Digital disaster evaluation and its application to 2015 M_s8.1 Nepal Earthquake

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Abstract. The purpose of the article is to probe the technique resolution of disaster information extraction and evaluation from the digital RS images based on the internet environment and aided by the social and geographic information. The solution is composed with such methods that the fast post-disaster assessment system will assess automatically the disaster area and grade, the multi-phase satellite and airborne high resolution digital RS images will provide the basis to extract the disaster areas or spots, assisted by the fast position of potential serious damage risk targets according to the geographic, administrative, population, buildings and other information in the estimated disaster region, the 2D digital map system or 3D digital earth system will provide platforms to interpret cooperatively the damage information in the internet environment, and further to estimate the spatial distribution of damage index or intensity, casualties or economic losses, which are very useful for the decision-making of emergency rescue and disaster relief, resettlement and reconstruction. The spatial seismic damage distribution of 2015 M_s8.1 Nepal earthquake, as an example of the above solution, is evaluated by using the high resolution digital RS images, auxiliary geographic information and ground survey. The results are compared with the statistical disaster information issued by the ground truth by field surveying, and show good consistency.

1. Introduction

The satellite and airborne high resolution digital RS (HRS) technologies have been developed fast since 1990s. The new technologies have been applied widely to the earthquake disaster monitoring and assessment. The typical and successful application evens are those of 1999 M_s7.6 Taiwan earthquake of China, 2003 M_s6.3 Bam earthquake of Iran, 2004 M_s9.0 earthquake and tsunami of Indonesia, 2008 M_s8.0 Wenchuan earthquake of China, 2010 M_s7.0 earthquake of Haiti, and 2011 M_s9.0 earthquake of the Pacific coast of Tohoku of Japan, etc. The high resolution image based methods have been widely studied for the extraction of building damage, earthquake induced geological disasters such as landslide, and road damage. While, as the mass RS data with high resolution and complexity of seismic damage features in image, The extraction of seismic damage are usually interpreted visually from images up to now. The effect of automatic extraction of seismic damage from HRS is remain in improvement. By the way, the conventional image pre-procession, seismic damage extraction and assessment in personal computer or intranet environment need also to be improved. At present, as the fast development of internet technology, it is available to interpret the seismic damage through resource sharing and collaboration over Wide Area Network. The RS data process and seismic damage analysis platform has changed from 2D map system to the 3D digital earth system with the development of digital earth techniques [1,2]. This enhances greatly the ability of seismic damage interpretation. The paper probes the digital earth based seismic damage extraction and assessment techniques with HRS images, discussed the effect of the application mode through the case study of 2015 M_s8.1 Nepal earthquake.

2. The basic idea of collaborating interpretation of seismic damage based on Digital Earth System (DES) on internet environment

As the same RS images are similar in spectrum and spatial resolution in whole disaster area, the RS based seismic damage interpretation is monotonous repetitive work. The precision of computer based automatic interpretation need to be improved. Although higher precision seismic damage distribution will be obtained by visual interpretation, the efficiency is relatively low and cannot meet the needs of timeliness requirement of decision-making for emergency and rescue. The development of seismic damage interpretation system based on DES solves the problem in a certain degree. On a digital earth platform, the RS data will be pre-processed, enhanced and shared (published) in the server-side, then a large number of users can view simultaneously the damage information on digital earth windows (3D) in multi-angles and the details in the client-side, in which the accuracy and timelines will be improved obviously through the parallel extraction of seismic damage by a large number of users in internet environment (figure 1).

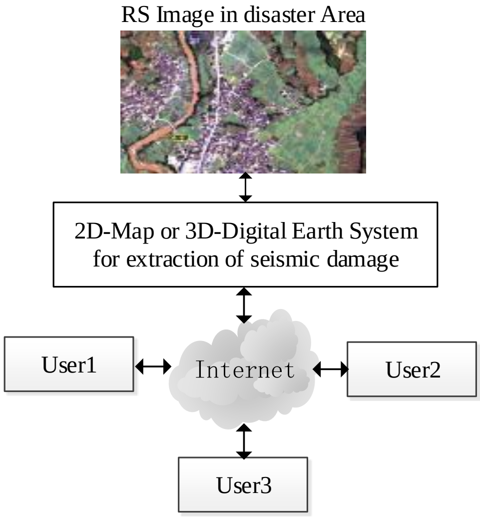


Figure 1. Work mode for seismic damage extraction based on Digital Earth System in internet environment.

