Representation of self-reported information usage during mobile field studies: Pilots & Orienteers 2

Jeff Axup
* Nicola J. Bidwell
Stephen Viller

School of ITEE, Information Environments Program
University of Queensland
St. Lucia, Queensland, Australia
Email: axup@userdesign.com
* School of Information Technology
Charles Darwin University
Darwin, Northern Territory

Abstract

This paper presents two representations of data arising out of an exploratory diary study of mobile behaviour. They were developed as user centred tools for analysing and communicating situated, self-reported data and understanding environmentally immersed actions of mobile users. The Information Flow Chart (IFC) focuses on use of environmental information and decision making. The Contextual Information Map (CIM) depicts spatial activity data. The representations were used to help understand navigation behaviour during the study. Based on this experience, we believe they can assist efficient analysis and presentation of contextual information and develop into useful tools for developers of mobile technologies.

Keywords

User modelling, diary studies, egocentric perspective, mobile ethnography, User Centred Design

INTRODUCTION

Field studies used to inform user centred development of mobile systems can result in a large quantity of data, creating challenges for both analysis and communication of that information to developers. In this paper we present two representational forms arising out of a study focusing on mobile technology use. They were developed to assist with analysis of the self-reported, in-context, navigation data and may provide a useful method for documenting and communicating the results of other mobile activity research.

Issues such as social norms of a location, presence of other individuals, structure of the communication medium and other variables greatly affect how mobile users engage in activities and use technology (Woodruff & Aoki, 2003). There are a very large number of variables in any mobile situation and determining which aspects are most critical to interaction patterns is difficult and time consuming. Selecting multiple perspectives based on their relevance to mobile activities can assist in gaining a more holistic view of contextual effects, as well as detailed perspectives of specific interactions. We posit that focusing on information used, locations of that information, and decisions made by users may be helpful lenses with which to efficiently view mobile activities.

A short-term diary study was conducted, which explored situated, landmark-based, navigation behaviour using low fidelity prototyping. Participants, playing the role of 'pilots', asynchronously and independently guided other participants, 'orienteers', along a route via navigation information in photos taken along a path. Information that is available to mobile users, and the ways in which they use it, is critical to resulting actions and behaviours which mobile technologies support. Users engaged in the navigation study referred to here, indicated that information available to them in the environment or the navigation photos greatly affected their ability to navigate. Two perspectives on the data were heavily indicative of task performance: information deliberately used to aid navigation and characteristics of landmarks in the environment.

We first describe background issues in User Centred Design and navigation, followed by a brief overview of the study and results relevant to the representations created. Next we introduce the two representational forms. Information Flow Charts (IFCs) qualitatively compared intended and used egocentric (viewer-centred), locational information between those guiding and those navigating. Contextual Information Maps (CIMs) provided a geospatial conceptualisation of navigation information and user movement. Next we reflect on the use of the methods and review similar techniques. We conclude by discussing the applicability of the methods for other contexts and indicate future research plans.

BACKGROUND

UCD for mobile technology

User Centred Design (UCD) represents both a collection of user-centric methods and more generally a philosophy for approaching technology design. UCD methods engage the user, their activities and their environment in all stages of a product's design and requirements generation. UCD typically uses an extensive initial research phase, coupled with methods for conceptualising users and their activities, followed by various kinds of low-fidelity prototyping. UCD methods are particularly suited for mobile technologies because it is critical that user characteristics, goals and environment be well understood for devices with a form hindering interaction (e.g. size, data input, display size) and where location affects usage.

Many methods of modelling user actions are not designed to capture the complexity and rapid change common in mobile environments. Additionally, determining and representing relevant contextual variables that affect behaviour in a particular activity is challenging. A number of methods for investigating the behaviour of mobile users have been developed. These include surveys, shadowing by external observers, remote usage tracking, simulated movement in labs, technology and cultural probes, self-video and diary studies. (Beck, Christiansen, Kjeldskov, Kolbe, & Stage, 2003; Colbert, 2002; Grinter & Eldridge, 2003; Mark, Christensen, & Shafae, 2001) Diary studies offer the benefits of self-reported, in-context data. Mobile fieldwork and resulting data analysis is often a time-intensive process, resulting in difficulties for timely identification of context-related behavioural patterns (Millen, 2000).

