GIS Interoperability Platform for Emergency Management in Local Community Environment

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SUMMARY

This is introductory paper presenting our recent work in the field of emergency management using GIS. Application being developed should provide tools necessary for spatial and temporal analysis of all data that can be of relevance to the process of emergency management. It should be noted that the data mentioned is usually gathered from geographically dispersed sources which are at the same time of heterogeneous nature. This is the reason why the significant part of the research will be devoted to intelligent integration of information based on ontologies.

KEYWORDS: *GIS, emergency management, interoperability*

INTRODUCTION

Emergency management has been the hot topic in recent times. Emergency events imply all events that endanger normal functioning of services and companies, endanger lives or resources (living environment) as well as events that are threatening stability of state. All situations resulting from fires, explosions, technological and traffic accidents, terrorist attacks, transport of hazardous materials all comprise hazardous events.

Individuals and organizations responsible for emergency management use many tools to preserve economic assets before, during and after a catastrophic event. Correct and timely information is a critical part of any successful emergency management program. In the design of an awareness program, spatial data becomes imperative just as much in emergency management analysis and planning as in process of supervision and control.

A geographic information system (GIS) can provide that sort of information and tools for the analysis of the spatial data and the representation of the results in spatial format.

Management of emergency events is performed in accordance with regulations defined by specific services taking part in described process (fire department, emergency technical services, health care services etc.) Integration of information gathered from all these services will provide needed knowledge required in the process of visual representation and analysis of hazardous events. This enables timely notification (using GIS interface) of current status of all relevant parameters.

This paper aims at providing a methodology of designing a GIS based system that can be widely used in all sorts of services that in any way handle sources and consequences of emergencies. In second section the paper discusses the use of GIS in existing systems and systems under development. The third section gives a short overview of architecture applied to *GinisEmergency,* application developed as a result of the research. The following, fourth, section presents possible directions of further research. Final section contains concluding remarks.

Product of the research will be GIS based system incorporating multimedia technologies used for hazardous events management and handling that can be used in specific emergency services as well as local municipality (when importance of emergency services activities in the process of hazards handling process is taken into account).

ROLE OF GIS IN EMERGENCY MANAGEMENT

Geospatial information is critical to effective, collaborative decision-making during emergency management situations. Emergency can be managed well through spatial planning and analysis of spatial data.

GIS can provide tools for spatial analysis of emergency events and display risk factors from the same geographic space. GIS is also a valuable planning tool. Also, integration of multimedia technologies with GIS will assure more efficient display of emergency events.

As already identified in numerous papers related to this domain [ESRIWhitePaper 1999., Zlatanova & Holweg, 2004.] several phases can be differentiated in the process of emergency management:

- Planning
- Mitigation
- Preparedness
- Response
- Recovery

Figure 1: Phases identified in a typical emergency management process

During emergencies, GIS enables emergency managers to quickly access relevant data about an affected area. However, the problem is that the needed spatial and non-spatial data is usually geographically dispersed and stored in heterogeneous databases. Types of data usually needed in emergency management can be classified as follows [Belaji et al. 2002]:

- Data on the emergency phenomena (for example, landslides, floods, earthquakes), their location, frequency, magnitude and so on.
- Data on the environment in which the disastrous events might take place: topography, geology, geomorphology, soils, hydrology, land use, vegetation and so on.
- Data on assets that might be destroyed if the event takes place: infrastructure, settlements, population, socioeconomic data and so on.

In order to make all the mentioned data readily available when it is needed and in the form that it is most easily consumed it is needed to solve two basic problems. These are semantic heterogeneity and geographic distribution of the relevant data. In designing GIS support system it is imperative to construct the platform that will solve both of these problems.

Semantic heterogeneity of the data sources causes serious problems. Domain experts use the concepts and terminology specific for their respective field of expertise, and use different parameters and different languages to express their model of a concept. Humans use their "common sense", i.e.

their knowledge about the world, to translate the meaning of foreign set of concepts and terms in their own terminology. Software systems usually do not have any knowledge about the world and have to explicitly be told how to translate one term into another. The use of ontologies as semantic translators is possible approach to overcome the problem of naming conflict and semantic heterogeneity. Recently, the use of ontology in information systems is discussed in [Guarino, 1998] and specifically in GIS building in [Deveogele et al., 1998, Laurini, 1998], and creation of GIS software components from ontologies in [Fonseca and Egenhofer, 1999]. Research on ontology is becoming increasingly widespread in the computer science community, and its importance is being recognized in a multiplicity of research fields and application areas, including knowledge engineering, database design and integration, information retrieval and extraction.

