Quantitative Detection of Damage in an Earthquake from Low Resolution Satellite Images

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Key words: earthquake damage rapid assessment, remote sensing image, spatial match, grey scale match, change detection

SUMMARY

In the emergence situation after a large earthquake, fast evaluation of the damage is really necessary for rescue team and recovery plan, even if it is quite rough. Remote sensing image provides a new information source for rapid estimation of earthquake damage. In the recent years, achievements on identifying seriously damaged area by remote sensing are reported, some of them are from high resolution images. A case study is presented in this paper, to see if a quantitative estimation of isoseismals can be drawn out from low resolution satellite images.

The Bachu earthquake (M=6.8) occurred on February 24, 2003 in Xinjiang, China, and destroyed large number of houses. Satellite images with low resolution (10m), pre- and post-Bachu earthquake, were adopted in this study. They are matched by a new method to reveal the gray scale change from the earthquake. Change detection is carried out. A probabilistic model for earthquake damage evaluation is preliminarily developed, by comparing the results of image process with the detail information from the post earthquake ground survey.

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1. INTRODUCTION

Earthquake is a fearful disaster. It can kill thousands of people in few minutes. Once it happened, we must assess the hazard, organize the succors, and rescue the wounded. Many earthquake examples told us: the faster assess, the more persons be saved.

Remote sensing image can be acquired very fast, can mirror the objective world entirely and distinctly, and provides a new information source for earthquake damage rapid evaluation. It is convenient, fast, effective way to evaluate earthquake damage with remote sensing data is all along a problem commonly attended by researchers in both areas of disaster prevention and reduction and of remote sensing technology application. Went through the initial stage of visual estimation, remote sensing image digitally processing based earthquake damage rapid evaluation method gets a delightful progress, along with the very fast development of digital image process technology, and the enhancement of positioning accuracy of remote sensing spatial data. The earthquake damage evaluation method by means of remote sensing image change detection and digital features that recently published is still in research stage. The researchers got the distribution of severely damaged area (Ellen Rathje 3, J.F. Zhang. 5,6, A. X. Dou. 1 etc), nevertheless seismologist divide the damaged area into different intensity zones, if the intensity of damaged area by changing detection between pre- and post- event satellite images can be detected, we can provide the necessary information for earthquake reconnaissance.

Among various methods, this paper investigates and discusses the effectiveness of change detection using low resolution satellite image. The remote sensing images pre- and post-Bachu earthquake on February 24th, 2003, in Xinjiang, southwest China, acquired by satellite SPOT (10m resolution), are collected in this paper. A. X. Dou (2003) compared the image pair of the same area coming from pre- and post-Bachu earthquake by calculating the subtraction, ratio, correlation and comparability coefficient, then got the damage area by making threshold. In this paper the pre- and post- earthquake images are matched by a new method to strengthen the gray scale change caused by earthquake. Analysis of subtraction and ratio images, the results of changing detection is carried out. A probabilistic model for earthquake damage evaluation is preliminarily built by comparing the analysis results with the detail information from the post earthquake ground survey. This paper attempts to build a method to identify the intensity of the damaged area in the satellite images.

2. BACHU EARTHQUAKE

2.1 Earthquake Effects

The Bachu earthquake (M=6.8) occurred on February 24, 2003 in southern Xinjiang China at 39.29 degrees north latitude and 77.15 degrees east longitude, according to the China Seismological Bureau. Depth of focus is 25.2 kilometers. Bachu is a country nearby Jashi country in southern Xinjiang, so this earthquake is called Kashi-Bachu earthquake too. This region located at the intersection of the three tectonic units: Tianshan mountain drape, Pamirs tectonic arc and Talimu basin. The occurrence frequency of earthquake in this region is highest in China (figure1).

