InfoRadar: Group and Public Messaging in the Mobile Context

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ABSTRACT
Previous research has sought to utilize everyday messaging metaphors, such as the notice board, in location-based messaging systems. Unfortunately, many of the restrictions associated with the metaphors have been unnecessarily re-introduced to interaction, and results from the previous field trials have been disheartening. InfoRadar builds on experiences with these systems by presenting improvements in user interface functionality and services. By providing a novel radar interface for accessing messages, desktop-like temporal storage for messages, location-independent message threading, filtering functionality, contextual audience targeting, multimedia messaging, social activity indicator, and voting, InfoRadar attempts to combine both public and in-group messaging into one system. A preliminary field trial indicates that location can act as a rich resource in engaging people to communicate while mobile.

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Location-based messaging, context-aware computing, mobile computing.

ACM Classification Keywords
H.5.2 User Interfaces, User-centered design; H.5.2 User Interfaces, Prototyping.

INTRODUCTION

Location-based messaging is based on the idea of associating virtual content with spatial context, giving the composer an opportunity for referring to the spatial context in the message.

In this section, we compare location-based messaging to related systems in computer-mediated communication. This comparison forms the baseline for the design, which is introduced in the next section. Finally, we evaluate the design and propose directions for future research.

Location-based messaging vs. virtual communities

Use of mobile devices for computer mediated social interaction is justified when the mobile context in interaction matters. Consider the following advantages of situated use in contrast to the non-context-aware virtual communities such as web-based meeting places.

Mixed Presence. A situated user is not only present in a real world place, but also in its virtual correspondent. Locality and the intermeshing of the two worlds facilitate building of social relationships. Consider, for example, virtually met buddies spontaneously meeting in the real world, or a community formed in a physical location being able to continue their relationship through participating to discussion in the corresponding virtual location.

Flexible self-representation. The positive aspect of being able to control how one is represented in the virtual world (e.g., avatar, alias, and self-disclosure) is that people are able to take actions that could normally have social sanctions in the real world [13]. On the other hand, it makes loafing, bullying, and other negative self-expression easier as well. However, whereas the authenticity of the self is always in question in the virtual world, mixed presence makes one accountable of actions at least to certain extent.

Instant Publishing. Users create and share content related to location (e.g., [11]). In order to capture and communicate content in its full richness, and in some cases when the situation still lasts, users need tools instantly available. Whereas post-hoc content production and publishing risk losing valuable information, as well as delaying communication, instant capture and publishing creates more opportunities.

Emphasized locality. Content created in a situation can be targeted to the appropriate audience by leveraging the context in which it is created. For example, attributes of the social, temporal and spatial context can be used to target the appropriate audience. Previous location-based messaging systems have used only the spatial context to infer the audience to which the content is relevant [5, 11].

Location-based messaging vs. face-to-face interaction

Similarly to virtual communities, situated messaging allows for asynchronous and remote communication -- both advantages to in-person communication.

Asynchronous communication. Whereas in face-to-face interaction co-location of participants is required, situated messaging enables people to interact asynchronously. By leaving virtual content to locations in an interactive system, users can receive also the attention and feedback of those not necessarily in the location synchronous in time.

Remote communication. Similar to virtual communities, in situated messaging users should also be able to exploit the ability to access content associated to locations remotely. This especially caters for effective group-communication by not restricting message threading to co-located users.

Location-based messaging vs. public displays

Public displays continue the evolution of bulletin and notice boards (e.g., [3, 10]). However, there are drawbacks in public displays for supporting messaging, in comparison to mobile devices.

Privacy of communication. Integrating the messaging system into a mobile device has the potential for supporting more *private* and thus personally meaningful communication. Disclosure of personal information is known to be reciprocated in communication [8], an effect that cannot be fully harnessed in public displays.

Pervasive publishing. Whereas with public displays the location of the displays is a decision of a third party, mobile devices allow users themselves to post content wherever they see appropriate, resembling more the interaction modalities in graffiti and toilet scribbles.

Previous location-based messaging systems

Existing location-based messaging systems using *mobile devices* have been based on the bulletin board metaphor [5, 11]. Although they have attempted to leverage the benefits of using mobile devices and WLAN-based internetworking, the systems only partly exploit the advantages of situated communication discussed above. In the following, we discuss them one-by-one.

