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ORIGINAL ARTICLE

Design and Field Test of Automatic Data Logger System for Portable Magnetometer using Raspberry Pi

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Abstract

A monitoring system for a field magnetometer was configured with assistance of a Raspberry Pi as a data logger. The suggested geomagnetic system uses a semi-real-time data transmission module. The system consists of two parts: a field-observation part and a data-center part. The field-observation part comprises a Raspberry Pi, magnetometer, LTE router, and power source, while the data center part takes samples at the site. The collected magnetometer data are then sent to the data center through the LTE router. The newly designed monitoring system was deployed and checked in Jeju-do island, and found to operate stably. The suggested system is promising in that it is simple and cost saving, providing at least physical insight and knowledge on the complex natural phenomena.

Key words : Raspberry Pi, Magnetometer, Data logger

1. Introduction

The Earth's geomagnetic field is an ever-changing phenomenon that influences human activity and the natural world in a myriad of ways. The geomagnetic field changes from place to place, and on time scales ranging from seconds to decades to eons. These changes can affect health and safety, and economic well-being. The geomagnetic field can disrupt electric power utilities and pipeline operations, and it can influence modern communications systems, spacecraft, and more (http://www.geomag.nrcan.gc.ca; https://www.ngdc.noaa.gov/geomag). Hence the geomagnetic monitoring is used for detecting changes of the earth's environment, i.e. ionosphere (Campbell, 2001, 2015; Thomson, 2014; Lastovicka, 2002), inside the Earth (Merrill et al., 1998; Merrill, 2010; Moroz et al., 2011), and observation of magnetic disturbances related to earthquakes (Fraser -Smith et al., 1990; Moskovskaya, 2012; Hayakawa et al., 2007).

Several equipments were developed for geomagnetic observation at the site, and tested at the fixed positions. There is no exception in Korea. The geomagnetic monitoring stations in South Korea include those operated by the Korea metrological administration (KMA), Korean space weather center (KSWC) of the National Radio Research Agency, and Korean institute of geoscience and mineral resources

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(KIGAM). KMA operates Cheong -yang observatory; KSWC operates observatories in Icheon, Gangneung, and Jeju; and KIGAM operates geomagnetic observatories in Hongseong, Daejeon, and Gyeongju. Each of these observatories monitors the total magnetic field and three geomagnetic components (north, east, and vertical directions).

Recent studies have been actively performed in an attempt to replace expensive conventional systems by a relatively simple Raspberry Pi. These Raspberry -Pi-based systems have several advantages; they are low-cost, compact, scalable, easy to customize, easy to deploy, and easy to maintain (Fedoush and Li, 2014). The Raspberry Pi is the size of a credit card and can be used as a micro -computer, having several components built in, including a single motherboard, 512 MB of SDRAM, a 700-MHz low-power processor, an HDMI, a USB port, an SD card slot, and a GPIO (general purpose io) port. It can use Linux-based Raspbian and Arch Linux as an operating system (Raspberry PI Fundation, 2014). Extensions using GPIO can be also used for education on basic programming as well as electronic circuits. Furthermore, in addition to being a low-power device, the Raspberry Pi provides a research environment of a level equivalent to that allowed by conventional computers in the remote-monitoring field, owing to its Linux operating system, USB port, GPIO port, etc. Dudas et al.(2014) developed a low-cost telecytology system using a Raspberry Pi with a webcam. They showed the development was probable at a cost under $100, which is 120 times lower than that of commercial products. Ferdoush and Li(2014) designed a wireless-sensor network system for environmental monitoring on the basis of a Raspberry Pi, XBee, Arduino, and RHT03, including temperature and humidity sensor.

Nevertheless there was no attempt to use a Raspberry Pi for the geomagnetic monitoring in the field in Korea. Many challenging and keenly enthusiastic young researchers in Korea have obstacles in financial issues. Therefore we propose herein a geomagnetic monitoring system that is relatively inexpensive, easy to move, and installable in a remote place. The proposed system includes a field magnetometer, a microcomputer for storing and sending data, a wireless internet dongle for providing a wireless internet environment, and a data server for storing data.

