OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Wireless sensor network system for inclination measurement using spirit level

G. Anne Nisha[1], Nalin Warnajith[2], Hiroshi Tsuchida[3], Atsushi Minato[4]

[1, 2, 4] *Graduate School of Science and Engineering, Ibaraki University,* [3] *Geotech Co.Hitachnaka, Hitachi, Japan*

ABSTRACT: *Landslide is one of the major sediment disasters causing natural catastrophes frequently. Monitoring the inclination of land is important to prevent and reduce the negative effects of landslide. While considering the large scale installation, the monitoring system should be stable and inexpensive. This paper deals with the development of a new low cost inclination measurement system and its application to a wireless sensor network for disaster prevention .When tested, inclination with a gradient of 0.002°of minimum accuracy was noted. Measurement data were compared with the data from commercial inclinometer.*

Keywords: *spirit level, landslide prevention, sensitivity, wireless sensor network (WSN), Raspberry Pi*

I. Introduction

Large number of landslides occurs around the world and it is very important to accurately measure the slight change in ground or sediment-related disaster in order to predict and prevent it. Landslide hazard monitoring and analysis can provide useful information for the catastrophic loss reduction and assist in the development of guidelines for a sustainable land use planning.

As per the report of the Ministry of land, infrastructure and transport in Japan, an average of 1180 landslides occur every year induced by natural phenomena such as rain, earthquake that results in the death or missing cases of 30 during the recent 10 years(2003-2012) [1]. Since landslides have become a major threat to the life and property of the residents and causes damage to the structures, an advance disaster prevention and prediction method is essential.

In the devastated area with a risk of landslide, monitoring the ground movement is necessary to predict the risk of landside. At present, there are several commercial equipments, which can detect changes of the land area. Even though these equipments can be used to obtain more accurate information, their cost is very high [2, 3]. So, the development of inexpensive and reliable equipments has become a social requirement at present.

As one of the prediction method, it is very important to extensively monitor the angle of inclination by installing the equipment in high landslide prone areas such as mountains and nearby structures, quickly measure and transmit any small variation in land position just before the disaster occurs.

Three type of surveying instruments that are commonly used in angle measurement at present are inclinometer, accelerometer and level gauge. Even though inclinometer is used in various cases, highly accurate products cost high and the commercially available low cost products have less accuracy. Accelerometer can measure not only the change in movement caused by the movement of humans and machines but also it can measure the change in motion due to gravity. So, it can detect the inclination angle of the object. Accelerometer can measure in a larger range, but the sensitivity is relatively smaller than the level gauge. Level gauge is an instrument to determine the angle of inclination with respect to the ground or a fixed object. Levels such as spirit levels, laser level and digital level are widely used in areas such as civil engineering, architecture and surveying. All these instruments are affected by electric noise which is the disadvantage.

Among them, spirit levels which are not affected by the electronic signal and temperature are widely used due to the features like low-cost, small size and easy to use. Since it is measured by visual observation of the human in general, it has problems of errors and man power. Here, the development of a device with low-cost and reliable accuracy which can measure the inclination automatically is required where the spirit level was photographed using the camera module and image processing is done on a PC.

II. Principle Of Measurement

Purpose of the study is to develop a simple and stable inclination measuring device, to predict and prevent disasters like landslides not relying on human visual and quantitative inclination angle measurement. Inclination measurement is the network system which can combine sensor and wireless technology and wireless sensor development. It has features like high accuracy, durability, small, cheap and versatile.

The proposed method is to calculate the angle and direction of inclination of the device by capturing the spirit level image using a camera and finding the position of the bubble from centre position in the captured image. The spirit level used in this experiment is specially ordered device with high radius of curvature of 20000mm.Fig.1 shows the conceptual diagram of the measurement technique.

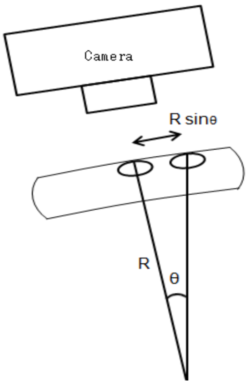

Figure 1: Conceptual diagram of the measurement technique

The spirit level is continuously monitored by the camera; the angle of inclination is measured by the change in bubble position. Instruction for the camera to take photograph was performed using microcomputer or personal computer.

