A POPULAR USAGE-BASED HAZARD WARNING SYSTEM

D. Bhattacharya[a,*], J.K. Ghosh[a], P. Boccardo[b], N. K. Samadhiya[a]

[a] Civil Engineering Department Indian Institute of Technology Roorkee, Roorkee Uttarakhand 247667 India. devanjan@gmail.com
[b] DITAG, The Politecnico di Torino, Turin, Italy. piero.boccardo@polito.it
* Corresponding author

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ABSTRACT:

Geo-deformation failures leading 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 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 warning process is generalized enough to be used for any other kind of natural hazard warning 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 provides a warning message based on decision of inference module and finally, warning module send the message to user. The system stands tested and validated for landslide susceptibility categorization at five sites. Currently implementation of rainfall and warning module is underway. The major outcomes of the proposed system will lead to the development of a warning system towards regional scale geo-hazard analyses and provide a support system for landslide disaster preparedness and mitigation activities.

1. INTRODUCTION

1.1 General

Disasters cause huge losses in terms of both life and property. Some well known disasters are volcanic eruptions, avalanches, floods, tsunami, earthquakes etc, but most persistent and pertinent in the Indian context 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(Dai and Lee, 2002) combined with contemporary crustal movements, varying slopes and relief(Dai et al, 2002), heavy rainfall, along with ever-increasing human interference in the 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).

Efforts are being made to reduce the number of casualties and losses due to landslides by warning the people in near real time (Chang et al, 1988; Chung and Fabbri, 1999), . Generally, people do not remain in touch with these systems for most of the time as they need additional gadget or set-up to inform. In such cases, they cannot be informed eventually by the by the conventional warning systems about the coming calamity. Generally, even in the most 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, we intend to initiate the implementation of a system that can be used to warn people in advance about landslides in the near real time. Such a system shall be extremely useful and cost-effective in minimizing the loss of life and property in a region. Most of the already projected disaster warning systems need a separate infrastructure to be built before their accomplishment, but here we plan to propose a disaster warning system that uses existing cellular network infrastructure in a region.

2. METHODOLOGY.

An integration of all modules and sub-modules for the system to be developed to meet the objective. The methodology is that the system implements extraction, based on legend matching, of information about causative factors from thematic maps, satellite images, and GIS layers, addresses expert knowledge rules (qualitative approach (Guzzetti et al, 2005)), conducts pixel-based reclassification of the input (compatible to the KB), rainfall forecast data from GPS, results in the evaluation of the intensity of hazard on the ratings of causative factors (deterministic method) (Ercanoglu and Gokceoglu, 2002) and the communication to the user is achieved using existing cellular network infrastructure available locally. This approach requires the data to be processed only at one terminal as well as we do not need to run any other application separately for every mobile phone. Every mobile service providing company 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 as 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 the 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, the system 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 the system includes the functionalities categorized into the input, the understanding, rainfall prediction module, the expert, the output or decision module, and the warning module. The expert module combines the knowledge bases and the inference scheme having a detailed knowledge representation scheme as shown in Figure 1.