GINIS EMERGENCY

Intelligent integration of heterogeneous data sources based on semantics (represented by ontologies) represents key factor for realization and usage of platform for integral management of hazardous situations. Semantic integration will allow for highly flexible information services as well as effective information exchange and integration. Connecting geographically distant and functionally and structurally different services for the purpose of establishing common management mechanism, this platform will enable creation of virtual organizations for hazardous events management.

In general, the purpose of the research is development of the metamodels, methodologies and tools to crate multimedia platform for integrated hazard maintenance.

GinisEmergency is using GeoNis (Stoimenov 2003, 2004) interoperability platform for integration and accessing distributed data required for emergency management.

The advantages of successful information integration are obvious for many reasons:

- Quality improvement of data due to the availability of large and complete datasets.
- Improvement of existing analysis and application of the new analysis.
- Cost reduction resulting from the multiple use of existing information sources.
- Avoidance of redundant data and conflicts that can arise from redundancy.

Objectives we are striving to accomplish include:

Access to distributed sources through a single integrated system

As stated in previous paragraphs users of GIS emergency management systems are of different specialities and usually have neither knowledge nor time to adopt their working procedures according to the source of the data they are using. So, a single interface used in all services responding to the same emergency is solving the communication problem.

Automatically resolving semantic heterogeneities

Closely coupled with the previous goal is fully automated semantic heterogeneities resolving mechanism. Regardless of the data source type the process of data requesting and visualization should be seamless. Again, already stressful work environment for emergency response personnel should not be further complicated by complex data request procedures.

Identify relevance of available data sources

Going from one extreme to another, abundance of available and displayed data can lead to reduced situation awareness. Especially in the field, the response teams should be presented only with the data relevant to their assigned task and in the form that will not clutter the devices they are using to access the system. This data filtering mechanism should be completely (or almost completely) automated and based on user profiles. These profiles should be based on context, geographic location, type of service etc.

Responsive query time

According to the nature of the developed system and its application, response time of various queries is very important. In response part of emergency management it is even critical and lives and critical resources may depend on it. This issue is mainly of hardware nature, but special attention should be devoted during system design to utilize available hardware resources most efficiently.

All cited requirements are fulfilled through GeoNis interoperability platform. GeoNis is a framework for interoperability of GIS applications that have to provide infrastructure for data interchange in the local community environment (Stoimenov and Djordjevic-Kajan, 2000). Data sources are local services and offices that own geodata in some format.

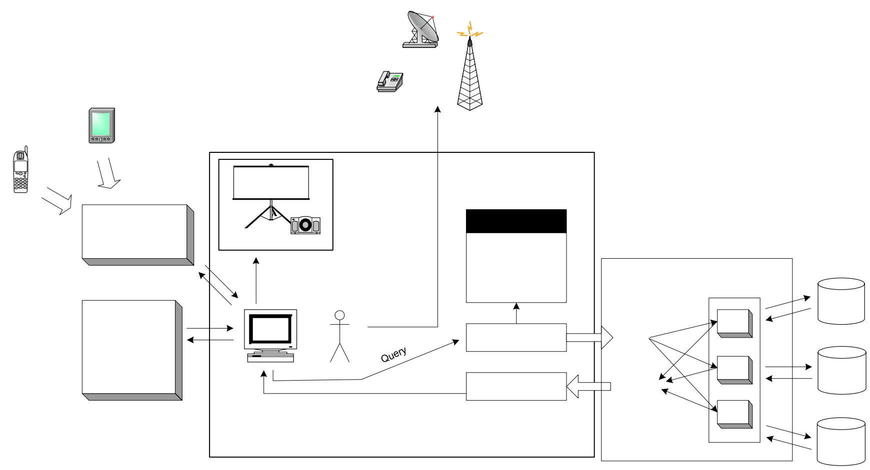

Figure 2: Proposed architecture for Ginis Emergency

GeoNis platform is inserted between C^3 (Command and Control Center) unit and specific, distributed GIC data stores. Its role will be explained later more thoroughly. Several of its components are also integrated in C^3 unit offering query translation services in order to enable interfacing with GeoNis. These components include Query generator (builder), Data catalogue and Data consumer.