2.1 Basic experiment

In this experiment, A USB connected digital microscope of 2.0 mega pixel was used to take photograph, the distance from the camera to the bubble top was set to 100.5mm.Radius of curvature of spirit level was 20000mm, Goniometer Model no. GNL18 / M was used to record inclination.

The Spirit level is fixed on top of the goniometer and adjusted in such a way that when the base is horizontal the bubble tries to remain at the highest point of the tube and moves along the scale. If the base is tilted to an angle in the range of +/-0.5°, the bubble will move to a distance. The number of pixels was set to 640x480. A digital microscope was used to monitor the bubble when the goniometer was being manually rotated by 0.01° [3]. The bubble movement from -5 to +5° was captured by the camera. Sensitivity of the system and the spirit level was determined. Inclination of the device changes to 0.000153° for the bubble movement of one pixel.

Figure 2: Goniometer readings and sensitivity calculation

2.2 Sensitivity calculation of spirit level

Since the spirit level used in this experiment does not have a division scale, it is necessary to confirm its sensitivity and precision. Further, a spirit level with high radius of curvature is difficult to manufacture and it has some error due to its flatness. So, it is necessary to calibrate the spirit level with goniometer and to measure the sensitivity of the spirit level. The sensitivity is directly related to the radius of curvature of the vial, longer the radius more sensitive the vial will be. Sensitivity of the spirit level is expressed as the angle of inclination for which the bubble will move in the spirit level.

Considering the change in pixel value as Δi and assuming a as the real space of 1 pixel, the relationship between the inclination of the device and the displacement of pixel is given by:

Amount of shift in the bubble's center position ΔX can be defined as

$$\Delta X = R\theta_x \quad (1)$$

Where R: Radius of curvature of spirit level

θ_x: device inclined angle(°.) in X direction.

a :Assumed as 1 pixel.

$$\theta_x = (a/R)\,\Delta ix \quad (2)$$

From (2), $\theta = \frac{a}{R}\Delta i$ (rad)

$$= \frac{a}{R}\Delta i \times \frac{180}{\pi} \quad (°) \quad (3)$$

$\Rightarrow a=10/193= 0.0518$mm/pixel

Real time system sensitivity can be calculated as below:

From (3), $\theta = (1/20000) \times \frac{180}{\pi} \times a$

$= 0.00286 \times 0.0518$

$=0.000148$(°/pix) (4)

System sensitivity observed from the experiment is calculated as below:

$$\theta = 1/16460.1 = 0.00015(°/\text{pixel}) \quad (5)$$

Below Fig.3 shows the sensitivity result of spirit level.

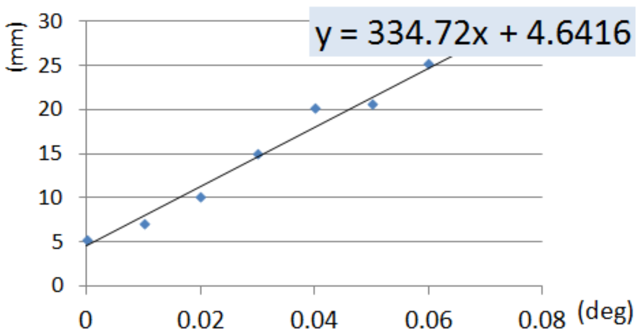

Figure 3: Sensitivity graph of spirit level (° Vs mm)

Sensitivity of spirit level obtained from the experiment:

$$\theta = 1 / 334.72 = 0.00299 \ (° / \text{mm}) \quad (6)$$

Spirit level sensitivity is calculated by taking radius of curvature as 20000mm
The real time sensitivity of the spirit level in mm/° is

$$\frac{\pi}{180} \times 20000 = 349\text{mm/°} \quad (7)$$

The spirit level sensitivity obtained from the experiment (6) is closer to the actual sensitivity (7). Similarly actual system sensitivity (4) and the observed system sensitivity from experiment (5) are closer.

