D-31 # BUILDING DAMAGE DETECTION IN THE 2010 HAITI EARTHQUAKE USING TEXTURE FEATURES OF HIGH-RESOLUTION SAR IMAGES

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ABSTRACT The 2010 Haiti earthquake occurred on January 12, 2010 with Mw7.0. It caused the collapse of many buildings in Port-au-Prince, the capital city of Haiti. In this study, multi-temporal TerraSAR-X (TSX) images were employed to detect the changes/damages in the urban areas of Port-au-Prince. The SAR backscattering coefficient data before and after the earthquake were utilized for extracting collapsed/damaged buildings based on the texture measures in terms of the Grey Level Co-occurrence Matrix (GLCM) within the layover areas of buildings. The results of mean, variance and entropy showed better agreement with the distribution of collapsed buildings than other GLCM features. About 75% of the collapsed buildings were extracted correctly.

KEY WORDS: Texture Features, GLCM, TerraSAR-X, Building Damage, 2011 Haiti Earthquake

1. INTRODUCTION

The 2010 Haiti earthquake with Mw7.0 occurred on 12 January 2010 at 4:53 PM local time. The event affected many parts of the country including cities like Jacmel, Petit-Goave, Leogane, and Port-au-Prince, the capital city of Haiti. About 105,000 buildings were totally destroyed and over 208,000 were damaged (Government of the Republic of Haiti, 2010). In order to grasp damage situation quickly after a natural disaster strikes, remote sensing is recognized as an effective tool. Especially, Synthetic Aperture Radar (SAR) sensors can observe objects on the earth surface without depending on sunlight and cloud-cover conditions.

Recently, the texture analysis of remotely sensed imagery became popular especially in land-cover classification (Haralick et al. 1973). Using the texture of pre- and post-event optical satellite images, damage detection of buildings has been conducted by several researchers (Miura et al. 2012). But only a few researches exist about building damage detection using SAR images.

In this study, the characteristic of texture measures in damaged buildings are examined using TerraSAR-X images obtained before and after the 2010 Haiti earthquake. The result of the texture analysis is used to extract collapsed buildings and its accuracy is examined.

2. THE STUDY AREA AND IMAGERY DATA

The study area focuses on Port-au-Prince shown in **Fig. 1**, which is one of the most severely affected areas in the 2010 Haiti earthquake. The yellow square in the figure shows the target area in this study. A color composite of the pre-event (September 17, 2008) and post-event (January 14, 2010) images is shown in **Fig. 2(a)**, in which several changed areas could be confirmed by increased (red) and decreased (cyan) backscatter. The acquisition mode of the images was StripMap with HH polarization, in the ascending path with the incidences angle of 39.32 degrees. Radiometric calibration was carried out to get the backscattering coefficient (sigma naught σ^0) with the pixel size 1.25 m. After this conversion, two pre-processing steps were applied.

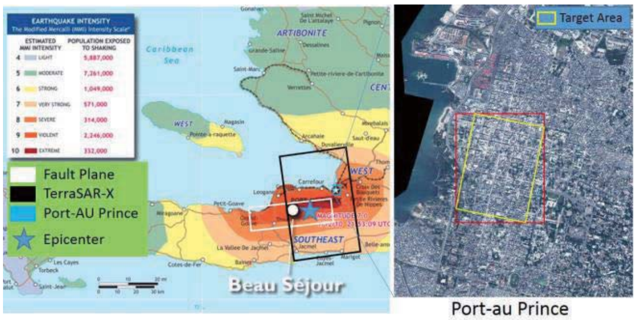

Figure 1. The 2010 Haiti earthquake and the study area

UNITAR/UNOSAT (2010) created building damage data for all the buildings in Port-au Prince by visual interpretation of high-resolution optical satellite images and aerial photos. The data include geo-referenced point data of the buildings and their damage classifications (4 grades) based on the EMS-98 scale (European Seismological Commission 1998), shown in **Fig. 2(c)** on the post-event optical image. The pre-event optical image taken by QuickBird is also shown in **Fig. 2(b)**. Based on this information, Miura et al. (2012) created the building footprints for a selected area in **Fig. 2(d)** in order to examine the spatial characteristics. In SAR images, building roofs are displaced toward the satellite in the

