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Crowdsensing location method of mining-induced seismicity based on the phone mobile sensor network

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ABSTRACT

To improve the positioning accuracy of a mining-induced seismicity monitoring system, reduce the monitoring blind area, and reduce the monitoring cost, based on the distributed idea, this paper proposes a positioning method of mining-induced seismicity based on the smartphone sensor network. First, smartphones used by workers and their families near the mining area were utilized to establish a mobile sensor network. Second, the simulated source points were meshed, and the objective function based on the standard deviation was constructed. An improved firefly optimization strategy was proposed. The inflection point backtracking method and smartphone sensor network exclude the discrete points strategy, namely, EDPS, to reduce the positioning error. Verification is done by the simulation experiment of the mining-induced seismicity location. Experimental results show that under the ideal condition of no arrival time error in the smartphone sensor network, all simulated source points can converge to the source position accurately with a positioning error of less than 1 m. However, compared to the detector, the arrival error of the smartphone is higher, and the positioning error is correlated with the arrival error. When the mobile phone arrival error is −1.0–1.0 s, the traditional algorithm positioning error is 216 m, which cannot achieve high-accuracy positioning. Researching the relationship between objective function value and positioning error, this work proposes and uses two optimization methods: (1) inflection point backtracking method and (2) EDPS. The absolute positioning error of the algorithm is reduced to 73 m. When the time error is −0.2–0.2 s, the absolute positioning error is reduced to 17 m, and the positioning accuracy is improved by 76.1%. The location method of the mining-induced seismicity based on the crowdsensing of a phone mobile sensor network provides a new method for mining-induced seismicity monitoring. It can be considered to combine with an underground microseismic system in the future, which is of great significance in saving the monitoring cost and improving the positioning accuracy.

KEYWORDS:
mining-induced seismicity, smart phone, group intelligence positioning, arrival error, exclude discrete points strategy (EDPS)

1. Introduction

Mine tremors are mine earthquakes induced by mining. When a mine tremor occurs, energy is released in a large area underground. In severe cases, it causes ground vibration, collapse, building damage, and even casualties underground [1], [2]. It is an important safety issue faced in mining activities. The mine tremor monitoring systems in many mining areas in my country are mostly imported from abroad, such as Poland's SOS and ARAMIS, and Canada's ESG microseismic monitoring system. Most of these systems are 24, 32 or 64 channels, with a limited number of seismic sensors. Most of them are arranged underground, with complex wiring, high prices, and difficulty in obtaining original waveform data. In recent years, with the development of technology, China has developed microseismic systems such as KJ551 and BSN [3- 5], which have obtained original data and given the time, spatial location and energy of mine tremors in real time. However, the positioning accuracy is still difficult to meet the actual needs of coal mine safety production, and large-energy mine tremor events still occur from time to time. In June, the General Office of the State Administration of Coal Mine Safety and the General Office of the China Earthquake Administration jointly issued the "Notice on Establishing a Mechanism for Sharing Earthquake Information in Rockburst Mines" [6]. The notice requires that when the provincial seismic network monitors a rockburst of magnitude 2.0 or above, collapse or other earthquake events within the rockburst mining area, it should immediately start sending earthquake information. According to statistics from the China Earthquake Networks Center and provincial seismic networks, from January to June 2021, many mining areas such as Yulin, Shaanxi, Jining, Shandong, and Ordos, Inner Mongolia experienced collapse-type earthquake events of magnitude 2.0 or above with a focal depth of 0 km. This type of earthquake event is mainly caused by coal mining, and has the potential to induce coal mine rockburst disasters and cause casualties, seriously affecting coal mine safety production and causing adverse social impacts. Since the location of mine earthquakes is shallower than the earthquake focal point and the ground shaking is strong, it is possible to consider setting up monitoring points on the ground. Studies have shown [7−9] that smartphone accelerometers can detect various daily vibrations within 10 km or less of the phone. 5 magnitude earthquake, the sensitivity to mine tremors is sufficient. With the development of technology, the sensitivity of smartphone accelerometers is still increasing. It can be expected that in the near future, it will be feasible to monitor and warn of mine tremors through smartphones.

