GEOMAGNECTIC MONITORING SYSTEM*

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СИСТЕМА ЗА АНАЛИЗ И ОБРАБОТКА НА ГЕОМАГНИТНИ ДАННИ*

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Резюме. *Множество изследвания в областта на земетресенията, проведени в последните години в райони с изразена сеизмична активност, са доказали, че промяната на геомагнитна активност е един от най-добрите показатели за предвиждане на земетресения в реално време. В тази статия е представена софтуерна архитектура на система за измерване и анализ на геомагнитна активност на райони с изразена сеизмична активност. Главната цел на този проект е измерване на различни геофизични фактори в тези райони, включително и геомагнитна активност. Системата е разделена в два отделни взаимно независими компонента − измервателни станции за следене на геомагнитна активност и предаване на получените данни до Централизиран сървър. Централизираният сървър от своя страна приема данни от всички регистрирани устройства и от външни източници, като NOAA / Space Weather Prediction Center (даващи информация за магнитни бури, които влияят на данните от GMS станциите) и USGS (United States Geological Survey, даващи информация в реално време за сеизмична активност из цял свят). Получената от всички източници информация се съхранява в база данни, от където става обект на обработка от множество алгоритми и методики за анализ, като интензитет на полетата, гъстота на магнитното поле, магнитен потенциал, изместване/изкривяване на полето и много други. Обработената, както и суровата информация, биват представени под формата на графики, достъпни през уеб базирана система.*

Ключови думи: *геомагнитна активност, сеизмична активност, магнитно поле, информационна система, софтуерна архитектура*

1. Introduction

In the recent years geomagnetic activity takes place in many earthquake research projects. The main goal of these projects has been to explore the relationship between geomagnetic changes and earthquake occurrences. The geomagnetic activity has been considered as a promising candidate for short-term prediction of large earthquakes and these seismo-geomagnetic effects are expected to be useful for earthquake prediction. A lot of

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researches have been stimulated by big earthquakes all over the world, mostly in Japan. Since the variation of the geomagnetic activity is changing frequently, real-time monitoring of the earth, and more specifically exact seismic regions, provides the best input for a real-time prediction.

The monitoring of geomagnetic activity include observation of magnetic, electric and electromagnetic field variations, related to seismic events on regions in Japan, China, Russia, California and other locations.

1. The local magnetic field changes related to large earthquakes have been actively observed in regions subject to earthquake activity (Breiner and Kovach, 1967; Rikitake, 1979, Honkura and Taira, 1982; Johnston, 1989). More specifically magnetic field changes have been observed on several earthquakes with magnitude bigger than 5 - North Palm Spring Earthquake - 8 July 1986, M=5.9; Loma Prieta earthquake, 18 October 1989, M=7.1; Tohoku Earthquake (Japan), March 2011, M=9.03;

2. The electric field variations of earth that occur before earthquake and more specifically seismic electric signals can be observed 6 - 115 hours before the earthquake and they have duration of 1 min to 1 hour an 30 min and their duration do not depend on earthquake magnitude. The seismic electric signals usually appear without any important changes in the magnetic field. Researches on the SES changes have been conducted in Greece:

1) SES recorded on August 11, 1985 on the short EW IOA dipole (L = 47.5 m). The corresponding earthquake (M, = 5.1) occurred on August 13, 1985;

2) SES detected by the EW dipole (L = 300 m) of NAF on July 17, 1988. The corresponding earthquake occurred on July 23 with M, = 4.4, 200 km southwest of Athens.

An increase of the lower atmosphere conductivity as well as the electromotive force generation, results in a redistribution of the atmosphere electric field. The growth of this field is due to negative charge on the Earth's surface with positive charge on the ionosphere lower boundary.

3. In many researches the electromagnetic variation in the Ultra-Low Frequency (ULF) anomalies are associated with the large earthquakes. The ULF has been established as a promising toll for earthquake electromagnetic studies as such emissions come from the crust of the source regions. In the early 90s the possibility which the ULF emissions could be associated with large earthquakes has become visible. ULF emissions which could be associated with earthquakes with Magnitude more than 6 have been discovered. The first recording of the UMF emissions which are earthquake related has been made by the research project Kopytenko 1990. They reported anomalous in the ULF emissions for the Spitak Earthquake 1988 with Magnitude 6.9. The second research has been conducted by the research projects Fraser-Smith 1990, Bernardy 1991 is associated with Spitak Earthquake Magnitude 6.9.

