USING WEB 3D GIS IN PREWARNING SYSTEM OF LANDSLIDE MONITORING

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Abstract: Web 3D GIS software is used to construct the geological three-dimensional information display of a landslide area. Lishan landslide is a case study for the research. Aerial photographs and DTM comparison are used to integrate the information into a geographic database system that links with the engine of the spatial database used as the basic image data for web browser. It integrates the landslide monitoring and prewarning system with Service-Oriented Architecture (SOA). SOA takes Web services into consideration and combines with Web 3D GIS software and open source software to provide process management that covers prewarning services, monitoring data services, image services, geographic information services, and disaster announcement services. It also adopts the fuzzy theory model to calculate the degree of risk for the whole area, combining geographic information with web server to provide real-time monitoring and prewarning information to users and decision-makers in order to build decision support system for the landslide monitoring network. Using Web services and GIS, the system provides real-time and decision information to users through the procedure control of SOA. The system will automatically activate the chart of emergency evacuation routes and disaster announcement service. It provides real-time monitoring data, and prewarning decision support in order to announce and prevent the disaster at the earliest time.

1. Introduction

This study utilizes the spatial analytic ability of GIS to establish a geological database for the comprehensive evaluation of slope stable in the whole area. Web 3D GIS software is used to construct the geological three-dimensional (3D) information display. Aerial photographs and DTM comparison are used to integrate the information into a geographic database system that links with the engine of the spatial database used as the basic image data for web browser. This study integrates the landslide monitoring and prewarning system with Service-Oriented Architecture (SOA). SOA takes Web services into consideration and combines with Web 3D GIS software and open source software to provide process management that covers prewarning services, monitoring data services, image services, geographic information services, and disaster announcement services. It also adopts the fuzzy theory model to calculate the degree of risk for the whole area, combining geographic information with web server to provide real-time monitoring and prewarning information to users and decision-makers in order to build a decision support system for the landslide monitoring network. Salewicz and Nakayama (2004) explained the relationship among database, simulation model, user interface, and decision makers in building a decision support system. Tah and Carr (2000) pointed out that vague terms are unavoidable in risk assessment and put forward a proposal for construction project risk assessment using fuzzy set theory. Kangari & Riggs (1989) presented an integrated knowledge-based system to describe risks using linguistic variables implemented as fuzzy sets. Cheng et al. (1999) proposed that fuzzy set theory can give a much better representation of the linguistic data. Therefore, this research proposes to use the fuzzy set theory for quantifying the linguistic variables (Buckley, 1985 and Saaty, 1986）. The management criteria are established for four states (“safety”, “attention”, “warning” and “danger”). The total weight of all combinations of situations monitored by each monitoring device is calculated through the FAHP to set up the analytic result of the weights for different degrees of risks, as well as to follow up the hazardous state of the landslide area. Decision support scheme for prewarning system of Lishan landslide incorporates the real-time monitoring information, analytic result of the risk degree, hydrogeological display, and site image of the landslide area.

2. Li-shan landslide

The landslide area studied in Li-shan village is located at the intersection of the east-west cross-island highway route 8 and route 7A in central Taiwan (Figure 1). Topographically, Li-shan is located at the west wing of the Central Ridge with an altitude between 1,800 m and 2,100 m. Most slopes dip to the northwest with slope angles between 15° and 30° down to the Teh-Chi Water Reservoir. In April 1990, an intense and spectacular landslide occurred in this area following prolonged torrential rain. The catastrophe led to a destroyed pavement foundation on route 7A and disrupted transportation facilities. This landslide also affected nearby buildings such as the Li-shan Grand Hotel that suffered severe settlement and deteriorated cracks. The accumulated rainfall from 10 April to 20 April was 585 mm, while the monthly rainfall record for that April was 957.5 mm. Both rainfall records exceeded the record of a 50-year return period based on the frequency analysis. The continuous rainfall could have caused a tremendous amount of water infiltration and accumulation inside the slope. The infiltrated water may have increased the pore water pressure, subsequently decreasing the effective stress in the soil or rock mass and resulting in the instability of the slope. Based on this, it can be confirmed that the rainfall-induced increase of water pressure is the main factor that triggered the landslide of the highly weathered rock slope.

Geologically, the Li-shan area is located in colluvial formations originally from the Miocene Lushan slate formation. Due to the dynamic tectonic activities as well as the high precipitation, the surficial slate formations in this area are highly weathered. It is strongly supported by the occurrence of slaty cleavages, foliation shears, and interlayers of silty residual soil. The results of the compression strength test show that the Lushan unweathered slate is about 2.76 ton/m^3 in unit weight (Shou and Chen, 2005).

