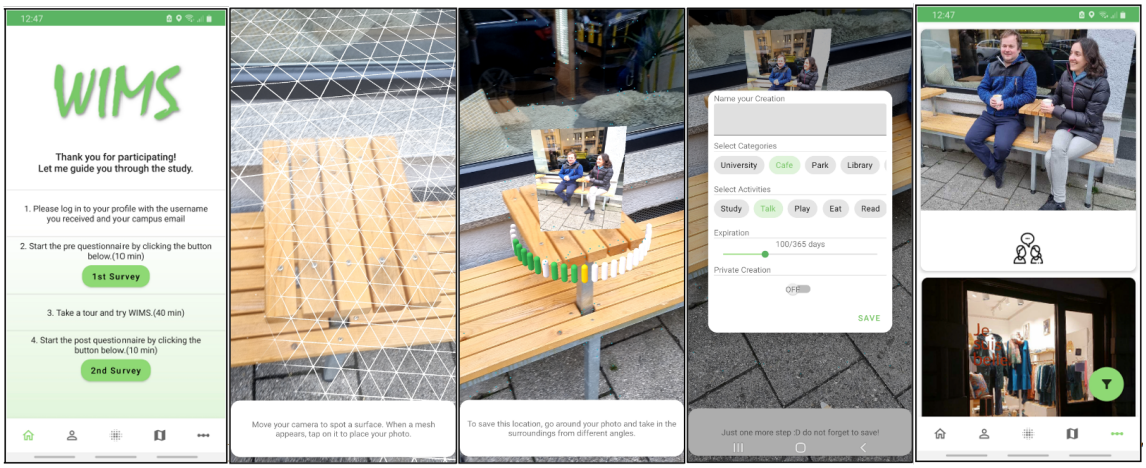
3 WIMS: CONCEPT AND SYSTEM DESIGN

We focused on implementing a prototypical location-based AR social network for anonymous, indirect social exchange [2, 39] that enables users to share personal stories [30] in the form of tagged photographs. By deciding on photos as AR media, we make use of them being a common medium for sharing points of interest that appeal to users' emotions [35].

Concept: We implemented a minimum viable product (MVP) version [19] that allowed for real-time content creation, sharing, and retrieving in situ. However, as this required a high focus on the back-end and system communication, we reduced the app's functionality to taking, positioning, and retrieving photos as AR content in the 3D real environment.

Front-End and Functionalities: We designed the graphical user interface (GUI) in a minimal and clean style using a light color scheme and relating the menu position and icons choices to similar app designs (e.g., *Google Maps*). The

functionality is limited to creating, anchoring, tagging, and navigating to content as presented in Figure 2. The home screen included a short welcoming message and the questionnaire links for the user study. The timeline, Figure 2(e), provided all created content, including user tags about activities and place descriptions that users could navigate to on an additional map screen.



(a) (b) (c) (d) (e)

Fig. 2. WIMS screens from left to right: a) home screen, b) planes to position the AR content, c) content anchoring, d) content tagging, and e) content shared in timeline with everyone.

Back-End and Development: We implemented an Android AR Application in Android Studio[5] together with Google's AR Core API[6] using the programming language Kotlin [16]. Among other reasons, the Google API includes Persistent Cloud Anchors (since version 1.20) that allow an easy and quick location-based anchoring of the created AR content. Furthermore, we integrated the Maps SDK for Android[7] to provide navigation functionality to the anchored objects. We used Google's Firebase Backend-as-a-Service (BaaS), including Storage, Database, and Analytics[8] as back-end. We tagged the created content with a custom keyand stored coordinates, content settings and activities tags inserted by the users using a unique user ID for data anonymization.

4 FIELD STUDY APPROACH AND METHODS

We conducted a two-phase field study: In the first part, we applied the walking & talking method [37] including the emotion wheel by Plutchik [33] with six experts (n = 4 identified as female, n = 2 as male), who were students in their third semester or higher. Then, we asked them to test WIMS and generate content for the second phase, which comprised user testing with eleven first-semester students (n=7 identified as female, n=4 as male). Each phase included a pre-and post-questionnaire accessed via the app. The study took an hour per participant, hereof 40min were allocated for the area and app exploration.