Mixed presence. The UIs used in previous location-based messaging systems have represented the virtual content in lists. This design reminds the user of existing interaction modalities of non-context-aware e-mail, not creating a feeling of being situated in a mixed-reality space. Additionally, the UIs used have not used implicit user traces that support social awareness [17].

Flexible self-representation. Previous systems allow for creating pseudonyms, therefore facilitating self-disclosure. But since they do not support awareness of other users using the system, they do not attempt to compromise between self-disclosure and accountability of actions.

Context-addressing. GeoNotes requires publishing to occur in the location the message refers to. We consider this unnecessary since the user should also be able to publish post-hoc.

Emphasized locality. The previous systems leverage context information by publishing the messages to those physically in the virtual location the message refers to. The rational behind the design is that this *location of access* implicitly defines the audience to which the message is relevant.

Asynchronous communication. Both previous systems build on the idea of asynchronous communication. However, by restricting access to messages only from the location of the message, the turn-taking in threading becomes unnecessarily restricted, reminding the interaction with physical notice boards.

Remote communication. Both of the previous systems effectively disallowed remote communication by constraining users being in the spatial context the message referred to. This severely hampered group-discourse initially sparked in a location to shift to location-independent, disallowed people to remotely explore remote locations by navigating the virtual message space, and introduced delay to communication of ephemeral situations.

USE SITUATIONS

A conclusion from the preceding analysis is that the advantages of location-based messaging may not have been sufficiently leveraged in previous research. Additionally, we argued that location-based messaging could effectively complement the social interaction in virtual communities, face-to-face interaction, as well as public and semi-public displays. We believe that location-based messaging is best suited to many-to-many communication where situation of use matters.

User needs study

To understand more of these situations we design for we conducted a user need study that focused on 25 adult urbanites living in Helsinki. Several different data collection methods were used, including focus groups, photo diaries, contextual inquiry, and shadowing. All observations were written down as *travel episodes*, depicting a meaningful journey between two places. From the over 1300 travel episodes, situations related to social interaction were inspected. User needs were identified by looking at situations problematic for the participant and where their routine course of action was not possible because of an obstacle in reaching a goal. (The method and results are reported in more detail in [9, 16].)

From these needs, we selected the most prominent ones (i.e., general for most participants, and reoccurring in the data) from the point of view of InfoRadar.

Need for contacting and meeting new people. We learned that when spending time in public and semipublic places, such as cafés, people observe others that occupy the same

space or just happen to pass by. A desire to meet new people in such situations was expressed by our participants. The courage to initiate a contact with such persons was lacking, however. Concerns were also expressed about interrupting the other while initiating a contact. People seem to be inspired to meet strangers from observing their appearance and personality.

Need for being aware of co-located friends. In crowded places, such as in the city center, friends often crossed each other's paths without noticing it, which was considered a pity. Conversely, in many cases it was delighting to meet a friend by chance.

Need for understanding surroundings. While traveling people tend to wonder about the history and background of establishments. They also have a need to get information quickly and easily on opening hours, agendas and timetables that are typically associated to physical establishments, such as shops, theaters and railway-stations. The tourist and tour guide applications (e.g., [1, 12]) have been designed to satisfy this need, but the kind of natural curiosity of ones surroundings could as well trigger discussion with the people more familiar with the environment, instead of using pre-packaged information for familiarizing with the environment.

Need for sharing opinions of surroundings. Incidents were observed where people were motivated to share opinions of establishments, for example of the controversial Museum of Modern Arts in Helsinki. We argue that this is an important character of people wanting to use others as a soundboard for their thoughts and building of communal awareness this way.

Role of spatial context

Based on the user requirements we identified how spatial context should be used in location-based messaging. Overall, we see the role of context (whether spatial, temporal, or social) as a *resource* necessary to be efficiently utilized in situated computer-mediated communication. Our philosophy in using context is embodied in the InfoRadar and explicated in the following five principles:

- *Enriched messaging.* Using spatial context for referencing aspects of the physical world in messaging, making communication of them *richer* and more *meaningful.*
- *Meeting new people.* Using spatial context for creating virtual "notice boards" for public social interaction where and when appropriate.
- *Inter-personal awareness.* Using spatial context for efficiently communicating of situations relevant for group members.
- *Public opinion.* Using spatial context for building awareness on issues relevant in the location.
- *Targeting an audience.* Using spatial context for targeting an audience in the public.

INFORADAR DESIGN

The InfoRadar aims at satisfying the above user needs by using spatial context. It attempts to facilitate both public- as well as group-communication – a concept difficult to implement using non-personal displays.

