SAR remote sensing monitoring of the Yushu Earthquake disaster situation and the information service system

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Abstract: The SAR system with its all-weather and all-time imaging capabilities emerged as a very important remote sensing data source for earthquake monitoring and disaster relief. After the recently occurred earthquake in Yushu county, Qinghai province, an airborne SAR system equipped with X-band dual antenna interferometric sensor and P-band fully polarized sensor has been successfully used in disaster monitoring and relief actions. The system is the first airborne SAR system with full intellectual property owned by China. This paper summarizes the Yushu Earthquake remote sensing monitoring and information service system, including the data, processing methodologies and information service. The emphasis is put on the application of airborne SAR images to disaster information extraction and assessment. First, the parameters characterizing the content of earthquake disaster remote sensing monitoring are determined, which include the information of urban and rural residence, infrastructure, geological disasters and farmland damage. The processing methodologies of optical and SAR data for earthquake disaster information interpretation, mapping and risk evaluation are presented. The process chain consists of quick geometric processing, change detection, quick target interpretation and quick spatial risk assessment for disaster. On the basis of the earthquake information including those extracted from remotely sensed images and other existing social and geospatial data, a system of Yushu Earthquake disaster situation geographic information service has been developed, to facilitate the management, visualization, and statistical analysis of the earthquake disaster information.

Key words: Yushu Earthquake, SAR, remote sensing, disaster monitoring and assessment

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1 INTRODUCTION

China is an earthquake country. Therefore, it is vital to effectively monitor and to assess earthquake disaster situation promptly after the earthquake, which can help protect against losses of lives and property. Synthetic Aperture Radar (SAR) is an important and indispensable technical means for disaster precaution, alleviation and relief at both national and regional levels because of its all-weather and all-time capability (Liu et al., 2010). After the Ms 8.0 Wenchuan Earthquake happened on May 12, 2008, Chinese Academy of Surveying and Mapping developed a Geographic Information Service System on Wenchuan Earthquake Disaster Situation, and achieved the management, visualization, and statistical analysis on earthquake disaster information. But at that time, SAR data was mainly provided by foreign countries, and its spatial-resolution was also limited.

At 7:49 AM, April 14, 2010, there happened a Ms 7.1 earthquake in Yushu county, Qinghai province. The emergency preplan supported by surveying and mapping was immediately launched by State Bureau of Surveying and Mapping. An airborne SAR system equipped with X-band dual antenna interferometric sensor and P-band fully polarized sensor quick responded and was successfully used in disaster monitoring and relief actions. The system is the first airborne SAR system with full intellectual property owned by China, where Chinese Academy of Surveying and Mapping is the leading developer. It took advantage of its all-weather capability and no limitation on flight height for image spatial-resolution, while avoiding the space and time occupied by rescue aircrafts. About 2000km² X-band and P-band airborne SAR images with 0.5m and 1m resolution were acquired after 12 air routes of two sorties. By quick geometric processing, quick data quality analysis, quick change detection, and detailed target interpretation on SAR images, technical supports were provided for earthquake relief, disaster assessment, and reconstruction planning.

On the basis of the practical work in Yushu Earthquake disaster situation monitoring, this paper puts the emphasis on the
methods and technical flow of SAR image processing in the application of monitoring and assessment of earthquake disaster situation. The existing problems are also analyzed.

2 METHODS AND TECHNICAL FLOW

2.1 Overall technical flow

The overall technical flow of establishing the earthquake disaster situation information service system of Yushu in Qinghai Province by SAR technology is illustrated in Fig. 1. The main processes include image preprocessing, disaster information interpretation, multi-source information integration, and information service system construction.

2.1.1 Image preprocessing

By preprocessing remote sensing images, especially SAR images, the image quality is improved. The preprocessing includes image enhancement, image transformation, fast geometric rectification, image registration, image fusion, projection transformation, image mosaicking, DOM production, etc.

2.1.2 Disaster information interpretation

By integrating the semi-automatic information extraction results and visual interpretation results, the damages areas are completely outlined, which provides foundations for statistical analysis on disaster situation. At the same time, the interpretation accuracy for different type disaster situation parcels is discussed.

2.1.3 Multi-source information integration

By geo-object association on the interpreted objects, non-spatial data spatialization, thematic data registry, and space-time consistence processing, the disaster situation information including texts, statistics, images and multimedia is seamlessly integrated.

2.1.4 Information service system construction

Based on the governmental geographical information platform “Geowindows”, the disaster situation information service system of Yushu in Qinghai Province is constructed by function integration packaging, system interface development, process design and function development.

