

# Context-Aware Messaging: How Personal, Spatial and Temporal Constraints Affect Text-Based Communication

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## ABSTRACT

There are academic and commercial drivers for context-awareness to play a prominent role in the future of mobile services. Implementing a complete model of context remains an unsolved problem, however, some contextual elements such as person, time and place are relatively easy to identify. We develop a simple context model incorporating personal, temporal and spatial dimensions and apply it to a context-aware text messaging service. We report a field study of the service, investigating how applying these fundamental contextual constraints to messages can affect the nature of communication between participants. The results suggest that although contextual constraints are not appropriate for all types of message content, they increase opportunities for situated chat in public spaces, improve group awareness between peers and facilitate conversations between people, some of whom would not otherwise communicate with each other.

## Author Keywords

Mobile messaging, SMS, context-aware, location-aware, mobile social software

## ACM Classification Keywords

H.4.3 Communications Applications

## INTRODUCTION

People routinely rely on voice calls and SMS messages to communicate with each other. Voice calls offer instant, synchronous interaction, whereas SMS offers us the ability to interact with each other asynchronously, at a convenient time. Time, however, is not the only factor that dictates whether we choose to initiate, respond to or act upon communications. People may wait until they are at a particular location, with a particular person or performing a particular activity to do so. Although technology currently allows us 'anytime, anywhere' communication [8], we

don't necessarily wish to communicate or be communicated with all of the time, everywhere. Furthermore, a communication may only be relevant in a particular context. Filtering messages according to contextual constraints may alleviate information overload, decrease 'spam' [4], reduce the burden of interruptions to a user [6] and overcome problems with forgetting to act upon a communication by delivering it at the moment when it is most relevant.

Although SMS continues to thrive, Blom et al. [3] point out that, in the face of quickly evolving mobile services, it is unlikely that the nature of SMS will remain unchanged. Additional features such as multimedia attachments have already been introduced, and more developed context-awareness is a potential further stage in the evolution of text based messaging. At present, most forms of communication take only the simplest 'personal' context into account, i.e. the identity of the recipient. Thus, the sender can place constraints on who receives the message. To develop full context-awareness we would require a complete model of context; a model which can capture all of the measurable components of a given situation [9]; for example not just who should receive a message, but also where, when, why and how they should receive it. Although sensor technologies are beginning to allow us to capture important contextual information there is still a reliance on inference rules, artificial intelligence or extensive training data to determine or predict those elements of context that cannot be accurately measured [2]. Kaasinen [8] suggests that before we can make the giant leap towards complete context-awareness we must first take a smaller step towards developing services that use more easily measurable elements of context, such as location.

## RELATED RESEARCH

Location is an important contextual element. Many context-aware applications being developed focus on location-awareness. Several free and commercial applications such as Zhiing, Dodgeball and GeoMe have incorporated location-awareness and it is becoming increasingly common for mobile devices to feature location-sensing technologies. Abowd et al. [1] note that 'nobody questions the value of incorporating context into (Ubi)comp) application development, particularly when the context is

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the location of individuals'. Locations, particularly in an urban environment, are often complex, with social protocols, conventions and values attached to them. These properties may have strong influences on the behaviours of those within them, or on the appropriateness of communication that takes place. For example, a message promoting items on sale in a particular store may be considered inappropriate when received at one's place of work, but more appropriate when one is standing outside that store. Perry & Shangar [12] highlight this point by discussing the importance of spatial communication. It is common for us to leave notes for each other at different locations within our environment, for example a note on the fridge reminding you to buy milk, a message slid under a door or an advertisement pinned to a board.

Although SMS is primarily used to facilitate one-to-one communication, location-based messaging can allow messages to be sent to an environment inhabited by a much larger number of users. LAMMS [3] is a system that was developed in order to explore a form of location-based communication. The system worked alongside SMS, allowing friends and strangers to communicate with each other by posting and receiving messages that could be tied to locations. These types of messages are an important form of human interaction, with contextual information influencing and informing our interactions [5]. The location of these messages gives them further meaning and places them in context, however, the properties associated with a particular location may fluctuate over time. LATTE [11] introduces the concept of temporal constraints applied to messages as well as the spatial ones used by location-aware services. LATTE is a location and time triggered e-mail system in which e-mails are extended to include dynamic consideration of location and time, to determine the appropriate recipients for messages. Nakanishi et al. [10] presented CAMS, a context based dynamic messaging system which used an amalgamation of schedule and location information of SMS, voice and e-mail recipients to redirect communication to an appropriate device or address. The system required users to register rules about which means of communication were appropriate in certain locations or at certain times. Messages and calls were filtered to the appropriate destinations using these rules.