Device

Positioning technology. We reason that the device used for location-based messaging needs to be based on a Personal Digital Assistant (PDA) or a mobile phone in order to be suitable for mobile use. The InfoRadar is based on a PDA (Compaq IPAQ) that is connected with an external GPS-device and a GPRS-transceiver attached to the card-slot of the PDA. The GPS-receiver incorporates an internal electronic compass, and together they are used for accurately locating the device outdoors and determining the orientation of the device. All internetworking between the devices is handled using client-server architecture, the server being used as a repository for storing all content created and accessed by the client devices. The communication between the clients and the server is implemented using GPRS-based mobile communications. GPS positioning was used outdoors, and a special version of WLAN indoors [14].

Casing. The devices were all integrated as one, resulting in a sturdy, weatherproof package of 40 x 150 x 300 mm size. The casing used was of a stiff nylon-like fabric with a rectangular hole cut into the cover through which the user could manipulate the PDA UI. The package could be unzipped to reveal its interiors. This process was required when changing the batteries of the GPS device and upon connecting the charger for the PDA. The users were instructed to take these actions every evening to guarantee a one-day standalone time. The case had to be opened also when switching the GPS device on and off. Since the GPS device consumed most batteries, especially when searching for satellites indoors, the users were instructed to switch off the GPS device indoors. Figure 2 presents the device interiors and the casing.

Radar View

The list-based user interface (UI) metaphor has been rather popular in context-aware computing. Both of the previous location-based messaging systems, E-graffiti and GeoNotes [5, 11], use an UI that presents the messages in a given location in a list. Since some of the users in the E-graffiti field trial criticized the system as a restricted e-mail system, Burrell and Gay hypothesized that it could be partly due to the list-based UI that reminded too much of the communication modalities used in e-mail, inhibiting people breaking free from the person-to-person messaging model

Figure 2. InfoRadar consists of a PDA supplemented with an electronic compass, GPS, GPRS receiver, a pen, and batteries packed to a nylon casing.

and shifting towards addressing an audience through locations.

We believe the UI used in location-based messaging should remind the user of the aspects of physical space, and give indication of how the content relates to the environment, providing a substantially different UI compared to e-mail applications. This design approach naturally has costs since such an isomorphic representation of content relative to the physical space requires orientation information and more accurate positioning than typically used in list-based UIs. For example, E-graffiti and GeoNotes both use rather low levels of location granularity by using WLAN network access node coverage areas as unique locations.

Virtual tourist guide applications typically rely on a map-based UI where the user position is refreshed on the map [1, 15]. But we wanted to allow versatile use also in situations where the appropriate map is unavailable. Therefore, we use a radar-metaphor instead that positions the user in the middle of the UI and all virtual content is arranged around the user (see figure 3). The electronic compass is used to render the orientation and distance of messages to accord with device's pointing direction. The result is an UI that strives for creating a sense of being in a mixed-reality space creating an isomorphic representation of the virtual content relative to the directly observable physical world, no longer requiring a map to enable reference between the virtual content and the physical space.

The *scanning radius* of the radar can be adjusted to change the scale used in the radar screen. Therefore, InfoRadar can be used to scan for messages nearby with high resolution or scan up to a maximum range of 12 kilometers with low resolution. The design enables the user to build an understanding of the immediate surrounding, while able to participate virtually in activity taking place at distance.

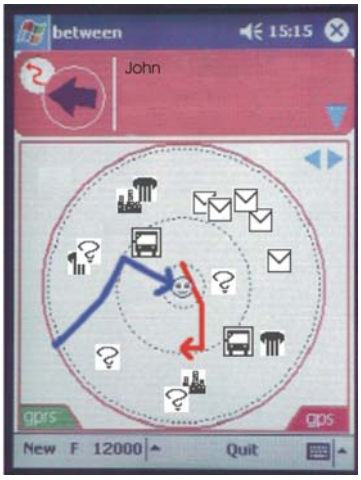

Figure 3. InfoRadar's radar interface showing messages and traces of other users. The user is in the center and the location-based messages are shown in accord to the orientation and distance from user.

