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MOPAS

Representing Modalities in Mobile Computing: A Model of IT-use in Mobile Settings

Representing Modalities in Mobile Computing

A Model of IT-use in Mobile Settings

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Abstract

Using IT in mobile settings differs from using IT in stationary settings. Thus, the strong influence of stationary computing in mobile computing, which can be observed, is unfortunate. Based on empirical studies of mobile work, this paper suggests a model of "IT-use in mobile settings." Environment, intentions and modality are used to explain the particularities of the mobile setting. Environment *is the physical and social surroundings;* modality *is the fundamental patterns of motion.* Intention *comprises applications, data and technology. The purpose of the model is to provide designers with a framework of concepts to understand and talk about how people use IT in mobile settings. It has been used successfully in MOPAS as a vehicle for reflecting about fieldwork and proposing design ideas.*

Introduction

Traditional stationary computing heavily influences mobile computing. Dominating operating systems for H/PCs (Handheld Personal Computers), such as EPOC and Windows CE, are based on the idea of an electronic "desktop." The desktop metaphor stems from office environments. It was adopted in the seventies to help people recall common features of office work when using GUI based personal computers (Winograd 1996). Many applications for Palmtops, such as *PocketWord* and *PocketExcel*, are miniature versions of traditional office applications. Word processors, spreadsheets, etc., were invented for the office to support the kinds of tasks in which office workers were engaged.

An issue that we would like to raise is *the suitability of adopting concepts from stationary computing in the design of mobile computing and communication systems*. Is mobile computing grounded in experiences from stationary computing, i.e., is it stationary biased?

One way of approaching the question is to consider the use of mobile computing in a mobile setting. For example, consider using the *Psion 5* palmtop while travelling in a crowded bus. The bus is crowded so that you have to stand up. The application you want to use is a web browser. You connect the palmtop to your mobile phone. Since you are standing, you have to use one of your hands to keep the balance. Thus, there is only one hand left for the mobile equipment. Because you are standing, you probably have difficulties to place the mobile equipment somewhere. Thus, you need one hand just to hold the equipment. So, how do you operate it? How do you use the keyboard? You need one hand not to loose your balance and one to hold the equipment. Using the keyboard is not easy.

What happens when you need to operate the mobile phone? Then you probably have to place the palmtop in your pocket. The mobile phone can probably, with some effort, be operated with the same hand that holds it. Let us say that you have the technology up and running and you in some way managing to use the web browser. Suddenly, the bus passes by an area that does not have good contact with the mobile phone network. The connection goes down. You then have to start all over again: dial the number to the modem pool, login, enter password, etc.

As the example above shows, using the H/PC to surf the Web in a mobile situation is indeed very different from using the PC in the office. Your PC is likely to offer a permanent, reliable and fast network connection. It has a big colour screen, a mouse, and a large keyboard placed on a flat surface. Browsing is fast and reliable, and you can use booth your hands to type.

Do the H/PC and mobile phone not offer the same basic functionality as a PC in the office? Is it not only a matter of performance? Will an integrated device comprising the functionality of mobile phone *and* H/PCs alleviate the situation in a fundamental manner?

We think that this may be too simple an answer. To explain this we focus on *effect* rather than *functionality*. By *effect* we mean what the user actually accomplishes. Effect is related to functionality, i.e., what the technology used offers. But, as the example above shows, turning functionality to effect takes place in a context. And as the bus example implies, the context plays a very important role. Although the H/PC offers similar functionality to stationary equipment in the office, albeit with lesser performance. The *effects* of the use situation are very different.

Accordingly, developing IT for mobile use based on ideas grounded in the stationary setting, could be unfortunate. In order to help designers to grasp the mobile setting, we suggest a model of the use of IT in mobile settings. The *purpose* of the model is to:

Provide *designers* with a *framework of concepts* to *understand* and *talk about* how people *use IT* in *mobile settings*.

We hope the model will help designers to invent new concepts and imagine new metaphors for mobile settings. The model, therefore, characterises ways in which the use of IT in mobile settings differ from the use of IT in stationary setting.

It is important to note that this is a design model, *not a theory of human action*. In the model, we introduce the notions of *modality, intention* and *environment* as candidates to understand the specifics of using IT in mobile settings.

Much research on mobile technologies has been concerned with resolving hard *technical* issues (e.g., Friday *et al*. 1996, Comparetto and Ramirez 1997). Significant and cogent contributions have been made to the body of research in mobile computing. Interestingly, mobile work is often made possible by stationary equipment, just as a stationary network usually facilitates mobile computing.

The *Prayer* framework for adaptation in mobile environments relies on a stationary backbone network, by which mobile terminals can connect wirelessly to their home domain. The model explicitly identifies applications that run on the backbone hosts and home domain as well as the mobile hosts (Bharghavan & Gupta 1997). Patel & Crowcroft (1997) argue that in the future many services that do not rely on the notion of a home domain will be developed for mobile users. Many authorisation schemes rely on cross-domain identification over the Internet. Even schemes that are designed to offer access control to “homeless” services, need some way of supporting billing, tracking and authentication.

