Computer-Supported Situated Work: Considering the e-Health Domain

Markus Klann

Fraunhofer Institute For Applied Information Technology (FhG-FIT), Schloss Birlinghoven, 53754 Sankt Augustin, Germany

Abstract. This article discusses the role and impact of upcoming technologies, most notably sophisticated mobile computing, for the support of skilled and situated human activities. To link this quite general discussion to the domain of e-Health, the article starts off by explaining how various activities in this domain have to be understood as skilled and situated and how they might be affected by future technological support. After giving an account of the characteristics of situated and collaborative activites the article briefly introduces three relevant proposals for Integrated Projects for the European Union's Sixth Framework Programme. All of these projects feature different e-Health application fields, including emergency response teams, the next-generation operation room, and long-term patient records. The remainder of the article is devoted to a number of research challenges that have to be met in order to realize the full potential of future technological support for these e-Health application fields.

1 Introduction

In the present article future technological support for skilled and situated human activities will be discussed as it is envisioned and developed in current and upcoming research projects in Europe and elsewhere. The prospective enhanced support rests on foreseeable innovations on both the hard- and software-level, including e. g. the general availability of large numbers of networked interoperable devices providing computing and communication services, as well as highly context-sensitive applications using sensory data and interaction histories to adapt their services to their users. In order to foster a joint understanding of this idea within the research community and support coordinated and consistent research activities the European Commission is promoting 'Ambient Intelligence' as a guiding concept. It signals the shift from isolated and singular computing devices that host a defined set of functionalities to a situation where large numbers of interconnected potentially small devices provide services by sharing resources such as bandwidth or displays and allowing for free roaming of applications. Evidently, this vision poses large numbers of research problems ranging from the development of new mobile devices, sensor integration, novel forms of interaction such as haptic or tangible interfaces, network protocols, algorithms for interpreting and reacting upon context-data to the social take-up

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process of these new technologies, security, privacy etc. The net benefit of such support consists in overcoming the de-facto separation of situated activites and conventional supportive information and communication technology (ICT). By providing all services through portable or even wearable devices and adequately integrating them as much as possible with skilled activities, research hopes to turn sometimes ackward technological crutches into true amplifiers of human competence.

Of course, application fields for such support of situated activities extend well beyond the domain of e-Health. Nonetheless, e-Health is a highly relevant field of application because of its diverse and sometimes extremely demanding requirements. Understood in a broad sense, e-Health comprises rather different domains of skilled human activity, ranging from surgical teams working in operating rooms, emergency response teams sometimes having to attend to an unknown number of unknown people in an unknown and hostile environment, laboratory personal, homecare services, etc. In most of these cases teams of highly trained specialists use complex technological equipment to collaborate in feature-rich situations under high time pressure and with very low or virtually no tolerance for error. Consequently, providing the right information and expertise at the right time and place without hampering the e-Health professionals in their primary task is as benefitial as it is difficult. For instance, adequate support has to meet very high standards of reliability, demand its user's attention only economically all the while ensuring awareness of crucial information and it has to provide reasonable fall-back procedures in case some functionality fails. Another e-Health aspect of technological support that is often overlooked is that more extensive and integrated forms of support might also entail health problems in terms of stress or ergonomic inadequacy.

In the following sections e-Health will not be addessed directly but as a highly interesting instance of a skilled and situated activity. The following section gives a more in-depth discussion of ICT-supported situated activities, including the central aspect of collaboration. In section 3 three project proposals will be presented that touch on e-Health aspects and that have or will be submitted to the EU's Sixth Framework Programme (FP6) with the involvement of the author. Finally, in section 4 some of the ongoing research questions that the author intends to work on in these projects are presented. In presenting this work, one of the intentions of this article is to raise awareness for these European research activities and create contacts with parties outside Europe that might be interested in becoming partners in future proposals or join existing projects later on for e. g. dissemination activities.

2 Computer-support for situated collaborative work

The characteristic feature of using mobile computer technology to support human work is that people can be supported in the very situation where they carry out their primary task. The great advantage of such support of situated activities is that it can take into account the situational context which defines to a certain extent what the task is and what its relevant features are. For this reason, human experts often depend on being in the task situation for accomplishing the task. Hence, the full potential of mobile support for situated activities is realized when the professional can integrate it with his competence to act in the task situation. These benefits carry over to collaborative activities in a natural fashion, being amplified by the additional social context of collaboration. The characteristic feature of mobile computer support for collaborative work is that the individual collaborators can extend their powers beyond their respective task situations by establishing network connections between distributed collaborators. The real potential of this is on the one hand to enable an individual person to better communicate the contextual circumstances of his task situation to remote collaborators and on the other hand to make a distributed task situation more observable and assessable as a whole.