Reading Messages

Previous location-based messaging systems have required the user to be in the location of the message in order to read it [5, 11]. However, there are two aspects of location-based messaging that speak for remote reading. First, the content of messages can be considered to have a lifespan, after which the content loses relevance. For instance, consider a message such as "I'll be skating here tonight." If the system disallowed remote reading, the user would suspect it unlikely for a message with a short lifespan to reach its audience, and therefore be unmotivated to post messages related to ephemeral situations. Second, it is possible that the audience for whom the message is intended is unlikely to visit the location of the message. Consider for example a message such as "Hey, I found a cool shop on this side street!" Remote reading being disallowed, people again would be not motivated to post such a message, because the message in essence is a location-based invitation motivating people to explore a new location and expand their knowledge of their environment.

Remote access is very natural using the InfoRadar. Since the UI represents all virtual content around the user in accord to the orientation and location of the device, content 10, 100 or 1000 meters away are all accessed using the same interaction modality: using the PDA pen the user taps on the message icon on the radar screen opening the message. But as the UI is operated without a map-overlay accessing distant content posted in locations out of sight is regarded more difficult than accessing nearby content associated to in-sight physical locations. This is because the user no longer has the directly perceivable physical space as a resource for determining what content is related to what aspect of the physical space, making navigation harder. To help in this task the user can however use the spatial arrangement of the messages together with the approximate direction and distance to the remote location for making a

distinction between different remote locations. Also, InfoRadar uses message categories that make a distinction between different types of messages (described below) and highlights unread messages, which provide cues helping remote access.

A novel feature was added after the pilot study: a *desktop* was added beside the radar that could be used for storing interesting messages. Messages from the radar could be drag-and-dropped to the desktop and could be later read and replied by the user. Consider, for example, picking up interesting messages from a side-street where you do not want to stay too long, then read them on the bus on the way home. The idea was built to improve the remote access to messages by enabling users to pick-up content for later use.

Composing Messages

While our design allowed for remote reading of messages, we had a reason why we wanted to restrict *remote writing* of messages. Specifically, we thought, that with the radar screen UI it is very easy to misplace messages by accident since the scaling is not fixed, and although the user could take into account the scale used, distance and orientation are somewhat difficult to estimate without a map-overlay. On the other hand, people have a natural habit of pointing at objects and establishments from a distance. Therefore, in order for the message posting to be as natural as possible, we considered that posting of messages from a small distance could be allowed. As a result, the system by default assumes that messages are posted in the current location of the user. But in order to perform a remote posting the user drags the message from the radar center using the PDA's pen and drops it in a location within 120 meters from the user. The design therefore tries to compromise between natural habits of referring to locations from a distance and the problem of disassociation of message content with spatial context.

However, the design does allow for *remote reply*. Since the reply messages are associated with the initial message posted at the location (creating a message thread), there is little risk of misplacing content, while facilitating location-independent discourse – something not possible with previous systems.

Filtering Content

Noticing the potential problem of cluttering the screen full of message referents when using large radar scan radius, we designed a very simple filtering mechanism that was based on the use of pre-defined message categories. When posting messages one of these message categories needed to be selected for identifying the category it belonged to. For viewing messages belonging to certain categories could be filtered out by selecting the categories in which the user showed little interest. Each of the message categories has a distinct symbol on the radar screen, facilitating selection. Anyhow, the filtering of messages was never the focus of our research, previous location-based messaging suffering moreover from the paucity of virtual content.

Contextual Audience Targeting

Burrell and Gay speculated on the need for users to post both private and public messages and implemented this as an option for users in E-graffiti [5]. Instead of composing public messages users preferred private when using the E-graffiti system (79% of all voluntarily posted messages being private, the rest public [5]). The outcome was that for a given user there were very few messages to read in any location. Subsequently, Persson and Fagerberg recognized that private messages do not contribute to the critical mass as effectively as public messages, and designed their GeoNotes system to support only public messages [11]. In this respect GeoNotes is probably better at attaining a critical mass of messages for a given user in any location. But it did not allow for remote access to messages, enforcing message audience only to those visiting the physical location. This can be considered as a kind of implicit audience selection forced by the system design that also promotes privacy of communication in a loose way by limiting access to messages by requiring presence in the location. Because we wanted to allow remote access to content (discussed above) as well as enforcing public messages to attain critical mass, we created a new *context-based audience targeting* concept that allowed the user to define indirectly using two context attributes, time and location, who could access the content they posted.

With InfoRadar the user defines the *lifespan* and *visibility* of the message when posting content. These attributes define the *context of access*. The lifespan defines the time from the posting of content before it is removed from the system whereas the visibility is the distance within which a user has to be in order to see it. This concept provides a flexible way for users to communicate of situations that are relevant for limited time, as well as indicating whether the content is relevant only when in proximity of the spatial context the content is associated with.

