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Image Change Detection for Earthquake Damage Assessment

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Abstract: The work presented here is concerned with the problem of Earthquake damage assessment using multi temporal satellite images. Remotely sensed data can provide valuable information for disaster assessment such as Earthquakes, Volcanic Eruptions, Landslides, Floods, Storm Surge, Hurricanes, Fires and Drought etc. Earthquake is one of the unavoidable natural hazards that cause lots of damages and problems to the economy, environment and the whole life of people. Prevention of earthquake is rarely achieved and such events continue to pose increasing threat to life and property. After the earthquakes, there is a need for rapid, accurate and reliable damage information in the critical post event hours to guide response activities. In this work, we focused on image change detection based Earthquake damage assessment. For experimental purpose, we have collected the pre and post panchromatic and multi-spectral images of Haiti earthquake which was occurred in 12 Jan 2010. Various image change detection methods are suggested in the literature such as simple differencing, statistical change detection, likelihood ratio test, PCA etc. We have proposed a Minimum Description Length (MDL) based method for image change detection. The results generated by the proposed method are quite promising in comparison to other change detection methods and are helpful for precise earthquake damage assessment.

Keywords: Change detection, Damage assessment, Minimum Description length, Remote sensing

I. INTRODUCTION

A natural disaster can be defined as some impact of an extreme natural event on the ecosystem and environment, and on human activities and society. The concept relies on the interaction of a natural agent—the hazard—with human vulnerability to produce a risk that is likely to eventually materialize as a destructive impact. In this context natural disaster are distinguished— earthquake, tsunami, landslide, flood, cyclone etc that we normally face in our country [11]. Earthquake is one of the unavoidable natural hazards that cause lots of damages and problems to the economy, environment and the whole life of people. Prevention of earthquake is rarely achieved and such events continue to pose increasing threat to life and property. After the earthquakes, there is a need for rapid, accurate and reliable damage information in the critical post event hours to guide response activities. In reality it is still difficult to obtain that information rapidly, because of interruptions in communication systems and access difficulties in remote areas [12].

Disaster damage assessment is an important task. Remotely sensed data provide valuable information for disaster damage assessment. Rao, examines the use of remotely sensed data in three different phases (Mitigation, Preparedness and Recovery/Response) of disaster management for different disasters such as Earthquakes, Volcanic Eruptions, Landslides, Floods, Storm surge, Hurricanes, Fires and Drought [7]. The most important and challenging part of the disaster management is the recovery phase, since the situation after the event is usually not clear little is known about what happened exactly, where it happened and how many people were affected. For effective allocation of limited resources, there is a need for information about the extent and the concentration of damaged area in critical hours following a disaster. Moreover, this information needs to be accurate, reliable and provided in a timely and appropriate manner. After a disaster, damage to critical lifelines, in particular telecommunication, roads, and power supply systems, creates limitations for the communication with the emergency agencies to get information about the current situation. In the case of the 2001 Gujarat earthquake, identification of affected villages took three days (Economic & Political Weekly, 2001). On the other hand, information coming from the field may not be reliable and accurate due to the stress and confusion in disaster area. Therefore, there is a strong need for information, which does not depend on actual access to the disaster area. Remote sensing systems can provide valuable information for response activities. The use of remote sensing technology provides quantitative base information about damage and aftermath monitoring to assist recovery/response operations and help response and relief specialist in the decision making.

Earthquake damage assessment using remotely sensed data can be carried out using multi temporal approach, which requires two images pre-damage and post-damage of the affected area that are compared to identify changes. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Image change detection algorithms are used to perform the Earthquake damage assessment. The goal of an image change detection algorithm is to identify the set of pixels that are "significantly different" between the post damage image and the pre damage image; these pixels comprise the change mask. Various image change detection method have been suggested such as simple differencing, statistical change detection, likelihood ratio test, PCA etc.

The proposed work presented the novel image change detection method for precise earthquake damage assessment using multi temporal satellite images. The rest of the paper is organized as follows. Section 2 gives the review of work that has already been done in this area. Section 3 gives the overview of the proposed methodology. Section 4 describes the experimental results and their analysis. Section 5 concludes the paper.

II. LITERATURE REVIEW

Detecting regions of change in images of the same scene taken at different times is of widespread interest due to a large number of applications in diverse disciplines. Early change detection methods were based on the signed difference image D(x) = I2(x)−I1(x), and such approaches are still widespread. The most obvious algorithm is to simply threshold the difference image. We denote this algorithm as "simple differencing". There are several methods that are closely related to simple differencing. For example, in change vector analysis (CVA) [1], [2], [3], [6], often used for multispectral images, a feature vector is generated for each pixel in the image, considering several spectral channels. The modulus of the difference between the two feature vectors at each pixel gives the values of the "difference image". Image ratioing is another related technique that uses the ratio, instead of the difference, between the pixel intensities of the two images [9]. DiStefano et al. [6] performed simple differencing on sub sampled gradient images.

