Understanding Mobile Contexts

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Abstract. Mobile urban environments present a challenge for context-aware computers, because they differ from static indoor contexts such as offices, meeting rooms, and lecture halls in many important ways. Internal factors such as task goals are different—external factors such as social resources are dynamic and unpredictable. An empirical, user-centered approach is needed to understand mobile contexts. For these ends, we present insights from an ethnomethodologically inspired study. The data consist of travel episodes of 25 adult urbanites (incl. elderly, single mothers, adolescents) in Helsinki. We present how situational and planned acts intermesh in navigation, how people create personal spaces while waiting, and how temporal tensions develop and dissolve. Furthermore, we provide examples of social solutions to navigation problems, examine aspects of multitasking, and consider design implications for context-aware mobile computing.

1 Introduction

Mobile technologies can be seen as new resources for accomplishing various everyday activities that are carried out on the move. People seem to have tremendous capabilities for utilizing mobile devices in innovative ways for social and cognitive activities. For example, mobile phones are nowadays used not only for talking but also for arranging ad hoc face-to-face meetings with friends, finding driving directions, fixing blind dates, and even chatting with unknown people. People seem to have vast resources for mobile lifestyle.

In its complexity, mobile lifestyle presents a challenge for context-aware computing. Context-aware devices are supposed to monitor the changing contexts of the user and to adapt in an appropriate way through interpreters, aggregators, and services [5]. Sensitivity to user's situation is necessary. For this end, mobile computers need "awareness" of several contextual factors: social, psychological, physical etc. What factors, and how they should be interpreted and acted upon, is the million-dollar question. The majority of the research in context-awareness cannot help us much in addressing this question, because it has concerned mainly what we call *static*, or fixed, indoor contexts—e.g., offices, meeting rooms, and lecture halls. Maybe because of the static nature of such contexts, it has tried to create rigid taxonomies and general "all-embracing" definitions of context—with a negligible success (see e.g. [3]).

Because of having deep social roots and involving dynamically changing environment, mobile context seems to be even tougher concept to be "defined". Therefore, deciding, from an armchair, which attributes are relevant is problematic. We believe that in order to be socially acceptable and useful, context-aware technology must be based on *empirical* knowledge of context, analysed from the perspective of social and human sciences. In this paper we describe such study. We will show how different aspects of mobile contexts are created and maintained by situated actions in everyday life. Furthermore, we will draw implications for the design of context-aware computing.

2 Our Approach

What goes into a context is a widely debated and controversial issue. There is a wide body of literature with a slight philosophical flavor concerning the issue [2, 6, 7, 11, 19, 21]. Attempts to standardize a definition of context have been made (e.g. ISO 13407 [12]). However, some researchers consider these conceptualizations too vague and general to be adapted to any *specific* design processes. The common objection is the following [11, 7]: Because context is tightly intertwined with users' internal and social—continuously changing—interpretations, it seems very difficult to capture context in any general sense that would support practical designers. Consequently, there have been doubts if the concept of context is of any use [20,11]. The demand for new approaches to tackle the problem is imminent.

This demand has been noted. For example, Dourish [7] has distinguished two strands of context-aware computing research. The first is informed by the research on physically based interaction and augmented environments. The other attempts "to develop interactive systems around understandings of the generally operative social processes surrounding everyday interaction" [7, p.231]. The study presented here falls under the second line of research. We hypothesize that situated actions vary richly in mobile contexts. Many actions and routines are performed simultaneously while being on the move. For these reasons, we believe, mobile contexts do not lend themselves to rigid general definitions or static taxonomies. Importantly, however, actions performed while moving and their contexts also have *regularities* that can be captured by context-aware devices. Regularities in mobile contexts presumably differ from those in static contexts.

Our starting point is that important contextual attributes are always determined by the *specific* use situation in loaded with different action resources: motives, plans, other people, mobile computers etc. To understand what is relevant for adaptive interaction, the use situation must be studied with *user-centred* methods. This paper contributes to empirical attempts in trying to understand how context-aware computing might make its place in mobile activities, especially in the rapid change of the contexts in everyday urban navigation. Our aim is to understand important characteristics of mobile contexts. How are different mobile contexts constructed and upheld by people's interactions with other people, available technology and the outer surroundings of action? What kind of resources do present technologies, such as mobile phones or

Internet cafés, provide for rendering people's everyday activities contextually accountable and by that way culturally meaningful?

