EMERGENCY GEOGRAPHIC INFORMATION SERVICES: A FRAMEWORK AND TYPICAL APPLICATIONS

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Abstract: We describe emergency geographic information services offering a solution to the problem of emergency management and emergency incident handling. This paper takes the framework of emergency geographic information service as objects of study. The framework is based on the integration of geographic information system (GIS), global positioning system (GPS), remote sensing (RS), office automation (OA), management information system (MIS) and decision supporting system (DSS) technologies. In the framework, seven application support tools such as plotting, disaster analysis, moving objects management, etc. are very important and can provide high service level to ensure public safety. The typical application results prove the feasibility of the proposed architecture and its alignment with widely established practices and standards, while the reaction of potential users who evaluated the system is quite positive.

Key Words Emergency Geographic Information Services GIS Emergency Database Spatial Analysis 3D Visualization

1 Introduction

Terrorist attacks at the World Trade Center in New York City in 2001, the tsunami in South Asia at the end of 2004 and Wenchuan earthquake in 2008 have again shown the indispensable need of geo-information services in reliable systems to help rescue operations. Emergency geographic information services are necessary not only for rescue teams but also for ordinary people in/around the area with emergency occurrences[1, 2]. Due to recent technological advancements, especially the increased availability and relative affordability of emergency management theories, GIS, GPS, RS, and many GIS-based decision support systems have been created[3, 4]. Emergency geographic information services are very important to various fields, such as emergency management, emergency recue, city planning, and environment monitoring[5]. How to obtain the emergency geographic information services has always been concerned by the researcher from the fields of GIS and emergency management.

Morin introduced a method for systematic analysis, modeling and visualization of a rescue scenario to support various aspects of emergency management and response including command and control, system analysis, training, evaluation, and transfer of lessons learned[6]. Derekenaris described a system offering a solution to the problem of ambulance management and emergency incident handling in the prefecture of Attica in Greece, which was based on the integration of geographic information system global positioning system and global system for mobile communication (GSM) technologies[7]. Heo revisited Parameter estimation in a regional flood frequency setting, based on a Weibull model[8]. Choi proposed a hybrid accident simulation methodology for nuclear power plants to enhance the capabilities of compact simulator by introducing artificial neural networks[9]. Renschler formulated a framework of consecutive scaling steps that provide a methodological structure allowing analyzing and propagating uncertainties and their particular effect on the decision-making process and discussed the importance of uncertainty inherent in Digital Elevation Models (DEMs) on volcanic hazard prediction for disaster mitigation and management[10]. Kwan outlined a system architecture and a network data model that integrates the ground transportation system with the internal conduits within multi-level structures into a navigable 3D GIS[11].

Since most existing systems are designed and developed for handling single emergency, there are serious limitations when applying these systems to disasters[12]. Emergency geographic information services must provide high service level to ensure public safety. Since spatial data resources play an important role in decision-making during the response phase of an emergency situation, emergency geographic information services can provide tools to more efficiently support of emergency management information needs. This paper takes the framework of emergency geographic information service as objects of study, studied how to obtain the emergency geographic information service of key technology and method. It used the related emergency management theories and 3S technology, experiences for reference.

This paper is organized as follows. The second section explains the relationship among emergency services, geo-spatial data and spatial information technology. The third section mainly outlines the overall architecture. The forth section presents the main functions during the emergency services and the emergency recue. The fifth section introduces the two typical applications. Finally, Section six summarizes the results of the paper.

2 Relationship among emergency services, geo-spatial data and spatial information technology

Geo-spatial data consisting of maps, images, DEM, and so on are already widely used in many of the emergency services, which is not only the main information resource for emergency response but also the base and the framework to integrate various emergency incidents information in emergency services. Spatial information technology such as GIS, RS, GPS, is an important support in emergency recue, which provides theoretical basis and technical assistance for the system. The relationship among emergency services, geo-spatial data and spatial information technology can be summarized as followed [1, 13, 14]:

(1) Geo-spatial data can be updated all the time and provide an overview of the disaster spread conditions and the affected and potential effected areas.

