Enabling Geographic Situational Awareness in Emergency Management

Bernd Resch, Dirk Schmidt, Thomas Blaschke

Research Studio iSPACE
Austrian Research Centers GmbH – ARC
Leopoldskronstrasse 30
5020 Salzburg

(bernd.resch, dirk.schmidt, thomas.blaschke) [at] researchstudio.at

Abstract: Knowledge about current conditions in the environment of a disaster site is a crucial prerequisite for successful and efficient emergency management. However, hitherto approaches only allow for post-processing mechanisms analyzing the situation with hindsight. The presented system accounts for a combination of prevailing sensor data with real-time processing mechanisms to achieve situational awareness for an instantaneous assessment of environmental conditions. The methodology combines sensor technologies, communication standards and the geo-collaboration concept to a sound and broadly applicable framework. A first prototype application, the eMapBoard, has been implemented and used in the real-time exercise GNEX06. The outcomes of this practical use are also discussed in the paper.

INTRODUCTION

Situational awareness is a basic requirement for all actors being involved in disaster operations, on-site as well as in the mission control centre. Kevany (2005) states that in such emergency cases, the geographical location is often the most necessary information for planning coordinated rescue actions. That is why geographic information systems (GISs) will gain crucial importance in disaster management in near future.

Recently, the term geo-collaboration has been widely used to describe concepts and implementations of GISs for emergency situations. The main focus of new implementations lies on interactive and intuitive user interface design and data integration from different sources as web services. Mittlboeck et al. (2006) state that maps on the internet offer substantial advantages compared to conventional paper maps such as interactive instruments like annotation functionality, individual scale adaptation, selection of the map contents etc. Traditional paper maps allow geographers to use it to synthesize, analyze and explore spatial information. It is obvious that the rise of Geographical Information Systems has stimulated these functions and has extended them (Kraak, 2003). Maps that used to be elaborate to produce can today be created in many alternative views by the single mouse click. Additionally, many more maps are produced and used, a trend multiplied by the development of Internet and especially the WWW (Peterson, 2003). Newly developed interactive geo-collaboration tools can be employed in a wide variety of application scenarios ranging from emergency planning in the case of a wild fire to the coordination of action forces during disaster management scenarios or infrastructure monitoring processes.

It is widely acknowledged that GIS plays a significant role in providing informational and analytical tools to communities directly victimized by disasters. Especially natural disasters can be largely ‘explained’ by GIS-compliant data sets and can therefore be predicted to a certain extent. Typically, disaster management depends on large volumes of accurate, relevant, on-time geo-information that various different organizations systematically or not systematically create and maintain (Blaschke & Schmidt 2006). In principle, most of this information is described in catalogues and is registered in geo-information infrastructures, such as the Infrastructure for Spatial Information in Europe (INSPIRE), based on OGC, ISO, and CEN standards. Some examples in the literature describe implementation of a GIS based tool for the support of technological risk management (e.g. Chrysoulakis 2003). But the number is significantly smaller than the number of natural hazard applications.

Next to various somewhat positivistic statements from the GIS community some empirical studies demonstrate the problems (e.g. Zerger & Smith, 2003; Mansourian et al., 2005). As stated by Castle and Longley (2005), the conception and design of emergency management systems is difficult as nearly no practice can be performed in real-world situations. From this demand, a team from the German Aerospace Center (DLR) and Linkoeping Universitetet, Sweden, designed the near-real-time exercise GNEX06 (German Aerospace Center, 2007), which took place in October 2006.

During the exercise, the geo-collaboration tool eMapBoard could be tested concerning its usefulness in disaster management operations by offering a web-based collaboration platform for different user groups. The application allows for dynamically importing external map data, adding geo-notes (files, annotations etc.) and creating map views, which can be shared with other users.

The next development step of the overall system will be a prototypical sensor web realization comprising different sensor types, which will be accessible via the internet. The implementation will be compliant with OGC's (Open Geospatial Consortium) Sensor Web Enablement (SWE) initiative, whose goal is to make different types of sensing devices discoverable, accessible and possibly controllable over the web.

The structure of the paper is as follows. Following this introduction, applied concepts and technologies for the eMapBoard approach are discussed. Then, the implementation itself is described with a focus on its practical use in the GNEX06. After a short outlook on future perspectives of the system, the paper closes with a brief conclusion.