To put this in concrete terms, using mobile computer technologies can help a physician to communicate his concrete problem situation when consulting a remote expert and it can help the chief of an emergency response team to assess a complex emergency situation and monitor and coordinate his team on the basis of the information received from his team members. Of course, similar processes have long been practised using simple technologies such as telephones, radio or post. But computer support can enhance these processes vastly by providing rich contextual information through sensors and user monitoring, as well as effective information processing such as filtering of irrelevant information and aggregation of multiple information sources.

In order to realize this potential of mobile computer-supported collaborative work, three fields of research have to be addressed:

1. The structures and processes of collaborative settings (e.g. work groups, expert consultation, etc.) have to be investigated and the potential benefits as well as issues of mobile computer support have to be evaluated.
2. Means of support in terms of hardware and software have to be developed that realize the benefits while avoiding or at least allow controlling the associated problems.
3. A methodology for deploying mobile computer-support has to be developed that assists the necessary changes in work practice and associated problems such as acceptance.

To start with, there are many different types of collaboration and most often a given collaboration is also changing over time. Consequently, mobile computer support is faced with highly diversified and dynamic requirements that cannot be fully anticipated at design time. On the one hand, this requires research on the spectrum of collaboration types and the processes that change them. On the other hand, it requires enabling the workers themselves to adapt their systems to the particular requirements of the current collaborative situation (cp. section 4.1). Empowering end-users to substantially adapt the systems is a prerequisite for the systems to become effective tools for the ever changing specific situational context of individual expert activities as well as efficient participation in a dynamic network of collaborations.

Apart from domain specific differences, a number of more general features also distinguish different types of collaboration: they can be ad-hoc or pre-established but loose networks and they can be in the form of trained communities with a specific collaboration culture. The collaboration can be self-organized or centrally controlled and there can be forms in between such as fully or partially autonomous sub-groups (e.g. cross-organizational collaboration). Collaborative settings can have more or less internal structure with different roles such as surgeon, anaesthesiologist, nurse and remote expert.

A particularly interesting type of collaboration occurs in trained and well-established groups - or communities of practice [Wenger, 2001] - such as a fire brigade or surgical team. In these cases the collaborators have formed a social network and group culture that defines standard behaviour patterns and endows the group with coherence, reliability and identity, allowing the community members to engage in a trusted and highly efficient collaboration.

As is well know from research in computer-supported collaborative work, support systems must be able to cater to the diverse and dynamic requirements of these types of collaboration and their associated processes, or otherwise they will either not be used or severely damage the collaboration's efficiency. Because of the dynamics of situated activities this is the more true for mobile collaboration support.

In the case of communities of practice the process of setting up the community, integrating new members and dealing with leaving members is of particular importance: efficient behaviour patterns must be found and trained, suitable members for different roles must be identified and new members must be integrated into the collaboration culture. Because of the distributed nature of mobile collaboration this calls for appropriate support by the mobile collaboration system. Other collaboration processes that have to be supported include decision making, problem solving, knowledge sharing, finding suitable collaborators, and skill dissemination through demonstration (see section 4.2).

On the level of mobile technologies, several kinds of support are known that have to be adapted to mobile collaboration support, including:

1. System adaptability: To accommodate for the diversity and dynamics of requirements between groups, within groups, and over time. Support compatibility of individual and group requirements (e.g. rights, scopes, consistency checks, negotiation processes).
2. Roles: handling of rights, duties, etc.
3. Awareness for collaborators and the group's overall status (idle, under stress, etc.). To support this, mechanisms for e. g. problem and conflict detection and resolution are needed.
4. Control: Procedures for escalation, coordination, notification services.
5. Interaction history or collaboration memory:
   (a) evaluation and debriefing
   (b) identification and reuse of effective interaction patterns
   (c) sustainable group experience
6. Modes of interaction and interfaces.
7. Support to assess the impact of individual activities in collaboration systems.

3 Three FP6 Project Proposals with e-Health aspects

The following three sections give a short introduction to three project proposals that include some highly relevant e-Health aspects and that have been submitted to FP6 or will be so shortly. The author has participated actively in the preparation of these proposals.

