ASSESSMENT OF AUTOMATIC STRUCTURE DETECTION THROUGH VARIANCE PARAMETERS IN HIGH RESOLUTION SAR IMAGES OF URBAN AREAS

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Abstract:

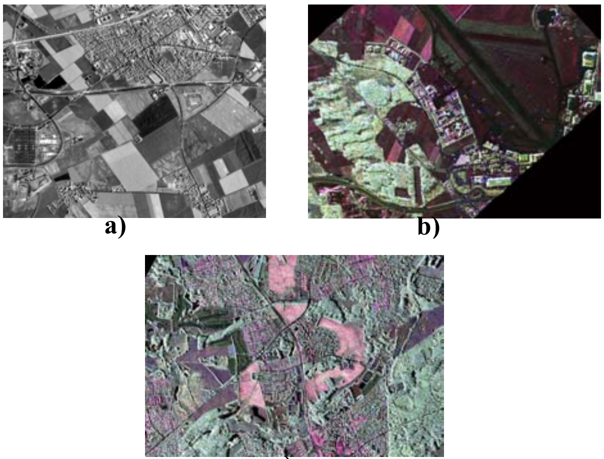
In this paper we aim at describing a method to extract information about urban structure on high resolution Synthetic Aperture Radar (SAR) images. The extraction of useful information from SAR images is a difficult task, due to the presence of the characteristic speckle noise but also for the geometrical and physical nature of man made areas. The technique proposed in this paper was used to improve the capability of urban detection, yielding a discrimination between urban areas and zones that present high value of mean intensity, as well as forested areas. It is based on the analysis of several variance images obtained from the original data through windows with different size. The performance assessment in urban areas is based on different measures, among which we mention: 1) comparison of mean value and variance of amplitude of different classes in the original data and in the variance images, 2) comparison of mean value and variance of different classes when increasing the size of the averaging window, 3) discrimination of zones with different physical characteristics through comparison with thresholds derived from the previous analysis.

1. INTRODUCTION

It is well known that in recent years Synthetic Aperture Radar (SAR) images with growing resolution have become available [1]. The advanced characteristics of the new spaceborne SAR systems, like COSMO-SKYMED, TerraSAR X or RADARSAT 2, and the large amount of data that will be produced, require algorithms for the analysis of this type of data. Particular interest is devoted to recognize and to analyze urban areas, for a reliable discrimination of man-made targets from surrounding natural media, present on the scene, and for monitoring the rapid changing of urban environment and population. The urban areas are characterized, with the current available resolutions, by brighter zones, due to the multiple reflection mechanism resulting from the wall-ground structure, and by darker zones, due to the shadows and to regions where only terrain contributions are present [2]. With this particular behaviour, an automatic information extraction in the urban area is a difficult task, in particular when applying segmentation techniques. Moreover, if the available data went through a quantization and saturation process, it is often difficult to discriminate urban areas from zones with a high mean value like forested areas, that present a high radar cross section because of the presence of the trees. Thus, a discrimination based on the mean value of the different classes in the scene doesn't lead to good results. In this paper we describe a particular technique to improve the information extraction of urban areas, based on the exploitation of the variance of the different classes in the image.

2. DATA SET

The proposed algorithm has been applied to three different images. The first one was acquired by the single channel X-band sensor AeS-1 over the test-site of Trudering (Germany), the second one was acquired by the fully polarimetric DLR ESAR sensor over the test-site of Oberpfaffenhofen (Germany), and the third one was acquired by the fully polarimetric C-band EMISAR sensor over the town of Copenaghen. These images show zones characterized by different classes, as urban areas, airport, roads, fields, forested areas. In all cases the pixel values of all the channels are real numbers, obtained from a saturation quantization process applied on the original images. The considered data set is shown in Fig. 1 in false colours. A detailed ground truth of the images is available to evaluate the performance of the technique proposed in the following.



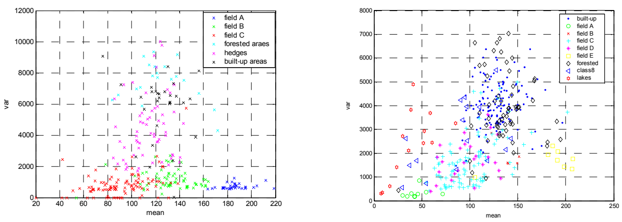
a) b)

c)

Figure 1: a) Trudering/Germany, b) Oberpfaffenhofen/Germany and c) Copenaghen/Denmark

3. METHODOLOGY

Observing the images, it can be seen that built-up areas are characterized by brighter zones and darker zones. The statistical properties of each class and the differences between zones with different physical characteristics can be observed in Fig. 2, where we plot the mean value vs the variance of amplitude for Trudering and Copenaghen data. The mean value and the variance have been estimated over the different regions present in the ground truth.



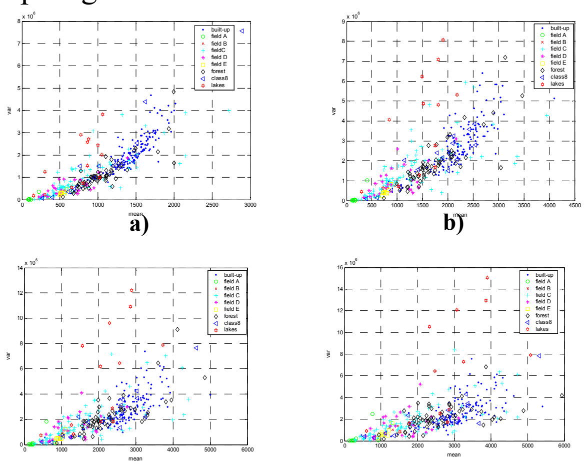
a) b)

Figure 2: mean value vs variance of original pixel: a)Trudering test-site, b) Copenaghen test-site.