[5]https://developer.android.com/studio, last accessed January 2022
[6]https://developers.google.com/ar, last accessed January 2022
[7]https://developers.google.com/maps/documentation/android-sdk/overview, last accessed January 2022
[8]https://firebase.google.com/products-build, last accessed January 2022

4.1 Questionnaires

The pre-questionnaire included demographic questions about participants' gender, age, number of semesters already studying and living in the same city, and a rough estimate of how many times they had explored the area before. In the post-questionnaire, we included the System Usability Scale (SUS) [6] and open-ended questions to evaluate participants' interaction experience. Additionally, we asked participants about their content sharing behavior based on the information classification by Osatuyi [32].

4.2 Approach

The study took place at and around the university campus. Therefore, we decided on a 500m radius that included cafes, restaurants, libraries, and park-like areas, which would be feasible to walk within the time frame. We installed the app on google pixel 3 phones if participants did not have an android or did not want to use their device. Otherwise, we asked participants to install the app on their devices for the study duration. After introducing participants to the study, they provided an informed consent form and filled out the pre-questionnaire. This followed the app testing. For each newly generated content, participants were asked two questions using the emotion wheel about what type of emotions they relate to the place and with whom they would want to share their pictures and experiences. Lastly, we asked participants to complete the post-questionnaire before receiving their compensation. The study received ethical approval from the LMU ethic board (No.: EK-MIS-2021-066).

Recruitment and Participants: We recruited participants via our university's mailing list and reimbursed them with 10€/hour. All gave their consent for data collection and processing according to the GDPR.

Phase 1: Content Generation with Experts: During the walking & talking method [37], the participant guided us, the moderators, to personally relevant places. At each place, we asked participants to create and share a picture via WIMS following the approach described above.

Phase 2: User Testing with First Semester Students: In the second part, participants explored the app by themselves with the instructions to at least navigate to one available content and create and share one picture, including filling out the questionnaire. We also added the place identity questions from the Abbreviated Place Attachment Scale (APAS) [3] to the pre-and post-questionnaire to evaluate the short-term interaction effect as already applied by Hirsch et al. [18]. Lastly, we asked about their feeling of social connectedness to the content creators to see whether we achieved the feeling of socio-spatial connectedness between student generations.

Data Evaluation and Analysis: We applied descriptive statistics for the questionnaire data and the analysis of the pictures. Additionally, one author coded participants' open-ended feedback thematically using the approach by [4, 5].

5 RESULTS

All our experts had studied for more than six and more than one semester at the university, and had lived in the city for over 1.5 years. Five reported that they had visited the area at least 50 times (M = 45, SD = 12.6). In comparison, all our first-semester students had studied and lived in the city for less than a semester. Six of the first semesters had never visited the area before and five about 1-2 times within the last year. In total, participants uploaded 53 photos (M = 3 pictures, SD = 1.2). All but two (15/17) would continue using the app also after the study and could imagine it useful also for other use cases, such as to support city explorations for tourists (11), for getting to know a new neighborhood (1), or for outdoor sports, e.g., to mark hiking trails (1).

SUS and User Feedback: Participants found the app well-integrated and easy to use requiring little learning effort. Figure 3(a) shows the SUS per participant. The biggest rating differences (also due to the different tasks) between experts and first semesters concerned the frequent usage of the app (experts: M = 2.17, SD = 1.2; first semester: M = 4, SD = 0.77). Experts also considered the app more cumbersome to use (M=3, SD=1.26 vs. first semester:M=1.73, SD=0.65), and were only moderately confident to use it (experts: M = 2.17, SD = 1.2 vs. first semesters: M = 4.27, SD = 0.79). Experts explained this in their comments with the currently cumbersome process of switching screens when navigating to new content.

