MAGNITUDE THRESHOLD REDUCING FOR A NETWORK OF CLOSE LOCATED MOBILE STATIONS

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Abstract. It is known that earthquakes of smaller magnitude occur more often. If the magnitude is decreased by 1 unit, the number of earthquakes grows about eight times. Reducing an amplitude threshold of the of registered kinematic components of Earth movements, first, is equivalent to decrease in the density of a network of observation and, secondly, allows to study of oscillations of small amplitudes, to determine their nature and common relations with other seismic and geophysical phenomena, interrelations.

Each seismic sensor is characterized by the radius of events detection of a certain magnitude. Stations of the mobile group have to be in close proximity so that the radii of event detection minimum magnitude intersect. If records of adjacent stations contain appropriate signal (amplitude, spectrum and arrival time), the seismic event is detected. However, the signal can be invisible at a high noise level. In addition, bursts of the noise may take place on neighboring stations simultaneously. We are feeling around for an answer to our difficulty by using an artificial neural network as a signal detector. What is more the artificial neural network will allow classifying seismic events by source type (earthquakes, landslides, nuclear or chemical explosions, collapsing caverns, etc.).

INTRODUCTION
Group of mobile seismic stations (GMSS) are a powerful tool for seismological research. They are essential when you are using non-standard methods of mineral exploration, to search for hydrocarbons, to seismic monitoring, as well as to earthquake prediction and solving engineering-geological problems. Mobile stations provide an opportunity to explore the regions of weak seismicity which usually don't have high density seismic networks. The lowest detection threshold of seismic networks is desirable when monitoring the natural seismic activity aimed to imaging the fault structures in 3D and to understanding the ongoing processes in the crust. Lowering the GMSS threshold allows to investigate in short terms the correspondence between microearthquakes and geological structures, to keep watch advancement of natural (slope phenomena, karst, and so on) and technogenic (frac propagation, deformation pit and so on) geomechanical processes. Similarly, it becomes of increased importance for monitoring induced seismicity due to underground operations. Achieving the maximum possible sensitivity of industrial seismic monitoring is a precondition for successful control of technological procedures. The monitoring system should be able to record the seismic events with M < -1 for grade control of acreage.

Sharing of network data can improve the detectability of seismic events in noise. However, the low-noise immunity of the mobile stations and the diversity of noise necessitate continuous updating and enhancement of the digital processing, allowing to work with seismic signals that are visually unapparent [1].

Operating conditions of stand-alone mobile station can be very adverse: on unprepared sites in the field, in the engineering constructions, in inaccessible places. Installing the sensor registration can be made by unskilled staff. To obtain high signal to noise ratio of data, significant effort is required to achieve noise attenuation in seismic data processing, which is costly in materials, and human and financial resources [2].

To increase the sensitivity of seismic observation it is possible make a network dense well and to optimize the station configuration. [3, 4] It requires an increase in the amount of sensors. Another method is resolution of the individual stations and the network as a whole - the selection of weak signals in noise.

GMSS has some similarity to the small aperture seismic array, which is also used to study weak seismicity [5]. However, there is a difference. If small aperture seismic array acts as a single station and serves a large area around it, a main object of GMSS is seismic monitoring within a network. Thus seismic event can be registered by one or two sensors only. In this case, it is important to separate the events from noise burst, but do not miss the event. It is necessary to have an estimate of the network, i.e. to know which the magnitude of seismic events are reliably detected by the network [6].
The station is usually equipped with short-period seismic sensors and geophones [7], the GPS/GLONASS receiver, the system of preprocessing, storage and/or data transmission.

Capacity of the existing seismic networks on the East European platform allows the monitoring of events with $M > 2.5$ for the most part of the platform, and $M > 3$ for a large part. The Mikhnevo small aperture seismic array can independently monitor (registration and location) all events with $M > 1.0$ at distance to 80 km [8].

Without appropriate precautions, the useful signals, which carry information from inside the Earth, would be hidden by noise signals from various sources. These noise signals must be kept below the level of the smallest wanted signal to be observed. In any case great care has to be taken to protect instruments from pressure, temperature, humidity and other environmental factors. Noise, which is emitted by changes in temperature and atmospheric pressure, is very powerful. At the same time, they are easy enough to filter (fig.1).

![Fig. 1. Data noise clearing from pressure signal [9]:](image)

- a - signal from the seismic sensor;
- b - atmospheric pressure;
- c - extracted seismic signal.

