Detection of survived buildings in tsunami-affected areas using SAR imagery. A case of study of Onagawa town

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1. Introduction

The 2011 Tohoku Earthquake Tsunami caused large damage in coastal communities along the northeast Japan coast. After the event, emergency response as well as relief actives where supported by remote sensing technologies employing satellite imagery. Although high-resolution optical images can easily capture changes on land surface, their acquisition are limited by weather conditions. Synthetic Aperture Radar (SAR) data, on the other hand, captures the ground surface regardless the weather and daylight conditions.

This study proposes a methodology to detect surviving buildings in tsunami-affected areas by using high-resolution SAR data. The main assumption within this method is that radar backscattering signals generated from survived buildings are stronger and isolated in tsunami-affected areas. Thus, this method calculates a two level segmentation and detects a survived building based on its geometric characteristics in the SAR intensity data. An initial application is conducted in Onagawa town by using two post-event TerraSAR-X images. Preliminary results suggest that survived building higher than two stories are well detected. However, buildings of one story are difficult to be detected because of the backscattering of surrounding debris, which causes a false detection in the second segmentation level. Finally, the results are compared and validated with field survey data.

2. Study area and SAR data

This study focuses in the washed away that were buildings observed at Onagawa town (**Fig. 1a**). This town was one of the hardest hit places by the tsunami. Regarding structural damages, 82,993 building were destroyed and 155,125 partially destroyed (National Police Agency, 2014). A notable example of the tsunami impact was observed at Onagawa town where 75% of the exposed building were washed-away (Gokon and Koshimura, 2012). The six overturned buildings found in this area showed the unique characteristics of tsunami impact to building structures at Onagawa town (e.g., Fraser et al., 2013; Mikami et al., 2012).

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The SAR data is composed by two post-vent TerraSAR-X (TSX) SAR images, the first scene acquired on March 16, 2011, 5 days after Onagawa town was hit by the tsunami, and the second scene acquired on August 24, 2011. Both TSX images were captured with HH polarization in descending path (STRIPMAP mode), and provided in EEC product format, multi-look detected and projected to the WGS84 reference ellipsoid. The details of the TSX data is presented in **Table 1**. The enhanced Lee filter Lopes et al. (1990) was applied to the sigma naught CSK intensity images to reduce speckle effect. To minimize the loss of information contained in the SAR images, the window size of the filter was set as 3×3 pixels. Finally, the CSK images were resampled at 1.25 m/pixel in a square size.

3. Methodology

Considering that the radar footprint characteristics of a damaged building are strongly dependent on the type and the extent of destruction Ferro et al. (2013). This method determines from the SAR scene a layover area based on the methodology presented in Liu et al. (2014). A template is created by shifting the building footprint in the direction of the SAR sensor. For instance, in the case of the first scene, based on the acquisition angles of the TSX images, 26.28^o incidence angle and 103.0^o heading angle (azimuth), the layover width increases in 0.49 m to the west and 1.96 m to the south for every 1 m increase in building height. According to the Japanese standards, 1-story house has a minimum height of approximately 2.3 m, therefore, the initial template is set assuming a 2 m of building height. The created template is shifted in the direction of the sensor, step by step, by increasing the building height at intervals of 1 m. The final layover-template is obtained when the template leaves the layover area. A first level segmentation is used to estimate the boundary of the layover-template, a threshold was introduced to classify the CSK image to a binary format (1 and 0 for high and low backscatter areas, respectively. In the binary image, the layover-template is obtained when the number of high backscatter pixels are less than 40% of the total pixels with the template. In this study, the threshold was fixed as -2 dB based on the observed building heights.

Table 1: Acquisition parameters of the TSX data employed in this study.

