Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography
Vol. 36, No. 3, 177-184, 2018
https://doi.org/10.7848/ksgpc.2018.36.3.177
ISSN 1598-4850(Print)
ISSN 2288-260X(Online)
Original article

IoT-based Guerrilla Sensor with Mobile Web for Risk Reduction

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Abstract

In case that limited resources can be mobilized, non-structural countermeasures such as 'monitoring using Information and Communication Technology might be one of solutions to mitigate disaster risks. Having established the monitoring system, operational and maintenance costs to maximize the effectiveness might trouble the authority concerned or duty attendant who is in charge. In this respect, "Guerrilla Sensor" would be very cost effective because of the inherent mobility characteristic. The sensor device with the IRIS camera and GPS (Global Positioning System) equipped, is basically battery-operated and communicates with WCDMA (Wideband Code Division Multiple Access). It has a strong advantage of capabilities for 'Disaster Response' with immediate and prompt action on the spot, making the best use of IoT (Internet of Things), especially with the mobile web. This paper will explain how the sensor system works in real-time GIS (Geographic Information System) pinpointing the exact location of the abnormal movement/ground displacement and notifying the registered users via SMS (Short Message Service). Real time monitoring with early warning and evaluation of current situations with LBS (Location Based Service), live image and data information can help to reduce the disaster impact. Installation of Guerrilla sensor for a real site application at Gimcheon, South Korea is also reported.

Keywords : Guerrilla Sensor, Early Warning System, Real-Time Monitoring, Risk Reduction

1. Introduction

Natural disasters such as landslides, earthquakes, debris flow, and sinkholes are geological hazard that can endanger human lives and property (Kunnath and Ramesh, 2010). Since we cannot prevent the occurrence of natural disaster, the best way to mitigate the disasters impact is through a disaster mitigation process. This process cannot completely minimize the damage, but it is possible to reduce the hazards through an early warning system (Schmitz *et al*., 2007). by giving more time to people in the evacuation process. The execution of early warning system based on real time monitoring, combined with advanced ICT (Information and Communications Technology) may become a good solution to mitigate the impact of geological hazard (Balis *et al*., 2013).

The use of Real-time monitoring technology has proved to be an invaluable tool for monitoring unstable slopes in South Korea. More than 70 % of the land profile comprises mountains and hills and this has increased the need for cut slopes in order to facilitate the national road infrastructure. A combination of extreme climatic conditions and heavy rainfall has created instability in many slopes throughout the region.

"Guerrilla Sensor", developed by GMG (Geotechnical Monitoring Group) Ltd. in South Korea is an early warning system based on real time monitoring with the mobile web is then proposed. Monitoring with Guerrilla sensor is an example of risk reduction with real time information.

Other than natural disasters, we can commonly find some facilities, slopes and walls that are under imminent threat

Received 2018. 06. 06, Revised 2018. 06. 12, Accepted 2018. 06. 28
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of collapse around us, but it costs a lot of money to retrofit them by removing completely the causes of instability, that is called 'structural countermeasure'. Even with some budget allocated for the refurbishment we can't fix them all at once, we need to decide how to prioritize based on a well-organized inventory included in the risk management system. Risk reduction by inventory management can be done by periodically updating the history information on all listed facilities during inspection of study. In case of limited budget, it is really hard for us to find or do something except on-foot site inspection. Non-structural countermeasures like 'monitoring using ICT' might be one of solutions for these circumstances. Once monitoring system is introduced, the maintenance and operation costs are incurred for as long as the system sits there. Guerrilla sensor based on IoT (Internet of Things), in this respect, would be very effective. Whenever and wherever the circumstances dictate it can be immediately installed and removed. It would be very much flexible and cost effective.

2. Related Work

A summary of disaster management projects using WSNs (Wireless Sensor Networks) can be found in Benkhelifa *et al*. (2014). There are numerous recent projects that use WSNs technologies to deal with emergency response and disaster management process by collecting data in disaster areas.

