POTENTIAL AND LIMITS FOR RECONSTRUCTION OF BUILDINGS FROM HIGH RESOLUTION SAR DATA OF URBAN AREAS

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ABSTRACT

State-of-the-art airborne SAR sensors provide images with a spatial resolution in the order of a meter and current developed space-borne systems will reach a similar resolution. First results of a leading-edge airborne SAR system have shown that objects of size even below a decimeter can be resolved. In such data many features of urban objects can be identified, which were beyond the scope of radar remote sensing before. Reflections of roof structures like eaves and ridges or wall structures like single windows appear well contrasted in the intensity image. Therefore, the focus of the image interpretation shifted from radiometric to geometric properties of man-made objects like buildings. The focus of this paper is to show the new opportunities and challenges for the analysis of urban areas, which arise from the availability of high-resolution SAR data. One main benefit is that additional object structures become now visible in the data.

INTRODUCTION

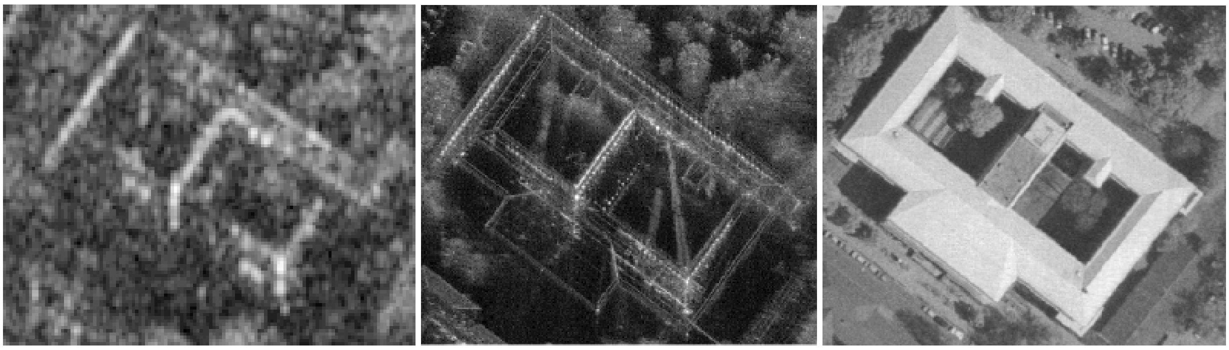
The image analysis concept for SAR data has to match the features of the studied imagery, e.g. the spatial resolution. In case of satellite data (like ERS 1 with about 25m resolution), the analysis is often restricted to radiometric image properties, even in urban areas. Usually a partitioning of the scene in different terrain classes (e.g. forest, grass, rocks, suburban, urban) is carried out, based on empirical statistical models [1] of the backscatter characteristic of mate-rials.

In the 90’s, airborne SAR sensors achieved spatial resolutions of about one meter in range and even better in azimuth. For example, the AER-II system [2] was capable of single-pass along- and across-track interferometry as well as of multi-polarization data acquisition. In urban scenes, the analysis of the polarization matrix is useful for the discrimination of man-made-objects from volume scattering (e.g. trees). Furthermore, techniques have been developed to distinguish superimposed scattering mechanisms in polarimetric InSAR data [3]. Due to the better resolution, geometric features of urban objects can be identified in such SAR images. Therefore, the focus of the image interpretation shifted from radiometric to geometric properties of man-made objects like buildings. Characteristics of those are piecewise plane surfaces, sharp edges, and a mainly linear, right-angled, or parallel structure. This peculiarity gives rise to frequently observed dominant scattering at building locations, e.g. caused by specular reflection at tilted roofs facing towards the sensor, double-bounce between the building facade and the ground in front and triple-bounce reflection at trihedral corner structures [4]. A further important building feature is the cast shadow on the ground behind. In general, the mapping of a certain urban area is heavily dependent on aspect and elevation angle [5]. The mentioned characteristics have been exploited for model-based structural image analysis approaches, e.g. for building reconstruction [6], damage detection [7] or the grouping of regular point structures [8].

