Challenges in Designing Interactive Systems for Emergency Response

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ABSTRACT
This paper presents research on participatory design of interactive systems for emergency response. We present the work by going through the design method with a focus on the new elements that we developed for the participatory design toolkit, in particular we emphasize the use of *challenges* and *visions* as ways to bridge between fieldwork and literature studies on the one hand and the emerging computer based prototypes on the other. Our case concerns design of innovative interactive systems for support in emergency response, including patient identification and monitoring as well as construction and maintenance of a situational overview.

Authors Keywords
Ubiquitous Computing. Palpable computing. Participatory design. Design visions. Prototyping. Emergency response.

ACM Classification
H.5.1. Information Interfaces and Presentation: Multimedia Information Systems - *Audio input/output, Video (e.g., tape, disk, DVI)*
H.5.2. Information Interfaces and Presentation: User Interfaces – *Evaluation/methodology, Prototyping, User-centered design*
H.5.3. Information Interfaces and Presentation: Group and Organization Interfaces – *Collaborative computing, Computer-supported cooperative work, Organizational design*
J.3. Life and medical sciences: Health, Medical information systems
K.4.1. Computers and society: Public Policy Issues – *Computer-related health issues*

INTRODUCTION

This paper is concerned with the design of interactive systems for emergency response and the design method applied. We present and analyze a set of design challenges that was derived from fieldwork and literature studies. We formulate a set of design principles and visions that address these challenges and we present a number of prototypes used to explore the visions and act as a basis for implementing real systems.

The prototypes cover: wireless collection and distribution of biomedical data; patient identification; support for construction and maintenance of a situational overview by use of different media e.g. video and pictures.

The work is a part of the PalCom project [28], a major four year research project involving 12 partners in six countries and sponsored by the European Union. The overall aim of PalCom is to propose a new software architecture for pervasive computing using a participatory design approach. The architecture is designed using a number of prototypes as vehicles for both exploring requirements and evaluating architectural ideas. The prototyping is done in a number of different domains, including the case reported here: *emergency response* with a focus on major incidents.

Emergency response

Emergency response demands fast and effective action, often in life-threatening situations. It requires collaboration between numerous people and groups: the personnel at an incident site, in the emergency vehicles, at the command and dispatch centers, at hospitals, etc. In addition, major incidents—like train accidents, industrial accidents and chemical spills—are characterized by having too few resources for the amount of work to be carried out.

The dynamic changes in the situation, including the position of victims, professionals, vehicles and other resources, makes it extremely difficult for anyone to obtain and maintain a situational overview, both on superior and specific levels.

Numerous devices and systems are used in emergency response including radios, bio-sensor equipment (e.g. for measuring the amount of oxygen in the blood), ambulances and fire engines with GPS, a national call alarm system, dispatch systems, and health records.

Related work

Taken broadly, there are several related relevant studies within the two main foci of this paper – suggestions for design of innovative systems for support in emergency

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response and new input to the participatory design toolkit. However, to our knowledge, no study has been reported that covers a similarly broad range of heterogeneous groups and situations (health care workers, ambulance personnel, firefighters, police, plus control rooms, emergency vehicles, incident sites, hospitals etc.). Similarly, this research takes an equally broad approach with an open-ended exploration and design agenda to develop an understanding of those participants and IT-based design proposals to support them.

Papers on design of innovative systems are focused on management support and collaborative systems. Starting with design projects of interest Myers et al [26], describes a flexi-modal large displays tool to support collaboration, communication and overview for people in a military command post. They stress the importance of being able to interact with the system in different ways, depending on the situation. Jiang et al [19] describe use of shared displays to support collaborative work of US firefighters operating under the Incident Command System. A similar system to support firefighters in the field is described in [6]. With a focus on counter-biological terrorism, Siegrist [33] has made a survey of technologies to support the different tasks during such incidents. Among those technologies, an interesting crisis management information system called ENCOMPASS is mentioned. This system supports collaboration, offers information to different responders depending on their needs, creates a common operational picture for responders at all levels, and can track victims at the incident site to hospital. In the Rescue project [25] focus is on improving information flows through disaster response networks that connect multitudes of response organizations and the general public. Holzman [15] describes a system of different technologies to support emergency medical care in the field. He focuses on mobile, field-based information systems, communication between the care providers in the field, and the exchange of data between the field and hospitals. Several papers from pervasive computing conferences and journals report on systems and architectures for emergency response. One of the more comprehensive efforts is CodeBlue, which is a protocol and software framework for low power sensor networks in emergency response [23].

