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"Shock-Eye" - A Beidou-Based Earthquake Monitoring and Early Warning System

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Abstract. China's earthquake activity is high in frequency, high in intensity, shallow in source and wide in distribution. It is a country with severe earthquake disasters. Earthquake disasters have brought huge losses to people's lives and property safety in China. Based on this situation, combined with Beidou's high-precision positioning and two-way communication technology covering millimeter level, supplemented by remote sensing and GIS technology, this paper aims to establish a new Beidou system-based seismic monitoring and early warning system to monitor the crust of earthquake-prone areas. The micro-deformation and motion situation, through the data exchange processing, construct a statistical analysis model, effectively predict the earthquake condition in time, automatically issue an early warning to the estimated area before the earthquake arrives, gain valuable time for personnel and property transfer, and form a simulated earthquake. The post-disaster scene provides technical support for the emergency rescue command after the earthquake. We call it the "shock-eye" system. At the same time, the system can provide services for medium and long-term earthquake prediction through observation and processing of massive continuity data.

1. Research background

The occurrence of an earthquake is essentially the result of the gradual accumulation and instantaneous release of strain energy inside the earth's crust, often manifested as crustal deformation of some form and magnitude. Based on this, we can monitor the earthquake and provide early warning by monitoring the small deformation and movement of the earth's crust.

In recent years, the application of high-frequency real-time GPS technology to earthquake early warning technology has become a hot spot in international research. Its biggest advantage is that it directly acquires the ground motion state, does not need to integrate the speed measured by the seismograph or the second integral of the acceleration measured by the strong seismometer, and does not produce saturation in terms of amplitude; on the contrary, the greater the ground motion the relative positioning accuracy will be higher. However, since its horizontal positioning accuracy is sub-centimeter, the vertical accuracy is one order of magnitude lower, so its sensitivity is relatively low. Therefore, in terms of magnitude estimation of large earthquakes, the best method at this stage is to combine high-frequency real-time GPS with traditional seismographs, which not only enhances the reliability of magnitude estimation, but also because GPS networks and seismic networks are usually



independent. Distributed, combined with two means will increase the coverage of seismic monitoring, reduce blind areas, and better serve earthquake warning. In recent years, two American scientists Crowell and Bock have proposed a method of using a high-frequency GPS observation network and a seismic network to jointly conduct an early warning system. This system has been applied to the Southern California region and has achieved good results.

2. Beidou satellite navigation system

China Beidou satellite navigation system is a global satellite navigation system developed by China itself. It is the fourth mature satellite navigation system after the US Global Positioning System, the Russian GLONASS satellite navigation system, and the European Galileo satellite navigation system. Beidou adopts the dual-star active navigation and positioning system, which can provide high-precision, high-reliability positioning, navigation and timing services for all kinds of users all round the clock and all day in the world, and has the ability of short message two-way communication.

Beidou is widely used in transportation, fishery, forest fire prevention, environmental monitoring and many other fields. In disaster prevention and disaster prevention, the application of Beidou can be used in disaster monitoring and forecasting, disaster prevention and rescue, post-disaster reconstruction, etc. It has unique advantages such as small environmental constraints, fast and accurate, and two-way communication.

3. Based on Beidou's earthquake monitoring and early warning system

The "Shock-Eye" system is mainly composed of five parts: displacement monitoring terminal, data communication system, data processing system platform, earthquake early warning system and seismic zone simulation display system platform (Fig. 1).

