

COLLABORATIVE CRISIS MANAGEMENT FOR PROTECTING CRITICAL INFRASTRUCTURES

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Abstract

In this article we focus on the collaborative aspects of crisis management for protecting critical infrastructures. The reported work represents one of the key cornerstones of EU sponsored FP6 project MEDSI. The main objective of the project MEDSI is to design and develop a software infrastructure for supporting collaborative decision-making of crisis managers. The most important requirements are to enable data and information flow between different actors involved in the crisis management domain, and to unify data sources, geographical information and information about critical infrastructures. Within this context, we first elaborate and discuss ideas of collaborative crisis management in the fields of Geographical Information Systems (GIS), Geospatial interoperability and Symbology. Then, we present an example user scenario of flooding the city of Magdeburg.

1. Introduction

Nowadays, the complexity of the living environment of the western world has increased considerably. This is especially evident in terms of critical infrastructure. One negative consequence of the above trend is manifested in the fact that the society has become more vulnerable. The threats caused by terrorist activities and natural disasters are gaining importance with respect to the classical war threats. A new term of "asymmetric threats" was introduced that flourish the weak when there is a difference of interest between two antagonists [9]. Therefore, advancing the field of

crisis management for protecting critical infrastructures has been recognized as one of the top priorities in European countries [12].

Crisis situations are usually unpredictable and typically cause considerable damage and disruptions. When the scale of an incident outgrows proportions that can be handled with existing means and facilities, the situation is named a crisis. Information is an important resource needed to respond to a crisis. To deliver the right information to the right people at the right time, which are the main goals of a crisis information system, an accurate assessment of the extent of the damage and the availability of still functioning infrastructure is required. The accurate assessment prevents information overload, which, if occurs, typically causes the same effect as if there were no information at all. Therefore, facilitating the integration of information from various sources through different media in a meaningful way is one of the main concerns in a response to a crisis.

The most important areas for application of information technology (IT) in crisis management are communications, situation assessment, prediction and judgment, and collaboration and coordination. IT facilitates exchange of information from, to and within the affected area. As the situation assessment is crucial for further activities, its quality needs to be estimated based on the knowledge about the ability of the actors to assimilate the information under stress. Moreover, the end result of assessment must be in the integrated form of voice, data and images, so that it can be used also to respond to the changing needs as the crisis evolves. Last but not least, the collaboration and coordination in terms of sharing resources (e.g. databases and data sources) and establishing effective communication networks represent the key elements for a successful response to a crisis.

The incorporation of modern information technology advances represent one of the key aspects of EU sponsored FP6 project MEDSI. The mission of project MEDSI is to employ modern information technology to increase preparedness to offer a prompt and coordinated response in emergency situations caused either by natural or technological disasters. The main goal is to design and develop software infrastructure aimed at supporting and enhancing decision-making capabilities of crisis managers, especially emphasizing collaborative aspects of the task. Potential users are private and governmental organizations, including city management, regional management, central institutions and agencies, international crisis management organizations, public safety and security forces, and intelligence services.

In the project there are 11 partners from 8 countries. The project started in the year 2004 and will last 18 months. The resulting MEDSI framework will be tested on three realistic user scenarios: fire and explosion of hazardous materials in the industrial area; terrorist attack to trains; and river flooding, which is described in more detail in the next section. The framework will support back-office mode and emergency mode. It will consist of several modules, including database module, GIS, symbology, modeling, simulation, messaging, decision support, resource management, and report management. The pilot implementation will be installed at Municipality of Holon in Israel.

Nowadays, the growing need for collaborative approaches in many areas of human activities is obvious. Following this general trend, the overall aim of the MEDSI

project is to develop an innovative system that provides integrated set of services to crisis managers and planners based on utilization of various data sources, particularly emphasizing the collaborative part of the crisis management. In the last decade, there were several attempts to build solutions that tend to improve the quality of decisions and actions in crisis and emergency management domain (e.g. project Formidable [4]). We believe that this aim turns out to be especially crucial in the area of protecting critical infrastructures against threats including natural disasters, industrial catastrophes and terrorist attacks. The main goal, therefore, is to increase preparedness to respond promptly and in a coordinated fashion in emergency situations.

