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Development of Automatic Earthquake Quick Report in China[1]

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This paper summarizes the different stages of the development of earthquake automatic quick report in China. In early stage, scientists and technicians mainly focused on the realization of automatic identification of seismic phases and automatic positioning in the network data processing system. Then, at the end of the Tenth "Five-Year Plan" project, Fujian Earthquake Agency, Guangdong Earthquake Agency, and China Earthquake Networks Center have independently developed their earthquake automatic quick report systems. Later, by taking advantage of the "multi-channel comprehensive trigger" mechanism, China Earthquake Networks Center has innovated a comprehensive trigger system for automatic earthquake quick report, whereby earthquake information can be instantly reported and presented on Weibo, Wechat, and CENC App.

Key words: Earthquake quick report; Earthquake imformation; CENC

INTRODUCTION

In the 1980s, the China Digital Seismic Network (CDSN), jointly established by China and the United States, was the beginning of digital observations in the Chinese seismic industry. In 1996, the China Earthquake Administration began to establish a seismic monitoring system called "China Digital Earthquake Monitoring System". And by the end of 2000, the digital transformation of China's seismic network was basically completed. A national digital seismic network and 20 regional digital seismic networks were deployed, marking the official entrance of the era of digital observation for China's seismic monitoring. Particularly, in the data processing system of the digital seismic observation network, automatic seismic positioning is an indispensable function.

With the gradual advancement of the digitalization of the China Seismic Network, especially with the construction of the China Earthquake Administration's Tenth "Five-Year Plan" Project, related techniques have been gradually improved from the initial automatic positioning to the recently independent automatic quick report system, and further to the current integrated trigger system. Finally, an instant and efficient seismic information

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release platform has been established, combined with the "2 SNS and 1 App" (Weibo, Wechat and CENC App) information release feature. Currently, automatic earthquake quick report is well-developed in China. In detail, domestic earthquakes can be automatically reported within 1 to 2 minutes, and overseas earthquakes can be automatically reported in about 10 minutes.

1 THE EARLY STAGE OF EARTHQUAKE AUTOMATIC QUICK REPORT

In the 1980s and 1990s, China Earthquake Administration set up and operated six major telemetry networks in Beijing, Kunming, Lanzhou, Shenyang, Chengdu and Shanghai, as well as some other local telemetry networks. The seismic signals were transmitted back to the record processing center by wired and / or wireless networks, and recorded by analog tape recorders and ink recorders. The analog signals were then converted into digital signals by the analog-to-digital converters for computer processing. The computer data processing system includes event determination, automatic processing, and human-computer interaction processing functions (Zhuang Cantao et al., 2007). At this stage, automatic positioning has been studied and practiced in the data processing system, and has gradually taken shape.

In the early stage of the China Earthquake Administration's Tenth "Five-Year Plan" project, seismologists mainly studied how to improve the accuracy of seismic phase identification. With the development of related research, the recognition of seismic phases (especially the initial seismic phases) has gradually been solved, and the research interests has turned to automatic positioning instead.

1. 1 Automatic Identification of Seismic Phases

The automatic identification of seismic phases is the basis of automatic seismic positioning. People generally use the ratio of short-time average to long-term average for the purpose of identifying seismic phases. In addition, several other methods have also been applied. The Guangdong Earthquake Agency has developed an algorithm for automatically identifying P and S waves using three-channal data, making automatic positioning practical. (Li Huiting et al., 2000). The Shanghai Earthquake Agency has proposed a "waveform variation increase" algorithm and a "no follow-up phase" criterion for automatic identification of near-seismic phases by the digital network, compiled corresponding programs, and tested them with real cases (Zhu Yuanqing et al., 2002). Tsinghua University, Yunnan Earthquake Agency and Shandong Earthquake Agency cooperated and proposed a set of methods based on the kinematic characteristics of seismic phases. Compared with previous methods, these methods can successfully solve the interval problem of phase recognition and determine the phase name by utilizing the function of automatic identification of seismic phases throughout the process (Yang Peixin et al., 2004).