The landslide area of Lishan is divided into four zones, West, Northeast, Central, and Southeast, based on the topography, geology, landslide blocks, and boundary of watershed. Eight monitoring stations were set up in this area. Each station was equipped with facilities such as the piezometer for measuring the groundwater level, the inclinometer for monitoring the ground deformation, and the extensometer for detecting the surface movement. Monitoring instruments for Li-Shan area were installed to measure the ground deformation and the groundwater level from 1995 but they were traditional instruments and equipment. Su et al.(2009) proves that TDR and GPS can be used in the long-term monitoring of high-mountain landslides and their interpreted methods and accuracy from 2004. From 2008, by combining the automatic monitoring station with internet embedded controller, real time monitoring results can be accessed through ADSL. Table 1 shows the instruments of every monitoring station. The location of auto-monitoring stations is shown in Figure 2.

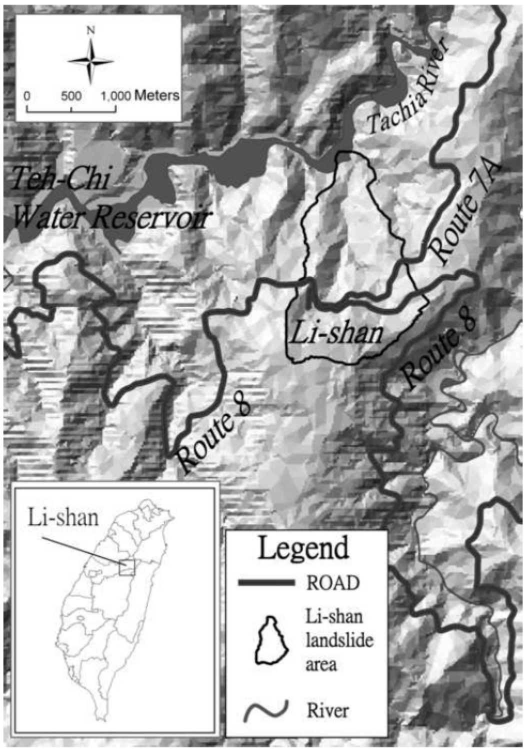


Figure 1. Topography of the Li-shan landslide

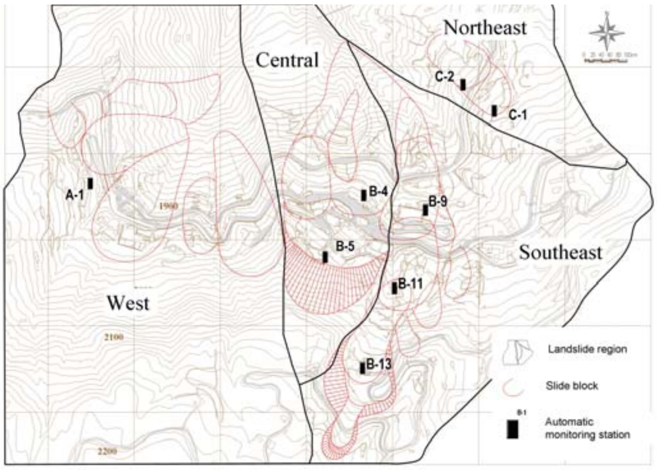


Figure 2. Location map of auto-monitoring stations

Table 1. Instruments of monitoring station in the landslide area of Lishan

Zone	Monitoring station	Instruments in the station
West	A1	Raingage, Piezometer, TDR
Central	B4	Piezometer, TDR
	B5	Piezometer, TDR, GPS
Southeast	B9	Raingage, Piezometer, TDR
	B11	Raingage, Piezometer, TDR, GPS
	B13	Piezometer, TDR
Northeast	C1	Raingage, Piezometer, TDR, GPS
	C2	Piezometer, TDR

3. Methodology

This research used web services to set up the decision support system of monitoring landslide. The system is multi-functional and expandability SOA, including database, GIS function and transforming database to web services layer via network. By way of internet, the user or decision-maker can quickly understand monitoring data or further inquiry prewarning data.

Zhang et al.(2007) define a common, open, and standardized architecture for Distributed Virtual Geographic Environment(DVGE) systems based on web services. The architecture of the DVGE system is the running structure of the DVGE system, such that its architecture will determine the stability and extensibility of the whole system. As Figure 3 shows, the graphics layer corresponds to the multidimensional presentation space, while the user layer corresponds to the personal perceptual/cognitive and social space.