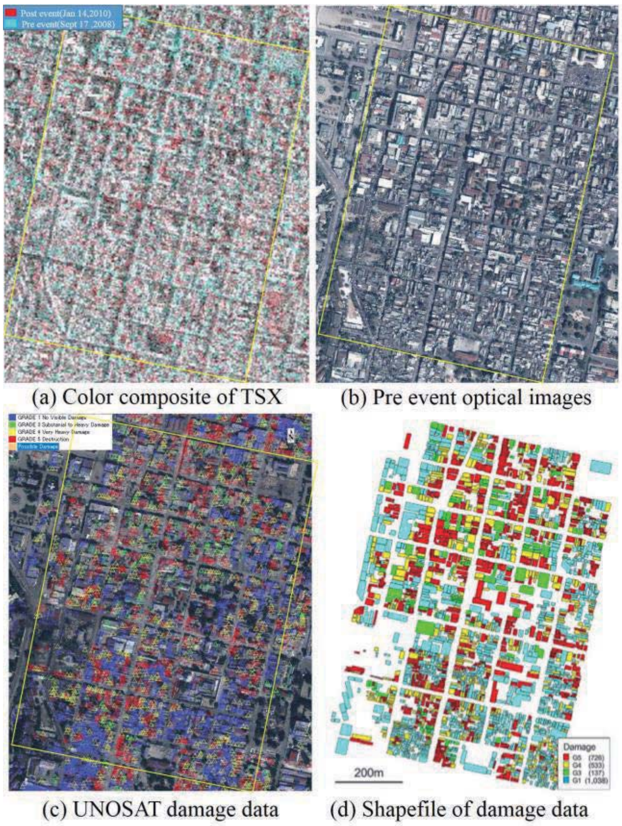

Figure 2. The target area: (a) color composite of TSX, (b) the pre-event QuickBird, (c) the post-event WorldView-2 image with the damage data by UNOSAT, (d) shapefile created by Miura et al. (2012).

ground range (Liu et al. 2013). Thus we used the shifted shape file of each building to examine how the GLCM works in the building damage extraction.

There are previous studies on the 2010 Haiti earthquake using TSX images (Uprety et al. 2013, Miura et al. 2016) and some using the texture of optical images (Miura et al, 2012). In this study, we try to figure out how the texture of SAR images works in building damage extraction in the 2010 Haiti earthquake.

3. TEXTURE MEASURES BASED ON GRAY LEVEL CO-OCCURRECE MATRIX

Among several image texture measures, the second-order measure known as the Grey Level Co-occurrence Matrix (GLCM) was used to see the relationship between the groups of two (usually neighbouring) pixels in the original image. The Lee filter was not applied to keep the texture's variety. The result of texture calculation is a single number representing the entire window. This number is put in the place of the central pixel of the window, and then the window is moved one pixel and the process is repeated for the entire image. The result depends on the direction of analysis (Horizontal: 0° or 90°, and Diagonal: 45° or 135°). In this study, we examine eight different GLCM features to see which texture is the best index to detect damaged buildings.