Some see mobile computing as a data management challenge. Certainly, a scenario with millions of users carrying portable terminals, communicating and sharing information with an equally large permanent network of computers, warrants a systematic approach to this new style of computing. Methods for handling mobility in large-scale system, location management, energy conservation and quality-of-service issues will have great impact (Imielinski & Badrinath 1994).

Alternatively, the focus has been on *describing* mobile aspects of work (Bellotti and Bly 1996). At the same time, however, we see a concern for the lack of *applications*[1].

This document is, therefore, primarily concerned with innovation; designing and implementing mobile information- and communication systems for real-world problems. MOPAS relies mainly on ethnographic studies of work and semi-structured interviews, but the active participation of industry partners contributes to making it equally a participatory activity. We think that a systematic approach to developing innovative and appropriate applications should rely on sound fieldwork and concepts.

One of the central concepts in mobile IT-use is *assistance-on-demand.* Together with the related area of *organisational memory* it has become a dominating theme of much work in this area. Albeit well-aligned with our perspective that mobile IT makes possible timely and context-dependent

[1] Cf. the panel on mobile computing applications at MobiCom’97.

access to digital and human resources, much work in these fields take a very cognitive and rationalistic approach. They build on models of human behaviour derived from theoretical and experimental work in other disciplines. We wish to complement these efforts with conceptual frameworks that are more closely aligned with the needs of designers and users, by building on empirical fieldwork of our own.

Several existing CSCW systems purport to facilitate one or several aspects of sharing experiences, for instance, QuestMap, Answer Garden (2), TeamBuilder, and Axis. QuestMap, previously called gIBIS and CM/1 (Conklin and Begeman 1988, Yakemovic and Conklin 1990), is an "organizational memory" system concerned with making decision processes explicit by capturing the argumentation. Answer Garden is a systematic attempt to augment the expertise of an organisation, motivated by "an impetus from layoffs, down-sizing, and internationalisation of personnel" (Ackerman 1994, p. 243). The system is concerned with making recorded knowledge and live experts available for the users. TeamBuilder aims to support spontaneous identification of expertise and subsequent co-operation between individuals and teams (Karduck 1994). Axis was an experimental "Community Memory" system, aiming to allow a group of people to pool their knowledge and make this knowledge freely available on the Internet. The system was designed partly as a conferencing system and partly as a hypertext database.

Existing work on organisational memory has, as shown by the brief survey above, mainly resulted in desktop systems for stationary users. The mobile aspects of flexible, distributed organisations require a different approach. For instance, the mobility requirement entails that the "expert" cannot be replaced by an "expert system" for organisational memory. People are mobile for good reasons, and the focus in the MOPAS project is thus on *supporting* knowledge workers, rather than replacing them.

The MOPAS project has resulted in a reference model for mobile IT-use, the purpose of which is to establish a conceptual common ground for designers and fieldworker in the new area called *Mobile Informatics*. The model describes mobile IT-use in terms of *modalities, intention,* and *environment.* The modalities may be diverse, but the model suggests the following instances: *stationary, walking, wandering, travelling* and *visiting*. *Technology* is a central part of the model, and describes intention together with *applications* and *data.*

The model offers a conceptual roadmap for innovative and application-oriented research in mobile informatics to include support for changing modalities (transformation), services (adaptation) and establishing new sessions in a mobile-aware fashion (initiation). Existing research in mobile computing could, in this framework, be categorised as optimisation.

We wish to combine empirical studies with the conceptual framework of the model to produce innovate, mobile-aware applications. By technical experimentation and empirical evaluation, such applications can inform re-design and improvement of the model and, thus, the research agenda.

How the model was developed

The research effort of discerning a fundamental model needs to draw on several sources in order to attain a general nature. Accordingly, we have relied on empirical data from several field studies. The studies have all investigated work practices that people in general would consider “mobile.” The field studies concern mobile consultants, auditors and surveyors at a large maritime company. This has been the main source of import to the model. The consultants classify and issue certificates for ships all over the world. This makes travelling a very important part of their work. Empirical data were collected by qualitative interviews and participant observation.

In previous projects we have studied:

- A dispersed and mobile IT support group at a pharmaceutical company. The group members were each responsible for one or two departments, and they spent most of the day wandering between the offices of the users.
- Mobile IT professionals in a central IT department of a distributed organisation.
- Mobile journalists at a radio station. The journalists report live from different places around the city. They spend most the time away from their home base.

Based on a compilation of these studies of mobile personnel, we have arrived at a model of mobile IT-use. The concepts derived constitute the model presented next.

What is mobile work?

Several important research concerns for mobile work support have been identified during the course of the MOPAS project:

Mobile work is business-critical. It is often costly to establish (even considering the cost of travelling only) than stationary work, disruption of sessions should be avoided if at all possible. Computer support for mobile work, hence, needs to favour sustained sessions, across modalities and technical breakdowns.

Mobile work is considerably more situated than stationary work, indeed, this is often the very reason that work was mobile in the first place. It is almost impossible to plan, since the precise unfolding of events in remote settings cannot be anticipated. At the same time, experiences made during mobile work should be documented for the benefit of co-workers. Mobile work therefore requires support for informed improvisation.

Work in remote settings renders familiar navigational mechanisms less usable. Navigation relies on the physical and logical layout of resources. In the case of mobile work these are not available. Therefore, mobile work requires improved support for remote navigation in human- and information resources.