1. The top layer is the data and model layer that is connected with the web services layer by database middleware, such as Open Data Base Connectivity (ODBC) and other middleware for the security of data. Thus, the top layer is the source of the DVGE system resources including the data resources for graphs, images and attributes, models, and other resources. 2. The web services layer is the core of DVGE system. It is made up of three parts. The first part is the deployment and registering of all web services including OGC web services, VGE web services, and other business geo-information web services. The second part is services management. The third part is control management. OGC developed and provided web services, such as web map service, web feature service, and web coverage services, while other business geo-information web services are developed and provided by other business organizations. 3. At the graphics layer, 2D or 3D graphic worlds including some VGE application systems are taken into account. These VGE application systems are reengineered and developed to support the binding and combining of web services. The graphics layer also includes virtual geographic space that is constantly updated, as well as the graphic representation of task-related geo-problems. 4. The user layer considers the user's knowledge base, technical capability, role playing, and ages. Also, the user's computer and network conditions are considered at this layer. Multiple participants can log into the same or different VGE application systems, and can collaborate by using the same web services.

The architecture of this research is the 4- Tier design such as data layer, web services layer, graphics layer and user layer respectively. As shown in Figure 4, HTML was used for user layer, and it is most important technology for graphics layer that defines the middle interface of design and exchanged data. Web services layer includes application rule and processing data, for instance XML, WSDL file and SOAP. Last, data layer is the source of the whole system, including the database system and the connection of remote space database.

Applying web services on the integration of slope disaster, the system is for decision-support and analyzing software via internet. It used SOA model of NetBeans IDE software with Business Process Execution Language (BPEL) procedure design that is to combine a lot of services and then return a set of operation results. The basic procedure of BPEL procedure is shown in Figure 5. First of all, BPEL engine receive the message which user inquired the data of the monitoring area and the system invokes automatically a service of prewarning decision. Then, it shows the degree of danger and BPEL procedure that was invoked by the management of monitoring. It calls out the services of the monitoring data, image, geographical information in order. If monitoring state is warning or dangerous, the system will suggest the decision-maker to invoke the service of emergency announcement.

The management criteria were set up for subsurface deformation by TDR monitoring, ground surface displacement by GPS monitoring, underground water level, and rainfall. It then classifies the risk degree as “safety”, “attention”, “warning” and “danger”. It has established an assessment model for management criteria by fuzzy theory. The system set up the distribution of fuzzy set for each monitoring station, applied the FHAP method, and got the weight of each landslide zone (weight 0.24 for the West, 0.5 for the Central, 0.10 for the Southeast, and 0.16 for the Northeast). The weights of all stations were determined after FHAP analysis, followed by monitoring stations B5, A1, C2, B4, C1, B9, B11, and B13 at weights of 0.41, 0.24, 0.10, 0.09, 0.06, 0.05, 0.04, and 0.01, respectively(Table 2). For reference of the decision-makers, the degrees are classified as follows: “attention” if the total score is greater than 72, “warning” if the total score is greater than 95, and “dangerous” if the total score is greater than 113.