(2) Geo-spatial data can provide real-time and authoritative spatial information, which can help crew to get a comprehensive situation overview and to be aware of the context of the disaster.

(3) Geo-spatial data resources play an important role in decision-making during the response phase of an emergency situation.

(4) Spatial information technology not only incorporates important geo-spatial data about the emergency situation at hand, but also has spatial analytical and modeling capabilities to facilitate better planning and decision making.

(5) Spatial information technology provides the visualization information about the areas of the emergency event and safety locations, ingress and egress routes.

(6) Spatial information technology can integrate other professional models to provide decision supporting information.

3 Overall architecture

The overall architecture is shown in Fig. 1. The framework can be separated into four general levels: data support layer, the base platform layer, the application support layer and the users layer. The data support layer is considered as a basic and important component of the framework. The base platform layer integrates various emergency resources to provide decision supporting information. The application layer serves as a support of decision-makers in all phases of emergency services. The users layer addresses all users in emergency services.

Data support layer: major responsibility of emergency database group is to manage the spatial data and the emergency resource data. To efficiently structure all this data, emergency database group is classified into eight categories. The fundamental spatial database is considered as a basic resource of the framework. The emergency database group integrates all data into an integrated spatial model. This allows a spatial evaluation of the data that is necessary for the analyses during use. It is impossible to have all data necessary or useful for managing emergency all the time. Usually, one does not know the point in time when a case of emergency comes up or what data will be useful or even necessary during the next case of emergency. Therefore the framework should provide different ways of accessing or integrating data.

The base platform layer: within the framework the base platform layer has to be organized for communication with the application and the database. The base platform layer is composed of GIS, RS, GPS, OA, MIS and DSS. The value and the function of GIS are the integration and the visual expression of all kinds of information. Though data sharing, spatial analysis and visual expression, GIS can help people to understand and deal with the emergency event. OA is the workflow operating system and the graphic-attribute integration working system for decision-makers in emergency services.

In the framework MIS is considered as an emergency professional information management system for data management, spatial analysis and decision integration. DSS provides rapid emergency decisions as the human-computer interaction information system.

