Tactical Information Visualization for Operation Managers in Mass Casualty Incidents

Mathias Wilhelm, Eva Burneleit, Sahin Albayrak

DAI-Labor/TU-Berlin, Ernst-Reuter-Platz 7, 10587 Berlin, Germany
{firstname.lastname}@dai-labor.de

Abstract. In mass casualty incidents, operation managers have to make decisions under highly stressful conditions. At present, the tactical information is mostly written down on paper-based worksheets, which are inconvenient to use. As a result, the operation managers tend to avoid the paper sheets and try to remember information which is error-prone. To overcome this issue, this paper presents an IT-supported tactical worksheet for touch devices. It describes a user-centered approach that gathers the requirements on the proposed worksheet from a comprehensive long term expert panel with three senior fire brigade officers, two of their assistants, three researchers, and one designer. To validate the specified requirements, a first prototype was implemented and pre-evaluated in a real mass casualty incident simulation with 20 casualties. The evaluation revealed further design and implementation aspects to be considered in future work.

Keywords: tactical worksheet, tactical decision making, tactical information visualization, mass casualty incidents

1 Introduction

In a mass casualty incident (MCI), operation managers are confronted with a great amount of information, which they have to process in order to make tactical decisions. Despite modern technologies, the information is still gathered by the on-site staff and communicated via radio, and by paper. In order to store and to structure all information, a so called tactical worksheet (TWS) is used. Interviews with senior fire brigade officers performed in context of this paper revealed that paper-based TWSs are stationary and inflexible due to their size (DIN/ISO A3 and larger). Additionally, more than one sheet is necessary because the operational information is dynamic and changes during the operation. Consequently, the information of the current worksheet has to be transferred to an additional one or, alternatively, it must be switched between the current TWS and the previous ones. Due to this overhead and discomfort, operation managers tend to avoid paper-based TWSs and manage all information in their mind. Interviewed senior fire brigade officers stated that because of the high stress, huge amount of information and long operational duration, they can lose control of the information management or even forget important information. In extreme case, this issue can cost life.

Addressing these issues, this paper proposes an electronic version of a TWS which is gathering and managing operational information in real time to support the operation manager in his decision making. The TWS was developed within the ALARM[1] project [7] aiming to develop modular IT-solutions which support emergency medical service providers and rescue staff in mass casualty incident response and training. In fact, the ALARM solution contains a ubiquitous computing infrastructure providing, for example, RFID tags in order to record information of casualties, handheld devices for the rescue stuff, cameras, mobile tablet computers and a robust AD-HOC network supporting seamless WLAN, GPRS, and satellite communication. This infrastructure allows a broad collection of operation information seeming appropriate for the proposed TWS.

In the following section, the paper gives an overview of the state of the art in which this work is motivated. In section 3, it describes the user-centered design process and the requirements gathered from the expert panels and interviews with senior officers and their assistants of the Berlin fire brigade. Based on the collected requirements, the TWS solution is described in section 4, which is presenting software development aspects in general as well as the user interface and the interaction design aspects. In section 5, the implementation of a first prototype and in section 6, its pre-evaluation is briefly described. The paper ends with a conclusion in section 7, in which the approach is discussed and an outlook presenting planned future work.

2 Related Work

To overcome the disadvantages of paper-based worksheets and to give operation managers support in an MCI, there exist different approaches. In the following, selected approaches will be presented and briefly discussed.

In [2], a multi-touch table solution supporting natural and intuitive interaction for the command and staff position is presented. This solution gives an overview about the current situation by visualizing the number and the location of casualties as well as of available rescue resources on a map. It is designed primarily for the leading medical doctor and it supports no input in order to send orders to the rescue resources.

A generalized support system for rescue staff is presented in [3]. The advantage of this system is that it can be connected with nearly any existing database, because it applies a semantic description for the data input. The focus of this project is more on generalized information and data visualization and less on supporting communication, e.g. for giving commissions to the rescue resources. A triage system providing information of the casualties for large displays and handheld devices is presented in [8, 1].

