THE DEVELOPMENT OF RAPID EARTHQUAKE DISASTER ASSESSMENT SYSTEM BASED ON SPACE-AIR-GROUND INTEGRATED EARTH OBSERVATION

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ABSTRACT

The Rapid Earthquake Disaster Assessment System in the area of "one Belt And one Road" (REDASBAR) is developed specially for the emergency extraction and assessment of seismic damage information based on satellite and airborne RS images as well as the ground-based seismic network monitoring and field damage survey, and for the support of emergency command and rescue decision-making. The system is characterized by the synthetical analysis of seismic damage information with space-air-ground based observation data by up-to-date methods. The paper introduces the system database, main functions and integrated platform, as well as the primary application cases.

Index Terms — space-air-ground based observation, earthquake damage extraction and assessment, earthquake emergency, decision support, software system

1. INTRODUCTION

The remote sensing technique has been successfully applied to emergency earthquake damage monitoring and assessment. Based on the researches and practices of monitoring and assessment, some software systems have been developed [1-4]. but many efforts have still to be made in order to improve the timeliness and accuracy of disaster information. Among them the disaster information acquisition, assessment method and system integration are three of the most important aspects. The acquired earthquake damage information should be a variety of sources from not only satellite and airborne images, but also ground-based seismic observation network and on-site emergency seismic damage information sampling survey. The uses of up-to-date methods, such as the deep learning methods and synthetical analysis combined with space-air-ground based data, are used to enhance the ability of disaster information assessment. In addition, the functions should be optimized to improve the performance of the software system. The Rapid Earthquake Disasters Assessment System in the area of "one Belt And one Road" (REDASBAR) is developed to meet the needs of emergency disaster assessment and decision-making support. The system is designed to run in MS windows environment. The software process spatial analysis with ArcEngine 10. The system is developed mainly by C# with the tool of MS Visual Studio 2019. Wang et al (2019) introduced the project object and main frame [5]. This paper mainly introduces the design of the database, main functions, integrated platform, and the primary application cases.

2. THE SPACE-AIR-GROUND BASED DISASTER INFORMATION SOURCES AND DATABASE

The REDASBAR system is designed to improve the timeliness and accuracy of earthquake disaster monitoring and assessment. Space and airborne RS images, and ground-based information, such as the peak ground acceleration (PGA), the quick report of earthquake parameters and later the focal mechanism solution and aftershock catalog produced by digital seismic network, and still later the on-site earthquake caused damage survey sampling data, are used. The space-air-ground integrated disaster information is very useful to enhance disaster assessment precision in different emergence stage.

Based on the space-air-ground based disaster information sources, the database of REDASBAR is designed and established with 10 subclasses: RS image database, basic geographic database, emergency basic database, seismic damage database, assessment database, emergency command decision database, emergency rescue decision database, ground-based seismic network monitoring product database, on-site damage survey database and system product database.

In order to meet the different needs of emergency assessment, 3 system databases with different spatial scale are established: the database in city scale with very detailed information to support the rapid disaster assessment, emergency command decision-making and on-site rescue action; the database in national scale with detailed information to support the rapid disaster assessment, emergency and rescue command decision-making; the

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database in range of “one belt and one road” countries and regions (BAR) with basic information to support the rapid disaster monitoring and on-site rescue decision-making in the case that the Chinese International Search and Rescue Team (CISAR) have been set off oversea for relief work after an earthquake catastrophe occurs in BAR.

3. THE MAIN FUNCTIONS OF SYSTEM

The REDASBAR include 9 main functions as followings (Figure 1):

(1) **Data File Exchange** is designed to transform format from input data to the system, or vice versa, from the system into output data. It also provides functions to import data into system, or export data from system.

(2) **Database Management** is designed to manage (edit, query and view) the system data with variety of types, such as vector data like fundamental geographic information, seismic network recorded PGA etc. data, extracted and assessed building damage levels, etc.; raster data like RS images, DEM, ground surveyed building damage photos, output thematic maps, etc.; structured or partly-structured data like vulnerability matrixes, building replacement prices, various parameters of assessment models, system metadata, etc.; non-structured data like assessment report documents, etc.

RS images are the most important data applied to extract seismic damages of buildings, roads and the earthquake induced landslides etc. The images used currently in the system are the high resolution (sub-meter and meter level) optical satellite images, such as the China GF-1, GF-2, GF-6, BJ-2, JL-1 etc., the ESA sentinel-2, the Germany RapidEye or other sources of satellite images which can be inputted and used by the system as TIFF/IMG format files. The very high resolution airborne optical images are also applied by the system.

(3) **Extraction of Seismic Damage** is designed to identify main seismic damage information from satellite and airborne images by use of up-to-date methods, such as building damage by using the fully convolutional neural network (FCN)，and incremental deep learning approaches [6], the road damage by FCN, and earthquake induced landslide by use of artificial neural network [7] and random forest.