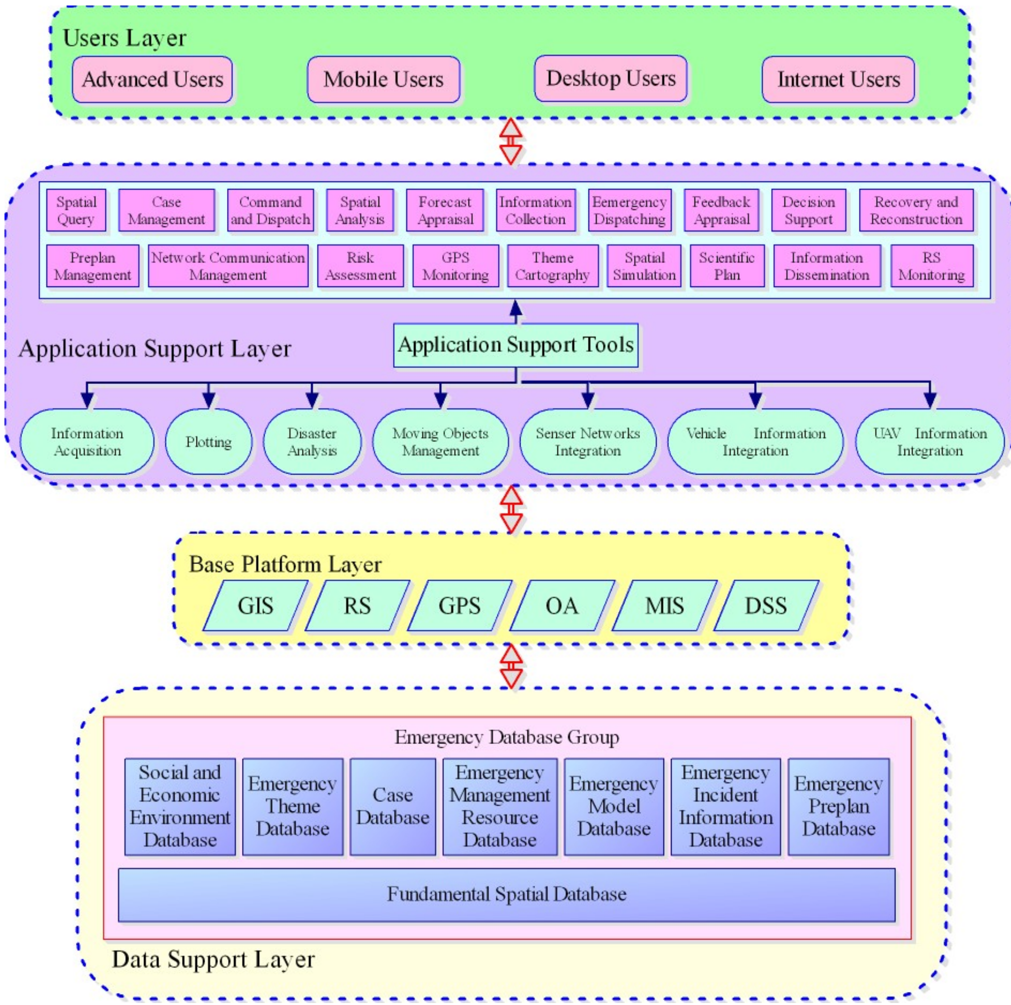

Figure 1 Overall architecture

The application support layer: there are mainly seven application supporting tools: information acquisition tool, disaster analysis tool, plotting tool, sensor networks integration, vehicle information integration, UAV information integration and 3D moving objects management tool, so as to provide powerful support for successful extension of the framework.

The users layer: to address all users in emergency services, different groups of users are provided: advanced users, mobile users, desktop users and internet users. Advances users are usually responsible for technical management and have to coordinate all the arrangements necessary to fight the situation. They use to display and analyze the spatial relationships among possible event locations, shelters and other emergency management facilities and resources, transportation routes, and population at risk. They also discuss possibilities and give orders to the rescue teams. Mobile users are both rescue teams, lower level decision-makers that have to give information to people that are on the way into the area of emergency, and people with handheld devices who can receive directions on their own. Desktop users and internet users have power computers, wired connection and their location is not of interest. Desktop users are any other specialists located in a variety of organizations that are asked to provide specialized data and expertise. They are sitting behind their desktop systems. Internet users are the general public and press that seek for information regarding the disaster. They are also using desktop systems.

This overall architecture allows a support of decision-makers in all phases of emergency management and even in different cases of emergency. To make it really useful, it has to sure the system fits the high efforts of emergency management – especially running in real time. To demonstrate how the system will operate in the response phase, we will use three different scenarios: flooding, terrorist attack and fire is urban areas.

This overall architecture actually would serve as a support of decision-makers in all phases of emergency management, in different cases of emergency and would be able to support different users. Furthermore, the framework has to provide an answer real-time or near real-time.

4 Main functions

The Federal Emergency Management Agency, USA divides emergency management into four phases namely: Mitigation, Preparedness, Response and Recovery. These phases are currently widely accepted by all kind of agencies all over the world [4, 15, 16]. The first phase is related to activities leading to a reduction of occurring emergency situations (e.g. construction specifications for building to resist at earthquakes, dykes to prevent flooding, etc.). Preparedness focuses the active preparation for occurring an emergency. The rescue forces (e.g. police, ambulance, fire brigade) are trained how to operate and cooperate in emergency situations. Response is an acute phase after occurring an emergency. Recovery is a phase after the acute emergency including all arrangements to remove arose detriments and long-term supply of irreversible detriments. The framework supports the emergency managers in planning and training for responding to emergencies in the pre-disaster phase, in coordinating and implementing rescue operations during the disaster phase, and in recovering and evaluating in the poster-disaster.