Multimedia Messages

As previous location-based messaging systems [5, 11] have supported only text-based messaging InfoRadar messages may contain also *digital pictures*. Since InfoRadar allows messages to be accessed remotely, we considered that users might take it into account when composing messages, and therefore want to add pictures to messages and transfer some relevant aspects of the spatial context to those reading the message remotely. In order to make multimedia messaging as versatile as possible, the InfoRadar package contains a compact-size digital camera that can be connected via infrared with the InfoRadar main device. After taking a picture, if the user wants to attach the picture to a message being composed, she/he selects the "attach image" option from the InfoRadar UI. Then, to send the image from the camera to the InfoRadar device, user selects the send image option from the camera. This procedure can

be performed without opening the InfoRadar casing, as long as the camera is pointed to the casing.

Social Activity Indicator

InfoRadar displays *traces* of user movements on the radar screen (see Figure 3 for an example). As the user selects one of these traces using the PDA's pen, the color changes from blue to red while displaying the user's contact information. The *contact* is a user-defined text string that can contain a pseudonym for identifying the user in public space, or the address for contacting the user outside the system.

The trace was designed to give a sense of social activity in locations (see more on social activity indicators, e.g., in [2]). As Burrell and Gay [5] suggest, the knowledge of audience being there (or not) could motivate users to post content; paucity of content being a problem in previous systems [5, 11]. However, the trace functionality in InfoRadar, as well as augmenting the sense of activity, also facilitates inter-personal awareness. But since InfoRadar also supports public awareness users cannot be forced identified using real identities. Therefore the use of user-defined contact labels. If users were prepared to share an address in the contact, such as an anonymized e-mail address, the trace functionality would ultimately facilitate users meeting new people – a need that became apparent in the user study.

In addition to direct benefits, activity indicators and inter-personal awareness also have indirect benefits. As discussed above, implicit user traces on the InfoRadar make users visible in the mixed-reality space, a factor that will possibly make users more accountable for their actions. This may help control socially unacceptable behavior in both the virtual and real worlds.

Voting

In order to satisfy the need for people sharing opinions related to surrounding spatial context we designed a tool that enabled inquiry of public opinion from a large audience. Using InfoRadar a user may, instead of a message, create a *poll* by composing a question that can be answered by "yes" or "no," and post it to a location. Users seeing the poll may cast their vote, and the system displays in percentages how people have voted. The intention of the voting system is to facilitate inquiry of public opinion from a large population, create communal awareness, and indirectly trigger discussion and activity elsewhere in the system.

PRELIMINARY FIELD EVALUATION

A preliminary field trial was conducted in order to give indication on the successfulness of the InfoRadar design. On a meta-level we were interested in finding out whether InfoRadar could facilitate group-communication by *enriching* current communications practices while facilitating people *engaging* in new social interaction with strangers using user-created situated content.

On a practical level we were interested in finding out how the different tools and functionality of InfoRadar cater to these ends. First, we wanted to find out if asynchronous and remote communication would allow message threading, not addressed in previous location-based messaging systems [5, 11]. Second, we wanted to understand how the audience-targeting tool worked, and whether it could be improved. Third, we wanted to understand how users adopted the idea of polling the public for general opinion. Fourth, we wanted to understand how the users perceived the UI and whether it was an improvement over list-based representation.

Method

Since previous experiments with location-based messaging systems have been evaluated in a campus context mostly by computer science students [5, 11] we wanted to test the device in a different setting. We expected more novel ways of using the system to emerge in the urban environment when the device was introduced as a part of daily life of people with less prior expectations in how such a system *should* be used, and more attention on how InfoRadar could solve the typical daily challenges of mobile life (discussed above).

We arranged two separate field trials, one with users with already established social relationships with each other, and the other with users with no prior social relationships with each other. The former field trial consisted of friends that knew each other from a theater where they practiced amateur acting; this group will be called as the *Theater Group*. The latter field trial consisted of people strangers to each other but who belonged to a vague community of people bound very loosely together by a common location. This location was selected as a shopping mall in downtown Helsinki, and all participants of this group either shopped frequently in the mall or worked there. The group will be called as the *Shopping Group*. Both field trials lasted for three weeks and in both cases the size of the group was limited to six because we could not produce more InfoRadars.

