Indexical Interaction Design for Context-Aware Mobile Computer Systems

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ABSTRACT

This paper presents findings from a current research project focusing on challenges of interaction design for context-aware mobile computer systems. These challenge are approached from a novel perspective on context-awareness; by exploiting knowledge about the user's context to create indexical user interfaces that carry a major part of their meaning implicitly through the settings in which they are used, thus reducing the need for explicit information representation cluttering the limited screen real estate of mobile devices. The project aims at creating a theoretical foundation for future research into interaction design with context-aware mobile computer systems and to develop the concept of indexicality as an interaction design principle for such systems. Achieving this, we are conducting a theoretical as well as a technical stream of research involving field studies into the context of mobile computer system use and experimental design, implementation and evaluation of prototype systems.

Author Keywords

Context-awareness, Indexicality, Mobile Systems

ACM Classification Keywords

H5.2. [Information interfaces and presentation (e.g., HCI)]: User Interfaces - User-centred design, Graphical user inter-faces, Screen Design.

INTRODUCTION

The last decade has seen an increased development and use of mobile computer technologies within a wide range of use do-mains. This includes general applications and services such as SMS, MMS, mobile e-mail and chat, wap- and miniature web-browsers; business applications for time managing and mobile access to cooperate information; leisure applications such as mobile game consoles, MP3 players and GPS route planning; and highly specialized applications for supporting safety-critical and information-intense mobile work activities within, for example, healthcare.

Currently, these applications typically run on conventional mo-bile computer devices such as personal digital assistants and mobile phones employing interaction styles similar to their desktop counterparts (for example WIMP and Direct Manipulation). While these interaction styles do make it possible for a mobile user to operate a handheld computer, the human-computer inter-action enforced by combining traditional interaction styles with the small screen sizes and limited means of input of mobile de-vices in a highly dynamic use context is far from optimal.

The prevalent use of traditional interaction styles for mobile computers means that the usability of mobile information and communication systems suffers from compact interfaces cluttered with information, and interaction requiring the user's full visual and cognitive attention. This limits mobile use of such systems (e.g. walking in the street or treating a patient at a hospital) where a lasting change of focus away from activities in the real world may not be possible. If mobile devices are to have higher usability for mobile users, interfaces must remain simple and the required interaction minimal.

Advantages in technology have made it possible for mobile computers to access information about the user's context such as their physical environment, location, social setting, and current activity (Dey, 2001; Dix et al., 2000; Gaver et al., 1999; Hinckley et al, 2000). Recent research in human-computer interaction for mobile devices has demonstrated that the usability of mobile computer systems may benefit from utilizing this information to tailor the information and functionality presented to the user in a given situation (Barkhuus and Dey, 2003; Cheverst et al., 2000; Cheverst et al., 2001; Fithian et al., 2003; Kaasinen 2003).

The potential benefits are several. By making mobile computer systems aware of their user's contextual setting, designers can use this information to present only information and functionality relevant in specific situations (Barkhuus and Dey, 2003; Cheverst et al., 2001). This way, the user interface can be simplified and the demand for user interaction can be reduced. Tailoring the interface to its context may also facilitate partial automation of repetitive and trivial tasks (Gaver et al., 1999). Also, making the system react to contextual changes may be used to increase security of data and users (Rantanen et al., 2002). An example of combining some of these potentials is a context-aware mobile patient record system. In such a system, interface and interaction complexity can be reduced significantly by tailoring the interface to the nurse's location (wards, hallways,

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operation rooms, etc.), current work activity, patients within proximity etc., and making the system automatically monitor these factors and react to changes (Skov and Høegh, 2006).

However, the promise of context-awareness for mobile information systems has not yet been fully realized in practice. So far, the impact on human-computer interaction design for commercial products has been insignificant. The reasons for this are many. Firstly, the concept of 'context' is still vaguely defined and understood on a theoretical level in relation to mobile computer use (Abowd and Mynatt, 2000; Dey and Abowd, 2000). For example, it is unclear how different aspects of the user's context influence their perception and use of different mobile information and communication systems. Also, it is still unclear exactly how to utilize knowledge about context in mobile computer interface design; how to decide what information and functionality to present to the user, what to leave out, and how to make use of information already implicitly present in the user's surroundings (Kaasinen, 2003). Finally, it is unclear what the limitations of context-awareness are in relation to mobile human-computer interaction and how users will react to and use such systems. For example, it has been argued that making mobile systems react automatically to contextual changes may result in unfortunate loss of user control (Barkhuus and Dey, 2003) and that the user interfaces for such systems must be designed carefully to prevent this problem.

