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Analysis of data using neuro-fuzzy approach recorded by instrumentation network installed at Mansa Devi (Haridwar) landslide site

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This paper presents a case study of landslide monitoring and early warning of Mansa Devi (Haridwar), located at Haridwar by pass road. Data recorded by instrumentation network installed at Mansa Devi (Haridwar) landslide site by five sensors (Rain Guage, Inclinimeter, Tiltmeter, Crack meter, Earth pressure cell) was analyzed and a relationship between rainfall intensity-surface parameters and landslide occurrence drawn with neuro-fuzzy approach for prediction of landslide and concept of early warning system is also described. Mansa Devi site is found rain prone and developed model demonstrates a fairly accurate prediction.

Keywords: Early warning, Instrumentation network, Landslide monitoring, Neural - fuzzy technique

Introduction

Landslide monitoring is required to determine extent, magnitude and style of landslide movement, for hazard analysis and emergency risk management and/or to assist in design and implementation of site remediation and/or mitigation works. Selected landslide site is located on Haridwar by pass road and on the slope of Mansa Devi hill. This site, composed of a series of interbedded clay stones, mudstone and sandstone sequences, belongs to Middle Siwalik Formation. This discontinuity pattern that is parallel or sub parallel to surface topography with interbedding of strong and weak rock sequences is highly prone to land sliding[1]. Landslide has occurred in two phases; in first phase, vertical subsidence of rock mass was involved, while in second phase failure of mudstone sequence was involved. Inherent strength characteristics of rock mass, which are combined with increased pore water pressure due to continuous percolation of water from two drainage sources located in periphery of landslide, is main cause for initiation of landslide. Mansa Devi hill has witnessed numerous landslides of varying sizes[2]. Involvement in most of the instabilities are breaking off, toppling and or sliding of mudstone or sandstone, which form over a period of time as debris at the foot of slope. This landslide completely damaged 300 m stretch of Haridwar bypass road and put in danger railway track, residential and commercial establishments of Haridwar Township[3].

This area is located on Haridwar bypass road that joins Haridwar township in south and village Kharkhari in north at a Longitude 78º10´4.8" and latitude 29º57’32.523 . In a geological map of Mansa Devi landslide area (Fig. 1), Mansa Devi temple is situated about 200 m away towards SSW at the top of hill. Railway track, residential and commercial establishment, is situated all along the base of hill. This area is covered under sub-tropical climate with heavy rainfall during monsoon. It is observed that 70% of rain fall is during July, August & September and light and heavy showers of longer duration also occur during December, January & February. Landslide, which occurred during 1998-2000, indicates that mass was mobilized slowly by continuous increase in pore water pressure over years, due to continuous seepage of water from channels located in immediate vicinity and overland flow from the road[3,4].

This study presents a case study of landslide monitoring and early warning of Mansa Devi (Haridwar) landslide site by analysis of data using neuro-fuzzy approach recorded by instrumentation network.

Experimental Section

Instrumentation Monitoring Network

Instrumental monitoring of landslide enables to evaluate amount of displacement in different areas and

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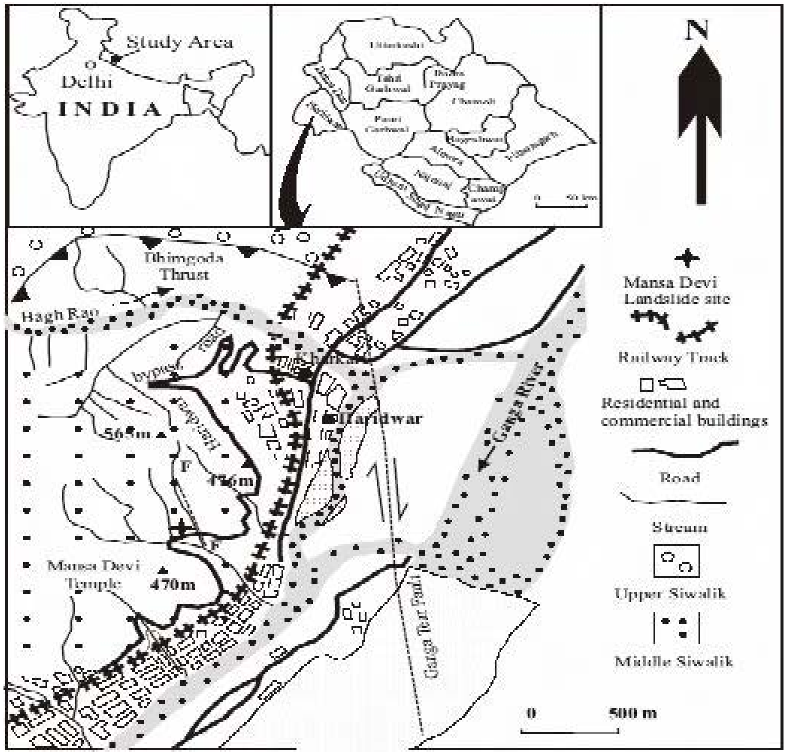

