Landslide Early Warning System for Rural Community as an Application of Sensor Asia

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Abstract

An early warning system for landslides was developed and deployed in Banjarnegara Region of Indonesia as a part of Asian Joint Research Project and Sensor Asia Initiative. A Fieldserver was used to collect data from several sensors and display them in a web page in real time. The system consists of a network camera, two extensiometers placed above and below the data collection point in order to check ground displacement, and a rain gauge to constantly check the antecedent as well as current rainfall which affect land movement. At the same time a water pressure gauge was also placed at a depth of 2.5 meters to measure the underground water level. The data from the sensors and the images from the camera are collected and stored in a database in an embedded Linux system.

The system applies an algorithm based on local observations by landslide experts to provide warning messages at several levels. The warning levels are determined depending on the data collected from the two extensiometers and the rain gauge. A graphical interface is also provided at the local site for community people to see the movement and the warning level.

The data and images collected at the site are also sent to a server at the Asian Institute of Technology (AIT) in Thailand, where it is possible to make it publicly accessible through the Internet. Since there are no stable infrastructures for Internet access available at the site in Banjarnegara, a GPRS modem has been used. The system collects data every 5 minutes and sends the collected data to AIT every 1 hour. This real time monitoring and early warning system can be an ideal implementation at landslide prone areas worldwide.

Keywords: landslide early warning system, sensor network, Fieldserver, SensorAsia

Introduction

It has been observed that the occurrence of landslides have increased in recent years. This has resulted in tremendous loss of property and life, mainly in countries that do not have adequate provisions for early warning systems and disaster prevention and mitigation measures. There is need of a real time landslide monitoring system which can gather data from sensors and publish them on the web for analysis by experts and for contribution towards rural community early warning.

An initiative call SensorAsia aims to develop and deploy a high density sensor network in Asia using Fieldserver which can be an ideal implementation for landslide early warning. Sensor Service GRID (SSG) is a core system of the SensorAsia initiative to realize "sensor plug&play" covering from installation of sensor nodes to visualization and publishing sensor data to applications. Thus automatic configuration of the data paths from the beginning to the application end is possible.

Indonesia is one of the countries which is highly prone to landslides because of its mountainous landscape and occurrence of heavy rainfall. A landslide early warning system was developed and deployed in Banjarnegara Region of Indonesia as a part of Asian Joint Research Project for Early Warning of Landslides led by International Consortium on Landslide (ICL), with collaboration from and Gadjah Mada University, Indonesia and the Asian Institute of Technology (AIT), Thailand. The early warning system allows data to be viewed locally and also sends the data to a web server in AIT for graphs to be published on the Internet. The location at Banjarnegara had already seen considerable land movement and was in dire need of such a system for its community.

Implementation Overview

The early warning system consists of a Fieldserver as its core component, which collects data from the following sensors:

i) Two extensiometers
ii) Rain Gauge
iii) Water Pressure Sensor
iv) Network Camera

The Fieldserver and other associated electronic and network devices are located in an outdoor box mounted on a fixed pole at position P2 as shown in Fig. 1. The invar wires of the extensiometers are extended from above and below the fixed position, such that they can measure land displacement movement in both directions at the two places. The fixed position is at pole P2, and the extensiometer wires are being extended from poles P1 and P3. Fig. 1

