A NEW ALGORITHM FOR BUILDING FEATURE EXTRACTION FROM SINGLE AMPLITUDE SAR IMAGES

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ABSTRACT

In this paper we present first results regarding the analysis of individual business district buildings on very high resolution SAR images. In particular, we focus on the filtering of the periodic patterns appearing in the layover area of the buildings, which are related to façade structure (e.g. floors, windows, balconies). The proposed processing chain is based on spectral analysis of the layover amplitude image, and exploits an adaptive filtering strategy to filter out the periodic components, in order to enhance the non-periodic component related to the presence of different objects on the portion of ground in front of the building, interested by the layover phenomenon. The algorithm is applied on a spotlight high resolution image of the business center of Naples, Italy.

***Index Terms*—** SAR, urban areas, spectral estimation.

1. INTRODUCTION

In recent years SAR images of urban areas experienced a huge increase in information content, due to the advent of new generation very high resolution SAR sensors (e.g. TerraSAR-X and COSMO-SkyMed). As a matter of fact, low resolution SAR images do not allow extracting relevant features of an urban area, because typical building features are pertinent to objects whose size is of the order of few meters (i.e., much smaller than the resolution cell). Nowadays, the situation is somehow reversed, because very high resolution images unveil a huge amount of features, whose relation with the objects present on the scene under survey is often very involved. The interpretation of these effects requires the joint use of appropriate geometric and electromagnetic models [1], [2].

The opportunity to observe in details the characteristics of individual buildings through very high resolution SAR sensors is exploited in this paper. In particular, we focus on images relevant to business districts, where skyscrapers or, more in general, huge buildings are present. For this kind of buildings the façade windows and balconies are built in such a way that trihedral corner reflectors are frequently encountered [3]. Therefore, in actual situations these features are located in the building layover zone on the SAR image, giving rise to regular quasi-periodic patterns, whose structure is related to floor height and, more in general, to balcony and window patterns. The possibility to gain access to this information can be of key importance in many applications, such as permanent scatterers interferometry, change detection and crisis management.

In the layover area of a building the periodic patterns related to the façade structure are mixed to the contributions due to objects present on the roof and on the terrain in front of the building. The possibility to filter out the periodic patterns from the layover area potentially allows the extraction of these latter contributions, and the monitoring of otherwise inaccessible scene features. As a matter of fact, in large cities, where a detailed knowledge of the building structures is frequently available, the extraction of the component related to the building façade structure is greatly simplified, and this kind of applications can be effectively implemented.

In this paper we present the first results regarding the automatic extraction of the floor height from single amplitude-only very high resolution SAR images of urban scenes. In particular, we apply effective spectral estimation methods [4] to estimate the spatial frequency of the patterns present in the layover areas in both range and azimuth directions: in fact, these frequencies are straightforwardly related to the height of the building floors and to the distance between different windows or balconies on the same floor. Once the shape of these pattern is retrieved, we propose an adaptive filtering technique, able to effectively remove the quasi-periodic structures from the layover image, thus allowing to separate the non-periodic component.

First results relevant to the application of the proposed framework on a case study in the business district of the city of Naples, Italy, are reported here. For this case an enhanced spotlight Cosmo-SkyMed image with 1x1 m^2 resolution was acquired and analyzed [5]. For the building of interest a rough vector model was also obtained.

2. METODOLOGY

The preliminary step of our analysis consists in the extraction of the layover area of the building of interest and of its orientation with respect to the azimuth direction. This

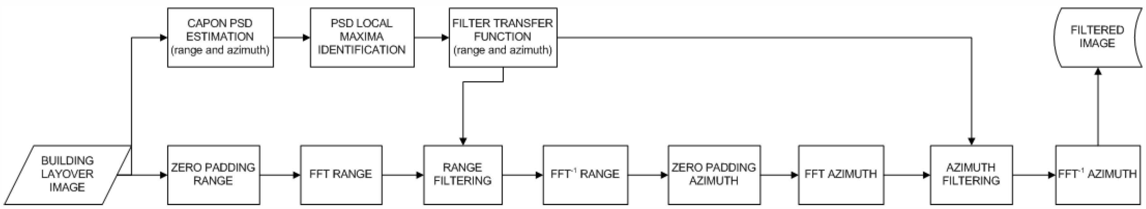


Fig. 1 Flow chart of the proposed algorithm.

step can be performed using a priori knowledge about the building (height and position) and simulation-based methods [6]. As an alternative, the authors are exploring the possibility of using a technique based on the specific characteristics of the unit SAR sensor response to identify and extract the double reflection line located at the basis of the building, thus obtaining a joint estimate of the border of the layover area and of the orientation angle of the building. Moreover, using appropriate electromagnetic models it is possible to estimate the height of the building from the double reflection line intensity [7], avoiding the need of external information (height) for the extraction of the layover area. Anyway, at the moment the extraction of the layover area is performed manually for our case study, where the façades of the considered buildings are oriented almost along the azimuth direction. However, in large metropolitan areas we can confidently expect that large part of building structure information can be retrieved using some kind of database (e.g., cadastral maps, digitized maps, vector models), so that this information can be used in support of the extraction of the layover; furthermore, the a priori information, such as the knowledge of the floor spacing can be used even for the extraction of the periodic patterns. In this latter case, the proposed method can be effectively used for the filtering of the periodic component, providing an image to be used for the analysis of the remaining contributions.