Fig. 1— Geological map of Mansa Devi landslide area[2]

then to understand landslide mechanism. To monitor Mansa Devi landslide, CSIO, Chandigarh had configured an instrumentation network around conventional geotechnical sensors (some sensors developed by CSIO) and indigenously developed data loggers[5,6]. A segment of developed instrumentation network was installed in June 2006 to monitor a small area of this slide round the clock, in association with Central Building Research Institute (CBRI), Roorkee. Complete system was operational round the clock from June 2006 to March 2009 and data was collected and analyzed.

Instrumentation has been designed around modern data acquisition system, advanced signal conditioners, digital data communication links and necessary software. Landslide monitoring system[7-9] consists of: i) Field units (FUs) located within landslide zone; ii) Local control station (LCS) at nearby stable area; and iii) Central Data Recording & Analysis Centre. FUs along with LCS make one independent system for a particular site[10]. Data analysis and interpretation is done at LCS to set various alarms and to detect likelihood of occurrence of any landslide. Network can be expanded to cover fairly large area simply by adding more number of FUs to LCS. Likewise, many independent area specific local networks can be hooked up to a master central recording and processing station via very small aperture terminal (VSAT) connectivity to form ‘National Grid for Landslides Monitoring’. In CSIO developed instrumentation network (Fig. 2), FUs consist of signal conditioner cum sensor interface unit, 16-bit data acquisition module, optical modem, optical fiber, power supply, solar panels, charge controller, battery pack and sensors namely inclinometer, tilt meter, rain gauge, crack meter, extensometer, piezometer, pressure cell and load cell[8,11]. A graphical view of all recorded data is shown (Figs 3-5). All selected components (cables, casing, sensors and other enclosures) are strong enough to withstand severe environmental conditions of landslide site under surveillance and remain operational round the clock over a very long time without quality deterioration. Installed system was operational on solar panel.

In this paper, prediction and early warning system for rainfall-triggered landslides is tested. A real time monitoring system, based on the data of sensors/ instruments selected according to characteristics of soil mass, and placed where first signs of movement are predicted to occur, could represent an effective tool for transmission of local and remote alerts, which enables immediate activation of emergency procedures.