Evidences for accumulating the ULF magnetic signatures before large earthquakes has been proved in the following researches: Molchanov et al.(1992), Hayakawa et al. (1996a), Kawate et al. (1998), Hayakawa et al. (2000), Uyeda et al. (2002), Gotoh et al. (2002), Hattori et al. (2002). Short tear predictions using the electromagnetic activity has been accomplished in projects as Hayakawa 1999, Hayakawa and Molchanov 2002.

2. Purpose of the Framework

It is important to predict the earthquakes with the magnitude bigger than 6 in a highly populated regions, especially in the big mega polices as Tokyo, Chile where they can cause significant damages and loss of lives.

The main purpose of this framework is a seismic monitoring of locations within urban regions that are especially vulnerable to damaging earthquake ground motions. Two methods has been established for observation earthquakes: the first one is direct observation of the geomagnetic changes and the second is detecting the seismic effects which have been taken place in a form of spreading anomaly of pre-existing transmitter signals. For this research one monitoring station should be located in a seismic quiet area as a reference, while the others should be located in areas of high seismic or crustal activity observing earthquake effects.

3. Architecture of the Framework

The presented framework is compounded by two logical components:

- Ground based GMS station for monitoring the geomagnetic activity, collecting the received data and sending it to the centralized server;
- Centralized GMS server, used for analyzing the received geomagnetic data and presenting the received results using charts and diagrams.

3.1. Hardware components of the Framework

Geomagnetic disturbances are monitored by ground-based measurement stations. The Power system of these stations includes PV energy storage system with Lithium-Ion batteries. The main functionality of the measuring stations is to record data received by two magneto sensors and the received data periodically is sent to centralized server for corresponding analyses.

The installed network of magnetometers with high sampling rate should cover areas within a distance of about 70-80 km.

The components for each of the stations are:

- Two (Anisotropic Magneto resistive) sensors – AMR Magnetometer Hi-resolution and short detection range; AMR Magnetometer Low-resolution and wide detection range;
- Hall Effect sensor, its main purpose is to trace the changes of the magnetic field, depending on the distance of the epicenter;
- SQUID (Superconducting Quantum Interference Device) sensor, its resolution can reach to 5aT (AttoTesla).

Each magnetometer serves as a three-axis magnetic field monitor. It includes three panel meters, one for each of the three axes representing the magnetic field sensitivity orientation: X-Axis (mT), Y-Axis (mT), Z-Axis (mT).

The geomagnetic data collected by the sensors is saved on local SD card. On predefined period of time, using GSM module, the collected data is sent to the centralized GMS server by the GPRS mobile phone network. This main purpose is to be achieved optimal energy consummation. Together with the collected data it is sent additional information about the current status of the measuring station - this includes current status of the power system, current state of the hardware device and the coordinates of the collected geomagnetic data.

3.2. Software components of the Framework

Once the collected data is sent to the centralized server, the user is able to access it with the developed framework of the information system, which relay on rights of managing mechanism. Software components of this system are: **Presentation layer, Data layer, Administration panel.**

- **Administration panel**

Since the developed framework is based on the right management mechanism, restrictions to the user access are applied. These restrictions are based on the previously assigned rights related to the system structure and associated with the users of the system. The current implementation of the Administration panel of the information system includes authentication management instruments that support users, roles, user groups etc. In the Administration panel it is possible: to define the administrators' accounts; to create or update roles; to associate different level permissions for each of the defined roles, to create or update the information content of the system.

Also using the Administration panel of the centralized server, the user is able to manage the devices of the ground-based measuring stations: to install new device or to remove existing one. With the Administration panel the user is able to observe the current state for each of the devices: current amount of the electric charge, received errors, etc. The protocol used for connection to the Administration panel is HTTPS.

- **Data layer**

The centralized server is receiving 'raw' data sent by the measuring stations. There it becomes object of the data analyses, based on different algorithms:

1) calculations related to average behaviour of the magnetic field (nT) and its variance (nT);
2) calculation of the electric field intensity.

The received information represents the magnetic field density for the three-axis: X-Axis (mT), Y-Axis (mT), Z-Axis (mT) for each second.

The magnetic field density for each axes can be represented as function $-f(x)$, (y), $h(z)$. These functions are represented as three graphs with a few of its tangent lines. We are searching for the slopes of the tangent lines we encountered on each of the graphs, or more specifically to find the derivatives of these functions.

$$f'(x) \neq 0,\ g'(y) \neq 0,\ h'(z) \neq 0. \tag{1}$$

Using the derivative of these functions we are able to follow the changes of the magnetic field density on particular period of time. The tangent lines are pointing towards increasing magnetic field density when their slope is positive, and correspondingly the tangent lines are pointing towards decreasing magnetic field density when their slope is negative. Following the points of the function where the slope of their tangent is zero, the function has local maximum or local minimum. That point is turning place for the function describing the magnetic field density.

