GEOWARNS: A System to Warn Geo-deformation Failure

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ABSTRACT

Geo-deformation failures leading to landslides cause huge loss to socio-economic infrastructures and personal life and property all over the world, specifically in hilly terrains. It is a localized phenomenon which usually gets triggered by rainfall. In this paper, a framework for a warning system based on prediction of failure of geo-deformation has been proposed. The system warns against rainfall-triggered landslides making use of a Knowledge Based System including a warning module. The system consists of the input module, the understanding module, rainfall prediction module, the expert module, the output module and the warning module. The input module accepts scanned images of thematic maps of contributing factors of landslides as well as output from rainfall prediction module, based on field observed GPS data. The understanding module interprets input information to extract relevant information as required by expert module. The expert module consists of a Knowledge Base (KB) and Inference strategy to categorize the given region into different intensities of landslide hazard, output module communicates a warning message to warning module provided by the inference module and finally, warning module proclaim the warning message to user. At present, the system has the capability to prepare a Landslide Susceptibility Zone map of a region and its extension to a prediction system is under development. The major outcomes of the proposed system will be towards development of a warning system towards local geo-hazard analyses and provide a support system for landslide disaster preparedness and mitigation activities.

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1. INTRODUCTION

Disasters cause huge loss of life and property. Some well known disasters are volcanic eruptions, avalanches, floods, tsunami, earthquakes etc, but most persistent and pertinent in hilly areas are geo-deformations causing landslides. The high susceptibility to landslides due to deformation of the vulnerable terrain is mainly due to a complex geological setting combined with contemporary crustal movements, varying slopes and relief, heavy rainfall, along with ever-increasing human interference in the hilly ecosystem.

Landslides cause property damage, injury, and death and adversely affect a variety of resources. For example, water supplies, fisheries, sewage disposal systems, forests, dams, and roadways can be affected for years after a slide event. The negative economic effects of landslides include the cost to repair structures, loss of property value, disruption of transportation routes, medical costs in the event of injury, and indirect costs, such as lost timber and fish stocks. Water availability, quantity, and quality can be affected by landslides. Geotechnical studies and engineering projects to assess and stabilize potentially dangerous sites can be costly. It has been estimated that, on average, the damage caused by landslides in the Himalayan range costs more than US $ 1 billion besides causing more than 200 deaths every year, which overall is considered as 30% of such types of losses occurring world-wide (Naithani, 1999).

So, efforts need to be done to reduce the number of casualties and losses due to landslides by warning the people in near real time. Generally, people do not remain in touch with warning system for most of the time as they need additional gadget or set-up to get informed. In such cases, they cannot be informed eventually by the conventional warning systems about the coming calamity. Generally, even in landslide prone areas, people do not carry any separate gadget to keep track of the future calamity. So a system that can use existing infrastructure, instruments and set-ups, which people use in day to day life, should be used for informing them. Cellular or mobile phones are becoming an essential part of human beings. With the revolution in communication system in recent years, almost everyone carries a mobile phone. Therefore, this is the handy gadget that can be used to effectively warn people individually and instantly. With this background, it is intended to initiate the implementation of a system that can be used to warn people in advance in the near real time.

The objective of this paper is to propose the planning of a system to warn disaster due to landslide using existing cellular network infrastructure in a region.

2. METODOLOGY

The GEOWARN system is proposed to be consists of integration of two broad divisions: hazard evaluation and warning proclamation.

The hazard evaluation has been implemented through several modules and sub-modules. The modules carries out automatic extraction of information about causative factors from thematic maps, satellite images, and GIS layers; address expert knowledge; conducts pixel-based reclassification of the input (compatible to the KB); forecast rainfall from GPS data; evaluate intensity of landslide hazard on the ratings of causative factors (deterministic method) and finally communicate hazard to warning division.

