# Creating a common operation picture in realtime with user-centered interfaces for mass casualty incidents

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***Abstract*—Accurate, accessible, and realtime information on the number, location, and medical condition of patients are critical for the successful management of mass casualty incidents (MCIs), where the number of patients exceeds the capacity of the emergency management service (EMS).**

**We present a concept of a collaborative infrastructure which generates a common operation picture in realtime. A complex, stressful and uncommon situation like an MCI creates strong psychological influences and burdens on the rescue workers. Based on our psychological findings we derived eleven special requirements for efficient and intuitive user interfaces in unstable, time-critical emergency situations. Taking the requirements into consideration we developed a concept to overcome the MCI through the combination of multiple devices. The devices are carefully chosen according to the task of the EMS personnel in the field as well as in the incident command post. Three different interfaces – PDAs for the rescue units in the field, tablet PCs for the incident commanders and a multitouch table in the incident command post – help the entire rescue team to gain efficient situational awareness.**

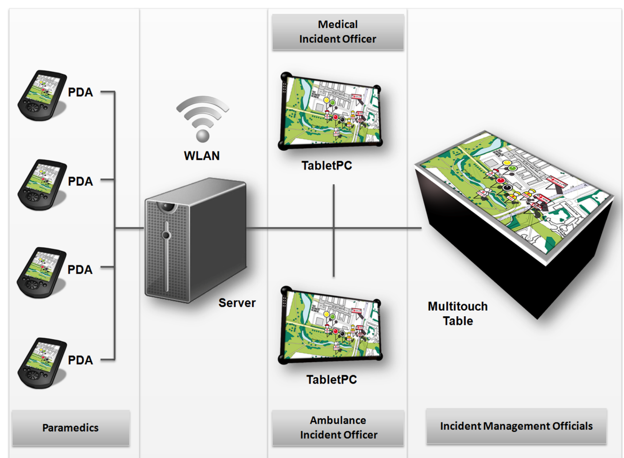


Fig. 1. UI concept: Paramedics are equipped with PDAs in order to track the patients indirectly. Paramedics, ambulance incident officer and medical incident officer are tracked directly via their devices (PDA, tablet PC). All positions are shown on the multitouch table in order to manage the MCI.

## I. Introduction

During Germany's Love Parade, a dance music festival held in Duisburg in 2010, 19 people died and more than 300 were injured. Mass casualty incidents (MCI) like this are sporadic but can be devastating, causing multiple deaths and more serious injuries. This enormous number of casualties causes a chaotic situation where more victims have to be treated than the emergency personnel is able to handle. It is a situation where a distributed yet collaborative infrastructure could efficiently address the challenge of management and coordination.

This paper presents the concept of such a collaborative infrastructure for the project SpeedUp[1]. It involves a table top multitouch interface for the emergency management personnel, a set of ruggedized tablet PCs for the incident commanders, and a set of ruggedized PDAs for the paramedics in the field, to help the entire team of rescue workers (see Figure 1).

Collaboration between all stakeholders is essential in an MCI. The paramedics who are treating the patients have to work in close collaboration with the higher commanding authorities of the MCI. Members of the latter group are the medical incident officers (MIO) and the ambulance incident officers. A successful management is very important, as the mismanagement of the MCI increases the risk that severely injured patients die unnecessarily [1]. To successfully overcome the MCI situation, communication and information exchange are essential.

This attempt introduces new challenges. First, a standard procedure to rescue victims in an MCI is already in place and we have to place our novel infrastructure within that operational space. Second, the need to provide intuitive user

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interfaces (UIs) that can indeed speed up the rescue process and help to save lives. Third, our setup has to be reliable and scalable to properly address a real MCI.

In the next section we introduce the triage process, which is performed in an MCI – before we give an overview about current projects, which support the emergency management service (EMS) during an MCI with electronic devices. Afterwards we present psychological effects and user interface requirements. Finally our proposed approach to handle MCIs is described.

