A Solution for Linking the Sparse Aligned Pixels in Multi-temporal SAR Sets

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***Abstract*-In the edge detection of noisy images, low rates of false alarms may be obtained only for high detection thresholds. Unfortunately, a high threshold reduces not only the false alarms, but also the rate of true detections. Consequently, in the detected image, the edges are constituted by spase pixels whose linking is a rather difficult task. This is, also, the case of SAR images, where speckle behaves like a strong multiplicative noise. The paper proposes a method for linking the sparse aligned pixels resulted from the linear structures' detection in multi-temporal SAR sets. Our method reposes on the Polar Transform (PT). Applied on the data volume represented by the multi-temporal sets and not a single image like in regular applications, the PT has a double effect : it links the sparsely detected pixels and, meantime, does a data fusion. This latter action enhances the ability of the PT.**

I. Introduction

The edge detection on SAR images is not an easy task. In these images, the terrain radar reflectivity is multiplied by a random signal - the speckle - that gives a very noisy aspect to SAR images. Because of this reason, in edge detection, the use of high thresholds gives very sparse detected pixels, whereas low thresholds give rise to high rates of false alarms. In both instances, the difficulty appears in the last stage of edge detection, i.e., pixels' linking.

In order to improve the ratio of detections vs. false alarms a pre-filtering is, usually, done, in such cases. The despeckling filter must be carefully choosen since, as it is known, any filtering is a tradeoff between noise reduction and preservation of the spatial/radiometric resolution. If the lost of resolution outperforms the gain due to speckle reducing, the final detection might be worse.

In this paper, we propose a method for linking the pixels of the linear structures detected in multi-temporal SAR images. With our method the pre-filtering is not anymore necessary, the ratio of detections vs. false alarms being improved by taking advantage of set redundancy. The basic idea of the method is to assemble into a volume the binary images resulted by applying an edge detector on each temporal channels and to turn it into a plane by means of the PT. This transform is known as an efficient tool for detecting and linking the nearly aligned pixels. In regular applications, the PT converts a plane into another plane. By defining it on a volume of data and not on a plane, the transform works, also, as a data fusion tool. Such an approach is very advantageous for our application, since the linear structures are, generally, perenial features of the scene. Consequently, they are present in all the channels and the detected pixels are scattered in the entire data volume.

The paper is organized as follows : Section II is a recall of the PT principle and of its algorithm. The method proposed for linking the sparse aligned pixels is given in Section III, together with some experimental results. The paper ends with conclusions.

II. The Polar Transform

The Polar Transform belongs to the class of "one-to-many" transforms. The best known of this class is the Hugh Transform [1] that associates to a point, a set of points constituting a certain sine curve. If the point coordinates are (a,b), the sine curve is given by the equation $p = a\cos(t) + b\sin(t)$.

The PT can be seen as an adaptation and a simplification of Hough Transform [2]. To a point (a,b), the PT associates – in the transformed space - the straight line with the equation:

$$ax + by = 1 \tag{1}$$

The point (a,b) is called *pole* and (1) is its *polar line.* To a set of points, the PT associates a set of lines. If the points are aligned, the set of lines constitutes a *pencil* (a set of intersecting lines). The knowledge of the intersection point (x_0, y_0) gives the equation of the points' alignment (inverse PT):

$$x_0 x + y_0 y = 1 \tag{2}$$

The alignment is the mere polar line of the intersection point (x_0, y_0). This property suggests the use of PT for extracting the linear structures from noisy images. In such images, the detection of the linear structure results in a set of sparse, aligned pixels. By polar transformation, for each detected pixel, a line is drawn on the transformed plane by incrementing the corresponding pixels. The intersection point of the pencil associated to the aligned pixels is a local maximum of the transformed plane. By detecting it, the linear structure can be reconstructed by inverse PT. In natural images, the detection of the linear structures gives only *approximately* aligned pixels. In this case, the pencil's lines do not intersect in a single point but in a cluster of points. The identification of (x_0, y_0) must be done, in these cases, by clusterization.

III. Method Description and Experimental Results

The method that we propose for linking the sparse aligned pixels resulted from the linear structures' detection in multi-temporal SAR sets, consists in the following steps:

- edge detection on each temporal channel,
- assembling of binary images resulted from detection, into a volume,
- conversion of the volume into a plane, by applying the PT,
- detection of the highest values in the transformed plane,
- linear structures' reconstruction by inverse PT.

Since speckle is a multiplicative component of SAR image radiometry, the edge detection on these images is, usually, done by a means ratio based method like Touzy algorithm (otherwise, the rate of false alarms is not constant). In order to reduce the time required by local mean computation, in our approach the speckle is converted into an additive noise by applying a logarithm on each channel, then the edges are detected by Sobels's algorithm (which uses pre-definite masks).

The PT converts the volume of detected pixels into a plane whose resolution is a parameter that must be fixed by the user. A low resolution provides, generally, a spontaneous clusterization, but it may introduce errors in the reconstructed line position (slope or shift). On the other hand, a too high resolution, scatters the intersection points, making difficult their clusterization. In our application, we have used a transformed plane of 1024x1024 pixels (a resolution four times higher than that of the temporal channels). This size provides a natural clusterization and does not introduce errors in reconstruction.

The experiments were done on a set of six multi-temporal PRI images from ERS satellites, acquired over French Guyana between 1992 and 1997. The scene – Cayenne neighborhood - includes sparse buildings, roads and a plane track. We have applied our method for extracting the plane track. The size of the original images is 1000x1500 pixels, but, in order to reduce the time of computation, we have processed only an area of 256x256 pixels around the plane track. This area is shown in Figure 1 (the radiometry is that of the first channel).

