Care & Prepare – Usability Engineering for Mass Casualty Incidents

Martin Christof Kindsmüller,
Tilo Mentler, Michael Herczeg
Institute for Multimedia and Interactive Systems
University of Lübeck
Ratzeburger Allee 160,
D-23562 Lübeck, Germany
{mck|mentler|herczeg}@imis.uni-luebeck.de

Timo Rumland
DIGITALYS GmbH
Barkenboomsweg 1
D-27619 Schiffdorf, Germany
timo.rumland@digitalys.de

ABSTRACT
Best possible pre-hospital treatment in the event of a mass casualty incident (MCI) is related to prioritizing rescue tasks and using rescue resources efficiently. Currently, information is almost always documented on paper-based forms and communicated by one-to-one talks, messengers, radio and mobile phone. Pervasive computer-based solutions are not established yet. Although the mere technological challenges are on the way of being solved within the near future, questions of usability remain. Concerning this matter, we propose an entangled User Centered System Design (UCSD) and Feature Driven Development (FDD) process and introduce the principle Care & Prepare. It is based on two fundamental assumptions. First, the whole design process has to care for the rescue personnel's' needs in these challenging situations and second, the rescue personnel has to be prepared for using these specialized computer applications in case of an MCI. Therefore, daily routine has to be the training foundation for these extraordinary operations.

Keywords
Mass Casualty Incident, Usability Engineering, User-Centered Design, Feature Driven Development

INTRODUCTION
Without regard to differences in national regulations and exact wordings, a mass casualty incident (MCI) can be defined as "an event, which generates more patients at one time than locally available resources can manage using routine procedures. It therefore requires exceptional emergency arrangements and additional or extraordinary assistance [30]. Due to the disproportions between casualties, rescue workers and material resources, dedicated tactics are necessary. Managerial structures and forms of organization must be adapted as circumstances demand [23]. Therefore, an MCI is very different from the sum of many individual emergencies. In order to ensure optimal pre-hospital medical treatment, patients and the severity of their injuries have to be the basis for all interaction.

Today paper-based forms, tables, patient records and plastic tags are used to gather and document required information (Figure 1). Depending on the specific system identification numbers or barcodes are used. These are supposed to ensure assignments of various documents to a single person. Communication, coordination and cooperation needs are met by a complex mix of face-to-face communication, radio calls, mobile phone talks and messengers.

Figure 1: Current documentation and information tools

Pervasive computer-based tools and systems are not established even in otherwise highly developed countries. Rather, most emergency medical services (EMS) still rely on paper to carry out daily job routine. Mobile solutions are introduced gradually. As an informal survey on the leading European professional fairs "RETTmobil 2010" and "Interschutz 2010" revealed, most stakeholders believe that it will take at least some months, if not years until a paperless workflow from patient to accounting is the rule rather than the exception.

A computer-based solution replacing and possibly extending the current paper-based systems has to be designed in due consideration of the following aspects:

- Its advantages will only be effective, if data can be entered and accessed efficiently and securely.

- Time consuming adaption and learning phases are not acceptable during an MCI. Any delay has to be avoided. The ability to use the system instantly in an effective and efficient way is of utmost importance.
- MCIs are rare events for a single EMS [1].

Disregarding these points can and most likely will result in faults and inefficiencies, which not only endanger general usability but can – in this field of application – as well cause a threat to the life or the physical conditions for the patients involved.

We pursue four objectives within this contribution. First we describe the state of the art of how EMSs are currently handling MCIs using classical means. Then we sketch how – mainly research projects – use advanced technology in order to improve the handling of MCIs. Third we present our approach Care & Prepare, where the focus is shifted from what can be done with modern technology to how technology can be applied to support the users in order to perform their demanding tasks. Finally we draft our specific development process that we use to ensure that our system will meet the demands of the users.

BACKGROUND AND RELATED WORK

Although first publications (e.g. [27]) pointed out advantages of computer-based solutions as opposed to paper-based ones almost 20 years ago, MCIs have not been high on the agenda of research and development departments. This changed rapidly after the terrorist attacks on September 11th 2001. As a consequence of these incidents and in preparation for upcoming major events, (e.g. the Soccer World Championship in Germany 2006) numerous research projects have been launched. Due to the various challenges associated with MCIs, they differ in scope and scale.

With a specific view to usability, two basic approaches can be distinguished:

- providing support of subtasks,
- providing pervasive solutions.