2.2 Fundamental data

Aerial photos, satellite images, fundamental geographic data, and thematic data of Yushu area are collected. SPOT5 image, IKONOS image and airborne SAR data before and after earthquake are used for interpretation. Detailed information for the adopted data is:

(1) Airborne SAR data: X-band dual antenna interferometric data and P-band fully polarized data.

(2) Optical image data: SPOT5 image and IKONOS image before and after earthquake, and aerial photos after earthquake.

(3) 1:50000 scale fundamental geographic data.

(4) Field work data from State Bureau of Surveying and Mapping and Ministry of Land and Resources, population data, social economic data, hydrological data, geological data, etc.

2.3 Technical methods

2.3.1 Monitoring criteria for disaster situation

Multi-platform, multi-temporal, and multi-sensor remote sensing images including satellite images, digital aerial photos, airborne X-band/P-band SAR images, and UAV digital images are acquired in this monitoring work. The existing 1:50000 and 1:10000 scale fundamental geographic data, population distribution data, social economic data, as well as thematic maps in the fields of land resources, transportation, hydrology, geology, agriculture and forestry of earthquake-affected areas are also collected. The monitoring criteria for disaster situation are established by referring the existing criteria on fundamental geographic data production, land resources inventory, geological hazard monitoring by remote sensing (Chinese Geological Survey, 2008), etc.

In the earthquake-affected areas, high-spatial resolution images and SAR images are mainly used for the following types of fast investigation by remote sensing:

(1) Town, and rural built-up.

(2) Infrastructure: transportation and communications sys-
tems, water and power lines, and public institutions including schools, post offices, etc.

(3) Geological hazards and environmental information, including landslides and debris flow.

(4) Damages on farmlands and forests.

2.3.2 Multi-source data integration for remote sensing monitoring

The acquired optical image can cover only limited region of the disaster affected area. In order to monitor the whole disaster affected area, the multi-source remote sensing data should be used. Digital optical images of the center of Jiegu town were acquired, so optical images are the main remote sensing data source and SAR data is used as auxiliary data. The monitoring of the edge of Jiegu town mainly uses SAR data as well as optical images taken before the earthquake. In this work, the monitoring order is first the concentrated residential areas, and then the scattered settlements in rural areas. The multi-source data including SAR images, aerial photos and satellite images are used together to cover the whole area and to perform the fast and accurate image interpretation. Firstly, the coverage extent of the acquired images is analyzed. Then, imaging processing and polarization synthesis are performed. Finally, geometric rectification, fusion, mosaicking, etc. are carried out. Where, self-developed software “SARMapper” is used for SAR image processing, and module “PixelGrid” of self-developed software “ImageInfo” is used for optical image processing. Different types of images often have big contrast on color, so images are superimposed directly and then interpreted under GIS environment (Zhang et al., 2008), which greatly reduces workload and data volume during network transmission.

2.3.3 Complementary advantages of SAR image interpretation and optical image interpretation

SAR images have interpretation advantages on enclosed pasture and its surrounding settlements, iron tower and facilities. However, collapsed housed can be easily seen on optical images. By utilizing the complementary advantages of SAR image interpretation and optical image interpretation, which is illustrated in Fig. 2, the earthquake situation of Yushu county is accomplished.

2.3.4 Fast interpretation of SAR image

SAR system has all-weather and all-time imaging capabilities. After earthquake, SAR images of disaster affected areas are acquired. By comparing with the optical images acquired before earthquake, change information before and after earthquake can be obtained, which can be further used for quick monitoring on typical ground objects. X-band and P-band SAR images are used for earthquake situation interpretation. After earthquake, there are lots of collapsed houses in Jiegu town, which can be easily interpreted on SAR images. Besides, damaged roads, bridges, dams, and facilities such as power towers can also be clearly seen on SAR images, which are shown in Fig. 3.

2.3.5 Disaster risk analysis

Disaster rating scheme can be obtained according to model superposition in GIS software using its powerful spatial analysis functions (Hu et al., 2007). By using this map, the visual interpretation results can be further verified.

3 DISASTER SITUATION SAR REMOTE SENSING MONITORING AND THE SERVICE SYSTEM

Aiming at the Yushu Earthquake, this paper investigates the image preprocessing methods, including image enhancement, image transformation, geometric rectification, image registration, image fusion, projection transformation, image mosaicking and so on. The methods of extracting houses, bridges, schools, power facilities, rivers, landslides from remote sensing images are discussed. Multi-source and heterogeneous disaster information integration method and Yushu Earthquake disaster situation geography information system construction method are introduced. The service system can provide technical support to the governmental management and decision-making.

