DETECTION OF BUILDING DAMAGE DUE TO EARTHQUAKES FROM HIGH-RESOLUTION SAR IMAGERY

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Damage detection of buildings soon after the occurrence of natural disasters is one of the important topics of satellite remote sensing. A number of studies have been conducted to identify damage situation of individual buildings from high-resolution multi-spectral sensors after damaging earthquakes in the world. In these studies, the damage grades of buildings were judged from optical images captured from the vertical direction. Hence the building damages such as mid-story collapse or damage to exterior walls were often overlooked because only the upper surfaces of buildings could be seen and thus such types of damage modes were mostly invisible. Although optical images can easily capture detailed earth surface information, the approach is limited by weather conditions.

In contrast, synthetic aperture radar (SAR) sensing is independent of weather and daylight conditions, and thus more suitable for mapping damaged areas promptly. Due to remarkable improvements in radar sensors, high-resolution SAR images are available with the ground-resolution of 1 to 5 m. The damage detection of urban areas using high-resolution SAR images has become quite popular recently. Due to the side-looking nature of SAR, the layover of buildings and the multi-bounce of radar among the ground and buildings occur. Utilizing the change in the backscattering intensity within the layover area of an individual building, this study attempts to detect the damage situation of building exterior walls due to the 2011 Tohoku, Japan earthquake and tsunami.

The Mw 9.0 Tohoku earthquake occurred on March 11, 2011 off the Pacific coast of north-eastern (Tohoku) Japan, caused gigantic tsunamis, resulting in widespread devastation. The earthquake resulted from a thrust fault on the subduction zone between the Pacific and North American plates. Typical building damages due to the 2011 Tohoku earthquake tsunami in our field survey were shown in Figure 1. The characteristic building damage by tsunamis is that damage was caused to building exterior walls or its lower stories, which is not the same with damage caused by strong earthquake shaking. We try to detect this kind of damage to building exterior walls using the side-looking nature of SAR. The strongest backscattering echoes from the exterior walls and double-bounce with the ground may be reduced after this type of damage.

Figure 1. Typical tsunami damage to RC and steel-frame buildings observed in our field survey after the 2011 Tohoku earthquake. The damage was concentrated to exterior walls and lower stories of buildings

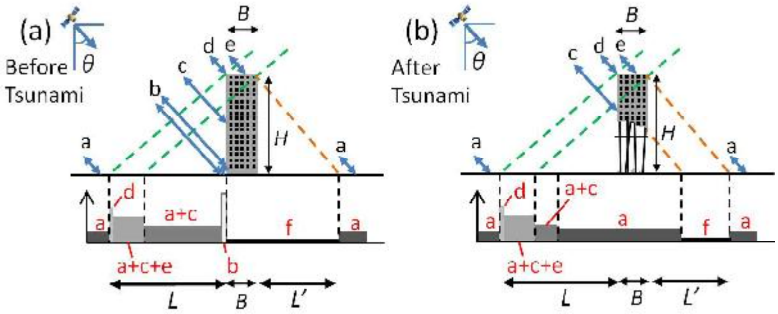

Figure 2. Schematic figure of SAR observation for an ideal tall flat-roof building. Amplitude of backscatter from an intact building (a), and that from a damaged building due to tsunami (b)

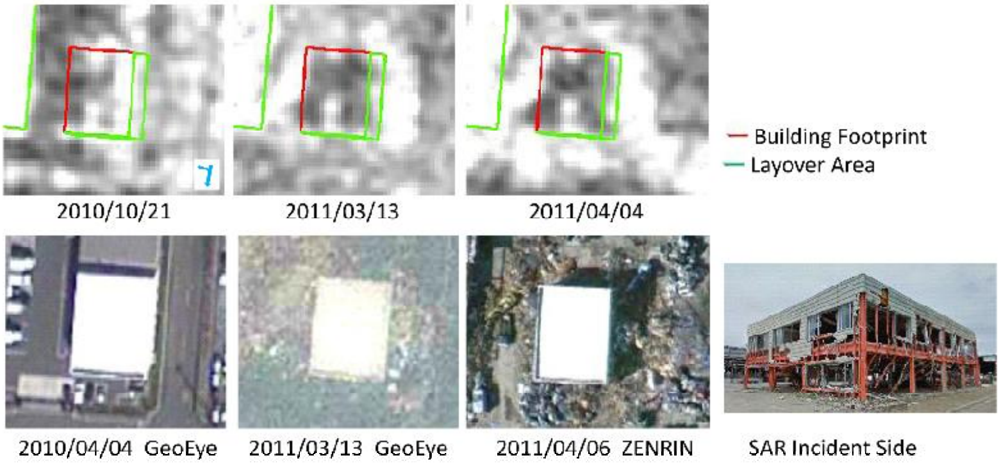

Figure 3. Close-up of the TerraSAR-X images at the three acquisition dates, the optical images of similar acquisition times, and a ground photo of radar incident side of the building extracted from Google Street View

In this study, we focus on the coastal zone of Tohoku, Japan. Three temporal TerraSAR-X images taken before and after the earthquake are employed, which we also used previously for detecting crustal movements (Liu and Yamazaki, 2013) and identifying flooded areas (Liu et al., 2013). The pre-event image was taken on October 21, 2010 (local time), while the post-event ones were taken on March 13 (two days after the earthquake) and April 4, 2011. All the images were captured with HH polarization and a 37.31° incidence angle, in a descending path. The images were acquired in the StripMap mode, and so the azimuth resolution was 3.3 m while the ground range resolution was 1.2 m.

The backscattering echoes of SAR from a stand-alone building can be shown schematically in Fig. 2, where the backscatter from the building shows layover on the ground range. In a usual case, the fringe of the roof-top exhibits strong backscatter and it leans toward to the direction of SAR illumination. The foot fringe of a building also exhibits strong backscatter due to the double-bounce of radar from the ground and building's exterior wall. The layover area corresponding to the building exterior wall is generally distinguishable in the ground-range SAR intensity image. Figure 3 shows a two-storied steel-frame building in the Sendai Port. The backscatter in the layover area was reduced after the building's exterior wall suffered from damage due to tsunami. This example demonstrates the usefulness of SAR imagery in damage detection of buildings, especially for their exterior walls.

REFERENCES

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