In addition to the user-centered empirical approach, two points are emphasized in this study. First, our interest is confined specifically to context-changes occurring on the move in urban public and semi-public places (typically somewhere between home, leisure activities, and work). In contrast to previous work that has involved restricted areas such as museums, offices or university campuses, we are interested in the interplay between dynamic context-changes, moving people, and their actions. Another point of departure to previous research is that we are specifically interested in the majority of consumers—the elderly, single mothers, and youngsters in this study—instead of, say, businessmen or researchers.

Finally, this study is an analysis of activities taking place in present-day urban environments. We do not try to predict the future on the basis of present-day technology. Instead, we believe that an understanding of present-day activities is necessary for gaining an insight on how future devices and applications could support or even challenge the present interactions in mobile contexts[1].

3 Method

The data was gathered using the principles of ethnographic participant observation and analyzed with an ethomethodological focus (see e.g. [10, 17, 24]). Twenty-five adults (names changed in the following) were observed in moving from one place to another during their normal days in the Helsinki Metropolitan Area. The study took place during the summer 2001. Five researchers spent 1 to 3 days with each participant. Video camera, digital camera, and field notes were used as tools of documentation during observations. The focus of our observations was on subjects' everyday activities, especially activities related to their urban everyday journeys. Our method has been *near* participant observation because we have been part of those social settings. However, we have been there as purely researchers, not as participants. A broader description of our data collection method is given in [13].

For the analysis of mobile context, observations were transcribed and represented in a notepad-like format. Photographs were presented on the left side of the notepad, and explanation of pictures and storyline were beside. Storylines were in the form of *thick description*, that is, including all the details we could observe and document. These documents were then divided to *travel episodes*. A travel episode consists of temporally organized (i.e., it has a beginning, middle, and end) action patterns depicting a meaningful journey between two places. "Meaningfulness" here means that actions were performed in sequences in order to fulfil a need. A special emphasis was given to finding *nodal events* (e.g., see [18]), that is, events where an action transformed the present context into another recognizable context. A good example of such nodal event is the space claiming act (see Section 4.2). These nodal events, if they were reoccurring throughout the data and carried out on the move by our subjects,

[1] Discussions about the usefulness of this kind of "Technomethodology" can be found from [8].

were analysed further. Specifically, we tried to identify means and resources by which these contexts are situationally contructed and upheld.

4 Characteristics of Mobile Contexts

We here describe five characteristics of mobile contexts. The characteristics can be seen as the sum of different resources and actions, by which the mobile contexts are situationally contructed and upheld, and which are utilized to render actions accountable. Characteristics presented here are 1) diagnostic of mobile contexts, but not so much of static contexts, and 2) recurring in many travel episodes. We present the characteristics closely linked to the constituting activities and give illustrating examples. Discussion of design implications is postponed to the last section.

4.1 Situational Acts within Planned Ones

When moving, people usually have a mental plan that represents how to navigate from place A to place B and what actions must be performed on the way in order to fulfill the plan. However, several actions can be performed in a situational, *ad hoc* manner during the journeys. One important aspect of mobile navigation seems to be that unplanned context changes lead to unplanned situational acts. Our participants often dropped or popped in somewhere or to somebody on their way to their primary destination (see Figures 1 and 2).

Lucy Suchman's [20] notion that plans do not simply determine action but provide resources through which individuals organize their own actions and interpret the actions of others in certain situations seems to be valid also in here. People keep their main target in mind while simultaneously doing something else, usually some minor scale activity. Thus, the pattern of the modern urban journey can be similar to those of Suchman’s native Polynesian navigators, who do not forget their final target although they are constantly reacting to their immediate environment, such as waves and winds of the ocean.

Certain contexts enable people to perform actions that are significant only at that specific moment. These actions do not necessarily replace the "main" plan; rather they are little *side-steps* on the way to the goal. However, the threshold for doing these side-steps has to be low if they are to be performed while still adhering to the main plan—otherwise the sidestep could become the main plan.

