Developing a System for Information Management in Disaster Relief - Methodology and Requirements

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ABSTRACT

This paper discusses our ongoing work on a system for collecting, managing and distributing relevant information in disaster relief operations. It describes the background and conditions under which the system is being developed and employed. We present our methodology, the requirements and current functionality of the system and the lessons learned in exercises and training, involving a large number of international disaster management experts. We found that the viability of this kind of tool is determined by three main factors, namely reliability, usability and frugality. The system has gone through many prototype iterations and has matured towards becoming operational in a specific type of mission, i.e. assessment missions for large scale natural and man-made disasters. This paper aims at making a wider audience of disaster management experts aware of that system and the support it may provide to their work. Other researchers and developers may find our experience useful for creating systems in similar domains.

KEYWORDS

disaster management, civil protection, information management, situation awareness, assessment, requirements

INTRODUCTION

Two trends are emerging in disaster relief missions. Firstly, international cooperation is increasing, which results in a need for close coordination and subsequently in a need for increased information exchange between organizations. Typically, governmental- and non-governmental relief organizations, either local or traveling from other countries, are participating in the relief operations. To harmonize the European response, the European Union started to improve the cooperation between the member states with its decision to create a “mechanism to facilitate reinforced cooperation in civil protection assistance” in 2001, aiming to provide structures and procedures for EU member states, while working together closely with the United Nations and its agencies.

Secondly, the amount of available information is nearly exploding. Satellite imagery from several satellite operators, vector data from sources like OpenStreetMap, or statistical data about the affected region are available, and the amount is increasing vastly during the relief operations. Data from multiple inputs, of multiple kind and quality has to be organized under time pressure and often adverse conditions. In consequence, specialized tools for information management have significant potential to support relief workers in their work.

STATE OF THE ART

Observing missions and exercises, we found that the adoption of modern IT-technology in disaster relief is fairly common and mostly pragmatic. Many relief experts are trained in using satellite communications and navigation in the field and very frequently employ readily available tools, such as Google Earth for obtaining aerial views and GIS functionality. Mostly standard office software is used for writing reports (Word, Excel), presenting situation overviews (Powerpoint) and in some cases for automatic synchronization (Groove). While these tools do support certain tasks, they are far from being adapted to the workflow and the working conditions in disaster management. As such, they lack tight integration of hardware and software that relieves the user from configuring and switching between components. In consequence, only a fraction of the potential to support relief operations is realized.

Reviewing Statement: This paper represents work in progress, an issue for discussion, a case study, best practice or other matters of interest and has been reviewed for clarity, relevance and significance.

Several projects and organizations have addressed the need for *integrated* tools to support communication and information management in disaster management. Among the most active of these projects is SAHANA (Careem, 2006). The SAHANA system is a web based application that supports the collection, registration and dissemination of data, such as involved organizations, missing persons, or available shelter. Offline synchronization of data is provided via exporting and importing database dumps. SAHANA uses Google Maps to provide a map view. Probably the largest project related to this topic has been carried out by the European OASIS (open advanced system for disaster and emergency management) consortium. This consortium has worked on a wide range of aspects with the aim to standardize the interworking of information systems used by emergency organizations (OASIS, 2005). Many proposed solutions assume uninterrupted internet connectivity in order to exchange data. Since networks are often affected by disasters, this assumption may be critically violated in actual deployment situations. Secure and reliable data exchange even under the condition of an *interrupted connectivity* is therefore crucial. Approaches such as autonomous data exchange in a peer-to-peer fashion and via mobile ad hoc networks are important to achieve reliability in the field (Capata, 2008; Faraotti, 2009; ESRIF, 2009).

METHODOLOGY AND DEVELOPMENT PROCESS

Integrated systems to support disaster relief operations in the field have only recently attracted significant interest in the civil protection and scientific communities. As a consequence, the knowledge base in terms of specific system requirements is still thin. Disaster management operations are domain- and situation specific and typically involve complex interactions of many actors in various roles. The insight and derivation of requirements obtained through user interviews or surveys therefore has its limits. In our opinion the involvement or even the participation in exercises and/or missions is essential in order to identify the relevant requirements. Close cooperation with assessment experts, logistics experts and other end-users throughout the development process supports rapid and target-oriented development, based on immediate user feedback and informal acceptance. In fact, we refined many of our initial ideas for functionality and features in the light of training missions and exercises we participated. This approach resulted in a strong demand for an evolving set of features.

Since the nature of missions and exercises is discontinuous, with highly intense activity for all actors over the period of a few days and often months between events, we had to define a development process suited for these temporal constraints. We have modified Boehm's well-known spiral model (Boehm, 1988) with the notion of an adaptive spiraling frequency. Following this Adaptive Frequency Spiral Model (AFSM), we perform an entire revolution through all three phases (definition, implementation, evaluation) within compressed time during high-frequency periods (Fig.1).