## II. Triage

The standard procedure called triage is conducted as soon as the first rescue workers arrive at the incident. The aim of the triage is to get an overview of the casualties. During the triage process, alive patients are sorted into three different categories— Red, Yellow and Green—ordered from high to low priority. Already dead persons get a Black tag. The color encodes on the one hand the level of injury and on the other hand the transportation priority. Red patients need immediate care and their transport has first priority. The treatment and transport of Yellow tagged persons can be delayed. They need immediate advanced care, but can wait until additional crews arrive. Walking wounded get a Green tag (lowest priority). They need little or no treatment and the transport can be delayed until last (lowest priority) [2].

The EMS in Munich is conducting the triage via the mSTaRT Algorithm (modified simple Triage and Rapid Treatment), which extends the North-American START Algorithm [3].

During the triage each patient gets equipped with a paper tag, where information on triage and treatment is documented. The tag is attached to the patient's neck or arm and contains a colored stripe. It helps the EMS to recognize the patient's category. This paper-based approach has the advantage that all emergency units have unrestricted access to the triage information. However, the disadvantage is that no central patient information is available. The triage data is bound to the patient and not directly visible to the incident officers. Therefore, the information about the triage is collected also on a sheet of paper. This sheet is later handed to the incident officers. A disadvantage is that paper based information cannot be spread to several persons at the same time. Furthermore if a patient's status changes all other documents containing this information have to be updated accordingly. Also the recording of the positions of the patients is cumbersome using paper tags [4]. However, this information is essential for the organization of an MCI and an optimal resource allocation [5].

## III. Related Work

In the following we present several projects which address multiple interfaces to generate and visualize a common operation picture (COP) for the management of an MCI. The data for the COP comes mostly from mobile devices, whereas the visualization is preferably on stationary devices like multitouch tables.

The *Emergency Management System* by Rausch et al. [6] presents an overview of all patients and paramedics at the incident. The system uses three devices with GPS - a medic unit to monitor vital patient data, a casualty unit to store patient data and a peripheral unit to measure and collect vital patient information. The collected data is transmitted to the command center and the medic units.

The SMART System (Scalable Medical Alert Response) [7] monitors also with a PDA and several sensors the patient vital signs and the patient location during an unattended waiting period in an overcrowded emergency department after triage was conducted. The patient wears a PDA in a waist pack. Attached sensors measure vital signs. An alarm is triggerd if critical critical data is measured and send to a caregiver.

Furthermore Gao et al. developed an electronic triage system, which includes electronic triage tags and PDAs to support documentation and communication [8].

In the aforementioned system the patient has to wear an electronic device in order to be tracked. In large MCIs which involve an enormous amount of patients the devices may cause trouble due to missing scalability. Electronic devices are quite expensive compared to RFID tags, which are used in our project and have a better maintainability [4].

Other projects also abandon electronic devices for each single patient. Killeen et al. [9] developed a system which is based on a PDA with a barcode scanner. An electronic medical record software replicates the standard paper triage tag. The paramedic scans the tag. The gathered information and additional information about medication and treatment is added to a list. This list contains all patient data and is transferred via a wireless network to all PDAs in the field. A list of patient data is generated through scanning the tags and entering additional information. However this system does not transmit the location of the patient.

US Navy's TacMedCS [10] tracks patient position via an RFID tag worn in a plastic bracelet. The position of the patient is determined as soon as the paramedic scans the RFID chip via the GPS enabled PDA. The leading commander accesses the data via a normal laptop. In our project we substitute the laptop with two interaction devices – a ruggedized tablet PC and a multitouch table. Both devices have several advantages compared to the laptop. Both devices are chosen according to the distinctive tasks in the field and in the incident command post. The incident commander working directly in the field needs a mobile device (tablet PC), whereas the emergency management personnel in the incident command post needs a large display and a collaborative device (multitouch table). Both devices are optimized for the usage in an unstable and stressful situation.

Multitouch tables in particular, are a natural match for digital support of map-based tasks. Common physical gestures such as sliding and rotating the map can be directly transferred to the digital representation, thereby easing the transition from paper-based maps. Additional functionality such as zooming the map, viewing real-time updates and issuing commands enhance the users' options considerably. Consequently, many general command-and-control applications make use of such devices. The Soknos project [11] uses a digital table for these tasks [12]. It aims to provide a general framework for management and visualization of data relating to catastrophic emergencies.