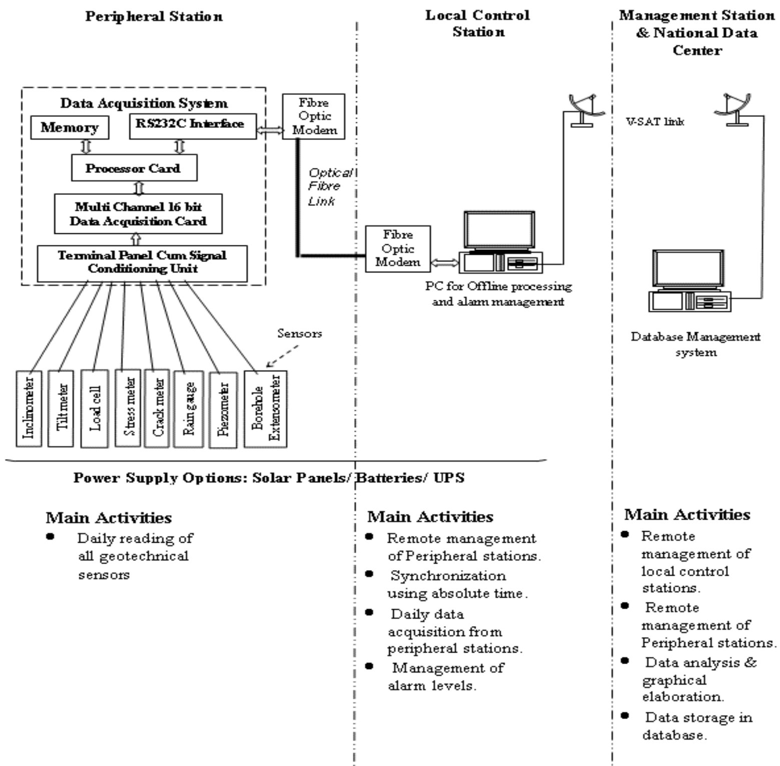

Fig. 2 — Instrumentation scheme for landslide monitoring

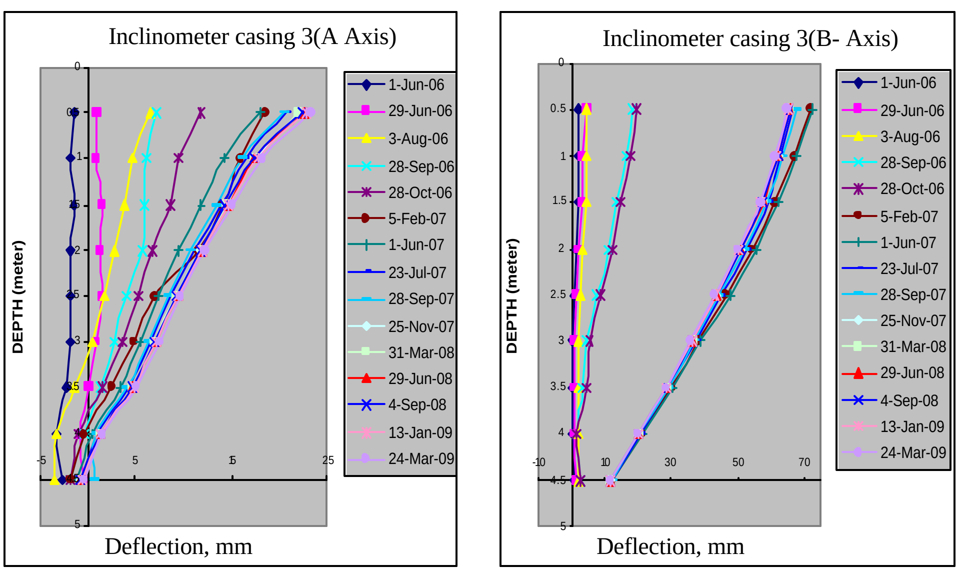

Fig. 3 — Plot of inclinometer data

To predict slope movements using back propagation neural network (BPNN), MATLAB has been used in this development[12]. Different toolboxes used were fuzzy logic, neural network (NN), and data acquisition toolbox. MATLAB provides a number of interactive tools that give access to many functions through a graphical user interface (GUI), which provides an environment for fuzzy inference system (FIS) design, analysis and