In [5], the multi temporal images are modeled as MRFs in order to search for an optimal image of changes by means of the Maximum a Posteriori Probability (MAP) decision criterion. The algorithm involves the simulated annealing energy minimization procedure. In [4], objects are first extracted from each image to be analyzed and a site model is constructed containing image segmentation maps and extracted object features, then, Object-level Change Detection (OLCD) is accomplished by comparing objects extracted from a new image to objects recorded in the site model and the differences are highlighted. D. Ozisik presented a post earth quake damage assessment using satellite and serial video imagery [7]. However, the use of remote sensing technology in disasters damage assessment is still limited.

III. PPOPOSED METHDOLOGY

The overall schematic diagram of the proposed work is shown in figure 3.1. In the present work, we have used geometrically corrected pre and post images of the same scene of the Earthquake disaster area. These images are the input to the image change detection algorithms. Image change detection algorithm generates the changed mask image that is helpful for precise earthquake damage assessment.

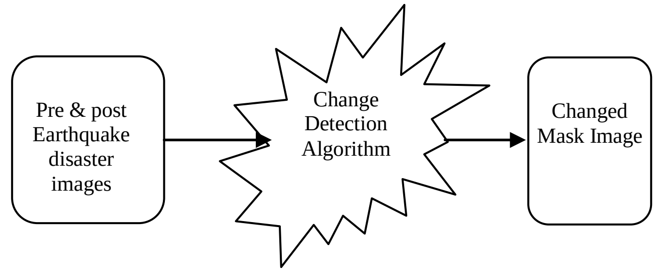


Figure 3.1: Earthquake damage assessment using multi temporal images

Image Change detection techniques try to detect and locate areas which have changed between two or more observations of the same scene. These changes can be of different types, with different origins and of different temporal length. We are given a set of images of the same scene taken at several different times. The goal is to identify the set of pixels that are "significantly different" between the last image of the sequence and the previous images; these pixels comprise the change mask. Various image change detection method have been suggested in the literature such as simple differencing, image ratioing, statistical change detection, likelihood ratio test, PCA etc. In the present work, we focuses on earthquake disaster images (before/after) and try to detect the change using change detection techniques for damage assessment.

We have proposed a novel Minimum Description Length (MDL method for image change detection based earthquake disaster damage assessment. The MDL principle selects the hypothesis that more concisely describes (i.e., using a smaller number of bits) the observed pair of images. We believe MDL-based model selection approaches have great potential for "standard" image change detection problems[8]. Following are the steps to perform image change detection using Minimum description length based method:

A. We estimate the noise variance for the pre and post disaster images for no change and change region detection. For the null hypothesis H_0, the variance is estimated from regions with no change where the variance in the difference image is lowest (Sigma0). For the alternative hypothesis H_1, the variance is estimated from regions with change where the variance in the difference image is largest (Sigma1).

B. We set the precision 0.01 and this precision is used to calculate the number of bits needed to store a floating point number. Calculation of number of bits needed to store the two sigma's with the given precision is performs by the following:

log2_s0 = log2(abs(sigma0)/precision + 1)
log2_s1 = log2(abs(sigma1)/precision + 1)

C. No we use the MDL principle for change detection. The Difference image for each block is assumed to follow a Gaussian distribution with mean and standard deviation that depend on H_0 and H_1. Now find the Gaussian normalizing constants using-

$$K1\_0 = (N/2)*\log2(2*pi*H_0\hat{}2)$$
$$K1\_1 = (N/2)*\log2(2*pi*H_1\hat{}2)$$

D. and normalizing constants using

$$K2\_0 = \log2(e)/(2*H_0\hat{}2)$$
$$K2\_1 = \log2(e)/(2*H_1\hat{}2)$$

E. Now we calculate the Description lengths for H_0 and H_1 using the formula:

H0_DL = log2_s0 + log2_mu + K1_0 + K2_0*(d_u'*d_u)

H1_DL = log2_s1 + log2_mu + K1_1 + K2_1*(d_u'*d_u)

where log2_s0, log2_s1 are the number bits needed to store two sigma's K1_0, K1_1, K2_0 and K2_1 are the Gaussian normalization constants and normalizing constants respectively.

F. Finally, we pick the one with the Minimum Description Length using:

```
if (H1_DL < H0_DL) then
        chmask(i,j) = 1
else
        chmask(i,j) = H0_DL - H1_DL
```

where chmask(i,j) is the binary change mask to show the difference between pre and post disaster images.