1. 2 Automatic Positioning

At the beginning of this century, China has experienced a full transition from the analog observation era to the digital observation era (Liu Ruifeng et al., 2008). Meanwhile, seismic automatic positioning has gradually become a function in the seismic network data processing system.

The China Earthquake Networks Center's data processing system ECUMS (Earthquake C language Unix Management System) has an automatic positioning function in the real-time processing subsystem when receiving and processing real-time data which are transmitted from 48 national digital seismic stations. Besides, corresponding technical treatments have been made for different background noise conditions at the seismic stations, and some positive effects have been achieved. (Song Rui et al., 2001).

When the regional seismic network completes the digital transformation, it is also significant to apply the method for automatic positioning. The Liaoning Earthquake Agency analyze the amplitude, period, and polarization of seismic P-wave and S-wave phases recorded by the Digital Seismic Observation Network, and further used these features to automatically identify seismic phases, providing a robust basis for automatic seismic positioning (Pan Ke et al., 2004).

With the rapid development of digital seismic network as well as the automatic positioning, researcher Zhao Zhonghe comprehensively analyzed the advantages and disadvantages of two typical automatic earthquake positioning methods, and proposed a unified scheme for comprehensive utilization of the two methods (Zhao Zhonghe, 2005), which laid a good foundation for the practical application of automatic seismic positioning.

2 THE DEVELOPING STAGE OF THE AUTOMATIC EARTHQUAKE QUICK REPORT SYSTEM

With the development of China's seismic monitoring network, seismologists have been aware of the importance of automatic quick report. They also recognized that the function of automatic quick report is not only a function of the data processing system, but may play more important roles in other related domains. Therefore, an independent system should be established and operated separately.

The Fujian Earthquake Agency put forward the development goals for the real-time quick report system of the regional digital seismic network, and analyzed the problems that should be solved in order to achieve this goal, including real-time data stream receiving, automatic identification of seismic phase, reliability of seismic phase, real-time seismic positioning, real-time drawing of contours at seismic phase arrival time, real-time calculation of earthquake magnitude, and real-time drawing of ground motion intensity distribution maps (Jin Xing et al., 2007). On the basis of this study, a set of real-time quick report software for earthquakes has been developed to realize the above functions.

The Automatic Quick Report System in Fujian is China's first independent operating system that clearly aims at automatic quick report. Its appearance marks the transformation from automatic positioning to automatic quick report of seismic analysis processing in China. The system initially used the Fujian Digital Seismic Network as the test and application platform. In September 2007, considering that the earthquake and network conditions in the Sichuan-Yunnan region is a good test site for the real-time quick report system, the Fujian Earthquake Agency cooperated with China Earthquake Networks Center to transplant the system software to the Sichuan-Yunnan virtual network. During the test phase, the results were only sent to a small number of test participants. After the Wenchuan $M_S8.0$ earthquake, the system performance has been improved by Liao Shirong et al. (2009), including improving the ability to distinguish double earthquakes, teleseismic misidentification exclusion, exceptions for real-time waveform stream service, seismic positioning and magnitude determination accuracy. The improved system was far more competent to automatically process earthquakes in the Sichuan-Yunnan region. By July 1st, 2008, the system has possessed the ability to send information about the basic parameters of an earthquake to a small number of relevant leaders of the earthquake system within approximately 2 minutes after the earthquake, providing reference for earthquake emergency response decisions (Liao Shirong et al., 2009).

After the Wenchuan earthquake, the public and the government have paid increasing attention to the earthquake information, which requires timeliness and reliability of the quick seismic report. In this context, the Monitoring and Forecasting Department of the China Earthquake Administration ordered the Guangdong Earthquake Agency to build a "fast-report backup system", the project that has been proposed in June 2008. After the completion of the project in December 2008, trial operation was conducted and accepted officially in June 2009. The system can automatically and accurately determine the seismic parameters within 3 to 5 minutes after the earthquake, and then send out earthquake quick report information (Wu Yongquan et al., 2011).