A promising and novel approach to interface design for context-aware mobile systems is the concept of indexicality derived from the semiotics. Semiotics concerns the meaning and use of signs and symbols. A semiotic approach to the design of context-aware mobile computer interfaces can contribute to a theoretical understanding of information representation and the design of context-aware user interfaces. From a semiotic perspective, information is viewed as representations of something else (their object). Faced with an interpreter, these representations cause a reaction or interpretation (figure 1). The semiotics operates with three types of representations: symbolic (conventional), iconic (similarity) and indexical (material/causal). Symbols and icons are ways of representing information independent of context like e.g. text and graphical illustrations. Indexes, on the other hand, are ways of representing information with a strong relation to, for example, their spatial and/or temporal context exploiting information present in the interpreter's surroundings. Indexical representations are e.g. used on signposts and information boards. Thus, for example, locating information in time and space, symbolic and iconic representations can be converted into temporal and spatial indexical representations (Andersen, 2001). As shown in (Kjeldskov, 2002) increasing the level indexicality results in a reduction of required symbolic and iconic representations.

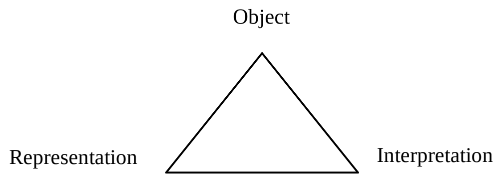

Figure 1. The semiotic relation between object, representation and interpretation

The idea of applying indexicality to interface design for context-aware mobile computers is that if information and functionality on a mobile computer can be indexed to the user's situation, then information already provided by the context becomes implicit and does not need to be displayed. Hence, the user's environment becomes part of the interface. On the basis of this, the limited screen real estate of mobile devices can be optimised to contain only the most vital content and the required user interaction with mobile devices can be reduced. As an example of this, an indexical mobile information service for patrons entering a cinema complex could be made temporally and spatially indexical by taking into account the time, location and social context of the user, providing only information about the upcoming movies playing within a limited frame of time (temporal indexicality) in that specific cinema (spatial indexicality) (Kjeldskov, 2002). The concept of indexicality was explored preliminarily in (Graham and Kjeldskov) and has proven to be a promising, but yet challenging approach to context-aware mobile computer interface design. Relying strongly on the user's knowledge about, for instance, where and when they are situated, successful design of indexical interfaces for context-aware mobile computers, however, necessitates a better theoretical understanding of what constitutes the user's context, and explorations of how indexing user interfaces to context can be done in practice.

THREE PROTOTYPES

So far, our research has involved the design of a series of indexical mobile context-aware prototype systems. Three of these are briefly described below exemplifying the explicit use of indexicality in mobile device interface design.

TramMate

TramMate (figure 2) is a context-aware mobile information service providing users with a route-planning tool for the tram based public transport system of Melbourne, Australia (Graham and Kjeldskov, 2003. It was specifically targeted at business employees who, during a typical workday, have to attend appointments at different physical locations. Informed by field studies of public trans-port use showing that people operated in the physical world by means of indexical references to contextual elements such as location, time, appointments and physical objects (i.e. trams and tram stops), the fundamental design philosophy behind the inter-face design of TramMate was to minimize information displayed to the user by making the system aware of and indexing to these contextual factors. TramMate does this by keeping track of the user's physical location, upcoming appointments and real time tram information. The design is integrated with an electronic calendar and alerts the users when they should commence their journey. While travelling to an appointment, an automatically generated "travelling" timeslot in the user's calendar continuously updates itself with information about the next step of the route, making use of indexical information representations refer-ring to time and the user's activity and location.

TramMate mediates contextual information by means of indexical information representation in a number of ways. The design makes use of indexes to location by adapting the content of the travelling timeslot in the calendar to current as well as planned future locations. Temporal indexicality is used by adapting the graphical size of this timeslot to estimated travel time for the described route. Placing the travelling timeslot next to the associated appointment indexes this entry to an upcoming activity. Indexes to the physical context are used by referring to specific objects in the user's surroundings such as a tram or a tram stop. Finally, absolute indexes to location are explored through references to specific physical locations and relative indexes to location and time are explored through references about distance from current location measured in walking time.