Since inside the shopping mall there is no GPS signal that could be used for location-based messaging, the InfoRadar used indoor location technology (discussed above) while the GPS module was disconnected. Therefore all communication in the shopping group was restricted to the confined space of the mall, whereas the theater group was using GPS positioning (discussed above).

Results

During the trials 66 and 34 proper messages were sent by the theater and shopping groups, respectively. In addition, 77 and 23 reply messages were sent by the theater and shopping groups, respectively. Based on the preliminary field trial it seems that the InfoRadar design motivates discussion related to aspects of the physical space since in both groups more than 60% of the initial messages were

related to spatial context (61% and 80% in the Theater Group and Shopping Group, respectively).

Group messaging

Based on the focus group discussions and the messaging activity observed in the theater group it was evident that such a closely-knit group enjoyed the mobile *group-communication* functionality provided by InfoRadar; one girl even refusing at first giving the device back. A lot of the discourse in the theater group, although initially related to spatial context, shifted to *location-independent.* One reason for observing many of the message threads shifting to subjects unrelated to the location of the initial message is a consequence of InfoRadar design and the current mobile phones (which all the theater group members had) being inappropriate for supporting group-communication. Since InfoRadar allows remote group-communication by replying to existing message threads, the users used this functionality also to discuss subjects not related to the spatial context. This indicates that group members are willing to engage in group-discourse when mobile. One participant even admitted putting the InfoRadar on the handlebar of the bicycle and navigating the virtual space while cycling. We hypothesize that being able to reference spatial context in content *enriches* communication between group members and makes the message more *meaningful.* Consider for example the following message intentionally taken out of context:

Yvonne (theater group): can you call this culture?

Referencing spatial context also makes message composition easier not needing to write as much.

Generally, however, we regard that in group-messaging the ability to reference the spatial context is not necessary. Using pictures the user could tell at least as much about the spatial context of reference. Naturally, it can be argued that spatial context matters, and a picture when accessed in the location it was taken (the use case in previous location-based systems) gives the richest meaning, but typically the need for immediacy of sharing in groups obviates this use case.

Public messaging

For the shopping group the ability to refer to locations in content and use locations for retrieving content in public space can be considered a versatile way of *engaging* in *public discourse* (considering 80% of the initial messages in a thread were related to spatial context). For example, consider the following message thread:

[15ht Dec. 15:16] **John:** Our daughter waited from early morning to see Santa Claus. But what happened? Excitement was too much. (See figure 4 attached to message).

[16ht Dec. 11:44] **Peter:** Typical. It happened with our "big" 3 year old too.

[16th Dec. 15:10] **Katie:** Unbelievable! Had the notice been in the paper or some other media?

Figure 4. Picture part of the location-based message composed by John.

In public messaging spatial context is a much more important resource than in group messaging, since in public communication the link between the content producers and consumers depends on the producer being able to effectively harness spatial context for targeting the unknown consumers.

Social context in audience targeting

The Santa Claus narrative gives an indication of the potential of public location-based messaging. But what makes situated public messaging work is how context is used as a resource for targeting the appropriate audience. In the observed scenario John and Peter's discussion acts as a trace of the events that took place in the location for Katie. Katie shares the spatial context of the shopping mall, although asynchronous in time, with John and Peter. But Katie also shares the same social space with them, as they all are parents of small children. Although InfoRadar only used attributes describing temporal and spatial context in targeting an audience, it is evident that in public communication this is not sufficient. In group communication the social space is defined by the group composition, but in public communication the temporal and spatial context may not sufficiently accurately define the audience to which content is meaningful.

Temporal and spatial context in audience targeting

As discussed above the posting of messages as well as polls in InfoRadar required the user to define the appropriate context (in respect to time and proximity) in which this virtual content could be accessed. This was expected to facilitate "*contextual audience targeting*" by giving the user more control on who could see the postings by defining the *context of access*. We expected both groups to use the lifespan and visibility range of the messages for communicating of ephemeral situations typical for mobile contexts.

In general the theater group used very large visibility range (7,6 km) for messages on average, logical since they were interested in communicating with the group that was dispersed around the city. Evidence of this is the 10,3 km average visibility range of messages replied to being much higher than the 7,6 km average. But despite the majority of the messages being intended for the whole theater group, people did make use of the contextual audience targeting capability in the InfoRadar. For example, one participant early on in the trial sent a kind of *contextual invitation* by composing a message "I'm on Kafka" (the cafeteria they typically hang out in), inviting others to join. The user defined the visibility range for the message as 80 meters and the lifespan as 24 hours. Since the situation is clearly ephemeral, it at first appears illogical to use such a long lifespan. But since the message content combined with the time of posting already indicates when a message is relevant, the lifespan can in fact be used for "I was here" type of communication, creating a kind of *explicit user trace* that fades eventually. In this respect the users deployed contextual audience targeting creatively by letting others know of one's past activity, while anticipating it being somewhat unlikely that their friends would join the ephemeral situation while it lasts.