Much mobile work is co-operative, especially given the two previous premises. At the same time, mobile workers have less awareness of the ongoing activities in the organisation. Since the abilities and capabilities of co-workers to participate in synchronous co-operative work are hidden, session control mechanisms are attenuated. Thus, support for transparent interaction management is required.

Business-critical work implies severe security concerns. This is problematic, especially, when the mobile workers has to rely on public or borrowed infrastructures for access to common information resources, or terminals are lightweight enough to be easily misplaced or stolen. The customer, whose equipment is used, is likely to have similar concerns. Overhead of use and hardware requirement must be minimal, on the other hand. Mobile work, therefore, requires mutually secure easy-access.

We propose to continue investigating, within these contexts, the following problem: *How can mobile workers successfully conduct business-critical mobile tasks when planning is difficult, resources are remote and invisible, and collaboration may be obstructed by security concerns.*

This problem points toward further investigation of seamless adaptation of mobile IT-support, new services and work processes at DNV. On one hand, it widens the scope from the MOPAS project by focusing on completion of business-critical tasks, rather than inspection work only. On the other hand, the problem requires a further evolution of the CheckRite concept into more general applications for mobile work. The problem, moreover, entails implementing new services for secure mobile network access.

Method

The empirical work was primarily ethnographic. Ethnography aims to describe what happens in a selected setting from the participants' own perspective (Hammersley and Atkinson 1993). The goal is to provide a rich understanding of what takes place in the workplace during an ordinary working day. Ethnography, sometimes called participant observation (Patton 1990), requires the researcher to examine the workaday activities in the organisation for a prolonged period.

The ethnography was complemented with qualitative interviews. We interviewed many members from different groups, such as surveyors and auditors. A "interview guide approach" was applied, in which the general topics are specified in advance, and the course of each interview directs the exact wording and sequence of the questions (Patton 1990). The interviews lasted for approximately one hour each and are all documented internally to the project.

To evaluate our suggestions of mobile IT-use are currently planning evaluation seminars. The initial design ideas have evolved along with their implementation. To validate new ideas, we need informal meetings with mobile DNV workers. Such informal procedures have been used successfully in CSCW previously.

A model of IT-use in mobile settings

The model described below concerns the use of IT in mobile settings. Its purpose is to provide designers with a framework of concepts to understand and talk about how people use IT in mobile settings. Because an important objective is to help designers to invent new concepts and imagine new metaphors for the mobile setting, the model reflects the ways in which using IT in mobile settings *differ* from using IT in stationary settings.

In describing the model, we seek to discern the characteristic properties of each concept. It should be noticed that this is a design model for designers, not a theory of human action for social scientists. We want to contribute to reflective thinking among computer scientists, not challenge the social sciences.

The model consists of the following categories: *Mobile IT-use,* which is the phenomenon that the model represents; *environment*, that is, the physical surroundings and organisational constraints of work; *modality,* describing the fundamental patterns of motion and *intention,* which is the working function, i.e., what the mobile worker wants to achieve. Intentions are supported by *technology,* which we conceive as the carrying platform or medium; *data* that represents relevant information and *application,* which is the systematic support for manipulating the data.

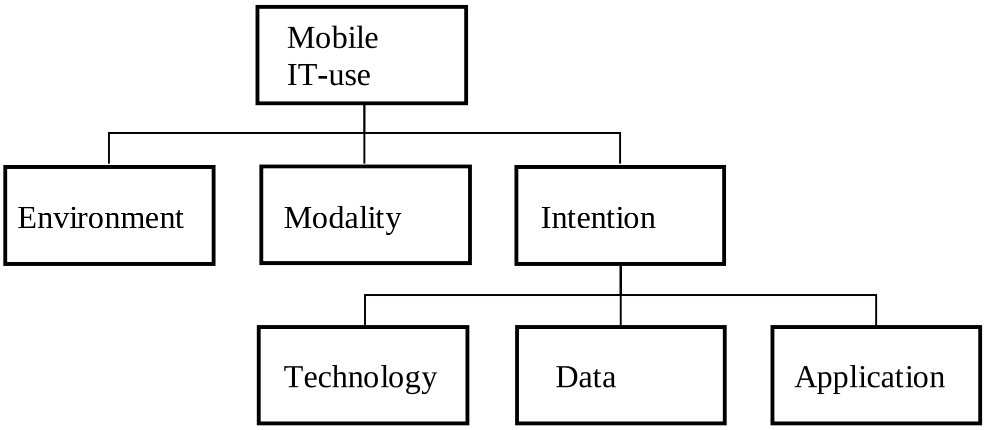


Figure 1: Overview of the basic reference model

This perspective on the model as comprising abstract categories only needs to be fleshed out with real-world occurrences.

The concepts of the model

The following examples show the kinds of instances that may populate the model:

Mobile IT-use. For instance, the act of a mobile surveyor on a supertanker outside the coast of Africa; following a check-list generated for this vessel to verify that the ship may keep its safety certificates.

Environment. In this example, the surveyor would have to inspect the tanks of the ship from within. In order to get close enough to perform a satisfying visual inspection of the steel walls of the tank, the inspectors use a raft and gradually fill the tank with water so that the rising raft takes them where they need to go. The tank is damp, warm and dark. Such an inspection is, not surprisingly, called a "steel safari".