The test was done using multi spirit level in order to increase the measurement accuracy. We used 3 spirit levels in this experiment since it is difficult to maintain the stability of the multi spirit level. So, continuous measurement was done until the bubbles become stable. Continuous measurement of data with 10minutes time interval was taken automatically with interval shot web camera and the change in spirit level was noted.

III. Continuous Experiment

Two types of models were developed for continuous measuring system (1) System-A using a small microcontroller and (2) System-B using small Linux box (Raspberry Pi). Below Fig.4.shows the conceptual diagram of the continuous measuring system.

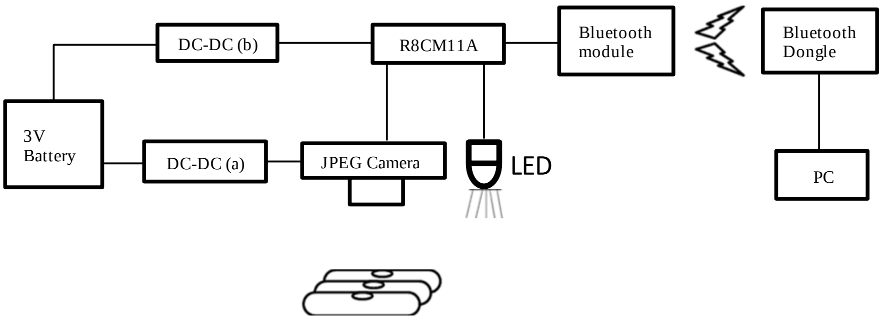

Figure 4: System-A: Sensor network setup

3.1 System-A
3.1.1 Description:

Below Fig.5 shows the experimental setup of the camera and multi spirit level. As an initial test the setup was placed on top of the 7^{th} floor of an 8 storey building and the change in the building was monitored continuously for about 6 months.

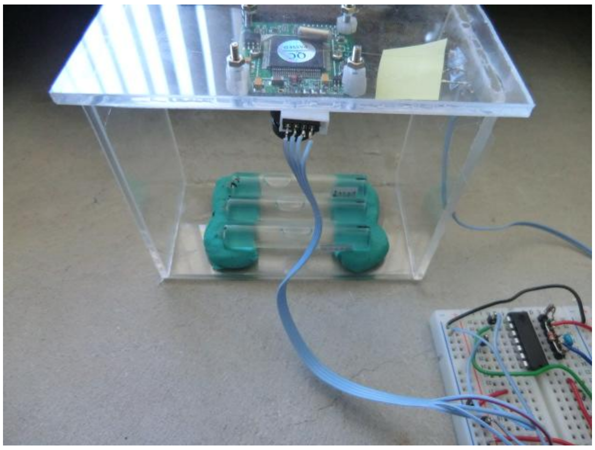

Figure 5: Experimental setup of camera and spirit level

Experimental method of the present study is to send instruction to the camera to take photograph and data transfer instructions using a single chip microcontroller Renesas R8C/M11A [4]. The serial JPEG camera of size 32mm x 32mm automatically captures the photograph of the spirit level. 3 spirit levels of R= 20000mm were fixed and a LS-Y201 (Link sprite JPEG color camera with serial UART interface with a resolution of 160 x 120) was installed at a distance of 10cm from spirit level, which was set to take photographs at a time interval of 10min. LS-Y201 camera works in DC 3.3V power supply [4].The output JPEG images with a dimension of 320 x 240 are transferred through UART serial communication with a communication speed of 38400 bps. RN41 Bluetooth is used to transfer the data to the PC side for a communication range of 100m, XBee wireless communication module can be used for a distance of up to 1km.

The microcomputer is powered at the time of taking photograph and the image data is transferred from the equipment to PC for every10 minute. LED is set to on and off for every 10 min while taking photograph. It is possible to calculate the angle of inclination of the device from the center position of the bubble in the captured image.