The warning proclamation is proposed to be achieved by communication through the existing cellular network infrastructure available in a locality. Usually, mobile service provider has network coverage through its service towers called as Base Transmitting Stations (BTS) under a Base Station Controller (BSC). The region covered by one base station is called a cell. Each cell is allocated a band of frequencies and is served by a base station, consisting of transmitter, receiver and control unit. Adjacent cells are assigned different frequencies to avoid interference or cross talk. At a particular time any mobile phone user is connected to a single cell only. When a mobile phone user moves from one cell to another, his base station is shifted from one to another by a phenomenon called Handoff. The phenomenon of handoff occurs only when the signal at the current BTS is sufficiently weak (less than a predefined threshold) and the other signal is stronger of the two. Cellular Radio Telephone also called cell phone, low-powered, lightweight radio transceiver (combination of transmitter-receiver) that provides services to users. Cell phones can display a short text message. Using this technology, GEOWARNS will communicate with the user and the user can in turn request the services he wants, too. The region is determined from the location database of the cell and hazard message communicated.

3. THE PROPOSED SYSTEM (Adapted after Ghosh and Bhattacharya, 2009)

The framework of GEOWARNS system includes the functionalities categorized into the input, the understanding, rainfall prediction module, the expert, the output or decision module, and the warning module as shown in Figure 1.

Input Module

In the proposed GEOWARNS system, the input module has been developed to accept scanned images of thematic maps of causative factors of landslides. Preprocessing of input images is done by passing through a 3x3 majority filter to clean their noises and to retain/ evolve well-defined regions in the images. Contextual classification of the images is done next, leading to segmentation of images into regions of identical themes. Following this classification technique, all pixels in similar regions get assigned with an identical digital code.

Understanding Module

The Understanding Module consists of a matching algorithm that emulates the map interpretation capability of a human interpreter. The algorithm is based on correlating the color code of the legends with the different color regions present in the map. This is being achieved by matching the digital values of the scanned legends with that of the digital values of the pixels present in the scanned maps (made available through input module). The explanatory string corresponds to a legend gets retrieved as information for the region. The strings defining the causative factors of a unit region are used for hazard evaluation. Based on the type of variable present in the terrain feature, the knowledge base of the expert module gets searched by an informed searching and matching technique to extract the hazard rating associated with the particular contributor factor. The understanding of the system consists of a matching algorithm based on *Complete Matching with Exact String match* approach (Boyer and Moore 1977). The algorithm is a variant of brute force algorithm that has been adapted to the needs of the KB. The algorithm consists in checking, at all positions in the string between 0 and *n-m*, whether an occurrence of the pattern starts there or not. Then, after each attempt, it shifts the pattern by exactly one position to the right. The algorithm requires no preprocessing phase, and a constant extra space in addition to the pattern and the text. During the searching phase the text character comparisons can be done in any order. The time complexity of this searching phase is O (mn) (when searching for $a^{m-1}b$ in a^n for instance). The expected number of text character comparisons is 2*n* (Ng and Abramson 1990, Walley 1996, Parsons 1996). This leads to understanding of the digital maps to correlate the information with the next functional module, i.e. the knowledge base.

Expert Module

The KB those have been incorporated in the system are derived from the Indian Standard Code IS 14496 [Part 2] (1998). The six causative factors with their sub-factors and ratings are stored in the Knowledge module. The KB has been represented in the system by an object-oriented KRS (Bhattacharya and Ghosh 2008). The inference strategy is forward chaining definite clause inferencing; the searching technique is informed searching (Elkan 1990, Chipman and Meyrowitz 1993) based on the known causative factors to be searched in the KB.

Inference Engine

The inference scheme picks up the facts from the input images and applies searching and matching logic to fire a rule. The searching and matching in this case is of the string derived from the legend with the strings in the KB to come up with a match using the same complete matching technique with exact string match, as used in understanding module. As soon as a match is found, the hazard rating of that factor is put in a variable, from the KB. This is repeated for all the causative factors and their ratings are stored in variables. Total estimated hazard (TEH) rating is calculated based on hazard ratings variables A, B, C … (IS 14496 [Part 2]: 1998) as:

TEH = A + B + C + …… , which can have maximum value 10 and the value so calculated determines the landslide susceptibility in that pixel region into one of three broad categories low, medium or high.