Modality. Typically, surveyors at DNV follow check-lists according to the systematic or geographical distribution of the installation. When things don't work as expected, they need to be repaired before the inspection can be concluded. Therefore, the surveyor usually ends up wandering the inspection route several times until the findings are satisfactory.

Intention. We use the term intention to describe the effects that the work is designed to accomplish. In the example of "steel safaris" the intention is to report a completed and satisfactory inspection of the ships safety system. The shipping company needs the certificate to continue operating, and the surveyor needs to get to the next job.

Technology is, for instance, manual documents, laptop computers and the available (or not) infrastructure such as telephony or transportation.

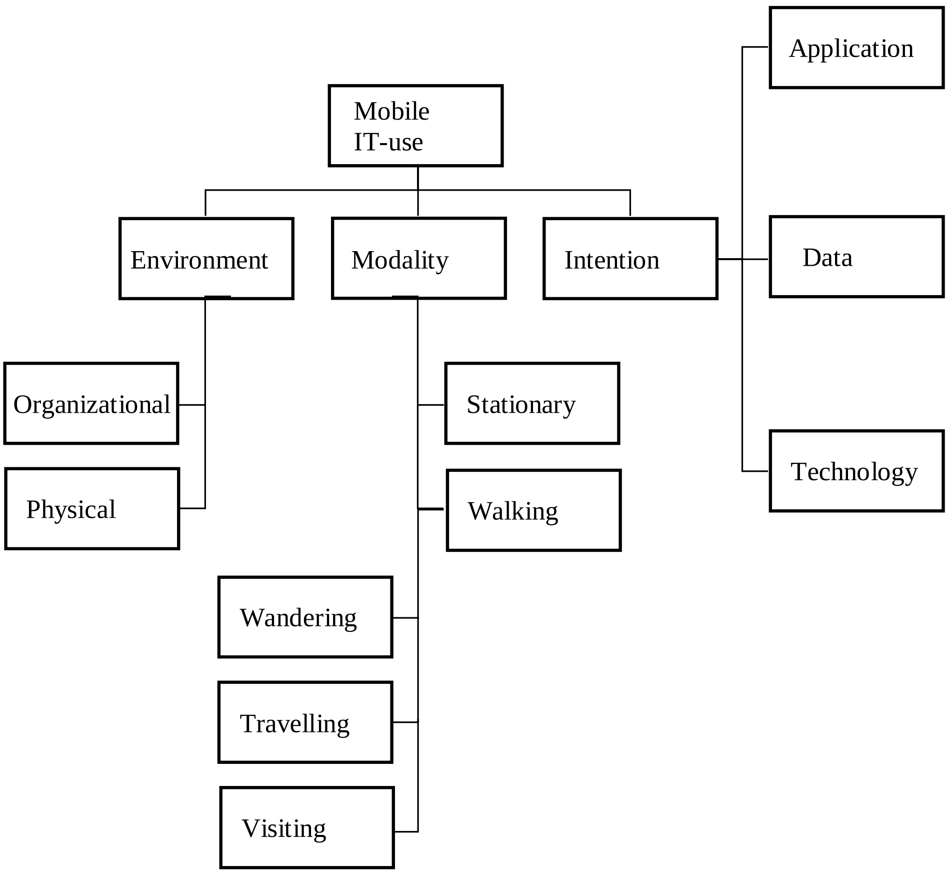
Data for conducting inspections of this kind may be verification check-points, certificate life-cycles or registers of classified suppliers, which contains data of all suppliers pertaining to different systems, which are classified by DNV to deliver services of a certain type, e.g., the maintenance of life-rafts.

Application supports the intention of work, by offering aids and processing of data. Examples in the DNV case may be manual checklists, generated by Nauticus, Sprint or CheckRite. Sprint is the predecessor of Nauticus and it is still the main repository of technical information about classification of existing ships. DNV Exchange is a system for managing the cycle of anticipated certification and verification orders. For the current example of a "steel safari", CheckRite is a good sample technology, used by some of the surveyors to generate geographical checklist of ships.

The details of the model

With a good apprehension of the fundamental categories of the model, we may now continue to populate it with some further categories. We consider that environments may be *organisational* as well as *physical.* Moreover, the technologies of focus in mobile IT-use can usually be pigeonholed as *stationary, moveable* or *portable. Finally, but perhaps most significantly, we conceive modality as being either stationary, walking, wandering, travelling* or *visiting.* Notice that these categories are proposed specialisation of the more fundamental concepts described above-we acknowledge that there will be mobile settings in which some of these don't fit and other categories mat need to be brought into the model to complement and refine the representation offered.

Thus, the full model can be illustrated as follows:



Notice that the relationships between the categories are left unspecified. They are not identical, and may even need further development in a case-specific way. The additional categories can be exemplified as:

Organisational environment comprises factors such as the formal and informal structures of form. Consider the example of DNV auditors in Oslo who are affiliated with DNV UK, when doing particular kinds of missions for which institutions in Norway may not yet be accredited.

Physical environment comprises the observable surroundings of our work, as made apparent by the example of surveyors on a steel safari.