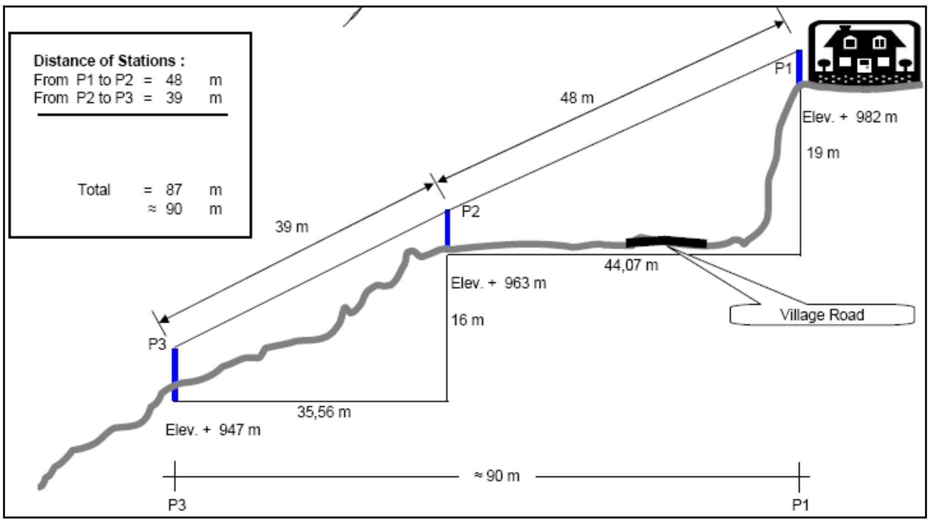

Fig. 1 Extensiometer Settings above and below the Fieldserver position

also shows the locations of houses and a village road which are community resources in danger.

The water pressure sensor is located near the Fieldserver (P2) and is placed at a depth of 251cm with intention of measuring ground water depth. The rain gauge and the network camera are mounted on top of the fixed pole P2 so that they are not obstructed by the foliage around. The instantaneous data from the sensors is collected by the Fieldserver and converted to digital form and published on web page. There is a separate computer system unit indoors which collects the data and puts them on a database. The data is also sent to AIT over the Internet. The outdoor Fieldserver box and the indoor computer unit are connected by a LAN cable.

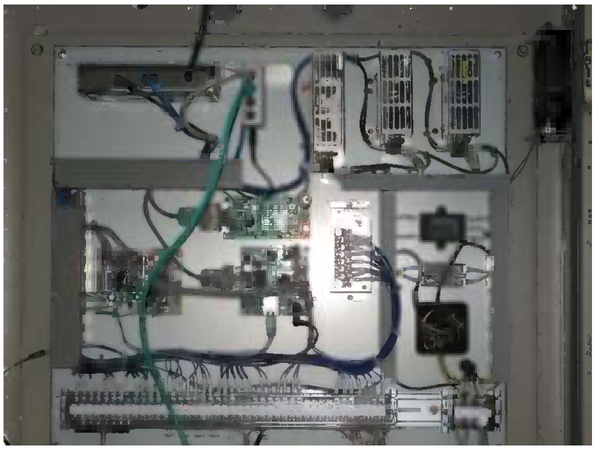

Fig. 2 The fixed pole with rain gauge and network camera, and the outdoor box with Fieldserver and other associated circuits

System Details

The Fieldserver is the device central to the landslide early warning system. The Fieldserver is an Internet Field Observation Robot that consists of a set of multiple sensors, a web server, an Internet Protocol (IP) camera, an Ethernet Local Area Network (LAN) module and a wireless LAN module. It can provide an outdoor solution for environment monitoring and it can be used for a wide range of real time sensing applications in farms and other facilities. At the heart of the Fieldserver are a built-in webserver and an Analog-to-Digital converter. The analog voltage from sensors are converted and shown on webpage as table formatted data.

The Fieldserver is equipped with a Toshiba IK-WB21A IP camera attached to it. The IK-WB21A network camera can deliver video or still images in real time using the Internet or an intranet. The camera is equipped with Ethernet network interface. The camera has built-in pan (left/right) and tilt (up/down) mechanism which can be controlled through a web browser to change the direction of the camera lens. The camera can also be preset to move to different rotation and zoom positions at fixed time intervals.

The indoor unit consists mainly of a mini PC running on Linux. Inside the Linux Box, the data from the sensors connected to the Fieldserver are collected periodically by a feeder program and stored in a separate database. The images uploaded by the network camera are also kept track of in the database through the feeder program. A part of the feeder program also has a Comma Separated Values (CSV) file generator. CSV files are generated periodically and transferred every 1 hour to the SSG server in AIT using SFTP. The purpose is to synchronize the database in the field to the database in AIT server. The images from the network camera are also transferred to AIT. Due to unavailability of stable Internet connections in the remote area, a GPRS modem has been used to connect to the Internet as shown in Fig. 3.

The figure also shows some details of the sensor connections. The rain gauge is of tipping bucket type and is connected via a counter to the Fieldserver through a serial interface. The water pressure sensor, which is a strain gauge, is connected via an amplifier to the Fieldserver. The network camera connects to the system with the Ethernet interface. As this area is also prone to power cut-offs, there are UPS back-up power units provided for the outdoor and indoor systems which supports up to several hours.

A wireless connection was first tested between the indoor and units, which was then replaced with a wired LAN connection, as the wireless link proved unstable due to lack of proper line of sight for WiFi signals.