Notifications

Although InfoRadar used a scheme for empowering the user to indicate whether a situation was ephemeral, the system didn't take full advantage of this information. Since InfoRadar didn't employ any notification schemes, users were likely to miss an ephemeral situation although in the appropriate context of access. During system design we reasoned that employing notifications would cause interruptions for users, interruptions not necessarily relevant in a given context of the user, but now we would recommend instead modeling what type of interruptions are relevant in a given context and using notifications in such situations.

Voting on general public opinion

Despite being designed for large-scale public use, the voting application was used rather actively by both groups. The theater group posted a total of 17 questions whereas the shopping group posted 12. Votes cast were rather few, 10 in the theater group and 22 in the shopping group. The scarcity of votes cast by the theater group probably being a consequence of the polls being spread out on a large area with limited visibility whereas being more concentrated in the shopping mall.

Results suggest that people would use such an application for:

- Joking and bullying.
- Using the environment as a soundboard for own conceptions and building communal awareness.
- Planning and developing business.

Consider the following polls (two per each of the three categories):

Peter (from theater group): Is William GAY?

Peter: Can only lords visit Lord Hotel?

Lauren (shopping group): Should this Christmas tree be real?

William (theater group): do you believe in that everyone of us are able 2kill another human being if the circumstances are right?

Katie (shopping group): Should the heating in the mall be turned up?

Katie: Do you think the Christmas sales start too early?

Traces

The traces, which were designed to create a feel of social presence and invoke activity in messaging, were considered based on focus group interviews as "exciting", especially when they moved in real-time, but nobody admitted trying to follow somebody else's trace. Because our system didn't log location information constantly, only when the user interacted with the device, we cannot say anything for sure on whether the traces in fact provoked explicit user activity in the system. We can only hypothesize that some of the messages observed related to individual people could have been inspired by the traces of the respective individuals moving on the UI. For the future, we suggest systems to allow for attaching virtual content to the users themselves (traces), not only to locations.

Naturally, the traces do help users looking up the location of friends, but since the traces in InfoRadar did not use notifications, InfoRadar did not provide proactive awareness of co-located friends (refer to other studies, such as [17] on inter-personal awareness in groups).

User interface

The radar view aimed at creating an isomorphic representation of the virtual world (of messages, votes, and traces) relative to the physical world. We hypothesized that this makes referencing between the two worlds cognitively less demanding. Also, as speculated by Burrell and Gay [5], conventional list-based UIs remind the user of e-mail type communication modalities, possibly restricting the user from taking advantage of location-based communication possibilities. Therefore the isomorphic UI representation used in InfoRadar is justified, although demanding technology capable of providing accurate location and orientation information.

During focus group discussions held after the field trials both groups were asked their opinion on the UI. Somewhat to our surprise the radar screen representation created mixed feelings. Some regarded a map-based interface probably better and said that the rotating messages when reorienting was confusing. Suggesting that people need to

stand still and orient the device slowly due to slight latency. The general consensus was that the UI without a map-layer was inappropriate for "finding one's way", a purpose it was never in fact designed for. Some on the other hand liked it and said they liked the virtual world "reoriented according to the direction the nose pointed in." Some confusion also resulted while using the InfoRadar in the multistory shopping mall, where the UI gave no indication of the elevation of the messages relative to the user. Users were left wondering what on the current floor level was being referenced. We would recommend future isomorphic UIs to indicate elevation but also to incorporate a tool for filtering out content on neighboring floors if complicating navigation.

Regarding the referencing habits of people we argue that people like to attach messages rather accurately to the location they are referring to. This was especially the case in the shopping mall context. For example, when a shopkeeper advertised a sale she posted the advertisement near her shop, and where a customer was positively surprised of the wide selection of records available he shared his delight by posting a message next to the record store. Also the theater group took care in posting their messages. For instance, one participant shared the key code used for accessing the apartment building she lived in by placing it in a location-based message in front of the building. Moreover, the results indicate that people seem to refer to locations with inconsistent resolution, sometimes referring to an individual object, or to an establishment, and sometimes just using location as a *resource* to target a particular audience on matters possibly unrelated directly with the location itself [7]. Therefore, since in location-based messaging people refer to aspects of the physical world with inconsistent location resolution, it would be justified to use high accuracy positioning to facilitate people referencing aspects of the physical world with different resolutions.

