Indirect Tracking of Patients in Mass Casualty Incidents

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Abstract:
In MCIs (mass casualty incidents) patient tracking is cumbersome when using paper based approaches. Due to the fact that the spatial positions of the patients are essential in MCIs, we equipped the relief workers with electronic devices. We analyzed two concepts for patient tracking: direct and indirect tracking. The indirect tracking turned out to be superior with regard to the requirements from Feuerwehr TUM (Technische Universität München). An implementation and evaluation of this concept was performed within the scope of the *SpeedUp* project[1]. This project focuses on the development of strategies for reacting in mass casualty incidents (MCIs) in an appropriate way. In this paper we describe the background, the requirements, the concepts, the implementation and the evaluation. Finally, the results are presented and discussed.

1 Background

In MCIs (mass casualty incidents) tracking of patients and relief workers is essential for the success of the crisis response. Tracking is the basis for presenting spatial information on mobile user-interfaces [NK07a]. Concepts for supporting the collaboration between relief workers and incident commanders have been discussed in [NEDK08] and [ENDK09]. General concepts for facilitating an overview in time-critical, life-threatening and unstable situations were presented in [NDP+09].

The first relief workers at the scene initially perform the MCI triage. Recording the patients' positions during triage is cumbersome when using paper based approaches. Nevertheless the spatial positions of the patients are essential for the organization of the crisis response [GHZ+06]. As soon as electronic devices are used by the relief workers in MCIs, the tracking of patients can be simplified a lot. In the past we performed different evaluations on the benefits of assisting relief workers with mobile devices, which have been

[1]The project SpeedUp is funded by the German Federal Ministry of Education and Research (BMBF) within the programme "Research for Civil Security" (May 1st, 2009 - April 30th, 2012, FKZ: 13N10175). Website: http://www.speedup-projekt.de

published previously: [NK07b], [End09] and [Pic09]. These publications focus on usability aspects of computer assisted triage. In this paper we show a complementary feature – the benefits of patient tracking for the incidents commanders.

Different publications deal with the usage of GPS tracking for rescue operations. The *Emergency Management System* from [RNSH09] uses direct tracking by equipping (1) incident commanders, (2) patients, (3) doctors and (4) relief workers with mobile devices. The research project *GÜTER* uses a GPS system for supervising transport routes. In the case of an MCI the spatial information is communicated to the relief units as described by [KHLP07]. In [SDL$^+$07] an approach to simplify the dispatch of ambulances by using GPS tracking is presented. Furthermore, the tracking of all ambulances simplifies the optimization of the overall spatial distribution as discussed by [Hil06]. By tracking the position of emergency calls both, misuses and mistakes, can be significantly reduced according to [GBD05]. Furthermore, [SM06] is confident that GPS and video data can be transmitted from the emergency caller to the control center in the near future.

2 Requirements

In order to facilitate a better assignment of relief workers, the tracking of the patients has to fulfill certain requirements. These requirements have been identified in collaboration with Thomas Schmidt, deputy fire chief of Feuerwehr TUM (Technische Universität München)[2]. We identified five basic functional requirements: **(F1)** The position of the relief workers has to be gathered automatically in order not to distract them, **(F2)** it has to be possible to explicitly initiate the positioning of a certain patient, **(F3)** the completion of the patient's positioning has to be done automatically, **(F4)** the patients' positions have to be transmitted to the incident commanders over the wireless network and **(F5)** grouping on the basis of the tracking information has to be possible. Additionally we identified three non-functional requirements: **(N1)** the solution has to be scalable, **(N2)** the system has to be cost-effective and **(N3)** the maintenance efforts have to be low.

Furthermore, the Feuerwehr TUM had two remarks: **(R1)** The possibility to extend the patient's position with additional information (e.g. triage category) would be useful and **(R2)** the relief workers would benefit from a visual feedback whether the acquisition of the patient's position was successful.