2. Automatic Magnetic Observation System

2.1. Overview of system

An automatic magnetic observation system (hereafter called AMOS) was designed, which consists of a field-observation part and a data-center part (Fig. 1). The field-observation part comprises a magnetometer that observes the magnetic field in real time; an automatic data-logger system (hereafter called logger system) that receives, manages, and sends magnetic data in real time; and a power source that supplies power to the magnetometer and logger system. The data-center part comprises an FTP (file transfer protocol) server that stores and manages the magnetic data sent from the field -observation part.

In the field-observation part, a Scintrex ENVI -MAG magnetometer was used. This is an outdoor magnetometer that can observe the total magnetic field with an observation precision of 0.1 nT and minimum observation interval of 0.5 s. The Scintrex ENVI-MAG magnetometer is a portable device that measures the magnetism of the Earth and streams observed data to a computer connected to a RS232 serial port. The logger system comprises an LG U+ LTE (long-term evolution) router (LG U+, Seoul, Korea) and a Raspberry Pi Model B (Element 14, Leeds, UK). The logger collects the received real-time magnetic data in a wireless -internet hotspot environment. Then the logger

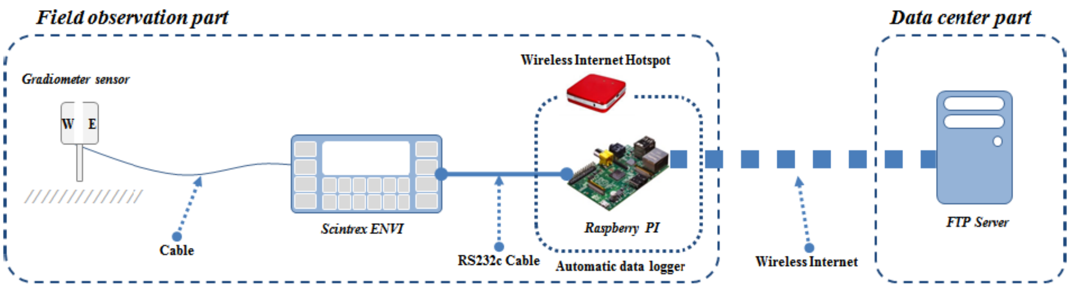


Fig. 1. Overview of AMOS (automatic magnetic observation system).

automatically sends them to a server. The data -center part provides an FTP server environment and receives the data being sent from the field -observation part.

2.2. Hardware of automatic logger system

The logger system comprises an LG U+ LTE router and a Raspberry Pi Model B. The LG U+ LTE router is a device that creates a wireless -internet hotspot by using the LTE network of LG U+, a telecommunication company in South Korea. This provides a wireless-internet environment similar to wireless AP (access point), in which wired -internet installation is difficult, and allows wireless devices such as laptops, cellular phones, and tablets to access the internet environment. The Raspberry Pi Model B get download the observed data streamed from the magnetometer in real time, stores them, and sends them to the FTP server. The FTP Server is used to store the magnetic data files sent from the Raspberry Pi.

In the operation of the logger, when the magnetic data observed in real time within a 1-s unit at a magnetometer installed in the field are streamed with an RS232c cable, the Raspberry Pi receives the data and stores them in an internal storage. Next, according to a schedule set by the user, the stored file is sent to an FTP server of the data center.

The RS232c serial connection between the Scintrex ENVI magnetometer and Raspberry Pi was configured to enable serial communication by connecting a Serial Pi (AB Electronics, Dorset, UK) to the GPIO port of the Raspberry Pi. For the wireless-internet-environment access of the Raspberry Pi, a USB-type nano-size wireless LAN card was used (Fig. 2).