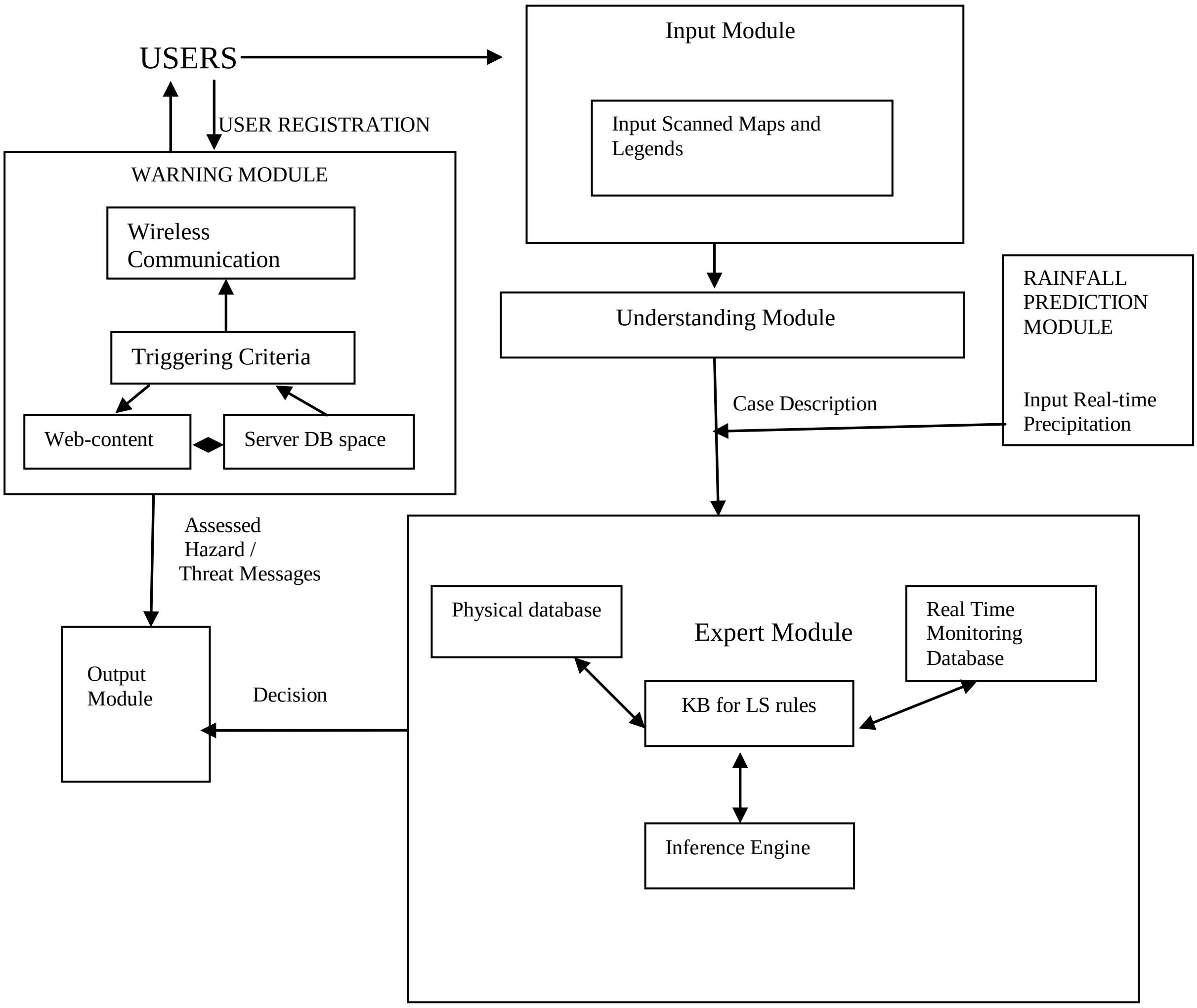

Figure 1 Architecture of GEOWARNS (modified after Ghosh and Bhattacharya, 2009)

Rainfall Module

An intelligent system based on the assumption that rainfall at any station depends on the amount of PWV, temperature, pressure, humidity, location (latitude), time (of a day) and day (in a year) etc. and their interrelations are chaotically dynamic. Thus, a soft computing based dynamic model has been proposed in the module study for short term prediction of rainfall in a station of interest.

