NEW MODELS FOR THE ANALYSIS OF HIGH RESOLUTION SAR IMAGES OF URBAN AREAS

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ABSTRACT

SAR (Synthetic Aperture Radar) images with very high resolution (till 1 meter) are now provided by new powerful sensors but their analysis, interpretation and classification are very hard when urban areas are under study. In this paper the high resolution in SAR images of built-up areas is faced with a model-based approach allowing detection and correct interpretation of 1 meter geometries.

1. INTRODUCTION

Thanks to the launch of a new powerful generation of sensors, like the Italian CosmoSkymed and the German TerraSAR-X, images with 1 meter resolution, both in azimuth and in ground range, are now provided and call for new interpretation skills, especially in those scenes where objects with dimensions comparable with the SAR resolution are present. This is certainly the case of urban areas.

It has been soon realized that currently available algorithms for advanced classification and/or feature extraction from SAR images of urban areas need to be updated to deal with the high resolution, because, to stress only two main points,

1. the statistics of the image could change (the general assumption of many scatterers in the same resolution cell may not be valid anymore);
2. new details are visible, considering that new geometries are now resolved (and must be taken into account in the process of retrieval).

In this paper this last point is discussed, trying to quantitatively analyze in which way the high resolution affects the general appearance of built-up areas, so to devise the proper models for the direct problem (the simulation chain) and the inverse one (classification and feature extraction).

The analysis relies upon a model-based approach previously introduced [1] and also applied both in the direct [2] and inverse chain [3-4] for the retrieval of geometric and electromagnetic parameters of isolated buildings from airborne SAR images with good resolution. That approach is here adapted to the case at issue of HR SAR images (Section 2).

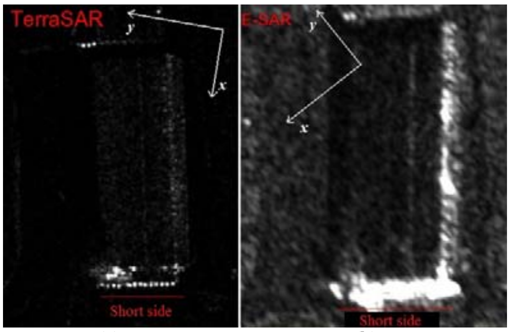
Previous results are confirmed and supported by new ones obtained by analyzing spaceborne SAR images with 1 meter resolution (Section 3). In particular, more attention is given to those appearances caused by 1 meter scatterers (e.g., small dihedral and corner reflectors formed by building shape) whose scattering was confused and melt with others in SAR images with lower resolution, while now can be clearly distinguished, classified and retrieved. The correctness of a model-based approach is then assessed showing that it can be used to retrieve some features from HR SAR images of urban areas. Moreover, an interesting comparison among images with different resolutions is also provided, thus giving special guidelines for approaching a correct interpretation and consequently for developing new feature extraction algorithms for urban areas.

2. SCENE DESCRIPTION AND RETRIEVAL APPROACH

The first impression one may have looking at 1 meter-resolution SAR image regarding an urban area is that of a very complex representation not trivial to understand. At the same time, that complexness seems the mirror of a really detailed scene which is finally detected with the right instrument.

In fact, a building with a complicated geometry including doors, windows, balconies, outer stairs etc., or even with different materials (for example concrete or bricks for walls and glass for windows) could hardly be distinguished in each part when low resolution SAR images are considered. Usually, in that case, the scatterings caused by the singular parts of the structure melt together affecting the grey level of a few pixels. Now, instead, in 1 meter-resolution SAR image the building details presenting dimensions in the order of the image resolution leave their own signature. This is leading, on one side, to a better representation of built-up areas but, on the other, to the need of new models, both geometric and electromagnetic, able to consider something more than canonical shapes or uniform materials. Our goal is that of describing the interaction between the radar signal

Figure 1. Optical aerel view of the building analyzed in the DLR airport area. (GeoContent GmbH)



(a) (b)

Figure 2. SAR images of building in Fig.1: (a) TerraSAR-X image; (b) E-SAR image

and the urban structures in an accurate and deterministic way, based on models, which may eventually be used as a guideline in inversion processes for feature extraction. This approach, previously adopted for successful quantitative retrieval [3-4] of some features of very simple buildings[1], needs to be extended to more complicated geometries for a more realistic representation.

A way this can be carried on is shown in the following with an interesting example demonstrating also how this step is crucial once high resolution SAR images are considered.

Two SAR images relevant to the same site are analyzed. As in [3], the site is the airport area of the German Aerospace Center (DLR), located in a suburban area of the little village of Oberpfaffenhofen, near Munich, where buildings quite well approximated by the geometric model adopted in [1], have been found. But in this paper we want to show how, starting from considerations and models in [1], we can move to analyze a bit more complicated geometries adjusting the models previously introduced to fit the new reality shown by high resolution.

We focus on a singular building whose optical aerial view is given in Fig.1. From that view and other pictures taken by visiting the site, after proper orthorectification, information about the main and the secondary structure of the building has been acquired and summarized in Table I.

This information has been used to support the interpretation of the SAR images relevant that building.

