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Spatial Information Technology for Disaster Management

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ABSTRACT

Most major geohazards such as floods, forest fire and oil spills occur suddenly, and require an immediate response. This paper describes the development and establishment a spatial information technology and engineering system that uses GIS and Remote Sensing technologies to detect, monitor and assess geohazards, including floods, forest fire and oil spills. The potential application of Remote sensing and GIS techniques for floods and oil spills is discussed. The oil spill risk management system study was developed for coastal zone of Peninsular Malaysia. The development of GIS database used remotely sensed data from Landsat TM, SPOT Panchromatic and MSS, AVHRR and air-borne images.

For the flood studies, Digital Elevation Model (DEM) was created for Klang River Basin from the input data of contour lines. DEMs stored the data for the slope analysis, terrain analysis and also visualizing for the flood simulation. SCS TR-55 Model was used to predict the extent of inundation and depth of flooding. Parameters of rainfall, land-use and hydrological relief were adopted as the main input data. These two case studies will provide the technical guidelines for in-depth study in GIS and remote sensing for disaster management.

Keywords: Spatial information technology, disaster management

INTRODUCTION

The world is confronted by the ever-increasing threat of the loss of life, property, and natural resources due to natural disasters. In the past three decades, the frequency of natural disasters has increased (Kriemer and Munasinghe 1991; Anderson 1991). A natural disaster is considered to be an event, triggered by a geophysical, or climatological phenomena resulting in, or having the potential to result in widespread loss of life and property, and destruction of the community's infrastructure of such significance that the community has to seek outside assistance to recover from the effects of the phenomena.

Advances in sciences and information technology (which include GIS and Remote Sensing) has given a way of solution to save the community. Spatial information technologies are extremely useful in the management of disasters because of these resources, activities, and natural conditions can be represented digitally as describe by McKee *et al.* (1998). This means that information about them can be:

- Collected by means of remote sensing using wireless communication to devices with sensors. The devices may be fix firmly, or may be mobile with wireless communication devices reporting their GPS-determined locations and sensed values.
- Displayed on computer displays on desktops, in vehicles, or handheld devices.
- Merged and analysed by GIS, which overlays and co-locates digital maps so that queries can produce new maps.
- Communicated over the same communication networks that carry voice and other kinds of data communications.

The integration of this remote sensing data and GIS as the operational tools will built up a proper system for disaster management. It is also expandable to include additional disaster-related data and models with their associated remote sensing data requirements and distributed data sources.

An important of environmental remote sensing to land resources management is its potential to map resources and to monitor changes that occur in boundary surface conditions over extended period of time. From the viewpoint of land management, the results of scientific research need to be interpreted and integrated in a practical way for "real time" application. The theories derived from scientific research need to be incorporated into a practical model; environmental and land management data need to be integrated; and a "real-time" methodology needs to be developed to evaluate, monitor and manage land resources.

The paper reviews the literature from a disaster management perspective followed by a discussion of the GIS literature based four phases of disaster management. Finally, the requirements for research on the application of GIS and remote sensing in disaster management are discussed. Examples of two types of the disaster, flood and oil spill study, are describe below by using the integrated scheme of remote sensing and GIS.

DISASTER MANAGEMENT

Disaster management in actual action constitutes a complex process. To understand their constituent, the process can be simplified into 3 major phase of action that is before, during and after the event.

Before Event (pre-event)

Phase one is before the event. It's constitute of two stages; the preparation and the prediction. During the preparation stage, the acquisition of data or more specifically, creating the database are the major focus task. The planning should start long before the disaster strikes and ready to access whenever the event occur. The database will recognize the area of interest with related features of disaster. Preparation for disasters can be done such as emergency plans, monitoring and also training of volunteers. Understanding the cause and needs of the disaster will conduct an action undertaken. Mitigation of disaster is also one of the preparation stage in order to prevent the disaster.

The second stage is the prediction and warning system. Real-time data or predicted data from other sources such as meteorological department or any detector used to observe the hazard by analyzing and modelling.