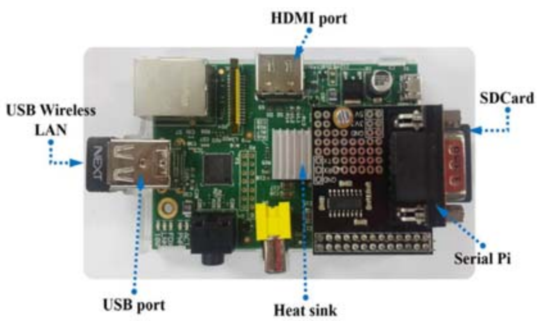


Fig. 2. Overview of Raspberry Pi-based automatic data logger system.

2.3. Software of automatic logger system

The software part of the automatic logger system was developed using Python and comprises the following modules: maglogger, maguploader_10, and maguploader_daily. The maglogservice was configured to be automatically executed by the init processor after Linux was booted. Because the Raspberry Pi does not have a separate power switch, it is automatically booted when power is

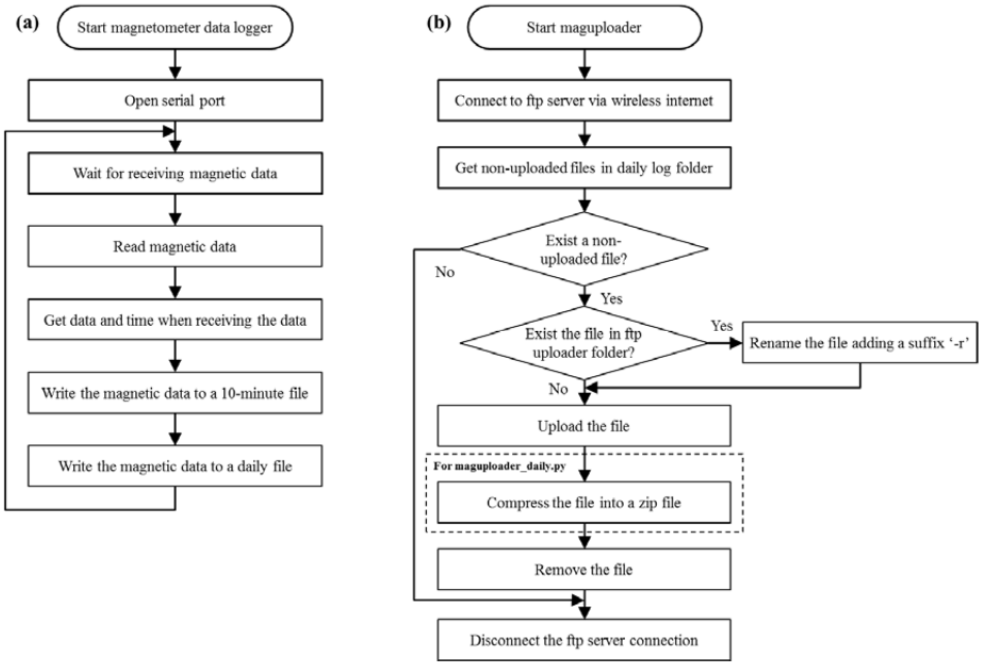


Fig. 3. Flow diagram of (a) maglogger and (b) maguploader modules.

supplied. Accordingly, the maglogservice was set to be called by the init processor so that problems such as power interruption could be resolved. The maglogger module automatically generates files in 10-min units and 1-day units for data received from the magnetometer by using the date and time and stores them in the internal disk. The maguploader module (maguploader_10 and maguploader_daily) is set to be called by crontab, which is a Linux scheduler, every 10 min and every day. The maguploader_10 module (Fig. 3a) is called every 10 min and transmits the magnetometer data saved every 10 min to the FTP server. The transmission process is as follows: (1) the module finds currently unsent files in the stored data; (2) accesses the FTP server and moves to the upload folder; (3) uploads the files found to the FTP server and deletes the files that have been completely uploaded; and (4) repeatedly executes step 3 until the files found are all uploaded.