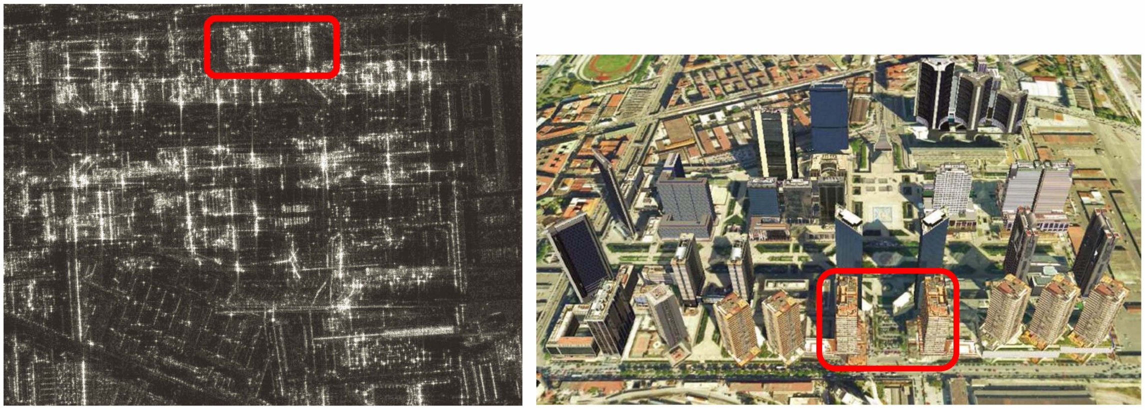
Once the layover area has been extracted and rotated to compensate the presence of a non-zero orientation angle between the building and the azimuth direction, we apply the algorithm detailed in the block scheme of Fig. 1. As a first step, the one-dimensional Capon spectral estimator [4] is used to obtain estimates of the 1D spectra along the range and azimuth directions of the obtained layover matrix. We use the Capon estimator for its high spectral resolution and to avoid leakage and high variance problems [4]. From the analysis of the obtained spectra we are able to extract the local maxima related to range (height of the floors) and azimuth (distance of windows and balconies) façade features. As already noted, this step can be supported by the a priori knowledge of relevant building features. Otherwise, in the range direction we search for local maxima located in the wavenumber range corresponding to admissible floor heights, while in the azimuth direction the two local maxima with the largest magnitudes are selected. From the knowledge of the local maxima we can synthesize the filter transfer function, as the ratio of the desired and estimated spectra, where the desired spectra is obtained from the estimated one removing the spikes related to the periodic components.

Once the filter transfer function has been obtained, we proceed to filter the image: we compute the FFT on a sufficiently fine grid in the range direction and multiply it for the transfer function. We than come back to the spatial domain, obtaining a range filtered image. Similarly, starting from this image, we apply the azimuth filtering, obtaining the final filtered image. With this procedure, we can obtain both the periodic structure related to the building façade and the non-periodic structure components pertaining to the roof and to the portion of ground interested by the layover phenomenon.

3. RESULTS

The proposed methodology has been applied on an enhanced spotlight Cosmo-SkyMed image of Naples, Italy, presenting 1x1 m^2 resolution. A subset of the image relevant to the business district is shown in Fig. 2 (a), while in Fig. 2 (b) a Google Earth 3D view of the same area is reported. The twin buildings considered in this work (towers of the Naples Bank) are marked in red in Fig. 2, and their 3D visualization is presented in Fig. 3.

The building closer to the sensor line of flight was considered for our analysis. The layover relevant to the building was manually extracted from the SAR image and the range and azimuth spectra were estimated from the extracted layover matrix. The graphs of the Capon estimated spectra are presented in Fig. 4. From the range spectrum we extracted the principal harmonic in the range direction, which after appropriate considerations on the image pixel spacing and look angle, provides an estimate for the height of the building floors equal to 2.7 m. With regard to the azimuth spectrum we can appreciate from Fig. 4 (b) the presence of two evident harmonic components corresponding to periods of 3.6 m and 8.7 m: they can be related to the presence of two different periodic structures in the azimuth profile of the building, which can be partly appreciated also looking at the building structure in Fig. 3. In Fig. 4 (a) the presence of three secondary spikes at a frequency lower than that of the main harmonic can be



(a) (b)