3 Concepts and Implementation

This section analyses two concepts for patient tracking: direct and indirect tracking. Direct tracking determines the patients' positions by attaching devices to the patients. Indirect tracking deduces the patients' positions from the positions of the relief workers. The indirect tracking bases on the assumption that patient and relief worker are very close to

[2]The 60 employees of Feuerwehr TUM are responsible for the research center in Garching, working in three shifts with twenty-four-seven service

each other when the relief worker performs the MCI triage.

When using direct tracking the accuracy **(F5)** is ideal, the explicit initiation **(F2)** and the transmission of the positions is possible **(F4)**. In order to track the relief workers **(F1)**, they can also be equipped with GPS receivers. However, the scalability **(N1)**, cost-effectiveness **(N2)** and maintenance requirements **(N3)** are poor for direct tracking. Extending the paper based patient tag with an GPS receiver and a wireless communication unit raises the price per tag tenfold to hundredfold. These increased costs as well as the necessity to use power supplies reduces the scalability of the solution. When using the indirect tracking, the scalability **(N1)**, cost-effectiveness **(N2)** and the maintenance requirements **(N3)** are ideal. Due to the fact that relief workers are equipped with GPS **(F1)** and wireless communication **(F4)**, these two requirements can be fulfilled as well. In order to provide an explicit initiation **(F2)** and an automatic completion **(F3)** a basic user-interface is needed for the relief workers. The most critical requirement for indirect tracking is **(F5)**. The fulfillment of this requirement can only be completely proven by an evaluation within an MCI exercise. By extending the basic user-interface the input of additional information **(R1)** and the visual feedback **(R2)** can be supported as well.

This short examination shows, that the indirect tracking is more likely to fulfill the requirements from Feuerwehr TUM. Therefore, we realized a prototypic implementation of the indirect tracking and evaluated it in an MCI exercise. The implementation was done in C#[3] on handheld devices with *Windows Mobile*[4]. The result of the implementation is shown in Figure 1 and described in detail in [Pic09].

Figure 1: Indirect tracking of patients with *Windows Mobile* handheld devices

4 Evaluation

The evaluation is of central importance to prove that the requirements are fulfilled, especially the requirement on tracking accuracy (F5). The evaluation of the tracking accuracy was performed within the scope of an MCI triage training at Feuerwehr TUM. In summary 36 people were involved in the evaluation: 10 mimes, 16 relief workers, 4 supervisors, 2

[3] http://msdn.microsoft.com/de-de/vcsharp/default.aspx
[4] http://www.microsoft.com/windowsmobile/de-de/default.mspx

technical coordinators, 2 training coordinators and 2 photographers. The scenario of the evaluation was the following: On a highway an accident with four involved cars has happened. Three severely injured patients are in each of these cars. The cars (A, B, C and D) were spread over an area of 10 meters x 50 meters. Eight teams performed the MCI triage with three different types of mobile user-interfaces and the paper-based approach. In summary 32 MCIs were trained by the relief workers, in 24 of these MCIs tracking data could be collected for the 12 patients. Theoretically 24 x 12 = 288 patient positions could be generated during the whole evaluation.

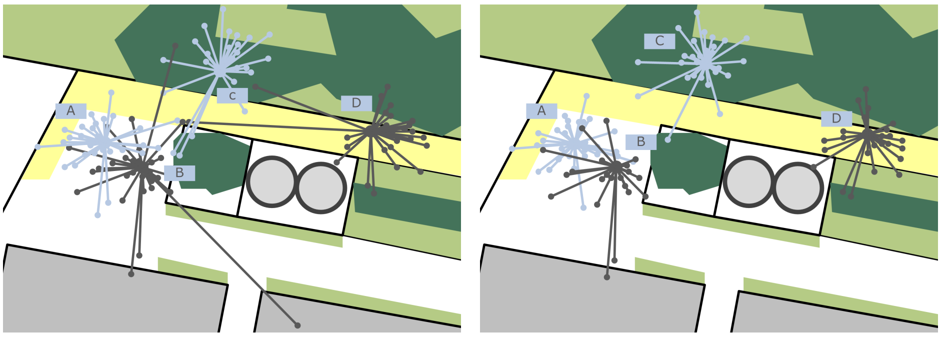
Organizational challenges as well as some technical challenges occurred during the evaluation. The technical coordinators were able to solve most of these technical issues in order to guarantee a proper course of the training. Due to the fact that low-budget handheld devices were used in this evaluation the batteries had to be changed several times during the training. The coupling of mobile handheld devices and GPS receivers via Blutooth turned out to be not that robust. In future evaluations ruggedized handheld devices with integrated GPS receivers will be used to avoid these hardware problems.