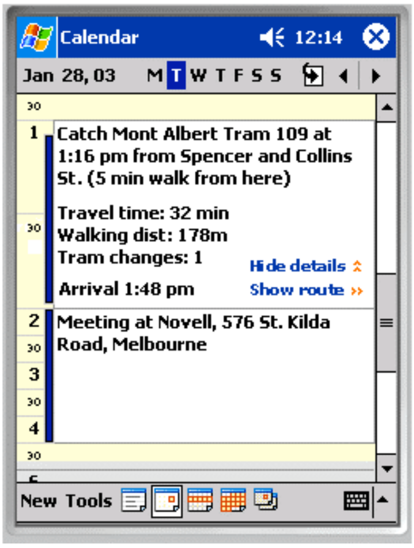

Figure 2. TramMate: route-planning information for public transport indexed to location and scheduled activities

MobileWARD

MobileWARD (figure 3) is a mobile context-aware Electronic Patient Records (EPR) terminal prototype, which automatically keeps track of contextual factors such as the physical location of patients and staff, upcoming appointments etc. (Skov and Høegh, 2006).

Studying the use of stationary EPR systems at a large regional hospital, we had found that the usefulness of such systems suffered from issues related to mobility, complexity, and lack of relation to work activities. Most nurses were concerned about the EPR system not being mobile while many of their work tasks required them to move between different locations. Due to the complexity of the EPR system, most nurses also found it difficult to locate the information necessary to be able to carry out their work. Finally, they experienced problems with the use of the EPR system because the data and structure of information in the system did not relate clearly to real work activities, locations and people (nurses, doctors and patients). However, similar to the study of public transport use, we also found that the nurses made large use of indexical references to these contextual factors in their work and in their use of the EPR system.

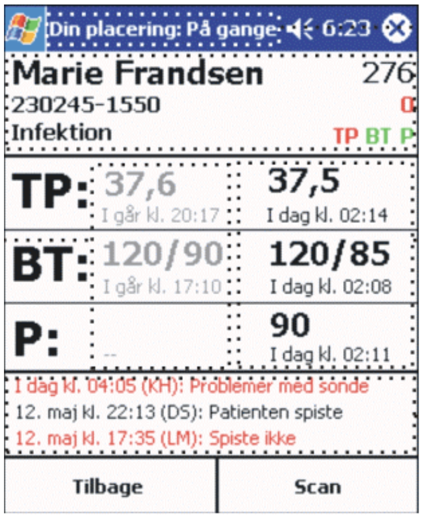

Figure 3. MobileWARD: Indexing patient information to patients in proximity, location and upcoming work activities

On the basis of these findings, a prototype context-aware mobile EPR system was implemented. In this prototype, indexicality is used to minimize and streamline the information presented to the nurses and doctors on the basis of the system's knowledge about their context. For example, the design takes into consideration that when presenting information about a patient, that patient will typically be physically present with the nurse or doctor, thus leaving out implicit information and taking them directly to information about the treatment of that patient rather than requiring them to navigate a complex database system (which is typically the case with traditional EPR systems). MobileWARD also indexes information and functionality to the nurse or doctor's physical location and ongoing as well as upcoming work tasks.

Just-for-Us

Our most recent indexical prototype system is a context-aware mobile web service, Just-for-Us, facilitating sociality in the city of Melbourne, Australia by providing the user with a simplified digital layer of information about people, places and activities within proximity adapted to users' physical and social context and their history of social interactions in the city (Kjeldskov and Paay, 2006).

Based on field studies of groups of friends socializing "out on the town", we identified key properties of the physical and social context which people used as reference points in their situated social interactions – the way they communicated and the way they made sense of the world around them. Informed by this, we designed and implemented a functional prototype, which pushed the use of indexical references to further extremes than in the previous two designs in order to gain deeper insight into the potentials and limitations of the indexicality approach through subsequent studies of use.