In the paper we first introduce the topic of collaborative crisis management and highlight its important features, particularly from the perspective of Geospatial interoperability using Geographical Information Systems (GIS) and Symbology. Then, we present a real user scenario of flooding of the river Elbe in the city of Magdeburg that is used to validate the architecture and functionality of MEDSI. We conclude by highlighting the most important points presented throughout this paper.

2. Collaborative crisis management

One of the first issues to take into account while handling collaborative crisis management is the interaction between the crisis center and the information providers not directly under its control. Providing a fast and appropriated response to a crisis situation demands a concerted action not only with all units operating in the field that are directly coordinated by the crisis center (e.g. policemen, firemen, healthcare, etc.), but also with other civilian infrastructures such as, for example, hospitals. Such entities do not respond to the same chain of command; however, a real-time communication with them is required despite the heterogeneous nature of their information systems.

Within the project MEDSI we propose and publish a simple web service based interface destined to fetch some basic but vital real-time information such as the number of available beds, etc. In the same fashion, web service based interfaces with sensor networks have been developed, providing real-time monitoring capabilities for environmental data, such as water level, which may be used to trigger an alarm in a pre-flooding condition.

Another type of web services is also used in MEDSI to obtain updated geo-referenced information, fundamental for accurate planning and informed decision-making process. MEDSI builds up on implementations of Open Geospatial Consortium [10] standards like Web Map Server [14] to retrieve geographic information (GI) in image format and Web Feature Server [13] to retrieve GI in Geography Markup Language [6], which are made available to the users by a powerful client, where a catalog browser allows them to choose the appropriate data sources. The chart in Figure 1 summarizes this collaborative approach.

By enforcing these standards, MEDSI intends to tackle the interoperability issues raised by the multiplicity of formats and heterogeneous ways to access this sort of

data, first in the scope of a single crisis management center and later across a network of MEDSI cells.