In table 1, it can be concluded that positioning, spatial query, 3D visualization, spatial statics and spatial analysis can be applied to any of the phases of the pre-disaster, disaster phase and poster-disaster.

Table 1 Main functions in emergency geographic information services

Phase	**Activity**	**Main functions**										
		Spatial data supporting	Positioning	Tracking	Query	Updating	2D maps	3D visualization	Plotting	Spatial statistics	Spatial analysis	Integrated professional models
Pre-disaster	Monitoring	○	○	○	○	○	●	●	○	●	○	○
	Forecast	○	○	○	○	○	●	●	●	●	●	●
	Preparing	○	○	○	○	○	●	●	●	●	●	●
Disaster	Alarm	○	●	●	○	●	●	●		○	○	○
	Response	○	●	●	●	●	●	●	●	○	●	○
	Command	○	●	●	●	●	●	●	●	○	●	●
	Disposition	○	●	●	○	●	●	●	●	○	●	○
	End	○	●	●	○	○	●	●		○	○	○
Poster-disaster	Recovery, evaluation	○	○		○		○	○		●	●	●

(“ ”represents seldom required, “○”represents required, “●”represents required very much)

In the pre-disaster phase: during the activity of monitoring, forecast and preparing, 2D maps, 3D visualization, spatial statistics and spatial analysis are the frequent GIS functions.

In the disaster phase: almost all GIS functions play an important role, especially positioning, tracking, plotting, spatial analysis, integrated professional models and so on.

In the poster-disaster phase: there is almost no need of tracking, spatial data updating and plotting, but spatial statistics, spatial analysis and integrated professional models are the important functions.

5 Typical applications

Emergency geographic information service can be extended to some important emergency services domain. The services are based on the spatial data and can help with decisions about the degree of hazard posed by the incident and the information could draw emergency response plans in order to prevent the incident.

5.1 Wenchuan Earthquake disaster Information Services System

Wenchuan Earthquake Disaster Information Services System (WEDISS) is based on the national fundamental geographic information data and high resolution satellite remotely sensed image. WEDISS with fast 3-D reconstruction of terrain can integrate multi-source RS images and disaster information (such as barrier lake, slide areas, mud-rock flow, broken roads, broken houses and so on) from the Ministry of Land and Resources, State Bureau of Surveying and Mapping. Multi-source images, DEM, place names, 3D models can be loaded dynamically. The data weren't limited to the resolution. WEDISS can support the function of overlap of spatial analysis results from professional departments and the function of the disaster spatial statistics analysis. In Wenchuan earthquake WEDISS provides information support and technical assistance for the leaders to explore the geographic environment, find out the disaster situation and evaluate the damage assessment. In Fig. 3, statistics of broken roads in Wenchuan earthquake can be obtained. We can also get the statistics of disaster information caused by Wenchuan earthquake in Fig.4.

