

Developing user centered maps and map symbols in mass casualty incidents - a qualitative interdisciplinary approach.

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Abstract: Handling highly dynamic scenarios as they arise in mass casualty incident (MCI) situations requires lots of information about the situation and an extremely usable display of IT based supporting systems that can assist in managing the incident. The rescue workers have to interact effectively with IT based rescue management support systems (IT-RMSS) in order to successfully manage the incident. In this paper we show how the results of qualitative culture studies can provide important insights into the design of displays that are to be deployed in settings like an MCI. We will show how the software engineering can profit from the results of such a study and how the results can be implemented.

1 Introduction

The SpeedUp project (BMBF)¹ is focused on Mass Casualty Incidents (MCIs) in Germany. An important goal of SpeedUp is to develop a generic framework for an IT-rescue management support system (IT-RMSS) practicable for all forces of BOS² (the so called authorities and organizations with safety responsibilities in Germany; we considered fire brigades, police and emergency medical services) involved in handling the MCI-scenario. As we already analyzed within the project, the BOS have different organizational structures, tasks, and cultural characteristics, which have to be taken into

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² Behörden und Organisationen mit Sicherheitsaufgaben

consideration in the development of an IT-RMSS. In previous studies within the project SpeedUp, cultures of the BOS – fire brigades, police and emergency medical services – were analyzed and described. Based on the findings of the cultural analysis, different user interfaces for an IT-RMSS were developed. The surfaces were developed according to the needs of the organizational culture and the roles of the various members of the BOS in an MCI.

In this way, the IT-RMSS provides all important information adapted to the needs of the different members of the BOS. The design of the separate surfaces is based on the observation that the needs of the BOS differ because of different organizational cultures and different problem solving processes and tasks. Hence it is important to present the information needed on the surface of an IT-RMSS separately for every BOS.

2 The influence of culture on usability

The influence of culture on the usability and the acceptance of technical devices is discussed in a variety of studies. Banse and Hauser [BH10] discuss the relationship of technology and culture. They state that technical systems as man-made objects have to be included in a certain (cultural) context of use. The influence of culture on the developmental context and the context of use plays a significant role regarding usability and the acceptance of technical devices. Beu, Honold, Yuan [BHY00] also deal with the influence of culture on usability and discuss how an infrastructure for intercultural usability can be engineered. They argue that the mere transmission of the user interface and the adaptation to format and character is not sufficient to ensure the usability of a product: „True adaption goes much deeper and takes into account different requirements of functionality.” Rather, the usage context, the infrastructure, the formation of the respective user groups, values and aspirations have to be taken into account within the adaptation of user interface: „It is crucial to develop a deep understanding of culture-specific requirements and differences, and to make them explicit.” Trillo [Tr99] also emphasizes the importance of cultural features into the development process: „User Centered Design emphasizes in-depth knowledge of the end-user, their needs and their environment. A key component in understanding these three areas of emphasis is culture.” In a literature review relating to cross-cultural Usability Engineering, Honold [Ho00] states that the knowledge in this area is very heterogeneous. She summarizes the different fields of intercultural usability engineering: the collection of culturally specific user requirements, rationales and culture-specific assessment of operational concepts. Also Honold [Ho00] emphasizes the impact culture has in the development and use of technical systems. The first culturally appropriate approaches to user interface design were guidelines. These guidelines were used in the international distribution of industrial (technical) systems. They point out the fact that during the design-process of user interfaces, time- and date formats, the use of colors and symbols and the design of icons have to be taken into consideration. Further information can be found at Nielsen (in: Brauch & Sarodnick) [BS06], who constituted three levels of cross-cultural influence on the user interface. On the one hand, aspects such as language or nation have to be considered. Furthermore, the user interface should be translated in a way the user understands it.

Though studies on usability are already widely used in the development process of technological products, and the influence of culture on usability was already examined in a variety of studies, culture studies, especially in the area of BOS, are still single cases.

Approaches that account for *the human factor* in technology design comprise classical usability studies applying quantitative methods [BKM08] as well as culture studies based on qualitative data. Culture studies however are seldom applied to the design of complex technological systems. One aim of this paper is to point out how cultural analysis can contribute to the overall usability of human centered technological solutions. Cultural analysis as a fieldwork is based for example on free observations, guideline based and narrative interviews, as well as document analysis. The data collected by these methods should provide a basis for the understanding of the specific concepts of behavior, communication and perception of the cultures which are in the center of the analysis. Based on a dynamic understanding of culture any kind of technology has to be integrated into these habits and routine operations to be accepted and to assure an effectively use by the end-user. From this point of view, classical methodologies of internationalization and localization of software like it is used by professional software developers seem to be not profound enough. Cultural analysis as a method of culture science not only allows evaluating the acceptance of a specific solution, but also allows identifying interesting statements of the general acceptance of technical innovations in organizational cultures.