Around 2009, the China Earthquake Networks Center independently developed and operated the "China and Global Automatic Earthquake Reporting Software System" with the efforts of scientific and technological personnel led by LIANG Jianhong. This system uses data from domestic and surrounding seismic stations to provide automatic quick report for earthquakes in and around the country, and uses the data obtained from global stations for automatic earthquake quick report in foreign countries. This automatic quick report system began its trial operation in November 2009 (Liang Jianhong et al., 2015; Yang Chen et al., 2013).

From 2007 to 2009, three sets of automatic earthquake quick report systems have been established, forming the three pillars of China's automatic quick report which contains comprehensive seismic information.

3 THE DEVELOPING STAGE OF COMPREHENSIVE AUTOMATIC EARTHQUAKE QUICK REPORT

3.1 System Layout

Since 2010, there have been three sets of automatic earthquake quick report systems in China, which are independently developed by different researchers and operated in different environments. In order to standardize the automatic quick report, the China Earthquake Administration formulated the "Regulations on the Automatic Quick Reports Technics (Trial) [2009] (135)". According to the regulations, the National Automatic Earthquake Quick Report System is composed of the China Earthquake Networks Center, five Automatic Earthquake Quick Report Sub-Centers in the North, Northeast, Northwest, Southwest, and Southeast regions (hereinafter referred to as the five major regions), and the National Earthquake Quick Report Backup Center.

The five major regional automatic quick report sub-centers are set up in the Earthquake Agency of Hebei, Liaoning, Shaanxi, Yunnan, and Fujian Province, respectively. The software is the automatic quick report system developed by Fujian Earthquake Agency. The five major regional sub-centers are responsible for automatic quick report of earthquakes in their corresponding areas. The Automatic Earthquake Quick Report Systems of the China Earthquake Networks Center and the National Earthquake Quick Report Backup Center are deployed in China Earthquake Networks Center and the Guangdong Earthquake Agency, respectively, and are responsible for the automatic quick report of domestic and overseas earthquakes (Yang Chen et al., 2010).

3.2 Result Collection of Each Automatic Quick Report

The results produced by the automatic quick report systems of the China Earthquake Networks Center, the National Earthquake Quick Report Backup Center, and the five major regional automatic quick report sub-centers are all collected and transmitted through the automatic EQIM server deployed at the China Earthquake Networks Center (Yang Chen et al., 2009). The results are then forwarded to the comprehensive trigger system (AU system) of the automatic quick report.

3.3 Evaluation of the Different Automatic Results

During the two years from 2010 to 2011, the three sets of automatic earthquake quick report systems were operating normally and continuously to produce quick report results. Yang Chen from the China Earthquake Networks Center led the evaluation of the outputs of the three systems (Yang Chen et al., 2013).

For domestic earthquakes, it took less than 90 seconds for the five major sub-centers to finish a report for most parts of the eastern China. The epicenter error was within 10 km, and the magnitude error was within 0.2. It took less than 120 s for the China Earthquake Networks Center to make a report for most parts of the country. The epicenter error was within 15 kilometers, and the magnitude error was within 0.3. It took less than 200 s for the National Earthquake Quick Report Backup Center to make a report for most parts of the country. The epicenter error was within 30 km, and the magnitude error was within 0.6.

For overseas earthquakes, it took less than 800 s for the China Earthquake Networks Center to make a report for most parts of the world, and the epicenter error was within 30 km. It took less than 800 s for the National Earthquake Quick Report Backup Center to make a report for most parts of the world, and the epicenter error was within 50 km.

The evaluation results show that five major sub-centers have sent 1 false alarm, the China Earthquake Networks Center has sent 3 false alarms, and the National Earthquake Quick Report Backup Center has sent 69 false alarms. Basically, no moderate-to-strong earthquakes were missed by the three sets of automatic quick report systems. The missed earthquakes are generally earthquakes $M<4.0$, and they are generally distributed in the areas with relatively few stations.

