Implementation of GMSTech – a New Practical Software for Microseismic Data Processing – for Estimating Event Source Parameters

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Abstract. Nowadays, microseismic monitoring has been utilized widely to detect fractures and permeability zones in many geophysics applications for exploration: geothermal resources, unconventional hydrocarbon resources, and many else. It is required to process microseismic data effectively and efficiently, but, integrated software for microseismic data processing is not available yet. We developed GMSTech (Ganesha Microseismic Technology), a Windows C# language based software which integrates complete functions and modules for microseismic characterization. In this paper, we discuss an implementation of one of the modules which can be used for calculating microseismic event source parameters: focal mechanism, using data recorded in the certain geothermal field. For estimating the focal mechanism, we developed a new simple algorithm based on grid-searching, clustering, and statistical analysis. In the results, our modules have successfully calculated the source parameters, and it is reliable for geothermal exploration. However, several factors such as coverage and number of stations may influence the results significantly, and moreover, this preliminary results still require further validation. Nevertheless, the GMSTech shows a remarkable performance, and it is more practical to be utilized for industry purposed compared to other software.

1. Introduction

In the past decades, microseismicity has attracted huge interest among geoscientists due to its ability to monitor fractures and permeability zones. Microseismicity is defined as a small seismicity, also commonly-known as microseismic events. Microseismic events relate to inelastic geomechanical fractures deformation for both natural or artificial. In many applications, microseismic monitoring has been developed broadly for geothermal industry [e.g., 1, 2, 3, 4, 5] and unconventional hydrocarbon resources [e.g., 6, 7, 8].

Unlike conventional active seismic exploration, the unknown source information such as the location (hypocenter), magnitude, origin time and focal mechanism should be addressed in microseismic monitoring, which leads to more complexity in data processing. The processing requires reliable software for imaging the microseismicity effectively and efficiently. However, the current existing software is available only for a specific processing module, and most of them are developed...
separately. We developed GMSTech (Ganesha Microseismic Technology), a Windows C# language based software which integrates complete functions and modules for microseismic characterization. The C# library is assisted by ILNumerics for reducing time consumption and providing improved visualization. Some modules have been described briefly in Rohaman et al. [9].

In this paper, we discuss an implementation of one of the modules which can be used for calculating the event source parameters: focal mechanism. The available widely commonly-used software for estimating focal mechanism, for example, are FocMec [10] and ISOLA [11]. The programs are unarguably robust and reliable, but, they lack user interfaces and are unintegrated with previous processing steps. The GMSTech compiled program is a Windows-OS-compatible GUI-based (Graphical User Interface) executable file, so it is easier and more practical to use.

For estimating the focal mechanism, we developed a new simple algorithm based on grid-searching, clustering, and statistical analysis. We validate its application using data recorded in the particular geothermal field. It can be observed that the GMSTech shows remarkable performance.

2. Algorithms

Generally, fault plane can move in four zones of movements depending on the in-situ stress condition of the area. In the movement, plane’s two sides displaced in opposite direction causing diverse polarity of incident wave at different areas. If a part of the plane moves toward a recording station, then the area will be defined as a compression zone. Otherwise, it is called a dilatation zone. In the vertical component, the movement is represented in first motion polarity of the waveform by up for compression, or down for dilatation.

Figure 1 depicts the algorithm we developed. The main input data is the first motion polarities observed in every station. To begin with, the grid-searching is conducted, similar to inversion process for hypocenter (x, y, z) determination [e.g., 12, 13]. The coordinates of strike, dip, and rake are generated randomly and then, its solution of the focal mechanism is drawn. Based on this solution, if the polarity error is smaller than the cut-off, it will be stored. This step will be repeated many times until we obtain sufficient samples of the coordinates. Secondly, the fuzzy cluster analysis is applied to all of the saved coordinates for estimating the most likely solution. A group of solutions is considered as one cluster based on neighborhood distance (in degree). Lastly, to provide the uncertainty regarding a non-unique solution, it analyses all produced clouds statistically resulted from the second step. To simplify it, we call this technique as the non-linear fomec

3. Implementation

We implemented this software to data recorded in a certain geothermal field located in the southern part of Bandung, West Java, Indonesia from January 2016 to November 2016. The microseismicity was recorded using 15 three-component seismometers with sampling rates of 100Hz. We then randomly selected several events around this study area and then, estimated their focal mechanisms using the non-linear fomec technique.

Figure 2 shows the GUI of the module for estimating focal mechanism. The required data to be inputted are information of all recording stations, relationship between source and receiver (azimuth and take-off angle), and observed first motion polarities for all stations respectively. It is required to set the parameters: number of tolerated polarity error as the cutoff, number of random numbers and number of attempt as the iteration steps in generating random coordinates, and maximum neighbor distance as the like hood distance in cluster analysis.
4. Result and Discussion
We took several samples varying in their magnitudes and the number of observed polarities, but, the non-linear technique failed to yield a solution for the events with the polarities less than five observations and also is unstable for six or seven observations. Otherwise, it works fine and reliable. It should be noted that the amount of observed data plays a significant role in this estimation, regarding the coverage of the monitoring stations to the source.

The total of 3 events’ focal mechanism was successfully modeled using this technique (Fig. 3). Generally, the sources depict a dominance of strike-slip mechanism. However, this results still need to be validated using other resources. Considering it as a preliminary result, this issue will be addressed in our further study.
5. Conclusions
Our modules have been successfully applied for estimating the source parameters. Shown by our implementation, it is reliable for geothermal microseismic monitoring. However, the data coverage and the number of stations may influence the results significantly. Nevertheless, the GMSTech shows an excellent performance, and its practicality makes it more suitable for industry purposes rather than to other available software.

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**Figure 3.** Map of microseismic distribution and three samples of focal mechanisms. Red dots are the hypocenters and blue reverse-triangles are monitoring stations.
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