Today, leading-edge airborne SAR systems can resolve objects of size even below a decimeter [9]. The focus of this paper is to discuss the new opportunities and challenges for the analysis of urban areas, which arise from the availability of high-resolution SAR data. Of course, one main benefit is that additional object structures become now visible in the data.

APPEARANCE OF BUILDINGS IN HIGH-RESOLUTION SAR DATA

The appearance of buildings in high-resolution SAR images is discussed using a subset of the test area Karlsruhe University campus (Germany). Fig 1a depicts an InSAR magnitude image of about one meter resolution, which was acquired with the AER-II sensor of FGAN in 1998 [2]. The very same part of the scene was mapped again in summer 2002 from the same aspect, this time with the new FGAN sensor PAMIR [10]. The resolution of this multilook amplitude image presented in Fig 1b is slightly better than 20cm in range and azimuth (X-band, HH polarization, off-nadir angle 61°). The sensor is capable to provide even better resolution, below one decimetre in both directions.



a b c

Fig 1. Building of test area Karlsruhe, Germany. a) AER-II image with one meter resolution, b) PAMIR image with resolution better than 20 cm, acquired in sliding spotlight mode, c) aerial image (30cm)

Comparing the two SAR images, obviously in particular buildings look very different. Only a small number of scattering events occur and superimpose inside the small resolution cell of high-resolution SAR. Hence, much more building features like edges and point structures become visible, which were averaged with their surrounding background in SAR data of coarser resolution. This results as well in a larger dynamic range data especially in urban areas, in case of the PAMIR image of about 70 dB.

Due to the presence of only a limited number or in the extreme case only a single scattering event inside one resolution cell, SAR polarimetry [3] is expected to be of growing importance, e.g. to determine the orientation of structures and to overcome the layover problem. An aerial image of the test scene is shown in Fig 1c. The PAMIR image and the aerial photo have about the same spatial resolution. Many features of the urban objects (buildings and vehicles) present in the scene can be observed in both images, but there are features, which appear in the SAR image but not in the aerial image and vice versa. Hence, a fusion of these complementing information sources for the analysis of urban structures seems to be fruitful [11]. Furthermore, new opportunities for building recognition from SAR data arise from the high level of detail.

As mentioned above not every feature in the SAR data can be understood by comparing it with the aerial image. Hence, for the discussion of some interesting features a photo is used, which was taken in oblique view from a neighboured tower. In Fig.2a a SAR image (August 2002) and in Fig. 2b a photo (February 2004) of the same building are shown. To ease the interpretation, the SAR image is shown rotated, according to the viewing geometry of the photo.

In the following, the potential of high-resolution SAR data for urban analysis is demonstrated with some examples. The eaves (1, 2) and the ridge (4) of the roof can clearly be identified as linear structures, even inside the layover region in the lower image part and at the rear building area. The roof planes appear dark, because they are made of metal plates and the signal is mainly reflected away from the sensor. Very interesting are the linear structures of equidistant point scatterers (3) located at the front walls close to the sensor. The most probable source of these effects are slighly elevated metal stripes connecting the metal plates on the small roof between the middle and the top floor. Despite the presence of some deciduous trees in front of the building, which were full of leaves at the time of the SAR data recording, the double-bounce scattering between the walls and the ground in front can be seen (5). At the backward facade of the right courtyard, the special structure of the row of windows (6) is preserved in the SAR image. On the terrace (7) in the middle of the building complex some small pillars and a railing (hardly visible in the photograph) are located. Those objects are mapped to point structures in the SAR image (Fig. 3). Surprisingly, the superstructure on the terrace can not be matched with a correspondence in the SAR image. The reason for this is not understood yet. At the parking lot (8) some cars are visible, even though their signal is partly obscured by layover from trees.