Stationary modality is working whilst at a fixed location.

Walking is the well-known local mobility of stationary workers, typically represented by short trips to the coffee-machine or copiers and visits to each other's offices. We consider this modality an omnipresent mobility, even for stationary work.

Visiting is working in different places for a coherent but temporal period of time, e.g., maritime consultants engaged in the classification of ships.

Travelling is working while travelling in a vehicle, such as an airplane or a train.

Wandering is working while being mobile locally, i.e., local, physical mobility of users, e.g., a distributed and mobile team of IT support staff.

The mobile kinds of modalities are illustrated in the figure below.

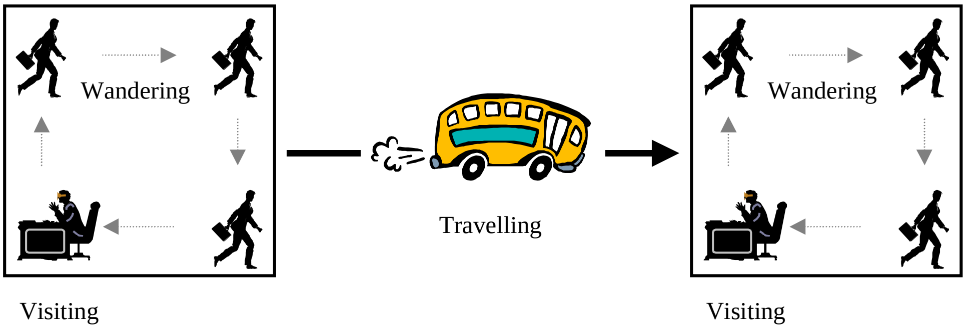


Figure 2: Mobile kinds of modalities

We believe that other modalities exist, and, thus, our proposals should been as examples of how to instantiate the model rather than designating the complete space of possible modalities.

Dimensions of the model categories

The model may be further elaborated by looking at the observable dimensions. We will not in this document treat the stationary or walking modalities, since they do not, per definition, relate strongly to out work in mobile informatics.

Travelling

For travelling, we believe that the *duration* of the modality may be of importance. There will be different support requirements originating from travelling that is of a long duration, compared to shorter ones. The *means* by which people travel is another important dimension. A car has different potential of support mechanisms than for instance a plane or train. Some people spend a high *percentage of time* travelling, and we foresee different IT support as being needed depending on this dimension. Other interesting dimension are *distance* and the nature of the *activities* (such as, for instance, preparing an expenses claim, reporting hours spent, preparing to give a lecture or reading ones email).

Visiting

Similarly, for the visiting modality, many important dimensions may be identified. The *duration* of each visit, or the *frequency* of visits, may be expected to bear on the need for IT-support. It is, moreover, important to consider situations in which the *cardinality* of participants are working together within the modality. Typical *activities* for the visiting modality include courses, brainstorming, counselling, revision and observing work practices. It will be of utmost important in this modality to support and integrate the use of several *different tools*, such as proprietary databases, text editors and collaborative systems.

Wandering

One of the most important aspects of supporting wandering is likely to be whether it takes *place* at the home base or remotely, i.e., at the customer's site

Organisational environment

The organisational environment may be characterised as comprising different *affiliations*. For instance, we have observed that people may be affiliated with the UK division of a large concern when doing certification work for which the Norwegian parts are not accredited. It is, moreover, significant that the *organisation* is sometimes simple, sometimes complex and that it may *consist* of few or many other stakeholders. The organisation *anchoring* of mobile work sometimes makes it even harder to plan than usually, and it is to different extents *autonomous*. Some organisations emphasise *improvisation*, whilst other may aim for *predictability* and *regulations*. Accordingly, the need to support *collaboration* may vary. On the customers' end, we see large differences in *attitude*; they may be interested, detached; trustworthy, ordinary; prepared or unprepared. The work *process* may be open or well defined.

Physical environment

We have also documented that the physical environment is of tremendous importance to the mobile worker. It is sometimes very *noisy*, and, thus, audio communication becomes unreliable. *Temperature* and *humidity* determines to a large extent what kinds of equipment may actually be operated in an efficient manner. *Lighting* may be ample or insufficient. Some spaces of work are *unsafe* and extra precaution may therefore have to be taken when using mobile IT. We even find that the *location* on a larger scale is brought to bear on the execution of work, e.g., when people are forced to consider different time zones.

Application, data and technology

Mobile work is sometimes paper-based, from considerations that are *practical* as well as *cultural*. The organisation may emphasise *standardisation* or *innovation* and there is always a need to assess the *fit* of a certain application within the scope of "getting the job done". Finally, we think that the *effectiveness* and physical *portability* of the technology need to be considered.

Based on the model offered above, the following argument can be given, assuming the following premises: Mobile IT is inferior to stationary computing in terms of performance and bandwidth. *For example, bandwidth is limited, keyboards are awkward and there is no desk on top of which to put the devices when typing.* At the same time, mobile IT design seems often to be stationary 'biased': de facto industrial standards have adopted the desktop metaphor and offer 'pocket' versions of familiar office applications. For example, there is Pocket Word (without styles) and Internet browsers (without support for Java and plug-ins), which, in addition, hardly display content but one line at a time.

