ZoneTrak: Design and Implementation of an Emergency Management Assistance System

Alexander Müller, Alireza Sahami Shirazi, Florian Alt, and Albrecht Schmidt

alexander.mueller@stud.uni-due.de alireza.sahami@uni-due.de
florian.alt@uni-due.de albrecht.schmidt@uni-due.de

Abstract. Though pervasive computing technologies are omnipresent in our daily lives, emergency cases, such as earthquakes, or fires often cause serious damages to the underlying infrastructure. In such cases rescue units rely on paper maps of the operation areas and important information are broadcasted either from a central unit or from other teams. This information is manually updated on the paper map, not only causing a lot of work but also being a potential source for errors. In this research we implemented a system that provides a positioning system to track forces and allows sharing information in real-time. Rescue units can annotate different zones and broadcast data to other units whose maps are automatically updated with available annotations. We show how such a system can be operated based on an independent infrastructure which makes it robust and reliable in emergency and catastrophe situations.

1 Introduction and Related Work

Nowadays, pervasive computing technologies are omnipresent hence facilitating many aspects of our daily life. In modern societies, mobile phones, Internet, and networked infrastructures help to ease communication, coordination, remote collaboration, and navigation. However, catastrophes such as natural disasters demonstrate the sensitivity of such environments to damage in the supporting infrastructure. On the other hand, emergency management in these situations is crucial. In traditional emergency operations each unit is equipped with a paper map of the surrounding area. Additional data, which are not available in the maps, are broadcasted through radio channels from a central unit and manually added to the maps. This approach is both time-consuming and error-prone.

With advances in technologies, especially in positioning and navigation systems, paper-based maps can be substituted with digital maps. The main advantage of such digital maps can be seen in their ability to be edited and updated using different information layers. A major issue of such a system is its reliability on resources such as computer networks which may be out of function.

In our research we explore how pervasive technologies, especially mobile phones, can facilitate emergency management even in situations, where infrastructures have been severely damaged or been completely destroyed. Modern mobile phones are equipped with keyboards, high resolution screens, and are often enhanced with different sensors such as GPS, and WLAN.

In this project we investigate how mobile phones can be used in emergency management operations. To do so, we identified requirements for emergency management organizations especially for the technical unit of Command, Control and Communication of the German Federal Agency For Technical Relief (THW). Two out of many responsibilities of this technical unit is to keep track of forces and coordinate operations. So we designed and implemented an emergency management assistance system, which supports these tasks by tracking positions of technical platoons, command squads, rescue and technical units in real-time using WLAN. When it comes to rescuing injured or trapped persons during emergency situations, one of the prevalent tasks is to ensure the safety of the rescue teams. One of the threats for such forces is lack of information about unknown positions and areas. Due to the fact that communication is inevitable during such operations, a robust positioning system has been supplemented with an annotation system used to annotate special areas and share information on potential threats. Annotations may include available threats in different areas (zones) and additional information from the central operation unit.

Researches in the field of emergency management or disaster relief so far mainly focused on providing a highly reliable adaptive assistance system for rescue in major incidents [1]. To push research forward, we propose to augment previously recorded strategic information with real-time information obtained during an ongoing operation. Therefore, we use methods to analyze communication and movement patterns as described by Pentland [2] and Raedes [3]. Pentland's research focusses on pattern discovery which can be used to determine deficiencies within organizations and even between specific units [2]. Reades described methods to analyze patterns in communication using Erlang data which maps physical positions and time to communication frequency[3].

While existing commercial systems[1] [2] mainly try to replace or improve traditional techniques, we propose to introduce pervasive computing technologies to increase safety of people while at the same time supporting a non-intrusive and reliable exchange of information among different organizational units.

2 Approach

Emergency management requires techniques, methods, and technologies which are highly reliable. However, widely available technologies, such as cellular mobile telephony and others are strongly relying upon existing infrastructure, making them unsuitable for use in emergency management. Our investigation on applicable pervasive computing technologies in emergency management showed that WLAN meets the demands for secure and reliable communication platform best even under difficult meteorological conditions.

In order to develop a reliable system, we used an interchangeable three/four-tier architecture consisting of a surveillance and management application, a middleware server for persistency, and a client application installed on mobile

[1] `http://www.emergeo.com/`
[2] `http://www.blackcoral.net/live/`

phones. For providing a positioning system an external map server is used to supply various information about an operation's location and to track / visualize positions of forces on the mobile client. The server uses map data from the OpenStreetMap project [3], which is a free and editable map. The mobile application reports the current physical position of units and new annotations to the middleware and the management application obtains all positions from a RESTful interface of the middleware server. Additionally, it acquires information from the middleware server and visualizes them on the map. Through the mobile application new annotation can be added to the map. Users can draw polygons to define different zones and they can add various information such as texts, images, and videos to these defined zones. The abstract architecture scheme in Fig. 1 demonstrates the distributed components of our system. To achieve robustness, we use WLAN connectivity only to establish a communication network and connect all tiers. This solution gives us this chance to setup a local network on operations' sites independent from any infrastructure.

The main role of the management application is to aggregate all kinds of data from available units in the areas and broadcast / share them among all teams based on responsibilities. We implemented the following extensions: (1) A major requirement in emergency management is to keep track of previous operations. It is particularly important to be able to analyze a non-static situation a-posteriori, so we implemented a method to replay the ongoing development of situations. (2) We developed several visual plug-ins, improving usual tasks such as route visualization, different visibility levels, and specialized view layers.

Being aware of the fact that emergency management organizations use traditional solutions for many years, we tried to make the system as adaptive and intuitive as possible for future developments. Its core functionality is based on the event aggregator design pattern, i.e. publish/subscribe and globally accessible objects by publishing them similar to events.

3 Interviews and Initial Findings

During a practice session of the cross-border pilot project on civil protection called EU USAR (Urban Search and Rescue) in Germany, we demonstrated the system and interviewed members of disaster relief organizations from different countries. We explained the system's functionalities and its application as an assistance system. We gathered valuable feedback which helped us to further improve the application and push the development further.

Most of the interviewed people encouraged us to push our research further and were interested in trying this system in a controlled exercise environment. However, some felt that certain features don't follow all terms and conditions of their nation's laws and regulations regarding emergency management. Their main concerns included annotations that can be misinterpreted and lead to wrong decisions, potentially insecure communication over WLAN, or features

[3] `http://www.openstreetmap.org/`

Fig. 1. ZoneTrak architecture scheme

of the system that could not be used due to lack of technology or budget. These responses support our expectations which led us to use a plug-in based management application able to activate and deactivate isolated components.

4 Conclusion

We presented a system supporting emergency management based on independent infrastructure. Through this system, units in operations have digital information about the surrounded areas, are able to annotate locations and can easily share them with the other units with the assistance of a mobile client. Results from interviews encourage us to continue the further development and deployment of the system. We envision that such systems, even with extended functionality, will be introduced in the near future. In oder to discover further application areas, we plan to use reality mining and field observations to get a more detailed insight into behavior patterns during emergency situations. Moreover, it will be possible to detect problems within disaster relief organizations such as a lack of communication between units.

References

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