During Event

During the disaster is the time when everybody have to make vital decision. The need for accurate information at this phase is very urgent. Normally, this phase occur short time after the predicted date. Various measures may include the information of area influence, transportation access, alert system, mobilization of resources, evacuation of victims to recognized safety places, suppression of the hazard and even the assessment of the immediate emergency needs. This is an important phase when a disaster manager, along with the community, has to make many vital decisions involving many agencies.

After the Event

The system may continue to move on restoration of damages into normalcy such as land use control, building regulations, or other non-structural measures. Damage assessment has to be done in written hardcopy or archive. Efforts to rebuild a better and more disaster-resistant community based on the experience of the disaster. Information and experiences in the disaster are documented for a better understanding and mitigation of disasters in the future. It is very important to equip the community with measures to cope with the disaster and reduce the vulnerability of the community to the damaging impacts of the disaster.

The action of each step is overlapped on each other and appears in cyclical pattern. The monitoring of the natural phenomena is continued for further study of the phenomena.

The System

The GIS and remote sensing technologies are evolve with the evolution in hardware and software. In development of an operational system, it is important to provide a real-time early warning system.

Data

One of the most important requirement for GIS system to work is the data. There are two types of data required for disaster response: static data and dynamic data (Boone 1995). Static data are the data that does not change very frequently, use to show the spatial area and features of interest. The database created by applying this static data are examples of information; are needs for creating the database could be population, demographic, location, topographical relief and etc.

Whereas the dynamic data refers to the event-specific and the available in real-time. Stage of event, spatial location, influenced area and types of event are some of the examples of the dynamic data.

The integration of these static and dynamic data is the main criteria in disaster management and the system of GIS is the best solution for this requirement. The process includes the incorporation and interpretation of data from various sources of agencies.

As the system will interfere with the various agencies and individuals, GIS should accommodate for the public access of data.

Software and Hardware

GIS is a technology in evolution with rapid advances in hardware and software. Selection of a suitable operating system is very important, as it is necessary to train people. For the final decision, to interact with the community, the software should support the multimedia function.

A survey of bidding vendors conducted by the State of Florida's Emergency Management Agency revealed that none of the GIS software products had the desired level of spatial statistical analysis capability (Bales and Loomis 1995). To make the investment in GIS more cost-effective, the multi tasking of the GIS with multiple agencies is suggested by Bales and Loomis (1995). However, it is the state of believing that between the requirement of the appropriate system and the impact of system management still fair enough.

Personnel

The person who takes charge of the whole process is someone that is well trained in these disciplines. Most of them are normally the scientist and engineers who are experienced in coping with the data handling and data manipulation. It is rather important for the disaster manager to be familiar with the capabilities of GIS so that he/she can put the technology to good use.

The Limitations of Disaster Management

Even though our information technology era has improved, we still confront some of the limitations such as the data, software, officer and even agencies.

The main limitation of the system will be the ability to get the real-time data from satellite receiving stations. The repeat coverage of some satellite are very long for example for Landsat TM, 16 days and SPOT will take about 26 days to orbit for the second image for each scene.

Though there have been rapid advances in the hardware in terms of speed, storage, and manipulation capability, the existing commercial software presents difficulties in serving all the needs of a disaster manager for example lacking of built-in spatial statistical capability. In some purpose of study, we need to interchange the data processing between the software in according to avoid the insufficient task of the certain software. In this case, the problem occur when data support system are. Furthermore more changing the data format in some case will eliminate some properties of data and which might be useful information.

The well-trained officer is another problem. Disaster management is still a profession in evolution and lacks of well-trained officials competent at using computers and other advanced technology (Drabek 1991). The problem of person in charge is very critical problem because without them, there is no action can implement.

Such institutional support may not be possible in many developing countries, providing a major obstacle to the use of this technology in areas most prone to disasters.