IV. EXPERIMENTAL RESULTS

The Earthquake damage assessment system is implemented using MATLAB. One of the screen shot of Earthquake disaster damage assessment system is shown in figure 4.1. We performed the change detection algorithms on pre and post damage images of the disaster area for precise earthquake damage assessment. For experimental purpose, we have collected the pre and post panchromatic and multi-spectral images of Haiti earthquake which was occurred in 12 Jan 2010. These images are the collection of Digital Global Imagery [10]. Figure 4.2(a) and (b) shows the panchromatic and Multi Spectral images of Haiti earthquake, respectively. The PCA, IHS, Wavelet, and the proposed IHS and wavelet integrated transform are employed to fuse the two image data sets. Figure 4.2(c) to (f) shows the fused images.

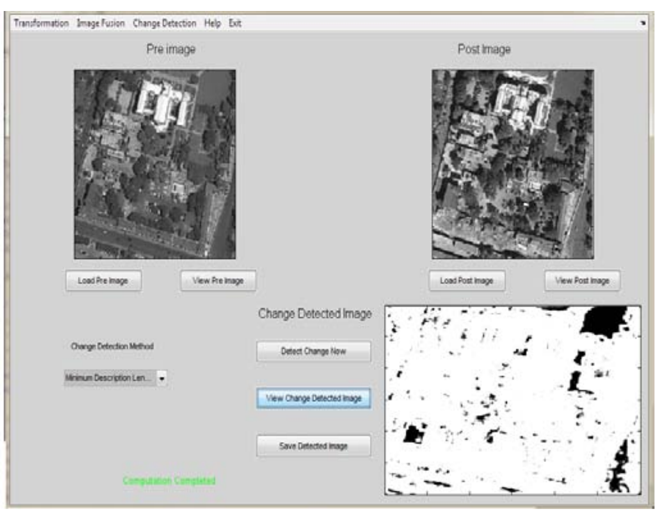
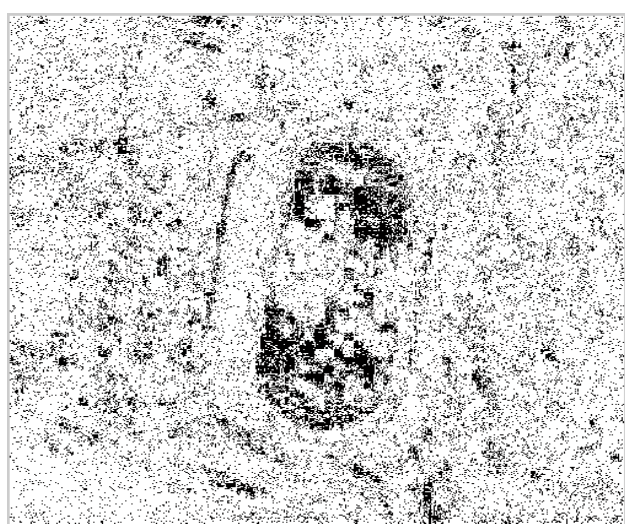


Figure 4.1: Screen shot of Image Change Detection

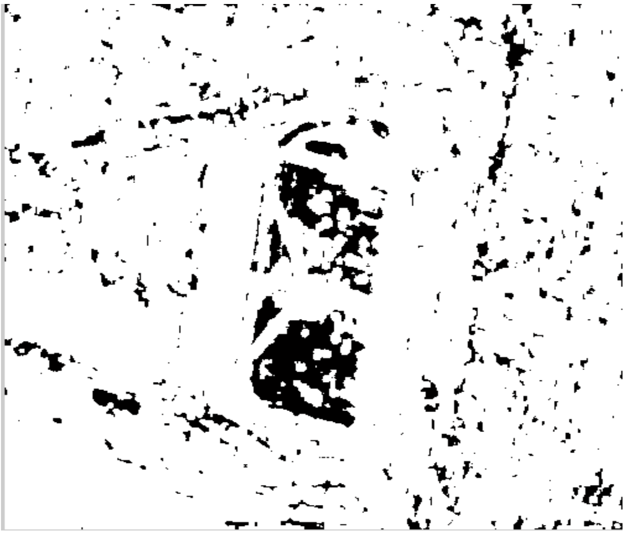
Various image change detection techniques such as simple differencing, Statistical change detection, Likelihood ratio test(LRT) and the proposed Minimum Description Length(MDL) principle based approach are implemented for image change detection. The change detection results of one image set are displayed in Figure 4.2.