Information Usage During Mobile Activities

Location and use of information within it, affects what methods of mobile communication are used as well as how users relate to their physical and social environments. (Colbert, 2002; Grinter & Eldridge, 2003) A recent study of Japanese mobile internet users found that as much as 4.7% of "most heavily accessed content" was traffic or transportation related *while the user was commuting*. Other information sources were used to similar levels while commuting and email and chat reached 75% (Sidel & Mayhew, 2003). Further, a study showed mobile SMS being used to 'meet up' 40% of the time, compared with 15% of non-mobile IM users using it for the same reason (Barkhuus & Vallgårda, 2004). Examples have been shown of separated individuals of a group using various forms of mobile communication during different stages of activities (Ito & Okabe, 2003). Different environments create different opportunities for communication and planning, and users actively change their actions to conform to physical or social constraints. This suggests that available information, available communication methods and location strongly affect mobile interaction.

Many mobile activities are likely to draw upon locational information resources in their environment. Everyday examples of this include: finding travel information (e.g. a bus-time table) making decisions en route (e.g. avoiding a crowded place); organising meeting places (e.g. on a large, central, easily seen set of steps); recognising destinations; or determining if an action is socially acceptable (e.g. looking for people smoking or ashtrays in a restaurant). While diversity in the locational information relevant to individuals will exist, some environmental resources are likely to be commonly used because of similarities in type of activity, user, time of day, location, goals or other factors.

The term 'micro-coordination' was recently created (Ling & Birgitte, 2002) to describe a specific pattern of coordinating actions, where a large number of short messages are used to gradually evolve group plans. In one study of SMS communication, planning activities was found to make up 25% of all conversations, and half of those involved micro-coordinations to meet (Grinter & Eldridge, 2003). This phenomenon is in large part a consequence of availability of a fast, cheap, communication channel supporting sending and receiving short messages in most locations. The structure and availability of communication channels such as this, have been shown to affect reciprocity, efficiency, accuracy and norm development within groups (Baron & Kerr, 2003).

PILOTS & ORIENTEERS STUDY

The Pilots & Orienteers study was conducted on a regional university campus to investigate landmark-based navigation behaviour using a low fidelity prototype in an unfamiliar environment. Three pilots independently photographed environmental features along their choice of route to one of 4 different destinations separated from an origin by a direct distance of about 360m. They had a twenty minute time limit for taking the photographs. Their intention was to provide sufficient information in a 10 image sequence to guide an orienteer to that destination. Pilots were not allowed to use in-situ textual route directional instructions (e.g. on signposts). The collection of 39 images captures, visually, 4 egocentric perspectives of spatial context thought to provide locational and directional information. Pilots also recorded, onto maps, the location where they took the photo and, on numbered sticky-notes, information they intended to communicate and their rationale for selecting particular features/perspectives/foci. Each 10-image set was placed in sequential order in a small flip-photo

portable album which enabled viewing of one photo at a time and easy sequential movement between photos. Each orienteer attempted to navigate a pilot's intended route using only a sequence of photos and their own situated experiences. They recorded their observations, while navigating, on a large sticky-note under each photo. This included information they used in the image, environment or from other experiences, conclusions derived, actions taken and rated their confidence in going the right direction and ease of finding the features in the image.

Orienteers regularly commented when they got lost or were frustrated with the navigational cues given in their photos. Two of the orienteers had minimal pre-exposure to the navigation area while the other two were unfamiliar with it. Two of the destinations were located in an area where modern purpose-built and heritage-age buildings are adjacent, while the other two destinations lay away from this area with heritage-age buildings surrounded by open space. Further, while participants were requested to stick to paths, one orienteer made detours across grassed, hilly areas. Foundationally, themes were generated phenomenologically by pilots and orienteers by direct reflection on their diary data in a post-race workshop.

Comments made by both pilots and orienteers reflected navigational information in the environment which they used, as indicated by the comment, "Corner of sign helped me orientate myself. Took a long time to find smoke stack." Orienteers commonly noted what they found confusing. "Ok, I think this is the roof from the building in the previous photo, but which way do I go? Is the background path the focal point?" They also commonly indicated why they decided to take certain actions in pursuit of their goal. "Lined myself up with the light bulb things. Going to end of path."