Of special interest is the field study based decisions of developing a system with speech input and audio output. Gröschel et al [14] have also experimented with speech recognition in the field with a primary focus on time recording of patient related activities. Petterson et al and Normark [30] report on field studies of the work done in emergency call centers, and describe how these studies can give input to design of IT systems. An outcome of their studies is presented in [29], where a design idea concerning unobtrusive, ambient displays and building on the field studies, is presented. Tjora [34] presents research in 38 Norwegian medical emergency call centers, where the focus is on how different forms of redundancy contribute to improve the work in handling emergency calls. Several other studies also describe the process going from field studies to design of prototypes, e.g. [10, 15, 19]. By use of experiments to understand human behavior in emergency situations, Schull et al [32] argue that people acting in such situations have to be confident with the routines, tools and other people they 'meet' and interact with. Such confidence or trust can be achieved through training and [10, 33] describe use of simulation tools for training. In [18, 33] it is argued that simulation tools used for training should also be used in real emergency situations. However there are dilemmas associated with testing new technology in realistic settings, where the settings are traumas and emergencies [4]. In [24] Mackay advocate supplementing participatory design with other design methods from different design disciplines. Indeed we have been inspired by design and solution-oriented approaches outside the PD field. Jungk and Müllert in [20] describe a three-step method directed at creating new solutions to practical problems—typically among a group of people with similar interests, like neighbors. The method contains a step where problems are 'negated' to translate them into visions. Probasco in [31] argues for the essential role of design visions in software development and notes that several (successful) projects don't have formal requirements.

METHOD

Our work is based on a participatory design approach [11] where the development of the design focus is part of the work of the project group and not something specified beforehand. In our case, a project group was set up to include IT and design researchers ('the researchers') as well as emergency response practitioners ('the professionals'). The core group consists of four IT researchers, one industrial designer, one ethnographer, three medical doctors, one police officer and one fire brigade officer. Two of the doctors as well as the two officers have extensive experience with handling major incidents on-site.

As part of the participatory design process, we did a number of field studies; we studied technology and literature; we identified and formulated the challenges we wanted to address; we developed a number of design principles and visions; we described various scenarios as a way to describe the visions; and we developed and experimented with physical mock-ups and IT-based prototypes. This process, however, is not a waterfall process. Rather it was iterative with many of the activities occurring in parallel. Thus, for example, work with mock-ups and prototypes are used to further develop design visions and scenario descriptions, which can then give rise to additional field work and in turn influence our understanding of design and implementation challenges [13].

When we began the work, we intended to use state-of-the-art PD, including fieldwork, scenarios and prototypes. However, as it turned out, the different kinds of reports from fieldwork, scenarios and prototypes did not function well as 'reminders' or 'guidelines' in our daily work. Thus the project group more or less spontaneously began to develop what we now call challenges, visions and design principles.

In the rest of this section, we briefly describe the main elements of the method we used, and then, in Sections 3 and 4, we focus on the novel aspect of the method, i.e. our use of *challenges, visions and design principles*. Taken together, Sections 3, 4 and 5 also present our design of innovative interactive systems for emergency response.

Fieldwork

Our project group has carried out a number of field studies to develop a better common understanding of 'emergency response' as a problem domain. We have considered different kinds of emergency situations and activities that occur at incident sites, as well as how those activities relate to hospital and command centre activity. We have studied the kinds of problems inherent in these activities and mechanisms of coordination, along with the kinds of technologies used and the needs and possibilities for improvements.

A large part of our field studies have been 'indirect', in the sense that they have drawn from everyday emergency work experiences, courses and training. We have, however, bolstered these investigations with familiarization and direct experience in major incidents as well. We have:

- Followed different emergency response professionals (doctors, paramedics, fire-fighters and police) in their daily work on minor incidents.
- Followed doctors (anaesthesiologists) while on duty in the emergency room, intensive care unit and operating theatre.
- Participated as observers in pre-hospital (emergency site) effort courses, with focus on both minor and major incidents.
- Participated as observers in trauma team training courses in the emergency room at the hospital.
- Participated as observers in pre-hospital major incident exercises.
- Seen and discussed videos from actual major incidents with the professionals who were involved.
- Studied portions of Katrina and Rita emergency response on-site.