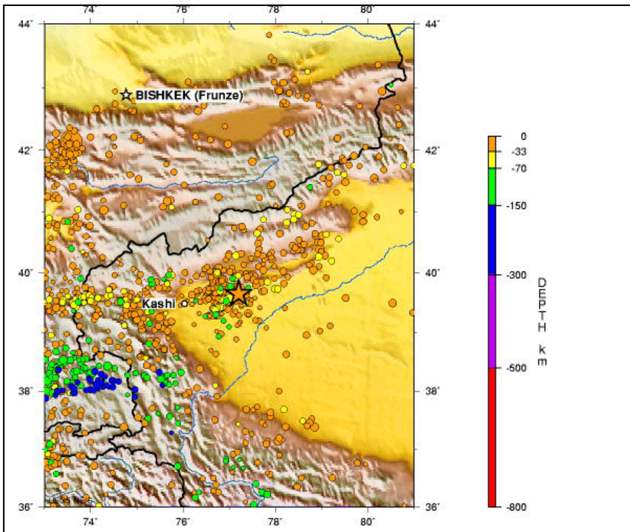


Figure1. Epicenter and the earthquake history of this region (From 1990 to present, plate boundaries in yellow)

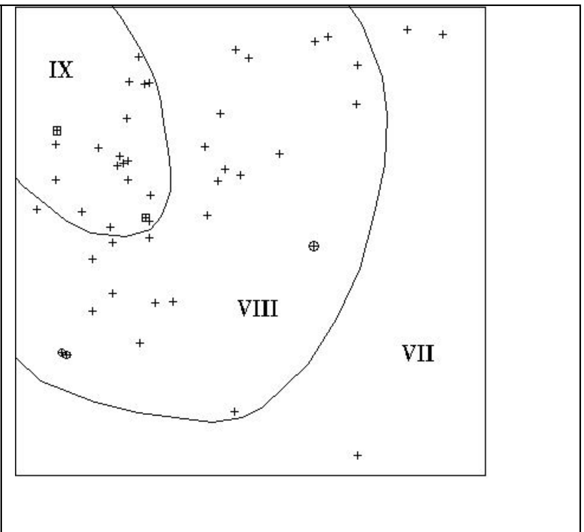


Figure2. Intensity zones of the damaged areas included in the satellite images according to ground survey reports.

In Bachu County seven villages of Qiongkuqiake Township suffered more devastation, Alager and Selibuya townships were badly damaged. Several other places including Jiashi County, Kashi city, Bachu County, Artux County and Markit County also felt strong tremors. There are 268 victims, 2058 persons seriously injured, and 4000 slightly injured. Additionally, 38, 259 farm animals were killed, 36,562 houses collapsed, 900 classrooms were broke down and 16 hospitals were destroyed.

The damaged areas of this earthquake are all poor counties. The houses in these areas were constructed by wooden beams and columns structure, and earthen wall. This type of structure was vulnerable to the earthquake. According to the post-earthquake ground survey reports and the satellite images, the author made a map (figure2) representing the intensity zones of damaged areas included in the satellite images.

2.2 Satellite Data

Two sets of satellite images were obtained from the SPOT satellite. The pre- and post-earthquake images were acquired on October 29, 2000 and March 5, 2003 with 10m resolution. A fraction was segmented surrounding the epicenter after Images were accurately registered.

3. CHANGE DETECTION

3.1 Histogram Matching

Among the various methodologies, change detection is a common method. Change detection algorithms can identify changed areas between pre- and post-earthquake images, but may be influenced by various changes not associated with the earthquake (e.g., vegetation cycle, clouds, sun angle etc). The differences of sun angle and atmospheric conditions at the times the two images were collected can be mitigated by co-register, but the images still contain changes that are not earthquake related, and thus may induce to incorrectly identify some damage areas. Ellen Rathje (2004) mitigated the error by detecting the changes between the pre-earthquake image and two post-earthquake images acquired in different time.

In this paper, a new method of histogram matching was studied to strengthen the change caused by earthquake. Earthquake destroyed the houses, and then the grey scale of these houses was changed between the pre- and post-event satellite images; on the contrary, the grey scale of other areas (e.g. field or desert) have less change caused by earthquake than residential areas. So the grey scale change of residential areas was useful to detect earthquake damage that ought to be strengthened, and the change of other areas ought to be lightened.