The Defined Delivery system (DeDe) [7] is a mobile phone messaging system that also uses contextual parameters such as time and location to define the context in which a message will be delivered. This system was trialed with a socially tight group of 7 individuals, revealing several novel messaging practices such as anticipatory greetings, contextually sensitive prompts and relieving mental load. It also exposed some usage barriers for context based messaging systems, most notably a sender's uncertainty of a message being successfully delivered. The DeDe study did not investigate how such a system might affect communication between individuals who are less familiar

with each other, for example by constraining messages to a location such that they can be received by anybody within that location. In this paper we report a field trial of a similar system of our own, which supports both person-to-person and person-to-location messaging. In addition the field trial reported here involved a group of participants with varying degrees of familiarity and communication with each other, extending the findings of the DeDe study for less socially tight groups. Our study also differs from [10] and [11] by allowing authors of messages to specify unique contextual constraints to each individual message, rather than the context for delivery being determined by the system, or pre-defined rules created by the recipient.

### CONTEXTUAL CONSTRAINTS

We developed a simple context model incorporating personal, spatial and temporal dimensions and investigated how placing constraints on messages using this model affects communication. Although our model is not a complete representation of context, we consider the three contextual dimensions discussed to be fundamental elements of any context model. Furthermore, they are measurable and do not rely on inference.

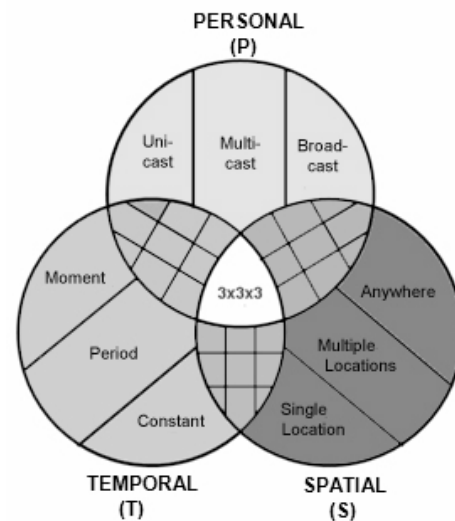


Figure 1. Contextual Constraints Model

Figure 1 shows the different combinations of constraints that can be applied to messages using personal, spatial and temporal dimensions of context. The personal dimension is divided such that a message can be sent to a single individual (unicast), a specific group of people (multicast) or to everyone using the system (broadcast). Similarly, the spatial dimension is divided such that messages can be sent to a single location, multiple locations or available anywhere. The temporal dimension is divided such that a message is available either at one specific moment in time, during a period in time or constantly available at any time. These constraints can be combined, giving many possible contexts for message delivery.

## SYSTEM DESIGN

Our messaging system integrates a Bluetooth-based location detection system, a messaging application installed on GPRS enabled phones and a messaging server. Messages sent by a user are transported over their phone's GPRS connection to the messaging server, where they are stored in a database. Users' phones automatically check for new messages at this server periodically (by default every 60 seconds). Any messages found for that user (i.e. matching personal constraints) are downloaded to her phone, however these messages are not necessarily displayed immediately. Messages are cached until the phone detects that the user's current context matches all of the contextual constraints placed on the message, at which point the user is alerted to its delivery.

For our prototype system, Bluetooth beacons within the environment serve as location markers. These are devices that simply transmit a uniquely identifiable Bluetooth address. Although other more accurate location sensing technologies exist, such as GPS, the 10-20m coverage of each Bluetooth beacon allows us to mark specific locations, both indoors and outdoors without having to specify GPS co-ordinates associated with a particular location or limit ourselves to locations with a clear GPS signal. The phones using the messaging application repeatedly scan for other Bluetooth devices and when a location marker is found the message cache is checked. Any messages that are constrained to be delivered at that location and time are then delivered. Each time an ambient device is detected the scanning device also requests its user defined name. Location specification within our system relies on the user being able to associate a beacon name with a place that they are familiar with.

In order to choose where to leave a message, the message sender selects a location from a list of 'favourites'. The user can add a location to the list when she is in range of that location's Bluetooth beacon, however, to avoid problems with users forgetting to add locations, the favourites list is also populated automatically according to the user's frequency of visits to a location. Since the system is able to detect both mobile and static Bluetooth devices, the favourites list may also contain references to other Bluetooth devices that are encountered. For example, the mobile phone of a work colleague might be added to the list, or a laptop in a bedroom at home. By adding these devices, users are able to leave messages not only at locations they frequently visit, but also attached to people they spend time with or devices they use.

## EMPIRICAL STUDY

The system was installed on 9 mobile phones and each phone was given to a person who had agreed to participate in the study. The participants (referred to in this paper as participants A-I) consisted of 6 males and 3 females with ages ranging from 19 to 24, all of whom were University students. All participants were accustomed to using text-



Figure 2. Bluetooth beacons act as location markers

messaging services on a daily basis. The relationships between individuals in the group of participants included a couple, housemates, friends, course mates and acquaintances. By including participants with varying levels of friendship and familiarity, we had a means of assessing the service's impact on communication across these relationships.

Figure 2 illustrates that the Bluetooth signals from each beacon can be detected within a certain radius. Five beacons were positioned at locations that were identified as being frequently visited by all of the participants within the study: the university entrance, library, bar, shop and computer science department. Each participant was also given a beacon to place at home.