In particular, Figure 2 shows that for different kinds of agricultural fields the mean value and the variance are lower than for the other classes. Consequently, agricultural fields can be detected by comparison the amplitude of every pixel with a suitable threshold. On the contrary, discriminating built-up areas from forested areas is more complicated, because they have similar statistical properties and the comparison with a threshold doesn't lead to a good result. The built-up areas are generally characterized by a high variability of pixel values, higher than for the other classes, and this is due to the geometrical characteristics of man-made areas, constituted by roads and regions where only the terrain contributions are present and by several kinds of buildings. A method to distinguish this class with respect to the others could be to consider the information derived from the variance of their pixels, that should be greater than for vegetated areas. To this aim, we considered different "variance images", obtained by applying a sliding window over the whole image, and evaluating the variance of the pixels inside the window. The different images were obtained considering windows of different sizes (2x2, 3x3, 4x4,etc.).

4. RESULTS

To understand the properties of the variance in each class we can compare the plots in Fig.2 with the equivalent plots referring to the variance images, considering different sizes of the averaging window. Every point represents the mean value and the variance of pixel in the variance image and the considered pixel are in the regions of the ground truth. Figure 3 shows the graphics for different windows in the Copenaghen test-site.



a) b)

c) d)

Figure 3: mean value vs variance of pixel in variance images: a) 2x2 window, b) 3x3 window, c) 4x4 window and d) 5x5 window.

In Figure 3 is possible to notice how the built-up areas become more differentiated from the forested areas when increasing the size of the window. To simultaneously compare the behaviour of the different classes with respect to the window size it is possible to report in a single plot the mean values of the mean and of the variance of every region for different sizes of the averaging window, as shown in Figure 4.

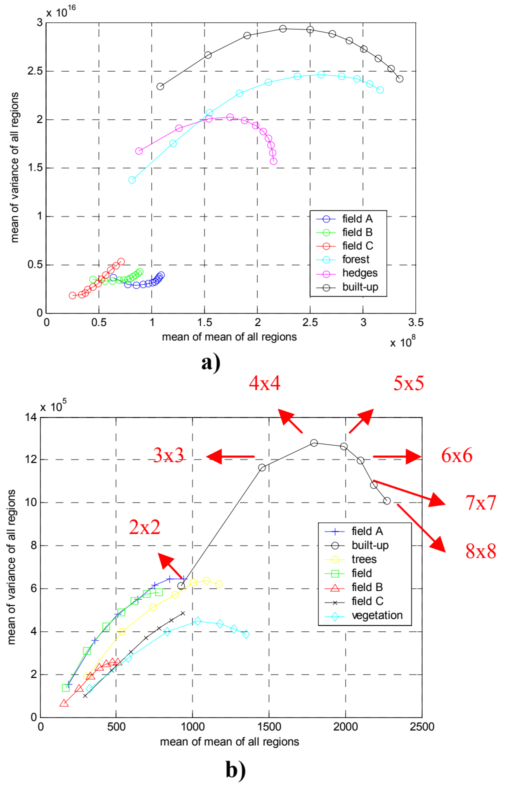


Figure 4: behaviour of each class with the growing of window dimensions for a) Trudering and b) Oberpfaffenhofen test-site.

In the previous graphics it can be observed how the variance for the built-up areas is higher than for the other classes, especially than for forested areas, and moreover a particular behaviour can be observed when increasing the size of the window: the variance increases with the size of the window, but the variability of the variance initially increases and then decreases. This is due to the characteristics of the class under attention: there exits a size of the window in which there is a maximum in the detection of variability of the structure. For each of the plots it seems to be 4x4 or 5x5. Applying appropriate thresholds with this kind of images, we can obtain better results in the detection of built-up areas than for the original data. To detect the different class with a comparison to a threshold, limiting the interferences due to the speckle, we can compare the original pixel considering as a mask the segments obtained using the Merge Using Moments segmenter described in [3] and considering three different values of P_{fa}. In table 1 the results of the comparison and the detection of built-up areas are reported for the Copenaghen test-site.

table 1: results for the built-up areas by the comparison with a threshold of original data and of variance images (Copenaghen test-site).

Window size	$P_{fa}=10^{-2}$	$P_{fa}=10^{-30}$	$P_{fa}=10^{-40}$
Original data	**44.75%**	**46.89%**	**49.78%**
2x2	**83.49%**	**85.90%**	**87.92%**
4x4	**89.91%**	**91.61%**	**92.90%**
6x6	**88.96%**	**90.46%**	**91.95%**
8x8	**87.41%**	**88.47%**	**90.31%**

As it can be seen, the comparison with a threshold leads to detect the built-up areas with a higher percentage in the variance images than for the original data. The better results are obtained for a 4x4 window.

5. CONCLUSIONS

In this work we have presented a method to extract information about built-up areas from high resolution SAR images, considering the variance of the pixel values for the different classes. Final results show how the built-up areas can be detected and separated from other classes when properly selecting the number of pixels considered for the estimation.

6. REFERENCES

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