The edge detection was performed with a threshold of 0.7. This is a high threshold as Figures 2 and 4 show (the number of detections is low). The plane track is, hardly, recognized in the sparse alignment of pixels in these figures. However, if the pixels detected in different channels are assembled by a logical OR, like in Figure 5, the track becomes more visible (due to speckle randomness, the detected pixels do not have the same position in all the channels). This shows that the set contains enough information for track reconstruction. The only problem is to grab it. This is done by means of the PT which melts all this information into a single plane.

The next step consists in maxima detection on the transformed plane. Since the plane track is rather thick, the detected trace is double. In order to reconstruct two lines, two maxima (the highest values in the plane) are identified. The lines corresponding to these pixels, obtained by inverse polar transformation, are shown in Figure 6. They perfectly match the plane track in Figure 1.

IV. Conclusions

The proposed method is able to reconstruct perfectly linked linear structures from nearly aligned, sparse pixels, detected on multi-temporal SAR images. The experiments have shown that our algorithm is very sensible to two parameters : the threshold of the edge detector and the resolution of the transformed space. A low threshold increases the rate of false detections and, consequently, the number of intersections in the transformed plane. These supplementary intersections may obscure the point corresponding to the linear structure. Another negative consequence is the increasing of the computation time required by PT.

The transformed plane resolution is another factor that decides on the algorithm performance. A too low resolution may leads to errors in the linear structure's reconstruction, whereas a too high one scatters the pencil's intersections, making difficult the clusterization.

References

[1]. K. Hansen, J. D. Andersen, "Understanding the Hough Transform: Hough cell support and its utilisation", Image and Computer Vision 15 (1997), pp. 205-218.

[2]. D. Vernon, "Machine Vision", Prentice-Hall, 1991.

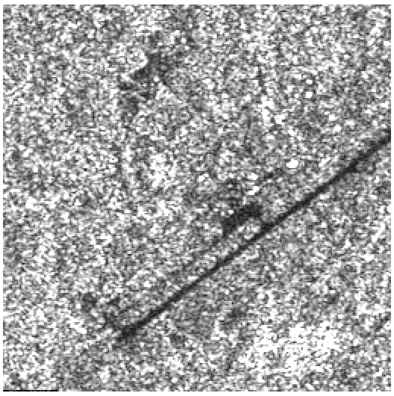

Figure 1. Area around plane track (first channel).

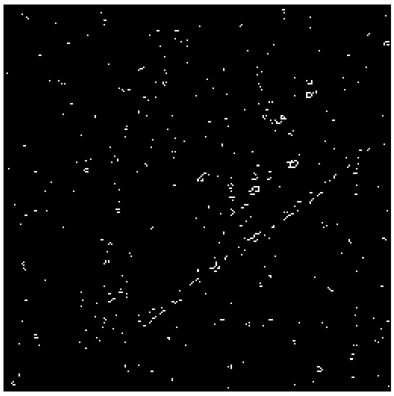

Figure 2. First channel after edge detection with threshold 0.7.

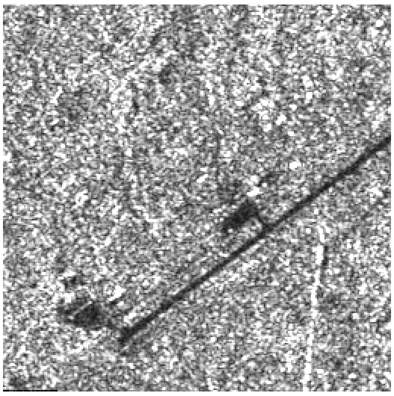

Figure 3. Area around plane track (second channel).

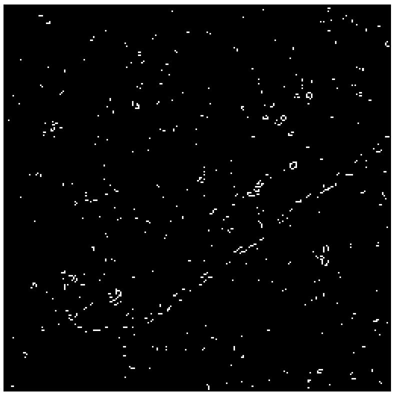

Figure 4. Second channel after edge detection with threshold 0.7.

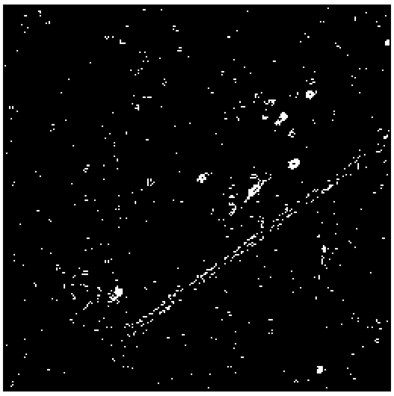

Figure 5. The logical OR of the six channels after detection.

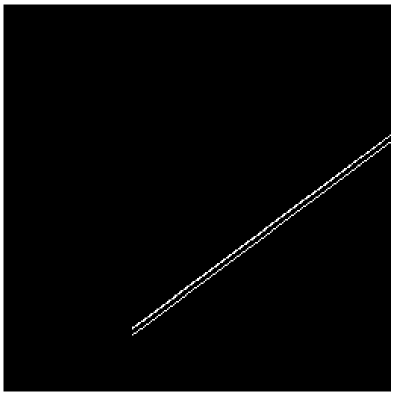

Figure 6. Lines reconstructed by inverse PT.

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