Before the participants began to use the system they completed a pre-study questionnaire/semi-structured interview to assess the nature and extent of their existing interactions with the other participants. They were asked to describe their relationship with each of the other participants and give details of their use of SMS, providing a basis for comparison when analysing changes in factors such as message frequency and content.

The study ran for 20 days, during which the participants divided their time between their homes in the city and the university campus. On the first day users were provided with the messaging service software and given an introductory handout and briefing. Each participant was given a description of the system, along with a list of example scenarios in which it could be used. Participants were not instructed to complete particular tasks or told how often to use the system. They were asked to use the context-aware system exclusively *instead of* SMS during the study, even if they did not apply contextual constraints to messages, so that we could log their communications. Only two of the participants (the couple) used SMS at all during the study. Participants were also discouraged from placing unnecessary constraints on their messages, providing us with greater insight into how and when they chose to use context in their communication.

Participants were also interviewed post-study, including

questions on how they felt their communication with others had been affected by their ability to place contextual constraints on messages.

## RESULTS

Figure 3 shows the number of context-aware messages sent on each day of the study. During this period all participants sent a total of 98 messages. The majority (66%) of messages were sent within the first week of the study. The number of messages sent decreased over the following two weeks, with occasional ‘spikes’ in messaging activity. Message traffic peaked on day 5 with 17 messages, approximately 20% of all messages being sent on that day.

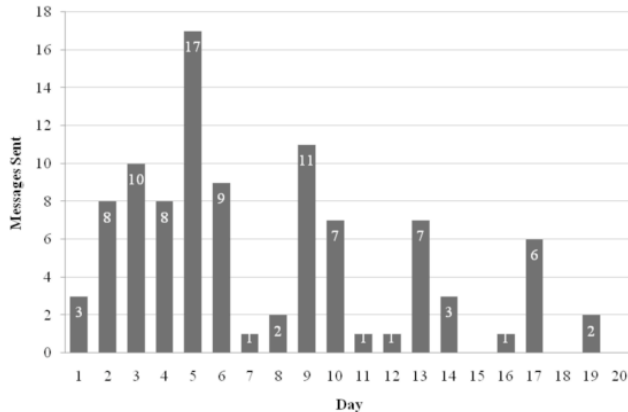


Figure 3. Number of Messages Sent Each Day

Users reported that the more intense use of the system within the first week of the trial was due to factors such as the ‘novelty’ of the application and their desire to test it and all of its functions. Users admitted that not all of the communication during this initial period was entirely necessary and would probably not have occurred without the introduction of the service. This behaviour is typical of many new services and applications in the early stages of adoption. One of the users described the ability to leave messages attached to locations or objects and to schedule their delivery as ‘introducing a sense of discovery’ to their messaging services. Most users reported that they found the use of the service a fun experience at first, because of the mystery of not knowing where or when they might receive a message, or what messages were out there waiting for them, although they stated that they did not go actively looking for them. These users also stated, however, that the novelty of using the service had begun to wear off in the second and third weeks of the study. They commented that the experience offered by the service and the motivation for using it had changed from fun to convenience.

Figure 3 shows that use of the system dropped dramatically on days 7 and 8, a Saturday and Sunday. A similar decrease in the number of messages sent using the system was also observed during the following weekend, on days 14 and 15. The post-study interviews revealed that users were less inclined to use the system at the weekends

because the nature of their activities changed. They explained that the weekends were used to perform different activities to those on weekdays and that the people they spent time with and communicated with were different. In many cases these were people who were not taking part in the study.

There was a second spike in messaging activity at the beginning of the second week, on day 9. The majority of the messages on this day were left by participants C and H, at locations on campus. They started conversations about the food on offer in the Student Union shop and the lack of people in the Student Union bar. After the initial burst of messages on day 9, there was a gradual decline in the number of responses throughout the week. Users felt that this was because conversations left at locations were very context-specific and did not often produce opportunities for the conversation to change topic. They felt that because they were posting a message that would be received within a specific context, it would be inappropriate for them to send the conversation in another direction. So, as conversation became strained, the number of messages sent gradually decreased.

## COMMUNICATION BETWEEN PARTICIPANTS

The pre-study questionnaires and semi-structured interviews were used to collect estimates of how frequently the participants communicated with each other using SMS before the study. Since they were instructed to use context-aware messaging and to avoid using SMS during the study, by comparing their estimates of SMS use to their recorded use of the context-aware system, changes in the frequency of communication could be estimated.

For each participant, Figure 4 shows the average number of messages sent per week, using both self-reported SMS and logged context-aware messages. For the couple (participants D and F), who were the most frequent SMS users before the study, use of context-aware messaging was much lower than their previous reported SMS use. They were, however, the only participants to use SMS during the study. The qualitative data collected pre- and post-study provided intriguing insight into the reasons.

