IT support for healthcare professionals acting in major incidents

Margit Kristensen, Morten Kyng, Esben Toftdahl Nielsen

Department of Computer Science, University of Aarhus, Denmark

Abstract

This paper focuses on development of it support for healthcare professionals acting in major incidents. We introduce the participatory design approach as adequate for analysis, design and development of technologies for use in complex environments and situations, and describe the actual participatory design efforts. Then we present our analysis of the need for it-support in relation to major incidents. The analysis concentrates on four main problem areas. These are: a) Use of biomonitors, b) Person identification and registration of data, c) Communication and d) Overview. We then describe the BlueBio biomonitor prototype, a wireless multifunction biomonitor. BlueBio data can be accessed by the healthcare professionals independent of where they are located and displayed on different types of devices tailored to the needs of the individual professional. Finally we discuss some challenges regarding the prototype development process.

Keywords: *Information Management, Medical Informatics Applications, Biomedical Technology, Emergency Medicine, Medical Device Designs, Participatory Design.*

Introduction

The purpose of this paper is threefold: first to introduce an approach to developing it-support for professionals based on participatory design, second to present our analysis of the need for support in relation to major incidents, and finally to present and discuss some of our initial designs of it-support.
Emergency situations demand fast and effective collaboration between the personnel at an incident site, in the emergency vehicles, dispatch centers and hospitals. Collection of medical data and communicating it between these entities is crucial to provide a good basis for patient recovery but it is often extremely difficult.
In addition major incidents are characterized by having too few resources for the amount of work to be carried out.
The continually ongoing changes of where victims and professionals as well as vehicles are, makes it extremely difficult for anyone to obtain and maintain an overview of the situation.
Today ICT support for the healthcare professionals is rather limited – and most of it is quite old fashioned and not well functioning.
Efforts to implement new technologies have been made, but often the new systems fail in supporting the complex and unique work regarding rescuing efforts, resulting in returning to the old ways of doing things [1].
In order to ground our development of new software systems in the complex and dynamic environments constituted by for major incidents we decided to use Participatory Design as the overall method in the project.

Methods and setting

The participatory design process

We have carried out a number of field studies and experimental workshops with a group of professionals working with major incidents. The purpose of these activities has been to obtain a better common understanding among the involved researchers and professionals of major incidents, the different kinds of activities going on at an incident site, which kinds of inherent problems it contains and the needs and possibilities for improvements. On this basis we are experimenting with a series of prototypes, beginning with suggestions for how to turn specific design ideas into physical mock-ups and progressing to rather elaborate prototypes to be used in settings that are as realistic as possible. The concrete research activities are carried out as an iterative process covering field studies, meetings, discussions, prototype development and experimental workshops with all the involved professionals ([2], [3], [4], [5], [6]).

Below the Participatory Design activities are described in some detail.

Field studies

An important part of really grasping the actions and infrastructures in the complex and dynamic world of major incidents is to live in it and observe it. Understanding how the professionals work during major incidents simply cannot be obtained through theoretical studies, questionnaires, interviews etc. alone. However, for researchers to live in the world of major incidents, studying professionals in direct action is obviously very difficult – in fact close to impossible. Major incidents (fortunately) occur very seldom and only a limited number of professionals have concrete experience in acting in

such incidents. Instead they have to draw on their experiences from everyday incidents combined with what they have learned from courses and training sessions.
For that reason we have carried out a series of indirect observations/field studies.
We have:

- Followed the different professionals (doctors, paramedics, fire-fighters and police) in their daily work on minor incidents and other different types of duties.
- Followed doctors (anaesthesiologists) on their duty in-hospital in the emergency room, intensive care unit and operating theatre.
- Participated as observers in pre-hospital 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 involved professionals.

Through the field studies of work as close to major incidents as possible we have obtained a basic understanding of what happens and how the work is carried out during major incidents. These studies have given us and the involved professionals a good foundation for uncovering problems and developing it-support.

Physical and digital prototyping

To aid the participatory design process we have developed physical mock-ups and software prototypes. These have been used as important artefacts in experimental workshops. Mock-ups have played a role as common artefacts in discussions and during simulated work. It is much easier to discuss and develop ideas – or get new ideas – when holding a physical representation of something in your hand. The mock-ups/prototypes have supported the participatory design process by providing a common point of reference for all participants. They have allowed researchers to get initial first hand experience with how to design systems for the demanding field that major incidents represent, both regarding the physical setting and the supporting software systems. Finally they have allowed the professionals to get hands-on experience with emerging technologies.