CONCEPTS AND TECHNOLOGIES

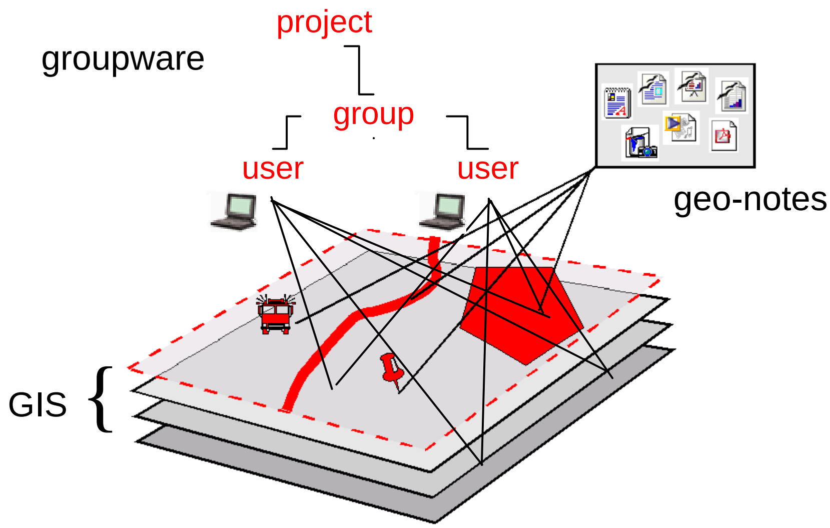
To enable a broad situational awareness by providing environmental parameters, processing them and visualizing them in a map, several concepts and technologies are necessary ranging from simple gathering mechanisms for raw sensor measurements, means of communication of the sensor network with the sever and appropriate presentation techniques for the user-tailored analysis outcome.

Geo-collaboration Concept

Recently, web-based geographic information systems (GISs) gained more and more importance. However, most implementations solely offer information and do not provide interaction and collaboration capabilities, which does not satisfy the needs of web-based collaboration platforms required in many areas such as disaster prevention, emergency management or protection of critical infrastructures.

For most crisis management processes, a self-evident communication structure between involved parties and the same interpretation of concepts, symbols etc. are vital factors of success (Groenlund, 2005). Having these requirements and the above application scenarios in mind, a structural variant of the geo-collaboration concept has been created, which is summarized by the following figure.

FIGURE 1
PRINCIPAL GEO-COLLABORATION CONCEPT STRUCTURE



As it can be seen from figure 1, the geo-collaboration model implies three pillar concepts. The technological basis of the system is made up by a layered GIS supplying geo-referenced maps. The possibility of interaction is provided by so-called geo-notes, implemented according to the familiar concept of ‘sticky notes’. Geo-notes comprise textual comments, all kinds of documents (images, PDF, videos etc.) and geographic objects (points, lines, polygons), which can be directly posted into the map. Finally, the whole map view can be made available to other users via a web-based collaboration platform, whereby access can optionally be restricted to user groups or single users.

Summarizing, the scope of the geo-collaboration concept can be described as a ubiquitous decision support framework allowing the integration of expert opinions resulting in a real-time availability of posted collaboration data such as maps, geo-objects, documents or comments.

Sensor Web Technology
The term “sensor web” stands for a network of sensing devices, so-called pods, which communicate and exchange information intelligently and autonomously. Sensor webs have to fulfill criteria such as interoperability (combination of different types of sensors), intelligence (autonomous decisions), scalability (extensibility) or a high spatial and temporal resolution of the measurements.

The long-term vision of sensor web applications can be subsumed by the following statement in Gross (1999):