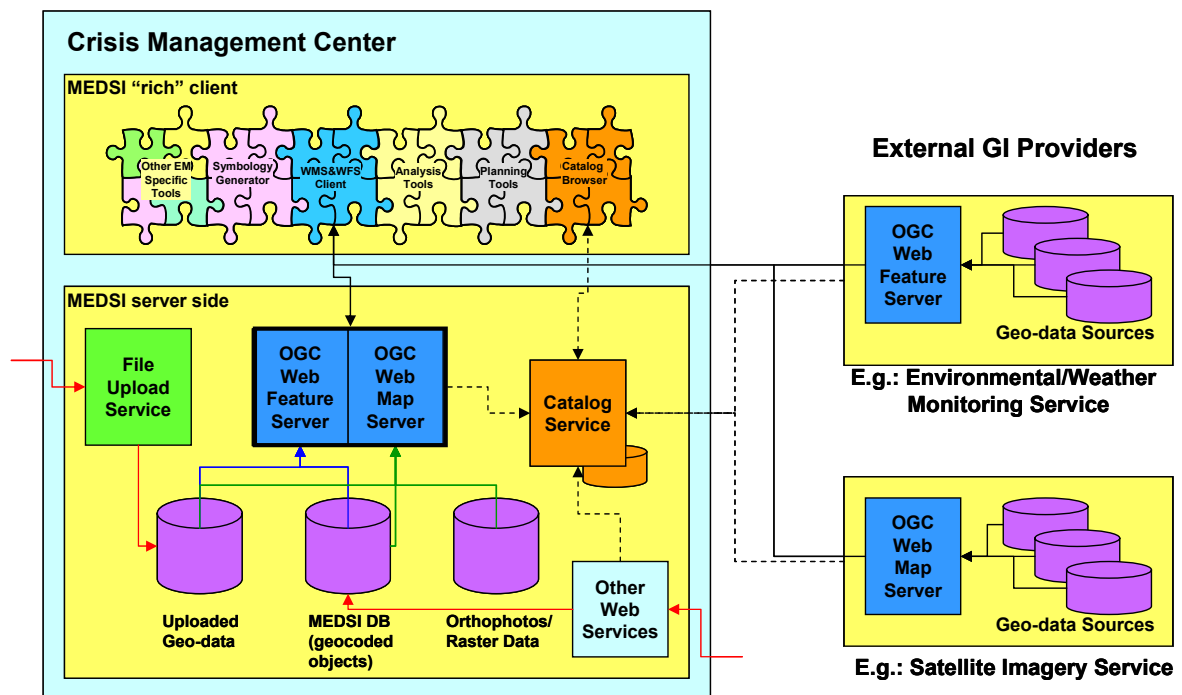


Figure 1: Interoperable GI access in MEDSI

One of the characteristics of the project MEDSI is that the most of functionalities operate over geo-referenced support [7], meaning that a crisis center would necessarily need to have its own GI repository. There is even stronger justification for that: during an emergency situation, the crisis center cannot depend on the status of its network infrastructure for regular operation. However, it's not the job of a crisis center alone to acquire and maintain all GI it may ever need, under the penalty of being unsustainable in economical terms. Having in mind the disparity of different interests, the only feasible option is that the crisis center makes an agreement with institutions that own and maintain geographical data as result of their daily work (e.g. municipalities). In such way, the decision makers are provided with updated information to support their decisions with no additional costs. Besides, such kind of arrangement could also cover the situations when, for some types of crisis, it is important to access environmental data in real-time (e.g. meteorological information in the case of a chemical hazard).

These combined requirements build up to the need of interoperable access to geographic data sources, maintaining a loose coupling with these institutions while being able to benefit from their updated sources upon request. A downside of this interoperation approach is the technological complexity needed to ensure a common way of finding and accessing GI data, relatively to a traditional integration perspective, which refers to a tighter coupling and suggests that the given information sources and semantic metadata descriptions are somehow coalesced together and can be queried as a single unit. Loose coupling across information sources, means not only using common ways of accessing data, but also sums up to the problem of

maintaining coherent semantic metadata descriptions through mechanisms such as ontologies.

Interoperability in geospatial information has been the subject of innumerable research works and standardization activities, many running under the wing of OGC [10], which has selected the protection of critical infrastructures as one of its key areas, through the establishment of lines of action such as the Critical Infrastructure Protection Initiative [2]. MEDSI has absorbed this experience, transposed many of the premises and concepts of this program to his own work, and built upon them to launch the assets of the European management decision support for critical infrastructures. At the GI access level, MEDSI is able to access any WMS or WFS compliant data source, respectively retrieving maps in a raster image format or as a GML, which is then displayed in the form of vector graphics. At the semantic level, MEDSI plans to use a catalog service to make these data sources available to the user, which encompasses metadata and a classification based on a proposed ontology.

Another aspect of collaborative crisis management deals with the working environment at the crisis center. Several actors with different expertise need to be able to interact swiftly, complementing each other's work. To enable this feature, MEDSI has identified the need of some kind of workflow mechanism encompassing geographic information. In this sense, it needs to be able to save the status of the workspace at a given moment with the aim of recreating it at another user's workplace, which then resumes the ongoing work. This is of particular importance when working with map-based tools, because even if the receiving user identifies the geographic data sources being used by the sender, it would be almost impossible to reconstruct exactly the same working environment (map extent, layers, etc.) by hand. Besides, there is another important benefit resulting from this functionality: the ability to re-create the geographic context behind a decision during a crisis situation at a later stage, which might prove itself useful in analysis and training stages.

3. Symbology

A collaborative approach to crisis management requires establishing a common "language" for team communication. Symbology takes an essential role for quick visual identification of the most important spots within the crisis geographical extent. Within the MEDSI project we have established a framework for the generation of symbols from a structured definition containing the symbol description. In addition, we expect to achieve some regulatory effects over this subject.

Symbols play an important role in identifying informative objects and are widely used in geospatial decision support systems and applications. The information content of a map can be measured with cognitive methods (e.g. [1]). Placing symbols often leads to information overload problem. Each symbol on the map consists of several parts. Typical parts are shown in Figure 2. Besides description, icon, fill and frame there are also some other features (for example, direction, severity of the manifestation, probability of a particular event, etc.) that can be incorporated in the symbol layout.