The Major Incident site

This section gives a short description of the roles of the different professionals together with an overview of the infrastructure of a major incident site.
There are many different professional players involved in the pre hospital effort in relation to major incidents: The police, the ambulance staff (paramedics), the fire brigade and the healthcare professionals. This calls for collaboration - and collaboration is crucial for the outcome of the professional's efforts. Coordination of all these complex collaborative activities is of critical importance. Moreover every major incident is unique so the coordination of the activities cannot draw upon experiences from identical situations.
The different categories of professionals have specific roles and act/interact within these roles and collaborate across them. The scene is organised with different types of professional managers responsible for each part. The *police manager* is the overall responsible. He coordinates and is responsible for the overall rescue effort together with the *fire fighting manager*, the *ambulance manager* and the *medical coordinator*. In practice the *fire-fighting manager* is responsible for the inner area – for getting people out of the risk area (e.g. from the crashed bus or train). The *police manager* is responsible for the outer area, including gathering and registration of not injured persons. The *medical coordinator* is responsible for the treatment of the injured persons in the waiting- and treatment area and for the transportations to the hospitals, together with the *ambulance manager*.
In major incidents victims are categorized and divided into groups according to the severity of their injuries (called triage) and later treated according to their category. The status of victims is likely to change and therefore paramedics monitor the status of individual victims in the waiting area. Unique accident cards, used to describe injuries and first aid efforts, are attached to victims to give hospital personnel an account of the victim. Victims should be registered. However, in the heat of the moment this is often assigned a lower priority and victims may arrive in the hospital without sufficient information concerning their identity and injuries.
Below we first describe the problematic areas identified through our analysis of the need for support in relation to major incidents, then we briefly list some design principles and finally we present and discuss our initial designs for it-support.

Identified problem areas

Through the fieldstudies, workshops and meetings with the different professionals we have identified the following four areas related with major incidents as very problematic:

- Use of biomonitors
- Person identification and registration of data
- Communication
- Overview

Below is a further description of the four problem areas.

Biomonitors

Today most medical equipment in an emergency situation is wired. The most commonly measured biomedical data today is ECG and oxygen saturation. The pre-hospital doctor and the paramedics evaluate these signals to reason about the condition of patients. They also look at the patient to observe color and respiration and other signs to form an overall picture of a patients' condition.
The use of biomonitors is severely hampered by the fact that data can only be seen if you are next to the display, which again has to be next to the patient – it is in this sense as immobile as the patient.

In major incidents biomonitors are hardly used – there is simply not enough biomedical equipment and most medical equipment is as indicated above is not very portable. Furthermore there is a limited amount of time to place the biomonitors on injured people. Lastly we have observed that even with limited use of biomonitors there is not enough professionals at the accident site to keep an eye on all the collected biomedical data – because the displays are only available right beside the injured people.

Person identification and registration of data

In major incidents an *accident card* should be filled out for each person. The card contains a predefined unique person identification number that is supposed to follow the person all the way from the place of the accident to the hospital. This is only possible if it is tied to the patient or the patient can hold it in his/her hand. In the major incidents we have talked through with involved professionals the accident cards were not used – there was no time to fill them out.
The only registration that went on was a registration of where which injured person was brought - and an injured person was not given a unique id – but was described e.g. like: "Woman, around 40 years, blonde short hair, injured in chest". During triage (sorting of injured persons into four groups) each injured person should be marked with a colored and numbered card, indicating to which triage category he/she belongs. The triage card should be attached to the patient. Examples from real life major incidents shows that the triage is done, but the injured persons are not explicitly marked with triage cards – the triage is verbally communicated or communicated by action.

Communication

Talking is carried out through radios or directly person(s) to person(s). 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 these do not work effectively. Thus the managers of each group usually have to find each other physically and try to stay together to communicate and coordinate. The radio network coverage is not good. This often makes radio communication between professionals at the accident site and other locations (hospital or police station) very difficult or impossible. Mobile phones are then used, but in incident situations the mobile phone nets usually become overloaded and then breakdown and cannot be used.
Communication of data is paper based (if noted at all), or verbally handed over from person to person or a group of persons.

Overview

It is very difficult to get and maintain an overview of the scene of the incident; the incident as such, injured and not injured persons, and available human and other resources. The involved professionals try to get such an overview, but there is very little support for this and today most of the overview is in the heads of the involved managers and maintained through their ongoing activity.

Designs

In this section we first list some design principles that have emerged during our analysis of the current situation and then we present and discuss our initial designs for it-support.