The study was conducted to explore in-context navigation behaviour and how egocentric views of the environment could be used to communicate navigational information. All orienteers found their destination while using navigational information in the photos, indicating that such pictures may be a useful method. Self-reported observations along the way indicated that information intended to be communicated by pilots was often not received or understood by orienteers. Several participants got lost for short periods. Themes generated during post-study interviews and analysis indicated that traits of effective landmarks or navigational aids included:

- matched perspective between guide information and situated perspective,
- similarity of appearance from multiple angles, in close proximity,
- functionally significant features,
- distinguishable from other objects, and
- familiarity with the objects in other environments

Photos which did not carry effective navigation information to guide orienteers were identified. This provided useful input to considering what information a navigational interface should provide. More details on the structure of the study and results are presented in another paper (Bidwell, 2004).

REPRESENTATIONS FOR ANALYSIS & COMMUNICATION

A large data set of comments, introspection and ratings was written by both pilots and orienteers while they were engaged in the navigation activity. This was coupled with 39 photos taken along their respective paths and feedback from debriefing interviews. This information was grouped into themes to identify commonly arising situations and problems encountered. One of the orienteers, the first author, became more deeply involved in the analysis during post-study review of the data. During his reflections on his situated self-reports he proposed that additional insight might be gained by developing structured analytical tools to manage, visualise, understand and probe the extensive data set. We sought to quickly and easily identify problem areas during navigation where sub-optimal decisions had been made relative to the user's goal and determine causes for them. We also sought spatial relationships between information objects used during the activity, so as to observe location-oriented patterns. Typically, experimenters or other design team members would not perform the mobile activity, and thus the spatial context of the environment must be clearly represented to analyse or communicate it.

The Information Flow Chart (IFC), follows the flow of information from the environment, to the pilot, to the photo, to the orienteer and to the orienteer's resulting action. The IFC focuses attention on information in the environment, visual depictions of that information and participants' recent and past experiences which affect behaviour. It also demonstrated the need for another representation, the Contextual Information Map (CIM), to graphically relate the location of information, orientation and spatial context.

Information Flow Chart (IFC)

The IFC is designed to assist in rapidly determining situations leading to behaviour by providing a summary overview of a user's behaviour during an activity in the sequential order it was performed. For instance, in Figure 1, Row 7, an ambiguous photo and a choice of multiple possible paths resulted in the orienteer taking the wrong path. The IFC contains entirely self-reported information and includes actions which were accidental or not predicted beforehand. The structure used emphasises information which the user drew upon for an activity, decisions about potential actions and user confidence levels throughout the activity. The IFC was used as a probe during a post-workshop interview to assist the participant in recall of the context of the experience and help review the causes of problematic areas during the navigation.

Structure of the IFC

Each IFC represents the information flow between a communicator and recipient of information during scenes in the narrative of a mobile engagement. Screenwriters separate a story into the components of 'sequence' and 'scene' for analysis, which is also a terminology suitable for describing mobile activities. Robert McKee explains, "A scene is a story in miniature – an action through conflict in a unity or continuity of time and space that turns the value-charged condition of a character's life. In theory there's virtually no limit to a scene's length or location." (McKee, 1999 p.233) Transitions in scenes occur when principal characters, actions or the *context or environment* changes. As in a movie the sequence of an IFC is not rigid, but a rough guide established based on the order of textual and verbal comments made by users. The most influential and important variables of their experiences are drawn out for easy comparison. In the current study an IFC was created for each pilot and orienteer pair, as shown by the extract from an IFC in Figure 1. The images in the first column provide a situated, visual context for each scene (a row in the table) and relate exclusively to information noted by the participants themselves. For the pilots and orienteers race, each scene in the IFC shows the pilot and orienteer comments on the same row, even though this actually happened at different time periods. Thus, the flow of information into the interface and back out to the orienteer is clearly depicted for analysis.