The author initially cut out the residential areas from the pre- and post-event satellite images referring to the local map to get the areas outside of residential areas image pair, and then matched the histogram of this image pair to get the changing formula to adjust the histogram of the whole post-event image. It was an attempt to improve the grey scale matching of pre- and post earthquake remote sensing images to strengthen the change caused by earthquake.

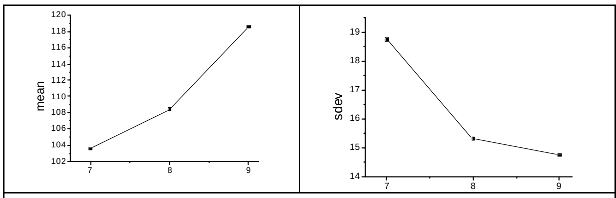
3.2 Image processing based on mathematics approaches

The subtraction and ratio algorithms were widely used in change detection. The two methods were used to calculate the gray scale of the two corresponding pixels in the same location in the image pair according to formula (1), (2).

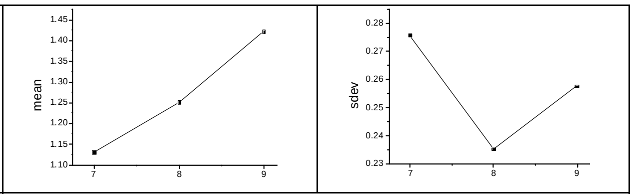
$$Z = |X - Y| \quad (1) \qquad Z = \frac{|Y - X|}{X} \quad (2)$$

X is the grey scale of a pixel in pre-earthquake image. Y is the grey scale of a pixel in post-earthquake image. Z is the grey scale of a pixel in operated image.

After the image pair for change detection is prepared, the grey scale difference and ratio are calculated by means of ENVI software. The statistic analysis for the residential areas with post-earthquake ground survey data is carried out, the values of mean and standard deviation of regions with intensities IX, VIII and VII are obtained, they changing obviously along with intensities IX, VIII and VII (graph1,2,3,4). Then a preliminary probabilistic model for earthquake damage evaluation is built.



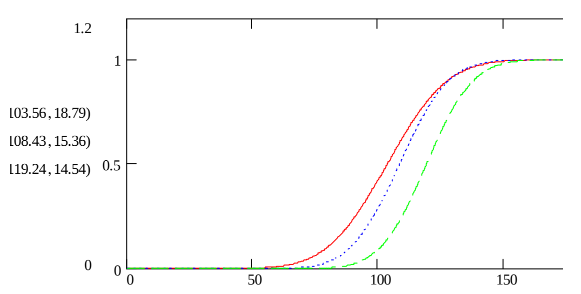
Graph1, 2. The mean and standard deviation of residential areas in intensities VII,VIII and IX of difference image.



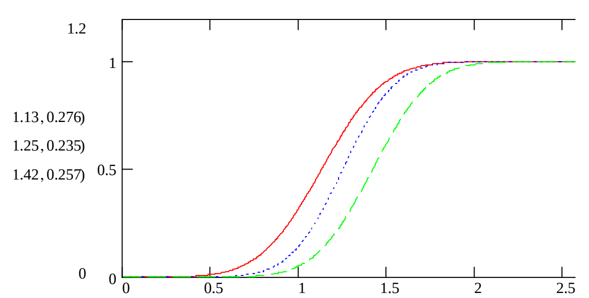
Graph3, 4. The mean and standard deviation of residential areas in intensities VII,VIII and IX of ratio image.

3.3 A Probabilistic Model

This paper chooses normal distribution function to describe the grey scale probability distribution in different intensities according to the calculated mean and standard deviation. Graphs 5, 6 show the grey scale probability distribution in different intensities of residential areas in difference and ratio images.



Graph5 The grey scale probability distribution in different intensities of residential areas in difference image.