GIS APPLICATION IN OIL POLLUTION

The Marine Spill Response Corporation, USA carried out a research and development (R&D) of an operationally optimised aerial remote sensing system for oil spill response to enhance oil spill containment and cleanup capabilities. Also, the Emergencies Science Division of Environment Canada had a mandate to develop operational oil spill remote sensing to respond to oil spill emergencies. The particular requirements for oil spill remote sensing include; short response time to minimise environmental impact, good discrimination between oiled and unoiled surface, and information on the location, distribution, and quantity of oil in the environment (Giammona *et al.* 1993; Fruhwirth *et al.* 1993)

THE GIS BASED OIL SPILL RISK MANAGEMENT SYSTEM

For the past two decade, coastal and marine application have benefited from the information derived from commercial satellite imagery and used GIS as a powerful tool to manage the oil pollution at the coastal area. Inm which, GIS applications are heavily dependent on both the timeliness and currency of the data they contain and the geographic coverage of the database. However, the remote sensing can provide timely data at appropriate scales to GIS context.

The Peninsular Malaysian water is fragile ecological and economic area with heavy ship traffic. The result is high risk of oil pollution, both intention and accidental. Oil spill detection by means of remote sensing and spatial management in GIS became possible with the advent of the integration data.

GIS-based risk management systems was developed and used the latest information technology to store data required for oil spill risks assess, response, planning, and risk management. GIS is the most efficient system for analysing and visualising a comprehensive range of variables, held in large databases, which relate to an oil spill. The effects of alternatives coastal zone development strategies can be tested and presented in an easily understandable format. Response co-ordinator may utilise this system to better understand and manage the incident under their responsibility.

This study discusses the work done utilising GIS and remote sensing technologies to develop an Oil Spill Risk Management System (OSRMS). This is a GIS-based prototype system, developed for Peninsular Malaysia focused on the construction of an integrated database for coastal management especially for oil spillage issues. The OSRMS is designed into three parts; there are development of GIS database, remotely sensed data processing, and the oil slick movement prediction.

It is crucial to identify the sources and risk in a spillage incident in order to formulate counter responses for the emergency situation alertly. However, there is a problem in incorporating critical stages of data and information needs for emergency management prior to impact, the immediate post-impact response period, the recovery period, and opportunity for mitigation are defined. In addition, oil pollution problem covers a large extent of spatial area, it is essential to have a response management system, which can manage the large collection of spatial geographic information and simplify all manipulation of data for analysis, and faster access for emergency co-ordinator to the best information possible.

THE SIGNIFICANCE OF STUDY

The OSRMS is designed to assist rapid and effective decision making in oil spill containment and clean up operation in Peninsular Malaysia coastal areas. Oil spill data, access and protection information will be placed in GIS database and interfacing it with a GIS database for rapid access, retrieval and query. While, the remotely sensed data as spatial data input were used to monitor and derive valuable information about marine water pollution, especially on oil spillage. These remotely sensed data including LANDSAT TM, SPOT Panchromatic and Multispectral Scanner (MSS), AVHRR and air-borne images were integrated in the GIS based oil spill risk management system for Malaysia coast in order to detect, assess the risk and handle the oil spills problem in an alert situation.

The information can be required from this system such as location of oil spills, quantity of oil spills, distribution of this in the affected area; for example location of the areas of heaviest contamination, the length of shoreline affected by the oil slick. An oil slick movement model was incorporated into this system in favour of predicting the oil slick movement direction and duration to reach the shoreline. Wind, wave and current are the main parameters for this model.

The GIS-based system can be used to establish the appropriate response and locate the dense areas in a slick and local surveillance, to permit clean up vessels to detect the oil to be cleared in rapid circumstances. This risk management system will allow new opportunities for assessment, multiple resource planning, permit viewing of the state's natural resources in ways out, therefore realised, improve the decision-making process, and provide a baseline for future assessments.

Thus, the information system described in this project will emphasize in the mapping, visualising, analysing and modelling capabilities of GIS software with a properly designed database management system for oil spill containment in Peninsular Malaysia coastal area.

Analysis of the image of the SPOT MSS in Terengganu oil spill clearing demonstrated the utility of satellite data as a means of detecting oil on the marine surface and of assessing the distribution of the oil that issued from the incident. Despite, it had prevented by cloudy weather, this satellite image was effectively in monitoring at 16 days intervals of oil spill cases along Peninsular Malaysia coastline.

Full integration of OSRMS and its modelling output will be undertaken by portable computer or response sites. In addition, OSRMS is also readily adaptable to other marine environmental management applications.