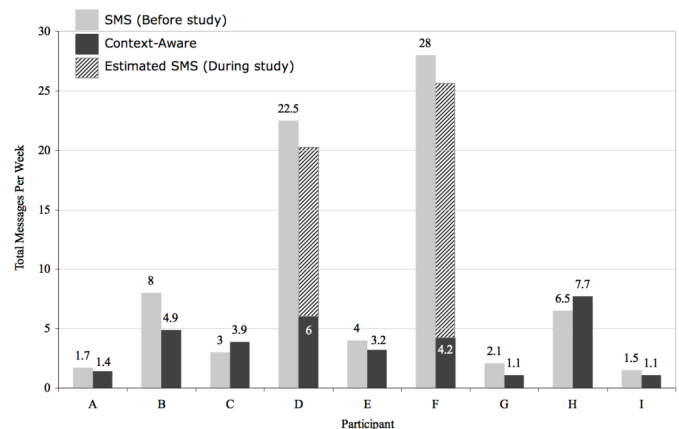


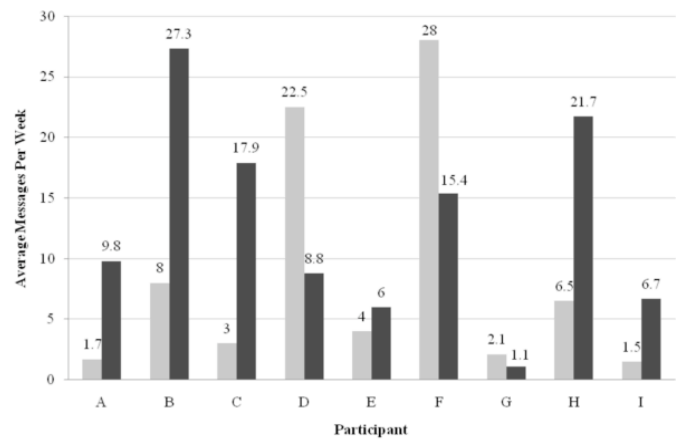
Figure 4. Comparing SMS and Context Aware Use

These two participants were in an intimate relationship, and their frequent communication with each other contributed to the large quantity of SMS messages they sent each week. When using the context-aware messaging service, they each communicated with *other* participants just as frequently as they did when using SMS before the study. Their apparent decrease in communication *with each other* was due to opting to use SMS rather than the context-aware messaging service to send messages to each other. This was partly because they felt that their messages contained personal information and emotional expressions and they were aware that message content was being observed for the study, but also because they did not consider contextual constraints appropriate for many of the messages they were sending. They suggested that messages with content based on ‘emotional expression’, such as the message ‘I love you’ should be free from contextual constraints, as emotions cannot be scheduled or tied to locations. This point is taken up below in a more detailed analysis of message content.

The medium-shaded areas of the bars for D and F in Figure 4 are an estimation of how much they used SMS during the study, based on D and F’s post-study comments and the average ratio of messages sent before the study to those sent during the study for all other participants. Accurate figures for D and F’s SMS use during the study were not collected as the context-aware system was intended to act as a replacement for all SMS communication between participants. A one-way ANOVA across all participants revealed no statistically significant difference between the weekly frequency of use for SMS and context-aware messages, including ( $f_{1,16} = 2.11$ , n.s.) or excluding ( $f_{1,12} = .142$ , n.s.) couple D and F’s estimated SMS use during the study.

During the post-study interviews, participants B and E stated that they began to find efficient ways of using the system to communicate, resulting in their sending fewer messages than they would normally send using SMS. Because the content of each message is relevant to the recipients’ context on delivery, these participants found that they did not have to ask other participants about their context. As discussed by Weilenmann [13], it is typical for part of a conversation to involve disclosure of the participants’ contextual information. These participants found that our system reduced the need for such conversation to take place, particularly as they became more accustomed to communicating in this way. This may have contributed to the overall decrease in messages sent as the study progressed, however a longitudinal study over a greater period would be required to establish whether users in general adapt to communicating in this way over time.

An important point to consider when analysing the frequency at which messages are sent is that the context-aware system allows users to specify constraints which make messages receivable by more than one person. A message left at a location with no personal constraints applied is available to anyone who visits that location. In



**Figure 5. Comparing SMS and context-aware messages received from each participant**

this case, a single message may be broadcast to many people, whereas an SMS message is more commonly used to facilitate one-to-one communication. Figure 5 shows a comparison of SMS and context-aware message sending frequency for each participant, treating broadcast or multicast context-aware messages as multiple unique messages. This provides a measure of how frequently others receive a message from each participant. Statistical analysis using one-way ANOVA revealed no significant difference between the numbers of messages received from each participant for SMS vs context-aware messages ( $f_{1,16} = .93$ , n.s.). However, removing the data from participants D and F, already identified as anomalous and who are outliers (i.e. more than 2 standard deviations from the mean) shows a significant increase in the number of context-aware messages received from each participant, compared to SMS ( $f_{1,12} = 5.97$ ,  $p \leq .05$ ). Although users wrote a similar number of messages, they often adapted them to suit a larger audience and sent them to multiple recipients. One user supported this finding in the post-study interview by stating that, in situations where she had considered starting a one-to-one conversation with another participant, she often chose to make the content of the message less personalised, and broadcast it so that others could participate in the conversation.