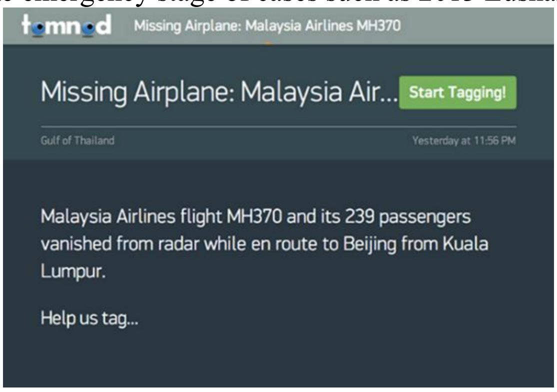
The examples of internet based disaster information extraction system will be found in the Internet environment. Such as the “DigitalGlobe FirstLook” developed by the DigitalGlobe Corporate [3]. The system provides to the volunteers the latest block images of a catastrophe events, for example, the Hurricane, the aircraft accident such as Malaysia Airlines (MH370, figure 2a), or the event such as 2015 M_s8.1 earthquake of Nepal; The volunteers will be allocated different block images for viewing, finding and locate the suspected damaged objects, and then reporting them (providing the information) to servers of DigitalGlobe.

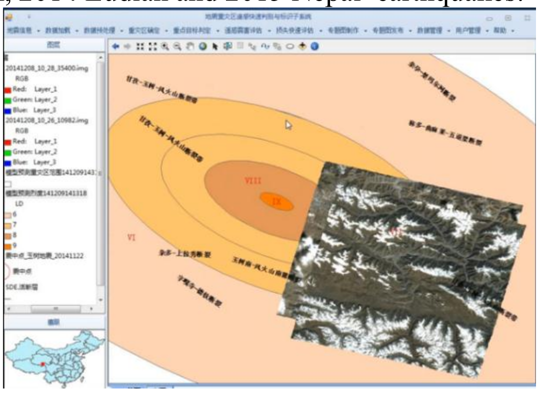
In order to improve the application ability of Chinese earth observation infrastructure for disaster reduction, the "National coordination system & data sharing service platform for spatial data acquisition, application & emergency response", also known as the "Reservoir emergency response platform", was developed by the Academy of Opto-Electronics (AOE), Chinese Academy of Sciences (CAS),under the grant of the Ministry of Science and Technology (MOST) of China [4]. The platform provides functions to coordinate various civil aerospace resources to acquire RS images of the disaster stricken area, and disseminate the data to relevant institutions involved in disaster reduction as soon as possible. The platform has been playing an important role in spatial data sharing of emergency response for Yushu earthquake in Qinghai, China, Lushan earthquake in Sichuan, China, Lushan earthquake in Sichuan, China, etc. by the authors.

The system is only a collecting and sharing centre of the earth observation data for emergency response without functions of damage extraction.

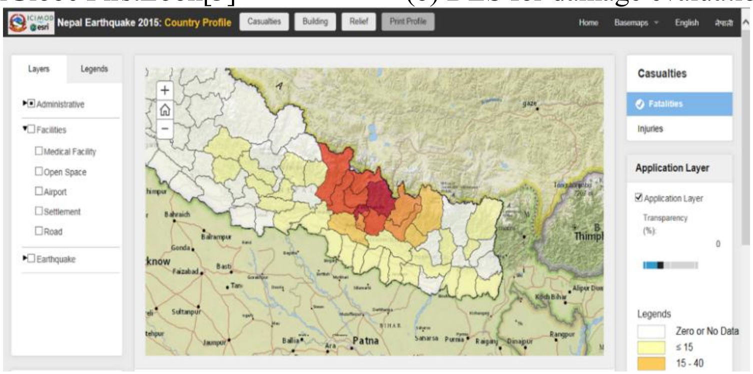
Other example is the information system of rescue and relief of 2015 M_s8.1 Nepal earthquake (figure 2c) by The International Centre for Integrated Mountain Development (ICIMOD), in which all the information associated the administrative, population and economic, casualties and geohazards, rescue as well as geographic data can be accessed. Although there are no interpretation functions in the system, the abundant information is very helpful for the disaster identification, decision-making of rescue and relief etc.

The last example is a digital earth system for the seismic damage evaluation (figure 2b) developed by the Institute of Earthquake Science (IES), CEA (Wang et al, 2015). The system has functions of fast estimation of seismic intensity, seriously damaged area identification, or the disaster information such as building damage, road damage, as well as earthquake induced landslides etc. based on the post-earthquake RS images. The system runs in the internet environment and thus provide a fast and 3D visual damage interpretation by multi-users, which plays a very important role in damage identification in the emergency stage of cases such as 2013 Lushan, 2014 Ludian and 2015 Nepal earthquakes.





