IT-Supported Management of Mass Casualty Incidents: The e-Triage Project

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ABSTRACT

Voice, analogue mobile radio, and paper have been successfully used for decades for coordination of emergencies and disasters, but although being simple and robust this approach cannot keep pace with today's requirements any more. Emerging and established digital communication standards open the door to new applications and services, but the expected benefit needs to be carefully evaluated against robustness, interoperability, and user-friendliness. This paper describes a framework for IT-supported management of mass casualty incidents, which is currently under implementation and study. The four pillars of the concept are handheld devices for use both in daily rescue operations and in disasters, autonomous satellite-based communication infrastructure, a distributed database concept for maximal availability, and psychological acceptance research.

Keywords

Mass casualty incident (MCI), satellite communication, distributed database system, database synchronization, e-Triage, human factors, stress, user interface.

INTRODUCTION

Mass casualty incidents (MCIs) normally overwhelm the regularly available rescue resources in terms of rescue personnel, transport vehicles, and hospital capacity, so that a particularly effective crisis management has to be applied. For this operation controllers and decision makers need a common operational picture as quickly as possible, so that capacities can be planned and each affected or injured person gets optimal care.

Paper-based triage and registration systems for MCI organizations are still state-of-the-art because they are robust and their usage is intuitive. Nevertheless the main drawback is that information about affected persons remains among the persons themselves, making disaster management considerably more difficult. Data can be duplicated/aggregated by manually copying triage tags only, which is a laborious and time-consuming manual process, and the normal medium for exchanging information are voice-based radio systems.

Besides tracing single persons passing the different stations of the rescue chain is practically not possible.

In general, for an operation control it is a challenge to get an immediate and accurate situation overview (i.e. number of victims, categories and their location) automatically leading to sub-optimality in deploying (additional) forces. Indeed, triage and registration performed at different places by different teams maintaining different lists which in turn have to be sorted manually is indubitably an error-prone approach. Furthermore, it can happen that all later attempts to track the way of single patients, their attendants and transport vehicles are

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not very successful, although this could be of key interest in scenarios with nuclear, biological or chemical hazards.

An important issue to be pointed out, too, is the fact that the majority of civil rescue forces consists of volunteers who – although being well skilled – usually have only little experience with large scale emergency situations or disasters and who operate not as strictly in a hierarchy as for instance armed forces do.

E-TRIAGE SYSTEM OVERVIEW

Within the e-Triage project an integrated concept for electronic registration of affected persons is under development. The approach consists of four main elements: autonomous communication infrastructure, electronic data recording, a distributed database system, and psychological acceptance research. In more details, the e-Triage system comprises a satellite-based communication system with terrestrial radio cells that can be installed in the operation area, matching end devices with dedicated application software for the registration of victims, and a distributed, self-organizing and self-synchronizing database system guaranteeing maximal availability without a single point of failure. (Donner, A., Adler, Ch., Ben-Amar, M., Werner, M., 2010).

Earlier works have already described concepts for and advantages of IT-supported MCI management, which can be applied not only to operations in the field, but also to emergency rooms of hospitals. A comprehensive overview can be found e.g., in (Nestler, S., Huber, M., and Klinker, G., 2009). Some of these system architectures include wearable sensors with wireless connectivity (e.g., Massey, T., Gao, T., Welsh, M., Sharp, J. H., and Sarrafzadeh, M., 2006; Gao, T. and White, D., 2006); others use radio-frequency identifications (RFIDs) in read/write mode (e.g., Nestler, S., Huber, M., and Klinker, G., 2009; Inoue, S., Sonoda, A., and Yasuura, H., 2008), which means that data is stored both in the RFID chip and transmitted from a handheld device to a database. Main differences between the e-Triage concept and approaches described in literature are:

- Sensors monitoring vital parameters of single patients might be a valuable tool in hospital environments, but for e-Triage the concept decision was to apply a simple classification scheme only.
- Triage tags (registration cards or coloured wristbands) are not used as data storage media. Instead, a triage tag is labelled with a unique identifier (ID) in different formats only (RFID, optical matrix code, human readable text).
- A distributed database system mapping IDs to persons is a key component of the approach. Not only hardware with optical/RFID scanners can be used to access patient data, but also notebook or desktop computers may be used for this purpose (with the database software running from external flash drives).
- User terminals are designed primarily for regular rescue services, so that in case of a disaster they are instantly available.

Maintaining technology for extreme situations only is for sure not a worthwhile approach. Instead, the e-Triage system is intended for a double-use, so that users are familiar with the devices from their daily work. The key idea is that ambulance cars are equipped with tablet-PCs, which are used for documentation: in Germany and other countries emergency physicians have to fill in a standardized paper form about anamnesis, diagnostic findings, description of injuries and diseases, temporal development of vital functions, and medication. This sheet is delivered together with the patient to the destination hospital. Electronic data acquisition allows an early (wireless) notification of the destination hospital before or during transport of the patient, and thus, additional time for preparatory activities.