OSRMS is intended to be a tool for detection and management of environmental emergency situation. GIS database and its functionality are powerful tool in visualising the results of modelling, and analysing and visualising potential impacts. As more data are collected, new layer can be produced, stored, updated and analyse to improve the sensitive and risk asses map or management system. In outline, benefits of OSRMS includes improved pre-spill assessment of sensitive shorelines that would require protection or clean up, improved capabilities to decide equipment deployment and clean up logistics, improved resource damage assessment and ability to conduct litigation for damage compensation.

Lastly, OSRMS is not only intended to be a detection system, it will also be a system for management and support when the emergency situation happens, and provide a baseline for future assessment.

FLOOD STUDIES

A system was developed to monitor and forecast flood event by using the advantage of remote sensing and GIS technology. The database was developed from infrastructure such as road network, hydrological data, topographical relief provided by JUPEM, land use aspect provided by DOE and also the real-time image provided by MACRES. The SPANS software is use as the platform for the study activity. This software have the reliable built-in spatial statistical capability required for the study.

Information from contour line, subject to DEM analysis to determine areas subject to flood inundation. Input data used are digital topographic maps with contours at 20m intervals scaled 1:10,000 project to Malayan Grid System. Flood prone areas defined from the structured model DEM. Interpolation algorithms, Triangulated Interpolation Network (TIN) are use as the scaffolding in the process of creating DEM. Information may be extracted in two ways, by visual analysis of graphic representation or by quantitative analysis of digital elevation data. For a 3-D viewing of the landscape, layers of information such as land cover and hydrographic can be overlaid onto DEM. The DEM will provide automatic layers for slope analysis, terrain analysis, hydrographic analysis and flood simulation.

Based on the historical data of flood (records), the subjected area are zoned to severity code of flooding and this area is known to be the aimed area when the big storm is predicted to strike.

The second phase of the study is the statistical flood forecasting modeling. SCS TR55 Model was used by adopting assumptions/limitations in use by the model. Rainfall data are accessed from DID branch, Ampang from raingauge site. Input data of various flood levels for the certain interested location will allow the early prediction of the extent of inundation and depth of flooding. Public are warned from time to time before the disaster strikes to reduce damages and more important are the lives.

For further research, this database can be used for in-depth study and updated for specific needs individually or agencies.

Using the data base and GIS spatial modelling operations, theories and principles derived from more traditional geographical research can be technologically applied to the real-world' land modelling operations, the system also provides the potential for "real-time" assistance for decision-making activities in flood mitigation.

CONCLUSIONS

There is a large literature relating to the use of GIS in understanding the physical and natural phenomena leading to disasters. There is less evidence of transformation of technical studies on particularm phenomena into information usable by the disaster planner and manager. Information on the people, socio-economic characteristics, vulnerability, behavior and perception, and institutional supports available are as important for responding to disasters as the phenomena itself. A lot of study is geographically referenced and GIS can be used not only as a management tool, but also as a tool assisting disaster research. The potential for the use of GIS for all aspects of disasters, including management and research, is very promising as more and more data becomes available in the real-time through advancements in remote sensing techniques and quick transfer of data. Networking capabilities in recent GIS products also holds promise for a distributed decision support system, particularly in circumstances which do not allow large investment in a large monolithic emergency information system. The limitations due to data, software and hardware, training of end users and the institutional capabilities of the disaster management agencies have to be addressed for the widespread use of this technology.

The integration of remote sensing with GIS techniques offers an effective tool for analysis of the risk management. The success of utilisation the remote system and GIS technology is the user can predict the risk of disasters in an efficiency and alert situation.

In short explanation, the advantages of the technologies are;

1. Allows long-term time series studies and storage of information for future situation.
2. GIS & remote sensing improves information accessibility. RS data covers larger area inspection saving in cost and time spend. GIS bring together vast amount of information from a wide variety of sources and applicable.

Improving the management of disasters remains a societal objective. Advances in science and technology have to be applied to mitigate disasters in order to meet this objective. Geographic information systems provide an invaluable tool which can largely assist in streamlining the response to disasters and help in informed decision-making by individual as well as public official.

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