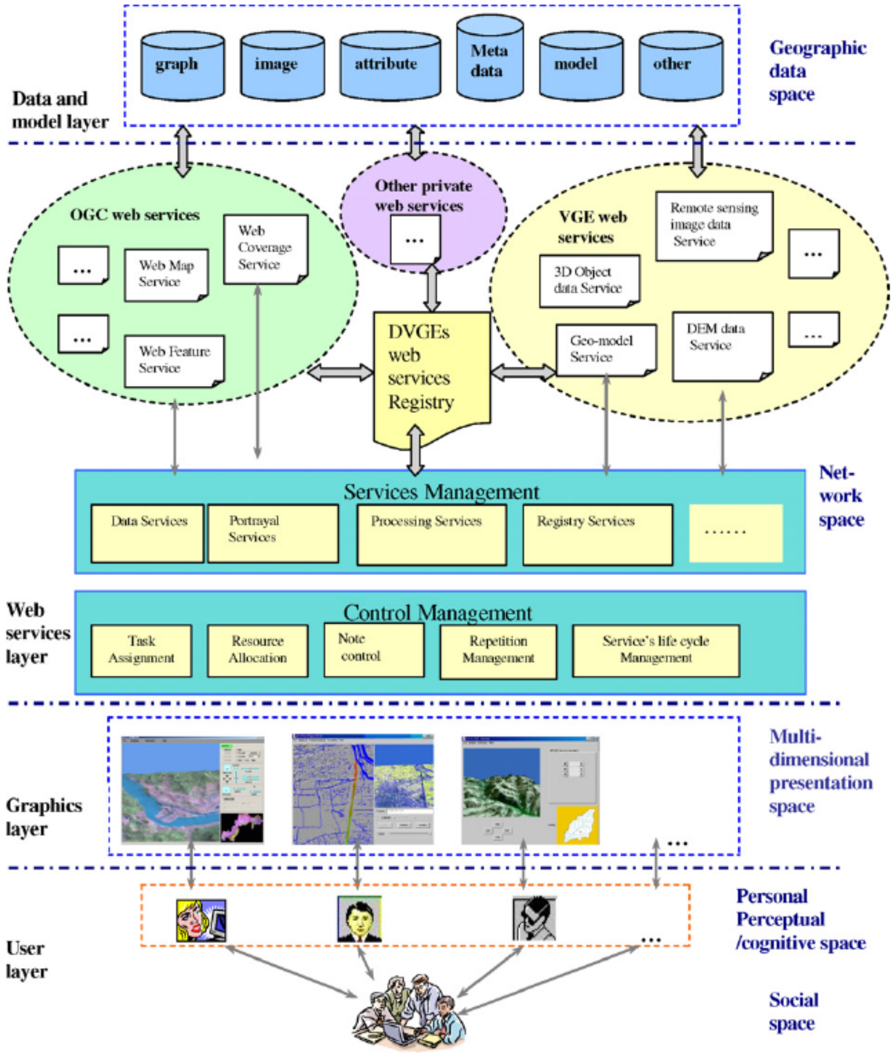
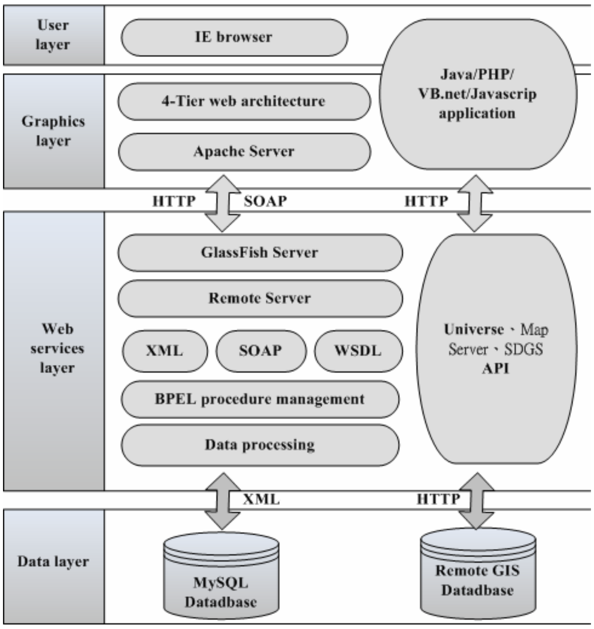


Figure 3. The architecture of DVGE system. (Zhang et al., 2007)



