Development of Safe Taiwan Information System (SATIS) for Typhoon Early Warning in Taiwan

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Abstract: Due to the particular geographical location and geological condition, Taiwan is constantly attacked by typhoons, flood, landslides, debris flows, and earthquakes. Those natural hazards had caused huge loss of lives and properties. To reduce the damages and losses caused by the natural hazards, an integrated and complete decision support system for decision makers is necessary. In this study, Safe Taiwan information system (SATIS), which includes two subsystems, response operation subsystem for staff members and decision support subsystem for commanders, is developed for preparedness and response of typhoon hazards. It is based on the Web-GIS framework that the disaster information can be distributed via internet technology. When typhoon is approaching, response operation subsystem is used by National Science and Technology Center for Disaster Reduction (NCDR) staffs to integrate real-time monitoring information, hazard models and graphical user interfaces to analyze and manage the disaster information such as the current position and possible path of typhoon, the spatial distribution of rainfalls, and potential areas of flooding, landslides and debris flows. The input data of this subsystem includes the basic maps, the real-time information of typhoon and rainfall issued by the Central Weather Bureau, the real-time water information from the Water Resources Agency, and the hazard maps indicating areas of potential landslide, debris flow and flooding made by NCDR herself to estimate endangered areas under the current typhoon. There are four main modules integrated into the subsystem including the rainfall monitoring and forecasting, the estimation of potential inundation areas, the estimation of potential landslide and debris flows, and the management of disaster information. The results of hazard risk analysis which include potential rainfall distribution, inundation and landslide risk areas, early warning messages, and total suggestion over the next 24 hours are finally demonstrated by decision support subsystem in the National Emergency Operations Center (NEOC) and help the commander to make the right decisions in disaster preparedness and response phases. In the future, SATIS will integrate social and economic information into the assessment of natural hazard vulnerability. It can help the commander to know the high-risk areas and make the right decision.
Keywords: GIS, Disaster Management, Decision Support, Hazard Models.

1. Introduction

In 2005, the World Bank issued “Natural Disaster Hotspots – A Global Risk Analysis”[1] indicated that Taiwan may be the most vulnerable place to natural hazards, with 73 percent of population exposed to three or more hazards, such as typhoons, flooding, landslides, debris flows, and earthquakes, which often cause series property damages and even life losses. Although it is almost impossible to avoid the occurrence of disasters and completely recover the damage caused by the natural hazards, the sufferings and risks can be minimized by developing decision support system for disaster management.

The general process of disaster management involves real-time disaster information collections, compilations, interpretations, analyses, predictions, illustrations and decision support. Monitors and detectors have to be installed to collect the real time disaster information. Databases and mathematical models are employed and integrated to process and analyze the hazards information [2]. It may be observed that advancement of information technology in the form of internet, Geographic Information System (GIS), remote sensing and satellite communication can help a great deal in planning and implementation of disaster management [3, 4]. In the past, GIS has emerged as a powerful tool for effective disaster management through mitigation, preparedness, response and recovery phases [4, 5, 6]. In disaster prevention phase, GIS using a variety of modeling techniques is used to analyze the large volume of data needed for the hazard and risk assessment and awareness [7]. It can also allow making available the risk maps and carrying out some basic scenario analysis.

Although the technique of GIS provides the basic ability for the disaster management, some researchers have noted that the current commercial GIS products are not able to facilitate real-time natural hazard risk management decision-making without significant modifications or integration with external hazard models. This restriction is urging the next generation of Decision Support System (DSS) which integrates GIS, internet technology, dynamic hazard models and graphical user interfaces, to provide effective decision support tools for disaster management. In this paper, Safe Taiwan Information System (SATIS) was developed for typhoon hazards. This system is base on the Web-GIS framework that the disaster information can be distributed via internet technology. When typhoon is coming, the DSSER is used to integrate real-time monitoring information, hazard models and graphical user interfaces to analyze and manage the disaster information such as the current position and possible path of typhoon, the spatial distribution of rainfalls, and potential areas of flooding, landslides and debris flows [8]. The results of hazard analysis and warning messages are finally delivered to the National Emergency Operations Center (NEOC) and help the commander to make the right decisions in disaster preparedness and response phases.

This paper will introduce the Safe Taiwan information system for early warning in Taiwan. A case study using the developing SATIS for typhoon hazard will be examined.