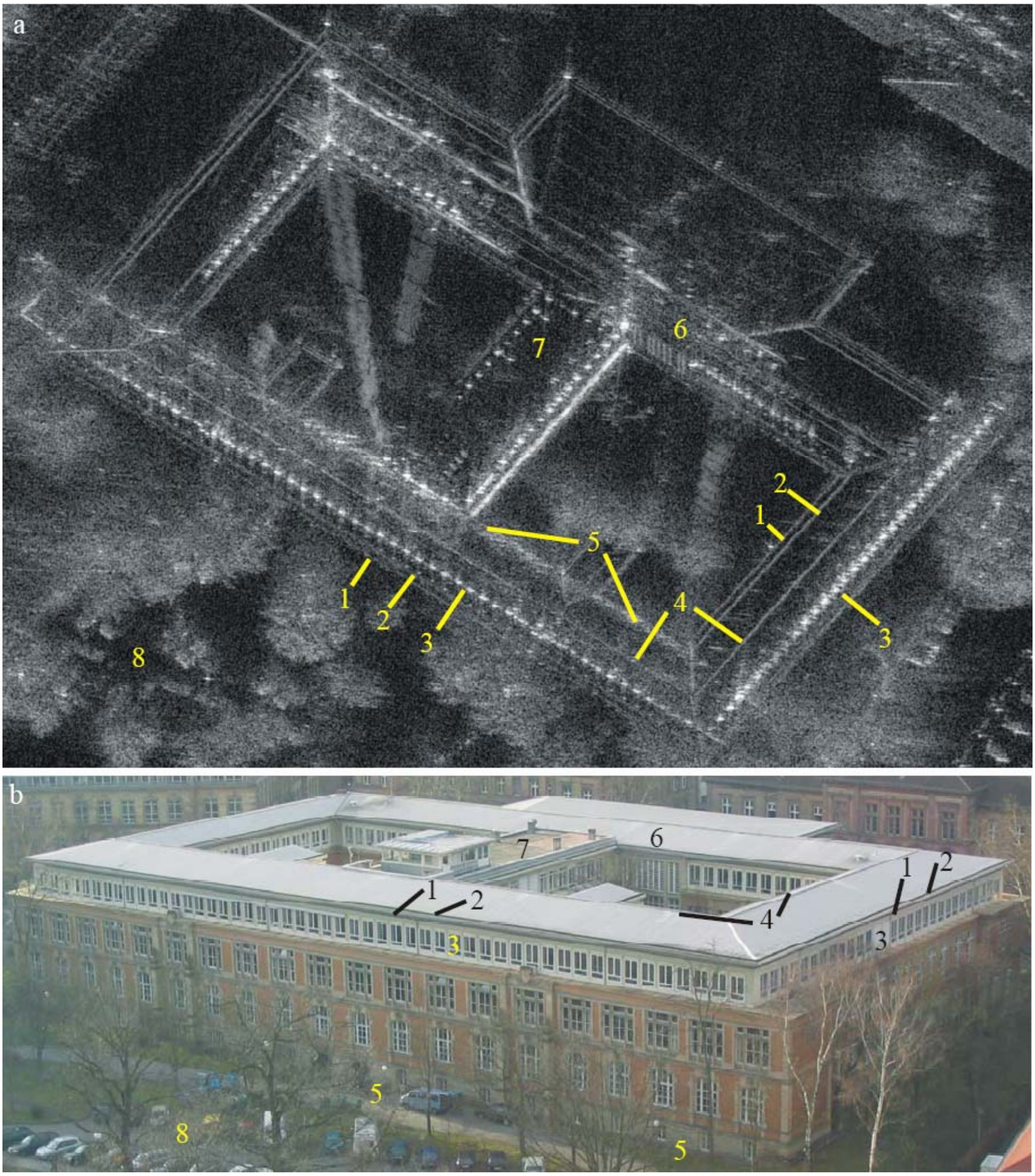


Fig 2. a) SAR image (range direction is bottom-up), b) photo (numbers 1-8 see text)

CONCLUSION

State-of-the-art high-resolution SAR sensors provide a detailed mapping of man-made objects, which could not be achieved by radar remote sensing only a few yours ago. Structural image analysis approaches were up to now either tailored for extended targets or the extraction of rather coarse scene descriptions. Based on the new high-resolution data, a much finer level of detail of the object recognition seems to be possible. Polarimetry is expected to be of growing relevance for the analysis of urban areas.