For the purposes reported here, a scene directly corresponds to the photos created by pilots to communicate significant changes in the environment to aid navigation. The picture roughly corresponds with the view of the environment the orienteer was seeking or seeing when using it to navigate. The scenes represent different spans of time, distances, and information conveyed. For example some scenes would be no more than a glance of the orienteer between visible landmarks, while another might be a 5 minute period of getting lost. The scenes emphasise changes in location and environment affecting behaviour and indicate qualitative parts of the sequence of an observed activity to aid analysis and communication.

The columns labelled 'Intended Info' and 'Info Used' record respectively, locational and directional information the pilot intended to represent in the photo, and the locational and directional information the orienteer used. Their adjacency allows an easy comparison between information intended to be communicated, actually communicated, and used. The 'Conclusion' and 'Action' columns link the information received by the user with their self-reported decisions and resulting actions. These allow explicit comparison between information used and resulting actions in the activity and identification of any actions which do not appear to directly facilitate the user's goals. The 'Confidence' column is a self-reported value indicating the appropriateness of the information during the current or previous scenes as perceived by the user. For the pilots and orienteers this value indicated the orienteer's certainty that he/she was following the route the pilot intended. Green cells indicate information transfer that results in high user confidence and red cells indicate problem areas.

Utility of the IFC for Understanding Mobile Behaviour

Since both the pilots and the orienteers were situated in the environment when they created and used the pictures, the IFCs depicted two different egocentric perspectives of the same usage environment by pilots and orienteers. For the study three types of information sources were classified for the 'Intended Info' and 'Info Used'. These were cognitive, such as memory or reasoning; media, which were the photos used as the navigation resource; and environment, such as landmarks and other environmental information.

Seeing information in the table format allows easier identification of issues in the development of themes. The 'Intended Info' and 'Info Used' rarely matched perfectly. This indicated, at a glance, differences between the locational and directional information the pilot intended to represent in the photo and the locational and directional information the orienteer used. For instance in Figure 1, Scene 5, the pilot observes the sunshades and direction while the Orienteer observes the windows and brickwork. Sufficient peripheral locational information (not consciously used and hence not shown in chart) might exist for identification; however, there is a difference in the emphasis. These results supported themes related to the distinctiveness of landmarks for navigation and differing semantic associations with landmarks in an image. Analysis of the diagrams indicated 15 problematic scenes out of a total of 42, for all participants. Problematic scenes across a number of users can easily be spotted because of their red colour-coding.

Figure 1: Information Flow Chart (IFC)

The well structured descriptive overview of the activity coupled with pictures from individual scenes within it, assisted post-hoc review of the pilots and orienteers race with one participant. In particular, thumbnail snapshots paired with self-reported comments encouraged rich post-hoc recall of experiences, which echoes experience in other methods (Buur & Soendergaardfontt, 2000).

Utility of the IFC for Informing Design of a Navigation Tool

The IFC draws attention to information with which orienteers navigated in the world and made decisions about potential actions. The first two columns represent information in the world which informs users about environmental features. This information integrates with information from other sources such as memory, and aids the user in recognizing informational cues to enable navigation (e.g. keeping to a path, judging distance, orientation , relative location and recognising environmental features.)

IFCs provoke insight into which parts of a prototype interface would have a high priority for revision by a design team. It indicates the likely causes of errors in the activity resulting from the type or qualities of information communicated. This can inform further analysis of the information provided during problematic scenes to determine the nature of confusions and information sources that should be changed. For example, in Figure 1, Scene 8 & 8.1, the orienteer was confused and had a low confidence rating because there were multiple possible paths and the photo didn't explicitly indicate which to take. Areas with low confidence scores indicate the provision of inappropriate information to the user during the current or previous scenes. However, inappropriate actions taken do not always lead to low confidence scores, so both values should be checked to identify communication errors.

Variations from anticipated task orders were observed (e.g. when users got lost or took a long detour to look at an object), consistent with situated action theory (Suchman, 1987). Analysis with IFCs suggested that orienteers became confused in situations when they perceived or interpreted the information differently from the pilots, despite its apparent clarity to the pilots. For example, an orienteer erroneously ascended a staircase positioned to one side of an image. This feature was seen as more peripheral to the pilot who consistently positioned features they intended the orienteer to focus upon in the centre of their image. Instances such as these tended to cause orienteers to detour from the intended route and record comments while trying to regain it. Analysis with IFCs also suggested that orienteers often did not use the information selected by pilots. Even more surprising is that orienteers sometimes ignored very prominent objects that were predicted as good navigational aids.