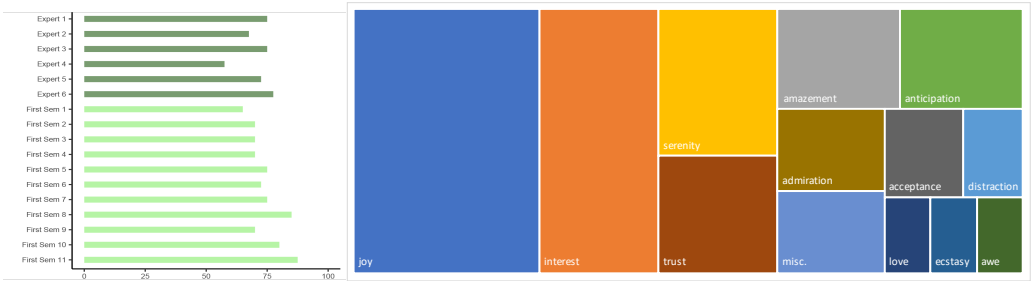
Content Sharing via WIMS: Participants indicated that they would want to share personal AR content mainly with friends within the app (77%; see Table 1), and sensational (56%), political (30%), and casual (57%) content with everyone within WIMS. Considering the content sharing ratio, participants would mainly want to share their posts with certain friends within WIMS (23%), which shows the need for varying social circles within the app. Thus, although situated in public, people still wanted to limit social sharing to given groups.

Table 1. Multiple Choice: Participants' indication of their sharing behavior according to the types of social media content.

Content Type	With certain friends within WIMS.	With certain friends outside WIMS.	With all friends within WIMS.	With all friends outside WIMS.	With all except some friends within WIMS.	With all except some friends outside WIMS.	With everyone within WIMS.	With everyone outside WIMS.	Only me.
personal	77%	47%	9%	5%	8%	5%	9%	0%	9%
sensational	39%	43%	22%	17%	9%	9%	56%	17%	0%
political	22%	17%	17%	17%	14%	9%	30%	14%	14%
casual	26%	26%	22%	5%	13%	17%	57%	9%	5%
Ratio	**23%**	**19%**	**10%**	**6%**	**6%**	**6%**	**21%**	**6%**	**4%**

Place Selection, Identity, and Socio-Spatial Connectedness: Participants shared places they visited to socialize, concentrate or relax, such as cafes, hidden areas within the university building, and parks. They related mainly positive emotions to the selected places and experiences as presented in Figure 3(b). The most mentioned activity was "eating" (for 55% of pictures), followed by "studying" (36%), "talking" (30%), "relaxing" (28%) and "reading" (26%). Additional activity tags included "meeting people" (19%), "having drinks" (17%), "sunbathing" (9%), "play" (8%), "do sports" (6%) and "walking" (2%). Comparing place identity before and after interacting with the app, we found a significant difference for first semester students (Wilcoxon Signed-Rank Test: W = 17; p = .04182 < α of .05) because they identified stronger with the area after their experience than before.

In the interview, all first semester participants (n = 11) rated the app as promoting the exchange with higher semester students and indicated that they would want to use the app to profit from their knowledge and experiences, e.g., *"Find small places not mentioned on Google Maps" (P6)*. Eight also felt more connected to content creators and thought that the app would foster their sense of community. Two stayed indifferent, and one felt only a little stronger connected and as part of a community. These participants explained the disconnected feeling with the lack of active communication, such as leaving comments or reactions to shared content. However, the majority (n = 9) appreciated the shared spatial experience and felt more connected by knowing what others are doing and where they spent their time, particularly, *"in a covid context with fewer in-person meetings[...]" (P9)*. Four participants also felt interested in getting to know the content creators, and another three appreciated the effort and collaboration.



(a) (b)

Fig. 3. a) SUS results: on average, experts rated the app with a 70.83 (SD = 2.94) and the first semesters 74.54 score (First sem., SD = 2.78). The biggest difference between groups shows the question about wanting to use the app frequently. b) Emotion wheel results: Participants related mainly positive emotions and experiences to the visited places. Misc. consolidates all one to three time appearing tags: distraction, awe, ecstasy, love, pensiveness, disgust, fear, optimism and relaxed.

6 DISCUSSION AND OUTLOOK

Our study showed that participants appreciated the location-based AR social network and the novel approach of exploring and connecting with one's surroundings and other place visitors. The experts rated the app more cumbersome but could also not explore the app to its full extend, taking into account the lacking content and their different task. Thus, we will focus less on the SUS and user feedback results than on content creation and socio-spatial connectedness below. Here, results show that the app fostered an implicit social exchange and could deepen users' place identity for new students in town, and thus, support building a hybrid society. The shared content was mainly related to positive emotions and casual or personal content.

