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An intelligent slope disaster prediction and monitoring system based on WSN and ANP

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ABSTRACT

Taiwan generally has large-scale landslides and torrential rainfall during the typhoon season. As Wireless Sensor Networks (WSN) and mobile communication technologies advance rapidly, state-of-the-art technologies are adopted to build a model to reliably predict and monitor disasters, as well as accumulate environmental variation-related information. By integrating WSN and Analytic Network Process (ANP), this study evaluates the weight of disaster factors that adopt the consistency index of pair comparisons on hillslopes. The weight estimation and classification of disaster factors are based on the K-means model to build the hillslope prediction model. *The Portrait-based Disaster Alerting System* (*PDAS*) is designed and implemented using the proposed disaster prediction model. The PDAS adopts Web-GIS to visualize the environmental information. Evaluation results of the system indicate that the proposed prediction model achieves more accurate disaster determination than the conventional method.

1. Introduction

Increasing numbers of natural calamities have occurred in Taiwan in recent years. These disasters often cause serious natural destruction after torrential rainfall or earthquakes, causing heavy losses to people's lives and property. The KALMAEGI typhoon damaged many parts of Taiwan in July 2008, due to the heavy torrential rainfall. Moreover, the survivors did not know how to report the disaster promptly to the authorities, so rescue teams could not locate the survivors. Therefore, wireless hand-held devices are required to transmit the multimedia information of disasters, such as images, sounds and characters.

Taiwan generally has large-scale slope failure and torrential rainfall to cause sediment disaster during the typhoon season. Those disasters often result in the serious nature destruction and create the heavy losses of people's lives and properties. The kind of hillslopes disaster is numerous, and this mainly discussing topic of thesis choose often appear slope failure for sediment disaster to study in Taiwan. It expects to make discussion with the topic this thesis that can help people and prevention and rescuing units to prevent and alarm creating disaster. It was usually the gold period to prevent and rescue disaster with taking place before and creating at that time. It had taken place relevant disasters that all the materials were afterwards to collect and study, and judge causing disaster factors in the past, the time has already had no enough to save a critical situation. Therefore, this research study and analyze the past slope failure as basis of consulting, and combining new information technology to propose two major system themes, which are prediction supporting model and awareness monitoring system, to assist and solve problems of disaster. At first the mainly causing disaster factors of slope failure must be discussed and selected, so survey and examine the trial zone environment in thesis research. Numerous environment causing disaster factors will be chosen, assessed, analyzed, then select seven causing factors which include gradient, soil characteristics, 24-h accumulated rainfall, vegetation index, soil displacement, soil hydrous and temperature, to cause slope failure. Then according to values of selecting disaster factors into designed prediction supporting model, the model system will assess and analyze the taking place disaster grade and possibility. In order to reach and develop early alarming effect, the prediction supporting model can make sure disaster preventing and alarming functions really, and the study also plans complemented monitoring and transmitting tools. The system will utilize these monitoring and transmitting functions to complete effect of pre-warning and informing immediately.

This study also mainly proposes and designs a real-time disaster information system, which is important for people to develop PDAS to assist the prevention disaster works, to obtain, inform, and display the disaster situation. In order to achieve forecasting

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and monitoring disaster functions, PDAS is also implemented using the proposed disaster prediction supporting model, which prediction efficiency model includes Analytic Network Process (ANP), Back-Propagation Neural Network Analysis (BPN), and Multivariate Statistical Analysis (MSA), to compare the adaptable model.

As Wireless Sensor Networks (WSN) and mobile communication technologies advance rapidly, state-of-the-art technologies are adopted to build a model to reliably predict and monitor disasters, as well as accumulate environmental variation-related information. The PDAS also combines multimedia transmission technology and quality of service (QoS) mechanism to reveal the real disaster situations, for example, the accurate position and the real-time image/video of accident events. Heterogeneous Network Users use the handheld devices to transmit and receive multimedia information about slope failure via the wireless/mobile and internet communications.

Accordingly, this study adopts Embedded Multimedia Communication technology to design the Portrait-based Disaster Alerting System (PDAS) in order to solve the space and time limitations. Users can use the hand-held devices with high mobility via wireless network (3G/GPRS/GSM) to obtain disaster multimedia stream service (Castillo-Effer, Quintela, Moreno, Jordan, & Westhoff, 2004). Additionally, this investigation also combines customized services, Location-Aware Service, Wireless Sensor Network, Multicast, Web GIS, Intelligent Agents and Analytic Network Process (ANP) (Neaupane & Piantanakulchai, 2006). The PDAS transmits the sensing and prediction information of the monitored area to the database system to analyze the data. Additionally, geographical information system (GIS) technology combines the analysis system and alarming mechanisms to operate the model. The detected materials then accede to ANP model to appraise, analyze and process sensing hillslopes disaster factor data. Finally, a warning message based on the analytical results is released to mark where the victim stays immediately on the Web-GIS layer. This information would inform the prevention and relief personnel about the disaster area clearly and quickly.