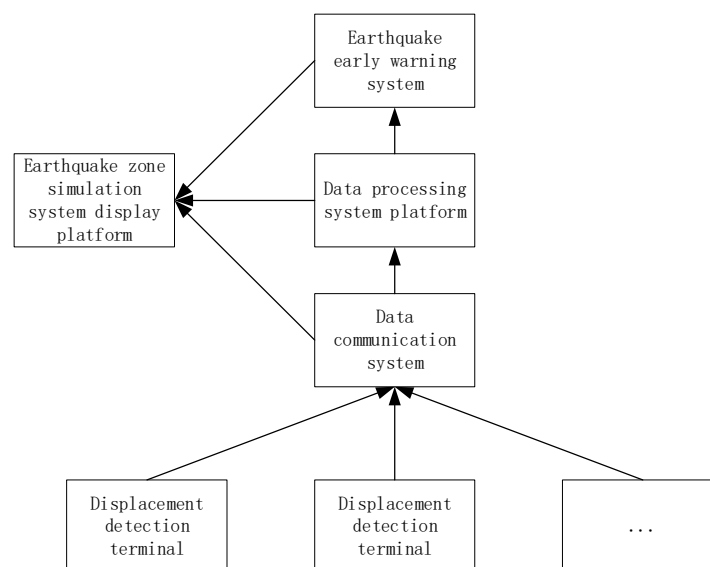


Figure 1 "Shock- Eye" - A Beidou-based Earthquake Monitoring and Early Warning System

During the work process, the displacement monitoring terminal collects the three-dimensional absolute coordinate change values of each monitoring point in real time, and after simple pre-processing, it is converted into a specific format, and the data communication system is communicated by using China Broadband Optical Fiber Communication or Beidou Satellite Communication. , transferred to the data processing system platform. The data processing platform stores and models the received data in real time to predict the possibility of an earthquake and the possible areas. If the predicted value is greater than the threshold, an early warning is issued to the predicted area

management platform. Finally, collecting the continuously updated terminal monitoring data, the earthquake zone simulation display system will visually display the earthquake disaster scene after the earthquake, and the Beidou two-way communication technology will provide strong technical support for the post-earthquake emergency rescue command.

3.1. Displacement monitoring terminal

The Beidou displacement monitoring terminal consists of all monitoring equipments arranged at different monitoring points and stable reference points outside the monitoring area and Cors stations near the monitoring points. Its main function is to monitor and collect different monitoring points and monitoring areas in real time. The satellite observation signal of the stable reference point is obtained and the monitoring data is obtained. After selecting the location and layout density of the monitoring equipment, we placed the Beidou satellite navigation monitoring equipment with the large-scale integrated circuit block GPS-OEM board as the core to collect information at the monitoring point, and adopted the high-precision relative positioning short baseline RTK. (Real Time Kinematic) solves and eliminates most of the errors in the observed data in a differential manner, thus achieving high-precision positioning. It mainly includes the monitoring point layout scheme, the selection and use of monitoring equipment, the layout and selection of reference points.

4. Monitoring network deployment plan

- (1) Initially set up monitoring points along the North China Seismic Belt and the Sichuan Longmen Seismic Belt, where the domestic population is relatively concentrated and the economy is relatively developed;
- (2) In the process of collecting monitoring data by using Beidou satellite navigation monitoring equipment, firstly, the monitoring points should be arranged to adapt to the topography and geomorphology of the area where they are located, to avoid the appearance of special data;
- (3) In the process of laying out the monitoring points, the characteristics of each monitoring point should be considered to be consistent, so that the monitoring data is finally comparable in the process of analysis;
- (4) The monitoring points are evenly distributed by the grid method and the concentric circle method.

5. Selection and use of monitoring equipment

Because the monitoring equipment is often placed in important buildings and in a certain depth of soil below the ground, the required equipment should be small in size and consume less energy. Therefore, the Beidou satellite navigation with the large-scale integrated circuit block GPS-OEM board as the core Monitoring equipment. The GPS-OEM board is the core component of the GPS receiver. The circuit board has the functions of receiving GPS signals, processing signals, outputting observation signals and positioning results, and performing secondary hardware development thereon, and can develop a satellite navigation terminal suitable for monitoring and early warning systems.

6. Setting and selection of reference points

The layout of the reference point is particularly important. Since the distance between the satellite distance monitoring point and the reference point is very large relative to the distance between the two points, the error is considered to be similar. The difference can be used to remove the error. The reference point coordinates can be used to calculate Monitor point coordinates. At the same time, the distance between the monitoring point and the reference point is required to be less than 10 kilometers, and the reference point should also be outside the monitoring area and not affected by the monitoring area. Based on this principle, we choose the right location to lay the benchmark.

6.1. Data Communication System

After collecting data from Beidou's displacement monitoring terminal, the data is transmitted to the data processing system platform through the data communication system of Beidou and the public

network of the operator. First, each communication station and the base station are equipped with communication equipment, and a heterogeneous communication network integrated with the public network operated by the operator and Beidou communication is established to ensure the security and reliability of data transmission and ensure the observation data located in different regions. Can be transmitted to the data processing system platform in time. Secondly, in the process of communication, information feedback mechanisms such as data errors and reception errors are established to ensure the correctness of data transmission, and a database backup mechanism is established to prevent data loss in the event of a data processing center failure.

