Landslide Detection Techniques: A Survey

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Abstract: Landslide is a physical phenomenon in which large amount of rock debris break or slide down the slope leading to destruction of large natural as well as material losses along with lives of many people. Massive losses are caused by landslides in different parts of world. In India landslide is popular phenomena of Himalayan region and southern Nilgiri Mountains. Such losses could be avoided if proper intelligence system is present which could inform about the event in advance or at least give information about landslide trigger factors like water content in soil, tectonic activity, disturbance frequency of anthropogenic activates, litho logy and various others. In this paper different landslide detection techniques are discussed.

Keywords: Landslide detection, Sensors, Satellite, Images, Monitoring.

I. INTRODUCTION

Technological advances have provided variety of tools which if properly assembled can give good estimation technique. Each technique developed can have its own advantages and disadvantages which technique to use depends largely on area under consideration because of large permutations and combinations of triggering factors. Over 6,000 people are feared to have been killed in the devastating floods, cloudbursts and landslides in Uttarakhand in June 2014. Overall loss experienced by India until now because of landslide alone is 400 million. Improved technologies or data base management and data representation are present today. Communication technologies consuming lesser power more range and lesser bandwidth are very useful. The different types of instrumentation and techniques are remote sensing or satellite techniques, photogrammetric techniques, geodetic or observational techniques, and geotechnical or instrumentation or physical techniques. [1], [9], [10], [14]

II. DIFFERENT TECHNIQUES

The different techniques of landslide detection which are widely used in different parts of world are discussed below.

A. Remote Sensing or Satellite Techniques

Satellite images in the optical region with high spatial resolution are used for producing landslide inventory maps and for mapping factors related to the occurrence of landslides such as surface morphology, structural and litho logical properties, land cover, and these factors change with time i.e. temporal changes.[1], [7], [11], [13]. Capability of repeat observations is possible. Images on soil moisture content could be observed. Infrared imagery provides types of information that is valuable for evaluating existing landslide and landslide – susceptible terrain like surface and near - surface moisture and drainage conditions, indication of the presence of massive bedrock or bedrock at shallow depths, distinction between loose materials that are present on steep slopes and are susceptible to landslides etc.[1]. Space borne Interferometric Synthetic Aperture Radar (InSAR) provides an excellent means of observing deformation over broad areas. High to medium resolution remote sensing imagery from different satellites in panchromatic and multi-spectral modes have been used. Example Images properties are in table.[3]

Table:1. Image properties of different satellites[3]

<table>
<thead>
<tr>
<th>Satellite /Sensor</th>
<th>Bands</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spa</td>
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<tr>
<td>Ikonos</td>
<td>Panchromatic</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Vis(RGB)-NIR</td>
<td>4</td>
</tr>
<tr>
<td>Spot 5</td>
<td>Panchromatic</td>
<td>2,5</td>
</tr>
<tr>
<td></td>
<td>Vis(RGB)-NIR</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>SWIR</td>
<td>20</td>
</tr>
<tr>
<td>Landsat 7</td>
<td>Panchromatic</td>
<td>15</td>
</tr>
<tr>
<td>ETM+</td>
<td>Vis(RGB)-NIR-SWIR</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>TIR</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>RGB</td>
<td>-</td>
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<tr>
<td></td>
<td>NIR</td>
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</table>

- RGB - Red Green Blue.
- NIR- Near Infra Red.

Various image processing techniques utilized are:

- Pre-processing
- Enhancement and color compositions
- Filters
- Indexes and transformations
- Digital classification

Images obtained from satellites are of different types depending on satellites and technology used for taking pictures for example true color images, infra red images, pan sharpened images, panchromatic images. Contrast images are used for differentiating large and small scale landslides.[2], [4]
Disadvantage:

Deployment of special satellites for landslide detection is very costly also occupying present deployed satellites with modern cameras is necessary. If any image is blurred it leads to wrong interpretation of data. Quality of image matters for

- High spatial resolution.
- Multi-spectral data collection.
- Stereoscopic viewing.

B. Photogrammetric techniques for landslide monitoring:

This technique is used for monitoring ground movements in mining areas. Aerial photographs present an overall perspective of a large area and boundaries of existing slides can readily be delineated on aerial photographs. Soil and rock formations can be seen and evaluated in their undisturbed state.

The accuracy of photogrammetric positioning with special cameras depends mainly on the accuracy of the determination of the image coordinates and the scale of the photographs. This is not satellite monitoring as special 3d cameras are installed at a height and below land terrain is observed.[2] The more the powerful camera the more will be the accuracy of the results obtained. Using a camera with \( f = 100 \text{ mm} \), at a distance \( S = 100 \text{ m} \), with the accuracy of the image coordinates of \( 10 \mu \text{m} \), the coordinates of the object points can be determined with the accuracy of \( 10 \text{ mm} \). Aerial photographs over temporal coverage with cost effectiveness is difficult.[1],[3],[7]

C. Ground-based geodetic techniques:

Deployment horizontal and vertical networks in the area of investigation and control equipment in the deform area. Horizontal or vertical movements of the nodes used to determine the amount of movement and estimating parameters. Production has stopped however because of cost.[6],[17]

Leica TM5100A high precision electronic theodolite is shown below:
D. Terrestrial Laser Scanning:

This technique uses Light Detection and Ranging (LiDAR) technology which produced detailed 3D images. Such scanners can provide 100 to 300 meters range while longest range could be 1 to 2 km. RGB color values are used in images. TLS scanner is mounted on a tripod providing good view of vertical features. This technique is used for monitoring post hazard damage like earthquake, study of soil erosion characteristics sea cliff erosion studies, trench volume calculations, landslide analysis. Several methods used for analysis are Principle Component Analysis, Support Vector Machines, and Image Differencing. Automated algorithms are used for filtering scanned data base. The result obtained is of the form of matrix. Different principles of pattern recognition are needed for analyzing the complex random patterns of data points of images. The image obtained from LiDAR is shown below: [2], [3]

Disadvantages of above method i.e. TLS:

This technique gives good vertical data but horizontal resolution is poor. To overcome this airborne cameras are to be used and then combining these two images to provide whole picture. For 3D representation we need to take images from different angles thus overall complexity is sure to increase. Moreover this technique is good for large scale scanning does not provide good small scale scanning. Thus many complementary methods are to use ad joint to this.