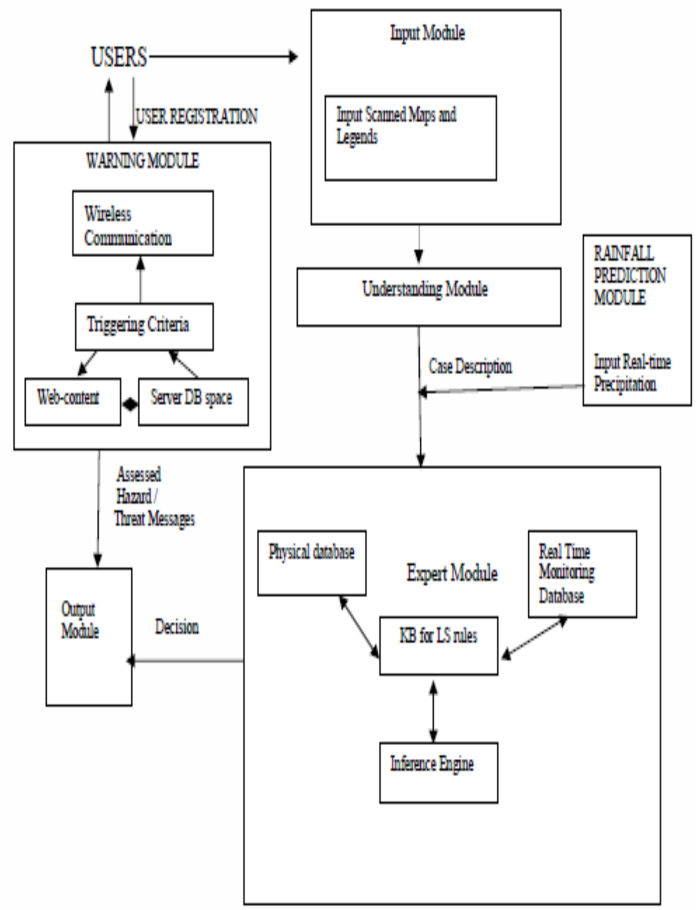

Figure 1. Architecture of proposed system (adapted after Ghosh and Bhattacharya, 2009)

3.1 Input Module In the proposed system, the input module has been developed to accept scanned images of thematic maps of causative factors of landslides.

3.2 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(Freese and Nel, 1993) present in the scanned maps (made available through input module). This leads to understanding of the digital maps to correlate the information with the next functional module, i.e. the knowledge base.

3.3 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 (Table 1 and 2) are stored in the Knowledge module. The KB has been represented in the system by an object-oriented KRS (Bhattacharya and Ghosh 2008).

Variable	Contributory Factor	Maximum LHEF Rating
A	Lithology	2
B	Structure	2
C	Slope	2
D	Relative Relief	1
E	Land Use Land Cover	2
F	Ground Water Condition/Rainfall	1
TEH	Total (maximum)	10

Table 1. Maximum LHEF Rating for different causative factors (IS 14496 Part 2 1998)

3.4 Inference Engine

The inference scheme picks up the facts from the input images and applies searching and matching logic to fire a rule(Fan et al, 1998). 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(Ghosh and Suri 2005). 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, according to the distribution shown in Table 3. And the value so calculated determines the landslide susceptibility in that pixel region into one of three broad categories low, medium or high.

Contributory Factor	Description	Category	Rating
a) Lithology	i) Rock Type	Quartzite and limestone	0.2
		Granite and gabbro	0.3
		Well cemented tetigenous sedimentary rocks	1.0
		Poorly cemented terrigenous sedimentary	1.3
		Slate and phyllite	1.2
	ii) Soil Type	Clayey soil with naturally formed surface	1.0
		Sandy soil with naturally formed surface	1.2
		Debris comprising mostly rock pieces mixed Colluvial	1.4
		Older well compacted alluvial fill material	0.9
		Highly weathered shale, phyllite and schist	2.0
		Younger loose material	0.7
b) Slope Morphometry	i) Escarpment/Cliff	> 45°	2.0
	ii) Steep slope	36° - 45°	1.7
	iii) Moderately steep	26° - 35°	1.2
	iv) Gentle slope	16° - 25°	0.8
	v) Very gentle slope	<= 15°	0.5
c) Relative Relief	i) Low	< 100 m	0.3
	ii) Medium	101 – 300 m	0.6
	iii) High	> 300 m	1.0
d) Land Use and Land Cover	i) Agricultural land / Populated flat land		0.6
	ii) Thickly vegetated forest area		0.8
	iii) Moderately veg		1.2
	iv) Sparsely vegetated		1.5
	v) Barren land		2.0
and so on ….			

Table 2. A sample of sub-categories of contributing factors along with their ratings (IS 14496 Part 2 1998)

Zone	TEHD value	Description of LSZ
I	< 5.0	Low Hazard
II	5.1 – 7.5	Moderate Hazard
III	7.5 – 10.0	High Hazard

Table 3. LSZ on the basis of TEHD (Adapted from (IS 14496 Part 2 1998))

3.5 Rainfall Module

An intelligent module to forecast rainfall from real time GPS data.

3.6 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 success of classification results is detailed in the paper (Ghosh and Bhattacharya, 2009). 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.