The Output Module

The output module stores the decision for each pixel as a function of the degree of threat for the region represented in that pixel. The x,y location parameters are also stored. For each pixel and its associated threat perception, an appropriate message is stored which would be accessed by the communication module to be sent to users moving into the region if threat perception is high. The location details from the x,y co-ordinates are useful here. Message is sent even if threat is low to bring in confidence to the user.

The Warning Module

The warning module (Figure 2) holds the network coverage details and the location of service towers / base stations in its database and display related configuration for a friendly GUI environment for the operator which is the web-application. This application is a JAVA program and has the logic of notifying the appropriate trigger. The level of hazard determines the trigger to be generated. There are separate ranges for mild, moderate and high hazard triggers. The trigger sub-module initiates the trigger and calls the communication sub-module. The network communication broadcast facility will be used to freely send short messaging services to all users of mobiles moving into an area which has been perceived threat prone. Alternatively a user can communicate his location and request the update of threat perception through a service called General Packet Radio Service (GPRS) on mobile. The output image obtained from output module is analyzed mathematically with the Base Station's database and the BTSs which either itself or whose range lies in the danger zones are marked. The output database about the warning message will be updated and the information will be sent to the server and the warning module is invoked. All the processing steps will be repeated again and again, at regular interval of time as desired.

Utilities exist that send web-based SMSs to groups at a time having subscriber numbers starting with say 99xxxxxxxx / 98xxxxxxxx etc. It should be started off with text messages notifying the threat. After having researched through compression techniques to send digital map images to the mobile users to view on screen, it may be used in the automated system also. It is intended to have a dedicated and owned web space to host the software interface which could send messages to users at any part of the country (Samarajiva 2005).

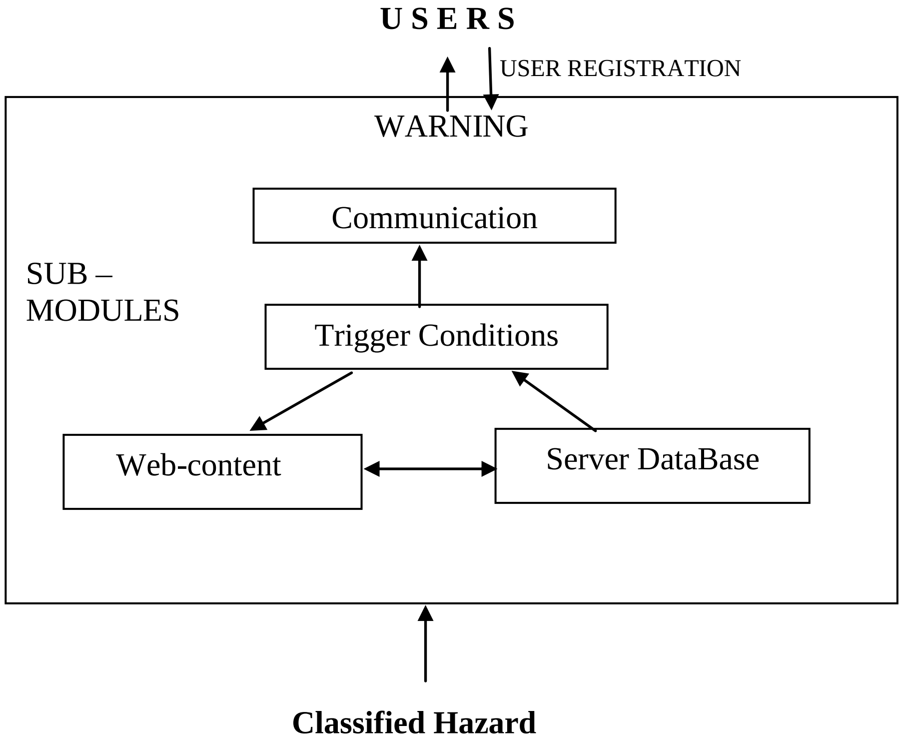

Figure 2 : Sub-modules of Warning Module of LANDWARNS

Any mobile phone is able to send short messages in the GSM network (Figure 3). However, to use this facility in a personal computer, the mobile phone must be connected with it.