Another system which combines multitouch tables and PDAs worn by personnel in the field is realized by Ashdown [13]. Here, particular focus is given to the aspect of a shared map workspace between commanders using the interactive table and field units using their wearable devices. An exemplary task aided by this scenario is way finding in devastated areas.

Other applications of interactive surfaces in the area of geospatial rescue management focus on single specific tasks instead. For example, Zibuschka et al. [14] show a system which supports the planning of large-scale events with the goal to avoid potentially catastrophic accidents through appropriate placement of rescue units and escape routes etc. Nobrega et. al [15] present an interactive flood visualization system which uses terrain data and physical simulations to predict the course of catastrophic flood events. Micire et al. [16] use an interactive table to plan routes for and steer remote-controlled search-and-rescue robots in a disaster area.

The aforementioned projects support the EMS in specific parts. However little research is done for user centered devices and user interfaces which help the entire EMS from the paramedics in the field up to the management personnel. Devices for our project are chosen accordingly to the task, the environment, the target group as well as the properties of the hardware itself.

## IV. Psychological Aspects and User Interface Requirements

In this section we present psychological aspects to be considered when developing user interfaces, for the emergency personnel working in an MCI situation. Based on these findings user interface requirements are identified.

### *A. The MCI: facing the need to act in a complex, stressful, and uncommon situation*

What does an MCI mean for the emergency services involved? Routine scenarios are usually small in scale and commonly handled by emergency response teams. However, an MCI represents an operation in which many different tasks have to be solved and coordinated by the rescue forces. Despite the alleged uniqueness of this situation each MCI features some common qualities [17]. MCIs usually occur suddenly, are hazardous to the life or the health of many people, and may pose a threat to the lives of emergency responders on-site. Yet, an MCI is a highly dynamic situation in which the emergency response teams face the need to act. Zinke et al. [18] describe characteristics of complex problems (like MCIs) and their psychological consequences:

- High dynamics of the situation: This can lead to time pressure.
- Quick decisions: Having to make those decisions can lead to an increased level of stress or anxiety.
- Uncertainty of the situation: Sometimes decisions have to be made based on incomplete information.
- Information overflow: Certain information (like upcoming further Emergency Response Teams, number of victims) keeps coming in.

Such psychological factors affect incident command officers as well as emergency teams and can increase their stress level or anxiety. Besides organizational conditions, tactics and operations they encounter the following psychological processes [19]):

- Shock concerning the incidence
- Anxiety about failure
- Anxiety concerning responsibility
- Noise and agitation on-site
- Physical needs (hunger, thirst, absence of recovery phases)
- Disorientation due to missing or inconsistent information
- Emotional concern

If rescue forces are overstrained by an MCI situation, the reaction on stress shifts the forces into an emotional, physical, and mental state that requires a quick and purposeful action to defensively respond to a threat [20]. The increased stress level can also increase the possibility of making mistakes. What does this mean for the tasks that have to be solved? How does wrong or misguided action occur?

Schaub [21] characterizes several causes of failures in complex situations like an MCI. On the one hand, the narrowness of the cognitive capabilities leads to a reduction of available information. This reduced processing of information leads to an increased prioritization of the current motive. For example, an ambulance incident officer of the EMS has to handle a lot of tasks simultaneously (assembly of the treatment site, requesting additional emergency support, realizing the instructions of the medical incident officer). Based on the limited cognitive abilities they might only pay attention to information regarding the assembly of the treatment site (current motive). Consequently, they could disregard or simply forget to handle other tasks (like additional rescue forces). A further cause of failure identified by Schaub, is the defense of one's sense of authority ("Which task am I able to solve fast and which task is especially conducive for me?"). Furthermore, rescue units may not establish sufficient foci. Sub-goals are not organized concerning their importance. No distinction between relevant and irrelevant problems is made. Thus, irrelevant tasks could be dealt with first. Furthermore, the rescue forces may resort to act in "Methodism": formerly successful methods are employed to the new situation ("I always did it this way."). Still, Schaub describes the problem of "Ad-hocism" which can lead to failures in complex situations. Measures are not planned adequately. Problems tend to be solved "ad hoc". There is no foresighted thinking. The above-mentioned causes of failures can lead to the following symptoms in acting during an MCI [19]:

- acting instead of thinking and planning,
- preferring fast and effortless solutions,

- avoidance of critical consideration of one's model for further discussions,
- disregarding information that disagrees with one's own impression of the situation, and
- physical symptoms (shivering, sweating, lack of concentration).

In summary, if stress increases, this can lead to false estimation, spurious action and mal-operation. The course of action could be disrupted. The more complex the course of action is in an MCI, the higher is the chance to fail. Thus, the quality in handling the tasks can be compromised. The three devices PDAs, tablet PCs and the multitouch table are supposed to decrease the stress level by guiding the emergency personnel through important decisions through adequate user interfaces. Complex operations are broken down into smaller steps, which simplify the complexity of the tasks. The emergency personnel should work with devices that support their work best. The devices should only show data which is relevant to their work.

Using the devices in the complex, uncommon situation like the MCI could also reduce the stress level by getting information on:

- the "actual" overall situation
- the position of operation leaders and action forces as well as operation resources
- Data about persons affected and their injuries

and also by supporting the communication between the EMS personnel (for example if the radio is overloaded).

### B. *Ethical burdens*

A further psychological factor of an MCI is the ethical burden. Those burdens can be emotionally incriminating for the rescue forces. The triage can lead to affordance of medical arrangement for one patient, but at the same time initially deny medical treatment for another patient. Thus, the unusual situation in an MCI enables the exclusion of medical treatment. There could be another problem for the rescue forces: they must be accountable for their actions (for themselves or to some external authorities) if one or more of the patients remained unattended. Such morally and psychologically burdening factors have to be considered in the development and designing of a technical device.

### C. *User Interface Requirements*

From the psychological aspects we derived the following User Interface (UI) requirements. Further key requirements are derived from expert interviews with firefighters, paramedics and incident managers from TUM Feuerwehr, a fire department with rescue service and from the Arbeiter Samariter Bund München, a German ambulance service. An expert interview is a specific form of a semi structured interview, which focuses on expertise in a certain field of activity (in our case MCI). Additionally, we we observed the EMS personal during their daily work as well as during specific trainings for MCI.

**Reduction of complexity:** Due to the narrowness of cognitive abilities of the EMS personnel in the MCI situation the complexity of the UI should be minimal.

**Clear information processing:** To overcome the information overflow a clear information structure which filters important data is required. A well-structured UI gives fast access to relevant data.

**Reduction of distraction:** There is a high potential for distraction during an MCI. Therefore, the UI should encourage the ability of the EMS personnel to concentrate on relevant tasks. For example by guiding the user through all relevant steps, the risk to forget subtasks is reduced. Even if an MCI is an extremely dynamic and complex situation, there are still tasks as well as information that must be processed in each MCI by the EMS personnel. For example the EMS personnel will always have to have information about the number of the injured persons (and how many persons are seriously injured). For example, the UI could suggest the task "Counting the injured persons first." (which will always be the first task for a paramedic on-site).

**Prioritization of tasks:** A lot of tasks have to be solved simultaneously. The UI can help to structure problems according to their priority. Subgoals could be organized according to their importance.

**Extension of current workflow:** We found that especially older persons tend to keep the established and well-known workflow and devices they have known for many years. Some of them had bad experiences with new technical devices and are therefore very critical towards new technology. Consequently the acceptance of the new technology increases by extending, and not by replacing, the current information flow and placing the interface as a seamless part of the process.

**Avoid time delay:** The UI should not slow down the current process of fast treatment of the patients.

**High reliability:** The UI needs a high reliability so the EMS can rely on the digital data at any time.

**Intuitive interaction:** MCIs are rare situations. User interfaces should thus be be intuitive and easy to learn. Even if the UI is not used for a long time, it should be possible to work with it efficiently. This can be reached if the UI is self-explanatory. Another advantage is, that the acceptance of new technology increases.