The maguploader_daily module (Fig. 3b), which is called once every day, has the same operation principle as maguploader_10. Unlike maguploader_10, maguploader_daily has a large data size and does not require backup. Therefore, a compression process and backup process are included for the case of data file loss during the upload process of the FTP server or after uploading. The transmission process is as follows: the module (1) finds unsent files from up to one day before the current day in the stored data; (2) accesses the FTP server and moves to the upload folder; (3) uploads the files found to the FTP server; (4) compresses the completely uploaded files into zip files and deletes the original files; and (5) repeats steps 3 and 4 until all the files found are uploaded.

If the internet access is disconnected during the file -upload process, these two modules are implemented

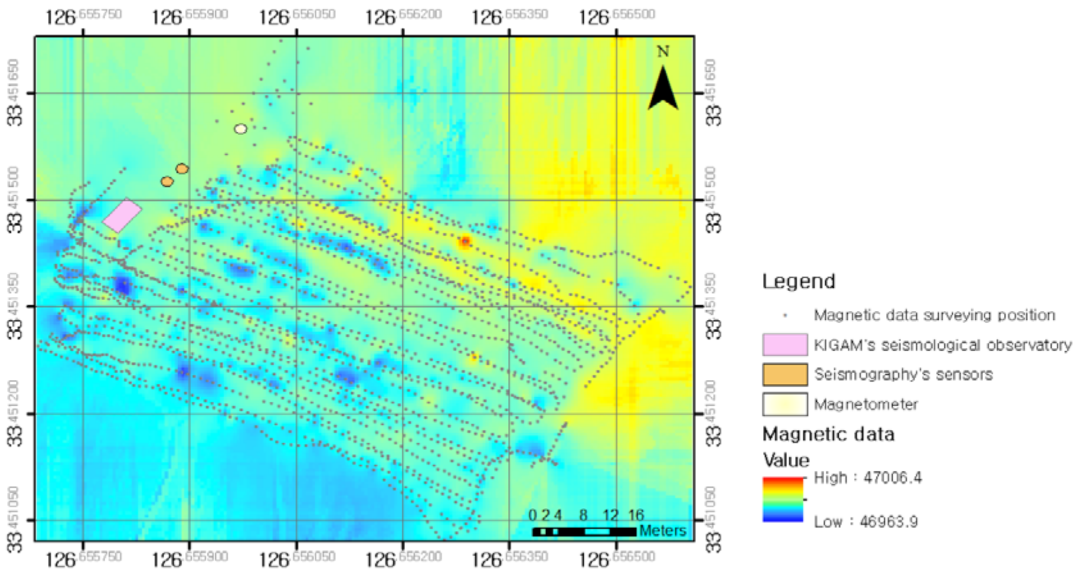


Fig. 4. Magnetic survey result of AMOS installation area.

to transmit the files at the next calling.

3. Field Experiment and Results

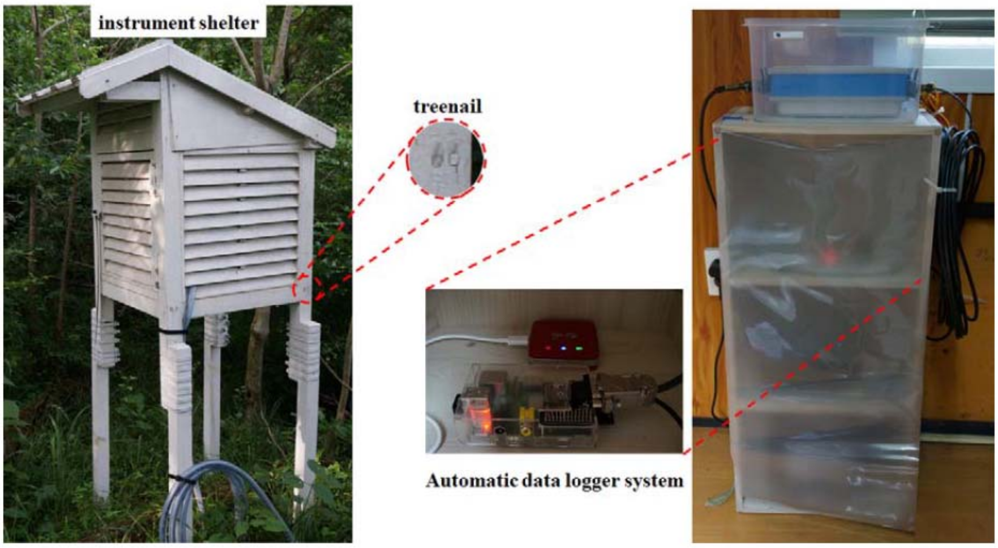
For the experiment, the following environment must be considered regarding the installed magneto -meter: (1) there must be no magnetic disturbance caused by surrounding man-made features; (2) there must be no drastic magnetic field change; and (3) stable power supply must be secured.