Via taking photos, the pilots in the study were effectively designing a low-fidelity prototype interface for users (orienteers) to interact with. Viewed in this light, the IFCs offer the potential for designers to see how mobile interfaces are actually perceived by users in-context, much as lab-based usability testing allows for non-mobile interfaces. Using task and information requirements self-reported by users engaged in an activity allows an interface to be designed in a bottom-up manner, based on actual recorded in-situ usage and avoids the tendency to prescribe logical task orders.

Contextual Information Map (CIM)

The CIM is designed to record and support analysis and communication of spatial activity data and to complement the IFC. While those navigating experienced the environment from an egocentric perspective, the patterns in their overall behaviour and information usage are best collectively understood from a higher level visual perspective. The aerial abstraction in the IFC supports review of location throughout the activity. It also provides a visualisation of the spatial relationship between the position of sources of locational information orienteers reported using and their resulting behaviour. It enables identification of environmental sources that are re-used and also provides a framework for distance between photos, orientation of photos, distance of sources and relationships between them.

Structure of the CIM

The CIMs were created by marking the positions and orientations of pilots during image creation onto a map, linking these to the relevant image for each location. The position of environmental sources of locational information used by orienteers was then added. Photos are colour-coded with object markers in the image to allow easy reference between the "on the ground" view of the participant and the bird's eye view of the map. Colour-coded arrows signify the location and angle of photos taken by pilots, and give an approximation of the route taken by orienteers. Colour-coding of object markers (circles) allows rapid understanding of which direction participants were looking and how far into the environment they looked. Some information was used in multiple scenes of the activity and consequently is colour-coded multiple times to show re-use.

Utility of the CIM for Understanding Mobile Activities

The geospatial conceptualisation of navigation incidents described by the CIM provided validation of certain themes and hints to others. For example, it validated the orienteer's preferential use of proximal (close-by) over