In Japan, a new sensor device has been developed for slope monitoring named as 'Miniature Ground Inclinometer (Uchimura *et al*., 2011). The device is a long stainless steel pipe with a small diameter; equipped with a MEMS (Micro Electro Mechanical Systems) tilt sensor, a geomagnetic sensor, and a control circuit. It detects the displacement in the slope by tilt sensors, with data correction based on the direction of the sensor units obtained by a geomagnetic sensor. But, some technical problems were found when the prototypes of the device were installed in the slope for depth 12m at the landslide area in Taziping, Sichuan Province, China. Instability in the sensor units due to a technical problem caused malfunction of the tilt sensors.

Therefore, an early warning sensor unit was proposed by the same authors that focused on only two parameters: the volumetric water content of soil and the inclination of the slope (Wang *et al*., 2013). The sensor unit is powered with batteries or solar cells and transfers the data via wireless network in real time. The data are transferred to a gateway unit which uses low power radio communication modules that are placed near the slope. The gateway unit collects the data from all the sensor units and sends them to a data server on the internet via a mobile phone network. The data are processed by the server, and any abnormal displacement of the slope can be detected. Thus, an evacuation warning can be issued for a precaution in case of failure. However, even the sensor unit can detect a quick movement during a heavy rainfall event, the image or visual data of the slope area is not available because there is no camera embedded in the sensor unit. This makes the visual monitoring of slope area limited even if there is a surveillance camera installed near the site.

Lee et al. (2010) proposed a novel multifunctional mobile wireless sensor that is encapsulated in waterproof packaging for monitoring debris flows. The proposed sensor system is assembled on the drainage line and will move along with the debris flow. It will collect the data and wirelessly transmit the collected data in real time to the base stations which are deployed along the sides of the drainage line. However, the sensor system only alerts the base station when debris flows occur for close monitoring. There is no way to tell nearby residents instantly what is happening.

The Malaysian company Rapid Matrix Sdn. Bhd. collaborated with University Kebangsaan Malaysia or the National University of Malaysia, to reduce the impact of disasters through an early warning system. The early warning system used Geo-WES (Geoseismic Wireless Extenso Sensor System) which is installed with the pipeline to detect landslides (UKM, 2011). The sensor system will alert the centers' control database if even one millimeter of movement on a slope. The centers will trigger SMS (Short Message Service) to registered users indicating the location and number of occurrences. However, since the system is based on the pipeline level, the image data of the surroundings is not available which makes the visual monitoring of landslide area impossible.

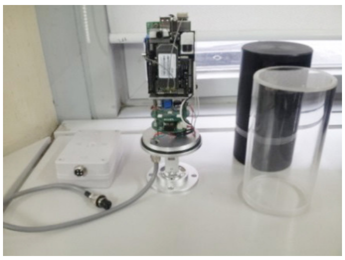
Yun *et al*. (2012) developed a photogrammetric UAV (Unmanned Aerial Vehicle) system application based on a smartphone as a payload for disaster area monitoring purpose. The real time image, location, and altitude data were obtained by smartphone in UAV photography system. Although smartphone function as a payload is very feasible for UAV system, only the images taken by the smartphone automatically loaded onto UAV. The system cannot record the surrounding image (video clip), which can limit the monitoring activity.

The Guerrilla sensor by GMG Ltd. can be used as an early warning system to reduce the impact of any type of disasters such as landslides or slope failure, earthquake damage, settlement detection, crack propagation in building and monitoring riverbank, as well as the civil constructed structure, like bridge culvert and dam. The sensor can send image and video in real time to the registered users through their smartphone. In addition, the smartphone's technology gives us unprecedented opportunities to improve existing processes of on-site monitoring management for the risk reduction.

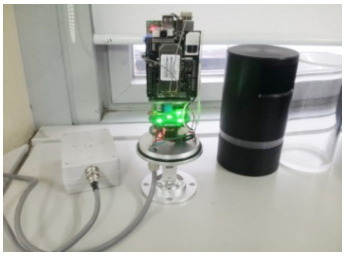
3. System Model

3.1 System design

The Guerrilla sensor (Fig. 1) by GMG Ltd. is equipped with IRIS camera i.e. small and compact camera, WCDMA (Wideband Code Division Multiple Access) module, and GPS (Global Positioning System) module. The sensor uses battery-operated power supply which can be immediately connected on the site. The microprocessor uses the Raspberry Pi which is connected to the 3G (3Generation) module. The camera is also connected to the 3G module to record the live visual image of the surrounding activities.