Another point we want to make here is that unplanned acts are often social in nature. From time to time, people may unexpectedly run into acquaintances—for example, people they know but have not seen for a while. Sometimes it takes time for people to recognize each other from a crowd. But since they’ve done that, they usually stop to chat about latest happenings—and sometimes it would be impolite to act otherwise (see Figure 3).

Fig. 1. Semi-planned sidestepping. Jane was on her way to a café to meet with her friend. She got off her tram in front of another café that provided an Internet access. She dropped in there to read her e-mails and then carried on to meet her friend.

Fig. 2. Popping in to a store. After missing her bus, Anne was walking from work to home. She noticed nice postcards in the bookstore window and decided to go in the store to have a closer look at the cards. She realized that she needed to buy one, since she was going to a party tomorrow.

Fig. 3. Ad hoc, unplanned side-stepping triggered by change in social context. Jane was riding in a tram in order to visit to her friend. While talking on the phone, she noticed her another friend, Albert, stepping in. Jane finished the phone call and went to Albert. They started to chat. Jane told him about her moving together with her boyfriend, about her new job, and about quitting her old job. Albert told her that he got out the civilian service, that he had moved to Helsinki, and that he was going to get a job.

4.2 Claiming Personal Space

People need space for themselves and for the action they are about to make. According to many psychosocial studies, the upholding of personal space is a universal need—only the dimensions of this space are culturally dependent. Public and semi-public spaces, a café for example, shape the use of space rather strongly. In some mobile situations, for example in the tram, the space must be claimed more actively by certain socially recognized actions.

Transformation to the private space triggers activities characteristic to that context. For example, space claiming in a bus is often followed by reading newspaper, watching out of the window, talking to a mobile phone etc. In our example (Figure 4), free newspapers are read when travelling alone. Using the newspaper, the reader claims a personal space [4]—a sphere of privacy in the middle of other passengers.

Another example from our data is a group of friends sitting around a table and sharing a newspaper, turning their backs to other people, and that way isolating from them. The number of people in the group seems to be an important factor affecting how spaces are claimed and actions carried out in the created context. People walk or ride alone, with or among other people. In that situation, a “territorial space” is claimed [4]. The group takes the needed space for example by indicating that it will not yield others while roaming ahead (see Figure 5). What is apparent here is the way spaces are transformed to one’s own places by using available resources. In trams the free

newsletters, and in groups the circling act, provide physical resources to mark the place socially. By this action the actor manifests herself from an outsider to a participant of a certain social activity. Many of the markers of changes in personal/group space, such as picking up the newsletter or forming a circle with friends, could be used as starting points in the recognition of transformation to new contexts.

Fig. 4. Newspaper marking a boundary of personal space. Jane was riding alone on a bus. All the passengers were reading a similar free newspaper. So did Jane. There were no discussions among the passengers.

Fig. 5. Gathering in a circle as a sign of claiming group space. Anne and Maija met Jaana at a metro station. They got together in a circle to talk about the clothes that Jaana had bought. They share a territorial space.

4.3 Social Solutions to Problems in Navigation

Navigation in urban spaces is difficult for a number of reasons. Maps are complicated and hard to remember, streets and buildings resemble each other, exact addresses are

difficult to keep in mind, and complicated bus routes are difficult to envision. These problems are usually solved in interaction with other people. When persons on the move come up against obstacles or are simply feeling unable to estimate their routes correctly, they often seek help via their social channels.

In our data, problems were solved with the help of mobile phone. For example, when people realize that a bus has already gone, mobile phones are quickly picked up from pockets. Telephone connection is invoked mainly for two reasons: for announcing that the schedule has changed, and for negotiating what to do next (see Figure 6).

From the point of view of context recognition, phone calls to important persons related to the activity in the middle of moving could be one predictor (i.e., a nodal event) of being lost in navigation.

Fig. 6. Missing a bus triggers social activity. Kaarina was on her way with her children to meet a friend. They missed the bus they planned to take and she called her friend in order to ask when the next bus is going. She preferred to call even though the timetable was in front of her. She presumed that her friend had time to speak with her before her visit.