Such fieldwork is, first of all, needed to give the researchers a better understanding of the domain, in this case emergency response. Secondly, it gives the project group as a whole a common pool of material that functions as a resource in discussions of problems, challenges, vision development etc. Third, through discussions of the fieldwork, the professionals gain a better understanding of their own work. This may lead them to formulate and take action regarding both organizational improvements and technical developments.

Technology studies and demonstrations

In order to get a better common understanding of the technological possibilities, we supplemented literature studies with a number of workshops where different state-of-the-art systems and devices were demonstrated and tried out. This ongoing activity is important in developing the 'technological imagination' of the project group and thus supports them in developing innovative, feasible design ideas.

Challenges

As a vehicle to bridge between fieldwork and state-of-the-art on the one hand and design principles, visions and prototypes on the other, we have developed seven challenges in designing interactive systems for emergency response. The challenges are grouped into three categories:

Challenges related to victims:

Challenge 1: Equipment is often tied to victims

Challenge 2: Identification of victims is difficult and error-prone

Challenges related to the professionals:

Challenge 3: Situational overviews are very incomplete and mainly in the heads of the involved professionals

Challenge 4: Communication on site is mainly face-to-face

Challenges related to IT:

Challenge 5: Equipment and systems change with every situation and even as specific situations unfold

Challenge 6: Equipment and systems vary considerably with respect to reliability and trustworthiness

Challenge 7: Suitability and immediate usability determines what equipment and systems are actually used

These challenges summarize the major issues to be addressed in designing support for emergency response. They are discussed in detail in Section 3.

Addressing the challenges:
Design visions and principles

In order to move from challenges towards design and implementation, we have developed a set of design visions and principles where we considered both the needs and priorities of the professionals and technical possibilities.

Design visions address one or more challenges, and do so in a way that directly points towards a design solution. Thus to address the challenge of equipment being tied to individual victims and not more flexibly available, we formulated a vision around *wireless medical equipment*.

Design principles address how to design in such a way that one or more challenges are met, but are not visions of a design. Instead they are essential qualities intrinsic to the design. To illustrate: in order to address the challenge of immediate usability, we formulated the principle of *familiarity*, that is the devices and systems designed for emergency response should, once deployed, be immediate usable by being familiar to the involved people.

Design visions and principles are discussed in more detail in Section 4.

Mock-ups and Prototypes

On the basis of the *challenges*, *principles* and *visions,* we developed and experimented with a series of physical mock-ups and IT-based prototypes. In each case, we began with suggestions for how to turn specific design ideas into physical mock-ups and then progressed to still more advanced IT-based prototypes. To illustrate: a number of physical mock-ups of bio-sensors and 'communication hubs' were constructed to illustrate relationships between form and different aspects of use, e.g. placing the sensor on a victim and moving a hub from a stretcher to an ambulance. Later, IT-based prototypes were developed that allowed for remote displaying of real biosensor data. However, with respect to form, the first prototypes represented a step back when compared to the most advanced mock-ups.

Explorative use in workshops

The next step in the design process was the use of mock-ups and prototypes by the intended users—in our case the professionals in the project group and several of their colleagues—in order to simulate future work practice, generate experience with their use, and identify breakdowns. This was organized in a series of workshops in increasingly realistic settings, beginning with a stretcher in a lab and one of the researchers acting as car accident victim and ending with a two day workshop in the form of a Future Laboratory [5] at an emergency response training ground, with three teenagers acting as victims and eight incident situations being enacted by ten professionals using the mock-ups and prototypes.

Through these workshops, we learned a lot about what worked and what did not in our designs. Often the breakdowns that occurred started discussions that in turn generated ideas for redesign [8, 35] and new ways of combining the prototypes to better support the needs of the professionals. To illustrate: the doctors at the incident site simply chose not to communicate with the Acute Medical Coordination centre (AMC) when they were busy handling patients. Later the AMC began using a remotely controlled video camera to decide when a doctor at the incident site was likely to engage in communication.