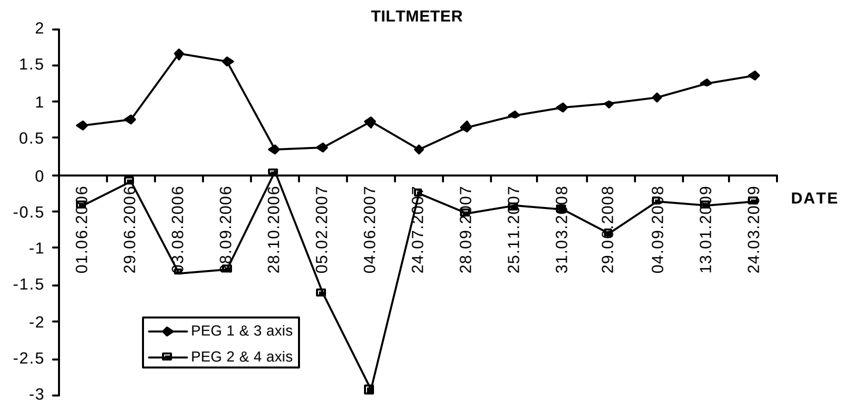

Fig. 4 — Plot of Tiltmeter data

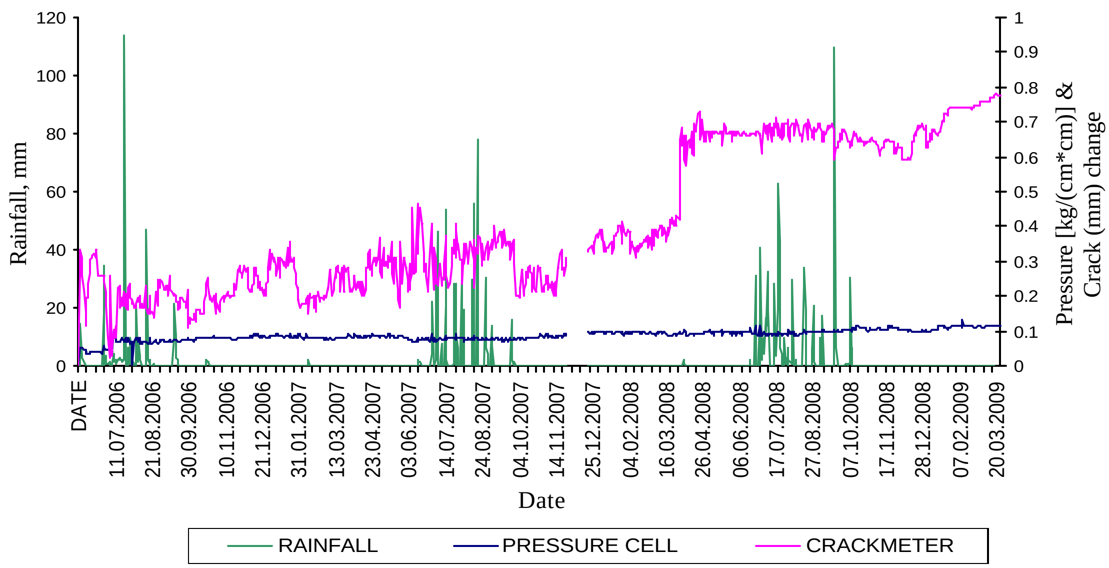

Fig. 5 — Rainfall, crack and pressure change graph

implementation[13]. A MATLAB based BPNN model has been developed, and data from case study was used to train and test developed model to enable prediction of ground movements magnitude using input variables that have direct physical significance[14] (Fig. 6). Soft computing techniques in ANNs, fuzzy systems, and evolutionary computation have been successfully combined, and soft computing have been developed[1]. For NNs, knowledge is automatically acquired by back propagation algorithm, but learning process is relatively slow and analysis of trained network is difficult (black box)[15]. In areas of high landslide risk, where dangerous situations can develop rapidly, neuro-fuzzy system are being used for monitoring and providing near real-time landslide information via alarm signal and via GSM Technology to researchers, emergency personnel and others assisting to assess developing risks[16].

Cascaded Fuzzy-Neuro approach was used[17,18]. Inputs from the set of five sensors (rainfall, surface crack, surface tilt, pressure, surface inclination) was taken into present program (input data recorded round the clock from June 2006 to March 2009), and presented to FIS, which fires one or more rules from rule base. Output(s) are then presented in conjunction with inputs, to NN for training[13]. Once training is through, network is capable of providing reasonable prediction values for new inputs (Fig. 7). This algorithm is site-independent, wherein number of input parameters and their corresponding weights can be modified as required.