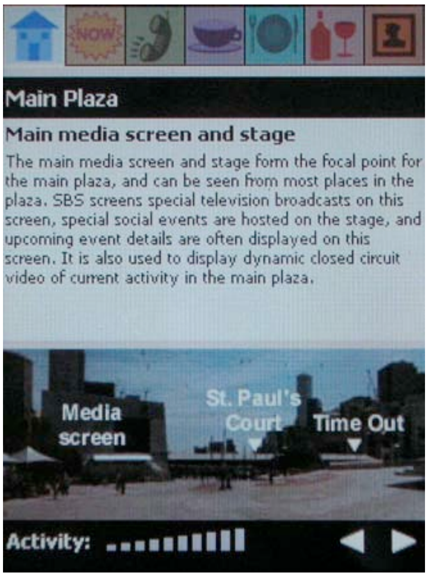

Figure 4. Just-for-Us: Indexing to the user's physical surroundings via augmented photographs

In the Just-for-Us prototype, indexicality was, amongst others, used to create strong links between the information in the system and the real world surrounding the user through augmented panoramic photographs pushed to the user on the basis of their location (figure 4). In this way, information in the system is indexed to the user's physical context "by proxy" of an interactive photographic representation. Interacting with this "poor-mans augmented reality" representation, the user can align information in the system with the physical world using implicit information cues in the environment such as the shape and colour of buildings and major structures.

Secondly, indexicality was used to reduce the specific information content presented to the user (such as recommendations of places to go for a certain activity) by tailoring it to the users current social group (who they are with at the time) and this group's shared history of socializing out on the town.

Thirdly, indexical references were used to generate qualitative way-finding descriptions referring to the group of users' familiar paths and places, rather than specific coordinates, thus exploiting their existing knowledge about a space (figure 5).

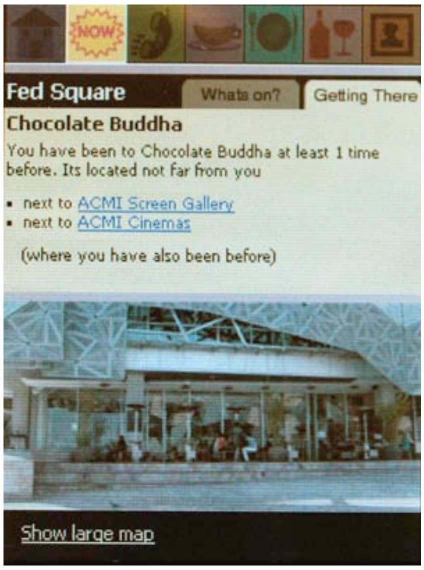

Figure 5. Just-for-Us: Indexical way-finding instructions based on physical context and history of visits

THREE EVALUATIONS

Because the use context plays such a fundamental role in the interpretation of an indexical context-aware interface, evaluating indexical mobile information systems is a particular challenge. For example, it can be questioned which settings – lab or field – would be most appropriate to conduct evaluations in. Enquiring into some of the challenges of evaluating indexical context-aware mobile computer systems, all three prototypes described above have been evaluated through comparative usability studies in both lab and field settings. As a part of this, we have over the last three years developed a mobile audio/video recording studio, which we can take with us into the field.

The TramMate prototype system was evaluated in Melbourne, Australia in 2003. This evaluation involved 10 people using the system for approximately 40-90 minutes. All users were familiar with mobile devices and frequent users of the public transport system of Melbourne. Half of the evaluations were carried out with the user seated at a desk in a usability laboratory. The other half was carried out in the field while the user was commuting around the inner city using the public tram system (figure 6). The evaluations were structured by a series of tasks identical in the lab and in the field. During the evaluations, the users were asked to think aloud and respond to questions from an interviewer. The evaluations were recorded on digital video. In the lab, this involved close-up views of the mobile device screen as well as overviews of the user and the interviewer. In the field, the cameraman shifted focus between close-up of the mobile device screen, the user and the interviewer and overviews of the overall use situation. The TramMate evaluation is described in detail in (Kjeldskov et al. 2005).