CHALLENGES

In this section, we discuss the seven challenges in designing interactive systems for emergency response that we have identified. These challenges were originally formulated based on our fieldwork and our analyses of state-of-the-art. As our work—and thus our understanding of the field—progressed, so did our understanding of the challenges. The challenges are the first step from fieldwork towards design, a step that has been discussed by several authors [2, 3, 7]. Briefly stated, the two main positions within PD are: (1) ethnographers can act as intermediaries between users and ICT-designers [16], (2) ICT-designers need ongoing interaction with users and their work in the field [22]. In our project we adopted position 2. Our design work is an open-ended process without any fixed specification, and indeed our understanding and interpretation of emergency response continues to develop. Thus we—the designers—need direct interaction with the work of the professionals in the field. In addition the whole project group should be able to use the pertinent insights from fieldwork intuitively to guide their design work. However, descriptions from fieldwork and scenarios are too detailed to function well as the only common reference points to the domain we are designing for. In our work we needed more succinct formulations to reflect our understanding and thus we developed what we now call the challenges. They are formulated—and later reformulated—by the project group, i.e. ethnographers, ICT-designers, users etc.

In our work the challenges are thus meant to be an updated record of our understanding of the field (emergency response) that then guide our design intentions (interactive systems for emergency response). Identification of these challenges helps organize our approach to system design, implementation and deployment.

Challenge 1: Equipment is often tied to victims

A predominant part of existing biosensor equipment used in emergency response, consists of biosensors wired to a monitor[1]. The use of such wired equipment is severely hampered by the fact that data can only be seen if you are next to the monitor, which itself has to be located next to the victim. Furthermore it is a cumbersome task to move a victim from one location to another when biosensors attached to the victim are wired to a monitor. When arriving at a hospital placing the patient in e.g. a scanner is also difficult, and so on.

Challenge 2: Identification of victims is difficult and error prone

Our research has shown that it is extremely difficult to obtain and maintain valid and credible identity of patients in emergency situations. First there is the 'true' identity of a person. This can only be established in a credible way when the person is conscious, or by third part identification Secondly there is the temporary id's used until the true identity is certain. There exist a number of means to create and maintain unique temporary id's for patients during emergency response, but studies of actual incidents show that their use is limited at the incident site because using them adds extra non-rescue time to the rescue effort. Thus in real emergencies, non-unique id's are most often used, e.g. "40 year, male, brown hair, leg injury". When arriving at a hospital, such id's are substituted with unique—but still temporary—id's. Tracking a victim across such id changes often creates problems. A shift from wired to wireless equipment (Challenge 1) would increase the problems with temporary id's and bio-medical data.

Challenge 3: A situational overview is very incomplete and mainly in the heads of the professionals involved

[1] Wireless bio-sensors, e.g. for measuring ECG, are used at some hospitals, but they are not suited for use on incident sites, e.g. due to the size of the wireless transmitter.

During emergency response it is very difficult for the involved professionals to build and maintain an overview of an incident site and rescue effort. The maps and sketches used are on paper and can only be shared by co-located people. Indeed most overview information is distributed across people, existing only in their heads. Hence it is difficult create a common understanding of the scene of the incident; the incident as such, injured and not injured persons, and available human and other resources. Planning the use of the area surrounding the incident is difficult, access routes for ambulances can be difficult to describe and communicate, danger areas hard to locate and thus to avoid etc.

Challenge 4: Communication on site is mainly face-to-face

Currently ICT support for communication involving the incident site is basically restricted to radios used for voice communication plus sending a few (4-6) push-button-commands, e.g. "arrived at the incident site". Typically each professional group (police, ambulance staff, medical staff and fire-fighters) uses their own radio frequency, which implies that the different professional groups cannot communicate with each other. The managers of each group in principle have a separate set of radios for their communication, but in practice the managers of each group usually have to find each other physically and try to stay together to communicate and coordinate.