A design methodology for interactive emergency management systems is presented in [5]. This methodology is applied on a task management system including a backend, decision and planning support, and a user interface for mobile devices. In [6], a design guideline for mobile checklist applications as well as a prototype imple-

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1 ALARM: Adaptive Lösungsplattform zur Aktiven technischen Unterstützung beim Retten von Menschenleben (in English: Adaptive solution platform to the active technical support in saving life)

mentation is presented. The guideline is focused on the different organization (e.g. police or fire brigade) involved in MCIs. It provides different features such as execution monitoring and logging.

All presented approaches support the decision process of the operation manager, but none of them accompanies the operation manager from the beginning to the end of the operation. Further, no approach discovers the whole spectrum of an operation. This is the starting point of the research of this paper.

3 Methodology

In order to develop a TWS tailor-made meeting the requirements of an operation manager, a user-centered design approach was applied. This approach is oriented mainly on the software requirement analysis and design process proposed in [4]. It consists of four stages (noted below) and was performed with three senior fire brigade officers and two of their assistants representing the stakeholders. The whole design process was guided and performed by two researchers and one designer from the institute of the authors. In the following, the different stages are listed in detail:

1. **Requirement Process**: At first, the relevant roles including their connection and the workflow of an MCI were determined by open interviews. The interviews were performed separately with each of the stakeholders and followed a formless structure. The stakeholders were asked to explain the whole workflow of an MCI. In this process, the interviewer made notes and asked questions in between. All determined roles were covered by the stakeholders.
2. **Requirement Elicitation**: This elicitation of the requirements of the stakeholders consisted of a combination of an open interview and scenarios. These scenarios were oriented on the gathered workflow in stage one. In this process, each stakeholder simulated a complete MCI workflow based on different paper-based TWSs investigated from different free available internet sources[2].
3. **Requirement Analysis**: Based on the information gathered in stage two, the relevant requirements were identified, structured and documented. Afterwards, a wireframe study was performed and discussed with the stakeholders in order to create the interaction concept and to model the cooperative workflow. Finally, mockups serving as design templates for the prototype implementation were created and discussed.
4. **Requirement Validation**: In order to validate whether the conceptual design meets the requirements of the stakeholders, a first prototype was implemented and evaluated in a small real simulated MCI with 20 casualties. During the whole simu-

[2] Tactical worksheet examples which were applied for the scenario with the stakeholders:
http://www.idf.nrw.de/service/downloads/downloads_hilfsmittel.php (accessed on 2012/08/22)
http://www.orgl-pm.de/Taktisches_Arbeitsblatt_MANV_PM.pdf (accessed on 2012/08/22)
http://snuconline.com/SNUC_Online.com/Tactical_Worksheets (accessed on 2012/08/22)
http://www.srpmic-nsn.gov/government/fire/sog.asp (accessed on 2012/08/22)

lation, the stakeholders working with a TWS prototype were observed and, afterwards, interviewed regarding the usage of the TWS. The gathered information was used to step back to stage three in order to perform the requirement analysis again based on this new information.

The information gathering process and the requirement analysis proved to be very time consuming. The following statement of a fire brigade officer highlights the difficulty of the requirement analysis: “99% of the decisions are decisions from the gut and only 1% is based on tactical information.” This means, that only few decisions are based on tactical information such as weather forecast, geographical peculiarities, or casualties and resources statistics, but these decisions can cost life. The main challenge was to identify exactly these requirements for the TWS in order to provide the right information at the right time.

4 Requirements

In the following, the identified requirements are listed and discussed:

Domain knowledge:

- *Up-to-date overview of all casualties*: Based on the casualty statistic, the operation managers plan the operation and manage the rescue resources.
- *Up-to-date overview of available resources*: Operation managers must be aware of the available resources at the operation. In particular, they must ensure that enough resources are available to transport the casualties to hospitals. Another aspect at a long-term MCI is that the operation managers are responsible for the crew. Therefore, they need to know the total number of resource staff involved in the MCI. These aspects imply that it must be recognizable which resources are still approaching and which already arrived at the operation location (and where they are).
- *Map*: Based on a map, operation manager can plan the operational structure, e.g. where the treatment area should be created.
- *Operational areas*: It should be possible to create the operational structure with the TWS. Further, it should be possible to assign a leader and resources to operational areas as well as to provide the visualization of their position and area on the map.
- *Dangers*: The dangers should be illustrated on the map including detailed information about the dangers.
- *Weather forecast*: Based on the weather forecast, operation managers plan the operational structure. For instance in case of a fire, they must mind the forecast wind direction in order to know the direction of the smoke.