In case of an MCI regular ambulance cars are very likely the first ones to arrive, and the graphical user interface of the tablet PCs is switched to a very basic mode since MCI organization requires in its initial phase only a very compressed subset of data about each affected person. A unique ID plus triage classification, possibly metadata like Global Positioning System (GPS) coordinates and a photo are sufficient for operation control to effectively deploy forces. At subsequent stations of the rescue chain more detailed data may be acquired (e.g., at the casualty station name, gender, residence, etc), but this is optional and not time-critical.

PSYCHOLOGICAL (HUMAN) FACTORS

Apart from the technical challenges the degree to which emergency forces accept the e-Triage system will depend primarily on psychological factors. A pre-emptive design of the technology, which accommodates the reduced cognitive abilities of emergency personnel operating under extreme stress, is crucial for a successful deployment.

The attitude towards technologies is influenced by personal failure, convenience and the ambiguity human vs. machine. The decision to accept the new technologies is determined by factors such as usability and first impression of the hardware. Relevant persons with and without experience using similar systems were interviewed. GABEK® WinRelan® (Zelger, J., 1999, 2008) was used for analysis. The GABEK method ("Ganzheitliche Bewältigung von Komplexität" – holistic processing of complexity) is a qualitative research method and is being used for detailed description and explanation of "problem situations" or for the step of analyzing field impressions, meanings, attitudes, experiences, and values. Conceptual networks, causal graphs, relevancy lists, and evaluation profiles enabled us to identify relevant topics like reliability, system stability, user-friendly surface with reduced complexity, communication processes, …) and problems (so as ignorance, anxiousness, uncertainness, knowledge about using technical applications based on private experiences, less experience working at disasters, organizational problems in MCIs, communication in MCIs with reduced communication infrastructure, …) as well as aspects for designing (so as reduced complexity for end user, different end user groups need different software products) the product (hard- and software). The perceived benefit for the user is determined by the belief that new technology will improve personal achievement. The results were integrated into the further development of the database, the software application, the electronic data recording as well as the communication infrastructure.

Think Aloud Protocols (Buber, R., 2007) were conducted while end users tested four possible end devices to find out the most usable one for e-Triage. The protocols were analyzed and evaluated with GABEK® WinRelan® by using conceptual networks. The results were crucial, finding the right end-device, which is being used for the next testing steps for graphical user interface and database programming etc.

The reluctance to use technology-related products was measured by a technophobia scale (Sinkovics, R. R., Stöttinger, B., Schlegelmilch, B. B., and Ram, S., 2002). The survey (254 ep) shows that the users are loading more low levels so that we can say they are more technophile than technophobe. Only the factor human vs. machine ambiguity is loading higher. Letting machines dominate the interaction is awkward and the user has critical distance against technology (Adler, T., Jakob, L., and Krüsmann, M., 2010).

Using KATKOMP, a category system for analyzing communication structures (Stempfle, J. and Badke-Schaub, P., 2002), while observing several trainings exercising MCIs with triage gives an impression of the flow chart of MCIs, the different responsibilities, and used communication tools of the rescue personnel (medical doctors, rescue personnel, paramedics, squad leaders). Communications in an MCI need cooperative work, coordination and strategic decisions as well as harmonizing differing knowledge finding shared situation awareness. Communication is often disturbed by the topography, wrong addressed or forgotten information, and transcription errors from written systems into technical systems.

Increasing users' safety and security means finding the right way of using the new e-Triage technology. Therefore a distinction of user interfaces for different user groups as rescue personnel, doctors, hospitals is as necessary as differentiations between disaster, mass casualty incident and emergency. Facilitating the extreme stress in a disaster, an MCI needs a data acquisition system reducing complexity as much as possible. Finding obstacles through different qualitative and quantitative methods and implementing solutions in new technology are necessary to raise acceptance of innovative products.

E-TRIAGE SYSTEM – ACTION SAFETY

An electronic registration system for MCIs requires wireless communication services, and since local infrastructures may not exist at all or can be destroyed, it is of paramount importance that at least a temporary communication system is set up. Even if a functioning network exists it is most likely already saturated by the affected persons using their mobile phones. Furthermore, rescue operations can be considered as spatially and temporally distributed events (e.g. arriving rescue forces, geographic extension), which an electronic system has to be able to cope with.