2. Case Study: SATIS for Typhoon Hazards

In recent years, National Science and Technology Center for Disaster Reduction (NCDR) has developed Safe Taiwan Information System for typhoon hazards. This system is based on the WEB-GIS framework that the disaster information can be distributed via the internet technology. SATIS, which includes two subsystems -response operation subsystem for staff members and decision support subsystem for commanders, is developed for preparedness and response of typhoon hazards. It is designed to integrate the real-time monitoring data, the dynamic hazard models and graphical user interfaces (GUIs) to provide disaster management decision support tools for emergency response. The input data of this system includes the basic maps, the real-time information of typhoon and rainfall issued by the Central Weather Bureau, the real-time water information from the Water Resources Agency, and the hazard maps indicating areas of potential landslide, debris flow and flooding made by NCDR herself to estimate endangered areas under the current typhoon. Fig. 1 illustrates the framework of the SATIS. There are three main stages for typhoon early warning, including the monitoring of rainfall information, the analysis of potential information for inundation areas, potential landslide and debris flows, and the demonstration of risk information for typhoon hazard. The functions of SATIS for these three stages will be described briefly as following.

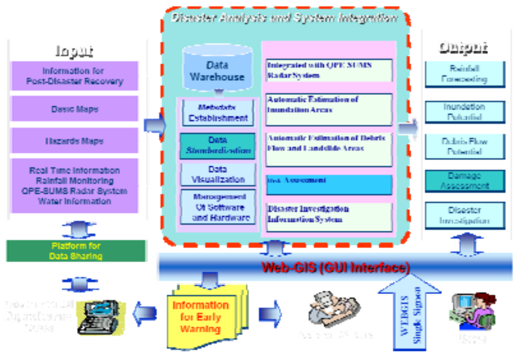
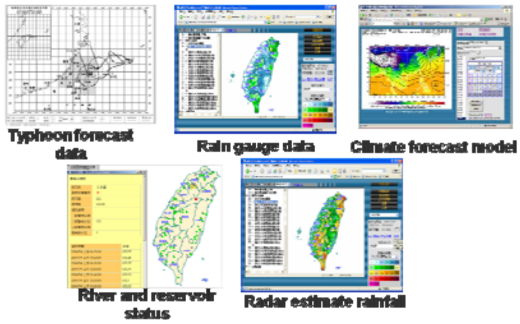


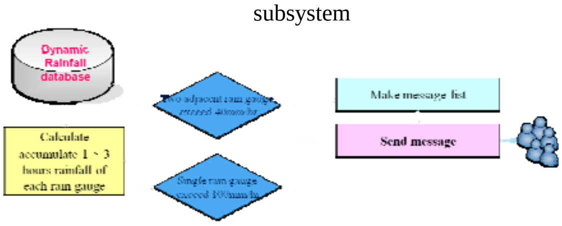
Fig. 1, Framework of SATIS

1) Monitoring of weather and water information

During the monitoring stage, NCDR staffs start using response operation subsystem to collect the typhoon information and performed preliminary estimate of its future track. The response operation subsystem integrates Typhoon forecast data, the real-time observations of rainfall data, climate forecast model, river and reservoir status and radar estimate rainfall distribution. These data are also calculated as the GIS layer which can be overlapped with other GIS layers such as the basic maps and potential hazard maps for further analysis. It is shown in Fig.2(a). In this stage, the response operation subsystem also can automatically send NCDR staffs the warning rainfall message which rules are shown as Fig.2(b). By means of warning messages, the staffs can recognize the damage areas easily during a typhoon attacking.



(a) GIS information in response operation subsystem



(b) Rainfall warning rule in monitor module

Fig. 2, Response operation system for monitoring

2) Analysis of potential information

In order to reduce the disaster of flooding, landslide and debris flow appropriately, an inundation and landslide monitoring model and an exact database of inundation and landslide potential maps are established by NCDR. For the analysis of potential inundation, the surface inundation potential maps of urban regions in Taiwan have been simulated using the inundation model under the 24-hour design rainfalls of 150, 300, 450, and 600 mm. The results are stored as the GIS layers into the database in advance. For the analysis of landslide and debris, there are 1420 debris flow rivers investigated in advance by the Soil and Water Conservation Bureau, Council of Agriculture. In addition, the Slopeland Disaster Reduction Division of NCDR has also recorded 3,629 historical debris flows and landslides which are stored in the database.