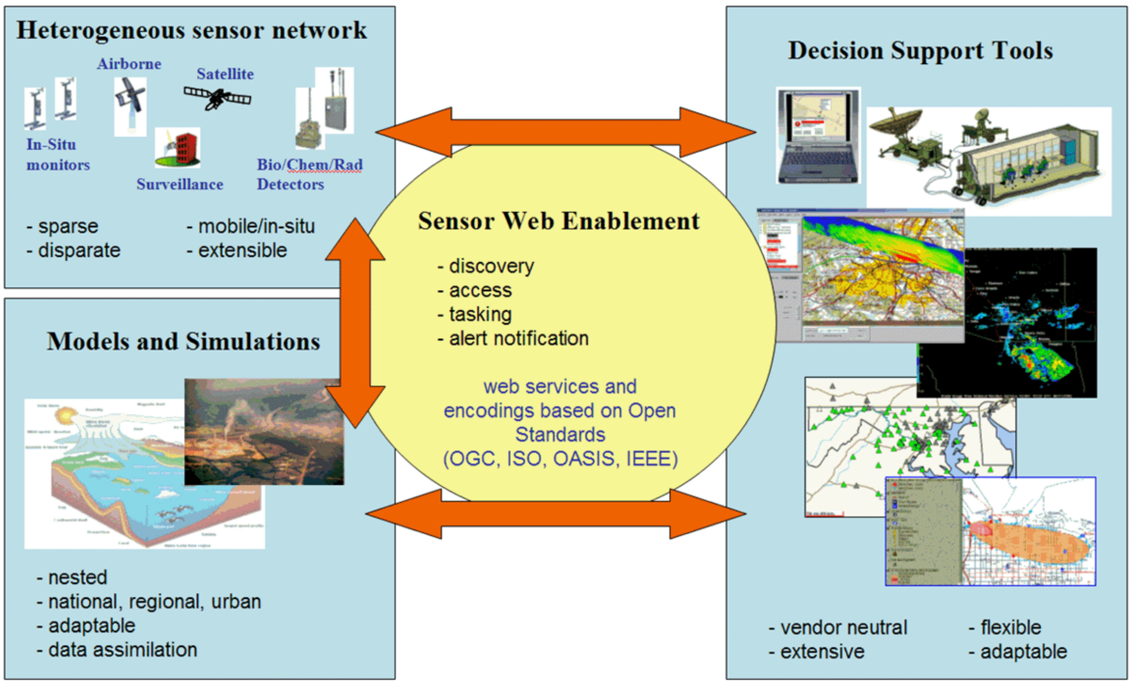
> “In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies--even our dreams.”

From this visionary perspective it can be imagined that autonomous sensor networks merging various sensed phenomena might influence our everyday’s lives. However, to make the data offered by different kinds of sensors combinable, a framework has to be created, which makes sensor data interchangeable. The following sub-chapter describes a new initiative to achieve this goal.

OGC Sensor Web Enablement
The Sensor Web Enablement (SWE) initiative is a standardized framework of the Open Geospatial Consortium (OGC) providing for a broad and easy discovery, accessibility and controllability of different sensor types in a standardized way.

The following figure illustrates the broad scope of the SWE initiative demonstrating the aim of interconnecting sensor networks, modeling mechanisms and decision support tools over the internet.

FIGURE 2
SENSOR WEB ENABLEMENT CONCEPT (Botts, 2006)



The programme comprises eight standards ranging from a sensor description language and a measurement data encryption structure to different services such as alerting mechanisms or sensor registries:

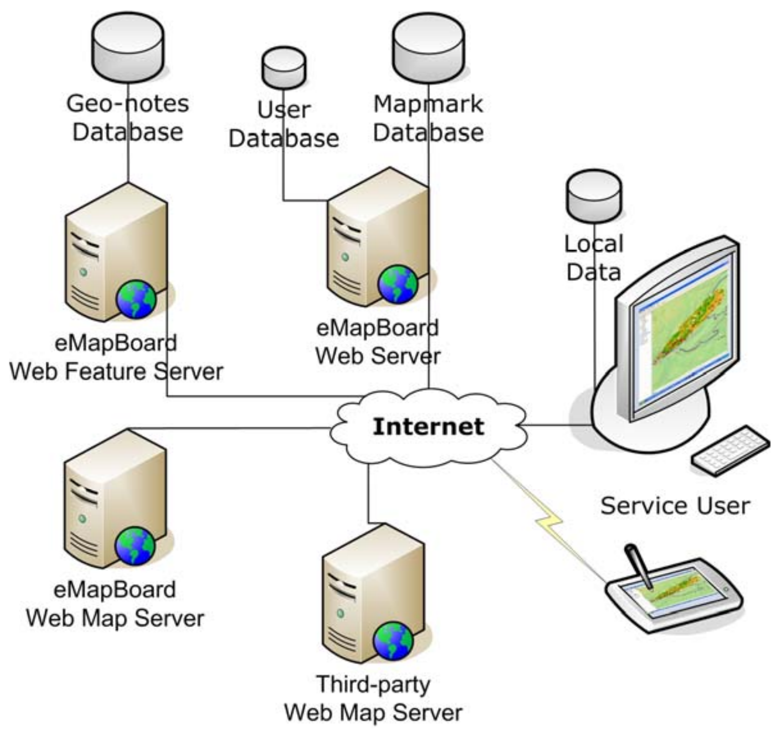
- Sensor Model Language (SensorML)
- Observations and Measurements (O&M)
- Transducer Markup Language (TML)
- Sensor Observation Service (SOS)
- Sensor Alert Service (SAS)
- Sensor Planning Service (SPS)
- Web Notification Service (WNS)
- Sensor Web Registry