### MESSAGE DELIVERY

During the study, 98 messages were sent by all of the participants. Of these, 89 (91%) were delivered to at least 1 of their intended recipients, meaning that 9 messages were not received at all. The explanation for this is that whilst contextual constraints aim to deliver the message to the recipient at the moment when it is most relevant, there is no guarantee that the message will ever be delivered. Recipients may never place themselves in the required context for delivery to occur. Four of the participants were critical of this feature of the system, stating that they found it frustrating that messages which they had taken time to write were not being received. This suggests that there may need to be a tradeoff between waiting for a message to be

delivered in the correct context and guaranteeing delivery within an acceptable timeframe.

Services such as SMS guarantee almost 100% delivery success. The context-aware system provides similar levels of reliability, however reliability within this system does not necessarily equate to the percentage of messages which are actually delivered, due to contextual constraints not necessarily being matched. One of the major obstacles for users of our system was that they required a new way of thinking about how they communicated with each other, abandoning the assumption that all of the messages they sent would be received. Users found that they needed to put much more thought into the constraints that they placed on messages, often predicting where people would be and at what times, in some cases sending multiple messages to cover several eventualities.

A problem with delivering messages according to spatial constraints was the limited coverage provided by the Bluetooth location beacons. The beacon within the library, for example, provided a Bluetooth signal only to the front half of the library on two of the five floors. Although users' phones detected the beacon on their entry and exit to and from the library, messages which were sent to them whilst they were in parts of the library outside of the Bluetooth coverage, were not delivered until they went to the exit. This problem could be addressed by introducing more Bluetooth beacons to mark a location, however this would then introduce extra complexity to location specification since a location could be represented by a collection of Bluetooth devices. An alternative approach might be to use GPS to mark spaces, but GPS coverage has its own problems. Reliable, accurate location tagging under diverse conditions remains a challenge for work in this area.

Although most participants received any messages left for them within seconds of entering the range of one of the location beacons, the discovery times for Bluetooth devices are not always consistent, particularly in busy environments with many other interfering Bluetooth devices around. The time taken to discover a device was notably longer in the busiest locations, because of the increased Bluetooth activity. Thus, if a participant walked past the beacon too quickly to discover it, she did not receive any messages left there. For example, one of the participants was sent a message which was intended to be received on his arrival at the university. The participant's phone did not detect the beacon at the university the first time he walked past it and so the message was not delivered to him until the beacon was detected on his departure from the university.

### USE OF SPATIAL CONSTRAINTS

Figure 6 shows the number of messages left at each of the fixed location beacons. A total of 38 of the 98 messages sent were tied to locations. The 'home' beacons within the study were used very rarely. Post-study interviews with participants suggested that the greater usage of the beacons

embedded within the campus environment was because they were situated in public spaces on campus and represented greater opportunities for conversation and socialisation. Private locations such as homes were not viewed in the same way and users commented that the types of messages they would leave at these locations were very different. The privateness of the message often reflected the privateness of the location at which it had been left. Messages left at private homes were always one-to-one communications, excluding other people from the conversation, or personal reminders sent from a participant to himself. Messages left in public locations contained less personal information and were addressed to larger groups of people such that the conversations could be shared.

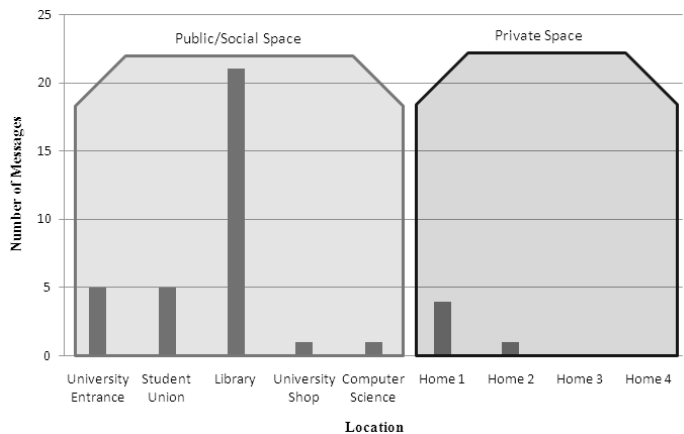


Figure 6. Messages Per Location

The library was used most frequently for leaving messages. It was considered to be the focal point of the university, at which all of the participants were likely to spend some time. Not all of the messages left there were directly related to the library itself; some were more relevant to the university area as a whole. This suggests that the system may require a hierarchy of location specification, for example identifying the entire university campus as a single location. Participants reported that it was often easier to leave a message at the library, where it was more likely to be received, than to predict other locations on campus which the recipient might visit, and that the relevance of the message would not vary significantly between these locations. The 'University Entrance' beacon was positioned at the main entrance to the university and was intended to act as a beacon which represented the entire campus as a single location. However, low usage of this beacon and feedback from the participants suggested that it would be preferable for any messages relating to the university to be available anywhere on the campus, rather than at a single location. Some of the participants used a different entrance to the university and so this beacon was often bypassed completely. This presented further evidence that a location technology with a much wider coverage area would be more useful. This is consonant with the experiences with all well-established communication technologies, such as cellular voice calls.