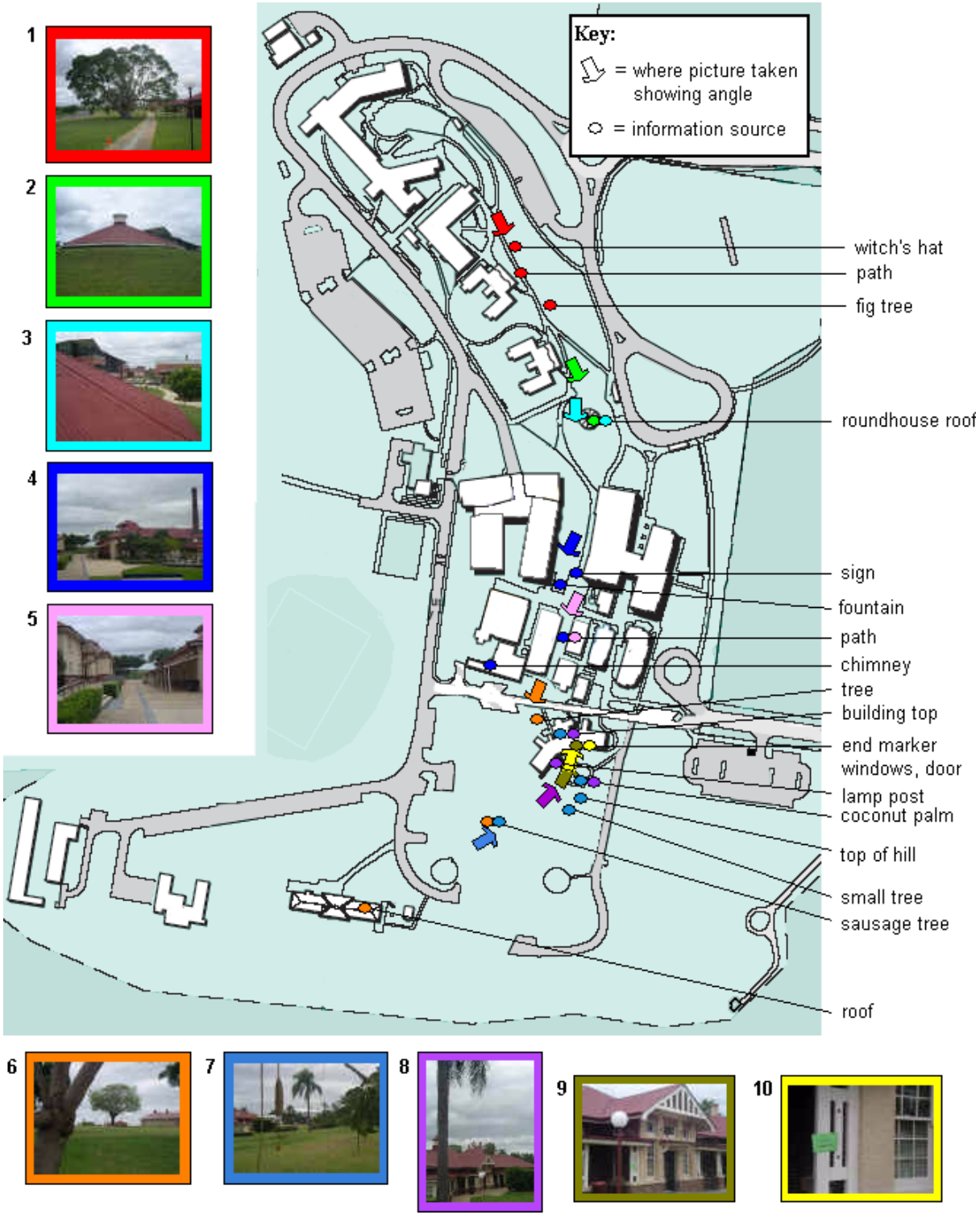

Figure 2: Contextual Information Map (CIM)

distal environmental features previously noticed during interviewing. In Figure 2, note positions 1-3 and 8-10 on the map for examples of proximal information usage. The CIM was particularly helpful in identifying that re-use of environmental location information sources became increasingly more frequent towards the end of the navigation activity. More profoundly for the discoveries of the study, the CIM identified that all information used by orienteers was distributed within a very narrow angle in the direction of the next navigation point. This indicates that pilots had successfully communicated their desired orientations to orienteers, perhaps in part due to the photographic medium they were using. The clear depiction of path travelled and information sources used relative to the start and finish points clearly shows non-optimal routes. In Figure 2, near the bottom, the

participant uses a roof and a sausage tree, to navigate which are far off the optimal path to their destination leading them to travel some distance away from their desired destination.

DISCUSSION

In the tradition of User Centred Design, mobile development should emphasize observations of situated, in-context, mobile behaviour to accurately inform and evaluate theory and design (Kjeldskov & Graham, 2003). Ethnographic studies can be time-intensive and result in design guidelines relevant to a specific situation. It is a challenge to summarize the important aspects of very rich context and behaviour to an external audience such as other members of a development team.

Various modelling methods, such as UML (Fowler & Scott, 1997; Mayora-Ibarra, Cambranes-Martínez, Miranda-Palma, Fuentes-Penna, & Paz-Arroyo, 2002), Essential Use Cases (Constantine & Lockwood, 1999) and Activity Diagrams (Yourdon, 1989) have been used to document user behaviour. Some methods specifically focus on mobile activities and some include modelling of context relevant to the activity. For instance, a study of mobile groups used a CSCW framework showing information feedback, feedthrough, relative location and movement in group collaboration tasks (Dix & Beale, 1996; Harr, 2002). In the process of abstracting out the high-level patterns, these methods may result in a loss of the contextual details (e.g. weather, surrounding objects, information available) which greatly affect user behaviour. Retaining awareness of the actual circumstances of use while looking for higher level patterns and applicability in other contexts is very challenging and frequently runs into framing and granularity problems.

While the IFC (Figure 1) bears a passing resemblance to traditional task analysis diagrams, it differs in that it records first-person diary accounts of in-situ behaviour and perception. The IFC has a table structure only to allow for easy comparison of similar steps in a scene and to format a long narrative sequence for display on paper. Sequence diagrams have been used to model interactions between system and user, and occasionally between multiple users mediated by a system (Hudson, 2001). They often take a software engineering approach, modelling specific data types being passed to and from the system and describe logical, expected interaction sequences instead of natural, observed sequences. Other approaches have been developed, however, which focus more specifically on representing sequences of human interaction arising out of fieldwork data (Viller & Sommerville, 2000).