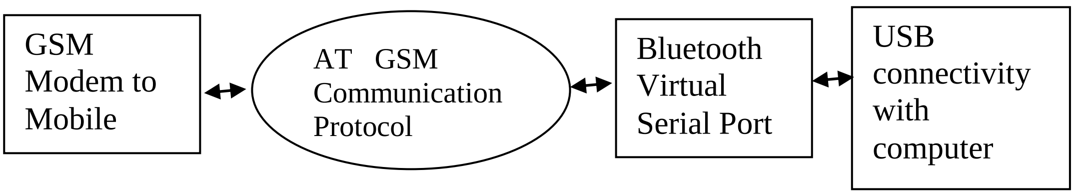

Figure 3 : Communication flow

There is a standard for serial connection between the modem and the PC, which is also applicable for the GSM device (GSM modem). First mobile devices were connected to the computers via cable (a real serial connection). Nowadays only pluggable GSM modems use real serial port to communicate with the computer; whereas ordinary mobile phones use Bluetooth connection (they use one of the Bluetooth services, the so-called virtual serial connection).

The AT communication protocol is a simple terminal protocol (Samarajiva et al. 2005). It means sending SMS by directly using the AT communication protocol and consists of typing several text commands in a terminal window, which is obviously not a user-friendly interface.

Headwind GSM modem driver is the application implementing this interface and providing a user-friendly GUI for sending messages from the PC (courtesy www.h-sms.com).

Regional warning systems could alert the general public to the potential landslide activity, although the amount and intensity of rainfall necessary to initiate landslides undoubtedly varies with site specific geological, hydrological, and soil or rock properties. Such systems can only provide information about the occurrence of landslide, and are thus most useful if used in conjunction with regional landslide hazard mapping for delineation of potentially hazardous areas and to determine the time of landslide initiation. A message may be defined to have a high effectiveness value of 1 if the message contains the mandatory elements as shown in Figure 5 below. The lower end value 0 is when the message is an empty message; i.e. dead air or text elements with null values. The compulsory elements include elements in the <Alert> "qualifier" elements: <Incident>, <Identifier>, <Sender>, <Sent>, <Status>, <msgType>, <Scope>, and the "sub" elements: <Info>, <Resource>, and <Area> (Waidyanatha et al. 2007).

4. IMPLEMENTATION

During the development of the system, it undergoes initialization with a fixed and distinct digital identification for each of the legends that are present in the thematic maps of the causative factors of landslides (Ghosh and Bhattacharya, 2009). The *district planning map series* of National Atlas and Thematic Mapping Organization (NATMO) is taken as source of thematic data and thus considered an index of Indian National standard. The system will be coded in Java as this programming language has facilities for implementing internet-based and intranet-based applications and software for devices that communicate over a network. Java programs consist of pieces called classes. Classes include pieces called methods that perform tasks and return information when they complete execution. Java programs take advantage of rich collection of existing classes in the Java class libraries, which are known as Java APIs (Application Programming Interfaces).

Figure 4 : Software Trigger for sending SMS (courtesy www.h-sms.com)

In the Java 2 Platform, Standard Edition (J2SE) having version of compiler JDK 1.5.0.03 it is possible to get Java Advanced Imaging (JAI) libraries that help in recognizing as well as manipulating different image formats. The connectivity with the KB is to be provided by developing a Java Database Connectivity – Open Database Connectivity (JDBC – ODBC) bridge with the help of JDBC-ODBC driver provided in the JDK. This facility is to be used by the system to obtain location and range of mobile network, and to store the output of the output module i.e. the warning messages for the danger zones / areas. An image is a two dimensional array of pixels. A pixel corresponds to a small, square area of image. Every pixel on an image has three attributes, i.e. its x-coordinate, its y-coordinate and its pixel value or the color value. The pixels with same color have the same pixel value. The different colors on the image represent its various classifications. Each classification is assigned a relative weight. For example in the landslide susceptibility zonation, each of the causative factors has some weight with which it contributes towards landslide occurrence. So the weights have been used successfully to evaluate landslide susceptibility. It can be taken further to include inputs for various natural hazards in this pixel by pixel raster format. The system once started will be a continuous process, and the software will go on processing the input images from the specified path and will keep on updating the database of output module storage. The warning information will then be retrieved by the Communications module and sent to bunch of mobile numbers in the danger zone.