1. Implementation and application of heterogeneous communication network Operation is carried out in two ways: mobile broadband optical fiber communication or Beidou satellite digital communication. Since the optical fiber transmission is relatively stable and the Beidou communication technology has a large delay, the default transmission mode of the displacement monitoring system is optical fiber transmission. When the mobile broadband fiber line is operating normally, Beidou satellite communication is not used. When the broadband fiber fails or other disasters such as earthquakes, meteorology, geology, etc. occur, the system automatically switches to Beidou satellite communication. After the transmission conditions return to normal, the monitoring system will automatically switch to fiber transmission.

7. The data communication system framework is as follows:

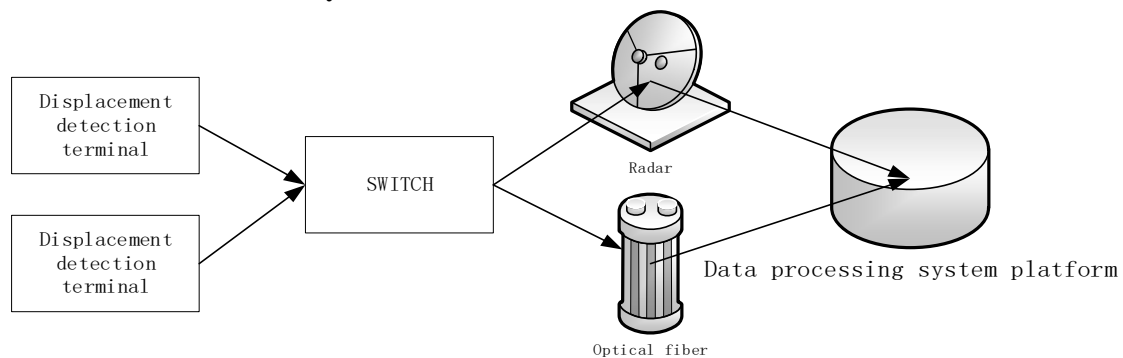


Figure 2 Data communication system

7.1. Data Processing System Platform

The data processing system platform is mainly composed of MySQL database management system, mathematical model calculation and deformation analysis, and earthquake prediction. First, a large amount of monitoring data received through the data communication system is classified and stored in the established database, and then the monitoring data is received and processed in the previous short period of time.

Since the distance between stations of the crustal deformation monitoring network is usually large, the traditional short baseline dynamic GPS data processing algorithm is difficult to obtain dynamic crustal deformation characteristics. Therefore, we use long-distance dynamic GPS data processing methods for data processing. For the problem of dynamic ambiguity decomposition in long-distance dynamic GPS data processing, we use dual-frequency observation data to construct the de-ionization observation to eliminate the influence of the ionosphere, and then use IGS to accurately predict the ephemeris to weaken the influence of satellite orbit error, and the tropospheric delay is used as an unknown, and the parameter estimation method is used to weaken its influence. Afterwards, through the processing and analysis of the monitoring data, the dynamic crustal deformation characteristics of several monitoring points in a certain monitoring area in a short period of time are obtained.

Since the monitoring network is generally planar or block-shaped, after acquiring the dynamic crustal deformation characteristics of several monitoring points in a monitoring area within a short period of time, we use the multi-face function model to interpolate the monitoring area and calculate

the dynamic crustal deformation feature of the localized monitoring area. The multifaceted function formula is as follows:

$$Z = \sum_{j=1}^n K_j * Q(x, y, x_j, y_j)$$

Where $Q(x, y, x_j, y_j)$ is the kernel function, (x_j, y_j) is the center point, and K_j is the pending parameter. For the convenience of calculation, we take n monitoring data points as the center point and select the same kernel function Q and smoothing factor δ at all center points.

After statistical analysis and calculation, the platform will generate a dynamic crustal deformation feature analysis map, which will display the displacement information captured by the monitoring terminal more intuitively.