Many of the messages with spatial constraints were sent from the location at which they were being left. Although the system allowed remote specification of spatial constraints, for example allowing a participant to leave a message at the library without having to be there, this feature was not used as frequently as expected. Our findings suggest that this was not due to the implementation of remote messaging, or because the list of favourites did not contain the required locations, but that physically being at a location triggered users to think about the messages they might leave there.

The beacons on campus were static, positioned at specific locations from which they were not moved throughout the study. However, mobile beacons could also be used during the study. These mobile beacons included devices such as mobile phones, laptops and PDAs. Only one message was left at a mobile beacon during the entire study. The main problem identified with the use of mobile beacons was that their device names did not conform to any rules or constraints, meaning that they were often not descriptive enough of the entity they were associated with. Devices with names such as 'My Phone' gave information about the type of device but not about the person or context it could be used to identify. A message could have been sent such that it was delivered when its recipient came in close proximity to another participant's phone, and therefore close proximity to that participant: e.g. A sends a message to B, to be received when B is with C. However, non-descriptive device names made it difficult for users to identify which mobile devices they should use to trigger the delivery of messages.

Another problem identified when associating mobile devices with entities such as people was that the mobile device was sometimes separated from the entity itself. Some users left their phones at home on certain days, or turned them off when not using them. Hence, attempting to detect the presence of an entity based on the presence of a device that they were expected to have with them did not always work.

### **USE OF TEMPORAL CONSTRAINTS**

Temporal constraints could be used to specify a moment or period of time in which a message could be received. After this period our system ensured that delivery could not occur. Users applied temporal constraints to only 8% of their messages, however analysis of the messages sent revealed that 50% of them contained content that was relevant for a limited period. Some users stated that placing temporal constraints on messages was sometimes an unnecessary burden, as they were confident that the message would be received before it became irrelevant. Placing temporal constraints required the sender to know – or at least believe – some information about the schedule and whereabouts of the recipient.

Participants' frustration at some messages never being delivered suggests that in some cases the constraints placed

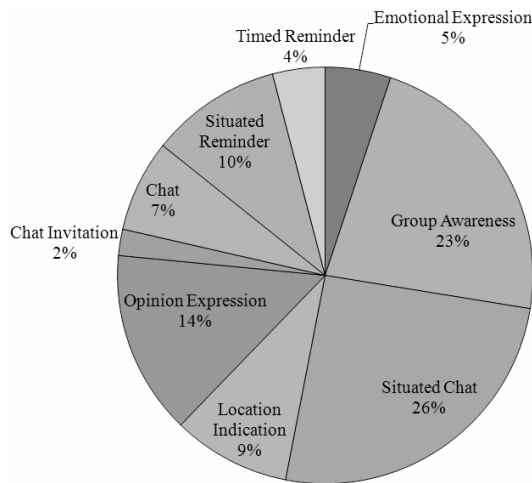
on messages represented an 'ideal' context for delivery, rather than an absolutely necessary context, and that once the opportunity to deliver the message in the ideal context has passed there could be an option to deliver messages regardless. This option was not implemented in our system.

The following messages, which were sent during the study, demonstrate the difference between necessary and ideal contexts for delivery. The message 'I see you made it then!' was left at the Library for participant B, after a discussion he had with participant C about walking up to the university campus. This message was only relevant when the recipient arrived at university and so the sender was happy to wait until the contextual constraints were matched for it to be delivered. If the contextual constraints were never matched then participant C would not have wanted the message to be delivered at all. The content of the message itself was directly related to successful constraint satisfaction.

A message reading 'E-mail me the files please?' is an example for which the sender would not always be willing to wait until the contextual constraints were matched in order for it to be delivered. It was sent to one of the participants, to be delivered when she arrived at her house. Although the sender of this message decided that it would be most relevant when received at home, where he knew that the recipient could access the files he was asking for, the recipient did not return home until the following day. This resulted in the message being delivered a day later than the sender had expected, longer than he was willing to wait for the files. In this situation the sender wanted to be able to specify a time by which the message would need to be delivered, regardless of context. Although placing temporal constraints on the message would have prevented it from being delivered too late, our system prevents delivery after the specified period has expired, and so the message would not have been delivered at all, rather than being delivered regardless of context.

### **ANALYSIS OF MESSAGE CONTENT**

Figure 7 shows a categorisation of the content contained within all messages sent using the system. These categorisations are based on those presented by Blom et al. [3] in their analysis of the LAMMS location-aware messaging system. Given that chat could traditionally be perceived as being relatively independent of location, Blom et al. investigated whether location-awareness could be considered irrelevant for the purposes of messaging. They found that this was not the case: between participants who were familiar with each other 61% of the first messages, in each conversation thread, contained references to a location. To perform qualitative analysis on the messages, they broke the content of messages down further. The same content categories were used for analysis within our study, with two additional categories to cover content relating to situated and timed reminders.