The analyzed data can be reached with web services. With this format users who want to extract the received results for their own researches can access them easily.

The centralized database also receives earthquake and solar storm information from additional data providers. This includes information of the following sources:

- NOAA / Space Weather Prediction Centre – gives information about the magnetic storms, which might have influence over the received data and the GSM module;
- USGS (United States Geological Survey) – gives real –time information about the seismic activity.

This data sources give information about the earthquake activity all over the World. A script is executed on a predefined period of time (5 minutes). This script is also part of the GMS server. It takes information about the earthquake activity for the area on which our measuring station is positioned. For each of the earthquake activity which has occurred in that area, it collects data related to its magnitude and depth, and on later stage it is compared with the results received by the station.

- **Presentation layer**

The presentation layer has an abstract layer for data access. This approach assures the systems will be able to use different data sources. It isolates the data source from the business logic of the framework.

The main purpose of this layer is to be possible for the user to access the received 'raw' data and also to be able to access that data after different data analyses. These results can be accessed by the web interface of the system. The user is able to observe the changes of the magnetic field density on particular period of time with the implemented charts and diagrams. With the presentation layer it is also possible to follow the current battery status for each of the devices part of the GMS station.

4. Conclusion

The study of the geomagnetic activity has important role in the earthquake hazard researches. The presented geomagnetic monitoring station should be used for researches in understanding the physics of earthquake-related phenomena as comparing and analyzing the received results. With the software components of the system the user is able to access the received results of the geomagnetic activity and to use them for research projects that take into account the interaction among observation, methodology, and physical model.

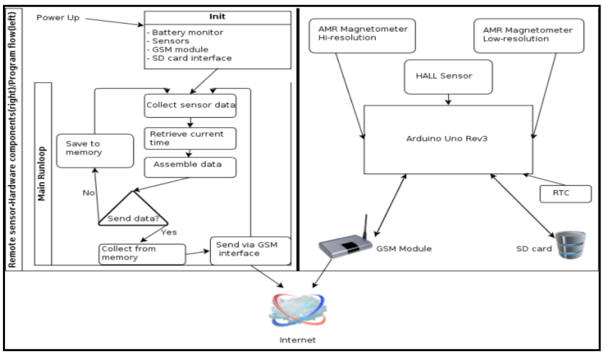

Figure 1. Hardware components of the Framework

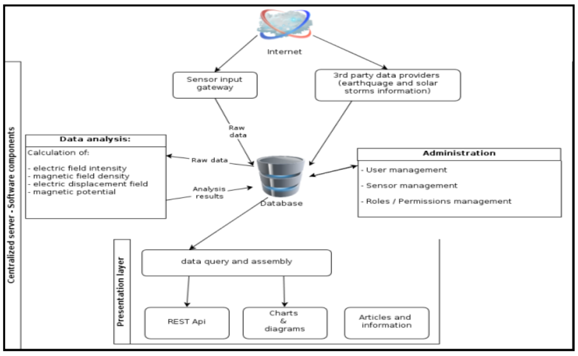

Figure 2. Software components of the Framework

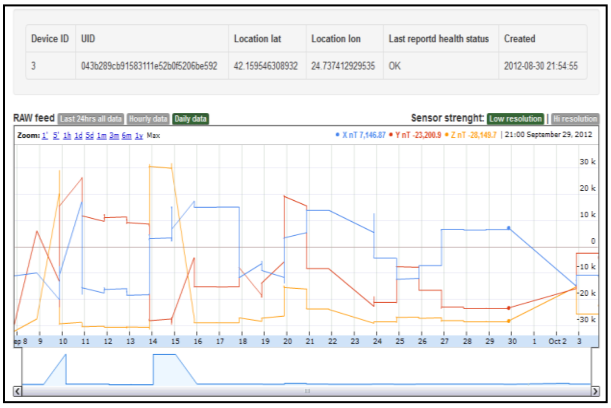

Figure 3. Chart of the data received by the two magnetometers with High and Low resolutions. The received information represents the magnetic field density for the three-axis: X-Axis (mT), Y-Axis (mT), Z-Axis (mT) for each second.

Figure 4. Location of the magnetometers and their coordinates are represented.

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