Additional information including a more detailed description of each SWE component can be found in Botts (2006)

EMAPBOARD: A PROTOTYPICAL SOLUTION FOR DISASTER MANAGEMENT
Accounting for the described requirements of geo-collaboration systems, eMapBoard, a first prototype of a geo-collaboration platform, has been implemented based on the DIALOGIS' open-source project D-Mapper (http://sourceforge.net/projects/d-mapper). Additionally, several design issues have been addressed as discussed in the following sub-chapter.

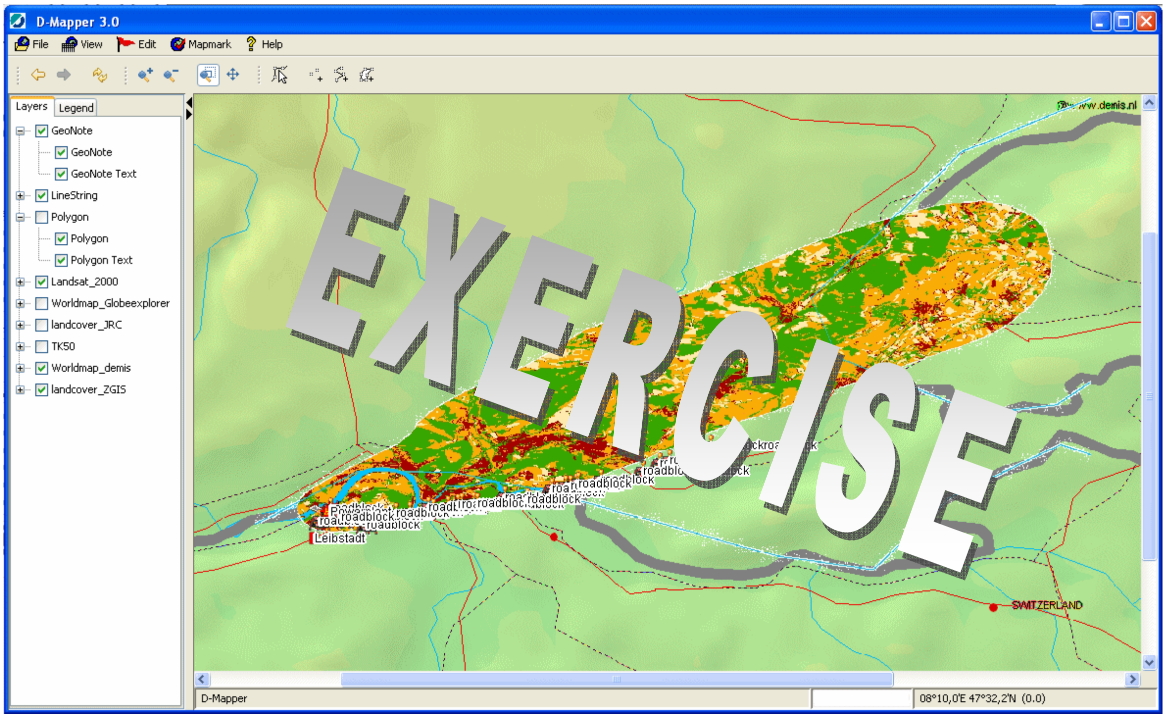
System Architecture
The system's topology consists of the central eMapBoard web-server, which distributes the Java Web Start application and manages the user and map-mark databases. Moreover, eMapBoard architecture comprises a Web Feature Server (WFS) used to access and alter the geo-note database as well as several Web Map Servers (WMSs), which provide the maps via a standardized interface. Finally, also local data repositories containing geographic features or image files can be integrated in the application.

FIGURE 4
EMAPBOARD TOPOLOGICAL ARCHITECTURE



User Interface
According to Haklay and Tobón (2003), the term usability for web applications is defined by five parameters, i.e. the learnability of the application, the efficiency of the tool to perform a certain task, the memorability of the steps of a task when it has already been performed once, the error rate, which can be seen from the user and the system view point, and finally the satisfaction for the user.
Accounting for these usability criteria, the user interface of eMapBoard application has been designed, which is shown in the following figure.