(4) **Collaborative Assessment of Seismic Disaster** is designed to assess the disaster levels synthetically and quantitatively according to the seismic damage information extracted from satellite and airborne RS images, as well as the seismic ground motion (PGA, etc.) or seismic intensity from seismic network, and the damage grade acquired by emergency field survey [5]. The collaborative assessments

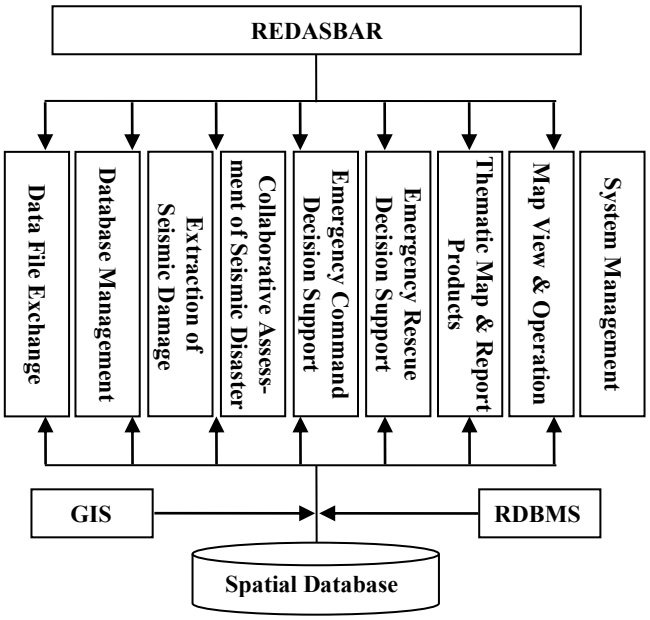

Figure 1. The main functions of the *Rapid Earthquake Disasters Assessment System in the area of "one Belt And one Road"* (REDASBAR)

of the seismic intensity distribution, or extreme earthquake-stricken area and so on, will give play to advantages of both the higher spatial resolution damage distribution extracted from RS images and higher precise PGA or instrumental seismic intensities.

(5) **Emergency Command Decision Support** is designed to give suggestion of emergency response level, the decision-making if emergency rescue team should set out, where is the best and safe camp of rescue team, and where are the rescue sites with high priority, etc.

(6) **Thematic Map & Report Products**, **Map View & Operation**, and **System Management** are common but essential functions for the system. Wang et al (2019) introduced the overall structure of earthquake emergency response demonstration platform [5]. Here they are omitted to introduce for simplify.

4. SYSTEM INTEGRATION AND APPLICATION

4.1. REDASBAR System integration

The database and main functions described above are integrated into REDASBAR system and shown in Figure 2.

In Figure 2. the upper line shows the main function menu corresponding to Figure 1. Under the main function menu there are key information of estimated or actual number of deaths, injuries, people in need of emergency resettlement, the epicenter seismic intensity, the suggestion of emergency

Figure 2. The integrated user interface of REDASBAR platform based on management cockpit

See context for a detailed description of each function.

response level, the estimated earthquake direct economic loss and the disaster area. Center-upper part is a map region showing distributions of earthquake, seismic damage, seismic intensity and many other information. Center-lower part is a table listing current earthquake event parameters. Left-upper part is a figure showing the estimated losses of each cities. Left-lower part is a table presenting the suggestion of the rescue and resettlement demands, such as number of emergency rescuers, materials for disaster relief, etc.

4.2. System application

The integrated system has been applied with functions of seismic damage extraction of buildings (Figure 3), roads and landslides from RS images based on variety of convolutional neural networks or other methods, and further the seismic damage level (Figure 4) and seismic intensity estimation on the disaster areas of earthquakes occurred in last decade. The practical quick post-earthquake assessments of seismic intensity and losses, etc. have also been implemented in last two years [5,8,11-14]. The results show an overall accuracy is up to 0.8 for seismic intensity (VII or greater, Figure 4). All the results provided useful disaster information support for the emergency common and rescue actions.

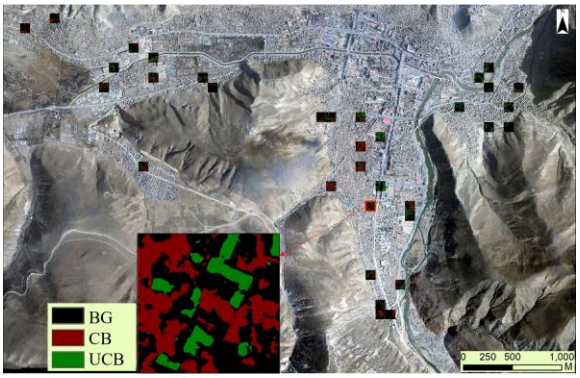

Figure 3. Remote sensing image and test area distribution with FCNN in the Yushu City of extreme disaster area caused by Yushu, Qinghai, China earthquake with Ms7.1 occurred on April 14, 2010 [8].
CB-clapsed building; UCB-un-clapsed building; BG-background

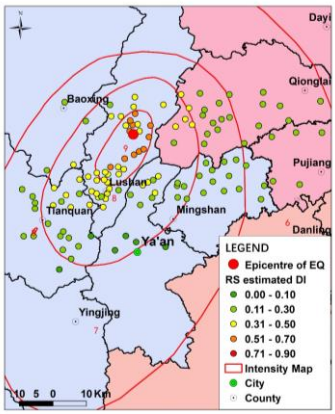

Figure 4. Seismic Damage Index (RDI) estimated according to the building damage level extracted from remote sensing image on the disaster area of Lushan, Sichuan, China Ms7.0 earthquake occurred on April 20, 2013 [9,10].

5. CONCLUSION

The paper introduces REDASBAR system, as an operational system according to space-air-ground integrated observation data and many up-to-date methods (as mentioned in section 3 of the paper) and models developed by the research group of the authors through the national key R&D Program of China (2017YFB0504104) led by the corresponding author, applied for earthquake emergency command and rescue action. In addition, the innovative features of the system are the integrated application of space-air-ground data, the emergency stage-based design of functions, interfaces and products, so as to improve the efficiency and effect of emergency response. The primary applications in recent earthquake events occurred in China have shown potential ability to support the earthquake emergency command and rescue action.

6. ACKNOWLEDGEMENT

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