(a) Guerrilla sensor without casing and before connecting with battery



(b) Guerrilla sensor without casing and after connecting with battery

(c) Guerrilla sensor with casing and after connecting with battery

Fig. 1. Guerrilla sensor

Basically, the Guerrilla sensor with Zigbee (Fig. 2) is the same sensor as Guerrilla sensor without Zigbee (Fig. 1). The Guerrilla sensor with Zigbee is two Guerrilla sensors that are placed side by side in parallel position. The Guerrilla sensor with Zigbee is using Zigbee to communicate with each other (one-way communication), while Guerrilla sensor without Zigbee is using WCDMA for its transmission system.

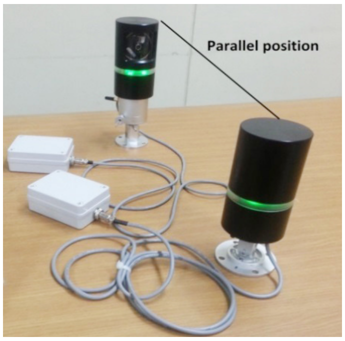


Fig. 2. Guerrilla sensor with Zigbee

The new 3G shield for Raspberry Pi as shown in Fig. 3 allows the connectivity to high speed WCDMA and cellular networks which contributed to the new IoT worldwide interactivity projects. Therefore, we use the features of the 3G and GPS module to send the data from the sensor to the GMG server as well as recording the video with the camera from the Raspberry itself. Table 1 summarizes more details about sensor hardware and specifications.

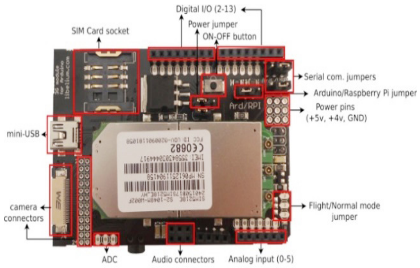


Fig. 3. Raspberry Pi

Table 1. Guerrilla sensor specifications

Function	Specification
Tension wire	Range: ±250 mm, Resolution: 0.5 mm
Inclinometer	Range: ± 30°, Resolution: 0.02°
Video camera	Image sensor: CCD Resolution: 320x240 (QVGA) View Angle: 100°
LED	5 LEDs (R,G,B)
Audio information	Buzzer (Beep Sound/Emergency only)
Location information	GPS integrated into 3D GIS
Transmission system	WCDMA, Zigbee
Power consumption	Standby mode: 12 V, 100 mA (1.2 W) Emergency: 12 V, 300 mA (3.6 W)

The sensor system (Fig. 4) is designed with sophisticated image processing facilities, so that activation of the camera occurs when preset threshold levels are exceeded. The system is able to pinpoint the exact location of abnormal movement and notify the registered users via SMS. The SMS contains a URL (Uniform Resource Locator) about LBS (Location-Based Services).

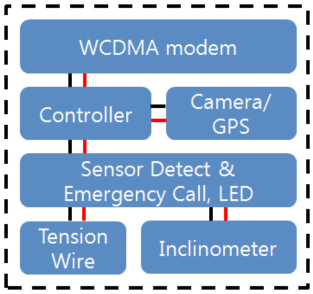


Fig. 4. Sensor system diagram

3.2 Proposed method

There are three conditions of the Guerrilla sensor operation which are:

1) The sensor detects the movement
2) No movement, but the server sends Request 1 to the sensor (video and data request)
3) No movement, but the server sends Request 2 to the sensor (data only request)

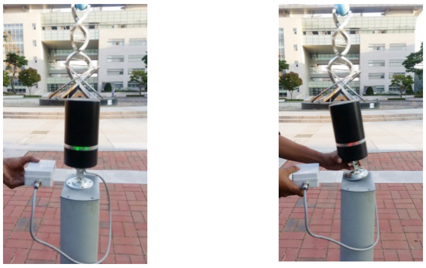
Condition 1: When the sensor detects the movement, it will directly send the signal to the camera to record the video in 15 second. Then, the video file will be sent in real time to the GMG server by using the File Transfer Protocol FTP (File Transfer Protocol) After recording and sending the video are finished, the sensor will immediately read the specific data of the sensor location and send it to the same server by using the Hypertext Transfer Protocol HTTP (Hypertext Transfer Protocol). The registered users will receive an alarm message via SMS in their smartphone that contains a URL about LBS.