**Task centered Hardware:** Every device must be carefully chosen according to the task which has to be solved with it. A paramedic for example needs both hands to treat the patient and therefore is not able to hold in one hand an additional device.

**Task centered UI** The type of interaction has to be optimized according to the properties of the device. For example, the ruggedized tablet PC is very heavy. In order to use the device comfortably, it should be possible to hold it in both hands while interacting with it.

## V. CONCEPT

We present in the following our UI concept consisting of three types of devices in order to support the EMS to manage the MCI. These devices are a set of ruggedized PDAs, a set of ruggedized tablet PCs and a multitouch table.

Our concept consists of three types of devices, in order to fulfill our predefined requirements. With these three devices we build a common operation picture of the MCI. The first device is a PDA for the paramedics, working directly on the field with the patients. The second device is a tablet PC for either the medical incident officer (MIO) or the ambulance incident officer, which are close to the incident area. The third device is a multitouch table, which is placed in the incident command post. An Overview of our concept is also shown in Figure 1.

Each emergency team, which consists of two paramedics is equipped with one PDA. One of them wears the PDA on the forearm. Hence, the paramedics are still able to work with both hands. Through a GPS sensor inside of the PDA, it is possible to track the paramedics' position. Furthermore the PDA contains an RFID reader to scan enhanced paper patient tags. Paper patient tags are common in order to conduct the triage. Information about the patient's health status and his treatment is noted on the paper tag. The enhanced paper tags are extended with a passive RFID tag. Through this extension the position of the patient can be tracked indirectly. Due to the close position of the paramedic to the patient, the position of the patient is determined as soon as the paramedic scans the RFID tag. Afterwards additional information can be entered on the device, like the triage category (green, yellow, red or black) [22] and [4].

All information is sent promptly to a central server through a local wireless network. The data from all emergency teams is collected at this central server.

The use of the RFID tag has several advantages. RFID is a durable and reliable technology. A passive RFID chip can store data. Data can be updated and critical data can be protected from overwriting. RFID chips are inexpensive compared to digital devices. If the connection to the central server is interrupted, the data is still available on the tag. The data travels with the patient and can be read at the next station even if there is no connection to the central server.

The collected information is presented on a map on the tablet PC of the ambulance incident officer and the medical incident officer [23]. This map gives a complete overview of the whole incident. The incident officers are informed immediately about the location and the triage category of the patient. The incident officers are also aware of the position of the emergency teams. Their positions are also transferred to the central server.

In order to ensure consistency for all emergency management personnel engaged in the incident we visualize the collected data from the mobile devices as a common operation picture on the multitouch table [24]. This table is placed in the incident command post, which is located close to the incident scene. On this table multiple incident officers can work collaboratively. Due to the additional on-time information the leaders of the MCI can react better and faster to the MCI situation. They have a better basis for making decisions for the allocation of their resources. Misunderstandings can be reduced through the enhanced communication and information flow. Besides the EMC, other authorities and organizations with safety responsibilities like the police or the fire brigade may work in close collaboration on the multitouch table. The table enables all stakeholders to gain a "situational awareness", in order to make timely, effective decisions during rapidly evolving events.

## VI. Conclusion

In order to be able to speed up the rescue process we were first investigating psychological aspects of an MCI. During an MCI rescue units have to act in a complex, stressful and uncommon situation. We pointed out special UI related requirements considering the circumstances of the real world scenario. With this background we developed a collaborative multi device concept containing a multi touch table, multiple ruggedized tablet PCs and multiple ruggedized PDAs in order to help the entire rescue team to gain efficient situational awareness.

In the future, besides giving a common operation picture, which is the basis for management decisions, we will also extend our multitouch application for interactive resource management. In the end the final multitouch application should be the central unit, which allows to identify requirements, order and acquire, mobilize as well as track resources. This complete collection of data is on the one hand a basis for decisions during the MCI, but it can be used also as a report tool after the MCI situation is overcome.

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