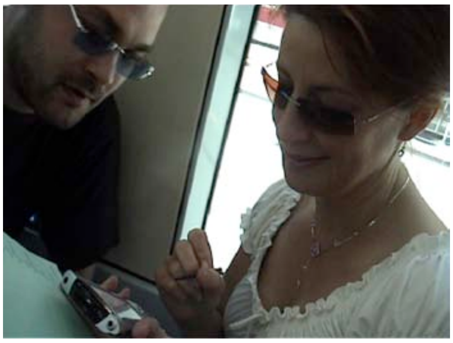

Figure 6. Field evaluation of TramMate using the public transportation system in Melbourne, Australia

The MobileWARD prototype system was evaluated in Denmark in 2004. This evaluation involved 12 people using the system for 15-40 minutes. All users were trained nurses and familiar with the use of electronic patient records. Half of the evaluations were carried out in a usability laboratory consisting of several rooms and a hallway furnished to resemble a section of a hospital ward with actors impersonating hospitalized patients (figure 7). The other half was carried out in situ at a large regional hospital involving real work tasks and real patients. The evaluations in the laboratory were structured by a series of tasks derived from an earlier field study of work activities at the ward. In the field, we did not enforce any researcher control over the evaluations but let the real world work tasks prompt the use of the prototype system. During the laboratory evaluations, the users were asked to think aloud. For ethical reasons, this was not possible during the evaluations at the hospital. Hence, interview questions were put forward during times where the nurses were in the hallway and after the evaluation had ended. In the laboratory, ceiling-mounted motorized cameras captured overviews of the nurses and "patients". Close-up views of the mobile device and user interaction were captured by means of a small wireless camera on a flexible arm to which the device can be attached. In the field, data collection was limited for ethical reasons, only allowing us to record the close-up view of the mobile device and not to film the nurses and patients. The MobileWARD evaluation is described in detail in (Skov and Høegh, 2006).

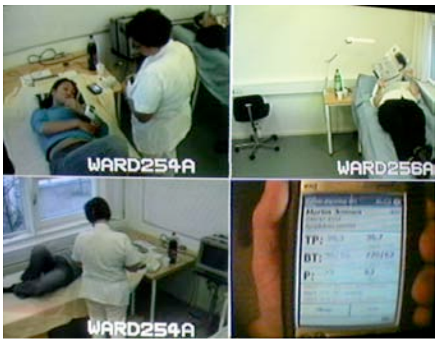

Figure 7. Laboratory evaluation of MobileWARD in a usability lab emulating a hospital ward

The Just-for-Us prototype system was evaluated in Melbourne, Australia in 2005. This evaluation involved 40 people (grouped in pairs of two) interacting with the system for 45-70 minutes. Again, half of the evaluation was carried out in a usability laboratory and half of them in the field. All pairs of users were familiar with Federation Square and frequently socialized there together. Being primarily interested in peoples' the use of the system and their response to its indexical interaction design, neither laboratory nor field evaluations were structured by tasks in the traditional usability evaluation sense of the term. Instead, the evaluations were structured by a set of overall prompts for use of different parts of the system and a list of corresponding interview questions. Figure 6 shows one of the field evaluation sessions of the Just-for-Us prototype system conducted in Melbourne, Australia during April and May 2005.

Figure 8. Field evaluation of Just-for-Us while socialising at Federation Square, Melbourne, Australia

Data was collected through note taking by the interviewer and by means of the newest iteration of our mobile audio/video recording studio developed as a part of the project. Using this facility, a wireless micro camera is attached to the mobile device transmitting a close-up image of the screen to a bag carried by the test monitor where it was mixed on the fly with a third-person view of the users allowing high-quality data collection as well as unobstructed user interaction (figure 9). Ensuring high-quality sound, users and interviewer were wearing directional wireless microphones. Mixed video and sound was recorded digitally on a 100GB AV recorder.

Figure 9. Wireless micro camera on PDA and video recording of participants, interviewer and surroundings with picture-in-picture close-up of PDA screen

FINDINGS AND DISCUSSION

Below, we present and discuss some of our qualitative findings about the use of indexical interaction design for context-aware mobile computer systems informed by the evaluations of the three prototype systems described above.

In relation to indexical interaction design, most importantly we found that, provided they have the right clues, people are extremely capable of making sense from small pieces of information and information implicitly present in their surroundings. They typically have no problem aligning information in the system with corresponding elements in the material world, including attributing names on the screen to physical places and correlating representations of activities with real work tasks and real people. A redundancy of indexes (i.e., labels, images, signs, text) facilitates alternating strategies for matching the virtual world to the real world. However, a problem with using the same implicit references in digital interaction is that it is much more difficult for a system to gauge the user's reaction and to respond to it as we do in face-to-face interaction when we perceive we have been misunderstood or more information is needed for clarification. In reducing the amount of information in the interface design of mobile devices it becomes very important that the information that remains provides the right clues for the user to interpret what the system is communicating.