As we mentioned before we developed different user interfaces for the IT-RMSS according to the needs of the organizational culture and the roles of the various members of the BOS in a MCI. As a specification of our cultural analysis we discovered the preference of digital maps and icons displayed on the IT-RMSS. Due to the importance of culturally appropriate user interface design, we developed a perception study in cooperation with our technical project-partners. Various members of BOS took part in this study. Based on the results of our culture analysis (BOS act related to different organizational cultures) several representatives of the main BOS represented in a MCI in Germany participated in our study. It was examined which maps the different types of BOS prefer on an IT-RMSS and what representation on maps (map symbols or tactical signs) they prefer. The map study is described below. The technical aspects of the study were designed by our technical project partners.

3 Maps and Maps symbols Perception Study

3.1 Sample

The subjects were acquired within the project. With the help of our application partners we could get in contact with the BOS (representatives of fire brigades, emergency medical services and police). We acquired the subjects from two different fire brigades in Stralsund and Munich/Germany, one police headquarter in Jena/Germany, and two emergency medical services stations in Jena and Stralsund/Germany. In this way we could acquire the subjects for our study. 22 Firefighters were involved in the study, as well as 23 members of emergency medical services and 29 police-officers.

3.2 Structure and Expiration of the Study

All subjects were informed about the project and the aims of the study prior to participating in the study. Each subject took part individually in a separate room. The study was presented on a laptop (15.6"). If the subject had any questions, it could ask the experimenter, who was with the subject during the study.

First, some demographic data (sex, organizational affiliation, professional experience in MCI, and probable position in a MCI, MCI experience in exercises and real incidents, years of service) were queried.

Based on the results of culture analysis within the project we created a map study as a simulation which consists of five different map types layers (digital road map, digital orthographic map, digital hybrid map, digital topographic map, digital black and white map) with information concerning site/infrastructure and two different representations of the rescue forces on the map (tactical symbols, map symbols). The task was to select a map view and a representation of the rescue forces. The simulated situation was described as an MCI on a highway in an unfamiliar place. Furthermore, the test person was informed that several BOS are already on site. As a support for the participant, it received a digital map which represented the actual over-all situation. The participant could adjust the map until it displayed the information clear enough to him. After setting the map the test person was asked to fulfil the second task. The second task was to estimate the number of rescue forces presented on the selected map view. The map-study was based on 2 hypotheses:

1. Knowledge and preference of tactical graphics decreases in positions lower than officer-in-charge/squad leader.
2. In unfamiliar areas detailed maps are preferred.

The registration of the demographic data and the preferences of the maps and maps symbols took place in an automatically generated excel sheet.

The simulated situation was described as follows:

„Imagine you are a [position of the subject in a MCI] in a MCI. It is a city / highway-situation in an unfamiliar place. There are already various forces of police, fire brigades and emergency medical services on site. The vehicles located on site are all filled by default. To support your work, you receive a digital map on a portable device that shows you the positions of the forces already located on site. You can adjust the map in the way that it is clear and understandable for you. Please select the optimal display - variant.”

The forces on the different maps (road map, orthographic map, hybrid map, topographic, black and white map) were presented in the form of tactical symbols, and then in the form of pictograms. The tactical symbols were presented in black and white, as this is the most familiar type of representation for the rescue workers and this is the way tactical symbols are used in trainings. The pictograms and tactical symbols represented

the position of rescue forces of fire brigades, police and emergency medical services and certain operational vehicles.



Figure 1: Example Option digital road map and map symbols



Figure 2: Example Option digital road map and tactical symbols

3.3 Findings

Based on the two hypotheses the following findings were discovered:

Hypothesis 1: Knowledge and preference of tactical graphics decreases in positions lower than officer-in-charge/squad leader.

Police: 69% were police officers that held a position below the MCI team leader level. 60% of these subjects preferred map symbols on a map. This could be an indication that knowledge and preference of tactical graphics decreases in positions lower than officer-in-charge/squad leader.

Fire Brigades: 55% of the fire-fighters held a position below the MCI team leader level. 45% of these subjects preferred pictograms on a map. This could be an indication that knowledge and preference of tactical graphics decreases in positions lower than officer-in-charge/squad leader.