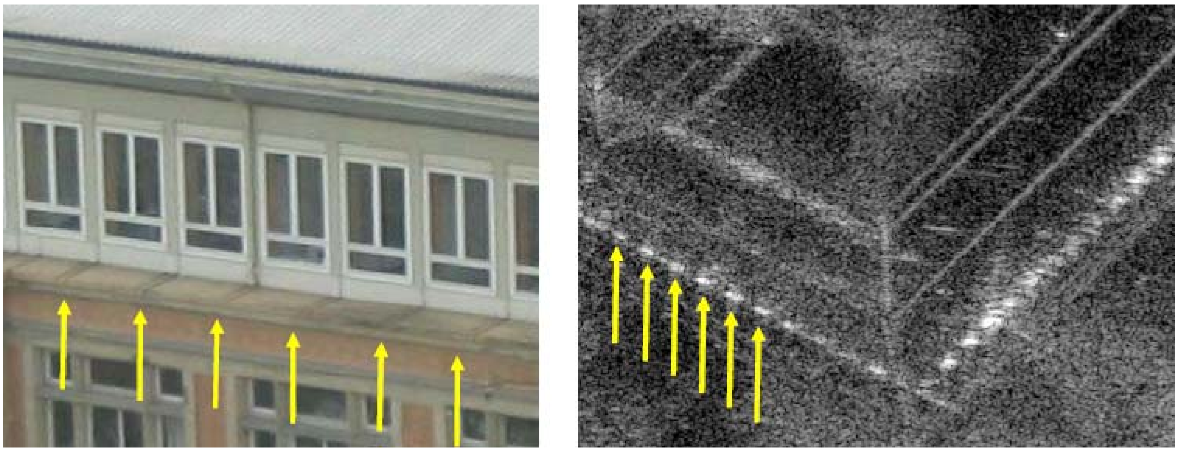


Fig 3. Detail structures on the row of scatterer (see Fig.2 area 3). a) SAR image, b) photo

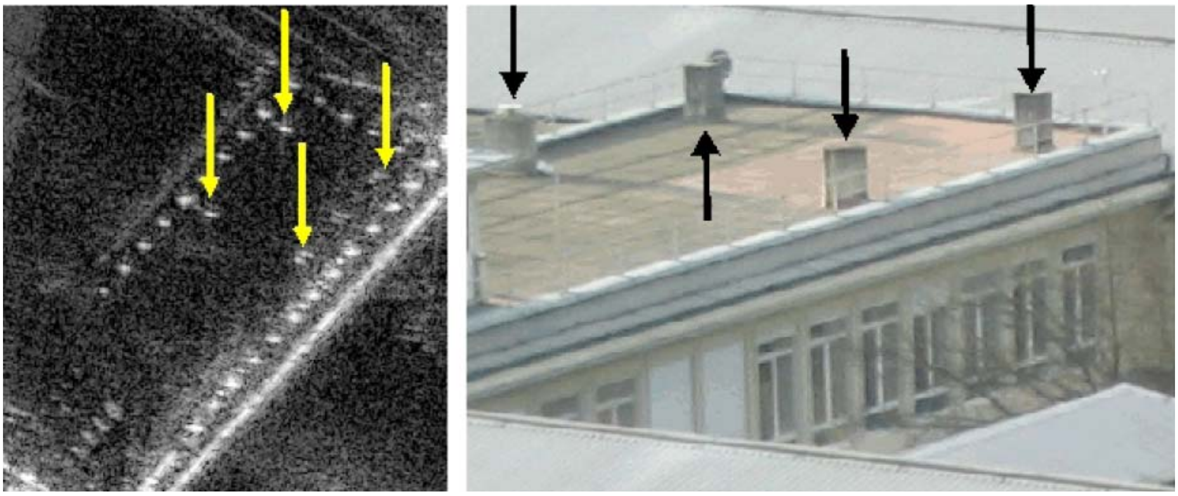


Fig 4. Detail structures on the terrace (see Fig.2 area 7). a) SAR image, b) photo

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