Supporting Subtasks

In the event of an MCI, paramedics and emergency physicians are confronted with several activities, which are not part of daily job routine. The 5-T-rule outlines the main task areas as follows [6]:

- tactics,
- triage,
- treatment,
- take care,
- transport.

Triage, as the process of determining a patient's priority of treatment based on objective criteria, is of particular importance. It can be called the single most import task except for basic life support [23]. It implies an order which is geared to saving as many lives as possible and utilizing resources efficiently.

Triage algorithms have been developed to ease the assessment of patients. Most of them (e.g. SALT, START, and CareFlight) are based on vital signs (e.g. respiratory rate) that can be determined without special utilities [10], [14]. In the end, patients are typically classified into one out of four or five categories.

Tactics, treatment and transport are often interrelated aspects of more extensive approaches. For that reason, our literature reviews showed no usability-related work which addresses one of these topics separately.

Taking care of people who are not seriously physically injured but affected by the incident is in the realm of interpersonal relationship. In order to handle, for example, missing person reports or contact witnesses later on, those persons have to be registered in the system as well.

Contrary to tactics, treatment, taking care and transport, triage has been addressed as a singular subtask by different projects and researchers. Jokela et al. presented an application system to simplify the process based on commercial mobile networks and regular mobile phones with integrated RFID technology [9]. Usability aspects had a lower priority. Inoue, Sonoda and Yasuura prototypically realized a triage system with RFID tags [8]. They measured times for input operations according to single text fields (e.g. name, sex and age) and compared performances with and without the application system. The TUMult-project concentrates on developing user interfaces for mobile devices to support rescue workers in performing triage [19]. They designed several concepts for keyboard and multi-tap input and proposed adaptive user interfaces [18], [20].

In addition, essential usability issues, e.g. combining electronic and paper-based approaches, related to MCIs were and are considered [17]. One of their findings is that "the introduction of RFID technology in MCIs leads to more challenges as […] expected" [16].

Addressing System Solutions

Besides designing and implementing extensive application systems, projects like WISTA, WIISARD, AID-N, SpeedUpor ALARM challenge several technical and organizational questions with reference to MCIs, e.g. how to deal with stampedes or how to define common quality standards and indexes [26], [29]. They are primarily focused on MCIs and widely disregard daily job routine of emergency medical services.

Chu and Ganz designed and prototypically implemented WISTA, a wireless telemedicine system for disaster patient care [3]. Instead of deploying proprietary hardware, they used off-the-shelf PDAs and based their two-layered system architecture on Bluetooth and 802.11g wireless connections. Main aim of the project was to demonstrate a budget-friendly solution in a testbed. In addition, simulation results proved the scalability of the system. Usability aspects had a lower priority.

The WIISARD project (2004-2008) addressed the issue whether medical care could be improved by means of wireless network technologies in the event of an MCI. Designed for the American Incident Command System (ICS) which differentiates three types of first responders, the final system consists of several hardware and software components [12]. Frontline workers who are responsible for triage und treatment on site are equipped with the WIISARD First Responder (WFR), a PDA with wireless network adapter and barcode scanner [11]. Mid-tier supervisors and teamleaders exchange clipboards and forms with tablet PCs [2]. The Command Center System, which is used by third-level first responders, is not explicitly connected to a certain type of hardware but features like maps or diagrams require a lager screen size than PDAs provide [4]. Furthermore, Intelligent Triage Tags (ITT) and different vital sensors are used to document and monitor patients' conditions [13].

Figure 2: WIISARD equipment [www.wiisard.org]

All components are interconnected by a mobile ad-hoc network. Special-purpose computers, so-called CalMesh nodes, provide a self-scaling network infrastructure and act as both wireless routers and access points [12]. Figure 2 gives an overview of the WIISARD hardware components.

WIISARD followed a classic participatory development process, which integrated first responders into the design teams. In addition, designers attended first responder exercises. Iterative refinements, based on experiences of five simulated MCIs, and a final evaluation study were accomplished.

The WIISARD system was evaluated according to the following key measures:

- decision and information quality,
- speed of patient processing,
- system scalability.

The results revealed potential advantages of a computer-supported mass casualty management system in comparison to paper-based solutions [12]. WIISARD was renamed to WIISARD-SAGE and is under ongoing development.