3.1.2 Method of calculation

X coordinates of the left and right of the image data of all spirit level are read and the below formula is used:

$$\Delta x1 = (x1+x2)/2$$
$$\Delta x2 = (x3+x4)/2$$
$$\Delta x3 = (x5+x6)/2$$
$$\Delta x= (\Delta x1+\Delta x2+\Delta x3)/3$$

Thus, centre position of the bubbles can be calculated.

Actual diameter of the spirit level: 10mm

Size of the bubble in pixel : width 87 pixels

Height 40 pixel

Diameter of the spirit level : 75 pixel

⇒1pixel=10mm/75pixel=0.133333mm

⇒ Real space of 1 pixel (a) = 0.133333mm/pixel

3.2 System-B: Using small Linux box (Raspberry Pi)

The measurement was done simultaneously by using a Raspberry Pi computer for validation. SD card is used to store the OS and all the data's needed. SD card in Raspberry Pi is similar to a hard disk in PC. So based on the requirement the memory size can be chosen. A 12V/5Ah battery with DC-DC converter is used to obtain the 5V power supply for the system. Linux based Python that comes along with Raspbian OS is used as a controlling program for Raspberry-Pi. Pyserial package is used for serial communication [5, 6]. Cron-tab technique associated with Linux distribution is used to execute the program automatically when Raspberry Pi is turned on.

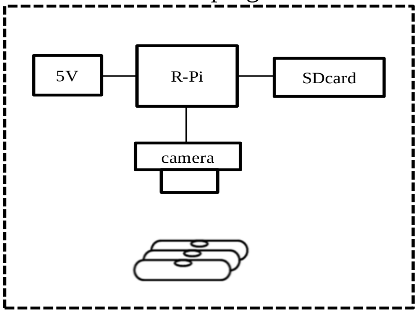

Figure 6: Schematic diagram of Raspberry Pi network

After conducting the basic experiment, the device was subjected to a continuous measurement of more than 6 months from September 2014.

3.3 Experimental Results

There is a constant movement of bubbles in each spirit level. Thus, it is possible to observe any minute change of the bubble. The tilt angle of device was calculated from the average position of the three bubbles. From the Fig.8 it is understood that the movement of bubble is stepwise rather than linear movement. It can be assumed that the stepwise movement of the bubble is due to the below two factors:

1. Friction between the liquid and the bubble
2. Inner surface of the spirit level is roughly smooth

So, for a better accuracy 3 spirit levels were used and the average was taken.

Initially it took 2 days to attain stability of the bubbles. So, there was some oscillation in the first 2 days. After that a periodic bubble movement was noticed. Since the imaging frequency is 10 minutes, 144 images were processed in a day. The bubble movement is smooth due to the friction between the bubble and spirit level.