4.4 Temporal Tensions

Time plays a crucial role in moving through urban areas. It has been argued that mobile devices free people from limitations of time and place. Our data, however, in agreement with previous work [14], firmly disagree with this. In fact, time and place are overemphasized in mobile contexts. Fluctuations of importance of time and space as contextual factors are here called *temporal tensions*. Temporal tensions are (loosely) analyzed to four stages: *acceleration, normal (anticipated) proceeding, slowing down, and stopping*. Some situations get accelerated so that many tasks should be done more or less simultaneously, and some prepared tasks may become impossible at the very moment. They can be carried out only if events unfold as anticipated. Sometimes everyday life gets "slower", or even "stops"; for example because of a suddenly cancelled appointment, misunderstood timetable of a public transport vehicle.

Fig. 7. Hurrying. Kaarina needed to run with her children because they needed to catch a bus. Before running they were in a fast-food restaurant, and the children didn't eat fast enough.

Fig. 8. Waiting. Maikku was swimming with her grandson. She rushed to the bus stop in order to go home in time, but after checking the timetable she noticed that she would need to wait for the next bus. After a while, she decided to call her son (the father of the grandson) to let him know that everything went well in the swimming hall.

The two temporal tensions emerging from our data are hurrying and waiting. When moving in a hurry, physical and social surroundings change rapidly but attention is directed mainly to space (e.g., shortest route) and time (e.g., monitoring time). In the middle of human and inhuman moving actors, finding the fastest route becomes im-

portant (see Figure 7) and co-ordinating the hastening requires all the attention of the person. Activities that need constant monitoring involve route selection, checking time schedules, informing related persons, and anticipating changes in the surrounding environment.

Sometimes people simply hurry too much, which results in waiting. Waiting can be then utilized, for example, by calling somebody as in our data (see Figures 6 and 8). Physical and social environments restrict what people can do while waiting. Talking on the mobile phone in public places has become socially acceptable during the last five or six years (in the Nordic counties), whereas projecting one's slides onto the wall with a laptop and portable video projector, for example, would be inappropriate in public places. The issues surrounding the problem of "waiting" are central for mobile computing and should be explored more by the future work.

4.5 Multitasking

The fact that navigating through an urban environment requires constantly paying attention to surroundings means that attentional resources available for e.g. interacting with a device are limited. We noticed that moving and waiting pose somewhat different demands on how the environment on the one hand and the task itself on the other are attended.

Navigation *while moving* obviously restricts multitasking. As discussed in Section 4.1, people seem to have a longer-term plan of navigation (e.g., "to go and visit parents") divided into sub-goals (e.g., "turn left in the next corner"). Therefore, monitoring the environment so as to notice if a sub-goal has been reached requires attentional resources away from other tasks. The requirement for attention is higher in situations involving more uncertainty, such as when getting more and more closer to a signal that indicates the fulfillment of a sub-goal (e.g., "the corner of the street"). Another attention demanding task is manipulating or creating sub-goals "on the fly" (e.g. inferring the shortest route when coming to a street-crossing). These are likely reasons why our participants tended to have less multitasking while moving than while waiting. However, when the route is familiar and navigation more automatic, more multitasking can be carried out. An extreme example is given in Figure 9.

While waiting, people tend to engage only in such multitasking that does not hinder them from noticing the signal in the environment that indicates the end of waiting. This signal constitutes a nodal event that must not go unnoticed. For example, making a call with a mobile phone while waiting for a bus does not interfere with the demand of seeing and waving a hand to the bus coming closer. In contrast, writing an SMS message or email would (since it requires eye gaze and hands) interfere with capturing this nodal event.