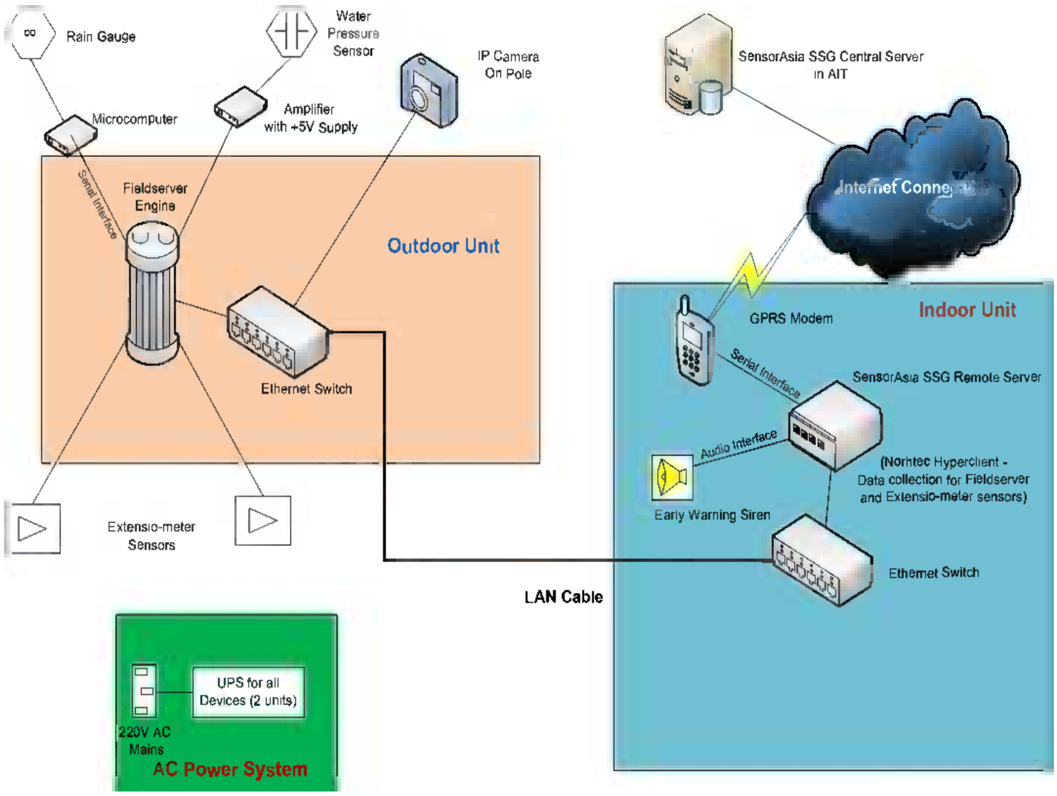

Fig. 3 Network diagram and system overview.

An audio interface has also been provided on the Linux Box which is designed to emit different warning tones depending on emergency levels.

Early Warning Criteria and Graphical Interface

The system applies an algorithm based on local observations to provide warning messages at several levels. The warning levels are determined by data from two extensionmeters, and the rain gauge. The warning criteria are described as follows (R24 and R72 are antecedent rainfall in 24 and 72 hours respectively, and e1 and e2 are displacement rates):

Warning I (First Warning, Yellow)
If (R24>100mm && R24 > 250mm-R72)

Warning II (Prepare for evacuation, Orange)
If (R24 > 150mm && R24> 350mm-R72) || (Warning I && (e1 > 2mm/hr or e2 > 2mm/hr))

Warning III (Evacuation, Red)
If (Warning I || Warning II) && (e1 > 5mm/hr || e2 >5mm/hr)

Besides provision to connect a loud speaker to emit different warning tones, a graphical interface is provided at the local site for community people to see the data which shows the warning levels using different colors. The graphical interface also shows the image from network camera the data from sensors in the form of simple graphs and tables. A monitor has been connected to the Linux Box at the local site for community people to view the status. We think that this kind of graphical representation of warning level which suggests actual actions people should take is quite important, because the raw observation data is not understandable for non-expert people.