Challenge 5: Equipment and systems change with every situation and even as specific situations unfold

This challenge has two dimensions. The first dimension concerns changes in systems over time and this includes the integration of new technological components. The second dimension concerns the dynamic changes to systems and equipment during emergency response. Emergency response personnel use several different systems and numerous different devices including radios, medical equipment, vehicles equipped with GPS, call alarm systems, dispatch systems, and health records. The devices and systems are not based on a common high-level design vision. More typically, they are poorly integrated and different elements are evolved, appear and fade almost independent of other elements sometimes creating problems with respect to "neighboring" elements. To illustrate: when specific equipment, e.g. ECG, in an ambulance is put on-line, a specific ad hoc solution is often chosen that does not apply to other ECG equipment. Thus in one case the technology used for getting ECG on-line went out of production, and due to the ad hoc nature of the design, it was a major job to get the transmission of ECG data up and running again.

As outlined above, emergency response involves many different people, devices and systems and during emergency response it is a challenging task to facilitate the dynamic changes they are subject to. To illustrate: Often radio communication between professionals at the accident site and other locations (hospital or police station) is difficult. Mobile phones are used in some cases, but in major incident situations the mobile phone nets usually become overloaded and then break down.

Challenge 6: Equipment and systems vary considerably with respect to reliability and trustworthiness

Emergency response is often a matter of life and death; therefore, the demands for reliability of the most critical 'patient-related' devices are especially high. To illustrate: Each ambulance only has one ECG device[2], and these goes through elaborate tests to get approval for sale and then undergoes daily testing. Less critical bio-sensors, e.g. oxymeters, sometimes fail—or seem to fail, but as there are numerous such sensors in each ambulance the doctor or paramedic to simply takes a new one.

Non-patient related devices and systems like radios and communication between radios and call alarm systems vary in quality; several are in the lower end of the quality spectrum. To illustrate: radio communications between the incident site and coordination and control centres are often error prone due to bad radio network coverage. At the bottom of the list with respect to reliability and trustworthiness are some systems that try to automate emergency vehicle dispatch. The character of the coordination activities in dispatch centers in emergency situations makes it very difficult to develop reliable systems that automate this work. In fact one of the most publicized IT failures was an attempt to develop an automated ambulance dispatch system [9].

Challenge 7: Suitability and Immediate usability determines what equipment and systems are actually used

Two recurring problems in the use of some of the existing support for emergency response is that it is not suited for real life emergency response and/or the professionals are not familiar with specific devices and systems. They have been trained in their use on special courses but in the hectic unfolding of an incident, the professionals often fail to use them efficiently and might stop using them altogether—or don't begin to use them at all, simply because they have not played a role in daily routines or because they were not suited for the job in the first place. To illustrate: special incident cards developed for use in major incidents are introduced to professionals at courses, but they are not used in real incidents. One of the major reasons for this is that it takes too much time to use them. Special radios for major incidents are sometimes forgotten because they are not part of the daily routines.

VISIONS AND PRINCIPLES

Our next steps towards new ICT support for emergency response are the development of design visions and principles addressing these challenges. In many cases, it is possible to change a challenge into a vision by 'negating' it, e.g. to negate the challenge 1 'Equipment is often tied to victims' to the vision 'Equipment is NOT tied to victims', cf.

[2] This device records the electrical activity of the heart in the form of an electrocardiogram.

4.1.1.This kind of negation is quite similar to the technique used in Future Workshops [20]. In some cases this kind of negation takes you a big step towards an actual design, in other cases it 'just' describes what one would like to have.

Again it should be remembered that the process is not a waterfall. Initial ideas for visions and principles surface early e.g. during fieldwork. And once they are formulated, both visions and principles are revisited and revised so that they at all times reflect the actual design visions and principles that the project is trying to realize. Also new ideas may be revealed in the process.

In addition, the design visions serve the important purpose of providing a background for the prototypes, of placing the prototypes in a use context. Specific prototypes—especially early in the process—will often realize rather limited parts of the vision. Therefore it is difficult for those members of the project team who are not involved in the daily work on development of prototypes to understand the role of the prototype as a vehicle for getting closer to the final result. Here the visions help. At the same time the prototypes– and the evaluations of them–help explore the feasibility of the visions.

In the following, we present those visions and principles that we have worked the most with. Specifically we have not prioritized development of a vision about communication in itself, but only to address communication as part of other visions.

Visions

The project group decided to formulate visions addressing the first three challenges directly because those three transform into valuable visions by negation.

Wireless Medical Equipment

To address the challenge of equipment tied to victims we formulated a vision of wireless medical equipment that is usable in all weather conditions, easily attachable to victims and communicates with a broad spectrum of devices.