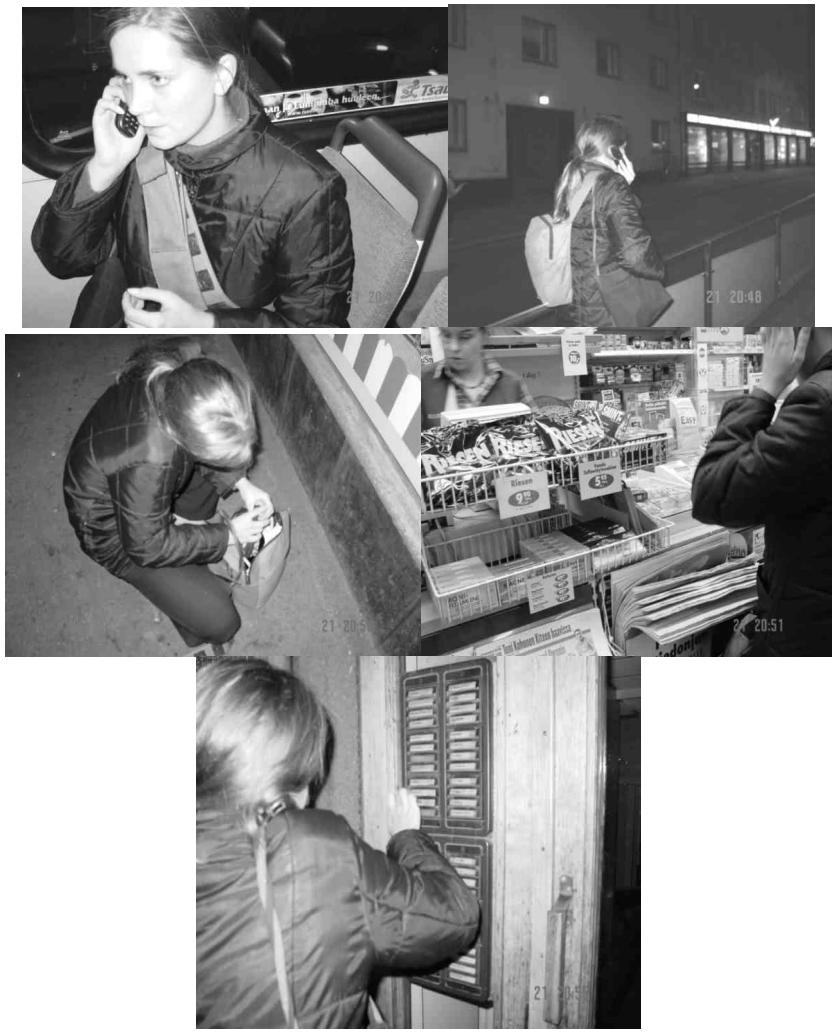

Fig. 9. Mobile multitasking. After her work shift, Jane took a tram to visit to her friend. In the tram she received several phone calls. She continued talking while stepping out from the tram, crossing the street, walking to a kiosk, grabbing some money out from her bag, actually buying the tobacco and trying to manipulate malfunctioning door bell buttons.

5 Design Implications

Empirical studies of mobile contexts offer a rich source for innovation of new context-aware services and for the design of underlying context recognition mechanisms. We conclude the paper by proposing what kind of context-aware functionality would be useful for devices aiming to cater mobility. These suggestions fall into three broad

categories: navigation, social awareness, and user interface. The purpose of these suggestions is not to advocate certain specific technological platform or infrastructure but to direct designers' attention to higher-level issues in mobility. If designers consciously take into consideration viewpoints from social and human science, context-aware devices can be made more useful, meaningful, enjoyable and socially acceptable. To support this point, we provide examples of applications (see also [13]).

5.1 Navigation

1. *Monitoring side steps.* The phenomenon of occasional side steps, for example reading one's email in an Internet café on a way to meeting friends (Figure 1), creates a challenge for route-guidance systems. Route-guidance systems could monitor and learn information about recurring side-step destinations (and activities performed there). This information could be utilized, for example, in a busy-alerting service that watched person's timetable and warned if the ongoing process might make him or her busy in the next phase. Understanding temporal tensions caused by side-stepping would be the key in creating this kind of service. This is also relevant from the viewpoint of affective computing [12], because temporal tensions are usually accompanied by changes in the emotional moods of the users (e.g. frustration about having missed the bus).

2. *Adapting to side steps.* The notion of situational acts within planned acts implies that it is important to allow users choose or create a route that is not necessarily the most shortest or fastest but is otherwise lucrative. Understanding side-stepping is relevant because travelling should not be just about moving from place A to B. Suggested routes should not be too rigid and optimised based on minimizing distance. Collected information about side steps could be used to support more flexible, customized routes. Ideally, routes would represent possibilities for beneficial side-steps such as reading one's email (Figure 1).

3. *Predicting navigation problems*. When coming up against an obstacle, for example not finding the way to a meeting place or missing a bus, people tend to find a social solution. In our data, this was achieved by calling to the friend (Figure 6). This could implicate a need for a supporting digital or live agent as in route-guide services (direct social navigation), or having available a representation of history of solutions other people have made in the same situation (indirect social navigation). For example, proactive agents are already in use in some car navigating devices that create a direct connection to a live person who advise the driver about the route, or even give advice in the case of a car accident. Important, agents could benefit from observations of common problems in certain mobile contexts. An example illustrating this kind of service could be a mobile agent available for people that missed their bus triggered by a bus station.

