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Using Mobile Hand-Held Computers in Disasters

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Abstract This paper discusses the design and prototypical implementation of a mobile user-interface to assist paramedics in disaster operations based on the mSTaRT triage algorithm. Due to the increasing use of algorithms in the disaster management the introduction of mobile hand-held computers stands to reason. The triage algorithm has been implemented on hand-held computers and tested in a disaster control exercise to evaluate its functionality in real situations.

Since mobile, computer-based triage systems for paramedics must not delay the care taking procedures, the major indicator to measure the performance was the time needed by the proposed system as opposed to current paper based methods. The evaluation results were positive.

Keywords Ubiquitous Computing · Mobile Healthcare · Disaster Management · Triage

1 Disaster management

In recent years, disasters in which people are hurt or die have occurred in high frequency. There are many causes for potential mass casualty incidents (MCIs): natural disasters, traffic accidents, as well as terrorist attacks. In MCIs the number of injured needing care exceeds the resources available to provide care. Therefore, in MCIs, relief units have to perform so-called triage processes in the first step prior to starting relief efforts. During the triage the severeness of all patients' injuries is estimated. Resulting classifications are shown as colored triage tags which the relief units attach directly to the injured. The triage is very time critical. Therefore the triage of one victim may not last longer than 45 seconds.

Instead of acting upon subjective intuition, the paramedics use triage algorithms guaranteeing more impartial decisions, for example the STaRT[1] or the mSTaRT[2] algorithm [1]. These triage algorithms use 3 to 4 categories to classify the injured plus one further category for dead people.

1.1 Reasons for using hand-held computers in disasters

Due to the increasing use of well-defined triage algorithms the introduction of mobile devices stands to reason. The digitalization of the currently paper-based triage algorithms has the advantage that the system guarantees a traceable step-by-step execution of the triage algorithm. In addition to the triage result the path through the triage algorithm can also be relayed to later relief units. The involved fire fighters and paramedics have stated that they welcome digital recordings of triage situations since such documents help them comply with their responsibility to document all actions. These recordings from the early stages of disasters can be useful later on to analyze how the process evolved throughout a – possibly unpredictable – chain of events.

Furthermore, the transfer of information between the relief units and the control center can be simplified and sped up once the triaging information is available in digital form, since it is no longer necessary for the relief units to personally bring the triage results back to the operation control center. Moreover, the introduction of hand-held computers enables the use of further technologies such as cameras or GPS in the future.

1.2 State of the art

Thus far, disaster triaging has not been much supported by electronic means. Current procedures are primarily based on paper-based communications[3]. In the hospital

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[1] Simple triage and rapid treatment
[2] modified STaRT
[3] e.g. tags and scribbled-down histograms on note-pads

environment, especially in some emergency departments, some prototypical triage programs have been developed.

Dong et al. have presented a novel computer triage program which has reached remarkable results when comparing it to standard triage [2]. Their approach considers the triage in well structured clinical environments. It is based on stationary devices which do not facilitate a mobile registration of the patients. A mobile recording of patient information was proposed by Skov et al., who designed a mobile patient monitoring system, including portable audio and video capabilities [3]. They identified numerous usability problems, especially concerning context-awareness. The system had to react to environmental changes and, in some cases, such context switches disturbed the planned interactions with the users. In other respects, this system also focused on the hospital environment. This environment is expected to be more stable and predictable than disaster environments.

In a-priorily known environments, such as hospitals, it is also possible to make interaction fit seamlessly into everyday activities as proposed by Tap et al. [4]. They developed a paper-based system for haemodialysis monitoring and focused on the interactional features. The proposed system is based on the paper Technology of Anoto, which facilitates a digital recording of annotations made on paper. The Mobile Emergency Triage (MET) system is another clinical system which supports the emergency personnel in making triage decisions [5]. While Michalowski et al. focus on the user-interface design, the interaction with the proposed user-interface is quite proprietary in the interaction possibilities as well as concerning the information visualization.

The existing prototypes focus on stable clinical environments, which differ significantly from unstable disaster environments. In order to design a mobile triage system supporting paramedics who are working in disaster environments, a disaster specific requirement analysis has to be performed. The urgent need for further improvements in disaster management has been stated by Mann et al. in their state-by-state survey in 2002 [6]. Arnold et al. also claimed that effective disaster response requires systems for information-sharing that enable responders to rapidly collect, process and contribute information [7]. Nevertheless, no current system is suitable for effective use in disaster environments.