3.1 Disaster situation information interpretation of Yushu Earthquake

The service system mainly achieves the disaster situation information interpretation, such as collapsed houses, collapsed schools, broken bridges, destroyed power facilities, damaged rivers, damaged dams, landslides, etc. The information of the collapsed schools in Yushu is shown in Fig. 4. The monitoring time and the area of parcels are shown in the information box of Fig. 4. Fig. 5 shows the information of the collapsed houses. The area of parcels and the order of the parcels are shown in the information box of Fig. 5.

3.2 Multi-source emergency information integration of Yushu Earthquake

Based on the basic geospatial data, a unified data integration framework is established. Through data transformation, projection transformation, data resample, geographical association, space-time consistence processing, spatial index generation, earthquake disaster situation information, collapsed houses, collapsed schools, broken bridges, damaged power facilities, damaged rivers, damaged dams, landslides, population, and earthquake intensity, is seamlessly integrated with multi-scale spatial information. At last, the Yushu Earthquake disaster situation information database has been formed. The integration of earthquake intensity information and spatial information is shown in Fig. 6. The sensible radius is 83.6807 km (Fig. 6).

3.3 Emergency information service system construction of Yushu Earthquake

Based on fundamental geographic information service interface, using B/S structure, the service system integrates information display, query, comparison and analysis, which achieves two-dimensional map and three-dimensional scene efficiently display of Yushu Earthquake area based on network environment, multi-resolution aerial and space image information display,
Fig. 2  Complementary interpretation advantages between SAR image and optimal image
Fig. 3  Interpretation plots of SAR image at X and P band about Yushu earthquake disaster situation
(a) X band; (b) P band

Fig. 4  Information of the collapsed schools
Yushu Earthquake information query, earthquake monitoring and analysis, comparison of images before and after earthquake, spatial statistics of population and economic, query of the distribution of the enterprises and institutions in earthquake area and so on. The system can provide information services for disaster relief, disaster planning and reconstruction. The house comparison of images before and after earthquake is shown in Fig. 7. From the Fig.7, The earthquake inflicted severe damage on the houses. The 3D aerial photograph image after earthquake is shown in Fig. 8.

3.4 Application

According to the unified arrangements of the earthquake relief work by the State Bureau of Surveying and Mapping, Chinese Academy of Surveying and Mapping launched emergency response mechanism of governmental geographic information services immediately. In accordance with the work ideas of “information integration, decision support, rapid delivery”, the earthquake geographic information system of Yushu in Qinghai Province is fast set up. The system was deployed in General
Office of the e-government of the State Council and directly provided information services for the country based on geographic earthquake monitoring, comprehensive inquiry, and statistical analysis. On April 18, according to the arrangements of the State Bureau of Surveying and Mapping, the system was installed in Qinghai Bureau of Surveying and Mapping, and provided services to the Qinghai provincial party committee leaders, Qinghai provincial leader and Qinghai emergency office, provincial Development and Reform Commission, Department of Land and Resources through the network. On April 19, the system was installed in China Earthquake Administration and National Disaster Reduction Centre of the Ministry of Civil Affairs. It provides services directly to the professional sectors for the earthquake analysis and evaluation.

4 CONCLUSIONS AND DISCUSSION

Airborne SAR system has the advantage of flexibility, which is fully reflected in this earthquake disaster monitoring. Lots of data of disaster affected areas are quickly acquired shortly after
the earthquake. This data are processed and then are used in the information service system construction to realize the interpretation, assessment and service for the comprehensive disaster situation information. Airborne SAR system plays an important role in disaster relief actions.

Because the available continuously running GPS base station is far away from the disaster affected area, the accuracy of differential GPS positioning is not good enough and the technique of geometric rectification without GCPs cannot be used at that moment. In this work, GCPs collected from optical images are used for SAR image rectification.

SAR image cannot be interpreted as easily as optical images. The interpreters must be trained in order to effectively understand information which is conveyed on SAR images. The absolute visual interpretation is time-consuming. Besides, because of the influence of SAR imaging mechanism and speckle noises, the subjective errors of visual interpretation are unavoidable (Yang et al., 2004). Therefore, interpretation algorithms of ground objects which are adapted for SAR images should be researched in order to improve the interpretation accuracy.

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REFERENCES


张继贤，黄国满，刘纪平

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2.1

SAR
2.1.2

2.1.3

2.1.4

2.2

2.3

2.3.1

2.3.2
2.3.3 SAR

\[ \text{SAR} = \text{ImageInfo} \times \text{PixelGrid} \]

2.3.4 SAR

\[ \text{SAR} = \text{GIS} \]

2.3.5 SAR

\[ \text{SAR} = \text{GIS} \]

3 SAR

\[ \text{SAR} = \text{GIS} \]
4

REFERENCES


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