When designing symbols for MEDSI we pursued the following principles:

- Icons are stored in a repository database, while the symbols are generated on demand from the icons using graphics utilities on rendered graphics canvas.
- The symbols that are commonly used in everyday life (e.g. parking sign) should be used.
- The novel symbols should be introduced in such a way that they minimize the possibility of confusion with other symbols.

The goal behind all those principles is to increase human performance and effectiveness in dealing with crisis situations. Dynamic symbol generation was also studied in [15]; they argue that such an approach is more adaptive and robust than traditional one.

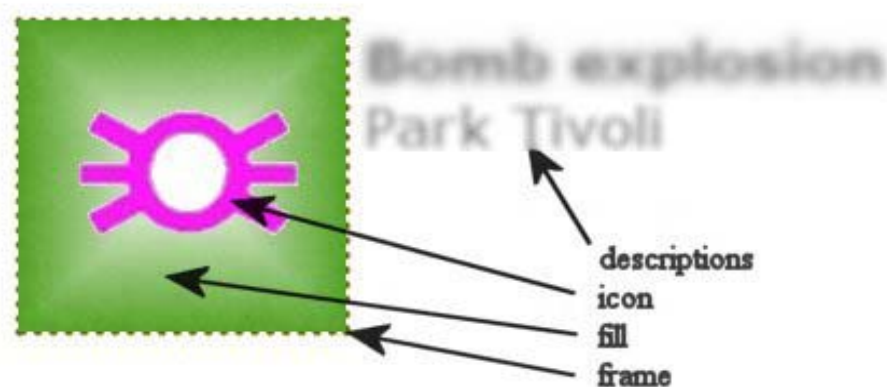


Figure 2: Components of a typical symbol: icon, fill, frame and descriptions

One of the principles in symbology module within MEDSI is specifically targeted to minimize is the risk of symbol confusion. An approach to symbology analysis is described in [3]. Cognitive aspects of symbol design and interpretations, like the effects of particular symbol features on human performance, are also considered [1]. The way we propose to handle this risk originates from business: assessing consumer confusion as a result of brand similarity [8]. As a result, the probability of symbol confusions diminishes, while increasing effectiveness in crisis management at the same time. The approach might seem overly complicated and costly at the beginning, but the long-term advantages that are foreseen for the period of system's utilization can outgrow the initial investments.

In the MEDSI project we have approached also the field of symbology standardization (e.g. [5]). Although the problem area is vast and the task might, at least at the first sight, seem overly complex, these problems can efficiently be solved by appropriate knowledge management [11], which, in addition to the technological solutions, needs to address also organizational, economic, legislative, psychological and cultural issues.

2. User Scenario for the city of Magdeburg

The state capital Magdeburg is located between Hanover and Berlin in the central Germany on the bank of the river Elbe. This river is one of the biggest rivers in

Germany and consequentially the cause for periodic natural disaster flood in Magdeburg. The defined user scenario for MEDSI is the special crisis situation of flooding, which actually happened in the summer of 2002. The flood event was triggered by unusual, but not exceptional, meteorological conditions resulting in heavy rainfalls in the whole federal territory of Germany as well as in other Central European countries. As a consequence of this general episode, the subject of the described user scenario is limited to the geographical location area of Magdeburg. The concrete crisis situation is triggered by the bursting of a dike in the downtown of the city and continues with the corresponding related events. This flooding event threatens an area of approximately 6.000 hectare, 20.000 inhabitants and 1.300 animals.

Based on different German laws, the structure of command and operation for the coverage of such kind of crisis situation is under the responsibility of each federal state like Saxony-Anhalt. These tasks are assigned to each local administrative district. Each administrative district has its own office for civil protection; for example, Office of Fire and Civil Protection is responsible for handling such situations in Magdeburg. This office arranges the Staff of Disaster Management for the coverage of a concrete crisis situation. This staff consists of 6 different teams, like, for example, Personal & Internal Service Team, Analyst Team, etc., and other personals like Expert Adviser and Connection Personal to other involved public and private organizations. In general, all these organizations are spread over the whole city area, providing the information for the coverage of crisis situation. According to the established organizational structure responsible actors for the MEDSI system were defined.