Design principles

IT support for major incidents should use familiar technologies

A recurring problem in the use of existing ICT support for major incidents is that the healthcare professionals are not used to work with it. They have been trained in its use at special courses but in the stressed and hectic unfolding of a major incident they usually fail to use it efficiently and stop using it – or don't begin to use it at all. To address this problem we have decided that the support we develop should not only be useful in major incidents – it should also help in smaller incidents – those which happen many times a day and are "everyday stuff" for the professionals involved. Through use of the technology in 'everyday' incidents the professionals build up the necessary routine that makes the differences also in major incident situations.

Redundancy

Technology will never function perfectly all of the time and when it fails it is important that alternative support exists at the incident site. Thus in the BlueBio system described below access to biomonitors is usually achieved through a basestation. However, if the basestation malfunctions it is possible to access biomonitor data directly with other Bluetooth enabled devices such as mobile phones and pda's. In the event of a communication failure local storage of data is supported.

Design ideas

Through the fieldwork and workshops a range of ideas for supporting professionals during major incidents have emerged:

- Use of ***wireless biomonitors*** *and* ***remote acess displays*** for viewing data
  – to be able to access information without being close to the monitored person, to make it easier to move the patient and easier to do different examinations.
- Building in possibility of ***showing triage category and change of category*** in multi biomonitor device (numbers, lights, sounds)
  – to help keep an overview of the situation and support the medical coordinator in deciding when to do what with the different patients.
- Use of ***different displays*** for showing data

– to provide support for different use situations (small handheld, stretcher, ambulance, hospital).

- ***Coupling*** of accident card information and multi biomonitor device.
  – to support registration and use of data registered from biomonitors and data registered manually.
- ***Person and resource location***
  – to be able to obtain and maintain overview of who and what is where (awareness) – both injured people, professionals and equipment.
- Create ***overview*** of the accident place, supplemented with information about e.g. risks, resources and injured persons – specific to each person's needs
  – to support the different professionals in their work.
- Support ***communication of different kinds of data*** (biosignals, text, pictures, videoclips) across professional functions and physical distances.
  – to provide for support from professional helpers, continuity and cooperation.
- Integration with electronic health records (EHR's).
  – to provide for having access to necessary information already in the EHR and to support continuity in the treatment process.

In the following we will focus on description of the designs that we have explored the most, which are those related to the collection and use of biomedical data from patients during a major incident.

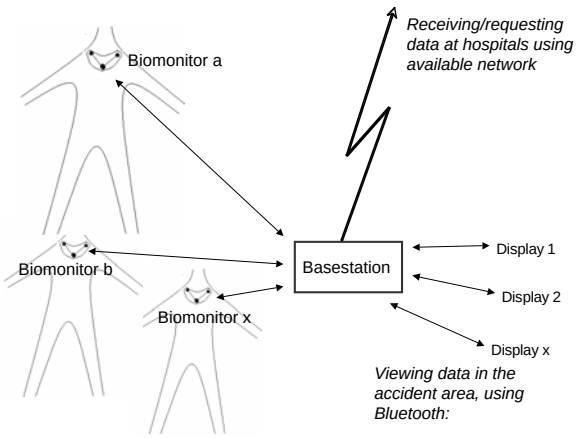

Figure 1: The BlueBio biomonitor system

The BlueBio biomonitor system

As mentioned above the field studies have shown that very few patient data are actually collected during major incidents even though such data could prove very beneficial for patient recovery. For this reason we – the researchers together with the professionals – decided to explore the characteristics of a biomonitor system to be used in major incidents.
The system – called BlueBio – monitors biomedical signals from patients by use of wireless biomonitors (See Figure 1). A BlueBio biomonitor is a small device that consists of 1-12 sensors (for measuring data such as ECG, pulse, and oxygen saturation) and a module for short-range wireless transmission of data (up to 100 meters). Right now we are working on software and physical design of a monitor that can measure ECG and respiration sound and -frequency. The placement of a BlueBio monitor on a patient is easy. It just amounts to removing a piece of tape from the monitor and then placing it on the patient. In the case that a doctor wants to get ECG data from a patient he places a monitor on the thorax, then the monitor automatically joins the BlueBio network, which makes it visible to other devices in the network and data from the monitor can then be collected and displayed from any device in the vicinity.

One or more basestations (See Figure 1) are deployed at the incident site to support doctors in accessing data from biomonitors and in communicating the patient data to non-local rescue units such as nearby hospitals or ambulances. The basestation

- enables short-range communication with nearby biomonitors – currently using Bluetooth,
- enables long-range communication of patient data. – currently using WIFI and GPRS which is needed to transmit data to for example EHR's at the hospital.
- keeps a temporary storage of patient data when no long-range connection exists or if it fails.
- provides a more efficient network infrastructure at the incident site.