2 Requirements

The demanding time restrictions for the triage process led to the requirement that a single triage process performed on the hand-held computer may not exceed 45 seconds. Otherwise the relief workers would be hindered by the introduction of a technical system and slowed down during their triage work. Another requirement is that the technical system presents only the relevant information in every step of the triage process. On the one hand presenting the user plenty of information will distract him from focusing on the essential. On the other hand too sparse information may lead to wrong decisions. The decisions themselves, however, may not be performed by the technical system autonomously.

Furthermore, any data which has been successfully stored on the hand-held computers may not be deleted during a disaster scenario. Every decision having been made by the relief workers during the triage process has to be traceable. Last but not least, it is required that the hand-held computers can also be used by paramedics who are usually wearing gloves during the triage process. In a disaster environment, it is too cumbersome to use the pen of the hand-held computer for the interaction.

3 General System Design

The unambiguous mapping between the patients and their records is crucial for the sound functionality of the system. This is not a trivial task in disaster scenarios, since patients and paramedics move about very dynamically, and triage processes may be interrupted due to unforeseen events of high priority.

The quick and precise identification of the victims can be done using bar codes or RFID[4] chips. Due to the fact that bar codes are already printed on the current version of patient tags, our prototypical solution used the bar codes for mapping the patients to their records. The continuing use of the standard triage tags moreover guarantees backward compatibility. The triage result can also be checked by teams working without mobile devices. There are also possibilities to work without the standard triage tags, by using image based methods for example.

In order to help the paramedics concentrate on the essential, in every triage step only the information needed for the specific decision is shown. The involved doctors emphasized that previous decisions must not influence the current decision. Therefore it is sufficient to show only those decisions which can currently be made at that point in time and to visualize only their direct consequences as shown in Figure 1.

A hand-held computer which can be used by paramedics who are wearing gloves has to offer larger buttons than typical applications for hand-held computers. This requirement limits the number of possible interactions significantly, since the screen size of hand-held computers is very limited [8].

4 Prototype implementation

Our current prototypical implementation focuses on evaluating the core question, whether paramedics will or will not be slowed down by using a hand-held computer. To

[4] Radio Frequency Identification

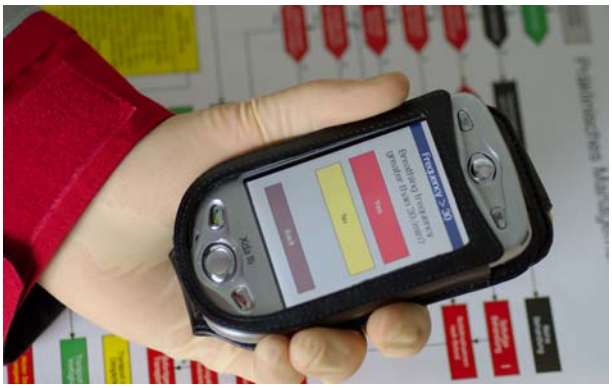

Fig. 1 On the hand-held computer only the decisions which are currently possible are shown as opposed to the paper algorithm where further information is available

this end, we currently do not consider all the interesting options (GPS, photographing the injured) which are possible when hand-held computers are used for disaster triage. Due to the fact that hand-held computers have never been used during disaster triage processes before, first of all the core question has to be evaluated. This evaluation – should the result be positive – represents the basis for further work which will focus on additional functionalities, such as peer-to-peer networks, precise localization and fast registration.

The hand-held computers contain a complete implementation of the mSTaRT-algorithm. The algorithm can easily be extended or changed via configuration files if different algorithms have to be used on the mobile hand-held computers.

In addition to the mobile user interfaces, a simple stationary user interface was implemented for the control center to show prospective advantages as a means of continuous communication between the relief units and the control center. The stationary system provides all relevant information and presents them in a concise way. After the first data transfers the stationary system is able to provide an overview of the situation, based on the triage results and processes.

The information available on the stationary system in the operation control center is also available on the mobile hand-held computers. Due to the smaller screens of the hand-held computer the displayed information must be reduced and thus presented concisely [8]: The mobile triage teams do not have to get an extensive overview of the complete disaster environment, but rather detailed information about the patient they are standing in front of. We were able to show all relevant details concerning one single patient on the small display of the used hand-held computers.

5 Evaluation design

The number of fire fighters, paramedics and patients needed for this evaluation depends on the quantity of triage processes required for the evaluation and on the level of realism. The more triage processes have to be performed, the more patients and paramedics are needed. In disaster control exercises with high realism every patient is triaged only once. This disaster control exercise, however, was performed with marginal realism concerning the quantity of triage processes per patient in order to increase the number of triage processes.