Based on our studies of indexicality in interaction design, the indexical references that are most easily understood are those that align with easily matched elements in the user's material world such as location and physical objects. It was also evident in the evaluations that people used redundant indexical interface references to corroborate their sense making of the interaction. They used a combination of words, labels, visible elements and activity visible in the real world matching them to representations in the interface, thus making multiple confirmations that the interface was referring to their current situation. For system developers and interface designers to be able to index to these elements, a solid understanding of the indexable attributes of the specific environment needs to be gathered during the projects' analysis phase.

Indexing to physical context

When specifically looking at the usefulness of physical indexical references we observed that people were good at using the outlines of their immediate surroundings, i.e., nearby buildings and structures, distant structures, or the skyline, to align the virtual representation to their physical world. People use distinct physical objects and landmarks in their immediate surrounds, i.e., coloured walls, media screens, satellite dishes, and in their distant surrounds, i.e., a river, a church, a tram stop, to align the virtual representation to the physical world.

Familiar places in the surroundings, i.e., specific high-rise buildings, railway stations etc., act as key anchor points, and indexing way-finding instructions to such distinct physical objects and landmarks makes sense to people. Using a physical quality of a place as a descriptor, i.e., "the black building", is also a successful reference. People also use labels in the virtual representation to match with signs and labels in the physical world and expect them to be there. Conversely, they expect clear labels and signs in the physical world to appear in the system as well.

Based on our evaluations, we found that physical indexicality, in terms of matching virtual representations with the physical world, is not difficult for people to do and they use a variety of visual elements to do this. The prevalent use of skylines and outlines of buildings, distinctive physical objects and landmarks indicates that even in providing a virtual representation of the real world in the interface, an efficiency of representation can be used. There does not seem a need for a representation that exactly visually matches the user's physical surrounds; instead the representation of key physical elements, familiar structures and outlines could be sufficient.

In relation to way finding, we often give directions to others by pointing out a feature in our surrounds closest to that destination, with a small set of instructions on how to proceed when they get to that point. The fact that using these distinctly visible objects for way-finding in a mobile interface makes sense to people means that way-finding instructions can make concise and specific references to the user's immediate surrounds and allow them to operate in a familiar way to get to that place, as they would with directions from others.

The use of labels and signs in the physical world to match with the same labels in the virtual world shows that people need to make multiple confirmations using redundant references to the real world. This analysis of physical indexicality indicates the important things to represent in a virtual representation of the real world when providing an additional layer of information about those places using indexicality.

Indexing to location

People generally understand when a mobile system adapts to their current location and makes use of spatial indexical references. However, they were sometimes surprised by this and uncertain about how to control it, and how to maintain access to information outside their current locational context. Showing that a system knows the user's current location generally made people perceive its content as trustworthy – however, getting the location wrong also had the straight opposite effect.

Our findings verify that indexing interface information directly to the user's current location is easily understood and people usually find that type of automatic adaptation useful. We are familiar with spatial indexicality through our experience of language and signage in the world that relates specifically to its location. Hence, it was easily accepted that an electronic "sign" (the PDA) would make use of the same kinds of implicit references to its location.

On the other hand, we also observed that when presented with information specific to their current location, people often expressed a desire to maintain access to information beyond their current context: information about other trams, other wards, other venues. It seems that the very presence of a mobile information system raises peoples' expectations about what information should be available when and where, which raises great challenges for mobile device interaction device.

Using places (trams, wards, bars) as an approximation of current location, rather than precise Cartesian coordinates was entirely adequate in this situation. People were convinced that the system knew exactly where they were, and based on this, they in turn believed that the system was also up to date with the information provided to them.

Indexing to social context

In using social indexical references people use their knowledge of familiar places labelled on the virtual representation to align it with the physical world, i.e., "I know Chocolate Buddha, it is over there". Indexing way-finding instructions to familiar places makes sense and people do not need detailed guidance to go there. People use familiar places marked on maps to orient that map and to resolve other places on it. In referring to people's familiar places, it is important to note that they do not necessarily know the names of familiar places. People like to get an overview of other people and their activities in their surrounding environment, and indexing information to this part of their context makes sense to them. On the down side, people were sometimes surprised when systems adapted to less obvious aspects of their social context, such as their personal history or shared experiences with their current social group. Also, people sometimes felt uncertain about how to control this behaviour by the system. In order to decode this type of indexical reference, they often needed a more detailed explanation about what the system was doing before they could understand it.