(a)

(b)

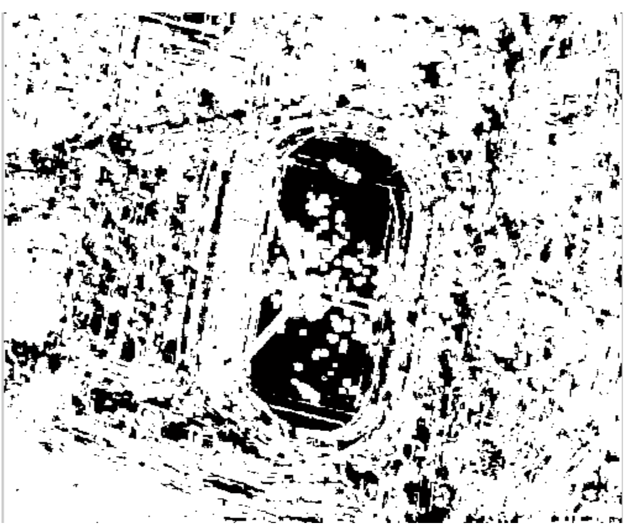


(c)



(d)

(e)



(f)

Figure 4.2: (a) Pre image; (b) Post image (c) Simple Differencing result; (d) Statistical Change Detection result; (e) Likelihood Ratio Test result; (f) Result of the proposed Minimum Description Length Based Method

The qualitative analysis i.e. visual analysis of the generated results clearly indicates that the results generated by the proposed approach are quite promising in comparison to other approaches. However, quantitative analysis is also required to analyze the generated results correctly. To quantify the performance of the change detection algorithms, we obtained receiver-operating-characteristic (ROC) curves for each algorithm by plotting the correct detection probability, P_D against the false alarm probability P_{FA} based on a devised truthing map for the dual set of grass-foot-prints. The area under the ROC curve determines the level of competency in the correct classification. A value of 0.5 suggests a mere hazarding of guesses whilst a value of 1 indicates correct classification every time.

To detect a change, an empirical threshold was applied to the changed map, this threshold value is critical because this affects how many changed pixels are missed and how many unchanged pixels are falsely detected. To avoid this issue of comparing thresholds a ROC curve is employed. This methodology is evaluated for each threshold value in a range whilst calculating the percentage P_D of changed pixels were positively detected and P_{FA} of unchanged pixels classified as changed. The ROC curve is a plot of (P_D Vs P_{FA}) values as the threshold changes. This will show the range of performances possible, without having to directly select comparable threshold values.

The ROC curves for all implemented Change detection algorithms are shown in Figure 4.3. In the figure, Dotted line: statistical Change Detection; solid line: Minimum Description Length testing; dashed line: Simple Differencing; dash-dot line: Likelihood Ratio Test.

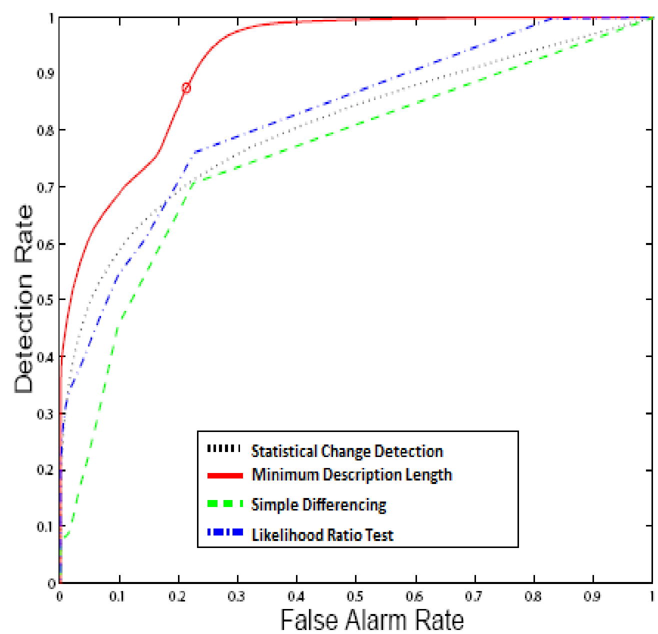


Figure 4.3: Receiver operating characteristics (ROC) curves for comparing the performance of image change detection algorithms

In these curves, the smaller thresholds are at the bottom-left portion of the curves increasing to a maximum at the upper right corner. Figure 4.3 indicate that the value of (P_D vs $P_{FA)}$ is almost equal to 1 in minimum description length change detection method in comparison to other methods. So that the result generated by the MDL based change detection have high possibility of correctness in comparison to other methods.

V. CONCLUSIONS

This research was proposed a minimum description length (MDL) based Image Change Detection method for earthquake damage assessment. The MDL principle selects the hypothesis that more concisely describes the observed pair of images. The Difference image for each block is assumed to follow a Gaussian distribution with mean and standard deviation that depend on hypothesis. Various image change detection methods such as simple differencing, Statistical change detection with Gaussian noise model, Likelihood Ratio Test were also analyzed, and their change detection results were compared to the MDL based method using visual both qualitative and quantitative approaches. Promising results were achieved with the proposed change detection method in comparison to other methods.

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