The Jeju Stone Park in Jeju-do island was selected as a test bed. Because there seems to be no factors that produce a magnetic disturbance, and the magnetic changes not large. Moreover, stable power could be supplied, as a seismological observatory operated by KIGAM (Korea institute of geoscience and mineral resources) was located nearby.

To examine the suitability of the Jeju Stone Park as an installation location, one Scintrex ENVI-MAG magnetometer unit was installed as a base station and another was moved around while the magnetic field was examined. The measured magnetic field variation was within a 42.5-nT range, from 46,963.9 to 47,006.4 nT (Fig. 4). Therefore it is concluded that the park provides a stable environment. Accordingly the AMOS was installed in the Jeju Stone Park to conduct a field experiment.

A magnetometer sensor was fixed and installed inside a meteorological instrument shelter, and the main body of the magnetometer and automatic logger system were installed inside the KIGAM's seismological observatory as shown in Fig. 5. Before installing the magnetometer sensor, all of steel nails that could produce a magnetic disturbance were removed from the shelter and replaced with wooden ones.

All the data sent from the developed AMOS are saved in file units in daily and minutes folders of the FTP server at the data center. Files in the daily and minutes folders are saved as yyyyMMdd.txt and yyyyMMddhhmm.txt, respectively. The daily and 10-min data comprise the date (yyyyMMdd), time (hhmmss), magnetic data, and standard errors



(a) (b)

Fig. 5. (a) Instrument shelter and (b) Automatic data logger system.

(Fig. 6).

The geomagnetic data observed by the AMOS during the period of September 1 to 30, 2014 were compared with the data observed at Cheongyang observatory of KMA. Data gathered by Cheongyang observatory can be freely downloaded from the Intermagnet homepage (http://www.intermagnet.org/). To compare the two sets of data, first, the noises in the AMOS data were removed using a wavelet filter (Fig. 7 top). Next, the wavelet-filtered AMOS data and Cheongyang observatory's data were compared (Fig. 7 bottom). In the Fig. 7 bottom, the

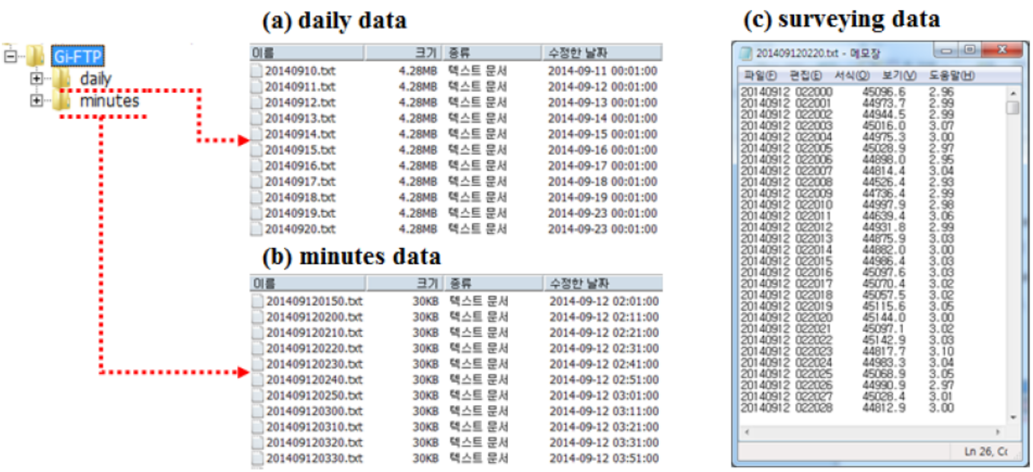


Fig. 6. Magnetic data stored on the FTP server at the data center.