In the envisioned C^3 facility typical user of the system is emergency manager. User interface presented to the emergency manager is a GIS application running on the workstation. This application is interfaced with other components: Resources Manager, Decision Support System and GeoNis interface towards data sources. GIS user interface incorporates various visualization devices ranging from simple monitors, video projectors and touch screens up to virtual reality sets and rooms. Standard command techniques are used implementing radio, fixed and mobile telephone lines.

Resource Manager component is keeping track of resources available in the field. All information from the environment concerning risk factors and information about developing emergencies is routed to the system through this connection. Mobile nature of the personnel in charge of this is dictating usage of mobile and hand-held devices for information acquisition and reporting. This part of the system heavily relies on wireless and mobile networks and also on various mobile positioning techniques (GPS as well as GSM, UMTS and WLAN locating methods).

Decision Support System is supposed to act as knowledge repository. This is the target database where knowledge acquired from recovery phases of previous emergency situations is stored. It also includes predefined response plans constructed in preparedness phases. Its role is to present emergency manager with a choice of response plans applicable to currently developing emergency.

Response and recovery personnel are already trained for these predefined procedures and ready to act immediately. Finally, DSS is basing recommended decision on data gathered from other GICs like location, distance, timing, dangerous hotspots etc. and assigning duties to various units, rearranging routing for vehicles etc.

As previously mentioned, GeoNis is a sort of buffering interface between C^3 unit and various GICs. Typical user of Ginis Emergency is not and does not want to be aware of terminology and database specifics of various GICs. Our goal is to define uniform query scheme that will be used by emergency manager to query distributed and heterogeneous data sources located in different GICs. This query is accepted and parsed by Query Generator (Builder) component of GeoNis. It will use information stored in Data Catalogue to gain top level knowledge of distribution of requested data among different GICs and construct needed number of queries specifically tailored for each GIS data repository specifications. Each of GICs data bases responds with a data set stored locally. The component for integration of responses arriving from different GICs is Data Consumer. The product of this component is single dataset implementing uniform data scheme and understandable by GIS application used by emergency manager.

The basic architecture of GeoNis framework is shown in [Stoimenov and Djordjevic-Kajan, 2003]. Each GIC contain GIS application and corresponding (spatial) database. GeoNis with ORHIDEA [Stoimenov and Djordjevic-Kajan, 2002] data integration platform has been developed in order to perform intelligent integration of information from multiple heterogeneous GIS (spatial and geographic), and non-spatial (thematic) data sources.

Each type of information source requires a wrapper/translator that translates information flow between information source and GeoNis system. In each node of GeoNis framework there exists GIS application and corresponding (spatial and non-spatial) databases. Data in local databases are accessible according to user privileges. Requests for specific data set are forward through local mediators. These applications may be either wrapped legacy applications or newly developed applications based on Ginis application development framework.

GeoNis solution to the problem of semantic heterogeneity is to formally specify the meaning of the terminology of each GIC (GI community, i.e. local service or office) using local ontology and to define a translation between each GIC terminologies (local ontologies) and an intermediate terminology (in top-level ontology). A semantic translation in GeoNis is developed for a particular domain, in our case for GIS applications in local community services, which deal with network data structures (local Telecom, water and soil pipe services, power supply services, and some local government services) [Stoimenov and Djordjevic-Kajan, 2003].

CONCLUSION

The significance of the research is in creating unique hazard management methodology and developing the software (based on the mentioned methodology) which can be applied in hazard management. The unique methodological approach, which provide data recording, manipulation and evaluation of hazard progress, risk estimation, possibility of preventive analysis and preventing hazards in order to decrease loss as effect of hazards (in the organizations and in nature), will be defined applying multidisciplinary research in proposed system implementation. Multidisciplinary approach is based on the new information technologies (GIS, Web services, ontology, semantic integration), expert's knowledge about structure and processes in the hazard management system, hazard emerging and possible effects on living environment, as also combine the knowledge of expert's working in different domains. This will improve the process of hazard management. The proposed models and services will be specialized for application in involved organizations and public services. So, the solution efficiency provided by proposed system will be especially valuable for local community and local authorities.

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