The basestation is small and lightweight and can either be placed in ambulances or in other paramedic equipment at the site. If a basestation is within range a biomonitor will automatically connect to it. On the other hand if no basestation exists or it fails then it is possible to communicate directly with a biomonitor from e.g. a mobile phone or a pda.

We conclude this presentation of the BlueBio system with two examples that illustrate its potentials in major incidents.
Example 1: The medical coordinator is the link between the treating doctors on the incident site and the ambulances. Hence it is important that she can obtain an overview of the condition of *all* the injured people. She may do this by viewing summary information from all the deployed biomonitors. An overview of data from all injured people help the coordinating doctor in deciding e.g. which patient should leave in the next ambulance.
Example 2: Seen from the point of view of a treating doctor it is important that he can monitor the condition of the changing set of the few injured people that he is responsible for.

The crucial thing to notice is that context changes rapidly during major incidents – one moment a doctor might require all the data from a specific patients biomonitor whereas the next moment (when the patient is put in an ambulance) he only wants to be notified when a biomonitor registers critical peaks in the patients' condition – and only until a doctor at the hospital takes over the responsibility.

Discussion

A number of characteristics have emerged from evaluating the use of the system in simulated major incidents. These are described below:

- It is crucial that the wireless connection between a display and a biomonitor is unambiguous defined – the doctor has to know for sure to what patient the data he looks at belongs. So working on use of wireless biomonitors has to be coupled with developing solutions regarding unique and visible person identification.
- The system should support 'maintaining an optimal situation through limited changes'. It could be that moving a patient from the stretcher in the waiting area to the ambulance stretcher and further into the ambulance automatically changed the default display of his biomonitor first to a display on the ambulance stretcher and then to a larger display in the ambulance itself.
- When the technology fails it should be very easy to recognize the failure. The user should be able to see what works and what doesn't work, and to exchange the units that do not work with units that do.
- Finally the system should help the user distinguish between failures belonging to the system and severe changes in a patient's conditions – if a biomonitor indicates that a patient is in a serious condition it should not turn out to be a biomonitor malfunction

Future Work

During the next phase of the project we will go on with further development of different prototypes. These will be tested and evaluated in iterative processes through experiments, where the prototypes will be used in more realistic settings – exercises in pre-hospital effort are on of the places we will use.

Acknowledgments

The work presented in this paper is part of the PalCom project [7]. We would like to thank all the professionals involved in pre hospital effort in Aarhus and our colleagues in the PalCom project for their enthusiastic cooperation. Also we would like to thank the three engineers, Slawomir Kucharski, Lukasz Kubala and Marcin Byczuk, that have been developing the BlueBio system.
The research presented in this paper has been partly funded by 6th Framework Programme, Information Society Technologies, Disappearing Computer II, project 002057 'Palcom: Palpable Computing – A new perspective on Ambient Computing (http://www.ist-palcom.org).

References

[1] Stephen Flowers. Software failure: management failure – amazing stories and cautionary tales. John Wiley & Sons Ltd., London, 1996

[2] Joan Greenbaum, Morten Kyng. Situated Design. In J. Greenbaum & M. Kyng (Eds.), Design at Work: Cooperative Design of Computer Systems. Lawrence Erlbaum, Hillsdale, New Jersey, pp 1-24, 1991,

[3] Susanne Bødker, Kaj Grønbæk, Morten Kyng. Cooperative Design: Techniques and experiences from the Scandinavian Scene. In A. Namioka & D. Schuler (Eds.), Participatory Design. Hillsdale, NJ: Lawrence Erlbaum Associates, pp. 157-175, 1993

[4] Morten Kyng.Scandinavian Design: Users in Product Development, In proceedings of CHI '94, Boston, ACM, pp. 3-9, 1994.

[5] Monika Büscher. Vision in motion, accepted for publication in: Environment and Planning A, 2005.

[6] Jakob Eyvind Bardram, Henrik Bærbak Christensen and Klaus Marius Hansen. Architectural Prototyping: An Approach for Grounding Architectural Design and Learning. Proceedings of 4th working conference on Software Architecture June 12 - 15, Oslo, Norway, 2004.

[7] www.ist-palcom.org

Address for correspondence

Margit Kristensen, Department of Computer Science, University of Aarhus, Aabogade 34, DK-8200 Aarhus N, Denmark. Phone: +45 8942 9303. Mobile phone: +45 2338 2281. E-mail: margit@daimi.au.dk