2. Research background and theory discussion

The Portrait-based Disaster Alerting System, (PDAS) is designed to provide (i) mobile user (MU), (ii) Hillslope Monitoring Sensor (HMS), (iii) Integrated Service Server (ISS), and (iv) Intelligent Hillslope Decision System (IHDS). The PDAS offers sensing and predicting information of the disaster area. Required research background and relevant technology for this study are (1) Geographic Information System (GIS) and (2) Wireless Sensor Networks (WSN).

2.1. Geographic Information System (GIS)

GIS develops geographical coordinate information that assesses space distribution and database management technology, as well as combines systems such as geographical mathematics and map surveying. GIS has two parts, namely subject and operation. Geographical information systems are adopted to store several different geographical information, there are two types including raster and vector. Digital geographical materials stored in geographical information databases are classified as Spatial Data, Geography Data, and Attribute Data (ESRI, 1996, 2000). Fig. 1 shows the operation of a GIS.

2.2. Wireless Sensor Networks (WSN)

Recently developed sensors can not only detect the goal and change of the environment, but also handle the collected data. However, some problems need to be considered. If a base station is far from sensors, then the sensors need to adopt the routing network method so that a lot of sensors group a path to transfer materials to the base station (Evans-Pughe, 2003). Additionally, the battery of sensors may not be replaceable, energy that is considered indispensable needs to be controlled when configuring sensor design and network management (Akyildiz, Weilian, Sankarasubramaniam, & Cayirci, 2002). The hardware structure of the sensor comprises four major parts, (i) sensing unit, (ii) processing unit, (iii) transceiver unit, and (iv) power unit. Sensors can be adopted in location systems, mobilizers and power generators. The system adopts an MTS420 sensor to accumulate temperature, and an MDA300 sensor to measure the soil water content (ECHO 10) and temperature (108-L) (Ruiz & Loureiro, 2003). A TMOTE SKY displacement sensor is adopted to obtain slope materials instantly, to combine and analyze ANP model to obtain the disaster weight, and to judge the probability of disaster at any time, as shown in Fig. 2.

3. System design

The PDAS is a four-tier system as shown in Fig. 3. Users can utilize various terminal devices that include PC, notebook, Tablet PC, 3G/4G mobile phone and *personal digital assistant* (PDA) to access PDAS. The Portrait-based Disaster Alerting System, (PDAS) is designed to provide (i) *mobile user (MU)*, (ii) *Hillslope Monitoring Sensor (HMS)*, (iii) *Integrated Service Server (ISS), and* (iv) *Intelligent Hillslope Decision System (IHDS).*

3.1. Mobile user site

Mobile user' sites provide functions such as location-based service, customized service, heterogeneous networks, web-based GIS. mobile users can adopt the terminal servers of hand-held devices to link mobile communication network or internet network, to login and use PDAS systems, and to perform GPS to locate

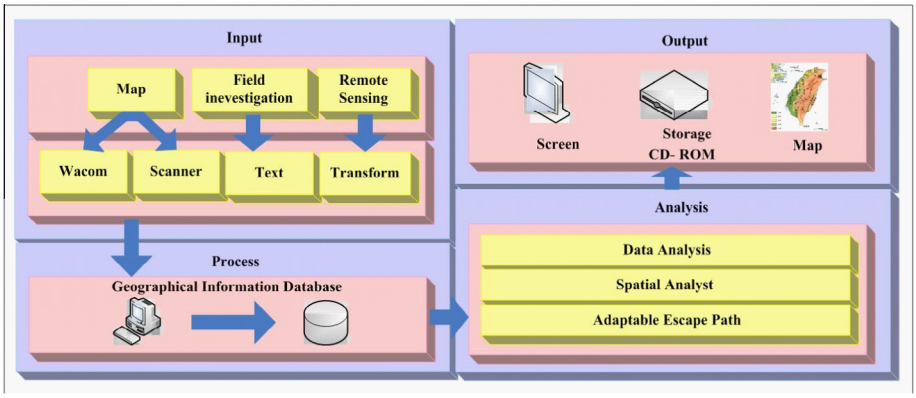

Fig. 1. The architecture of Geographic Information System.