Condition 2 & 3: If there is no movement detected, the registered users can request two types of command; Request 1 and Request 2. For Request 1, it will be the same with sensor detection action as in condition 1 While the request 2 is used for giving an instruction to the sensor in order to send only the data in the surrounding area. This type of request will be useful for routine checkup area.

4. Working Mechanism

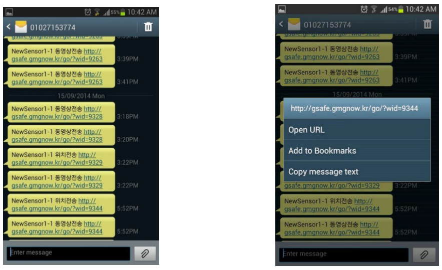
4.1 Guerrilla sensor

The working mechanism for condition 1 of Guerrilla sensor will be explained in this section. After connected with the battery, the green LED (Light Emitting Diode) light from the sensor indicates the normal state as shown in Fig. 5. But if there is any movement detected, for example, if we tilt the sensor, the LED light changes from green to red color. In other words, when the tilting degree exceeds the threshold value, it will trigger red LED light. Red LED light indicates danger state and the sensor will automatically capture the image of the surroundings. The registered users will be notified directly via SMS with a URL link to LBS as shown in Fig. 6.



(a) Green LED light indicates normal state (b) Alert by tilting will trigger red LED light

Fig. 5. Tilting Guerrilla sensor triggers alert



(a) User received SMS (b) User can click the URL which link to LBS

Fig. 6. Location notice URL via SMS in user's smartphone

After clicking the URL, the user will be directed to the GMG website where the sensor location is determined on the map by GPS as shown in Fig. 7. The location on the map by GPS is integrated into the 3D GIS (3-Dimensional Geographic Information System) which allows the system to pinpoint the location of abnormal movement.

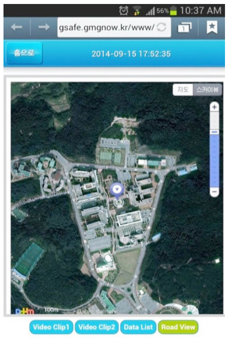


Fig. 7. Location on the map by GPS

In Fig. 7, the GMG website shows the three options of Video Clip1, Video Clip2, and Data List. The options of Video Clip1 and Video Clip2 will show 15 second video clip of surrounding area captured by the sensor as shown in Fig. 8. Users can monitor the disaster-prone area through this video clip to mitigate the disaster risk. IoT-based Guerrilla sensor would be very effective for non-expert residents in risk area since they can monitor and handle it by themselves based on real time monitoring with the mobile web.

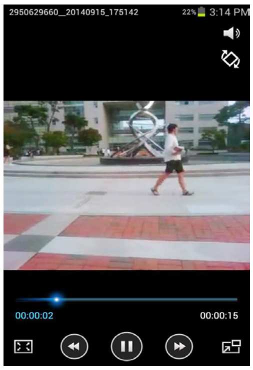


Fig. 8. Video clip (15 second)

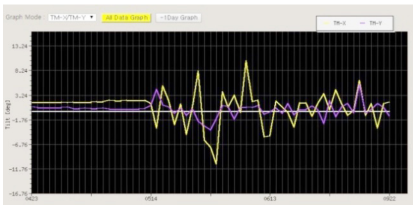


Fig. 9. Data information (Tilting)

One of the principal features of the system is its effective use of computer technology to provide measurements in real-time making full use of the internet for remote access to the data. More recently this has led to a novel approach to observing incipient slope failure using intelligent network cameras.