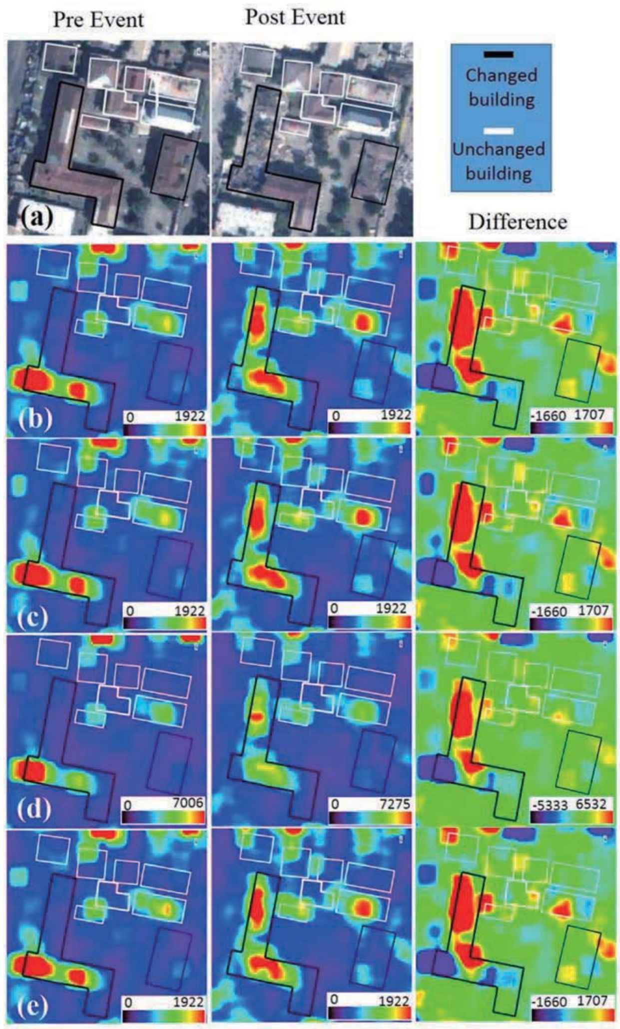

Figure 3. Change situation of GLCM variance in a sample area: (a) the pre- and post-event optical images, (b) the standard index, (c) displacement change, (d) grey-level change, (e) direction change.

Window size 11×11 (13.75m×13.75m) were applied to SAR image to calculate the GLCM value considering the building size (10 to 15 m in one length) in the target area. First, we examined the differences by changing the direction, displacement and Grey-level parameters in the GLCM's *variance*.

Figure 3 shows a small sample area within the target area, in which the black polygons are collapsed (G5) buildings whereas the white squares were other damage-grade (G1-G4) buildings after the earthquake. As shown in **Fig. 3(b)**, we set the standard point (Angle 0°, Displacement 1 pixel and Grey-level 32). Then we changed each index to find the best agreement as shown in **Fig. 3(c)-(e)**. The difference of Grey-level 64 shows a better result than that of Grey-level 32, only some missed detections seen, especially in the top and right direction of the right changed building. The changes of angle and displacement in the building damage detection were not so significant as shown in the figure. Hence in this study, Angle 0°, Displacement 1 pixel and Grey-level 64 were adopted in extracting damaged buildings.