Problems with positioning technology

Current technology, unfortunately, turned out to be hardly reliable for providing accurate pervasive positioning needed for the isomorphic user interface in InfoRadar.

High-resolution indoors WLAN-positioning system was reliable and accurate, but the GPS-based version of InfoRadar was not. This discontent, however, was largely anticipated since GPS was being used as the sole positioning technology in the demanding urban context [18]. During design we tried to take into account the urban operating conditions by using the latest successful location reading for refreshing the UI, therefore making possible navigation even in conditions where the connection was lost sporadically. In such situations InfoRadar indicated (with the GPS status indicator turned red, see figure 3 bottom right-hand corner) there being no GPS signal, inferring the UI possibly misplacing the user if mobile. However, since we did not want the prevailing operating conditions to restrict the user from posting content, the InfoRadar took a calculated risk when content posting was not disallowed under such conditions. This decision being conscious, since we did not want to cater to the paucity of content observed in previous systems [5, 11] by restricting the opportunities to post content. Anyhow, we recommend future systems to explore more intuitive heuristics for the user that compromise effectively between the two extremes of restricting and allowing content posting in situations where accurate location information sporadically turns inaccurate. One solution could be to use a multi-modal UI (see, e.g., [4]), letting the user choose a high-resolution isomorphic representation navigation mode when conditions allow, reverting back to the default conventional UI mode less prone to inaccurate positioning.

CONCLUSIONS

Our philosophy in designing for location-based messaging has been to use context as a *resource.* We use context to enrich messaging, facilitate making of new acquaintances, facilitate inter-personal awareness, communicate public opinion, and target an audience. Our approach does not attempt to recreate the interaction modalities of physical community messaging systems, such as notice boards, but instead is based on satisfying needs of mobile users. In InfoRadar we attempted recreating the advantages of virtual communities (remote and asynchronous communication, and self-disclosure using anonyms) while leveraging on the advantages of situated communication possible with context-aware mobile devices.

Our theoretical and limited empirical evaluation suggest that:

- In group communication the ability to reference spatial context can enrich and spark new communication, however, mobile imaging and group sharing of such media is probably a better solution to referencing spatial context.
- In group communication contextual audience targeting (using spatial and temporal context) is useful for communicating of situations that are relevant for others based on their context. We call this *contextual inviting* where the delivery of the message depends on the recipient's context.
- Being able to reference spatial context does not imply that discourse should be restricted to the location referenced. Groups need to share content also in location-independent manner to allow for location-independent turntaking.
- When targeting an vague audience (typical for public communication) situated content distribution can leverage attributes of spatial, temporal, and social context. Previous systems have only leveraged spatial context, and introduced unnecessary restrictions for use.

- Polling the public can be regarded as a versatile tool for building communal awareness on issues related to the spatial context.
- Theoretically an isomorphic UI is advantaged compared to list-based representations by creating a feeling of being immersed in a mixed-reality space where referencing between the virtual and physical world is natural. However, we suggest using multi-modal UIs that allow more effectively taking into account remote access to locations and the sporadic fluctuation in positioning accuracy.

We argue that being able to reference spatial context in messaging is more valuable for *engaging* in social interaction than *retaining* existing ones. When social relationships exploited in content sharing mature, the significance of location diminishes, sharing becoming more versatile in a location-independent manner. However, even group communication does benefit from harnessing spatial (and temporal) context, as illustrated with *contextual invitations.*

We regard the role of context in *engaging* strangers in communication with each other as important. First, people should be equipped with mobile tools to target public audiences with attributes that limit the general public to a meaningful audience for the content to be communicated. Second, when social relationships develop in the process of social interaction, the application should be able to take discourse "out of context" and cater for the formation of closely-knit groups that preserve a sense of intimacy.

We regard that situated public and group communication should be build into the same application. Such design would create opportunity to public communication involvement by leveraging the more pronounced group communication usage. However, the InfoRadar design has to be improved to allow for more effective location-independent discourse, which we regard predominant when social relationships are well-established. Also, to cater for intimacy in self-disclosure, groups should be able to construct their private virtual space (not addressed in InfoRadar).

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