Credible Patient Identification with Minimal Administrative Effort

To address the challenge of victim identity we formulated a vision of unique id's that are usable in all weather conditions, easily attachable to victims and readable by humans as well as a broad spectrum of devices. This unique id should be combinable with other ways of identifying victims, e.g. descriptions of injury, of incident mechanism and pictures.

Dynamic support for situational overview

To address the challenge of situational overview, we formulated a vision of a broad spectrum of ICT support for overview—much of which should be usable outdoors and some of which should be usable at night. Devices should include interactive screens in different sizes, some for multiple co-located and/or distributed users, and most communicating wirelessly to create a shared information space [1]. Data should include bio-sensor data, victim id's, maps, aerial photos, video, tracking (i.e. position), links and text. A major contribution of the ICT support should be to make e.g. sketches on maps easily sharable among non co-located people.

Principles

The three IT related challenges were—like the other four—identified as important challenges based on our fieldwork and analysis of state of the art, but they are different in the sense that they do not lend themselves to being transformed into visions of design. Instead they describe general characteristics of the environment. These three challenges are also the least specific to emergency response. Indeed many of those who want to design ICT support for real life situations where several groups of people cooperate in complex work will face similar challenges. Below we formulate three principles that address the challenges.

Embrace change

To address the challenge of a changing set of equipment and systems we formulated the principle of *embracing change*. This principle is inspired by the requirement embrace contextual change cf. [12]. Systems and devices should be designed to support the users in handling changing contexts. In addition this principle states that systems should support the use of a changing set of available resources. To illustrate: if no specific Bluetooth hub is available, a system should be able to use a Bluetooth-enabled mobile phone or PDA as a substitute or be able to accommodate no connectivity. In addition to the immediate benefit of applying this principle, we are investigating if it can contribute to a more stepwise change and refinement over time of the systems and devices used.

Technically we are applying this principle through the use *assemblies*, as developed in the PalCom project [28]. In PalCom the notion of assemblies has been introduced to describe the dynamic combinations of devices and services on the use-oriented level as well as on the programming level—as a representation of what the user considers as a whole during a specific task [17]. One purpose of an assembly is to provide some functionality based on its constituent services. The services available to the assembly may well be changing, but this does not mean that the required functionality is not continually present. To illustrate: One bio-medical display may be replaced by another display as the assembly moves from one context to another, as when a patient is moved from the ambulance into the operation theatre where a larger display might be available. Thus one concern of an assembly is to manage such dynamic changes to its set of constituent services, while providing a stable interface to its user.

Understandable reliability and trustworthiness

To address the challenge of varying degrees of reliability and trustworthiness we formulated the principle of understandable reliability and trustworthiness. One of our ideas is that when a component does not function correctly, alternatives should be available through designed redundancy. In addition, systems and devices should, of course, provide means for error recovery and contingency handling. However, even the most reliable and/or sophisticated technology will not function satisfactorily all of the time even when redundancy and error recovery is built-in. And when it fails to a degree where the professionals decide that something needs to be done, it is important that the status of systems and devices are inspectable and understandable—both locally at the incident site and by remote users.

Technically we are applying this principle through the use of the ability to make different aspects of running software visible by different means of introspection and we provide tools for inspecting and/or changing the state of a running system. To illustrate: In the PalCom framework Corundum [27], it is possible to dynamically access the inside of services and thereby dynamically change behavior such as the level of logging and to whom exception information is distributed. These characteristics are core parts of the present software architecture proposal as developed in the PalCom project [28].

Familiarity

In order to address the challenge of suitability and immediate usability we formulated the principle of familiarity, stating that devices and systems designed for emergency response should, once deployed, be immediate usable by being familiar to the involved people. Embodied in this is also that the devices has to be easy to use. The suitability of devices and systems to the work at hand is supported through the experimental use and evaluation of prototypes in realistic settings.

MOCK-UPS AND PROTOTYPES: EXPLORING THE VISIONS

The next element in the process was the development of 'families' of mock-ups and prototypes, where each family explored one of the visions. Furthermore, our design principles have been applied in the development of the mock-ups and especially the prototypes.