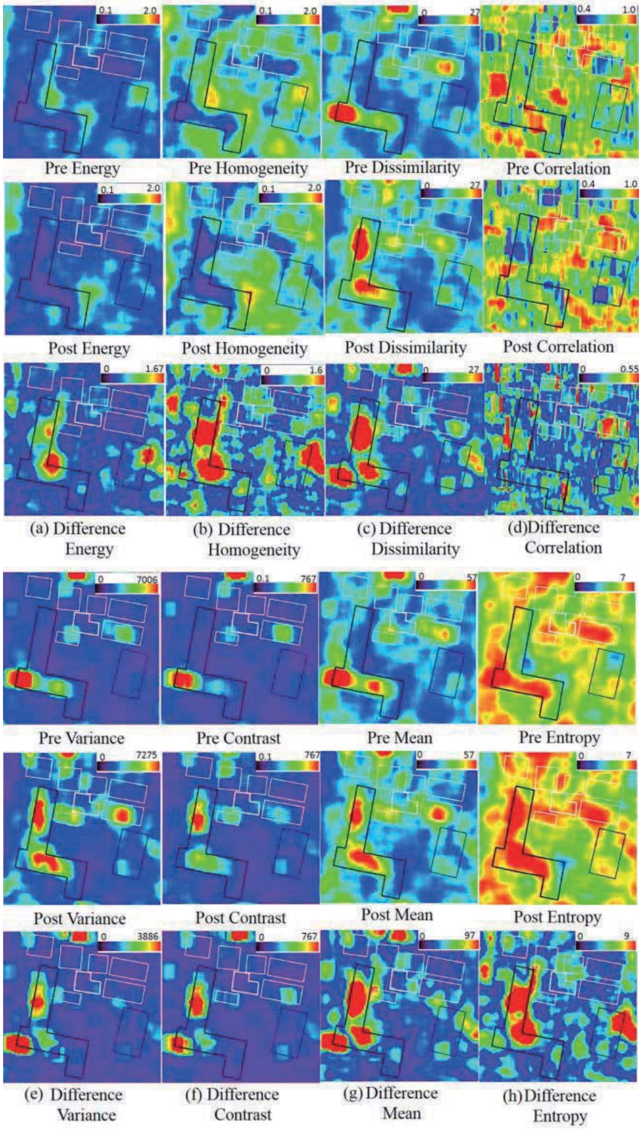

Figure 4. GLCM features: (a) energy, (b) homogeneity, (c) dissimilarity, (d) correlation, (e) variance, (f) contrast, (g) mean, and (h) entropy.

The result of the GLCM texture measurement is shown in **Fig. 4**, where the top row shows the results for the pre-event image, the middle row for the post-event image and the bottom row for the absolute difference. Generally each texture measure shows a good result, but the result of correlation **(d)** is not good as the others. The results for variance, contrast and mean show almost the same pattern because they belong to the same statistical texture group. According to **Fig. 4**, the texture features of the difference show more significant characteristics for the damaged and non-damage buildings. Thus, the indicators of the difference will be used in this study in order to examine how texture feature works in damage detection.

In order to choose the best texture measure in building damage extraction, we calculated the extracted percentage of each indictor in an individual building (2 damaged and 9 non-damaged buildings) in this area (**Table 1**). The

Table 1. Percentage of the extracted pixels by the texture features in the building polygon.

	Building	Percentage %							
		Energy	Homogeneity	Dissimilarity	Correlation	Variance	Contrast	Mean	Entrophy
		≧0.4	≧0.4	≧3	≧0.25	≧272	≧50	≧7.8	≧2.1
G5	1	7.7	33.6	34.5	9.0	29.1	23.3	39.7	32.1
	2	13.1	17.2	4.5	9.4	0.0	0.0	4.1	19.2
	Total	8.9	29.7	27.4	9.1	22.1	17.8	31.2	29.0
G1-G4	3	0.0	0.6	2.0	36.8	0.0	2.0	5.1	0.6
	4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	12.6	0.0	0.0	0.0	0.0
	6	0.0	15.1	0.0	6.3	0.0	0.0	0.0	7.7
	7	0.0	0.0	2.5	0.7	0.0	0.0	6.5	0.0
	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9	0.0	0.0	0.0	0.5	0.0	0.0	6.8	0.0
	Total	0.0	2.2	0.7	10.1	0.0	0.4	2.2	1.2

percentage was calculated by the ratio of the number of high-value pixels (red and yellow colors in **Fig. 4**) to the total number pixels inside the building polygon, which was used as the G5 threshold of each indictor. As shown in the table, the results of homogeneity, dissimilarity, variance, mean and entropy for the G5 buildings are more than 20%, and that of mean shows the highest value of 31.2%, shown in yellow color. For the less-damaged (G1-G4) buildings, energy and variance showed the best result (0%), which means no commission error in this example, shown in the orange color. Entropy showed good combination of the percentages for the G5 and G1-G4 buildings comparing with the other indicators. According to this result, we chose mean, variance and entropy as the indicators for extracting possible damaged buildings.