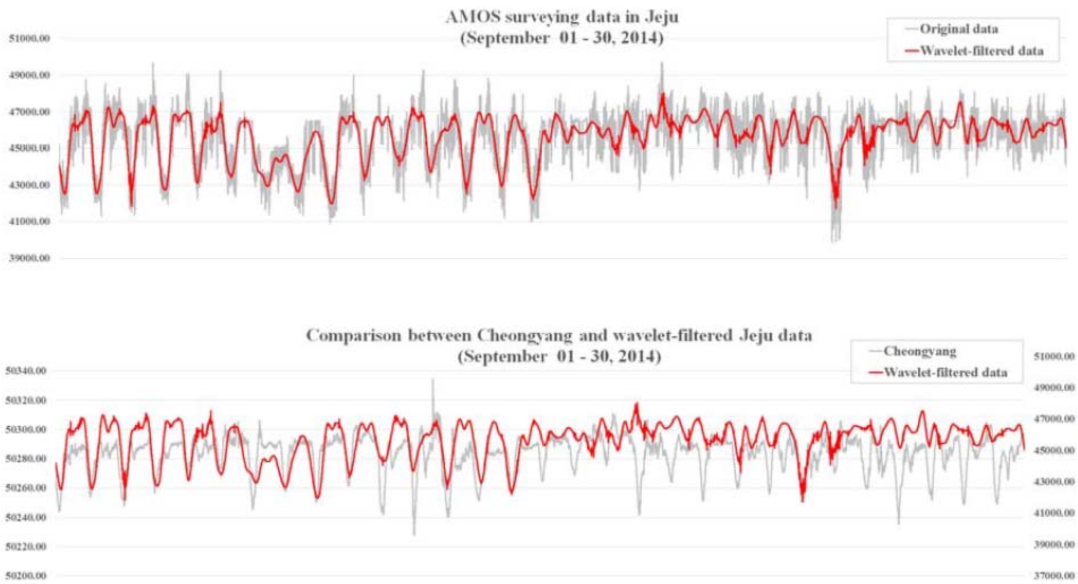


Fig. 7. Comparative plot of Jeju AMOS data and Cheongyang intermag observatory data (top). Wavelet-filtered Jeju data (bottom). All are September 01～30, 2014 data.

gray dots represent the data measured at Cheongyang observatory, and the red dots represent the wavelet -filtered AMOS data. The data observed at Cheongyang observatory exhibited a geomagnetic variation range of ~110 nT. In contrast, the data observed at the AMOS exhibited a value of ~10,000 nT, and after the wavelet filter was applied, the value decreased t o 6,400 nT. It appears that the noises are large in the AMOS data, owing to the characteristics of the magnetometer model used. Nevertheless, although the noises were large, the trend in the daily change was similar to that observed at Cheongyang observatory. The noises of the magnetometer occurred regardless of whether the logger system was connected to the magneto -meter. Hence, the noises shown in the AMOS data were not caused by the logger system.

4. Conclusions and Discussion

A newly developed monitoring system for a field magnetometer was configured with assistance of a Raspberry Pi as a data logger and deployed and checked in Jeju-do island. The system shows acceptable operation and it is concluded that a remote data-acquisition system can be set up conveniently by connecting the automatic logger system developed in this study to a portable magnetometer or another geophysical monitoring device. The proposed system is promising in that the field test provides reasonable behavior of its member as a whole. Besides the system is simple and cost saving. The geomagnetic monitoring enables the preparation of simple graph or tables for practical use by those responsible for earth environ -ment surveillance. It is noted that one method could not cover all the collection of the geomagnetic information in an optimal way and a multitier approach may be a better strategy. The suggested system is expected to provide a base toward physical insight and knowledge on the complex natural phenomena.

Acknowledgements

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