Wireless Medical Equipment

To explore the vision on wireless medical equipment, we have developed a set consisting of five physical mock-ups and two IT-based prototypes. A characteristic of this set is that all elements facilitate retrieval of biomedical signals from victims on the incident site.

The mock-ups

The mock-ups were built based on four suggestions for design of wireless biomonitors and one suggestion for a design of a wireless communication hub.

We explored different physical shapes of wireless biomonitors to be able to understand and realize the vision. To illustrate: Compared to the first mock-up, the second one was rather large in order for fire fighters to be able to handle it with cold fingers or while wearing gloves. However, in a Future Lab, we discovered that it now did not easily attach to the patient because of its size, and if attached to the patient's back it was too uncomfortable to lie on.

The prototypes

The prototypes in this set are two versions of the wireless biomonitor system *BlueBio*. See [21] for a more detailed description.

The first prototype is a biomonitor system that can transmit ECG signal wirelessly from biomonitors on patients to a special touch-display. It provided a means to explore what kinds of uses wireless transmission of real biomedical data could provide. On the other hand, the first generation biomonitor system was in many respects a step back compared to currently available products, which e.g. have more advanced processing and storing capabilities.

The second prototype is a biomonitor system that can receive ECG signals from biomonitors and distribute those in an ad-hoc network infrastructure (such as an incident site). Furthermore it consists of ICT-services that can display the biomedical data anywhere in the network such as in ambulances and hospitals. Being able to display the ECG signal in many different locations and on different kinds of devices is a step towards applying our design principles. The first ability provides for redundant means of displaying the signal. For example, if the PDA breaks down, a mobile phone can be used instead. The latter lets us design systems that can actually run on devices that are familiar to the professionals such mobile phones and PDAs.

The ECG signal is among the most common of the signals that assists doctors in analyzing the condition of a patient. Selecting ECG as the first wireless signal that we provided in the prototypes serves the purpose of the biomonitors being used not only in major incidents, but also in daily emergency response work. Furthermore doctors can relate to ECG signal because it is a very common signal, not just in emergency response, but also during operations and in other daily routines. Taken together, we based the prototype upon ECG as a way to apply the principles of familiarity and trustworthiness.

Credible Patient Identification with Minimal Administrative Effort

To explore the vision on credible patient identification with minimal administrative effort we have developed a prototype that makes it possible to augment the abstract descriptions of victims with pictures of the real victims.

Pictures of victims

The concrete prototype was created by taking a prototype from another subproject and modifying it. It is an assembly of three different services: a camera service, a storage service and a display service. Together they form a picture service to which other services can subscribe and thereby receive a picture whenever the camera produces a new one.

The prototype contributed to better patient identification because practitioners at the AMC and trauma-room were able to receive pictures of the victims and augment those with their mental images. In addition it made us realize that more work is needed on this subject. Specifically, during a Future Lab, we saw that the doctor at the AMC had to work with three displays: one running the prototype which displayed pictures of injured patients, a second with biomedical data, and a third with a live video from the site. Having pictures, biomedical data and live video in the early stages of the rescue work was indeed appreciated because they could get a feeling of the scope of the incident, but since the prototypes were not integrated, the doctor had difficulties relating the patients in the pictures to the biomedical data and to the patients in the live video.

Dynamic Support for Situational Overview

The vision on situational overview was rather broad so we decided to explore it through a series of different prototypes. In the following we introduce the two prototypes with which we have worked the most.

Situational Overview from Live Video

The first was a horizontal prototype based on web cameras and other off-the-shelf software and hardware. It consists of a web camera on the incident site, e.g. on top of an ambulance, and a transmitter for streaming the video footage to the AMC and trauma-room wirelessly. The first generation prototype did not contribute very much to the vision around establishing a situational overview, because it was difficult for the AMC personnel to identify the objects in the video– the prototype did not have functionality to track specific objects such as victims or vehicles. However, as pointed out earlier, the prototype slightly changed the way AMC personnel got in contact with personnel at the incident site. First since the video footage also showed the doctors, they used it to help decide when a doctor at the incident site was likely to engage in communication. Second they used it to judge whether or not the doctor actually reacted when contacted. So instead of supporting the vision around providing situational overview, it established a redundant means for engaging in communication, which again increased the level of trustworthiness in communication because the doctors were able to see if a person reacted when contacted.