4. EXAMINATION OF COLLAPSED BUILDINGS BY PROFILE LINE

Examination using a profile line was performed in order to observe the characteristic of each indicator for collapsed buildings, as shown in **Fig. 5**, in which the green line means the pre-event and the red line the post-

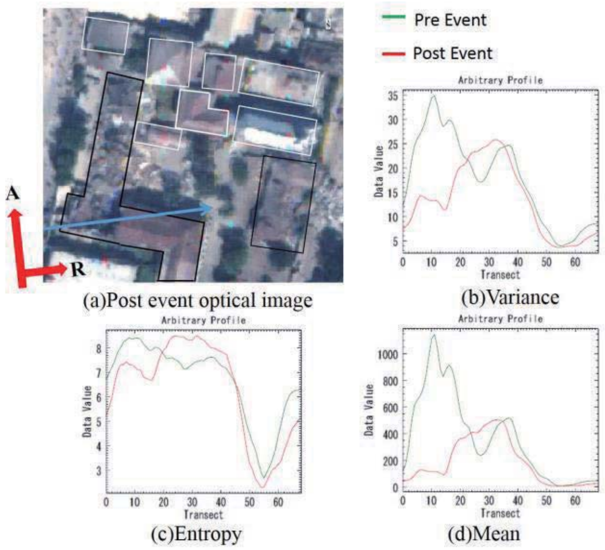

Figure 5. Examination of collapsed buildings by Profile Line: (a) Post event optical images with profile line, (b) Variance, (c) Entropy, (d) Mean.

event indices. As shown in **Fig. 5 (b)** and **(d)**, the variance and mean present the similar trend, the post-event values for the collapsed part of the building (Profile line 8 m to 28 m) were decreased while the unchanged part showed no much change. On the other hand, the entropy showed no clear change for the collapsed part, as in **Fig. 5 (c)**. These observations are considered to be caused by the changes in the building's roof and wall (Zakeri et al. 2015).

5. EXTRACTION OF COLLAPSED BUILDINGS USING TEXTURE FEATURES

The obtained variance, entropy and mean features from the absolute difference image are shown in **Fig. 6**, where the white polygons indicate G1-G4 (in EMS-98) buildings and the black polygons G5 buildings. The high texture values inside a black polygon indicate the changes occurred after the earthquake. The variance for the collapsed (G5) buildings shows less change than those for the entropy and the mean. A detailed comparison on the relationship between the damage grades and the texture values will be provided in the near future.

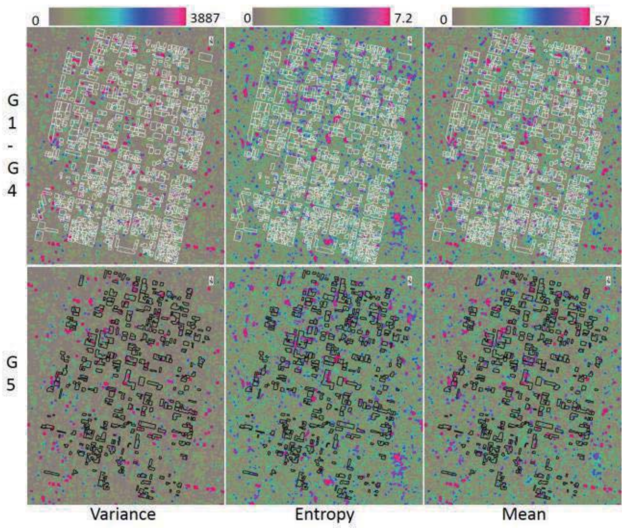

Figure 6. GLCM features to be used as indicators in building damage extraction for the entire study area: (a) variance, (b) entropy, (c) mean.

6. CONLCUSIONS

Building damage extraction using the GLCM texture features was attempted for the TerraSAR-X image pair acquired before and after the 2010 Haiti earthquake. In this study, Angle 0°, Displacement 1 pixel, window size 11×11 and Grey-level 64 were adopted for the texture analysis when extracting collapsed buildings. The entropy, variance and mean features showed better agreement with the distribution of collapsed buildings than other features. Thus, those three indicators were used to classify G1-G4 and G5 buildings. Examination using profile lines was also performed in order to observe change characteristics of the texture measures at the damaged location.

A further study will be conducted to demonstrate the usefulness of texture measures for damage extraction of buildings from high-resolution SAR data.

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