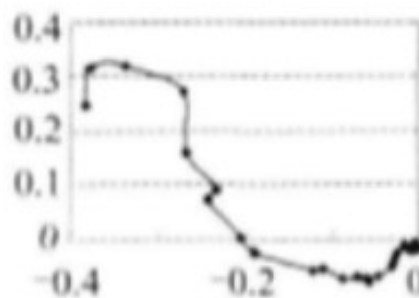


Figure 3 Dynamic crustal deformation feature analysis

At the same time, we use the trend extrapolation prediction method to predict the earthquake condition and generate the earthquake condition prediction, which includes the time of the earthquake occurrence, the area that may be affected, the intensity of the ground motion and the possible level.

In addition, in order to improve the accuracy and stability of the calculation results and better study the crustal deformation and motion law, the system can observe and process the massive continuity data. For example, the weekly monitoring data is combined with the post-emergency precision ephemeris for post-joint joint calculation, and the time series analysis of the displacement changes of each monitoring point and the whole is performed, and the overall displacement status of the monitoring area is made according to the period of the week, the month, and the year. Analysis, generate corresponding charts and text reports, and provide services for medium and long-term earthquake prediction.

7.2. Earthquake Early Warning System

The early warning system responds according to the analysis results of the dynamic crustal deformation characteristics. Once the displacement change exceeds the set threshold k , the Beidou short message communication function is immediately sent to the local Seismological Bureau and the Central Seismological Bureau in the relevant area to issue early warning information. The local earthquake bureau and the Central Seismological Bureau jointly made a decision-making response.

When the earthquake sends the warning information, the data processing system platform encrypts the communication content including the ID number of the Central Seismic Bureau and the local Seismic Bureau, and then forwards the inbound through the satellite. After receiving the communication application signal, the ground control center composed of the Central Seismological Bureau and the local Seismological Bureau receives the outbound signal from the receiving satellite navigation terminal, demodulates and decrypts the outbound message, and obtains the communication content. After the ground control center integrates the ground physical information, it can be de-

densified and re-encrypted into the outbound broadcast message with continuous communication function, and sent to the masses of users through satellite to play a timely warning role.

The whole system is characterized by high integration, real-time monitoring and rapid response, ensuring the timeliness and effectiveness of early warning information, and minimizing casualties and property losses.

7.3. Earthquake area simulation display system platform

The significance of the earthquake zone simulation display system platform is to simulate the disaster scene of the earthquake zone by establishing a three-dimensional map of the ground motion intensity in the post-earthquake area to assist the rescue department to successfully carry out the preliminary rescue work.

This platform mainly relies on 3D GIS technology and satellite remote sensing image technology. Combined with the spatial geographic information of the earthquake zone, the monitoring data collected and transmitted by the displacement monitoring terminal simulates the damage of different earthquakes in different locations and systematically. Simulate the post-disaster scenario.

The method used in this system platform is briefly described as follows. First, the aerial image map is processed to display a three-dimensional earthquake disaster scene in three dimensions. Finally, through the processing of the monitoring data to obtain the ground motion intensity map, combined with the terrain, building structure, traffic network, power and rivers and lakes in the affected area to simulate the earthquake damage of the surface structure in the event of an earthquake, then different methods are used to analyze different data, and finally the 3D GIS is used to represent the generated earthquake disaster scene.

This system platform can provide reliable first-hand information for disaster relief personnel to make correct decisions and direct front-line work. Combined with Beidou's all-weather, all-day two-way communication technology, we can collect on-site disaster information and transmit the command information in a timely and effective manner, and establish a real-time channel between the first line of the disaster area and the command center.

8. Summary

The "Shock-Eye" system is based on China's autonomous Beidou satellite navigation system, which uses precise satellite positioning technology to accurately monitor the three-dimensional positional changes of the earth's crust. The data received by each monitoring station is transmitted back to the data processing control center through the heterogeneous communication network formed by the public network/Beidou communication for real-time processing and solving, real-time online monitoring of the earthquake monitoring area for 24 hours, and monitoring through the monitoring station. The high-precision calculation processing of data achieves the purpose of earthquake warning. The system has clear ideas, high technical feasibility, reasonable design, or will bring good news to the earthquake workers.

With the continuous breakthrough of Beidou technology and the continuous popularization of mass application, we also have full confidence that Beidou will quickly bear heavy responsibility and radiant heat in earthquake monitoring and early warning.

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