The second prototype is the *SiteTracker* prototype, developed as part of the On-Site sub project in PalCom [28]. It is designed to track objects of interest both in and outside its field of view. It is an assembly of three devices: a GPS, digital compass and a video camera. The GPS continuously provides location information, and the digital compass directional information of where the video camera is pointing. A special *SiteTracker* display service is then able to overlay the video footage with information that shows where the object of interest would be, which makes it easier to track objects such as victims, vehicles and fire fighters. The only requirement of an object of interest is that it has to be able to deliver a GPS coordinate to the *SiteTracker*.

Service Introspection and Inspection of Remote Services

The majority of the prototypes that we have developed are based on an extroverted programming style introduced in [27] where services automatically expose what they can do (e.g. provide ECG signal), what they are doing (e.g. transmitting a picture) and what they have been doing (e.g. history of message exchanges). Basing the prototypes on this programming style have allowed for inspection of services at a remote location. To illustrate: At a Future Lab, the doctor at the AMC was receiving pictures from the incident site. At one point the doctor was waiting for a picture that did not show up immediately. By use of a *service inspection tool,* one of the prototype developers at her side connected to the remote picture service and inspected its current state. From the service inspector, it could be seen that the picture service was actually in the process of transmitting the picture, however it took a long time because of heavy load on the wireless access point at the incident site. This is an example of resolving an unexpected incident without disturbing the rescue personnel on site. We foresee other situations where the extroverted nature of our software services allows for error recovery with minimal involvement from already overburdened rescue personnel.

FUTURE WORK

Work will continue on developing prototypes and mock-ups that explore the design visions described above, including their technical and organizational feasibility. In particular we will experiment with wireless biosensors for sound, multi-modal victim id's, tracking of victims, emergency response personnel and of essential resources. Biosensors for sound can give valuable information on the most critical parameters in evaluating a victim's condition, particularly airways and breathing. However, doctors are currently not familiar with evaluating sound without being next to a patient. It is thus an open questing how such possibility integrates into emergency response work. Currently we are combining unique ids with pictures of victims. One of our next steps will be to create tags with unique ids that combine different 'read modes' e.g. human readability at short distances, automated (camera-based) visual recognition and RFID. Furthermore we want to experiment with the use of descriptions of injuries and injury mechanisms as ways of referring to victims. Trustworthy tracking of victims, rescue workers and essential equipment will be of major interest and is being investigated in several projects. However, current solutions are either very imprecise or require some infrastructure to be in place prior to an incident, see e.g. [23]. We will experiment with combinations of different approaches including time delay and signal strength for radio signals, RFID, visual tracking and movement sensors.

Communication will continue to play an important part in our prototypes, and in particular we will experiment with adding possibility for different means of asynchronous message communication such as voice, text, pictures and other annotations. One of the open issues is if and when such messaging may help and when it will just lead to messages queuing up etc.

Finally we will continue our work on developing design methods, with a focus on simple, usable additions to the PD toolkit. Currently we expect to work with improving PD with respect to design of software architecture and with respect to the step from prototypes to products.

DISCUSSION

The work presented here is–to our knowledge–unique in its broad coverage of heterogeneous groups and situations and in its broad approach with open-ended exploration to understand the participants and develop design proposals for IT-support. Our work has demonstrated the usefulness of participatory design in several ways. We believe that our design proposals are at the front of pervasive computing research, cf. e.g. [12, 23] and at the same time they have been evaluated and developed further in several 'close-to-real-life' sessions. Such sessions play a crucial role in exploring the effects of new design suggestions when innovative technology is deployed and used. In comparison, Lorincz [23] focuses on technical feasibility rather than addressing the (human) problem of relating biosensor data to the person as the source of data.

When we began the work, we intended to use state-of-the-art PD, including fieldwork, scenarios, mock-up, prototypes and Future Laboratories with their 'close-to-real-life' exploration of new designs. However, as it turned out, the different kinds of reports from fieldwork, scenarios, mock-ups and prototypes did not function well as 'reminders' or 'guidelines' in our daily work. Thus the project group more or less spontaneously began to develop what we now call challenges, visions and design principles. These have functioned well in our work in the project group and at the same time have been useful tools for communicating to people outside the project group about the work.

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