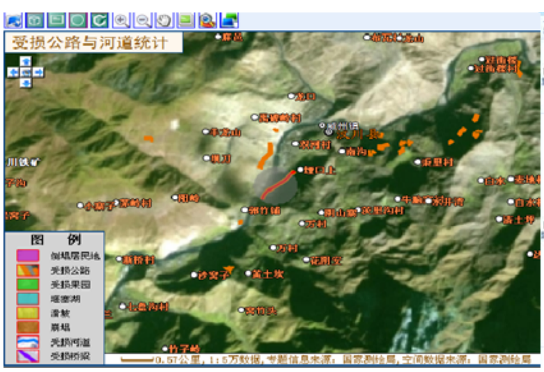

Figure 3 Statistics of broken roads

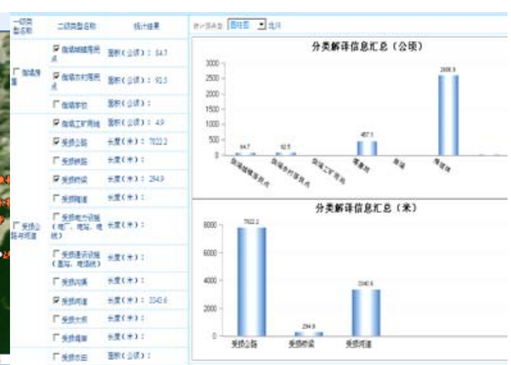

Figure 4 Statistics of disaster information

5.2 The Safety Monitoring and Control System

The Safety Monitoring and Control System (SMCS) employs global positioning system and advanced network technology. SMCS is based on the electronic maps and can obtain real-time positioning information about monitoring vehicles to prevent any security issues.

Technology principle of SMCS is shown in Fig. 6. Positioning information obtained by monitoring mobile station including GPS, Beidou Satellite Navigation and Positioning System and maritime satellite communication system is transformed into the ground station of satellite by satellite communications. The data is transformed into the command center through the data-exchanging center. Moving objects information based on 3D visualization and message processing are shown in the command center. At the same time, the scheduling information is transformed into the mobile station by the command center to realize real-time information communication between the mobile station and the command center. SMCS can monitor and control the mobile station.