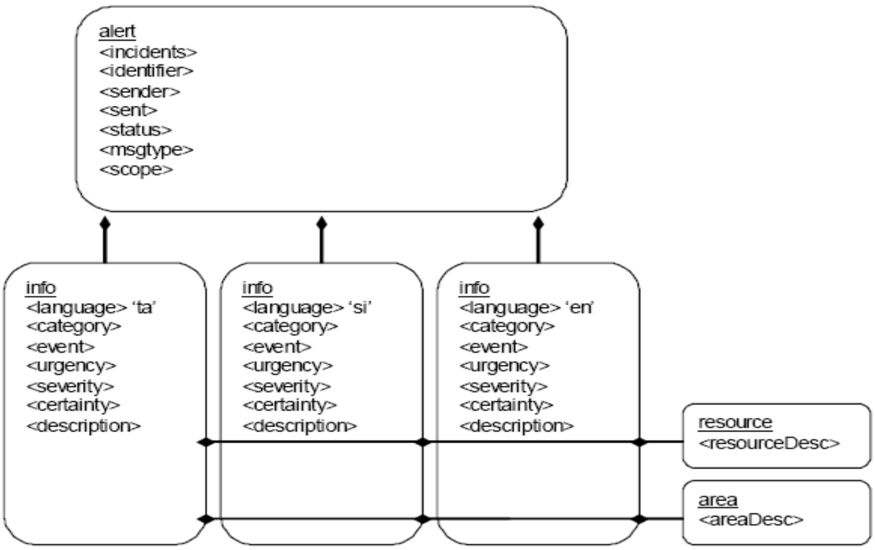

Figure 5 : Some elements defined for a hypothetical message format

5. DISCUSSION

A Knowledge Based System is under development for proclamation of warning to a geo-deformation failure. The system is based on the criteria of contributing factors causing landslides. The system makes use of NATMO maps for contributing factors and GPS real time data for rainfall forecasting. Thus, a warning system for rainfall-triggered landslide disasters is proposed to be made available in local prospective. This type of warning system for disasters could provide policy planners with overview information to assess the spatial distribution of potential landslides. An evaluation of the full capability of the system is possible only after its final development. The need for validation and improvement of the proposed system will require updating the geospatial database and real time field data, regularly and exhaustively.

The system can be extended to any other region by replacing the Knowledge base in the developed system and incorporating the maps of the contributing factors along with legends and real time GPS field data.

6. CONCLUSIONS

The technology towards disaster prediction has a bright future. The various projects and programs going around the world illustrate that disaster prediction is a topic of concern to scientists and policy makers alike. Landslides, hurricanes, tornadoes, floods, earthquakes, tsunamis, and volcanoes all show that the effective use of disaster predictions not only requires advanced technology but also requires that society consider the entire process of prediction – hazard evaluation, forecasts, communication, and use of information with equal priority to all the stages.

The objective of GEOWARNS is to help mankind to better sustain by avoiding casualties and damage caused by landslides. The system is designed in such a way that it can be enhanced to be used for several other predictable disasters stated above. Moreover the preciseness can be increased by encompassing minor factors, along with the major factors. As the system is independent from the mobile service provider implementation so it will result in better scope for implementation. The system is designed to do mass processing so that the different kinds of disaster can be predicted by making modular enhancements. The iterative method and operator free approach causes the system to work at all times and eliminate the chances of human errors. The integrated approach for a warning system using existing infrastructure to facilitate public warning is a big task and work is progressing towards resolving uncertainties and making the system as generalised as possible.

Because nobody can predict the future with certainty, and because much remains to be learned, the society must understand the limits of scientific predictions and be prepared to employ alternatives. Wisely used, however, disaster prediction has the potential to reduce society's vulnerability to natural disasters and to be warned in advance about landslides in the near real time as part of a warning and support system as well for disaster preparedness and mitigation activities.

REFERENCES

Bhattacharya, D. and **Ghosh J.K.,** 2008. " Evaluation of Knowledge Representation Schemes as a pre-requisite Towards the Development of a Knowledge Based System", ASCE Journal of Computing in Civil Engineering, Vol. 22, No. 6, pp. 1-8.