(a) DigitalGlobe FirstLook[3] (b) DES for damage evaluation by IES,CEA[2]



(c) Information system of rescue and relief of 2015 M_s8.1 Nepal earthquake by ICIMOD [5]

Figure 2. Examples of damage interpretation system or information platform based on 2D map (block image) or 3D digital earth in internet environment.

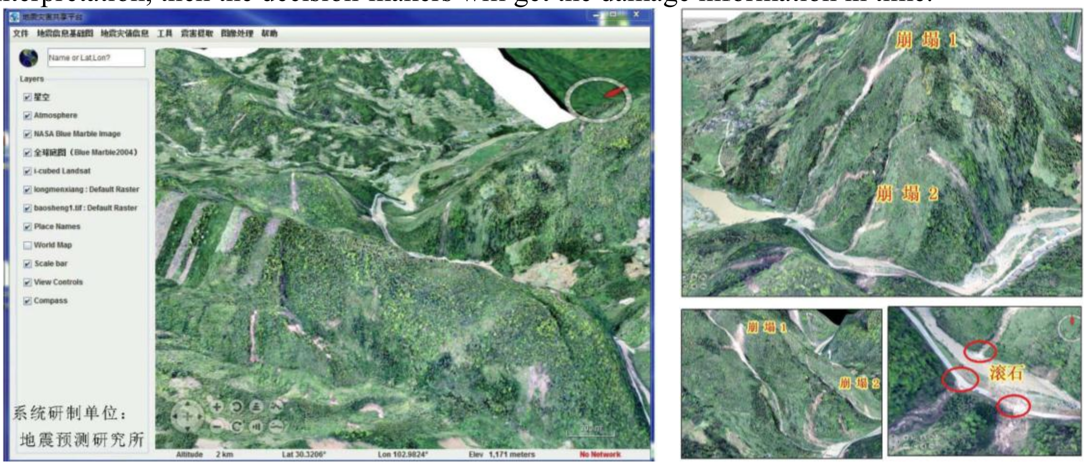
3. General functions of DES-based quantitative evaluation of seismic damages

The seismic intensity is usually applied to present the disaster scale and extent, essential for the emergency rescue and relief. According to "Seismic Intensity Scale of China" (GB/T 2008), the seismic intensity can be determined by the seismic damage index, the latter will be estimated quantitatively by field survey. based on the individual building damage, but it usually takes too long time to meet the need of emergency rescue. Wang et al (2003,2008) developed a RS-based seismic damage estimation method [7,8]. It estimates quantitatively the seismic damage index based on the individual building damage grades extracted from satellite or aerial borne very high resolution remote sensing images (VHR) acquired immediately after an earthquake. The damage index in a settlement, as statistical unit, is the sum of proportion of each building damage grade weighted by the mean damage index (1.0, 0.5, 0.0 respectively to collapsed, partial collapsed and un-collapsed grades). The seismic damage index equivalent to the ground truth on each residential unit will be obtained through the conversion relationship between damage indices by the field survey and by extraction from RS images of historical earthquakes [9].

The conventional method extracts the damage grade of individual building from 2D RS images by visual identification or automatic classification of damage grades. But the precision and timelines is usually low. The digital earth system provides a new tool to interpret the building damage, landslide or other earthquake induced geological disasters with stereo and more accurate images in 3D visual environment developed by IES, CEA [1,2], as shown in figure 3. Besides, the DES runs as a client on the Internet, which implicates that many users have possibility to join the interpretation work at the same time and will meet the needs of timelines in the emergency stage.

The DES for damage evaluation developed by IES,CEA has functions in the earthquake emergency stage as following [1]:

(1) To provide RS image data management functions such as upload and publish of RS data.
(2) To provide maps of background in disaster area, such as the administrative zoning map, earthquake epicentre distribution, population distribution, building distribution, chorography map etc.
(3) To view the pre- and post-RS images in earthquake-stricken areas.
(4) To extract damages of buildings and lifeline systems, landslides and other disasters from RS images on DES by internet users.
(5) To provide services of real-time collection of damage information interpreted by internet users and publish at the server-side. Thus the users can understand the process and take collaboration of interpretation, then the decision-makers will get the damage information in time.



(a) The main interface of DES (b) The collapse hazard and rock shed

Figure 3. The application of DES, developed by IES,CEA, to interpretation of geological disasters induced by 2013 M_S7.0 Lushan earthquake. The text shows collapse; Circle shows rock shed.