It seems like this is a conceptual, rather than a technical cul-de-sac, since "users' needs", in these terms, will always exceed what mobile computing can offer. But as the following argument demonstrates, this can be conceived as a result of a naïve design paradigm.

Is advanced document management or internet-based multimedia publication purposeful operations for mobile workers? Are there mobile use contexts where a typewriter-metaphor based terminal with a connected keyboard and screen will be useful at all? Consider the example of electrical maintenance workers equipped with a desktop metaphor-based device. When operating the device as afforded by its design, i.e. sat down in from of the user in one arms length distance, the objects of work, which are switches and power cables in a roadside cabinet, cannot be reached. If the device, on the other hand, is put down on the only other flat surface, which is the top of the cabinet, then the display cannot be seen when squatting to reach the switches and cables[2].

We assert that this is not an extreme example. Working with mobile consultants, journalists, surveyors and inspectors (typically mobile workers according to any definition) such work situations continually occur.

The use context of stationary computing is stable. Available applications are also part of the use context. Within a stable use context, there has therefore been a tendency of confusing the applications offered by the technology with the (achievable) effects.

When the modality changes, the available applications change, but perhaps the intentions of one modality is also likely to differ from those of another. For instance, the mobile worker is likely to want to publish drafts at remote sites, rather than the final copy of a document, which may represent the intention “certification”, for which a formal process of registration might have to be activated.

The desktop metaphor in mobile computing is, thus, a symptom of the confusion of intentions and application in a stable use context. Only when the modalities are constantly changing, like in mobile computing, it becomes apparent that this contributes to a problematic design paradigm. In order to open an alternative design space, an alternative conception of mobile IT-use seems warranted.

Applications for mobile work

Based on empirical studies of mobile workers at Det Norske Veritas, supplied with previous and ongoing work at Astra Hässle, Sweden, IMiS-Veritas, Sveriges Radio, Gøteborg Energi, Hydro Data and Telenor Installasjon we have, for the MOPAS project, proposed new mobile applications. The remainder of this white paper briefly summarises some of the ideas.

Application ideas

The empirical work at DNV has clearly shown that surveyors’ work may be described as highly improvised and “unplanned”, thus depending to a large extent on local co-ordination. Much of the work is about checking the work of others. It is highly skill- and experience-based. There are almost always rules that stipulate their judgements, but on the other hand, rules are always subject to judgement.

[2] Thanks to John Olav Olsen and Emil Koth-Töfte for supplying this example.

The modelling effort documented above in this white paper has contributed to make empirical findings as generally applicable as possible.

The result of this effort is, thus, the following application ideas:

CheckRite (the demo)

This application is described in detail elsewhere, and we will therefore but briefly summarise its rationale:

- Surveyors often use checklists
- Official lists are available,
  - based on the vessel class
  - sorted by system functionality
- Privately shared lists offer complementing support:
  - based on experience
  - sorted by "geography", i.e., the efficient route through the layout of a ship

Based on our previous projects with Gøteborg Energy and Telenor Installasjon, we assert that checklists comprise a general tool for many types of work. We therefore propose a "sibling" application, the deviation report, for certification work.

Certification work

Certification work is usually considerably more long-term (6m-2y) and, therefore, "plannable" than the work of surveyors. It comprises:

- Marketing
- Education
- Planning
- Certification
- Revisions
- Annual audits

Short-term, that is, within each inspection, it may consist of:

- Studying advance documentation
- Interviewing
- Observation
- *Writing deviation reports*
- Registering hours & travel expenses

In the remainder of this section, particular emphasis will be put on discerning a proposal for a deviation reporting applications. The main reasons are:

- *Deviation reports are described by the auditors as "part-of-the culture", i.e., and integral to their work.*
- *They may be seen as a generalisation of the CheckRite demonstrator.*

Deviation reports

The main outcome of the short-term certification process is the deviation reports. They constitute the main vehicle for process improvement at the customer's end. A deviation report is, in its current manual form, a semi-structured document, which records data about the customer and the item, plus a free-form description of the observed deviance.

A concluding meeting is held 30 minutes after the inspection finishes, and the deviation reports is the main source of data for auditors preparing a summary presentation. This is today a manual process, often conducted in a borrowed office or meeting-room.

A final report is also produced; the process of which may be more time-consuming. It turns out that it may also not be very important, at least DNV are currently conducting an investigation into new requirements for such reports. In many other countries, the final report is simply hand-written at the customer's site, but the tradition in Norway stipulates that a far more detailed and well-formulated report is written and submitted to the customer at a later stage.

Design rationale

This section describes the design rational of the Deviation Report application in more detail. First, it is clear that certification work can be better supported "in the field". Today, auditors complain about portable equipment, such as laptops and printers being too heavy to carry around. Bear in mind also that customers today want "value-added" inspection, in order words they see it as a dialog with knowledge transfer effects. It may be the case that traditional input devices and the "solitudinal" ways of operating existing applications may end up "standing in the way" of the actual product that is offered, which is the inspection itself rather than the reports. Moreover, and in accordance with this, auditors are concerned with discovering new deviations, making sure not to walk in their own track from the previous inspection. They also told us that there is sometimes a need for peer-dialogue, for instance in order to discern better formulations of deviancies or to interpret the rules and regulations in a situated fashion.