Visual perception is very important to humans' ability to navigate and understand their environment. Depictions of the visual environment in which complex mobile interactions take place, may be a useful tool for accurately capturing the immersed experience of the user. A similar approach to the hybrid intrinsic/extrinsic visual representation shown in the CIM (Figure 2) was used to depict situated navigation information and movement patterns of an architectural space in Melbourne, Australia (Paay, 2003). These depictions offer a similar understanding of use of space, but don't convey how users experience or respond to locational information. We have also used a hybrid textual/visual view in the IFC (Figure 1) because the meaning of the text is less ambiguous and direct when paired with the visual features of the environment in which it originated.

The analysis method developed for this study is most appropriate for situated, phenomenologically influenced methods such as diary studies, where observations are detailed and small details have great impact on behaviour. The quantity of data yielded by such studies makes detection of critical details difficult. Triangulating between traditional analysis of detailed data and high level, holistic, structured abstractions can help to identify patterns of behaviours and relationships between information used and acted upon. Each type of representation offers a different perspective of the users' experience of the activity.

Although being user-centred usually infers focusing on those engaged in the activity being studied, in this instance it also means awareness of the needs of those conducting the analysis and attempting to understand the results of the study. From this standpoint, documentation methods are another form of interface to be designed to meet the needs of its users, and researchers and designers represent the secondary and tertiary user groups. Mobile HCI practitioners often work to tight deadlines where any field work needs to be rapid, and the results communicated succinctly and effectively, and preferably visually, to team members with diverse backgrounds (McCrickard, Chewar, & Somervell, 2004; Millen, 2000). User-centred research and documentation methods are needed to support usability practitioners, who in turn use these methods to ensure the requirements of their own users.

A number of improvements are suggested for effective use of the representations. As the organization of the representations resulted from the types of information participants elicited, not all types of information categories were comprehensively collected. Consequently some the IFCs, for some users, had sparse areas. Other studies should be structured specifically to enable consistent collection of the information shown in these representations, in addition to other interesting variables. Additionally we found that the game-oriented structure of the study emphasized speed over quality of feedback and resulted in less self-reported data during the activity. The success of thumbnail snapshots paired with self-reported comments in eliciting recall of

experiences suggests an additional 'Post-hoc comments' column in the IFC would be of benefit to phenomenologically grounded feedback, if used shortly after the activity with participants. This information might assist in determining the cause of communication errors.

CONCLUSIONS & FUTURE WORK

This research has produced two representations of self-reported data produced during a mobile collaborative activity. The Information Flow Charts and Context Information Maps focus on how information used by participants affects resulting actions and the spatial characteristics of information resources in the environment. It is hoped that depicting mobile behaviour in this format will aid data analysis and assist meaningful communication of mobile ethnographic results to development teams. We intend to find new methods of studying and representing mobile activity to contribute to existing UCD methods.

The IFC and CIM representations were optimised for research on landmark navigation, but with minor modifications they may assist the analysis and communication of salient relationships in other mobile collaboration activities. In a collaborative activity, an IFC could be used to analyse what information becomes available to a group as a whole, and whether it affects decision making or resulting actions. A CIM could be used to depict the routes travelled, transportation used in various phases, locations where communication was initiated and environmental information utilized. The resulting analysis would be helpful in guiding and communicating the design of a mobile, electronic, entertainment guide.

We are currently conducting a study of synchronous, mobile, collaborative, group communication which will utilize variations on the representations presented here. In particular we expect usage of the method to reduce the time required to organise large quantities of data prior to reviewing and analysing it. Once a basic structure for data collection and display has been agreed upon, it may be possible to automate some of it. For instance the flip-photo album style interface used in this study could be simulated on a pda or tablet computer enabling in-situ capture of participant comments and automatic data collection, collation and storage, in order to tabulate and graphically depict it. This could increase turnaround times for teams involved in rapid development and may encourage them to include more field work in their process. To ensure a user centred approach to the design of the representations, we intend to test the usability of the IFC and CIM with usability practitioners and introduce user involvement in their design.

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