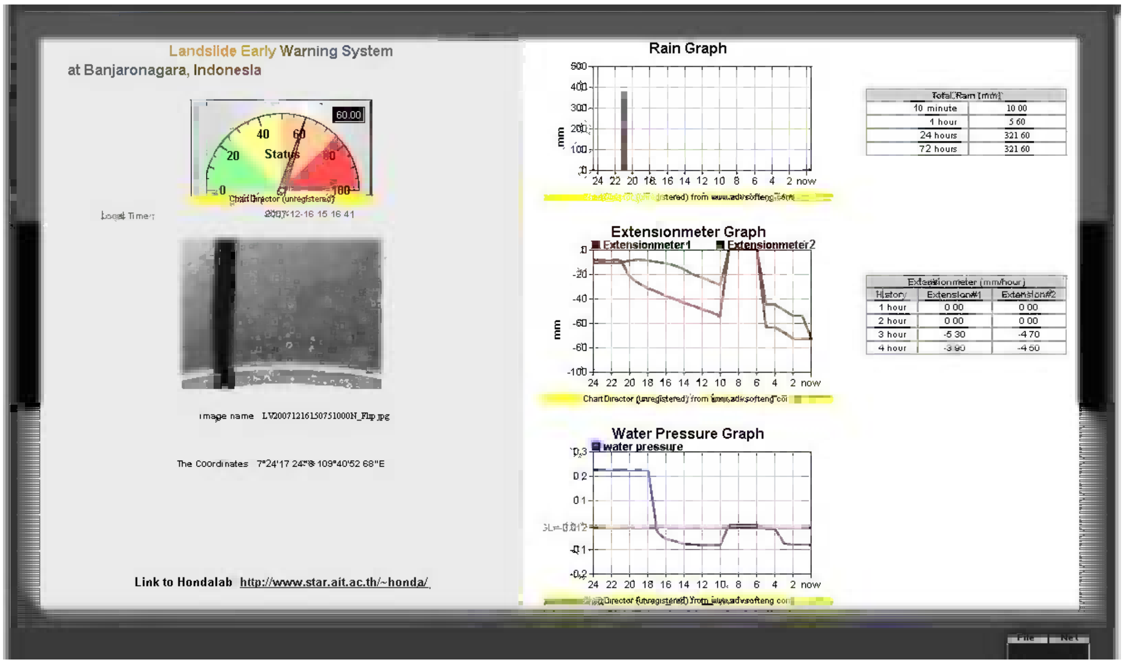

Fig. 4 Graphical Interface for local and global viewing

The same graphical interface can be made available on the Internet with the data and images being sent to the SSG server in AIT, Thailand.

SensorAsia

We have been proposing Sensor Asia Initiative to promote high density field observation networks using field server. Sensor Service Grid (SSG) will provide the core technology and platform to achieve this initiative all over Asia using sensor networks and GIS technology. SSG is based on OpenGIS specifications to provide standard sensor service, many high level web-services for end-users, such as sensor plug&play and securities. We envision that anyone can install sensors, archive sensor data, and get graphical visualizations with off the shelf sensors without the need of highly skilled sensor/network engineers.

SSG will provide a set of useful services and several client applications that drive the flow of sensor observations from sensor nodes to various kinds of users. The users may be public users who use internet browsers or Google Earth to visualize data of interest, or advanced users who want textual data and may submit further processing requirements, grouping of sensors, generation of sensor alarms etc. The SSG community is dynamically formed to share sensor resources. Sensor observations is seamlessly retrieved, processed, and integrated and delivered electronically to end user on demand. The SSG provides a platform for ubiquitous and open sensor networks. The queries and response to/from sensor nodes are based on standardized XML. At the core of the implementation is the OpenGIS Sensor Observation Service (SOS). Sensor data are formatted in standard Observation and Measurement (O&M) encodings.

Discussion

We realized that although the GPRS Internet link works well in laboratory testing, it is not so stable in field application. The data coming from the Banjarnegara to AIT is interrupted quite often. Although the publishing of data on the Internet may be hampered periodically by this, the warning system for rural community at the local site is not hindered in any way. The local community people will be able to make full use of the early warning system and data viewing capability. The data publishing on the Internet can always be done as and when the Internet connection is available.

Although this early warning system has not yet been 100% perfected, we believe that this real time monitoring system can be a model for implementation at landslide prone rural community worldwide. Coupled with SSG, such sensor systems can find wide application in not only landslide early warning, but also other types of disaster prevention and mitigation systems, in environment and agriculture monitoring, in industries, securities and to support our daily life.