The Data List option (Fig. 9) will show the data information read by the sensor such as displacement, tilting, and soil moisture. Such information is very important, especially for the experts to analyze the surrounding conditions of risk area. In addition, the data management system is less complex since no data logger is needed for data retrieving.

4.2 Guerrilla sensor with zigbee

Basically, the working mechanism for Guerrilla sensor with Zigbee is the same as mentioned in the previous section. The Guerrilla sensor will communicate using Zigbee which enables the sensor to monitor the other sensor if tilting or any movement occurred.

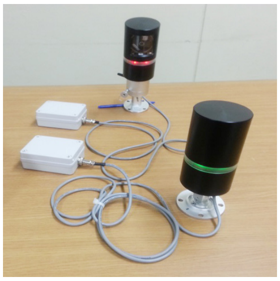


Fig. 10. Example of tilting Guerrilla sensor with Zigbee to trigger alert

From Fig. 10, when the tilting degree exceeds the threshold value, it will trigger red LED light and the sensor will automatically capture the image of the surroundings of other sensor. Fig. 11 shows 10 second video clips of surrounding area captured by the both sensors. Monitoring purpose will become more efficient since video clip from both sensors are available at our fingertips.

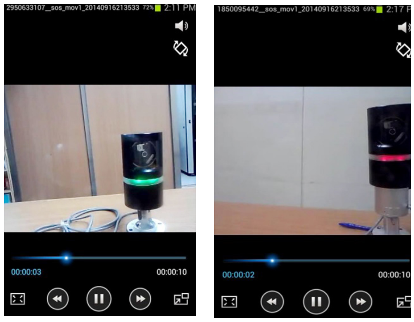


Fig. 11. Video clip (10 second)

5. Real Site Application

A series of field tests were conducted to examine the validity of Guerrilla sensor for real site application. The real site application for Guerrilla sensor will be explained in this section. The Guerrilla sensor has been installed on an unstable slope (Fig. 12) at Gimcheon, South Korea on 15 Sep. 2014. This slope moves gradually during every heavy rainfall event which causes an imminent threat of collapse.

Fig. 12. Slope at Gimcheon site

Fig. 13. Installation takes less than 30 minutes for one Guerrilla sensor

The sensor was installed at Gimcheon site in less than 30 minutes (Fig. 13). It is an easy and quick installation. The sensor was tilted to check its functionality on the site directly. When the tilting degree exceeds the threshold value, it will trigger red LED light and the sensor will automatically capture the image of the site surroundings. Then, the sensor will send SMS text alert via mobile phone for the URL location of Gimcheon site. Fig. 14 shows the URL for location on the map by GPS via SMS and Fig. 15 shows a video clip of the Gimcheon site surroundings area for about 15 second.

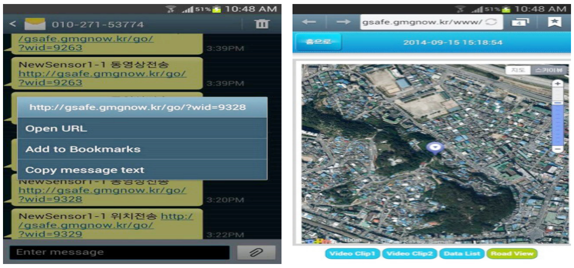


Fig. 14. Location notice URL via SMS and location on the map by GPS in user's smartphone

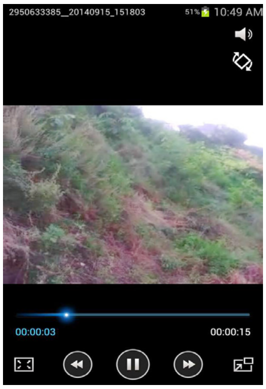


Fig. 15. Video clip (15 second) of surrounding area of Gimcheon site

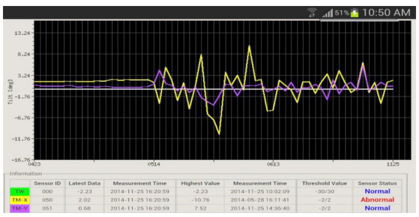


Fig. 16. Data information (Tilting) of Gimcheon site

The graph (Fig. 16) shows the abnormal displacement of the sensor at Gimcheon site. Fig. 16 summarizes the tilting data information of the Guerrilla sensor. The data is stored in the GMG server on the internet, thus the data can be browsed anywhere and anytime through the mobile website by just clicking the URL in the SMS.