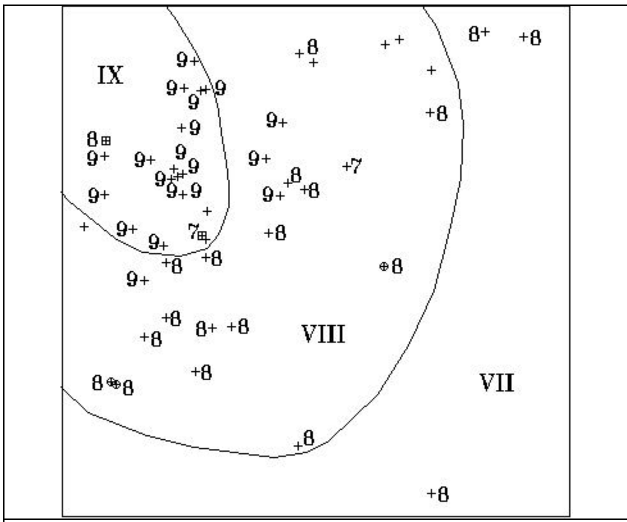


Graph 6 The grey scale probability distribution in different intensities of residential areas in ratio image.

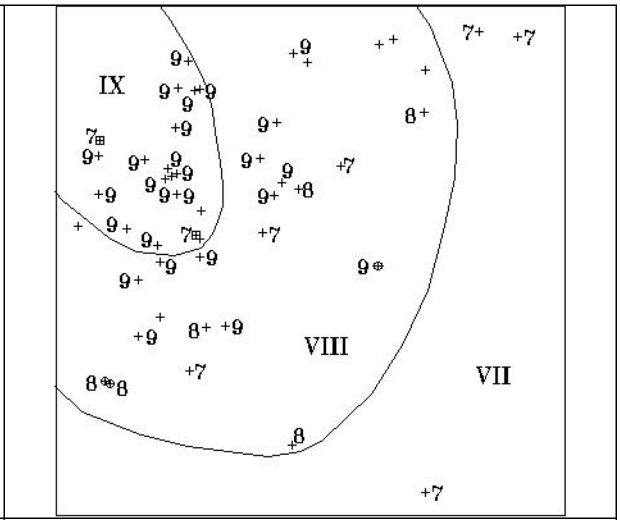
The red real curve, the blue dot curve and the green dashed curve are corresponding to intensities VII, VIII and IX.

3.4 Identification of the intensities of damaged areas

As internal checking, the probabilities of three intensities in every residential area are calculated from the values of mean and standard deviation of the grey scale in the area in difference and ratio images, the intensity with the maximum probability is compared with intensity in the area from post earthquake ground survey (graph 7, 8), to show the reliability of the method developed in this paper.



Graph 7 Identification of the intensities of damaged areas in difference image.



Graph 8 Identification of the intensities of damaged areas in ratio image.

The intensities of the residential areas in IX intensity zones with maximum possibilities were consistent with the ground survey result both in difference and ratio images. In graph 7, the identification of the intensity of residential areas in VIII intensity zones take on good prospect, but have bad result in VII intensity zones. In graph 8, the intensity of the residential areas in VII intensity zones can be identified, but the identification in VII intensity zones is not so well.

4. CONCLUSIONS

This study examined the potential use of low-resolution satellite images to identify the intensity of the damaged area. The county of Bachu, which was damaged during the Feb.24, 2003 Northern Xinjiang Bachu-Jiashi earthquake, was used as a test bed for this investigation. The pre- and post-earthquake images (10m resolution) of Bachu were obtained and used to investigate earthquake damage detection using change detection methodologies based on mathematics.

This paper attempted to put forward a new method to strengthen the grey scale change caused by earthquake, and lighten the change caused by other reasons. The method was actualized in histogram matching of Bachu pre- and post-earthquake satellite images. This approach had a good effect in the following change detection between the pre- and post-earthquake satellite images.

The ratio and subtraction algorithms were used to calculate the grey scale difference of the pixels between the pre- and post-earthquake. According to the statistic analysis, the author attempt to describe the probability distribution in different intensities of residential areas with normal distribution function both in difference image and ratio image. In comparison, the intensity of the residential areas in IX intensity zone can be identified with maximum probability and the identification of the intensity of the residential areas in VII, VIII intensity zone were difficult, but this difficult can be solved by combining the two identification result coming from difference and ratio images.

Through the validation of this earthquake case, the paper built a preliminary method for earthquake damage evaluation based on the present result with the method of remote sensing images change detection, and it needed more earthquake cases to verify and developed.

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