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Building detection and radar footprint reconstruction With automated method of single VHR SAR Images

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ABSTRACT:

To ensure a reliable, consistent, and fast extraction of the information from the complex SAR scenes, automatic information extraction methods are essential. Focusing on the analysis of urban areas, which is of prime interest of VHR SAR, in this paper, we present a novel method for the automatic detection and 2-D reconstruction of building radar footprints from VHR SAR scenes. Unlike most of the literature methods, the proposed approach can be applied to single images. The method is based on the extraction of a set of low-level features from the images and on their composition to more structured primitives using a production system.

Then, the concept of semantic meaning of the primitives is introduced and used for both the generation of building candidates and the radar footprint reconstruction. The semantic meaning represents the probability that a primitive belongs to a certain scattering class (e.g., double bounce, roof, facade) and has been defined in order to compensate for the lack of detectable features in single images. The space borne synthetic aperture radar (SAR) systems Cosmo-SkyMed,TerraSAR-X, and TanDEM-X acquire imagery with very high spatial resolution (VHR), supporting various important application scenarios, such as damage assessment in urban areas after natural disasters.

It allows the selection of the most reliable primitives and footprint hypotheses on the basis of fuzzy membership grades. The efficiency of the proposed method is demonstrated by processing a 1-m resolution TerraSAR-X spotbeam scene containing flatland gable-roof buildings at various settings. The results show that the method has a high overall detection rate and that radar footprints are well reconstructed, in particular for medium and large buildings.

Index Terms:

Building detection, building reconstruction, production system, remote sensing, synthetic aperture radar (SAR), urban areas, very high spatial resolution (VHR).

INTRODUCTION:

In the last decade, very high spatial resolution (VHR) space borne remote sensing sensors (e.g., Quick Bird, Worldview-2, Cosmo-Sky Med) acquiring data with meter or sub meter resolutions became widely available. These data have the potential to be employed for various important application scenarios, such as

[1] The monitoring of changes in urban areas .

[2] The characterization of urban areas (e.g., slum mapping).

[3] Surveillance of the effects of violent conflicts .

[4] The crisis management after natural disasters (e.g., earthquakes).

For the latter application scenario, space borne VHR synthetic aperture radar (SAR) sensors, such as CosmoSkyMed and TerraSAR-X, are of particular interest, due to their independence on the solar illumination and the relative insensitivity to the weather conditions One of the main drawbacks of VHR SAR is the complexity of the images, mainly owing to the speckle effect and the side looking geometry of the SAR sensor, hampering the interpretation of the data by non-SAR experts. This is particularly true for urban areas, where the data are mainly characterized by layover, multibounce, and shadowing effects of the buildings. Therefore, to support the widespread usage of VHR SAR, robust automatic information extraction methods are essential.

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Different techniques for building detection and reconstruction from VHR SAR images have been presented in literature. A method for the extraction of buildings and the estimation of their height from stereoscopic airborne radar images was presented While a building extraction method using dual aspect SAR data was presented.

An algorithm for building reconstruction from multi-aspect polar metric SAR (PolSAR) images was presented The polar metric information is exploited by employing an edge detector effective on polar metric images. The retrieved edges are then parameterized by means of the Hough transform to generate the building footprint hypotheses.

A method for the detection of buildings from single-aspect PolSAR data combining edge and area features with Markov random fields. Presented a semi-supervised method for the estimation of building dimensions in VHR SAR temporal scenes based on the analysis of the shape of building shadows.

MODELING OF BUILDING RADAR FOOTPRINTS IN SINGLEDETECTED VHR SAR IMAGES

The key characteristics of buildings in SAR are the layover, double-bounce, and shadowing effects which are caused by the side-looking and ranging properties of SAR sensors. To illustrate this, Fig. 1 shows a schematic view of the scattering profile of a simplified flat-roof building model. In this figure, the building in the middle, which is modeled as a rectangular box, is imaged by a sensor with incidence angle θ.