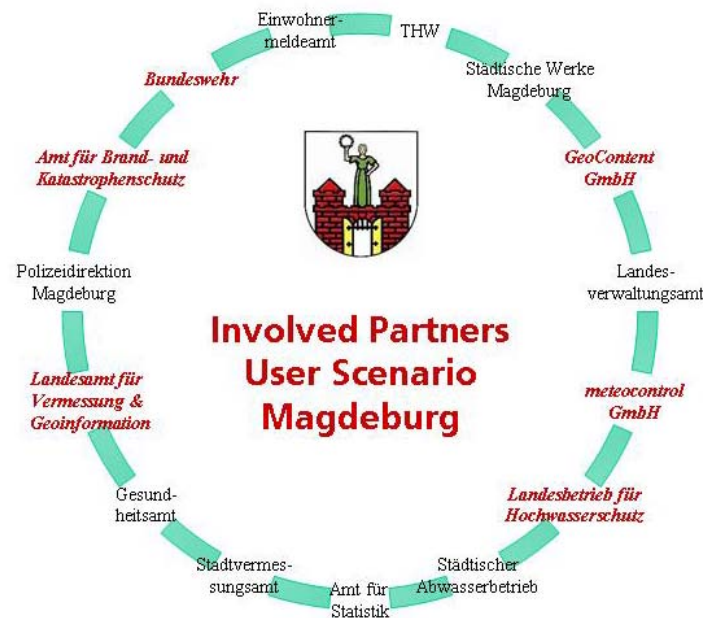


Figure 3: Organizations and partners involved in MEDSI user scenario for the city of Magdeburg

In the case of emergency all governmental and nongovernmental organizations, offices and private companies are legally bound to support the Staff of Disaster Management through the provision of personal resources, equipment, etc. and by

providing of the required information. One of the main objectives of MEDSI project is the integration and preparation of this kind of information like geographical and non-geographical data for supporting the decision-making of crisis managers. The user scenario for the city of Magdeburg is supported by all of the involved organizations and partners (shown in Figure 3) that are responsible for the coverage of crisis situations. These partners provide online and offline information in the following areas:

- Electricity, water and gas network information,
- Information about hospitals, disposal, aid resources,
- Official topographical data according to ATKIS,
- New quality air photo maps,
- Environmental information like weather (wind direction, weather forecast), water level, water level forecast and traffic information, etc., and
- Infrastructure data like road traffic, waterways, etc.

The described user scenario will allow the MEDSI partners to validate not only the suitability of the proposed architecture but also the application of instantiated MEDSI system in a real user environment.

5. Summary

The paper discusses the topic of emergency response through collaborative crisis management. The ideas elaborated in this paper are included in the project MEDSI, which is EU sponsored FP6 IST project. The main goal of MEDSI is to design and develop software infrastructure aimed at supporting and enhancing decision-making capabilities of crisis managers, especially emphasizing collaborative aspects of the task. The result of the project is state of the art framework that enables data and information flow between different bodies involved in the crisis management domain, and unifies data sources, geographical information and information about critical infrastructures.

To facilitate communication with external datasources MEDSI framework proposes and publishes a simple web service based interface. Web service protocol is also be used for interfacing the sensor networks. The major functionality of MEDSI relies on OGC standards like Web Map Server (WMS), Web Featured Server (WFS) and Geography Markup Language (GML). By obeying these standards, high interoperability between internal and external system components is achieved. The next important step in achieving geospatial interoperability is the introduction of the relevant standard. Besides already accepted ones, MEDSI consortium is also actively involved in standardization activities.

In the field of symbology, we introduced a few principles for symbol design within the project MEDSI. First, symbols are generated on demand from the icons using graphic utilities. Second, the symbols that are used in everyday life should be used as such. Third, while constructing new symbols the probability of confusion should be minimized. All these principles have a common goal to increase human performance in dealing with crisis situations.

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Author biography

Bojan Cestnik is the general manager of the software company Temida and a researcher at the Department of Knowledge Technologies, Jožef Stefan Institute, Ljubljana, Slovenia. His professional and research interests include knowledge based systems, decision support systems and machine learning. He has been responsible for several large-scale software development and maintenance projects.