3.1 wearIT@work

The project proposal for wearIT@work has been submitted to the 2nd Call of FP6 on October 15. Within wearIT@work a considerable number of major organizations from research and industry have defined a joint and integrated research and development process to turn wearable and mobile computing into a truly productive asset for professionals in all sorts of work areas. In particular, field studies and tests will be conducted with partners operating in the fields of surgery, emergency response, automobile production[1] and aircraft maintenance. The overarching aim is to shape technology in such a way as to make it a seamless everyday commodity for professionals, for example by integrating it with the clothing and by providing unobtrusive user interfaces. Using this wearable and mobile computing platform, context-sensitive information and communication services will be developed that provide access to relevant information at anytime and anywhere. In the context of e-Health, wearIT@work will address the interaction of surgeons with the multiple devices in an operating room, following the approach to replace or augment all of the devices' interfaces with a single interface that the surgeon can access and operate through wearable devices, e. g. a head-mounted display. The benefit of such an interface will be to unite and aggregate the large number of information sources and control interfaces in a single consistent one that poses a smaller cognitive load on the surgeon and allows for sophisticated awareness support of relevant information. Secondly, wearIT@work also addresses emergency response teams working in hostile environments, such as fire brigades. In this context, monitoring the team members' vital status and leading the team based on this information is a matter of life and death. Coordination of medical attention in potentially large-scale emergency situations is a second aspect.

3.2 AmbieLife

The AmbieLife proposal has likewise been submitted to the 2nd call of FP6. It is strongly rooted in the 'Ambient Intelligence' (cp. Sec. 1) vision and one of its contributions would be to develop an architecture for networks of interoperable devices that provide their services to the network and thus allow for a seamless configuration of services that the individual devices could not provide alone. Obviously, such a network architecture is a prerequisite for attaining a high level of both flexibility and service quality in heterogenous device networks,

[1] Compare [Morgan et al., 2002] for an interesting account of this application field.

such as in an operating room. The second and at least as important aspect of AmbicLife is the idea of the Personal Information Space as the place where people can store and organize all of their information and that they can access from everywhere using whatever devices their current environment has to offer. When talking about skilled and situated activities one key benefit of the Personal Information Space would be that it can retain past experience embedded in their situational context, making it easier to reactivate, reassess, extend and share such experiences that are at the heart of human expertise. Within AmbieLife the connection with e-Health will be established by investigating the use of Personal Information Spaces for patient records in a hospital setting. While bearing substantial benefits in terms of access to information and diagnosis this usage also comes with serious issues in terms of security and privacy.

3.3 Human Work

The Human Work project will be submitted to the 2nd call of the so-called 'Priority 7' field within FP6, closing on December 10. As opposed to the preceeding two projects this one is not primarily oriented toward research on information and communication technology but towards research in the humanities and social sciences, as is required in 'Priority 7'. The main focus of this project will be on investigating the changes in work processes as brought about by the use of new technologies. To this end particular attention will be paid to the tacit dimension [Polanyi, 1983, Polanyi, 1998] of competent human activities and how it relates to novel means of support. As explained above mobile computing technologies allow for integrating support narrowly with the supported activities. Accordingly, the most exiting potential of mobile computer support is not about bringing explicit information to users but is about amplifying existing competence by providing sophisticated tools that people can assimilate to their tacit skills. Secondly, Human Work will also address the health risks associated with using new technological support.

4 Pertinent Fields of Research

To realize the functionalities and associated benefits discussed in the preceeding sections a number of research problems have to be addressed and resolved that are not specific to the e-Health domain but nonetheless highly relevant to it. Research at Fraunhofer FIT does also include very e-Health specific work like navigation support for minimal invasive surgery. But in the following sections three examplatory research fields at Fraunhofer FIT will be discussed that are relevant to a number of application fields including e-Health.

4.1 Adaptation Processes

End-users want IT-systems to meet their requirements. Capturing these requirements and letting software-professionals implement them is a workable approach only if the requirements can be identified and remain stable over time. As stated in the introduction, end-user requirements are increasingly diversified and changing and may even be difficult to specify at a given point in time. Going through conventional development cycles with software-professionals to keep up with evolving end-user requirements would be too slow, time-consuming and expensive. While end-users are generally neither skilled nor interested in adapting the systems they are using at the same level as software professionals, it is very desirable to empower users to adapt systems at a level of complexity that is appropriate to their individual skills and situation.

But adapting systems to users during usage does not necessarily require dedicated activities on the part of the user. Adaptive systems monitor their users' behaviour and other contextual properties, like the current task or situation, and use different approaches, notably from Artificial Intelligence, to automatically adapt themselves . One important approach to increase system adaptivity is to increase this contextual awareness by taking more contextual properties into account and to set up user models to better assess how the users' requirements relate to different contexts.

Nonetheless, the distinction between system adaptability and adaptivity is not so sharp in practice. Users may want to stay in control of how systems adapt themselves and might have to supply additional information or take certain decisions to support system adaptivity. Conversely, the system might try to preselect the pertinent adaptation options for a given context or choose an appropriate level of adaptation complexity for the current user and task at hand, thus enhancing adaptability through adaptivity [Klann et al., 2003, Oppermann, 1994]. The following two sections explain adaptivity and adaptability in some more detail.