3.4 The Development of Comprehensive Release Strategy and Automatic Quick Report Triggering System

After two years of comparative test operation, it is found that the three sets of automatic quick report systems are generally stable. Compared with traditional manual quick reports, automatic quick reports have obvious speed advantages. Most domestic earthquakes can be completed within 2 minutes with high accuracy. However, missed reports and even false alarms may exist. Besides, there are a few relatively large errors in the position and magnitude information. These are common problems in the automatic quick reports around the world, mainly determined by factors such as station density, network layout, and speed model, etc.

Each of the three systems has its own advantages and disadvantages. The automatic quick report is released to public, thus the impacts and consequences of false alarms are much more serious than missed reports. Therefore, the principle of "prefer type II error to type I error" is adopted in the release mechanism and strategy. The comprehensive automatic quick report release adopts the "multi-channel comprehensive trigger" mechanism, in which multiple independent automatic quick report systems are parallelly running. Furthermore, the mechanism is aggregated by the automatic EQIM system, and determined by the comprehensive review platform to synthesize the final results. The rule of synthesis is that when over one of the three systems give positive results, the review platform will perform weighted synthesis on the results of each quick report channel (Yang Chen et al., 2014).

According to the aforementioned "multi-channel comprehensive trigger" mechanism and synthesis rules, the comprehensive automatic quick report triggering system (AU System) were developed by the team leading by Hou Jianmin from the China Earthquake Networks Center, and contributed by Miao Fajun and others from the Jiangsu Earthquake Agency. On April 1^{st}, 2013, the document "Regulations for Automatic Earthquake Quick Reporting Technology Management (2013 Revision)" issued by the Monitoring and Forecasting Department of the China Earthquake Administration began to be implemented, and the results of the automatic quick report began to be released to the public through officially recognized channels, marking the official entry of China into the "automatic quick report era".

4 DEVELOPMENT OF THE DIFFERENT RELEASING METHODS

In the past, earthquake quick report information was sent out through telephone and fax. However, with the popularization of mobile phones, it has become an urgent problem for seismologists to publish earthquake quick report information by sending messages with mobile phones. The Hebei Earthquake Agency developed the seismic information release software using the characteristics of GSM, and the information can be sent via mobile phone SMS (Liu Shengguo et al., 2006). On this basis, the China Earthquake Networks Center used the SMS modem pool to replace the single SMS transmitter technology, and then established a set of earthquake quick report information release system of China Earthquake Administration, which exhibited excellent effects in practical applications.

As the 12322 short number was put into use and the shortcomings of the SMS modem pool equipment appeared, Zhao Guofeng et al. converted the quick report SMS transmission mode from the modem pool to the 12322 short number gateway, and resolved the matching problem between the official quick report and the automatic quick report, as well as the follow-up service of the automatic quick report SMS (Zhao Guofeng et al., 2014). The 12322 Short Earthquake Message Service System has been officially put into operation at the China Earthquake Networks Center since April 2012.

After a strong earthquake, the location of epicenter undoubtedly becomes the urgently needed information. For this reason, Hou Jianmin et al. developed an application for smart phones. When a user receives a short message of the earthquake quick report, the user can view the local geographic information as well as other information (Hou Jianmin et al., 2013).

With the popularity of the "2 SNS and 1 App", Hou Jianmin and his colleagues from the China Earthquake Networks Center, have successively developed information publishing platforms such as the Quick Seismic Network Report of China App, official Weibo account, and official WeChat account. In particular, great progress has been made since the launch of the official Weibo account. So far, the follower number has reached 8. 67 million, making it one of the most influential SNS accounts.

5 CONCLUSION

The automatic earthquake quick report in China has become more and more mature, and the relevant scientific and technical personnel in the seismic industry have been working hard for the continuous improvement of its stable operation, high reliable output, and rapid release functions. It has currently reached the target "as soon as people feel the shake, earthquake information can be presented on the phone immediately."

Meanwhile, with the progress of the "Quick Reporting of Earthquake Intensity and Early Warning Project", it has become a common goal for the seismic industry that "people will receive earthquake information first and then feel the earthquake vibration".

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