Needs:

- *Tasks and Requests*: In order to keep the operation manager aware of the given tasks and received requests from the subunits, the whole task and request handling should be covered by the TWS and it should keep track of the task status.
- *To make notes and sketches*: One expressed request was the possibility of making notes via voice, stylus input or picture snapshots in order to document the opera-

tion, to send the rescue coordination center additional information/impressions of the operation, or to add some important notes.

- *Remember/alarm functionality*: Caused by the high impact of stress, operation managers tend to forget the time. This issue can lead to forgetting periodic occurring tasks (such as giving a situation report to the rescue coordination center) or frequent checks of the state of given assignments/requests.
- *Documentation*: At present, no reversion-save documentation system has been found recording the decisions of the operation manager and the overall operation progress. Such documentation is very useful for the review and the post-analysis of the operation as well as for the training of rescue staff. Furthermore, it could be useful for the operation manager to clarify the operational decisions in case of any legal actions.
- *Checklists*: The importance of checklists was noted in nearly all interviews within the first and the second stage of the design process. A checklist should contain frequently occurring tasks at each MCI such as to wear a signal vest signing to be the operation manager, to create a treatment place, or to give the situation report to the rescue coordination center. In order to create one, some example checklists from the fire brigade were received. All fire brigade officers disliked the checklists in the wireframe concept. It was recognized that they have not to be reminded of everyday business duties. However, it was discovered that they need to be reminded of periodic tasks such as to give a situation report to the rescue coordination center.

Design aspects:

- *Strict hierarchal chain of commands*: The TWS must not violate the strict hierarchal chain of commands. For instance, a sub-operational unit leader should not be able to send a request for additional resources (e.g. for transporting casualties to the hospitals) to the rescue coordination center.
- *Simple to use*: MCIs as well as their simulations occur very rarely. Thus, it can happen that operation managers have no contact with the TWS for month or even years. Consequently, all user interfaces must be intuitive, easy to use and robust.

5 Concept

After the identification of the requirements on the TWS, the following six workflow use cases were created in order to design the interaction workflow: alerting and drive, arriving and role changing, situation assessment and situation report, giving commission and sending a request, (sub-) operational units, and information and note area. The design is based on the requirement, that all important operation information must be visible on one view. Additionally, the design concept should be transferable to different touch devices, e.g. large multi-touch tables, tablets or smart phones. To fulfill this requirement, to create the interaction concept and to model the cooperative workflow, a wireframe-based prototype was developed (Fig. 1). Particularly with regard to the requirement of displaying all relevant information on one view, the design concept has been split into the following four equal sized areas (Fig. 2):

- *Map area*: This area provides the following full multi-touch-based interactive views: a street map, a combination of a satellite view and a street map, an object plan if available, and a free sketch/note area. The two map views include the illustration of (sub-) operational units, dangers, casualties and some additional information such as wind direction.
- *Information area*: Here, the over-all operation information is displayed ranging from arbitrary information such as operation address, (operation) time, to casualties and resources statistics.
- *(Sub-) operational unit area*: In this area, all (sub-) operational units are listed providing specific information such as (sub-) operational unit leader, assigned resources, or casualties in this (sub-) operational unit.
- *Task and Request area*: This is a management area providing an overview of all given tasks/commissions and received requests, as well as an log view documenting the inputs of the user and incoming events, and a note and documentation area allowing to record or to write down some notes.