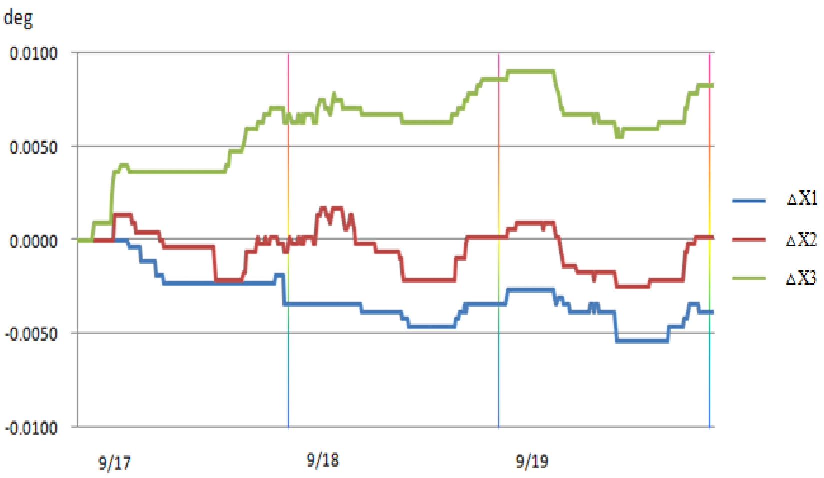

Figure 7: Initial bubble movement with oscillation

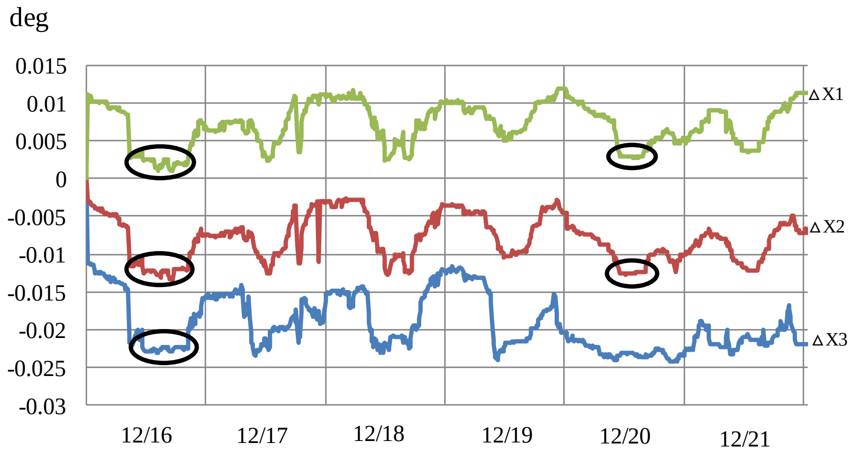

Figure 8: Continuous experiment graph

3.4 Correlation between spirit levels

After attaining stability, correlation between each spirit level was calculated in order to find the relationship between bubbles in each spirit level. The significance level of this correlation depends on the distortion and the bubble movement. Correlations between the bubbles are shown in below Fig.9 and Fig.10. When compared to Bubble 2, Bubble 1 and Bubble 3 have little more distortion and hence a correlation of 0.9 was obtained.