Boyer, R. S., and **Moore, J. S.** 1977. "A fast string searching algorithm." *Com. of the ACM* , 20(10), pp. 262–272.

Chang, S.I., Yan, C.W., Dimitroff, D., and **Arndt, T**. 1988. "An Intelligent Image Database System", IEEE Trans. On Soft. Engg., Vol. 14. No 5, pp. 681-688.

Chipman, S., and **Meyrowitz, A.L.** 1993. "Foundations of Knowledge Acquisition: Machine Learning." Kluwer Academics, pp. 40-60.

Chung, C.J. and **Fabbri, A.G.** 1999. "Probabilistic prediction models for landslides hazard mapping", Photogrammetric Engineering and Remote Sensing, 65(12), pp. 1389-1399.

Dai, F.C., and **Lee, C.F**. 2002. "Landslide characteristics and slope instability modeling using GIS, Lantau Island, Hong Kong", Geomorphology, 42, pp. 213– 228.

Dai, F.C., Ngai, Y. Y., and **Lee, C.F**. 2002. "Landslide risk assessment and management: an overview", Engineering Geology 64, pp. 65–87.

Elkan, C. 1990. "A rational reconstruction of nonmonotonic truth maintenance systems." *Artificial Intelligence*, 43, pp. 219-234.

Ercanoglu, M., and **Gokceoglu, C**. 2002. "Assessment of landslide susceptibility for a landslide - prone area by fuzzy approach", Environmental Geology, 41, pp. 720–730.

Fan, C., Ye, X., and **Gu, W**. 1998. "A Knowledge-based Scene Understanding System", IEEE Trans. On Software Engg., pp. 731-733.

Freese, R., and **Nel, A.** 1993. "Focus of Attention in Image Understanding Systems", IEEE Trans. On Software Engg., pp. 80-84.

Ghosh, J.K. and **Bhattacharya D.,** 2009. "A Knowledge Based Landslide Susceptibility Zonation System", ASCE Journal of Computing in Civil Engineering, (Under review).

Ghosh, J.K. and **Suri, S**. 2005. "A Knowledge Based System for Assessment of Landslide Hazard", Proc. of Indian Geotechnical Conf., Ahmedabad, pp.393-396.

Guzzetti, F., Reichenbach, P., Cardinali, M., Galli, M., and **Ardizzone, F**. 2005. "Probabilistic landslide hazard assessment at the basin scale", Geomorphology, 72, pp. 272–299.

IS 14496 (Part 2):1998. Indian Standard Preparation of Landslide Hazard Zonation Maps in Mountainous Terrains - Guidelines. Part 2 Macro-Zonation, Bureau of Indian Standard, New Delhi, pp. 1-19.

Naithani, A.K., 1999. The Himalayan Landslides, Employment News, 23(47), pp. 20-26.

Ng, K.C., and **Abramson, B.** 1990. "Uncertainty management in expert systems." *IEEE Expert Systems*, 5(2), pp. 29-48.

Parsons, S. 1996. "Current approaches to handling imperfect information in data and knowledge bases." *IEEE Trans. on Know. and Data Eng*., 8, pp. 353-372.

Samarajiva, R., Knight-John, M., Anderson, P., and **Zainudeen, A.** 2005. National Early Warning System Sri Lanka: A Participatory Concept Paper for the Design of an Effective All Hazard Public Warning System Version 2.1, LIRNEasia and Vanguard Foundation. Available http://www.lirneasia.net/projects/completed-projects/national-early-warning-system/

Samarajiva, R. 2005. Mobilizing information and communications technologies for effective disaster warning: lessons from the 2004 tsunami. New Media and Society, 7 (6), pp. 731-747.
Waidyanatha, N., Gow, G., and **Anderson, P.** 2007. Hazard Warnings in Sri Lanka: Challenges of Internetworking with Common Alerting Protocol. Proceedings ISCRAM2007, pp. 281 – 293.
Walley, P. 1996. "Measures of uncertainty in expert systems." *Artificial Intelligence,* 83, pp. 1-58.

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