**Figure 7. Message Content Categorisation**

Situated chat was the most common type of message sent using our system, with 26% of all messages containing some content based on the location at which the message was received. In the pre-study questionnaires and interviews, users had been asked about the nature of their communication with each other and were asked to recall and select, from the list of content categories, which types of content their messages to each other contained. Participants reported that they rarely used situated chat in their SMS communications, giving a mode value of 2 on a 6-point Likert scale from 1 (to a very limited extent) to 6 (to a very great extent).

Figure 8 is an excerpt from the server message log, illustrating the situated chat messages that emerged when using the context-aware system. This conversation took place over a period of 3 days, as participants arrived at the library and received the messages at different times. When discussing the use of situated chat messages, participants felt that the context-aware system supported this type of content far better than SMS. Participant H said that he would not have sent the initial message shown in Figure 8 using a service such as SMS, as the message would have made very little sense to recipients receiving it outside of the correct context.

The message sent by participant H triggered a conversation involving 4 other participants. The original message was broadcast to all users within the library, however not all of the responses were broadcast. This allowed separate public and private threads to develop from the same conversation. While this was a feature of the system that was welcomed by its users, some confusion occurred when private messages were replied to publicly, e.g. broadcasting a response to a unicast message, as this meant that some participants did not receive all of the messages within the conversation. Again, this is consonant with experiences in other forms of communication, notably email, but is not currently supported through other mobile communication technologies such as SMS. Participants suggested that it

Sender (Participant)	Message
H	The library looked better before they put all these ugly signs up. Id rather they spent money on getting more desks
F	Yeah I agree
C	Yeah the pictures of trees are a bit hippy-ish!
E	Hippyish? I wouldn't call it that. I like the colours but not the actual things. I wish they'd spend money on more plug sockets!
B	looks really childish, delp like a nursery in here now
F	what does delp mean? u forgotten how 2 spell?
B	oops, typo! should be feels!
H	With spelling like that perhaps u should be in a nursery!

**Figure 8. Situated Chat Messages**

would be better to enforce responses that matched the 'publicness' of the original message.

One of the participants described the advantage of this system over SMS as 'removing the need for an instrumental reason' to send a message to a specific person. Instead he could begin conversations with anyone who happened to be in a similar context to that which triggered the conversation. Thus, the system provided conversational triggers by removing the 'awkwardness' of starting a topic of conversation which people might not find appropriate to their current context. This also served to encourage communication between participants who rarely communicated using SMS.

Messages with content relating to 'group awareness' accounted for 23% of all messages sent. These messages either provided or requested information about the status of other group members, e.g. what they were doing, who they were with, how they felt, etc. Blom et al. [3] found that a system which enables an entire group to communicate with each other fills a need that may only partially be served by SMS. Our participants supported this view, claiming that they sent more messages relating to group awareness because of how easily they could multicast or broadcast to groups.

5% of the messages sent within the study contained some form of 'emotional expression', however this was identified as the most common type of communication in the study conducted by Blom et al. Our participants were reserved about revealing their emotions, particularly in situations where a conversation involved multiple participants, not all of whom were close friends. As reported above, two of the participants preferred to use SMS for messages containing emotional content and suggested that contextual constraints for these types of messages were not necessary. However, the reverse was true for 'opinion expression'. Blom et al.

found that location based messages containing ‘opinion expression’ did not generate further discussion. Our findings, in contrast, suggest that opinion expression played an important role in encouraging communication between participants and benefited greatly from the ability to apply spatial constraints, which could tie messages to locations. Figure 7 shows that 14% of messages contained opinion expression. These messages were commonly accompanied by content relating to situated chat. These ‘situated expressions of opinion’ tended to trigger conversations amongst several participants.

11% of messages were used as reminders, all of which were given appropriate contextual constraints such that they were received at the location or time required. 7% of messages were purely situated reminders, 1% were purely temporal and 3% were both situated and temporal. Users left reminders for themselves and for each other. In the pre-study questionnaire none of the participants indicated that they used SMS for this type of communication. The ability to create context-aware reminders and alerts was seen as valuable by participants.

### RELATIONSHIP BETWEEN CONTENT AND SPATIAL CONSTRAINTS

Figure 9 shows the distribution of message content for each of the locations on campus. With the exception of the Computer Science department, approximately 50% of the messages at each location contained situated chat. Participants reported that they did not visit the Computer Science department as frequently as other locations, so it was unclear whether this was the cause for the low number of messages left there, or whether it was related to the nature of the space itself. The wide distribution of situated chat is in contrast to other types of message content, which were found to be more specific to certain locations. Most of the situated reminders could be found at the entrance to the university, allowing the users of the system to remind themselves or each other of tasks which they had to carry out while at the university. Although these messages were left at the entrance, their content was often relevant to the entire university campus, rather than specifically to the entrance. Participants were told before the study that this location beacon could be used to represent the entire campus, and so they may have felt some obligation to leave messages there that were relevant to the university as a whole. However, the library received most messages, many of which were also relevant to the entire campus, demonstrating that participants adopted their own ideas about what certain locations represented.