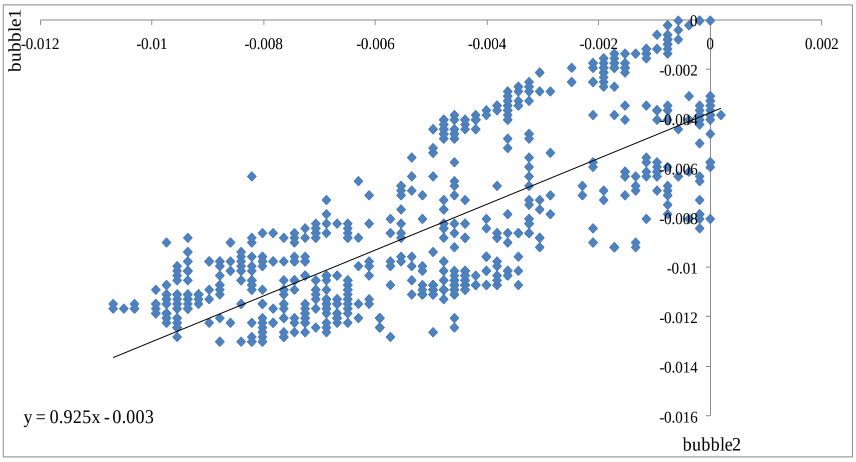

Figure 9: Correlation between bubble1 and bubble2

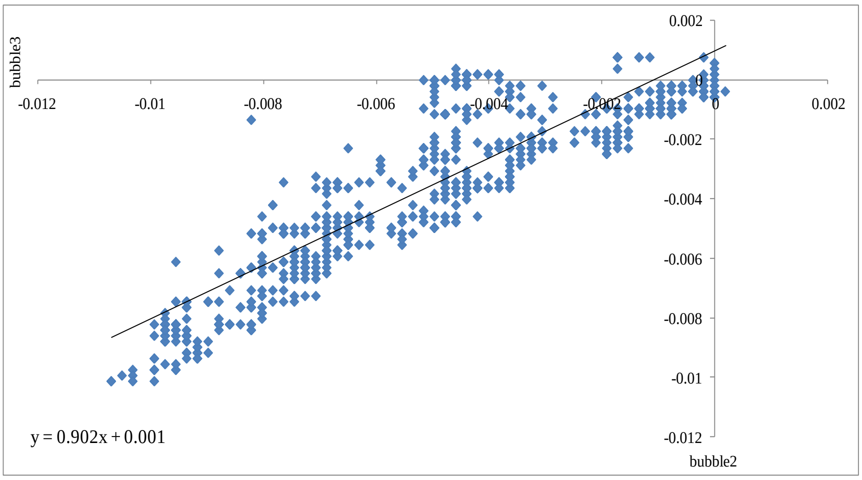

Figure 10: Correlation between bubble2 and bubble3

3.5 Average bubble movement

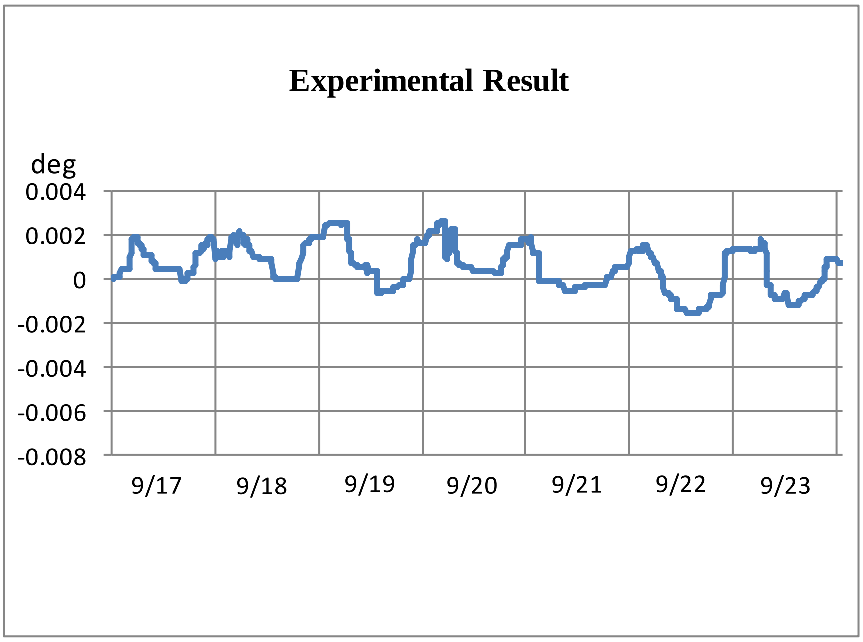

Figure 11: Average of bubble movement

Angular change of the building can be seen from the above graph, it is noted that there is a periodic change in bubble movement due to the weather conditions like sunny, rainy, cloudy, etc... Bubbles move with a regular angular variation of about 0.002° and with regular amplitude of about 0.001°. The maximum value of angular variation is about 0.008°.

From the weather report it is understood that on sunny day bubbles changes comparatively more than cloudy and rainy day.

IV. Image Processing

In order to automate the measurement, image processing techniques are required to automatically determine the position of the bubble. In this method, it is sufficient to find the specific area corresponding to the bubble from the target image.

Figure 12: Template matching

Processing is a programming language which is developed from languages such as C and simplified Java [11]. Processing was done both manually by clicking the edge of the bubble image x1, x2, x3, x4, x5, x6 and obtaining the corresponding coordinates and from the average of 3 bubbles the position and the angle of inclination can be calculated, and automatically using Open CV. Open CV which is a free image processing library by Intel was used in this research. Template matching was done using Open CV 2.4.10 in visual C^{++} 2008 Express Edition [5] [12]. There are several comparison methods in Open CV, in this experiment

CV_TM_SQDIFF method is used. Initially template and input image is read and it is converted to binary image then the corresponding region was searched using the CV_TM_SQDIFF template matching method and the match was displayed in the rectangular region. Above Fig.12 shows the template matching result obtained using Open CV.