People liked it when their device automatically gave them information relevant to their current or intended activity in a place. However, using activity as a descriptor for a place, i.e., "the sitting steps", was not found to be a useful reference because people saw it as too open to personal interpretation. Our findings also show that if a system knows about a person's history of interactions in a place (a tram stop, a hospital ward, a bar), then it can use this information to index to – just as a group of friends might when referring to places and activities they have shared. In making references to elements of a person's physical surrounds, either for giving information about that place or for providing way-finding instructions, the use of references to known familiar places and past visits helps them to orient that information in respect to their existing knowledge. This is how we reduce complexity in face-to-face interaction. Rather than giving a step-by-step description of how to get to an unknown place, we simply describe it as "next to" or "across from" a place that we know the other person is familiar with, either from our shared experience of that place, or because it is a highly visible or well-known landmark. Knowing that people do not always know the formal names of these places needs to be factored into the design of these socially indexical references.

In the evaluations it was also discovered that allowing a system to draw inferences on behalf of the user's context was not always well understood and well received. This was somewhat unexpected because our field studies had indicated that people often wanted that particular information in those particular situations. However, it seemed that when information is provided automatically by a digital device, it is not trusted to the same extend. Also, the lack of user control sometimes bothered the users because it interfered with their current activity or they did simply not like an electronic device to be making decisions for them. On the other hand, representing social context (such as the presence of others in the user's surroundings) was very popular because it allowed for people to draw their own conclusions and make their own decisions. This indicates a need for further investigation into the use of social indexicality in context-aware interaction design

SUMMARY AND CONCLUSIONS

This paper has outlined an ongoing research activity into the challenges of interaction design for context-aware mobile computer systems. We have explored the concept of indexicality as an interesting new approach to interaction design for this emerging class of mobile systems, and have outlined three examples of context-aware prototype systems where this concept has been deployed in practice and evaluated through user studies.

The fundamental idea behind indexing information and functionality on a mobile device to the user's context is to facilitate a reduction of the information necessary to be presented explicitly to the user and relying on implicitly present information instead. In relation to the use of the three context-aware prototypes exploring this principle described above, our evaluations have shown us that people are generally highly capable of making sense of sometimes very reduced and fragmented information – depending on the contextual factors adapted to and provided that the right clues for the interpretation of information were given. Mobile computer systems may be made smart – but so are their users.

For example, we found that presenting information indexing to the user's location is typically understood right away without explanation needed. Also, providing minimalistic way-finding descriptions that index to the user's familiar places made immediate sense to most users (for example, "next to the ACMI cinemas" or "corner of Collins and Swanston St.") and facilitated finding their own path to a destination. However, indexing information to the user's social context, for example, who he or she is with at the time (patients or colleagues at the hospital, friends out on the town, etc.) was often initially found to be unclear when not indicating that this was what the system was doing, and required more clues provided in the interface. As an example, factoring the favourite places to socialise of friends they are currently with into recommendations in the Just-for-Us system was seen as a helpful aid to activity planning but was not immediately understood by some users. Similarly, most users found indexing information to their history of interactions to be very useful (for example, ranking information about places around them based on their past visits or adapting to apparent preferences for using particular tram lines), but many of them expressed a desire for being able to control such ranking mechanisms and requested to have full control over information captured and stored by the system about their physical whereabouts and who are with, when and where.

Inspiring further research, our evaluations have consistently also revealed a series of challenges with this approach. First of all, we learned that people are often surprised when a mobile system adapts information to their current location, social setting etc. They are not used to systems operating in this way and are sometimes uncertain of how to control it. Secondly, different people and different situations require different levels of indexicality, and some mechanism for adjusting this is needed.

The reported research project is still ongoing and further indexical context-aware mobile prototype systems are being developed and evaluated. Particularly, we are in the process of developing a series of design heuristics for context-aware mobile interaction design on the basis of findings across our evaluations making use of indexical references to context. Also, we are currently exploring further the potentials of merely representing hidden dimensions of context (i.e. social context) rather than trying to automatically adapt to it – relying on people, not computers, to be intelligent.

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