4. *Enhanced awareness of navigation-related changes in remote contexts*. To address the problems of waiting for environmental signals (Figure 8) that indicate an important forthcoming context change, we suggest considering devices that "boost" these signals. For example, a vibration of a mobile device could indicate that one's bus is approaching the bus stop. This service would free resources for other, potentially

more interesting, activities. Our analysis in Section 4.5 implies that it is important that interacting with the device does not interfere with the noticing the signal in the environment that indicates the transformation from one (e.g., waiting) to another context (e.g., going to bus).

5.2 Social Awareness

5. *Communication of context information.* At the beginning of mobile phone conversations, it is very common to both ask about and describe one's own contextual situation [4, 15, 23]. During the temporal tensions of hurrying (see Figure 7), contextual information would be useful to prevent unnecessary waste of time in calling to a person too busy or unavailable for communication. Context-aware technology could provide additional representational tools of the present or remote environment (e.g., what resources are present in the present or remote context or in what availability state other social contacts are or how likely they are to know an answer to the problem).

6. *Recognition of personal spaces.* The observation that people need to create one's personal space, or place, or, "bubble" (see Figures 4 and 5) points out that issues of *privacy* are important in mobile context maybe even more central than in, say, work environments where people usually know each other. A somewhat trivial user interface design implication is that on the one hand to services should be provided efficiently to all group members, but on the other hand privacy of the participants of the territorial space should be maintained. For example, the display's visibility angle should be easily changed from single user to a group use. Group spaces also pose challenges for auditory user interface design, because they should adapt to the need of personal space and possibly extending this personal space in the future to a private virtual space as well (compare this idea e.g. to “Geonotes” [9]). It could be fruitful to consider in more detail what the *ad hoc* groups’ virtual space claiming would mean in future services and how could it be technically achieved. There already are prototype services that can be used to overlap the physical and virtual worlds and to turn the virtual space into a location-dependent social place. This can be done for example posting interactive virtual post-it notes on a physical place (see e.g. ”Geonotes”[9]). It could be fruitful to consider services that would extent the claiming of individual/ group space out to the virtual space as well.

Personal spaces are more, however, than just a user interface issue. Personal spaces are important indicators of user’s activity and willingness for different types of services. We propose here that context-aware devices could try recognizing acts of space claiming because they are indicators of these context transformations.

7. *Representation of nearby associates*. Ad hoc meetings among persons who know each other (Figure 3) might be arranged easily (also in virtual space) if persons on the same route, or on the routes near each other, would be aware of each other’s movements.

5.3 User Interfaces

8. *Adapting interaction modalities.* Our participants rarely just "walked" or "waited" but instead engaged in multiple activities simultaneously (Figure 9). Multi-tasking naturally gives rise to multi-modal interfaces. Traditional PDAs, for example, require both hands and visual attention to operate, which is clearly inappropriate for mobile contexts in which some modalities are preserved for other tasks. On the other hand, nomadic user interfaces (designed for interaction while walking) might be too clumsy and awkward for situations where all modalities are available such as when waiting for a longer period. Context-aware adaptation in the selection of input/output modalities and interaction styles is thus needed.

We want to point out that all of the five characteristics discussed in the previous section involve some "marker" of context change that context-aware computing might be able to recognize and act upon, and all of these context-transformations lead to contexts that presume different modalities. We propose that recognizing user's temporal tensions (e.g., waiting vs. hurrying), side-stepping off the route, acts of space claiming, and social solutions to navigation problems, might offer valuable indicators of what modalities are needed in monitoring significant signals in the environment (e.g., seeing the bus coming while waiting), because they all mark changes between context where different tasks, modalities, and goals are prominent.

Acknowledgements

We thank all other between project researchers, among others Salla Hari, Sauli Tiitta, Tomi Kankainen and Esko Kurvinen. Moreover, we are grateful for our industrial partners Alma Media, Elisa Communications, Nokia, Sonera, and SWelcom.

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