We selected 12 subjects with paramedical education for the evaluation of our mobile user interfaces. Every team consisted of two paramedics, one giving triaging instructions and the other one examining the patient accordingly. Different teams obtained the course of instructions either from the paper-based algorithm or from the hand-held computers. A total of 6 mimes were examined this way. Afterwards, the mimes changed their appearance and behavior to new patient types [5], and the paramedic teams conducted another round of triages. In this second phase, teams who previously used the paper-based version, switched to the hand-held computers, and vice versa.

6 Evaluation results

The 12 paramedics who evaluated the developed hand-held computers were asked to rate our approach in a questionnaire. The average age of the 8 subjects who finally participated in the survey was 34.4 (RMSD: 4.6), they were all male, all of them were paramedics. The portability of the hand-held computers was rated positive, there had been no problems to take these mobile systems to the patients. As far as the handling of the devices was concerned, no clear trend could be determined. The subjects were neither dissatisfied nor content with the handling. This indicates that it may be possible to further improve the handling. Readability was a question which had been intensively discussed before the evaluation. In the questionnaire the subjects rated the readability very positively. The distraction caused by the use of hand-held computers was quite low, the subjects had no problems to concentrate on the triage task. The results concerning the time and the intuitiveness were also not significant. This part of the evaluation shows no negative trends. The lack of positive results already shows the still remaining space for improvement.

In addition to the subjective questionnaire we have conducted an objective evaluation, measuring the time needed for every single triage process that was performed during the disaster control exercise. Although the teams

[5] The overall distribution of difficulties, however, was similar

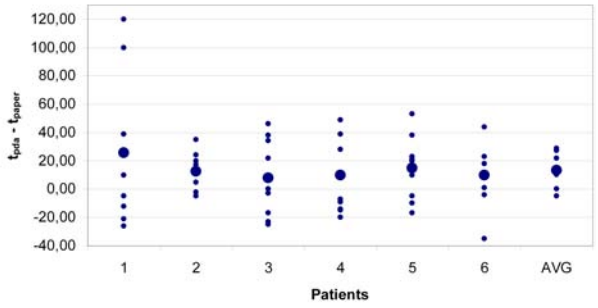

Fig. 2 Additional time need per triage process when using hand-held computers instead of the paper based approach.

always strove to triage the patients as fast as possible, the teams needed about 13 seconds longer when using the hand-held computers (AVG: 39, RMSD: 26) than when using the paper based approach (AVG: 26, RMSD: 17) as shown in Figure 2. The fact that the first triage process with the hand-held computers took substantially longer time is eye-catching. We did not train the paramedics during the preparation phase; the evaluation results, however, show that training can decrease the time needed for the triage processes extensively. The average time required for the 2nd to the 6th triage process is 5 seconds lower than the average over all six triage processes.

The next disaster exercise will include training in the preparation phase. Therefore, we expect that the time when using the technical system approximates the time when using the paper algorithms. We would like to stress, however, that the limit of 45 seconds has not been exceeded on average. Consequently, the mentioned requirement concerning the triage time was fulfilled by this developed prototype. Although the introduction of mobile hand-held computers in the disaster environment is challenging, we succeeded in developing a first suitable prototype.

7 Conclusions and Future Work

The paramedics and doctors who where involved in the disaster control exercise are convinced of the advantages of technical triage solutions. The next step is to extend the capabilities of the mobile triage units and to evaluate them regularly in further disaster control exercises. When extending the functionality of the mobile triage units, the concept of defensive and careful data acquisition must be extended as well. The aim of the technical systems is the assistance of the triaging relief units and not the obstruction of the relief units by demanding continuous attention. There are quite a number of issues that need to be considered before hand-held computers can be deployed in real outdoor settings. This paper did not study the dependence of hand-held computers on environmental conditions. The readability of the hand-held computers might depend on the ambient illumination. The glare of the sun might lead to reading problems as well as darkness might influence the readability. Extreme weather conditions such as rain, snowfall, frost or heat ask for the usage of weatherproof and robust hardware. Furthermore, the reserve energy of the hand-held computers must last during the complete disaster. As disasters differ significantly from everyday life, mobile solutions designed for the use in disaster environment will also significantly differ from existing technical solutions. Nevertheless, this paper tried to show that the use of hand-held computers in disaster areas is possible, provided that the requirements analysis takes the specific disaster environment into account and the system attends to these requirements. The further steps will be to find out how extensive a network between all the relief units working in disasters can be established, a localization of the triaged patients is possible and how the patient records can be stored more efficiently.

The long term contribution of the proposed prototype and its successors is not to avoid disasters, but to increase the chances of survival of the involved victims by providing a more efficient resource allocation.

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