Emergency Medical Services: 74% of the representatives of the medical services held a position below the MCI team leader level. 70% of these subjects preferred pictograms on

a map. This could be an indication that knowledge and preference of tactical graphics decreases in positions lower than officer-in-charge/squad leader.

Despite the training of rescue forces lower than officer-in-charge/squad leader is not focused on tactical signs and they mostly do not use them in their daily operations, 40% of the police officers, 55% of the fire fighters and 30% of the Emergency Medical Services personnel preferred tactical signs on a map. This could be an indication that the forces truly know tactical signs or may think they need to know them.

Hypothesis 2: In unfamiliar areas detailed maps are preferred.

Police: 83% police officers preferred digital road or orthographic maps, which are more detailed to them than the black and white, digital topographic or hybrid maps. This could be an indication that detailed maps are preferred in unfamiliar areas.

Fire Brigades: 91% of the fire-fighters preferred digital road or orthographic maps, which are more detailed to them than the black and white, digital topographic or hybrid maps. This could be an indication that detailed maps are preferred in unfamiliar areas.

Emergency Medical Services: 83% of the representatives of the emergency medical services preferred digital road or orthographic maps, which are more detailed to them than the black and white, digital topographic or hybrid maps. This could be an indication that detailed maps are preferred in unfamiliar areas.

A majority of the BOS - members surveyed preferred detailed maps and map symbols as a representation on the user interface of an IT-RMSS. Despite we did not consider rescue forces higher than the rescue forces “on site” within our hypotheses 1 we found an interesting additional result: five out of nine surveyed police officers which held the position “police commander” preferred pictograms instead of tactical symbols. So team leaders might not necessarily always prefer tactical signs. Based on our findings (user-specific requirements regarding preferred map types and preferred map symbols) our project partner was able to implement certain map types into the IT-RMSS. Also based on our findings, our project partners developed a set of map symbols which are presented below.

4 Emergency Map Symbols

The map study result indicates that the preference for tactical signs on a map decreases in positions lower than officer-in-charge / squad leader both for fire brigades as well as for the medical service. Therefore we developed a set of symbols within the SpeedUp project together with people working in the rescue service as well as in the fire brigade field. These new symbols are different to the official set of tactical signs [Ka03]. We designed first those symbols which had the highest relevancy for our project, focusing on the emergency medical service. These were representations for patients, medical service personnel as well as for the emergency vehicles.

4.1 Requirements

Several challenges for map symbols in crisis management are identified by Robinson et. al. [Ro10]. Some of them are in common with the requirements we identified in close collaboration with the TUM Feuerwehr, a fire brigade from Munich/Germany. (1) The symbols should have a high visual distinctness. However this is challenging as the more visual features the symbols have in common, the harder it is to identify the correct symbol [Tr86]. (2) Our map study showed that some problems occur with the comprehension of the tactical signs. Our aim is that the newly designed symbols need to be intuitively understood without reading the definition of the symbols. (3) The symbols should “pop out” against the map background. To ensure this one has to consider, that the map background can be bright or dark and can have several colors, can be very detailed or can be in uniform color. In any case the symbols must segregate from ground. (4) The symbols should point to an exact location. (5) The symbols should be visible on different devices (PDA, TabletPC, Multitouch Table), which have various resolutions. (6) The devices are used also outdoors. Yet, a bright lightning condition influences the display readability negatively, so we have to assure that it is still possible to identify the symbols on the map.

4.2 Realization

In several iterations with feedback from the emergency professionals we developed the following representations for patients, emergency medical personnel as well as emergency vehicles (see Figure 1). All symbols have a pin shape, where each head represents a different person or vehicles. The official tactical signs do not cover all of our cases [Ka03]. For example the official set does not differentiate between the different triage categories. Only one patient symbol exists. Our RFID based triage system makes the triage information digitally available to the emergency personal at the incident [Ne10]. Therefore all symbols need to have the various triage categorieencoded.

Features of the symbol set:

Our symbols have the following features. (1) In order to reach a high level of distinctness within the item set, we use different basic shapes for different symbol categories (patient, EMS personnel, and vehicles). Treisman found that the human visual system responds more towards simple properties such as orientation, colour or curvature [Tr86]. Also in the Homeland Security map standard (ANSI 415-2006 INCITS) the frame shape was used to represent the symbol categorization [Ro10]. In our case, persons are represented through a roundish shape, while vehicles have a more rectangular shape. Within the category of persons we distinguish between two subcategories - patients and emergency personnel. The subcategory patients are represented through a circular shape. Whereas the emergency personnel consists of two parts - a shape for the head and a shape for the body. (2) Taking simple properties such as abstract simple shapes for the symbols makes the symbols easier to distinguish by the human visual system [Tr86]. However, the more a pictorial symbol corresponds with the real world the easier it is to understand the symbol [Cl89]. Our symbols are not as abstract as the tactical signs and additionally we limited the details as far as possible. In a future study we will test, if the meaning of the symbols is easier to find out than the tactical signs. (3) In order to make sure, that the symbols segregate from bright as well as dark ground, they have two features. The first feature is that the head of the pin is surrounded by a black line. This makes it visible when it is positioned against a bright