The Advanced Health and Disaster Aid Network (AID N) was following the same goals as WIISARD. Requirement analysis, technology development and evaluation framed the three main phases of this project. Development was organized as a "cyclical build-demonstrate-rebuild process" [28]. The overall system was tested in a simulated mass casualty event and evaluated with the aid of a questionnaire. The results indicate that EMS personnel, hospital administrators and other public health staff could improve their understanding of processes and conditions. Nevertheless, one main finding was that "technologies must be used every day, if they are to be successfully used in a critical situation" [28]. Furthermore, the principle of familiarity is introduced as follows: "Match the system with current practice: Integrate systems to in non-disruptive ways to promote use during routine ambulance runs" [5]. These statements indicate that the training for rare and extraordinary incidents has to be integrated in day-to-day operations.

THE CARE & PREPARE APPROACH

Designing and deploying a Mobile Data Gathering System (MDGS) for handling MCIs is a challenge for many reasons. The whole process from analyzing the working context and the needs of the users to premature test runs and field tests are ethically as well as legally very difficult.

Experiments under controlled laboratory conditions on the other hand have to be questioned as well because it is very hard to simulate the extraordinary circumstances of an MCI in all its facets. To meet these challenges we propose a new approach named "Care & Prepare" as a principle for designing and deploying support systems for handling MCIs.

A Definition of Care & Prepare

The two pillar structure of our approach is based on two basic principles:

- Care: An application for managing MCIs and its user interface in particular have to be designed in consideration of users' context (physical, mental, temporal). A system has to be tailored to meet the constraints of the human cognitive-perceptive system in these particular situational conditions.
- Prepare: The cornerstone of handling an MCI successfully is to be prepared. Highly trained routine behavior is formed in day-to-day practice of paramedics and emergency physicians. A system for handling MCIs therefore has to be a "natural" extension of MDGS for regular rescue und transport missions.

This principle is in line with Quarantelli's remark that the difference between an MCI and daily job routine "is one of kind rather than degree" [24]. While this is obviously true for medical treatment strategies and other aforementioned aspects, this statement is no indication for strictly divided application systems. Rather, this principle takes into account that MCIs are rare events in terms of a specific EMS and is based on the assessment that routine can only be derived from intense and regular application [7].

Guiding Principles: The Users Specific Situation

Drilling down the extraordinary circumstances of an MCI leads to a set of statements describing the users' (rescue personnel) situation:

- users have no or very limited experience in handling MCIs;
- users are under very high physical and mental load;
- users have to accomplish a large number of unusual tasks in parallel and under high time pressure;
- users have to act under, most likely, unique circumstances.

To keep these points in the focus of our process of designing and deploying, it is not sufficient to simply follow standardized system and user interface design principles as for example using the newest standard user interface style guide for the intended platform. Our review of related work (see above) shows clearly that the development of adequate and robust technology does not necessarily lead to a system that is usable in case of an MCI. However, some of the design flaws of existing systems could have already been overcome by applying standard usability engineering approaches.

To design an application system that is usable in case of an MCI, we propose an entangled approach of User-Centered System Design (UCSD) and Feature Driven Development (FDD) that is based on the Care & Prepare principle [21], [22].

To prepare users to be able to handle a system in case of an MCI, we propose that the MDGS provides training for MCIs within the regular day-to-day business. This should be accomplished by using similar support systems for handling MCIs and regular rescue and transport missions. Speaking in terms of software engineering, support for an MCI should be provided by an additional module of the same MDGS framework that is used for handling the regular day-to-day business.

As a result of different documentation and information requirements and also because of the extraordinary workload and time pressure, input masks and dialogs cannot be the same for handling MCIs and regular missions. Nevertheless, a consistent user interface can support action planning and execution. In terms of Norman's model, a familiar user interface shall minimize the gulf of execution [21]. Well-known feedback mechanisms, error messages and colors have a favorable effect on the gulf of evaluation. This will help to stabilize and deepen the users' mental models of the application system. This in turn is supposed to lead to more efficient and more effective usage patterns even in demanding situations.

Project and Development Process

As already mentioned, we follow an entangled approach that combines UCSD and FDD to keep the project and development process focused (Figure 3).

Classic elements of UCSD (e.g. user studies, interviews) will be complemented by:

- observing MCI exercises;
- accompanying paramedics and emergency physicians while they are using the MDGS in regular missions;
- evaluating the usability of the MDGS in regular missions;
- attending emergency medical aid and MCI-related workshops.