Monitoring with real time information using Guerrilla sensor would be very effective for risk reduction because there may be enough time to alert the nearby residents before the slope failure happened. Issuing timely information for residents to avoid slope disaster is beneficial to avoid greater disaster.

6. Conclusion

In this paper, an early warning system based on mobile web and Guerrilla sensor is proposed. The execution of early warning system based on real time monitoring combined with advanced ICT is a powerful solution to mitigate the disaster risk. Monitoring using IoT-based Guerrilla sensor would be very effective for risk reduction with real time information.

The successful application of the real-time monitoring system provides a unique opportunity to utilize new technology in situations requiring innovative techniques to solve critical safety issues in susceptible slopes. Where circumstances dictate, the proposed system can also offer cost effective solutions to the real-time monitoring of geotechnical structures.

One of the principal features of the system is its re-use based on mobility, which might be rather simple for the whole process involving in 'Installation', 'Removal', 'Reinstallation'.

The Korean Peninsula, due to monsoon climate, has four distinctive seasons. Heavy rains tend to concentrate on several summer months, which never rains but pours once started. Unlike the conventional system, that is once introduced the maintenance and operation costs are incurred for as long as the system sits there, the Guerrilla sensor would be very much flexible and cost effective if we choose 'a Period of Concentration' such as the rainy season of monsoon period.

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Acknowledgment

First Author of this study appreciates funding provided from Kumoh National Institute of Technology

References

Balis, B., Bartynski, T., Bubak, M., Dyk, G., Gubala, T., and Kasztelnik, M. (2013), A Development and execution environment for early warning systems of Kunnath, A.T., and Ramesh, M.V., Integrating or Natural Disasters, *13th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid)*, pp. 575-582.

Benkhelifa, I, Nouali-Taboudjemat, N., and Moussaoui, S. (2014), Disaster management projects using wireless sensor networks: An overview, *28th International Conference on Advanced Information Networking and Applications Workshops (WAINA)*, pp. 605-610.

Kunnath, A.T. and Ramesh, M.V. (2010), Integrating geophone network to real-time wireless sensor network system for landslide detection, *First International Conference on Sensor Device Technologies and Applications (SENSORDEVICES)*, pp. 167-171.

Lee, Huang-Chen, Banerjee, A., Fang, Yao-Min, Lee, Bing-Jean., and King, Chung-Ta (2010), Design of a multifunctional wireless sensor for in-situ monitoring of debris flows, *IEEE Transactions on Instrumentation and Measurement*, Vol. 59, No. 11, pp. 2958-2967.

Schmitz, G.T., Rutzen, W., and Jokat, W. (2007), Cable-based geophysical measurement and monitoring systems, new possibilities for tsunami early-warnings, *Symposium on Underwater Technology and Workshop on Scientific Use of Submarine Cables and Related Technologies*, pp. 301-304.

Uchimura, T., Towhata, I., Wang, L., and Qiao, J.-P. (2011), Miniature ground inclinometer for slope monitoring, *Proceedings of the 14th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering* (ATC3 Session), Vol. 1. pp. 2047-2052.

UKM's Early Warning System for Landslides in the Pipeline (2011). Available at: http://www.ukm.my/news/index.php/en/research-news/714-ukms-early-warning-system-for-landslides-in-the-pipeline.html (last date accessed: 2 March 2015).

Wang, L., Nishie, S., Seko, L., and Uchimura, T. (2013), Study on field detection and monitoring of slope instability by measuring tilting motion on the slope surface, *Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering*, pp. 2277-2280.

Yun, M., Kim, J., Seo, D., Lee, J., and Choi C. (2012), Application Possibility of Smartphone as Payload for Photogrammetric UAV System, *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. 39 (Part B4), pp. 349-352, http://www.cooking-hacks.com/documentation/tutorials/raspberry-pi-3g-gprs-gsm-gps (last date accessed: 5 Feb. 2015).