The first image has been acquired by the airborne sensor E-SAR and the second one by the spaceborne TerraSAR-X radar. Main radar and image parameters are summarized in Table II. Except for the height of flight and the resolution, the images have been acquired in very similar conditions. A particular look of each image is given in Fig.2. We carried on our study in three main steps:

1. Starting from the models in [1], we derived the expected SAR appearance of the building at hand, given its geometry (information in Table I retrieved by optical images has been assumed as ground truth) and the radar look angle and view;

TABLE I. BUILDING GEOMETRY

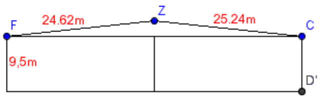
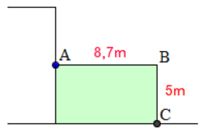
Main structure 	Width	116.45 m
	Roof - Left side	24,62 m
	Roof - Right side	25.28 m
	Height	9,50 m
	Roof Height	11,3 m
	Roof Slope	4,07°
Secondary structure 	Height	5 m
	Width	8,7m
	Length	42,2m

TABLE II. RADAR AND IMAGES PARAMETERS

	E-SAR	TERRASAR-X
Height of flight	4,5km	514,8km
Incidence Angle	55°	51°
Polarization	VV	VV
Carrier frequency	9,60GHz	9,65GHz
Azimuth Resolution	1,8m	1,2m
Ground Range Resolution	2,0m	1,0m
Azimuth Pixel Spacing	0,7m	0,5m
Ground Range Pixel Spacing	0,7m	0,5m

2. the expected presence of each contribution (mainly single and double scattering) and relative position has been verified by extracting and measuring the corresponding lines and areas in the TerraSAR-X and E-SAR images respectively;
3. differences presented by step 2 applied at each image have been discussed and finally addressed to the different resolution of the SAR images by a more refined measuring operation on the TerraSAR-X image.

Results of step 3 are discussed in details in the next section.

3. NEW DETAILS IN HR SAR IMAGES

Let us focus on the short side of the building. It is indicated in both SAR images in Fig.2. In step 1 of our procedure, once we assume the simple geometry in Table I and the same material for each part of the building, we should expect, as main contributions, the presence of two brilliant lines due to the phenomenon of double scattering arising from the two dihedral configurations presented by this side to the sensor. Geometrical considerations, based on the knowledge of radar look angle and view as well as the building geometry, allow to know the distance we should measure on the SAR image between these two lines, evaluated as 4.65m in the ground range image.

Then, these lines have been looked for on both images (step 2): in the E-SAR image, see Fig.2b, these lines can be hardly distinguished whatever byte-scaling is performed as an entire area shows a quite homogeneous brilliant scattering; in the TerraSAR-X image, instead, two lines have been found even if are not both clearly visible in Fig.2a where the image has been properly byte-scaled to emphasize the single brilliant points along the short side (which are not distinguishable in Fig.2b).

But here the distance we measure (step 3) between the two lines is 8.74m which does not fit the expected one. An analysis has been lead to understand the nature of these contributions, in particular of the line with the single bright points. Let us suppose that the less bright line is really due to the dihedral in A (see Table I, first column, second row), the distance of 8.74m seems to correspond to the ground range distance between A and the point B or something in the slant-range-surroundings of B, for example the top of the façade. Actually, the façade appears as in Fig.3. The bright points seem to correspond to the line of windows. As a proof, we measured the mean distance between the bright points in the SAR image: it is 3.09m against the 3.16m obtained by the optical images, which is a really interesting result even if it needs further analyses. In fact, the second line of windows is not so clear and this could be due to the slant-range closeness of the two lines (their contributions probably melt in the SAR image). Moreover, it would be interesting to understand the nature of the bright points, which seems more electromagnetic (a metallic line is at the top of each window) than geometric. Instead, the absence of the double reflection line due to the dihedral in C (see again Table I) may be of geometric nature as all the open windows do not contribute to the double scattering and, moreover, the ground in front of the short side presents a vacant part due to the stairs to the underground floor. Further studies are in progress to verify these matters.

4. CONCLUSIONS

An application of the retrieval approach based on models [1] has been presented. The models have been adapted to fit the more complicated geometry under study and above all the new details visible on HR SAR images. The contemporary use of proper models and HR SAR images shows to be a good candidate to explain the complex appearance of urban areas. More information about the approach will be given at the conference.

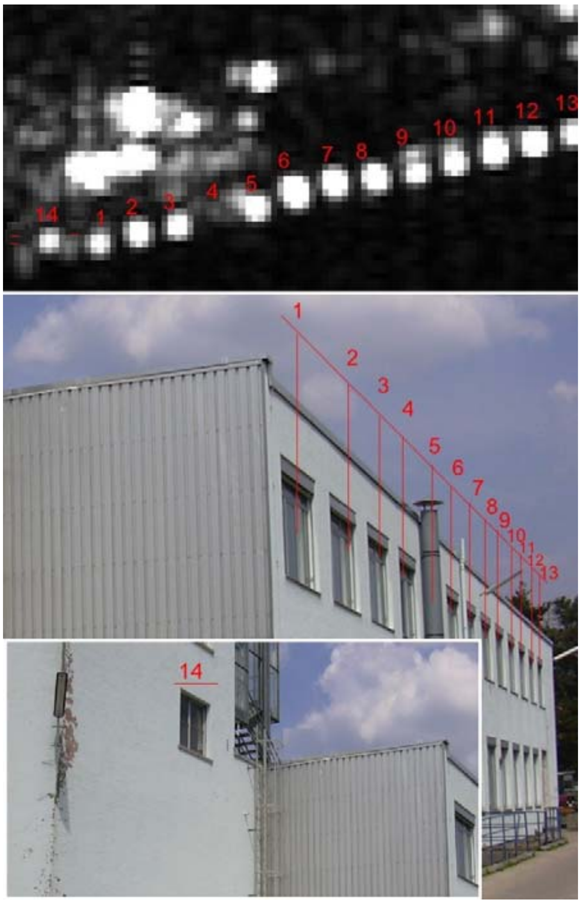


Figure 3. Comparison between SAR image and ground truth. Top: zoom of the short side of the building in the SAR image in Fig.2a; Façade of the short side.

8. REFERENCES

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