E. Fibre-optic sensing system for monitoring debris flow:

Landslides and other related activities, such as rock falls, debris avalanches, and debris flows, usually produce ground vibrations and loud noises. Monitoring ground vibrations is accepted as a reliable way to detect the occurrence of such natural hazards. Various sensors have been utilized to record ground vibrations generated by debris flows. Among these sensors, geophones are most widely installed in systems monitoring debris flows. However, ground tremors generated by the landslide-related disasters are significantly smaller than ground vibrations caused by earthquakes, and have a higher frequency range. Consequently, these tremors can only be detected within a relatively short distance. Although this shortcoming can be overcome by installing sensors close to
the origins of disasters, deploying long cables results in high signal attenuation and transmission uncertainty in mountainous regions.[16,17] Fibre optic sensors have recently been devised to detect various physical signals. Their light weight, immunity to electromagnetic interference, high sensitivity and very low optical loss, fiber-optic sensors can be potentially utilized to monitor landslides and the related disasters, which usually occur in mountainous regions far from available electricity. Furthermore, the fiber optic sensors can be multiplexed, offering the possibility of large numbers of sensors supported by a single fiber optic line. If the sensors are well distributed, a fiber-optic sensing system for monitoring regional composite landslide-related hazards can be established. This type of experiment was first performed on Ai-Yu-Zi Creek and the Chu-Shui Creek both these are located in Nantou Country, Taiwan. The ground vibrations caused by debris flows were sensed by a FBG Accelerometer (Gavea Sensor GS 6500) and the associated light source, data logger and photo detector are provided by a Braggscopc (Fiber Sensing FS 5500). Four FBG Accelerometers were deployed along the two Creeks. The Braggscope was located at the front data-receiving center, a small house built near the place where electric power supply was available. The system was could be tested of the sensitivity of the sensors and the functioning by applying artificial seismic vibrations. The received data could be analyzed to show that the received signals own the correct frequency character.[15]

F. Senslide: Landslide Early Warning System:

Senslide, a distributed sensor system for predicting landslides. Senslide arose out of a need to mitigate the damage caused by landslides to human lives and to the railway network in the hilly regions of India. This solution applies ideas from distributed systems to a collection of cheap sensor nodes interconnected by wireless links. Landslides can be caused by the increase in strain due to percolating rain water in rocks fissures, causing rocks to fracture and slide down the slope. Senslide uses an array of inexpensive single-axis strain gauges connected to cheap nodes (specifically, TelosB motes), each with a CPU, battery, and a wireless transmitter. Sensor data is then collected by distributed measurement nodes and forwarded across the wireless network towards a data collection point. This collection point aggregates data and may perform further steps like data pre-processing and compression. Finally, data is provided via a wide-area network like GSM/UMTS for secured remote access via the Internet. In the ScatterWeb product line, the data collection point is called the ScatterGate. A set of measurement nodes and one ScatterGate in a ruggedized version can be seen in the following figure. [6], [7], [16], [17]

The following picture shows the installation of a WSN using components from ScatterWeb for the study of warming effects in the Swiss Alps as part of the project SensorGIS.[16]

The point measurements made by individual sensors are propagated to a set of “base stations” that have GPRS and/or 802.11 connectivity to each other. In addition to their improved network connectivity, base stations are located in places with access to ground power, and have more computation and storage resources than the sensor nodes. A subset of the sensor nodes are designated as aggregators that collect smoothed local data, and create spatial summaries. These aggregator nodes communicate with the base station
providing summary data at adaptively adjusted frequencies. The stress versus strain characteristics of five rock samples is shown. The end-point of each series is the fracture point of the rock.[16]

![Graph](image-url)

**Fig. 9** Measured stress vs. strain characteristics of igneous rocks.

The X-axis is stress in Newton/m². The Y-axis is the A-to-D converted voltage in proportion to the strain on the rock. Modern sensor networks, like ad hoc wireless sensor networks can be used. Technology used for communication is UWB providing greater accuracy. In 2002 FCC (Federal Communications Commission) released UWB licenses for free use. [6]

Disadvantage of this kind of system is we need to have as many as 600-700 sensor nodes in a single patch. Thus complexity of this system is more. UWB frequencies can interfere with other frequencies. Cost of all the instruments required and their supply is a major problem. [6]

### III. CONCLUSION

Thus continuous monitoring of landslide responsible factors and there values cannot be obtained from above methods. The newer method could be developed such as using sensors for whose values are continuously monitored using GUI for readers. Graph analysis of direct values will lead to better prediction by experts in Environmental geology. If values exceed threshold level then system proposed could raise an alarm immediately. Communication from study area to master computer uses Zigbee or ad-hoc or any other technology which is promising, upcoming, consuming lesser power and sufficient range and quality of transmission.

### IV. REFERENCES


[10] Safeland, 7th framework programme, "Living with landslide risk in Europe" October 2010,