4. The DES-based quantitative evaluation of building damages due to 2015 earthquake, Nepal.

A strong earthquake with M_S8.1 occurred near Gorkha, Nepal at 11:56 am (6:11am, UTC) on April 25, 2015 (84.7°E, 28.2°N) with a depth of 20 km. 34 minutes later, a strong aftershock of M_S7.0 occurred with a depth of 30 km in the area near Pokhara (84.8°E, 28.3°N) to the northeast of and about 5 km away from the epicentre of the main event. About 12 hours later, another strong aftershock of M_S7.1 occurred to the southeast of the main earthquake area (85.9°E, 27.8°N) at 12:54 pm on April 26 (UTC +5:45), with a depth of 10 km. 17 days later, still another huge earthquake of M_S7.5 struck Nepal (86.1°E, 27.8°N) at 12:50 on May 12, with a depth of 10 km. The earthquakes caused extensive damage to buildings and thousands of deaths and injuries It is reported that, by the end of May, the death toll is about 8953, among which 218 caused by the event occurred on May 12.

After the earthquake occurred, many satellites immediately acquired high remote sensing images, such as WorldView, GF1/2, ZY2/3, et al. in disaster areas during the emergency stage. We used images of GF and ZY for disaster estimation, which were applied to support the emergency and rescue. After that the RS images, including WorldView (0.5m), were used to support the extraction of building damages, lifeline system damages and landslide et al., which is applied by China team of field investigation of damages and losses in the disaster areas in Nepal during from June 6th to 20th, 2015. The disaster information was extracted mainly with DES before and during the field work stage (figure 4).

(a) 3D view (from northwest to southeast)

(b) 3D view from southwest to northeast

(c) The collapsed frame house

(d) The hazard and rock shed of

Figure 4. 3D view (a & b, from Worldview image) and photos (c & d, by field survey) of building damages in Chautara, Sindhupalchok, induced by 2015 Nepal earthquakes.

Compared to 2D view, images on DES will provide more clear disaster information and its possible causes which might be observed from multiple orientations. The RS image features of building damages, landslides and other disasters will be established by comparison and analysis of RS images and field survey as examples shown in figure 4.

Based on the processing and analysing of the pre- and post-earthquake high resolution RS images, combined with the field survey, the building structure types and their damages were interpreted. Then the distribution of damage level of buildings due to Nepal earthquake was obtained and shown in figure 5 (Wang et al, 2015). The results show that, the spatial distribution of building damage exists obvious influence of the combination of different structures such as stone, masonry and RC frame buildings, the locations of main event and strong aftershocks, as well as the distribution of active faults in the disaster area. The seriously collapsed areas are mainly located surrounding the epicentres of main event (M_s8.1) and strong aftershock (M_s7.5). But the two regions are separated in space. Those residential areas with very few buildings collapsed are large enough into one region. The distribution is identical to the damage distribution determined by ground survey [11].

5. Discussion and Conclusion

The authors in the article reviewed the advance of RS-based methods and techniques of disaster information extraction and evaluation, probed the technique resolution and examples of collaborating interpretation of seismic damage with 2D map system and 3D digital earth system (DES) based on the internet environment, introduced the general functions of DES-based quantitative evaluation of seismic damages developed by the Institute of Earthquake Science, China Earthquake Administration. Then described the application of DES to the seismic damage extraction of 2013 Lushan, China earthquake and 2015 Nepal earthquake.

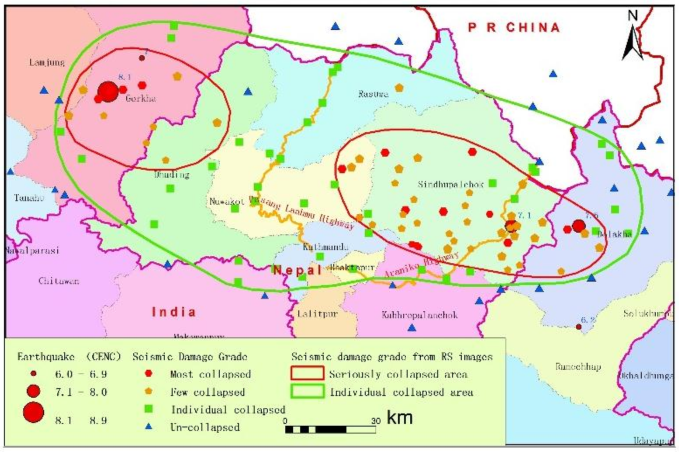


Figure 5. Distribution of damage grade of buildings due to M_S8.1 Nepal earthquake interpreted from RS images [10].

The primary application of DES in the earthquake emergency and later field survey and loss estimation of latest damage earthquake events, such as Lushan earthquake and Nepal earthquake et al, shows great advantage in the seismic damage information extraction. It featured faster, more precise which are crucial to the decision-making for emergency and rescue. While more effort should be put to realize a good service-oriented, closely collaborative on internet, digital earth system for emergency seismic damage information interpretation.

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