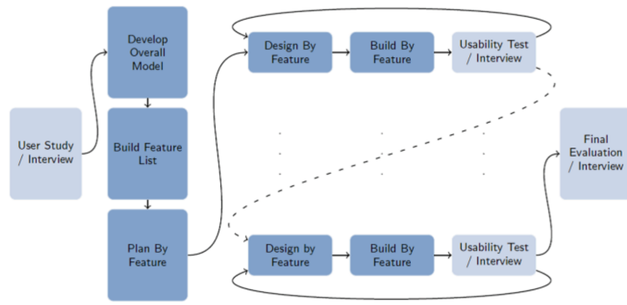

Figure 3: Process model combining FDD (dark blue) and UCSD (light blue) [25]

Combining these and scientific information, features can be derived. Natural dependencies between these "small, client-valued function[s]" [22] and a prioritization process will lead to a sorted list of feature sets. To work through the list, we use the iterative and incremental process of FDD. By using an entangled FDD/UCSD process as our software engineering paradigm, we are able to quickly roll out feature-sets, as well as keeping them close to the users' needs and expectations through repeated user-feedback.

In connection with our Care & Prepare principle, this approach allows usability tests for single features which may even be integrated in the MDGS for regular missions. Those are much less time and safety critical. Therefore, design flaws could be revealed without threatening patients. Finally, the overall system will be evaluated according to standard UCSD standards.

To summarize: the Care & Prepare principle is incorporated in our FDD/UCSD process in various ways. UCSD activities based on small feature sets that are iteratively rolled out assure that the users' needs are early and repeatedly taken into account (Care). Being able to roll out feature sets as a module of a general MDGS framework allows to test and even train them in the regular day-to-day business – even before the whole MDGS to handle MCIs is completely developed (Prepare).

General Principles for MDGSs

Figure 4 gives an overview of our proposed MDGS. The overall design is based on the assumption that an MDGS that follows the C&P principle has to be technically feasible and suitable for handling day-to-day rescue and transport missions as well as MCIs.

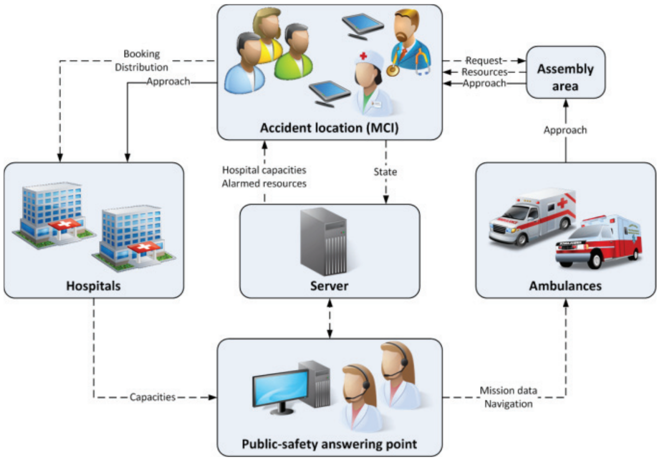

Figure 4: Handling of MCIs as an integrated part of general MDGS

The basic features as shown in the figure are:

- All rescue workers (paramedics, emergency physicians, team leader, and incident commander) are using the same handheld device, most likely a rugged tablet PC.
- All stakeholders (public-safety answering point, crisis squad, hospital staff, and rescue teams) are kept in the loop. They are aware of all necessary information. The users are guided by dialogues that are simple enough to be still useful even in very demanding situations.
- The location of every patient and rescue worker is made available by location-based services for the stakeholders in command.
- Ambulance crews are informed on their way to the area of operation as well as while waiting at the ambulance assembly area. Supplying this information to the rescue workers can help to cope with anxieties and help to prepare them for the situations they will be confronted with [15].
- All relevant information is stored on central servers for ad-hoc as well as post-hoc analyses. This information can be very useful to implement organizational learning and gradually improving the whole man-machine-system over time.

At the moment our project is still in a first prototypical state. The goal is to integrate the system as a module into the R2-System, an end-to-end solution for regular transport and rescue missions, of the DIGITALYS GmbH. The most important single maxim in order to successfully deploy a system, which is functional, usable and acceptable, is to involve the users early, repeatedly and consistently during the development process. We achieve this by following an entangled approach that combines UCSD and FDD and involves the users, as well as (at least) computer scientists, psychologists and designers.

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