The annotations refer to backscattering from the ground surface surrounding (in this 2-D figure before/behind) the building. Acddenotes the layover area where scattering from the ground, from the vertical building front wall and from parts of the flat roof are superimposed since these parts have the same distance to the sensor.

The vertical front wall and the surface area in front of the building compose a corner reflector resulting in the bright double-bounce effect b. The scattering area that is only characterized by scattering from the roof is denoted by d.

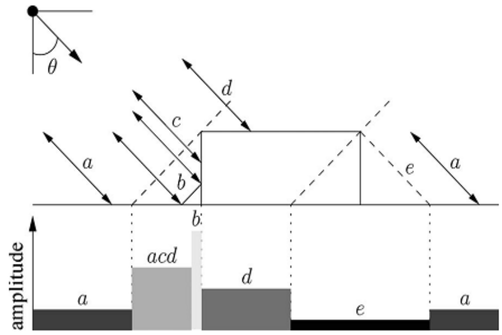

Fig. 1. Scattering model for a flat-roof building with viewing direction from left. The different gray areas at the bottom of the figure symbolize the amplitudes.

For gable-roof buildings, the theoretic scattering signature is slightly different As shown in Fig. 2, the signature has a second bright scattering feature acd at the sensor close side resulting from direct backscattering from the roof. The extent and the strength of this feature depend on the relationship between θ and the roof inclination angle α. For α=θ, the strength of this feature is maximum, whereas its extent is minimum. Moreover, we found that in actual 1-m-resolution TerraSAR-X and Cosmo-Sky Med data, this second bright scattering area is also detectable for buildings with a high aspect angle where we show actual scattering signatures from gable-roof buildings with small and large aspect angles, respectively.

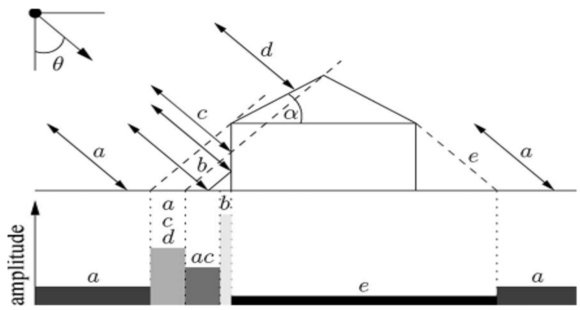

Fig. 2.
Scattering model for a gable-roof building with viewing direction from left. Here, the roof inclination angle α is smaller than θ. The different gray areas at the bottom of the figure symbolize the amplitudes.

PROPOSED TECHNIQUE FOR THE AUTOMATIC DETECTION AND RECONSTRUCTION OF BUILDING RADAR FOOTPRINTS:

The proposed technique for the automatic detection and reconstruction of building radar footprints from single VHR SAR images is suited for meter-resolution data.

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Buildings are assumed to be approximately regular parallelepipeds, with rectangular base, or compositions of parallelepipeds. The minimum building size which can be handled by the algorithm depends on the specific building characteristics.

As a reference, buildings with a base with a main side shorter than 10 m and a height lower than 5 m with no relevant scattering centers are likely to be not detected in meter-resolution images.

The radar footprints corresponding to very tall buildings have a high probability to be detected. However, additional features and rules would be necessary (with respect to the algorithm specifications reported in this paper) in order to handle properly those situations.

The algorithm does not require the buildings to be isolated. However, it may provide better results on isolated buildings. In fact, such buildings usually show a clear shadow feature, which is exploited by the algorithm to improve the detection performance. Very close buildings may be detected as single structures,

The proposed technique is composed of six main steps:

1) Preprocessing and feature extraction.

2) Generation of primitives.

3) Analysis of primitives.

4) Generation of building radar footprint hypothesis.

5) Selection of hypotheses.