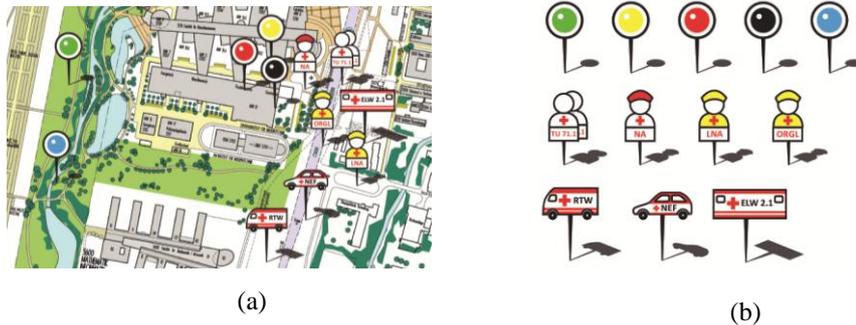


Figure 3: Symbols on map (a) and for overview on a white background (b). First row: five patient symbols for the five different triage categories; second row: medical technician unit, emergency doctor, medical incident officer, ambulance incident officer; third row: advanced life support vehicle, emergency doctor vehicle, incident command post.

background. The second feature ensures the visibility against a dark background. The filling of the symbol is either bright (leading emergency doctor, emergency doctor) or if not then we added a white border, see for example patient symbols. (4) In order to show the exact location, we use point symbols. Pins point to the location where the person or vehicle is positioned. In order to find the end of the pin faster, a shadow is added to the pin. The crossing of the shadow and the pin's needle marks the exact location. (5) We tested the icons on different devices (PDA, TabletPC, Multitouch Table) with different resolutions in order to ensure that all of them are useful on different devices. (6) As the devices where the map is shown are used outdoors we optimized the colours so that they

are as simple as possible to distinguish. It is especially important to identify the colours of the patients as the basic shape is the same for each patient category. They only differ in the colour of the head of the pin. Several tests were done under bright sunlight conditions and with various devices in order to find the best colours for the symbols. In a future evaluation we would like to test semantic features and how good the symbols can be detected on different maps. We also will design a symbol set, which is usable by colour blind people.

5 Map types and Architecture

As one of the main components of the IT-RMSS, a module to display the actual MCI situation using digital maps should be developed in the context of SpeedUp. In addition to the newly developed icon set mentioned in the previous chapter, a complete visualization of the complex MCI location requires the map data on which the actual damage situation represented by the icons can be projected. Based on the results of the map study presented in chapter 2, a requirements analysis had been conducted to determine the functional, conceptual and structural requirements and properties of a map component to display the current situation in case of an MCI.

5.1. Map types

Digital maps are already used in various areas, providing a variety of applications. In the domain of rescue management, especially in MCI, the use of digital maps represents a great benefit in the presentation of the current MCI situation. For the most accurate presentation of the current situation in addition to the widely used digital road maps or satellite photos, further geographic data is needed. Due to the high level of abstraction and the reduced information content, the standard maps are clearly represented, but do not provide the necessary information accuracy and density of the damage location needed by the rescue forces. Therefore, it is necessary to provide more types of maps with different information content and accuracy. The following types of maps are determined as interesting for the domain of rescue management regarding their information content:

- **Digital road maps** are designed to represent the road network as accurately as possible, with the surrounding landscape presented with little information content. Digital road maps are the basis of any vehicle navigation and allow route planning as well as geocoding³.
- **Aerial/Satellite photos and orthographic maps** allow looking at the real landscape from a bird's eye view. They are small, photographic images of our landscape and are taken from airplanes using special cameras or satellites straight down or up at a slight angle.

³ Process of finding associated geographic coordinates from other geographic data, such as street addresses or zip codes.