When a typhoon attacks Taiwan, the potential maps can be used to analyze the possible inundated areas and time of duration under the different raining condition. When typhoon is coming, the procedure which is integrated into SATIS automatically selects the potential layers which indicate the possible flooding, landslide and debris flow areas and disaster level every three hours from the database according to the forecasting rainfall. The estimated results can also be modified manually via the user interface of response operation subsystem according to the real rainfall situation. The information of potential areas will be very helpful for the decision supports for emergency operations for flooding, landslide and debris flow disasters. Fig. 3 shows the data flow for analysis stage.

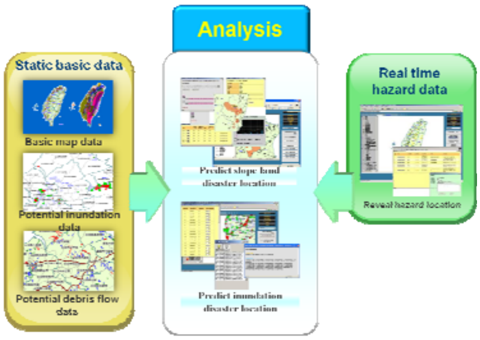


Fig.3, Data flow for analysis stage

3) Demonstration of risk information

Real time and early warning information for the typhoon hazard is very important to the decision makers in relief and rescue phase. This information usually affects the results of rescue actions. How to demonstrate the monitor and analysis information effectively are the important issues for the activity of disaster relief and rescue. Using the powerful database to handle and analyze data, the decision makers can make the best decision for the emergency response immediately. The purpose of this stage is to establish a subsystem to provide different risk information for the disaster decision making during a typhoon attacking Taiwan. The decision support subsystem can be improved effectively after integrating these monitoring and analysis information.

In fig. 4, the decision support subsystem is illustrated as a GIS distribution layer that enables the decision makers to be aware of the rainfall situation, flooding and landslide potential risk areas etc and do an appropriate emergency response.

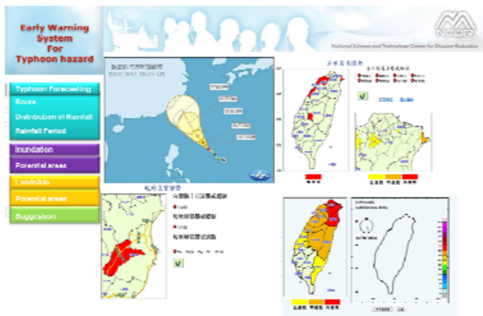


Fig. 4, Demonstration of the risk information

4) Evaluation of Damage

For recovery phase, it is important to control and recover the damage. Remote sensing image is a helpful tool for disaster investigating, especially for the disaster location which traffic was injured after typhoon and the investigators couldn't get to. The remote sensing image subsystem provides the images before and after disaster. It also could overlap the damaged areas which are interpreted by NCDR staff for evaluating damage scale. In fig. 5, Formosa II satellite images are provided in this subsystem. Users can get a grip on the damaged areas and situation of river deposition via the images.

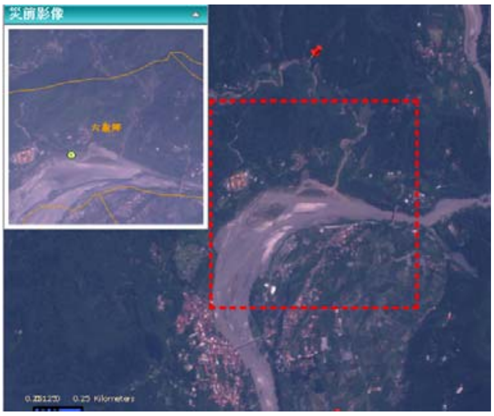


Fig. 5, Satellite images before and after Typhoon Kalmaegi, 2008

3. Conclusions

This paper introduced Safe Taiwan Information Systems for typhoon early warning in Taiwan. A decision support system for typhoon hazard is developed for the case study. It is an essential component for disaster management, especially for disaster response. The further step for SATIS, it is important to establish hazard risk maps which include social and economic factors, such as land use, population etc.

Many organizations, including fire, weather, water, and soil agencies, in different levels of governments in Taiwan have had their own emergency information management systems. The further step is to team up the information divisions of associate research centers, establish a data warehouse as an information service platform with XML/GML-based data exchange standards and SOA technology, and join international cooperation projects. In the future, Safe Taiwan Information System will be upgraded to be a real decision support system, where more intelligent reasoning and prediction models should be installed together. It also will share the risk assessment information with relative organizations.

It is highly expected that we will have a more successful disaster management system if we are able to fully employ the powerful capability of computer systems, web-based technology, and telecommunications device.

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