6) 2-D radar footprint reconstruction.

In this section, we show the results obtained by applying the proposed technique to a real meter-resolution large SAR image. After a brief description of the used data set, we show and analyze qualitatively the results obtained on the whole image.

FIGURE-1

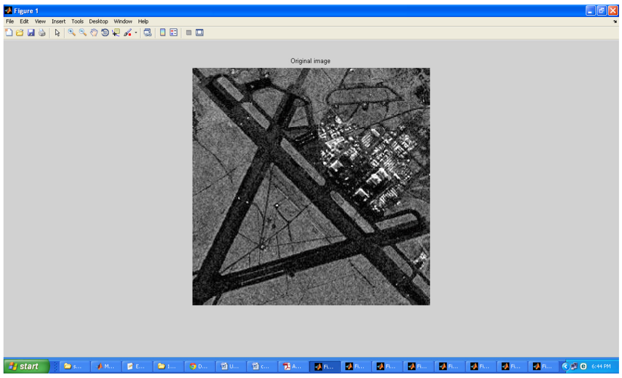


FIGURE-2

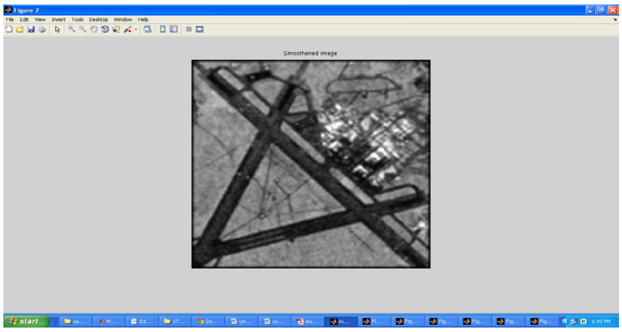


FIGURE-3

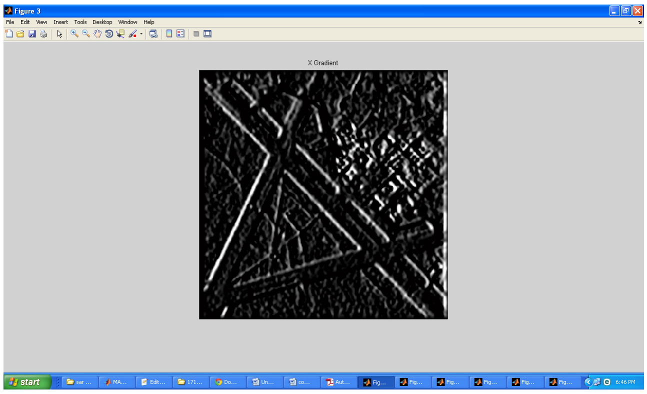


FIGURE-4

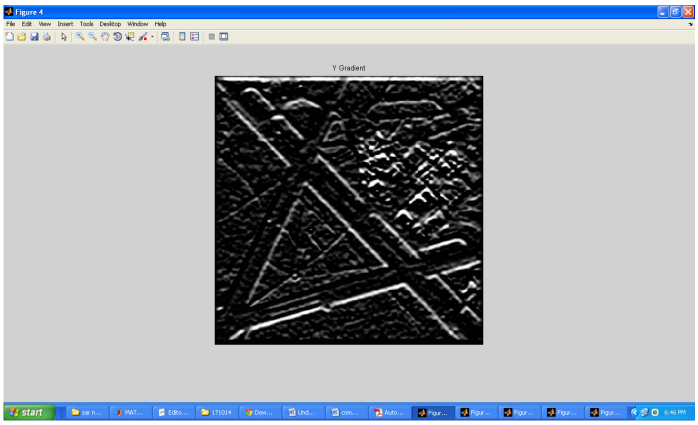


FIGURE-5

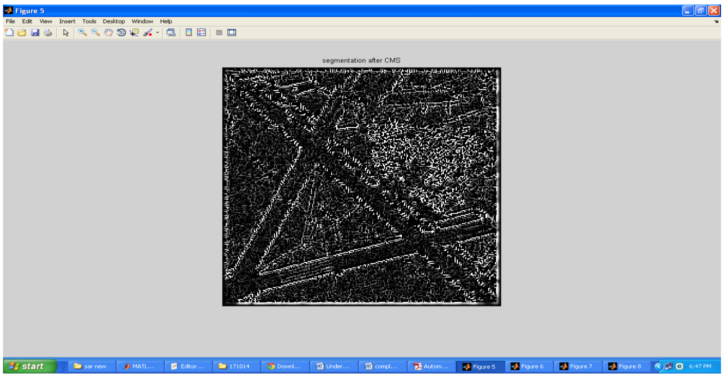


FIGURE-6

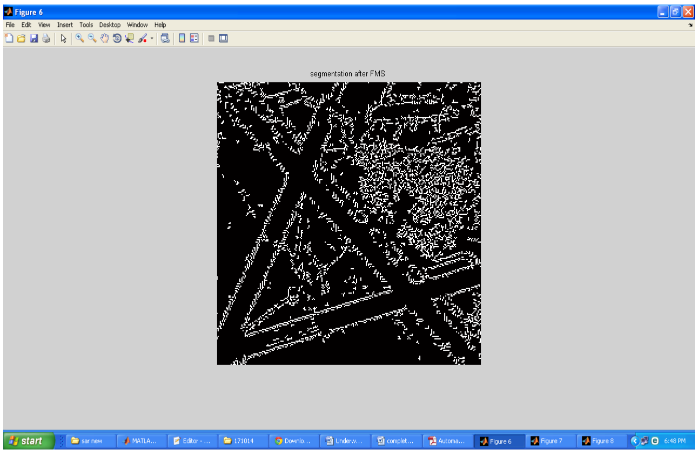
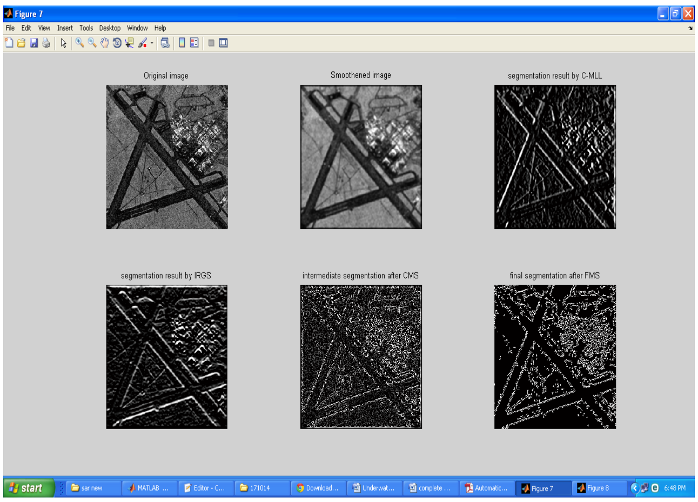


FIGURE-7



CONCLUSION:

The problem of the detection and reconstruction of building radar footprints in VHR SAR images has been addressed. Unlike many other methods presented in the literature, the proposed technique can be applied to single VHR SAR images. Moreover, by exploiting the reconstruction of the shadow areas, height retrieval techniques can be also applied to estimate building heights. To make it possible to use the proposed technique on large VHR SAR images in near real time, we also proposed and implemented for the processing of large VHR SAR scenes.

The proposed method is suited for meter-resolution SAR images. However, it can be extended and tuned for higher resolution airborne data by introducing new types of primitives, composed objects, and rules. Moreover, new semantic classes for the primitives should be defined, as finer scattering mechanisms become visible in sub meter data. The experimental results obtained on a large meter-resolution SAR image confirmed the effectiveness of the proposed technique.

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