Even minimal passive temperature protection - foam cap - significantly reduces the seismic noise level. The most effective tool for reduction of influence of temperature and pressure is the optimal filtering [10]. This signal processing can be performed directly at the station in automatic mode. It allows you to not save the data of temperature and pressure. Application of pressure and temperature sensors at the station does not lead to a large increase in the cost of network.

**DATA PROCESSING**

Data processing is performed, firstly, to detect useful signals in background noise, to exclude noise splashes from consideration and, secondly, to determine the parameters of the recorded seismic events (hypocenter location and depth, magnitude). Detection of signal in noise in our opinion is not given enough attention.

The majority of algorithms is based on the concept of STA/LTA ratio and is designed for strong events registered at many stations. Unfortunately, they usually fail in the case of detecting weak events in the presence of seismic noise and a large number of disturbances, which are treated by typical detection
algorithms as seismic signals. The presence of high noise requires an alternate method of seismic detection capable of recognizing small seismic events [11].

The first stage is the processing of each station data. The application of neural network technology allows selecting a signal even if the noise amplitude exceeds the useful signal [12]. We have used several types of neural networks. Each of the neural networks was used to analyze the initial two seconds of the sensed earthquake accelerogram.

The second stage - a comparison of records of neighboring stations [13]. After the detection on single stations had been calculated, some methods of comparing them were applied. It was chosen to simply check whether the detection on one station coincides with detection on other stations. Then a voting process was used. An event is detected when it is detected two stations at least.

If at one station the signal is registered, and the accurate signal isn't present at next, it means that, either the signal of an earthquake is detected incorrectly, or at the neighboring stations the signal is hidden by noise.

Let the signal was recorded at station «Lutowiska» (Fig. 2), but the characteristics of the seismic events was difficult to determine.

![Fig. 2 Example GMSS location in the south of Poland.](image)

Assume that the station is the closest to the epicenter. Then time shift of a signal at the nearest (40 km) station «Hołuczków» will be from zero (if the earthquake occurred directly between stations), to such time interval, for which the seismic wave travels distance between stations. In this interval it is necessary to look for a record of the event. It is necessary to add to this interval the time during which the signal changes from the first arrival up to a maximum value. First, you need to spend clipping. If the amplitude of the signal in this interval is below than required (note: amplitude attenuation depends on the progressive increasing distance from the epicenter), the registered signal at station «Lutowiska» is false.

It is convenient to use the neural network again as the detector of the signal. [14]. The neural networks learning capabilities, which differ them from other mathematically formulated methods, are provided by the unique structure of neural networks and allow the development of neural network based methods for certain mathematically intractable problems. The training set was prepared on the basis of period from 06 to 10 October 2008. We used the recordings of Belgian network of mobile stations. They were precisely studied and 167 seismic events were found. Among them were regional events, teleseismic earthquakes, as well as a few technological explosions. We used noise records too. This gave a reasonable number of detections and quite good sensitivity, with the lowest detected magnitude $M_L = 0.4$. The problem discovered at the early stage caused a lot of false detections.

CONCLUSION

Records from GMSS are usually of worse quality than from permanent networks, because less time and effort is spent on site selection and deployment. Signals of weak seismic events are difficult to identify in noisy and disturbed data.

It is necessary to efficiently recognize local events and automatically locate them. Developed software further should be a kernel of system of monitoring. The detection from at least two stations is a useful tool, although some events are then missed.

Software should provide:
(1) Decrease the quantity of seismic sensors in the network, necessary for confident detection and a location of micro-earthquakes in comparison with a technique that in use now;
(2) Exception seismic sensor embedding under a layer of distribution of technogenic superficial waves from the man-made sources;
(3) Exception signals from meteorological sources on seismic records;
(4) Improvement of characteristics definition quality of the centers of micro-earthquakes at the expense of detection phases of micro-earthquakes in noise,
(5) Inclusion of other methods of the analysis of microseismicity, such, as a method of a seismic issue tomography at use more robustness schemes of data processing expanding possibilities of the microseismic data analysis.

The developed software will raise localization resolution of the centers of micro-earthquakes.

Application of this technique will provide:
- decrease in magnitude of detected events,
- increase of earthquakes detection reliability,
- increase in the radius of low-amplitude signals location,
- decrease in density of GMSS.

A detection algorithm has to reduce a number of false detections in order to make it possible to manually check all detections.

This method of seismic event detection proved its efficiency and eventually it was used as a convenient tool for small local event detection.

The authors presented the development of technology networks of mobile stations using several different methodology including neural networks.

REFERENCES