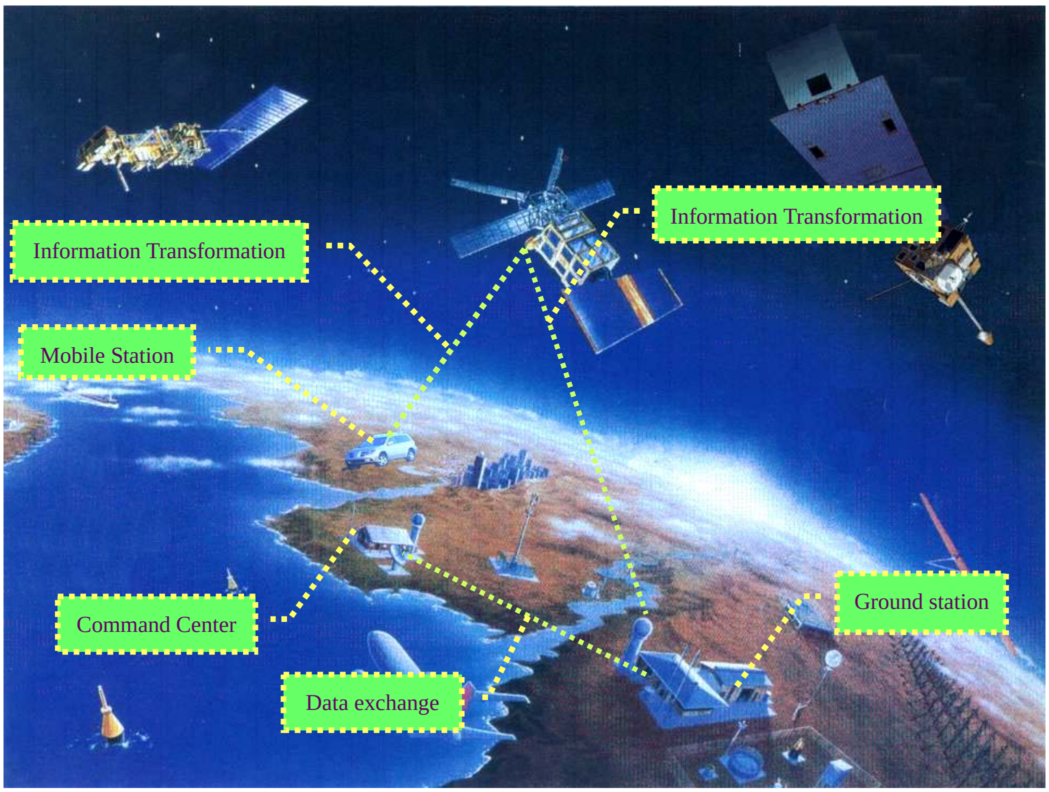

Figure 6 Technology principle

Main functions of SMCS include vehicles' navigation, vehicles' real-time positioning, vehicles' real-time scheduling, alarming, self-protection navigation and so on. In Fig. 7, the red lines are the vehicles' trajectories. As we can see, we can get the vehicles' navigation and vehicles' real-time positioning to track at any time.

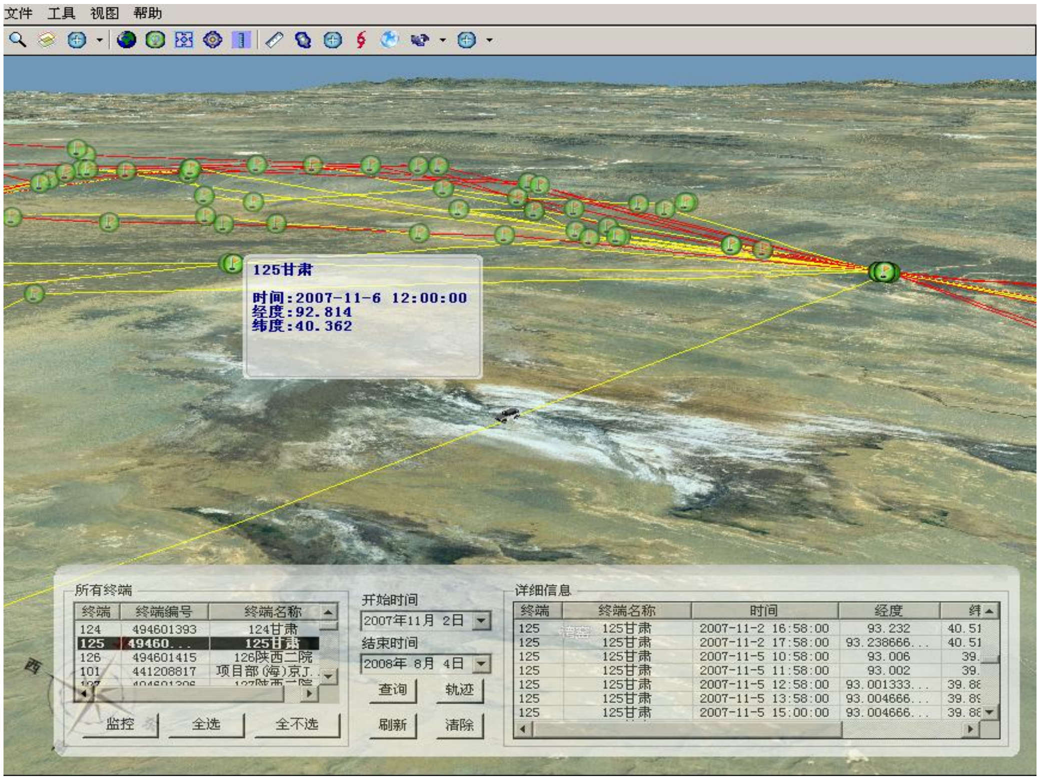

Figure 7 Moving objects monitoring

6 Conclusions

3S technologies and methods were useful in emergency geographic information services. Emergency geographic information services will be one of the difficult questions in the field of GIS and emergency management in a very long period. It is very important for the practical use to provide emergency services. In this paper we have presented our concept to be used in emergency geographic information services. This paper outlines the important elements of the emergency geographic information services, including the overall architecture and main functions. The results of the typical applications indicate that emergency geographic information services have potential to contribute in significant ways to quick emergency response.

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