A case for mobile deviation reports

We suggest implementing a demonstrator of a WAP-based Deviation Report. The design should allow auditors to *Talk*, to customers (whilst providing input mechanisms and feedback that are very non-intrusive) and with colleagues (which may work elsewhere). It should be structured as a checklist requiring minimal input, and offer a selection of previously used formulations from simple menus. The Deviation Report should have *compile and export mechanisms* that aid the preparation of the concluding meeting and support compilation of the final report.

Supporting our assertion that this application represents a great potential for generalising CheckRite is that fact that similar use cases were observed at Astra Hässle and Hydro Data.

Reduced paperwork

We believe that a Deviation Report application may reduce paperwork for auditors by aiding the deviation reporting process. It could assist auditors in sharing data and formulations within and between projects. It could even automatically be counting hours used. It may offer templates for final reports, partially completed with the deviation reports thus registered, and even help plan the inspection by showing which steps were taken on previous visits.

The mobile Deviation Report should provide access to deviation reports from the last inspection, and it may even be fruitful to consider *situated planning*, by leaving pointers to follow-up next time.

"Assistance-on-demand"

We also think that a WAP-based Deviation Report could offer simultaneous support for data recording and communication. Thus, auditors should be able to maintain contact with colleagues and databases for "assistance-on-demand" in a non-intrusive way. The telephony platform could be used for SMS as well as voice or Intranet access. It may even, at some point in the near future, allow digital pictures to be taken, transferred and discussed with remote partners.

It is important that the application allows individual auditors to maintain their personal network, and find out who has been involved in this part of similar process processes, in order to exchange experiences and improved the *organisational memory*.

Summary of WAP-based Deviation Reports

We believe that the proposed application may contribute to:

- Reducing paper-work, bearing in mind, also, that customers act on deviance reports, not the final report.
- "Assistance-on-demand", by offering email, SMS, and voice communication in combination wit non-intrusive recording of observed deviancies.
- Avoid redundancies and add value with new insight from colleagues, past and future inspections.

Our proposal aims to support "multi-modal reflection" in inspection work. It generalises CheckRite to implement a mobile Deviation Report system, which supports data capture and relevant reporting. We also speculate that the system may contribute to breaking the isolation of mobile workers, in such as way that the customer perceives added value rather than disruption.

From model to general systems

During the MOAS project, we have found that innovative application ideas keep originating from fieldwork. *The conceptual effort that pivots around* *the basic reference model seems to bolster generalisation and point to important areas of concern.* Clearly we need more empirical work to establish the usefulness of each concrete application, but we see, also, that the model will be able to serve as a framework on top of which to build a toolkit for developing support for mobile work. This may make the innovation process more efficient in the future.

Related application ideas

The remainder of this section briefly introduces a research agenda and some application ideas for the next MOPAS project.

The research agenda focuses on mobility, in combination with potentially bandwidth-demanding applications, such as videoconferencing and graphics (for synchronous consultation and co-operative work) and common information spaces (for asynchronous assistance-on-demand and on-site updates to large databases).

The following is a list of important research problems within some of the domains of mobile IT-use:

Mobility of "heavy applications"

One significant problem of mobility is related to the use of lightweight devices with small or even no displays and keyboards. There is considerable interest in how the services that users have come to rely on can be efficiently deployed to a mobile setting. Given the limited processing power and small storage capacity of such devices, it seems reasonable to assume that the network and server infrastructure will need added functionality.

Security

One striking aspect of supporting mobile work, as opposed to mobile computing in a strictly technical perspective, is that many mobile workers rely on borrowing terminals and the fixed infrastructure in remote sites. There is therefore a need for research into the security aspects of such mutual arrangements, where the user, as well as the host, have important security concerns that may need to be negotiated.

Multimedia

Since mobile work is intrinsically hard to plan and organise (after all, that is why the user has to be mobile in the first place), mobile IT-use poses a series of difficult research problems. Especially, the ability to bring existing services into new domains is a challenge. For instance, moving from one network segment to another, changing terminals or work taking a direction in which the ongoing service cannot be operated in the usual fashion, requires the adaptation or transformation of data and programs to deal with a new situation.

Common Information Spaces

Mobile platforms offer limited processing power and storage capacity. At the same time, the wireless infrastructure cannot always be relied on, for instance if servers fail or become overloaded or the terminal moved beyond network coverage. This means that the network should, ideally, be able to provide robust back-up services for business-critical mobile applications.

Matching each of these domains, the following applications ideas are candidates for developing and testing demonstration prototypes in the experimental environment of MOPAS.

WAP-MOTILE (MObile Tactile Input for a Lighweight Environment)

This application should offer the possibility of simple, tactile input for mobile telephones. It can be conceived as a virtual keyboard, operated only with three buttons, and relying on the shared functionality of the network and target applications for advanced operations. A small prototype is already being developed in another project.

WAP-SEA (Secure Easy Access)

This application idea aims to offer secure and easy user registration, directory services and authentication from remote environments which have not been prepared in advance, using WAP-based protocols.