6.1 Study Limitations

Some limitations have to be considered that mainly consider our research probe. Our application provided limited functionality for social exchange in its initial version requiring the implementation of more active communication channels. This also relates to the AR content, which is based solely on photos taken by participants and placed in 2D within the 3D real environment. However, we focused on photos, as they are the primarily used social media content type [23] and support emotional connections [24]. As 3D content creation is getting easier, future studies could explore how 3D and 2D content differ in terms of shared location-based AR experiences. This does not necessarily limit the potential of location-based AR social network but mainly considers how we implemented our prototypes functionality.

6.2 User Created Photos as Location-Based AR Social Media Content

Our participants shared places associated with personal, positive experiences that participants had used for socializing, recreation, or concentrating on their studies. The uploaded content consisted of a mix of personal and casual, yet mainly casual, information, and no sensational or political content [32]. This is in line with online social media, where the content mainly relates to personal events [31, 32, 36]. Therefore, sharing in the location-based AR social network resembles sharing information in online social media platforms. Considering the intended sharing behavior reflected in Table 1, we additionally see the need to introduce privacy settings for the content so that users can feel comfortable sharing personal content knowing that, e.g., only certain friends would have access to it. This introduces further research questions of how the content management of location-based AR social media content should be handled,

in the back-end but also for users and different relationship levels. Besides the GUI, the content management needs to include the process of content creation, positioning, and finding in space while keeping it scalable. Our current implementation ignored, e.g., movement risks [12], such as falling or hitting physical obstacles due to digital visual clutter. Yet, envisioning hundreds of photos anchored at the same place, the AR content might clutter the augmented environment, distract users and increase the risk of collisions in the real world. This strengthens the social anxiety, the "media panic", discussed around location-based AR that raises awareness toward the user's and others' physical health and safety risks [27]. Another outstanding discussion concerns data privacy and misuse of such apps, where, e.g., businesses could take advantage for integrating customized advertisement [15]. It requires further explorations about, e.g., content management and how to provide users with a small selection of relevant content only.

6.3 Increasing Socio-Spatial Connectedness and User-Place Relationship

A part of fostering a user-place relationship is to embed interfaces and their content contextually [20, 41, 43]. Location-based AR social networks support the user to draw logical or personally relevant connections between the content, interface, and physical surroundings. Similar to other location-based AR applications [13, 14, 18, 25, 28], our app increased the feeling of socio-spatial connectedness for first semester students showing that location-based AR social networks facilitate shared spatial experiences under social distance. Participants appreciated the local knowledge sharing, the learning from others about their surroundings and felt more connected through the shared personal experiences. It shows that the app successfully conveyed culturally relevant experiences [30] of other community members [7, 11] spatially embedded in the augmented physical environment. Considering prior work in relation to our findings, we argue that location-based AR social networks can support overcoming the limitations from digital, screen-based presentation [44] and foster attachment and user-place relationships.

6.4 Location-based AR social networks: Application Scenarios

We reflect on participants' suggestions for other location-based AR social networks for, e.g., urban tourism and hiking:

Urban tourists are oriented to prior visitors' activities, including the type of pictures they took or what they looked at [10, 35]. A location-based AR social network could facilitate the process of identifying points of shared interests and foster a common understanding of a place without disturbing other place users [17]. Yet, this still requires strategies to avoid movement risks or traffic accidents [12]. Similarly, hikers could learn through others' posts about how a natural site might look like during another season of the year or what dangers other hikers might have experienced at a certain trail section. Challenges in the latter scenario would concern the content management and notification settings to avoid destruction of the natural environment and recreational activities [34].

Both scenarios concern different user groups and content. Nonetheless, we see common benefits when applying location-based AR social networks: they increase contextualization, and thus, understanding, awareness, and connectedness to the location, its characteristics, and content creators. At the same time, there are severe challenges that require future research into strategies to mitigate or overcome them.

6.5 Outlook, Summary and Conclusion

We developed an android app that combines LMSN and location-based AR to foster socio-spatial connectedness among higher education students. Our results support a positive effect on the user-place relationship and the feeling of connectedness to other content creators. It shows that location-based AR social networks can foster a sense of community and support building a hybrid society while allowing for more active, direct place exploration. Our work

also showed various research potential for our application and location-based AR social networks, in general. User content management, when being confronted with exponentially increasing AR content in the physical environment, how to avoid movement risks, and the potential increase in media panic, are important consideration points for future developments. We hope to spark a discussion on how to proceed with our implementation considering the challenges discussed above and look forward to a fruitful exchange on the future of location-based AR social networks.

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