FIGURE 3
PRINCIPAL EMAPBOARD USER INTERFACE



As shown in figure 3, the simple user interface contains a standard menu bar including functions such as adding a map, setting a map-mark, adding or editing a geo-note or different export functions. Moreover, the tool supplies a symbol-based short-cut menu, with which simple map operations such as zoom, pan etc. as well as geo-note functions (add, edit, delete). The left-hand side of the interface presents a layer-structure to the user. The order of the WMS-layers can be arranged in a simple and intuitive manner as the layers are organized in a familiar "table of content" structure.

The eMapBoard in GNEX06

The GNEX06 exercise was carried out as near real-time exercise during a period of 33 hours. Its objectives were to (a) evaluate the effectiveness of cooperation in the Global Monitoring for Stability and Security (GMOSS, http://gmoss.jrc.it) network, (b) benchmark developed algorithms and tools and (c) evaluate products against the requirements of users (relevance). In respect to the last two aspects, the exercise addresses the general requirement under the European Global Monitoring for Environment and Security (GMES, http://www.gmes.info) Programme to test and practice service delivery under realistic scenarios.

Three teams, whose members were distributed over Europe, were coordinated from The Hague (The Netherlands), Salzburg (Austria) and Oberpfaffenhofen (Germany) and obtained identical tasks and a set time concerning a scenario, which comprised an assumed accident in a nuclear power plant in Switzerland close to the German border.

A field report, which will not be described in detail here, showed that eMapBoard has proven an easy-to-use geo-collaboration tool with basic GIS functionality. eMapBoard has been used in GNEX06 as an interactive situation map including different data sources such as classification results, a local plume shape file or different WMS base maps, as it can bee seen in figure 3. The application is well-suited to support the real-time collaboration tasks of different involved parties like executive authorities, rescue organizations, governmental officials, or other interest groups.

PERSPECTIVE: REAL-TIME GIS ANALYSIS

In its current state, the system can serve as a geo-collaboration tool focusing on visualizing different types of information and offering some simple GIS features. In a next step, a web-based geo-processing mechanism will be implemented providing more advanced GIS analysis functionality such as kriging, inverse distance weighting (IDW) interpolations etc. In combination with a sensor network measuring a number of environmental parameters, this system offers real-time analysis components in contrast to hitherto post-processing approaches, i.e. current sensor data can be combined with external data repositories and complex process models to achieve up-to-date information layers.

This combination of sensor data with advanced server-based geo-processing methods results in a sensor-enabled situational awareness for a wide range of 9-1-1 end applications. One sample scenario is to model the propagation of a wild fire using e.g. wind data, the area of the fire, forest coverage in the vicinity, vegetation types, road networks and water supplies for the action forces.

The most striking advantage of the complete system is that hitherto GIS approaches, which offered GIS functionality only in resource-consuming desktop applications, can be replaced by web-based analysis tools. Therefore, the GIS operations are performed on server-side whereas the results are sent to the client, which can e.g. be an internet-connected personal computer in the mission control centre or also a tablet PC used by action forces on-site. This allows for a real-time situational awareness making emergency and rescue actions much more efficient.

CONCLUSION

The paper describes a research project aiming at establishing a conceptual and a technological framework for coupling sensor web architectures with new server-based analysis mechanisms. Currently, the project progress comprises a prototype application named eMapBoard, which implements the geo-collaboration concept and demonstrates the benefits of web-based geo-information systems by offering a range of simple GIS tools. Its functionality and usability was evaluated during GNEX06, a near real-time exercise simulating an accident in a nuclear power plant. Concluding, it can be stated that eMapBoard has proven an easy-to-use geo-collaboration tool, which simplifies the cooperation between different involved parties such as local authorities, the mission control centre, action forces and other decision makers.

Sensor and communication technologies help gain spatial and environmental conditions awareness based on up-to-date measurements of GPS or Galileo receivers or different environmental data sensors. In order to turn these measurement data into valuable information for decision making, they have to be (geo-)processed and provided in an intelligent, task-oriented, and intuitive way. Thus, the coupling of sensor web technology with server-side geo-processing services in connection with a user-centered interface provides situational awareness for decision makers and action forces as well as a comprehensive collaboration tool using geo-referenced information.

In conclusion, it has to be stated that GNEX06 was a very valuable event for the evaluation of strengths and weaknesses of eMapBoard as the design process of applications for emergency management is difficult because of the lack of real-world assessment conditions. Thus, similar exercises would be desirable for research institutions and decision makers to be able to practice emergency procedures under quasi-real-world conditions.

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