WAP-MADCAP (Mobile-Aware Distributed Conferencing Application)

Managing the interaction itself is an integral and potentially heavyweight task for users of mobile applications. This task is made genuinely more difficult in a setting where the user may have to *move between different modalities*. This application should offer a general console for operating and adapting mobile telephony *applications*.

WAP-BEE (Best Effort Engine) Server

Since mobile environments cannot guarantee access or performance, whilst at the same time mainly hosting business-critical applications, we propose an application that performs rule-based scans of the user's local environment, in order to offer a distributed cache that can be accessed whenever the mobile system can get hold of it. The underlying idea is for no mobile host to ever run below its maximum capacity. The available storage space and processing power should be opportunistically used to anticipate problems following a breakdown in infrastructure or functionality.

One important rationale when selecting and outlining these four application ideas for development and testing in future MOPAS projects is that, conceivably, they can be also offered as generic components for further use in application development, in other words, as extensions to existing frameworks.

Discussion

The starting point for our investigations was the lack of innovation and new applications for mobile workers. We share the views of Abowd *et al.* (1997) when they maintain that although effective use for mobile technology will give rise to an interaction paradigm shift, it is difficult to predict what that shift will be. The model presented in this paper aspires to aid this process. Relatively few researchers are involved in establishing a set of maximally beneficial mobile applications. Our model contributes to this enterprise.

Mobility is essential also in work that is not designated as *mobile work.* It supports interaction and offers awareness, and is essential in the use of shared resources.

Bellotti and Bly report on a field study of distributed work at a consulting firm, in which they found much more mobility than anticipated, in particular what we previously called walking. Their paper points to shortcomings in parts of CSCW (Computer Supported Co-operative Work) research that exclusively concern itself with desktop support (i.e., *stationary* modality). They found an interesting relationship between *modalities* and *intentions* in this example of *mobile IT-use*: While local mobility is integral to local collaboration, it often severely penalises long distance communication.

One way of proving the value of the conceptual contribution of this paper could be to show how it adopts existing designs and fieldwork within this area. Abowd *et al*. (1997) describe a set of prototypes of a mobile, context-aware tour-guide. They are particularly concerned with maintaining and exploiting data from the use context, namely *location* and *orientation*. This is more than just data, in our model, however, since it uses the *history* of locations (and thus the modality of users) to offer a better suite of applications to the mobile user.

The model could frame this application idea in the following manner:

Mobile IT-use: The application supports visitors to the lab, presenting them with necessary information to navigate the building, understand the projects and enjoy the visit.

Environment: IT research labs usually do not adhere to a significant layout, i.e., it is impossible to say what people do only by glancing. Although visitors are frequently from abroad, such labs are usually not sign-posted in many (if any) languages.

Modality: Typically, tourists walk. They are usually content to carry a book or handheld device, but not with larger, expensive items which restrict the freedom of mobility. Tourists do no stay for long, however, they are likely to, in this case especially, stop and talk with "the natives."

Technology is, as in the many of our field studies, manual documents, laptop computers and the available (or not) infrastructure such as telephony or transportation.

Data for tourist guides may include co-ordinates of position and orientation, "invisible structures" such as organisational charts or project information, notes, and real-time voice.

Programs support the intention of visiting. Abowd *et al* (1997) suggest many interesting solutions for the mobile tour guide: personalised tours, language translation, note-taking, synchronous communication and group interaction. Some concrete services suggested were *Cartographer*, *Librarian*, *Navigator*, and *Messenger*.

Many more applications are well covered by the model, even if mobile IT-use is not on their agenda.

Hagimont and Ismail (1997) describe a protection scheme for mobile agents, in which access to objects is controlled by means of mutually suspicious agents. It is concerned with the use of mobile code to support *stationary work.* It is still possible to apply the model to the *use* of the protection scheme, for instance in the *shared calendar* example of the authors.

The overarching phenomenon, in this example, is *mobile calendar use.* The intention may be described as *effortless organisation of meetings*. An *agent* is the program that manages calendars, and creates *proposal objects,* i.e., data. Technology is manifested as *networks,* which may or may not be connected. Agents exchange *tokens,* as access right signifiers. These tokens realise part of the organisational environment, inasmuch as they can limit initiators' capability of manipulating the calendar of their boss, or it may be physical, if no server exists to negotiate capability requests. In a truly mobile use situation, the meaning of environment is even richer, insofar as it may constrain the possibilities of operating the technology in the first place.

Pratel and Crowcroft (1997) present an almost identical approach. They describe a ticket based service access for the mobile user. In this case, mobile IT-use is targeted with *tickets* instead of *capabilities*. It falls nicely within the model, and brings especially to the fore:

- The relationship between available *applications* (for which tickets are "purchased"),
- mediating *technology* and
- the use context of *environment* and *modalities,* which direct the users' intentions and continually introduces constraints such as, for instance, which service provider is available.

It is important, again, to emphasise that the model is a dynamic instrument for systematic innovation of new application ideas for supporting mobile work. It will change during a process that is more important than the model as a product in and by itself, namely the creative design of mobile IT and its organisational use context.

Conclusion

This white paper has described a design-oriented reference model of mobile IT-use. The model holds up well to new empirical cases, and we have shown that it can be used to capture central aspects of existing mobile computing research. We believe that this model will provide useful pointers toward a future research agenda.

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