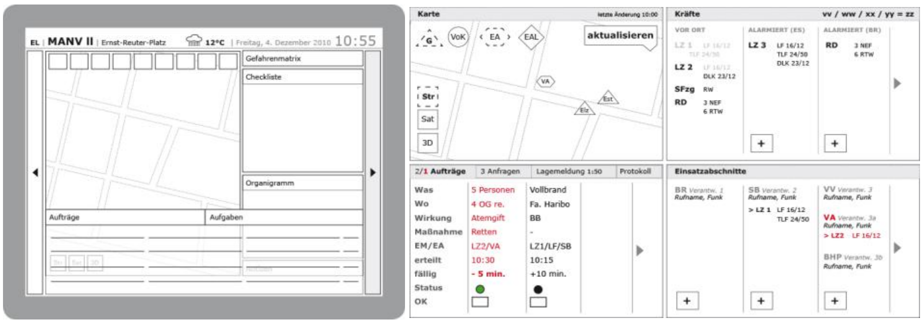

Fig. 1. Wireframes for the TWS at different design/conceptual phases (left is an early version and right an advanced one).

Fig. 2. The final mockup showing the four area design.

In order to provide a more detailed and larger view, each area can be resized by a short single touch inside an area expanding buttons. It is also possible to enlarge two areas at the same time. Last, but not least, the TWS supports drag and drop actions between the different areas for special interactive elements, e.g. dragging an operation unit from the operation unit area on the map. Thanks to a modular design, all areas and their interactive elements can be used as single modules. Therefore, it is possible to transfer the whole concept to smaller screens.

Besides the requirements concerning interaction and design aspects, further functionalities were considered in the conceptual phase such as an automatic sending of the situation report (because the TWS holds all information to be given in a situation report and thus, the operation manager does not have to be reminded to do it), reminding of special events (e.g. that not enough resources are available to transport the casualties or to check the state of given commissions), and a role rights management component controlling and managing the displayed information for all roles.

After the wireframes were accepted by the fire brigade officers and their assistants, mockups were created. These mockups served as design templates for the prototype implementation.

6 Requirement Validation

To validate whether the design concept meets the requirements of the operation manager, a preliminary prototype was implemented and evaluated in an MCI simulation with 20 supernumeraries acting as casualties. This simulation was originated to perform an integration and cooperation test of all components developed in context of the ALARM-project [7]. Consequently, the simulation did not claim to simulate an MCI.

Aligned to the ALARM-project solution, the TWS receives and sends all information from/to a local server, the so called local platform, via ActiveMQ[3]. The local platform is the central element of the operational structure. It gathers all accruing operation information from mobile clients such as triage or transport information. Every time new information is coming in, the local platform forwards this information to the TWS. The TWS prototype itself was implemented in Java using MT4j[4], supported no input functionalities, and was deployed on a Motion J3500 tablet PC[5].

The simulation consisted of only one treatment area which was already build-up at the beginning. During the whole simulation, one researcher accompanied the operational manager and noted everything related to the TWS including issues, the way of interaction, and remarks of the operation manager. This intermediate evaluation revealed open design issues such as the difficulty of reading color-coded casualty statistics in bright daylight and new requirements such as more variations of the casualty statistics, and the wish of recognizing possible problems in the triage process such as the need of more rescue staff for the triage. The notes from the simulation are currently analyzed and will be considered in the requirements analysis again.

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3 http://activemq.apache.org/ (accessed on 2012/08/22)
4 http://www.mt4j.org (accessed on 2012/08/22)
5 http://www.motioncomputing.com/products/tablet_pc_J35.asp (accessed on 2012/08/22)

7 Conclusion

In this paper, an IT supported tactical worksheet supporting operation managers in their decision making was presented. It includes the comprehensive requirement analysis and conceptual aspects. Although the requirements were established in context of the ALARM project for the Berlin fire brigade, they should be general enough to apply to other fire brigades. Finally, a preliminary prototype was evaluated in a real MCI simulation with 20 casualties in order to validate the design concept developed from the identified requirements. The evaluation revealed useful feedback to the design which has to be still analyzed. Based on information gathered from this analysis, the requirement analysis as described in section 3 has to be performed again. Furthermore, it will be considered how the ubiquitous computing infrastructure of the ALARM solution can be used to recognize critical situations at the MCI. The reworked design concept and an enhanced prototype implementation will be tested on a real MCI simulation with about 33 casualties.

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