5 Results

In the MCI scenario the relative accuracy is more important than the absolute accuracy. Assumed that all GPS receivers have a divergence of 100 meters in the same direction, the relocation of patients is still possible. In the case, however, that one device has no divergence and all other devices have a divergence of 100 meters in the same direction, the relocation of patients is no longer possible. In the evaluation the positioning of the patients was only possible when the GPS receiver had a signal during the initiation of the positioning process. Instead of the mentioned 288 patient positions only 252 patient data sets were created and only 193 patient positions were relayed. There are three reasons for the reduced number of positions: (1) technical problems with the device, (2) technical problems with GPS receiver and (3) problems with the triage workflow. Some relief workers just forgot to initiate the positioning process and no patient position could be stored in the system.

The accuracy of the indirect tracking was influenced by three factors: (1) Influence of the indirect approach, (2) influence of the specific GPS receiver and (3) influence of GPS itself. The video recording of the evaluation showed that the relief worker is often not that close to the patient when initiating the positioning process. Regarding the influence of the specific GPS receivers significant differences between the three GPS receivers could be identified. Due to the fact that only the relative position is relevant, the median was calculated from all positions for each vehicle and all divergences were calculated relatively to the median. The mean divergence is 6,71 ($\pm$ 7,31) meters, the highest divergence is 43,5 meters as shown in Figure 2(a).

When analyzing the different devices isolated, the most inaccurate device has a mean divergence of 11,05 ($\pm$ 7,31) meters. The other two GPS receivers have an isolated error of 4,86 ($\pm$ 3,79) meters or rather 4,35 ($\pm$ 3,81) meters. The maximum divergence of



(a) GPS positions (all) (b) GPS position (corrected)

Figure 2: GPS positions of the patients and allocation to the vehicles

43,5 meters was also caused by the most inaccurate receiver, the other two receivers had a maximum divergence of 14,6 meters or rather 20,1 meters. An ANOVA[5] showed, that positioning is significantly ($> 95\%$) worse with the most inaccurate GPS receiver. The spatial illustration of the errors in Figure 2 demonstrate that no allocation to the vehicles is possible when using the positions from all receivers (Figure 2(a)). When excluding the inaccurate GPS receiver, however, as shown in Figure 2(b), an allocation to the vehicles is possible in cases when the distance between two vehicles is at least 25 meters. The patients of vehicle A and B are still grouped together.

6 Discussion

In summary three groups can be arranged on the basis of indirect tracking information: (1) Vehicle A & B, (2) vehicle C and (3) vehicle D. We discussed the results with Feuerwehr TUM and the grouping was considered to be ideal for three reasons: (1) regions are more important than vehicles, (2) A and B are within sight and (3) C and D are not within sight. In the future we have to analyze in what way the incident commanders can benefit from this indirect tracking approach.

The requirements could be fulfilled by the evaluated implementation in the following way: **(F1)** The positioning of the relief workers could be performed automatically, **(F2)** the positioning of the patients was initiated explicitly, **(F3)** the completion of the positioning was done automatically, **(F4)** the positions could be transmitted to the incident commanders – with the described limitations and **(F5)** grouping of patients is possible – assumed that only the most accurate GPS-devices are used. Furthermore, the scalability and cost-effectiveness is guaranteed by using low-cost RFID chips **(N1, N2)** and the maintenance efforts are low due to the fact that passive tags are used.

[5]The ANalysis Of VAriance (`http://www.statsoft.com/textbook/anova-manova`) tests whether the means of several groups are all equal

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