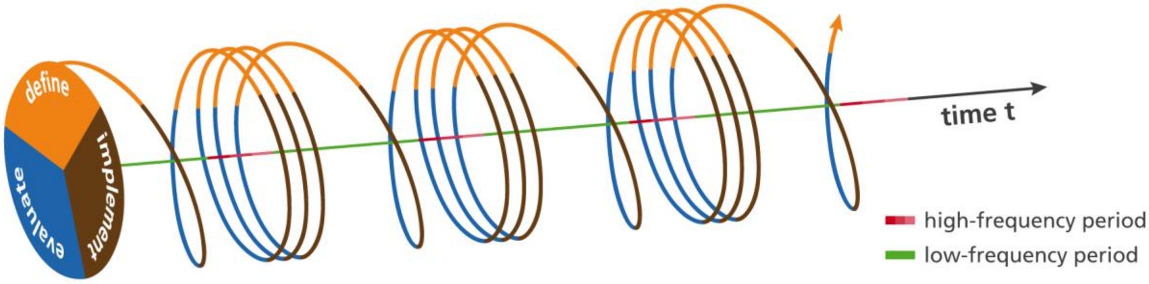

Figure 1. Adaptive Frequency Spiral Model (AFSM)

A high-frequency period is an exercise or mission during which new requirements are collected each exercise day and are taken into account for system improvements that are made until the next day, upon which they are immediately evaluated. This allows utilizing every exercise like a breeding reactor with an accelerated evolutionary process of selecting and shaping features and functionalities.

Prerequisite for successfully carrying out these high-frequency periods is a flexible and robust software platform with good support for user interface development, persistence, communication, sensor interfacing and sensor fusion. Nevertheless, only a subset of new requirements is suitable for the rapid prototyping during the short high-frequency periods. Therefore, the wealth of new substantial requirements is carefully catalogued and, next to long-term tasks like system design principles, are subsequently implemented during the low-frequency periods.

SCENARIO

The following example of a natural disaster shall illustrate the application of the system. The scenario is fictuous but resembles the situation after the earthquake on Haiti in January 2010. An earthquake of magnitude 7.0 with epicenter about 15 km south-west of the capital Port-au-Prince has caused severe damage and casualties. The local response capacity is exceeded and the Haitian government has requested international assistance. In order to obtain an overview of the situation and determine the needs in the disaster area, the European Commission sends an assessment team to Haiti. The team is composed of disaster management experts from different European countries: a civil protection and logistics expert from the Danish Emergency Management Agency (DEMA), a firefighter from Paris Firefighter Department and a civil engineer from the German Federal Agency for Technical Relief (THW). After the team is briefed and equipped in Brussels, it travels to Haiti. Upon arrival in the country, the experts immediately start to assess the situation, collecting information about damage, the need for water, food, medical support, shelter and the state of the critical infrastructures such as communication or electric power distribution networks. While the team members are well-trained civil protection experts, they also have to assess assets they lack detailed knowledge about, such as the airport's navigation equipment. The team reports back to its headquarters daily. Based on its findings, suitable relief teams and supplies are selected and sent to the disaster area.

REQUIREMENTS

The team has to collect, process and forward complex information in very short time. A useful tool would support its users in obtaining and managing the vast amount of complex information without requiring additional skills or team members and facilitate tight integration between the experts in the field, at the operational base and at headquarters. Based on the analysis of standards in civil protection (UNDAC, 2003), experiences from previous disasters (Townsend , 2006) and related work (DeLeoni, 2007; Blecken, 2008), as well as participation in EU's Assessment Mission Courses (AMC) and the feedback from disaster management experts, we defined a basic set of requirements for an information management system in the field of disaster relief. These requirements are divided into functional requirements which describe the behavior and provided services, and non-functional requirements which describe the characteristics for systems used in disaster management missions.

Functional Requirements

Data Management – The system has to handle geo-referenced information, such as points of interest (POIs), maps and vector data (polygons, lines, points) as well as other information, such as text documents or status information about other involved units. It has to offer report forms that support assessing specific objects like important infrastructures, such as airports or power plants. These forms help the assessment experts in the field to ask the relevant questions and communicate the facts to others.

User Interface – The User Interface needs to provide a situation map for visualization of all geo-referenced data, preferably by using a 3D globe metaphor, familiar to most users from Google Earth. The software should also be able to execute basic GIS functionality, like changing the order of maps or their transparency (e.g. to compare pre- and post-disaster maps). The globe should be the central visual element so that users can achieve comprehensive situation awareness and therefore all other interface components need to be arranged around it.