- **Digital terrain models** describe the relief of the earth's surface by a regular or irregular point grid, where for each grid point the location and height is known.
- **Digital topographic maps** offer through their precise and detailed representation of the earth's surface a wide range of applications. Information content, reliability and the geodetic accuracy make it a valuable resource for scientific and technical planning tasks.
- **Cadastral maps** include all parcels, land rights and buildings of a place, so that the geometric location of all parcels and their boundaries, parcel names, buildings and uses are shown.
- **Hybrid maps** are a combination of two or more map types and their information content. Thus, it is for example possible to project the road network map onto a satellite map to increase the perception of the environment.
- **3D maps** can be viewed as a composition of digital terrain models and satellite images and enable tilting the map, which enables a 3D effect. This also makes it possible to integrate 3D models of buildings to the map which increases the perception and the information detail of such buildings.
- **Service network maps** contain information about the infrastructure such as electric and telephone cables, water and gas lines.



Figure 4: Cadastral map, topographic map, orthographic map, terrain model

5.2 Architecture of the map component

As a result of the conducted requirements analysis, some functional and structural requirements have been determined, which the map component and its architecture should satisfy. The so determined functional requirements are:

- Support for different map-types and map-provider
- Consistent use of the same data set (situation data)
- Transparent user interaction with the map component

The implementation of these functional goals requires a flexible and dynamic structure of the component, which supports the integration of different map types and their different structural and functional characteristics. Therefore, the most important structural property for the implementation of the component is:

- Uniform interface definitions, which must be implemented by the various map components to simplify an extension with new components

To meet the functional and structural requirements, the structure of the component was implemented using the combination of two patterns of software engineering, the strategy pattern [Ga84] and the facade pattern [Ga84], which together provide the necessary flexibility while reducing complexity. By applying the strategy pattern, the desired interchangeability through general interface definitions of the different map modules can be achieved while the facade pattern encapsulates the access to the complex functions of each map module, thus reducing their complexity and increasing loose coupling. Figure 5 shows the structure of the joined pattern.

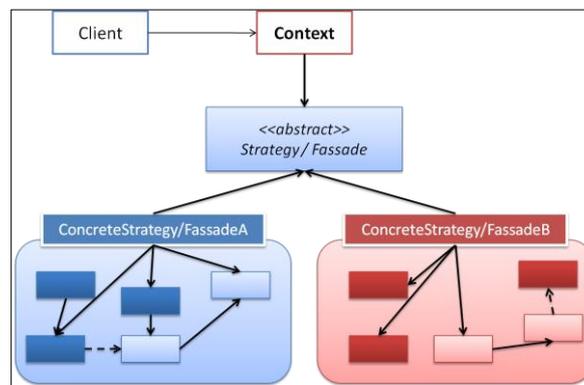


Figure 5: Structure of the joined pattern

Each map module corresponds therefore to a concrete implementation of the abstract class *Strategy* and its defined sub-modules. Through the realization of the strategy pattern and its clearly defined interfaces, each existing map module can be replaced at run time by another, whereby the user can transparently switch between the map types. In doing so it does not matter which underlying technology the map modules use or whether the maps are rendered locally or accessed via a web service from the Internet. In addition to the realization of the user requirements, the component was implemented in a way to support the developer during development through a well structured and easy to understand architecture. For this reason, the presented structure in this chapter was separated from the real functional implementation of the IT-RMSS map module, which uses the specified structure, and realized as a structural component. This structural component basically corresponds to a definition of different interfaces for the various sub-components which together constitute the total structure of the map component. The implementation therefore consists in a framework or guideline that can be used to easily and quickly implement a dynamic map component.

6 Conclusion, Outlook and Future Work

An IT-RMSS should support a faster reproduction of on-site information management through various terminal equipments, shorter information access times, and the improvement of shared assessment of the situation for operation forces. An IT-RMSS needs to support the responsible force in organizing the supply and logistics, in addition to the exchange of operation forces. Therefore, an overview must provide clear and good visible information of available operation resources, forces and the surrounding infrastructure. The user-interface of an IT-RMSS needs to be designed to be user-friendly, so that operation forces do not have extra burdens. In this paper we have argued that major incidents like MCIs ask for an effective interaction of rescue workers with their IT supporting systems. We also sketched how cultural studies can be used to identify the basic requirements for the development of technological solutions. We described how the results of culture analysis can be used to focus the design of emergency communication management systems on the user requirements. With this method we hope to bring the technical solutions closer to the visual habits and needs of the rescue workers from different organizations and with that an enhanced use of necessary IT technology in MCI. We showed how the software engineering can profit from the results of such a study and how the results can be enhanced during the developmental process by the engineers and finally be implemented. For demonstrative purpose of the functionality and to be able to verify the requirements and demands of the map component, a first implementation was created. As part of the IT-RMSS, the map component was already used in several practical examinations in the context of the SpeedUp project.

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