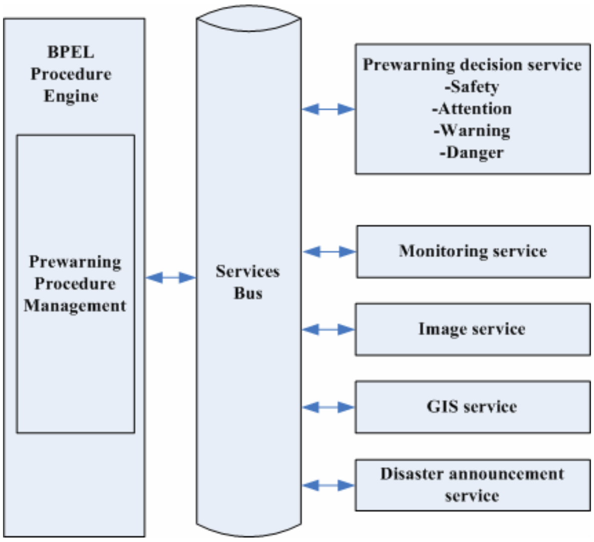


Figure 4. Basic architechure of the system

Figure 5. SOA procedure of landslide monitoring

Table 2. Fuzzy weight of general assessment factors

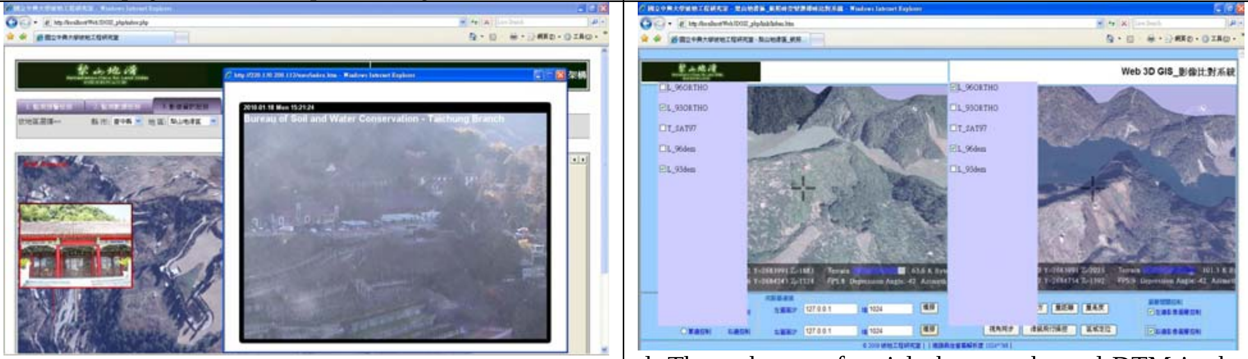
Zone	Weight	Monitoring station	Weight	Multiplication	Sequence
West	0.24	A1	1.00	0.24	2
Central	0.50	B4	0.18	0.09	4
		B5	0.82	0.41	1
Southeast	0.10	B9	0.53	0.05	6
		B11	0.36	0.04	7
		B13	0.11	0.01	8
Northeast	0.16	C1	0.36	0.06	5
		C2	0.64	0.10	3

4. Results and Discussion

This system used SOA to provide for prewarning monitoring function as a service, real-time monitoring data as a service, image as a service, geographical information as a service and disaster announcement as a service. it combines multiple web services and landslide management criteria. The homepage of this system is shown in Figure 6. It is the architecture of SOA and sequent frames of website. These services offer real-time and decision-making data for manager or user. First webpage is the prewarning service(Figure 6a). According to the fuzzy theory with determining management criteria that calculated the total scores of historical monitoring record of the rainfall, groundwater level, TDR, and GPS. This webpage show the risk degree of landslide monitoring with indicators of safety, attention, warning and danger. Then second webpage is monitoring data service. Other functions of webpage are image service, GIS service and disaster announcement service respectively (Figure 6b and 6c). It developed a prototype client application for prewarning system of landslide monitoring in Lishan. Figure 6d shows a snapshot of the application of 3D terrain comparison in the difference period. The left side of the image is the terrain before landslide happened, while the 3D frame on the right shows the terrain and scene after landslide happened. DEM data is used to construct the 3D terrain, while the remote sensing image that has been merged with WMS and WFS is pasted onto the 3D terrain. It can look up the terrain's elevation value and the volume change value. The prewarning model is programmed into a Java and exported as a web service that calculates the risk degree of disaster.

a. The webpage of real-time prewarning decision

b. Display of real-time monitoring data



c. Display of real-time video on site

d. The webpage of aerial photographs and DTM in the different period

Figure 6. The website of web 3D GIS in prewarning system

This model can be subsequently written into the decision-making system to show the real-time monitoring data on the website of a single monitoring station and the risk degree of a whole landslide. The exhibition webpage includes real-time data such as the rainfall, underground water level, TDR, GPS, and other observation data. Data would be refreshed every 20 seconds to display the real-time data. The fuzzy theoretical model for the comprehensive estimation of each zone is incorporated into the webpage to display the risk degree of each zone. Figure 6 illustrates the state of the monitoring station on the website. Indicators are used to show the current state of the landslide area in Lishan (Green = Safety, Yellow = Attention, Orange= Warning, Red = Danger) with WEB 3D GIS software.

5. Conclusion

This study sets up the management criteria for subsurface deformation by TDR monitoring, ground surface displacement by GPS monitoring, underground water level, and rainfall. It then classifies the risk degree as “safety”, “attention”, “warning” and “danger”. It has established an assessment model for management criteria by fuzzy theory. The system set up the distribution of fuzzy set for each monitoring station, applied the FHAP method, and got the weight of each landslide zone (weight 0.24 for the West, 0.5 for the Central, 0.10 for the Southeast, and 0.16 for the Northeast). The weights of all stations were determined after FHAP analysis, followed by monitoring stations B5, A1, C2, B4, C1, B9, B11, and B13 at weights of 0.41, 0.24, 0.10, 0.09, 0.06, 0.05, 0.04, and 0.01, respectively. For reference of the decision-makers, the degrees are classified as follows: “attention” if the total score is greater than 72, “warning” if the total score is greater than 95, and “dangerous” if the total score is greater than 113.

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Decision support scheme for landslide prewarning system incorporates real-time monitoring data, analytic result of the risk degree, 3D hydrogeological data, and images of the on-site monitoring system. Using the criterion of decision support system, judgement can be made easily and quickly for slope disaster. And, decision for response in regard to local residents' safety can be made by computer automatically.

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