	Heading angle	Look direction.	Incident angle
2011-03-16	193.87^o	Left	26.28^o
2011-08-24	190.21^o	Right	35.29^o

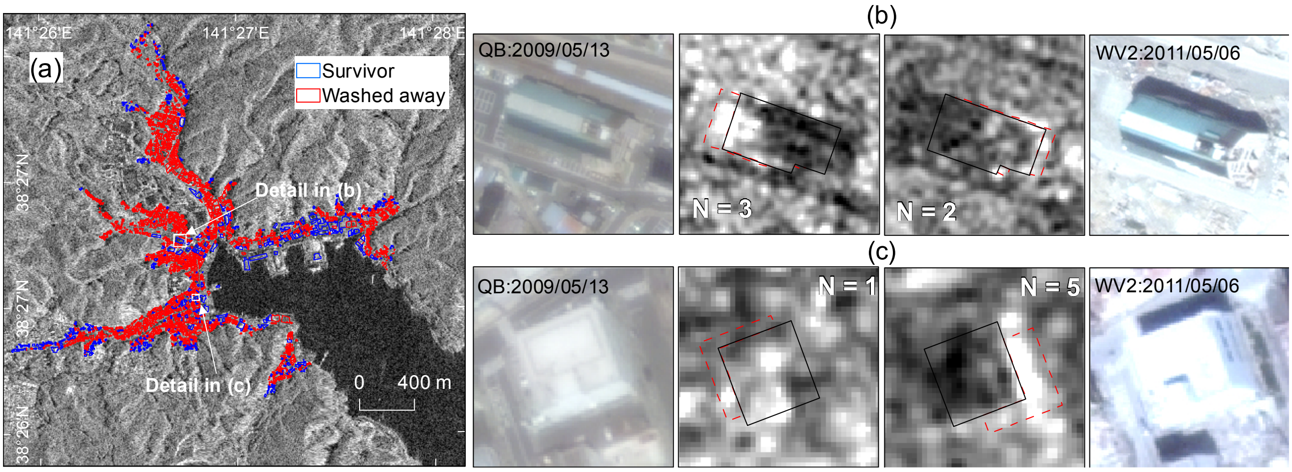

Figure 1: (a) shows the study and the MLIT survey data (footprint GIS vector data). (b) and (c) show examples of the estimated layover-template . From left to right: pre-event optical images (Quickbird: 2009-05-13), first TSX scene, second TSX scene, and post-event optical image (WorldView-2: 2009-05-13). The solid black polygon shows the GIS footprint vector, and the red dashed polygon shows the final estimated layover-template.

4. Result and Conclusion

Figure 1(b)-(c) show examples of the estimated layover-template using both SAR scenes. In the case of **Fig. 1(b)**, the initial footprint was shifted 3-times (3 story building) and 2-times (2 story building) for the first and second scene, respectively. This small difference implies that the method successfully detected the survived building in both scenes. In the case of **Fig. 1(c)**, the building footprint was shifted 1-times (1 story building) and 5-times (5 story building) for the first and second scene, respectively. In this case, the method cannot detect the survived building in the earliest scene (2011-03-16). Based on the comparison of the pre- and post-optical images, this building remained still at least 4 months after the earthquake. As a result, the building can be detected in the second scene (latest image). Therefore, in the case of **Fig. 1(c)**, the method gives a false detection due to the backscattering characteristics of the surrounding areas of the target building. In order to verify our method, the 310 survived buildings in Onawaga town, slight damage class according to the “Ministry of Land, Infrastructure, Transport and Tourism” (MLIT) survey data, were selected. An accuracy analysis gives an overall accuracy of 61% with a kappa coefficient equal to 58%. The method still need to be improved. A future work is to include optical satellite images to support the estimation of the layover-template.

In this study, a method to detect survived building using post-event SAR image was presented. The method estimates a layover-template from the SAR scenes. This method was tested using a 1.25 m resolution TSX SAR image of Onagawa town. The initial results show that the accuracy of the presented method depends on the surrounding characteristics of the target building as well as its footprint size. However, this method was implemented to combine vector and raster data in a GIS-based platform, which means that there are no limitations on the shape of the building footprint.

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