Adaptivity The aim of adaptivity is to have systems that adapt themselves to the context of use with respect to their functionality, content selection, content presentation and user interactions. Systems displaying such adaptive behaviour with respect to the context of use are called context- or situation-aware.

One aspect of situation-awareness is related to properties of the user itself, like the level of qualification, current task or previous behaviour. Traditionally, these properties have been captured in user models, which have been processed to generate appropriate adaptive behaviour. Currently, situation-awareness is continuously augmented by taking more and more situational properties into account . In particular, various sensors are used to gather information on properties relating to the physical environment of the context of use, like the time of day, location, line of sight, level of noise, etc. Other situational properties of the context of use of a particular user relate to what may be called the social environment, being composed of other users, communicative and cooperative interactions, shared artefacts and common tasks. One example of such an adaptive system would be a tourist information system on a mobile computer that presents specific informations based on its users location, movement, profile of interests etc.

The basis for a successful and effective information and communication system is providing information and functionality that is relevant and at the right level of complexity with respect to the users changing needs. As these changing needs are largely related to the situational properties, relevance and appropriate complexity can be supported by system adaptivity, which is to say by automatic proactive selection and context-sensitive presentation of functionalities and contents.

The objective of adaptivity is to assist the users by proactively supplying what they actually need. This way, users are not distracted from their primary task by searching and selecting. A good quality of such adaptivity clearly depends on complete and accurate user- and context-models, as well as on correct conclusions derived from them.

At Fraunhofer FIT development of a Contextualization Framework is under way that will provide a modular architecture for acquiring sensory data and other contextual properties, interpreting and integrating this information and deriving appropriate context-aware system activities.

Adaptability The aim of adaptability is to empower end-users without or with limited programming skills to customize or tailor computer systems according to their individual, context- or situation-specific requirements.

Approaches to adaptability include:

1. End-user-friendly programming languages , see e. g. [Repenning et al., 2000]
2. Programming by example[2] respectively Programming by demonstration, see [Lieberman, 2001]
3. Component-based tailoring, see e. g. [Stiemerling et al., 1999]

By avoiding costly and time-consuming development cycles with software engineers whenever possible, such approaches allow for fast adaptations to dynamically changing requirements by letting the end-users put their domain specific expertise to the task of system customization. While currently still being in its infancy with simple adaptations like macros for word processors or e-mail filters, more sophisticated forms of adaptability should enable end-users to become the initiators of a coevolution between the systems they are using and their own requirements as defined by their tasks, level of expertise and current working context.

Work on adaptability has been consolidated over the last two years in the European FP5 project EUD-Net [EUD, 2003, Klann et al., 2004]. EUD stands for end-user development and has been promoted as a unifying term for the various adaptability approaches.

For the domain of e-Health the concept of adaptability or end-user development is highly significant because it empowers domain experts such as doctors

[2] Taken as a conscious activity and not as an accidental side-effect to usage, Programming by example constitutes a case of adaptability. But as it also requires system activity, namely deducing some function from the users behaviour, it may also be considered a case of adaptivity.

and nurses to use their expertise to modify the ICT systems they are using more quickly and accurately than would be possible with the help of professional developers.

4.2 Knowledge processes

When dealing with human competence traditional approaches in ICT often tried to formalize expert knowledge and provide this explicit information to users in a decontextualized way. Problems with ageing and maintenance of such explicit knowledge as well as with interpreting and transposing it to changed problem situations has started research on alternative ways of making expert knowledge available. One such approach is to use profiling techniques to evaluate and describe the skills and expertise that a given member of a community has and to use these expertise profiles to bring members seeking and members providing expertise together for communication and collaboration. At Fraunhofer FIT a modular ExpertFinder framework has been developed that allows for plugging in different profiling and matching algorithms.

4.3 Design and Deployment Processes

Challenging the conventional view of 'design-before-use', new approaches try to establish 'design-during-use' [Dittrich et al., 2002], leading to a process that can be termed 'evolutionary application development' [Morch, 2002]. These approaches are means to handle the dynamics of requirements. One particular difficult and important aspect concerning the heterogeneity of requirements arises because of cultural differences in the user community, both on the professional and ethnical level. Consequently, empirical ethnographical studies are an important means to identify and understand the diversity of requirements and they are a prerequiste for developing systems that are equally usable across cultural boundaries and in multi-cultural teams.

5 Conclusion

The present article has discussed the relevance of future computer-supported situated activities for the domain of e-Health. It has given an account of some of the associated research challenges and of how these are being addressed in current EU research project proposals. It would be a very positive effect if this article can spark an interest in these research activities, maybe make some of them a little more transpartent and eventually support research collaboration with partners from outside Europe in the context of FP6 or elsewhere.

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