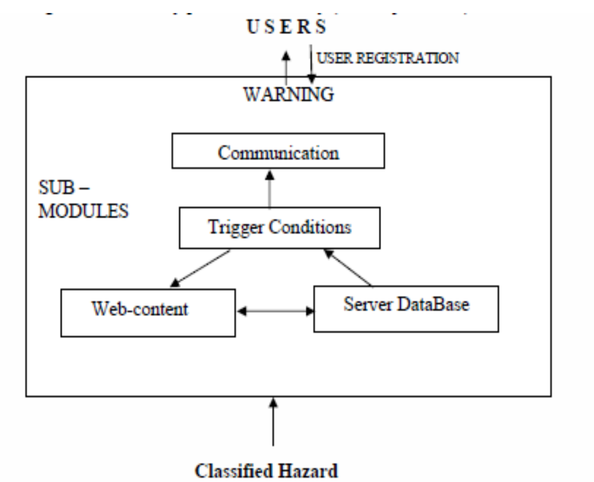

Figure 2. Warning module

3.7 The Warning Module

The warning module (Figure 2) holds the network coverage details and the location of service towers / base stations in its database. It also has the 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 communications broadcast facility can 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 SMSes to groups at a time having subscriber numbers starting with say 99xxxxxxxx / 98xxxxxxxx etc. We should start 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. We would need to have our own web space to host the software interface which could send messages to users at any part of the country (Samarajiva 2005). Any mobile phone is able to send short messages in the GSM network (Fig 3).

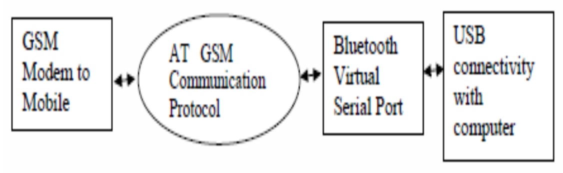

Figure 3. : Communication flow

However, to use this facility in a personal computer, the mobile phone must be connected with it. 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 on when landsliding would occur, and are thus most useful if used in conjunction with regional landslide hazard mapping to both delineate potentially hazardous areas and determine the timing of landslide initiation. A message may be defined to have a high effectiveness value of 1 if the message contains the mandatory elements. 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 (Figure 4) 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).

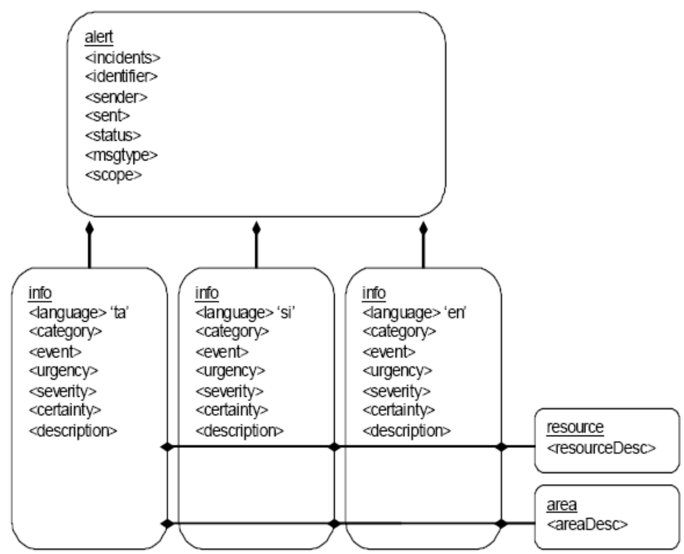

Figure 4. Some elements defined for a hypothetical message format

4.0 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 (Table 1). 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) as shown in Figure 5.

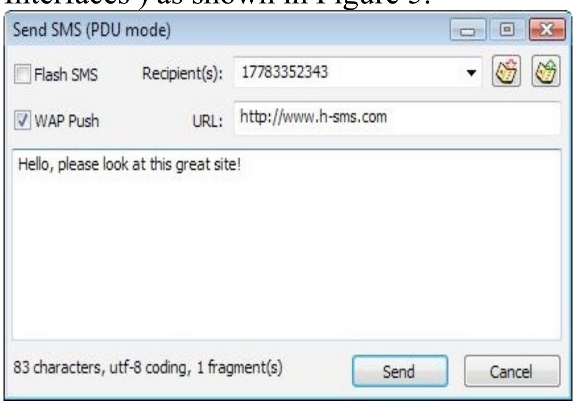

Figure 5. Software Trigger for sending SMS (courtesy www.h-sms.com)

In the Java 2 Platform, Standard Edition (J2SE) having version of compiler JDK 1.5.0.03 we can 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 factor has some weight with which it contributes towards landslide occurrence. So we have used the weights 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 bunches of mobile numbers in the danger zone.

5.0 Discussion

A Knowledge Based System for proclamation of warning to a geo-deformation failure is under development. And as is evident from the architecture of the system, warning can be proclaimed for any disaster just by altering the input and knowledge base. 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 perspective. 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, more and more.

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.

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