Communication Technologies

During a rescue operation two different areas can be defined: the on-site segment with rescue forces in the field and the disaster-safe segment with remote coordination facilities. Both segments can be connected using a backhaul communication solution: terrestrial or satellite. In case the backhaul technology is not available, the on-site communications are still possible locally. The envisaged communication system restores the necessary networks in the on-site segment and connects them to the disaster-safe area. The relevant terrestrial network services to be backhauled are IP telephony, GSM, Terrestrial Trunked Radio (TETRA) and Wireless LAN. The chosen satellite technologies are Inmarsat BGAN and a commercially available Ku-Band/VSAT (very small aperture terminal) system. On the one hand, Inmarsat BGAN has an advantage of being globally available, which is not the case for many other satellite communication solutions (at least at the present time). On the other hand, Ku-Band/VSAT-based terminals support higher bandwidths at the price of more bulky terminals and antennas. The main goal of the e-Triage communication system is to allow the synchronization of the databases located in the on-site segment and disaster-safe areas. Additionally, voice services of IP, GSM and TETRA telephones will permit coordination of the rescue forces working in the field.

The BGAN-based system uses lightweight and rapidly deployable technologies. It is built in a small suitcase, which can be carried by one person and can be deployed within minutes. The prototype is 56 x 35 x 23 cm and contains a battery pack for a few hours runtime. A more powerful system is under development for use in mobile command centres, which is based on Ku-Band/VSAT satellite technology and which offers more capacity at the cost of increased set-up time.

Data Management

The e-Triage system does not use a fully centralized data storage approach because of reliability and availability considerations. The underlying storage technology is a distributed database system (DDBS) which has to cope with a variety of different network technologies including terrestrial wireless and satellite as mentioned above. A basic assumption for the design is that, on the one hand, the network topology might change at any time. On the other hand, all involved communication links are not reliable so that intermittent network outages might occur (e.g., end devices leaving the coverage area of the locally installed radio cells).

Nodes of the DDBS are installed in all mobile user terminals (tablet-PCs), at communication nodes, and in the disaster-safe area. The DDBS has to discover joining and leaving nodes and (re-)joining nodes have to be synchronized with the core DDBS.

The key advantage of this architecture is that a possible (intermittent) network link interruption (e.g., caused by leaving the coverage area of a radio cell) is addressed as central design aspect. Even with no network connectivity at all, it will be possible to synchronize database nodes by exchanging USB memory sticks.

User Interaction and Security/Confidentiality

There are different types of users of the e-Triage system ranging from teams in the field performing the triage to local and remote operation controllers.

A key design rule for the user interfaces is that users always get adequate feedback within reasonable time. If a user interface requires potentially complex actions (e.g., triage algorithm), then ad hoc support is offered. Each application will include a multiplicity of error prevention, ranging from a check of the right format of date and time fields to the verification of the formal logic of the users input. In the envisaged system each error message will be explained in the user’s subject-specific-language, so that the user is not confronted or annoyed with any technical overhead.

Specific data (e.g., GPS location) is saved automatically, so that automatic reports can be generated. The software supports different user functions on the basis of role management (e.g., initial triage, second advanced triage, squad leader etc). A user interface for a novice user will be designed in a way so that every button and input field is self-explanatory, whereas advanced application windows will be only accessible for expert users having passed an extensive training on the system.

Each evaluation version of the user interface will go through different field trials, arranged by the project consortium.

The users in the remote/ disaster-safe area will use a normal computer which is connected to the Internet. Since operational command centres and rescue force leaders need timely information about type and number of injuries, a secure service oriented reporting system is under implementation, so that each affected or injured person gets the right care at the right time. e-Triage is based upon a service oriented architecture which was chosen to give the system a maximum of adaptability to other systems.

For processing highly sensitive patient data it is absolutely mandatory to address confidentiality requirements. e-Triage local on-site applications implement programmatic authentication, requiring the user to explicitly supply credentials, which are then validated using the local operating system security. The users in the remote area, namely hospital personnel or control centre operator are authenticated through web-based mechanisms when they connect to the web server. e-Triage uses the approach of authorisation through roles. Various roles are created for our system and access rights are assigned to these roles instead. When each party is authenticated, the credentials applied to the party are mapped to the party's role, which then determines whether or not the party is authorised to access a particular function. It is ensured that the sent messages stay private, because they are routed through secure channels on the remote area and encrypted on the on-site. Auditing (internal and external monitoring) is used by each application on the mobile end device, the communication suitcase and the remote area.

CONCLUSION

This paper has given a brief description of the e-Triage research project, in which an electronic registration system of affected persons after a MCI is under study. The system is designed to be used in large disasters as well as for regular rescue services. Tablet PCs with optimized graphical interface software are used in the field to register patients, and the acquired data is transmitted automatically either by means of existing and available terrestrial GSM/UMTS cellular networks, or by means of autonomous radio cells which are connected to core data and telephone networks with satellite links. With this approach operation controllers, decision makers and hospitals have timely access to the same level of information so that a common operational picture can be developed. For different users different graphical user interfaces are developed, which helps to handle the work under extreme stress.

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