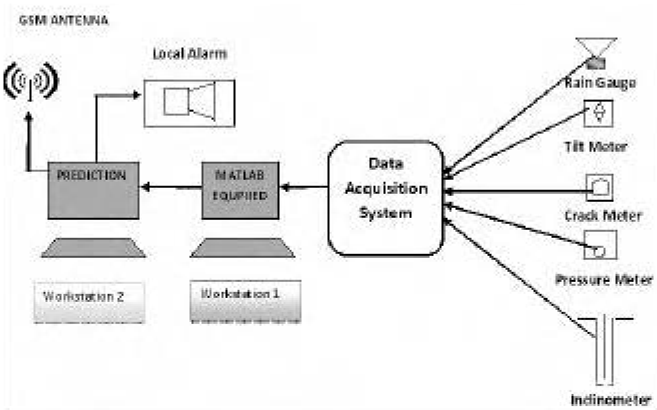

Fig. 6 — Block diagram of the system

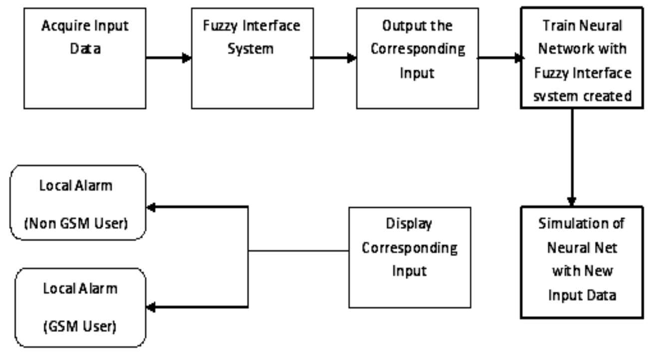

Fig. 7 — Data flow diagram

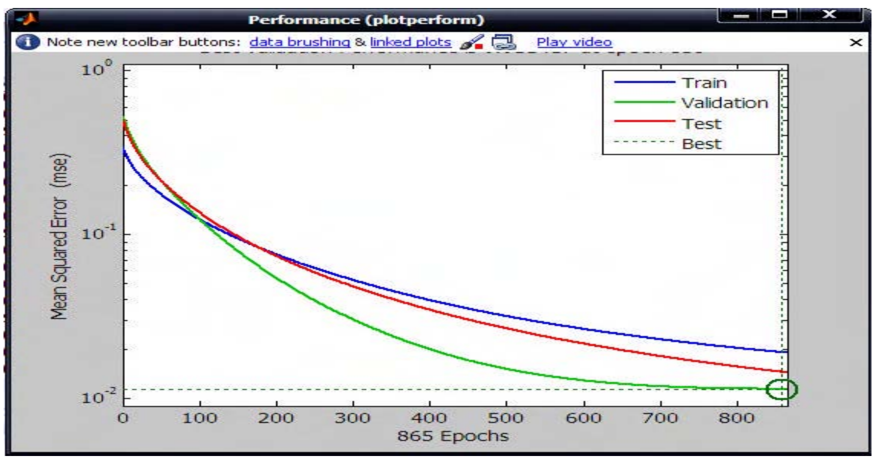

Fig. 8 — Performance graph of network

Fuzzy system outputs of different sets of value of input are taken and are used for training NN[14]. For present input and training data set values, sample data and fuzzy output are used as training data[19] (Table 1). A feed-forward networks trained with BPNN with command line functions of neural tool_ net = is made (Fig. 8). Network was trained, until it has learned relationship between example inputs and targets used with BPNN, is two-layer feed-forward network[16]. Call to newff created a two-layer network with 20 neurons in hidden layer. Numbers of neurons in output layer are automatically set with the number of elements in each vector of target. Net=train (net,input,target); after training of created network[12,20]. Early warning signals are generated in two ways: i) A sound/hooting device is used as an external device using MATLAB DAQ toolbox to generate this alarm[15]; and ii) GSM modem has been used with AT commands and HyperTerminal program of Microsoft Windows to send SMS message.

Table 1—Neural trained data values obtained

R	C	T1	T2	P	I1	I2	Trained value of neural
72	0.4	1.37	-1.6	0.15	23	26	0.2494
117	0.52	1.46	-1.89	0.1	10	65	0.4141
142	0.62	0.5	-1.6	0.15	22	54	0.5712
150	0.35	2.6	-2.8	0.1	23	67	0.5431
155	0.82	2.82	-3.2	0.25	29	90	0.8393
158	0.96	1.54	-3.6	0.3	29	97	0.9151
160	1	3	-4	0.3	30	100	1

Results & Analysis

Instrumentation network, which was designed, developed and installed at selected site, operated round the clock satisfactorily. Some minor problems noted were like breakage in wires due to movement of wild animals at the site and blocking of rain gauge due to tree leaves and dust particles etc. and that was repaired immediately

Table 2—Prediction result in text form

Test data for neural								Prediction text result
R	C	T1	T2	P	I1	I2	Neural output	
0	0	0.69	-0.404	0	0	2.059	0.0973	Conditions are normal
18	0.26	0.76	-0.072	0.05	0.946	4.521	0.2961	Conditions are going harsh
0.5	0.16	1.64	-1.32	0.06	6.6063	4.136	0.3646	Conditions are going harsh
0	0.29	1.26	-0.412	0.09	22.88	65.35	0	Conditions are normal
114	0.34	1.5	-1.6	0.07	24	74	0.3393	Conditions are going harsh
46	0.24	1.6	-1.6	0.07	22	72	0.0868	Conditions are normal
54	0.37	1.8	-2.2	0.07	23	66	0.3623	Conditions are going harsh
78	0.32	2.2	-1.2	0.08	22	56	0.4046	Conditions are going harsh
62.5	0.38	1.4	-1.6	0.01	22	65	0.0836	Conditions are normal
110	0.27	2.2	-2.6	0.01	27	70	0.5678	Inform to local government

as security personnels were in constant touch with CSIO and CBRI. Unfortunately, data acquisition system was out of order from 26 November 2007 to 19 December 2007 and no data is available for this period. After maintenance and recalibration, data acquisition system was reinstalled on 19 December 2007 and new initial data set was obtained.

Data of five sensors was collected by network installed at site. Using this data, graphs showing variation in measured data with time have been drawn and efforts have been made to analyze variation to relate with ongoing landslide process. On the basis of data recorded so far, it is observed that this particular site is still an active landslide site and there is an inclination in slope and tilt in surface; in rainy season, there is more inclination, crack, and tilt. Table 2 shows numeric predicted values (varying from 0 to 1).

Conclusions

Neuro-fuzzy based landslide prediction and early warning system was developed in MATLAB environment with toolbox functions. Real data recorded from site was tested through warning system. Prediction value for site is found good. This site in normal rain condition is found safe and in high rainfall duration some changes are found and at a very few situations it is found to be an alarming or near alarming condition.

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