V. Discussion And Conclusion

A minimum accuracy of 0.002° was measured as a result of the test conducted in the 8 storey building. The Minimum accuracy of the system depends on factors such as resolution of camera, movement of bubble and distortion of camera.To increase the accuracy of the result Geometric distortion has to be considered for the image data. Two common types of distortion are barrel distortion and pincushion distortion [13] [14]. Distortion was tested with a graph sheet plotted with plots and the image data was captured. The result was checked for how it appears on the optics, when conducted result shows error of 1-2%. Left part of the image is distorted a little bit more comparing to the right part of the image.

It should be noted that the spirit levels are very sensitive to variation in the temperature of their surroundings, since they change the tension of ether vapour in the vial. Hence the spirit level should be used in controlled temperature conditions. The resolution can be increased by using a camera with high pixel resolution or by minimizing the distance between the spirit level and camera as much as possible.

Even small changes in land position can be measured successfully from this experiment and the obtained measurements were proven reliable. As the setup cost and power consumption is very low, it can be implemented in large scale. The major advantages of the proposed method are that it is not affected by electrical noise and it is less susceptible to temperature changes. The Raspberry Pi system is compact and can be used as a standalone system and the data can be saved in SD card. When using multi sensors in the experiment system-A can be used. The user can choose from the two methods based on the target field. Both the system-A and system- B can be connected to the network and the inclination data can be viewed globally.

Anyhow, measurement cannot be done when the liquid inside the spirit level is inflated at high temperature or when it is frozen at low temperature causing the disappearance of the bubble. Hence field observations in such extreme hot or cold regions should be done with a temperature control device.

The analysis is used to evaluate the factors related to land displacement measurement, formulate the measurement technique and to predict the landslide hazard in future.

The inclination measurements in this study, was performed for the purpose of considering the development of disaster prevention system. In particular, inclination measurement in combination with sensor and wireless technologies and to develop the network system is the final goal.

REFERENCES

[1]. Okada Kenji:Global Warming and Landslide Disaster, *The Japanese Geotechnical Society,57(4),6-9,(2009)*

[2]. Sasahara Katsuo, Tamura Keiji *(2010) "Simulation model of surface displacement of steep slope made of granite soil under middle scale rainfall", Journal of the Japan Landslide Society: Landslides 47(3), 155-160.*

[3]. Mo Yang, Masanori Itaba, Atsushi Minato, Satoru Ozawa *(2013) "Development of perpendicular sensor and Its Application for Raging", ISCIU6, 75-76.*

[4]. *Renesas Products,* <http://am. renesas.com/ products/mpumcu/r8c/r8c1x/r8c12/index.jsp>, [12-12-2014]4

[5]. *https://www.sparkfun.com/datasheets/Sensors/Imaging/1274419957.pdf*

[6]. Upton, E., and Halfacree, G., *Raspberry Pi User Guide, Wiley Publishers, (2010), p.1,*

[7]. Donald Norris, *Raspberry Pi Projects for Evil Genius, McGraw-Hill Education publishers,2014.*

[8]. Membrey, P., and Hows, *D. (2013), Learn Raspberry Pi with Linux, A press Publishers, p.xxv.*

[9]. *CANMORE ELECTRONICS CO., LTD.,* < http://www.canmore.com.tw/>. [16-January-2015]

[10]. *XBee®;ZB-DigiInternational,<http://www.digi.com/products/wireless-wired-embedded-solutions* /zigbee-rf-modules/zigbee-mesh-module/xbee-zb-module#overview>. [16-January-2015]

[11]. Keiji Taniguchi*:Image Processing Engineering,P.124-126*

[12]. Gary Bradski, Adrian Kaehler *Learning OpenCV: Computer Vision in C++ with the OpenCV Library*

[13]. Ravi.c.Gupta,*Remote sensing Geology,* Springer-Verlag,*P.123-125*

[14]. Qiang Wu, Fatima.A. Merchant, Kenneth.R. Castleman,*Microscope Image Processing,Elsevier,P.34-40*

[15]. Maria Petrou, Costas Petrou,*Image Processing the Fundamentals, Wiley Publishers, (2010),*