As my country's coal resources are developed in depth, the research on mine tremors involves many aspects [10], among which accurate earthquake source location is the key to mine tremor research [11]. At present, there are many methods for mine tremor location [12], and most of them are based on the Geiger method, such as the classic least squares method, which has a small amount of calculation and a fast calculation speed, but it is easy to generate ill-conditioned equations. [13] proposed a regularized solution to the problem of ill-conditioned equations. [14] proposed a simplex-simulated annealing hybrid algorithm, which roughly determines the position of the global minimum value by the simulated annealing algorithm, and then uses the simplex algorithm to accurately calculate the global minimum value. [15] proposed a robust estimation method based on it to enhance the anti-interference ability. [16] A microseismic source location algorithm based on grid search-Newton iteration method is proposed. The grid search roughly determines the global minimum position, and the high-precision microseismic source location is obtained through the Newton iteration method. The swarm intelligence optimization idea has been used in many fields [17], [18]. [19] proposed a rock mass microseismic source layered location method based on particle swarm algorithm. Most of the above mine earthquake location methods use high-precision microseismic pickups to obtain data. No method for mine earthquake location using smart phones has been found.

With the development of science and technology, the functions of smartphones are not limited to communication. The motion, electromagnetic, gravity and other sensors installed on smartphones make smartphones a signal receiver. By sensing the surrounding environment, smartphones can help users complete a series of tasks such as navigation, positioning, games, and human motion recognition [20]. Therefore, based on the idea of "crowdsourcing" [21], this paper uses smartphones used by mining workers and others, and proposes a method for crowd-based positioning of mine earthquakes based on smartphone sensor networks through Internet collaboration. The purpose is to study the feasibility of using smartphones to complete mine earthquake monitoring tasks. By establishing a mobile sensor network composed of hundreds or even thousands of accelerometers, monitoring task distribution and data collection are carried out. The trigger of the mobile sensor network is used to determine whether a mine earthquake occurs, and the location of the earthquake source is determined when it occurs [22]. This method breaks the traditional idea of using underground mine earthquake stations for monitoring, and makes full use of the extensive, dense and random distribution of ground mobile phones. It is low-cost and cannot be matched by professional mine earthquake equipment. This method provides a new idea for improving the accuracy of mine earthquake positioning.

2. Conclusions

(1) It is feasible to use a mobile sensor network based on smartphones to replace traditional microseismic detectors for mine earthquake monitoring, with low monitoring cost and wide monitoring coverage. The accuracy of picking up mine earthquake arrivals is improved by using the NTP Internet Time Protocol on smartphones for regular time synchronization, which provides a hardware foundation for microseismic monitoring on smartphones.

(2) By initially gridding the simulated source points, establishing an objective function based on standard deviation, and improving the serialization of the firefly optimization algorithm, the mine earthquake event location can be realized. When the smartphone is relatively close, the location of the mine earthquake event can be realized.

The large monitoring error is proposed by using the inflection point backtracking method and the discrete point exclusion strategy to reduce the positioning error of mine earthquake events.

(3) Through a large number of simulation experiments, the monitoring error of smartphone arrival time is changed, and the superiority of the inflection point backtracking method and the discrete point exclusion strategy is verified. By effectively excluding smartphone data with high arrival time error, the positioning accuracy of mine earthquake events is improved. When the mine earthquake wave velocity is 3850 m·s−1 and the random error of smartphone arrival time monitoring is −1.0～1.0 s, the mine earthquake positioning error can reach 73 m; when the random error of arrival time monitoring is −0.2～0.2 s, the positioning error is 17 m, and the positioning accuracy can basically meet the on-site needs.

(4) With the development of smartphone chips and 5G wireless network transmission technology, mobile phone mobile sensor networks will be able to realize more functions in the future. It can be considered to be integrated with the underground microseismic system. By continuously improving and optimizing the algorithm, it will have broad application prospects in the positioning of mine earthquakes, earthquakes and other events.

3. References

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