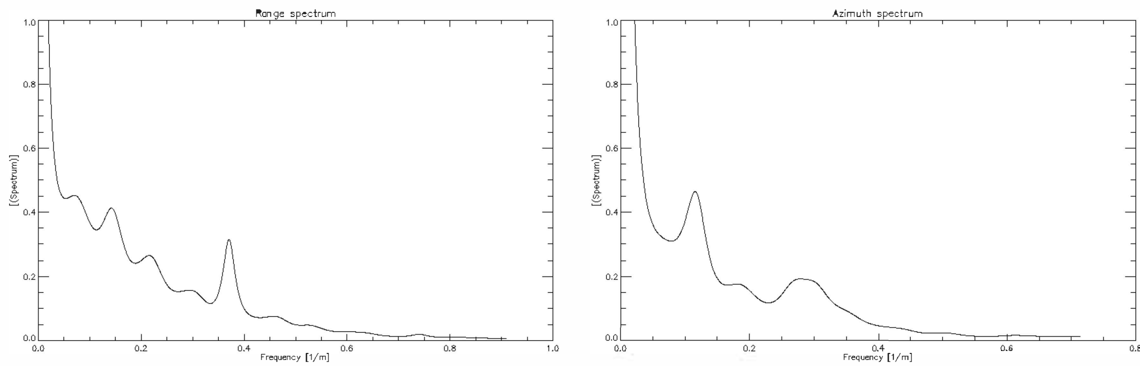
Fig. 2 Cosmo-SkyMed image of the business district of Naples (a); Google Earth 3D view of the same area.

Fig. 3 3D view of the twin buildings considered in the paper.

appreciated. Actually, these can be due to the presence of low frequency signal components related to the presence of the roof return in a restricted part of the layover pattern. In fact, the presence of the roof returns in the layover can give rise in the frequency domain to a zero-frequency centered sinc, whose secondary lobes can appear in the low frequency region of the spectrum.

Once the estimates of the maxima of the spectra are available, the harmonic estimates can be used to implement the filtering of the layover matrix according to the rationale reported in Fig. 1, in order to separate the effects related to the building façade from those related to different objects present on the soil interested by the layover area or on the building roof. Indeed, what we observe in the layover area is a combination of features related both to the building façade and to other objects present on the roof and on the portion of ground interested by the layover phenomenon. As a matter of fact, the proposed technique allows separation of these features, thus opening the way also to the identification of objects (e.g. cars) in a region that would be otherwise inaccessible for analysis. In Fig. 5 we present the results of the filtering of the periodic components, in both the range and the azimuth direction. In particular, we show the original extracted layover area in Fig. 5 (a) and its version filtered in Fig. 5 (b). In the filtered image the features present at near range are probably related to roof returns: in fact, it can be appreciated from Fig. 3 that complex structures are present on the roof of the selected building, which give rise to involved multiple reflection phenomena.

Finally, in Fig. 5 (c) we show an image obtained selecting only the periodic structures identified in the previous algorithm step. The image was obtained through the application of truncated sine functions with appropriate periods on the original layover image. Looking at the image we can fully appreciate the periodic pattern which constitutes the signature of the observed building. This pattern can be potentially used in selecting and grouping



(a) (b)

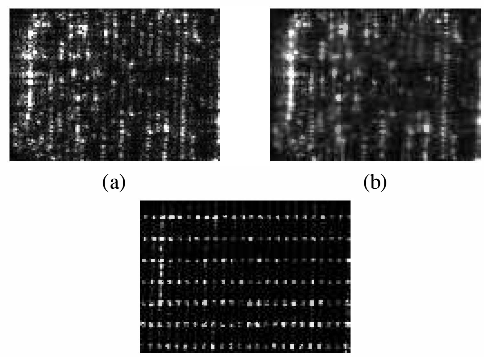
Fig. 4 Average range (a) and azimuth (b) spectra of the layover pattern.

permanent scatterers candidate points [8] or in change detection applications in urban environments.

4. CONCLUSIONS

In this paper we proposed a new algorithm for the extraction of periodic features from the layover pattern of individual buildings in very high resolution amplitude-only SAR images. The proposed framework is based on spectral estimation and adaptive filtering. It provides as output both a version of the image where the periodic components due to the building façade structures are filtered out, and, complementary, an image where only the periodic pattern is present.

In prospect, the proposed framework can be used for the estimation of floor heights and windows distances of business district buildings, for supporting selection and grouping of permanent scatterers candidate points or for change detection applications. Finally, it is even more relevant the fact that through the filtering of the periodic features from the layover area we are able to unmask the objects present on the building roof and on the portion of ground interested by the layover phenomenon, thus opening the way to the analysis of otherwise inaccessible scene features.



(a) (b)

(c)

Fig. 5 Original layover matrix (a), filtered layover matrix (b), and layover matrix with selection of the periodic structures (c). Near range is on the left.

5. REFERENCES

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