Device Control – The system is responsible for device control and sensor data fusion. To relieve the user from configuration tasks, the system must be able to manage additional sensors like GPS receivers, 3D compasses or network devices such as satellite terminals, automatically. Data from external sensors has to be processed, such as fusing data of several positioning sensors in order to increase the position accuracy.

Synchronization – The system needs to synchronize information among its instances. Such instances may be located in close proximity in the field or somewhere else in the world. Specifically, the system has to cope with sporadic network connectivity and opportunistically exploit connectivity whenever it becomes available.

Non-functional Requirements

Usability – The user works in a stressful situation, under high pressure and in an exhausting environment and is not a computer expert. The user should not be occupied by setting up and operating software, preventing him/her from mission-related tasks. In consequence the goal is to offer a simple and easy to use system while reducing any configuration effort as much as possible. Only essential functionality should be offered in order to minimize complexity. If configuration or setup is unavoidable, the system needs to support the user to do this.

Autonomy – Disaster missions are unpredictable with respect to the availability of any local infrastructure. Hence, the system has to be able to work autonomously. All vital functionality needs to be realized without a network connection to centralized components. Furthermore, electric power may not be available, at least for some time. The system has to bridge that gap with internal power sources.

Reliability – Basic functionalities need to work even if parts of the system fail because of unpredictable conditions or events (graceful degradation). To ensure the overall reliability of the system, releases need to pass through extensive examination, since system updates are nearly impossible during missions.

Integrity – Any decision making crucially relies on the integrity of the provided data. Therefore, the system needs to represent the reliability of the source (e.g. “completely reliable”, “usually reliable”, “unreliable”) and the credibility of the information (e.g. “confirmed by other source”, “doubtful”, or “truth cannot be judged”).

Interoperability – The system must be open to exchange information with other systems. Useful external data, such as already adapted information in Google Earth, ArcGIS or other related systems should be importable. Accordingly, the information gathered in the system must be exportable in a standard that can be utilized by other frameworks.

Frugality – Resources are generally limited in disaster relief, be it money for the involved organizations or resources like power, communication bandwidth or time during the disaster management operations. Hence, the system cost for acquisition and operation should be low. The system needs to implement an efficient and economic way to select the most favorable network link, as for instance satellite links cause high costs. The system should be robust against environmental influences while maintaining small dimensions and weight in order to ease handling and transportation.

IMPLEMENTATION

Performing many revolutions of the development spiral we have developed a system (Angermann, 2009) that fulfils the requirements given in the previous section. The system tightly integrates software and hardware components (tablet computer, BGAN satellite modem, GPS camera, etc.) and is currently undergoing final tests before being released for assessment missions (Fig. 2). The system has been specifically designed for usage by disaster experts without IT-background and includes a highly optimized user-interface and fully automatic synchronization.

name	visible
Larnaca Petroleum	☑
Nicosia Airport	☑
Asprokremmos Dam	☑
Pafos International Airport	☑
Pafos City Harbour	☑
Pafos City Center	☑
Pafos City Overview	☑
Cyprus west	☐
Cyprus east	☐

Altitude 3 km Lat 34.8880° Lon 33.6268° Elev 5 meters

Figure 2. Disaster Management Tool (DMT) Mapcase-Hardware and Demonstrator-Software screenshot

Our predominant paradigm to achieve utmost reliability is “graceful degradation”. This paradigm ensures continued usability in the presence of incomplete data, partial system or user failures. An example illustrates the concept: a digital photograph is imported into the system. Under ideal conditions the image is already geo-referenced (camera with GPS module). In this case the coordinate encoded in the image file is used. If no GPS coordinate is present in the image file (standard camera, or no GPS lock on the camera) the systems tries to obtain a position from the external GPS sensor attached to the system. If this fails, the coordinate of the middle of the map view is taken. In all cases the position can be modified manually. Similarly, synchronization between nodes is stepping down through various communication means, eventually storing information until connectivity becomes available.

CONCLUSIONS

To handle the growing amount of heterogeneous information in multinational disaster management operations, new tools have to be developed. In this paper, we presented the requirements for such a tool and the methodology we used to obtain them. The resulting requirements have been divided into two categories: The functional requirements describe how data management, user interface, device control and synchronization should be designed. The non-functional requirements result from a special focus on the extraordinary conditions in disaster management; these are usability, autonomy, reliability, integrity, interoperability and frugality.

Following these principles, we implemented a system called the Disaster Management Tool (DMT). While the system is now capable of catering to assessment missions or the assessment phase of a relief mission, its core has been designed to allow the tool’s functionality to naturally evolve into supporting subsequent phases and tasks, such as on-site coordination of multiple relief teams and in a more distant future into serving as a versatile and cost-efficient tool to coordinate among individual members of relief teams.

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