Although group awareness messages accounted for a high percentage of message content sent within the study, Figure 9 shows that a very small proportion of these messages were tied to locations. When users wanted to enquire about the whereabouts or plans of others they instead chose to broadcast messages so that they could be received anywhere. This suggests that although location is one of

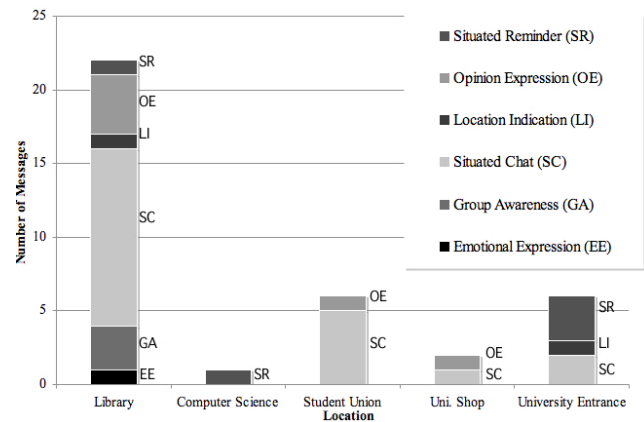


Figure 9. Distribution of Message Content

the most important contextual elements, it is not relevant to all types of messages. Messages containing expressions of opinion were often tied to locations offering services to the users (either free or paid), such as shopping, food and drink, computing facilities or book rental. The university shop, bar and library were all subject to expressions of opinion, while places which did not offer such services were not. Use of the messaging service in this way suggested that it could act as a medium for people to leave comments or reviews at locations, e.g. reviews of restaurants, comments on events, recommendations for places to shop, etc.

### CONCLUSION

The addition of contextual constraints introduced a sense of fun and discovery to a mobile messaging service, however the novelty had begun to wear off after a few weeks use, giving way to a sense of utility. Participants used the system to send messages just as frequently as they had when using SMS, however the ability to broadcast and multicast meant that a larger audience received many of these messages, helping them to maintain a greater awareness of the activities of others, especially those with whom they had weaker social links. Participants often adapted their messages to be less personal so that they were suitable for broadcast or multicast, in an attempt to increase opportunities for conversation. They also found that as the system encouraged multi-user chat threads, the standard SMS inbox presentation of messages was not always easy to use when trying to keep track of a conversation. Messages with strongly personal content such as emotional expression were not often sent using the context-aware system, partly because participants did not want their messages to be seen by the researchers, but also because they felt that messages with such content rarely needed to be accompanied by contextual constraints.

Spatial constraints were most commonly used to leave messages at public locations. Participants regarded the system as a social tool and therefore social spaces presented the greatest opportunities for conversation with others. Messages within private spaces, such as homes, were often directed towards participants with strong ties to the sender,

for example close friends, housemates, or even the senders themselves, to act as personal reminders; the privateness of the message often reflected the privateness of the physical space in which it had been left.

Situated chat and opinion expression were common types of message content tied to locations, both benefiting from users being able to use cues within the environment as conversational triggers. In some cases participants directed messages solely to locations in order to converse with anyone who might be there. Shared context provided common ground and helped participants to overcome awkwardness when starting conversations with less familiar people, however because a conversation was often associated with a particular context, there were limited opportunities to sustain a conversation by shifts in topic.

By knowing the context in which a message would be received, disclosure of context during a conversation often became unnecessary, leading to more efficient communication (viewed positively) or less conversation (viewed negatively), however it took time for participants to adjust to communicating in this way.

Many users found the context-aware system to be more demanding of the sender than systems such as SMS, as they often had to predict the context of a recipient, deciding where and when the message would most likely be delivered. A common response was to send multiple messages to cover several eventualities. Another common response was to simplify the contextual constraints that were used. Temporal constraints were underused: only 16% of messages containing time-sensitive information were given temporal constraints by their senders, who anticipated that other contextual constraints would be matched before the message content expired. This, however, did not always happen and so users became frustrated when some of the messages they had sent were not delivered. This corroborates one of the major findings from the study of DeDe [7].

As a prototype, our context aware messaging system demonstrated the potential for exploiting a simple context model, based on a few fundamental and measurable dimensions of context and without the need to rely on inference in the system. This approach brought several benefits, and users found the system both useful and enjoyable. But the inherent simplicity of the system may have increased the demands on the users, requiring them to perform some of the inference that might otherwise have been attempted within the system. As users adapted to these demands, they found ways to exploit the system's features to support their requirements. Further wide area and longitudinal studies are needed to evaluate the potential for widespread adoption of context aware messaging, and we are currently planning another larger study.

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