# Linear Structures' Detection on SAR Multi-temporal Sets Using the Polar Transform

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***Abstract*-The Polar Transform (PT) is an efficient tool for detecting and linking the nearly aligned pixels. The method proposed in this paper uses this ability of the PT in order to extract the linear structures in the multi-temporal SAR images with strong speckle. Our algorithm consists in three steps: homomorphic channels' summation, edge detection and linear structure extraction by PT. The homomorphic summation reduces data dimension and, meantime, filters the speckle. Since, in the sum image, the residual noise is additive, the edge detection, in the second step, is done by using Sobel's detector, which is a low computation algorithm. The resulted binary image is transformed by using the PT. The linear structure is detected by looking for the maximum in the transformed image and, then, it is extracted by inverse polar transformation. The reconstructed linear structure has the same position like in the multi-temporal images and its pixels are perfectly linked.**

## I. Introduction

The difficulty of edge detection in SAR images lies in speckle that, in this kind of applications, behaves as a strong multiplicative noise. When edge detection is done by a mean ratio based method like Touzy algorithm, the use of a high threshold gives very sparse detected pixels, whereas a low threshold gives rise to a high rate of false detections. In both instances, the difficulty appears in the last stage of edge detection, i.e., at the pixels' connecting operation.

In this paper we propose a method for linear structures' extraction from SAR multi-temporal images with strong speckle. Our method consists in the following proceeding: speckle reducing by channels' homomorphic summation, edge detection by Sobel's masks and linear structure's extraction by polar transformation.

In edge detection, for a given threshold, the ratio of detected pixels vs. false alarms may be improved if the speckle is previously reduced. A condition is, of course, to not blurr, meantime, the edges. In our approach, we use a very simple but efficient despeckling method consisting in the summation of the logarithmated channels [1]. This filtering method has more advantages: it provides an uniform speckle reduction over the entire scene, whatever the channels' radiometries, it does not blurr the edges and it is fast. The uniform despeckling is important for the second step of the method. It is the condition to have a detection with a constant rate of false alarms. In the filtered image, the channels' radar reflectivities and structures are mixed. However, this effect does not impair linear structure detection, since ones needs only a convenient contrast and not a real one. Besides, the linear structures being perennial features, the risk to lose them by summation is very low.

In the filtered image, the residual noise is not anymore multiplicative like speckle, but additive. This allows the use of a simple edge detector like Sobel's operator, which requires only a low computation.

The last stage of our method consists in extracting a perfect linked linear structure by means of the PT. The principle of this transform and the description of its algorithm are given in the next section.

## 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 [2] 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 [3] can be seen as an adaptation and a simplification of Hough Transform. To a point $(a,b)$, the PT associates – in the transformed space - the straight line with the equation:

$$ax + by = 1 \qquad (1)$$

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

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$(x_0, y_0)$ gives the equation of the points' alignment (inverse PT):

$$x_0 x + y_0 y = 1 \qquad (2)$$

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. Experimental results

The proposed method was tested 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 that was extracted by our method. The size of the original images is 1000x1500 pixels, but, in order to reduce the time of computation, only an area of 256x256 pixels around the plane track has been processed. This area is shown in Figure 1 (the radiometry is that of the first channel).

The image set has been processed as follows:

- summation of the logarithmated images,
- edge detection by Sobel's masks
- polar transformation of the binary image obtained by detection,
- detection of the two highest values of the transformed plane,
- construction, by inverse PT, of the two lines corresponding to the isolated maxima.

By homomorphic summation, the set of six images is reduced to a single image (Figure 2). The plane track can be easily recognized, although the scene radiometry has changed.

Since the residual noise in the sum image is additive, the edge detection has been done by Sobel's detector (conceived for additive noise). Figure 4 shows the detection results for a threshold of 0.43. Since the plane track is rather thick, the detector trace is double. At the left (Figure 3), the same detection was performed on the image in Figure 1, previously logarithmated. Although the linear structure has approximately the same relevance, the number of detected pixels on the entire image is much higher because of the stronger noise.

The next stage consists in a polar transformation of the image in Figure 4. The transformed plane of PT is not necessarily of the same size like the original image, as in DCT or Fourier Transform. The resolution of the transformed plane is a parameter 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 worked on a transformed plane of 1024x1024 pixels (a resolution four times higher than that of the original space). This size provides a natural clusterization and does not introduce errors in reconstruction.

In order to reconstruct two lines like in Figure 4, the coordinates of the two highest pixels were identified, by looking for the maxima. The lines corresponding to these pixels, obtained by inverse polar transformation, are shown in Figure 6. They perfectly match the plane track in Figure 2. The same procedure applied to the image in Figure 3 leads to the erroneous lines in Figure 5. In this case, the points corresponding to the real lines are obscured by the intersections generated by the great number of false detections.

## IV. Conclusions

The method proposed in this paper is able to extract perfectly linked linear structures from multi-temporal SAR images with strong speckle. A condition to obtain good results by this method is a correct tuning of the algorithm's parameters, i.e. detector threshold and transformed plane resolution. The experiments have shown that a high rate of false alarms or a low resolution may easily lead to erroneous results. Another important conclusion is that the method abilities are enhanced in the case of multi-channel images where data redundancy allows improved detection by appropriate pre-filtering.

## References

[1]. D. Coltuc, R. Radescu, "On the Homomorphic Filtering by Channels' Summation", Proc. IGARSS, 2002.

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

[3]. D. Vernon, ”Machine Vision”, Prentice-Hall, 1991.

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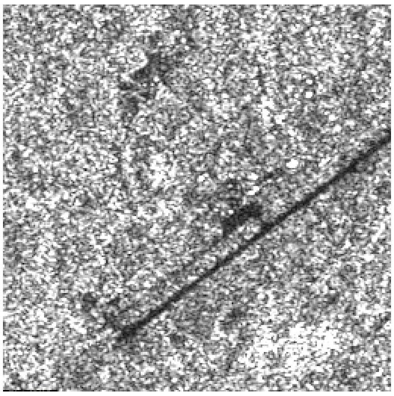

Figure 1. Area around plane track (first channel).

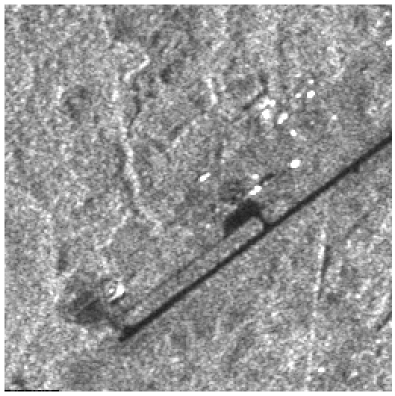

Figure 2. Image filtered by homomorphic channels' summation.

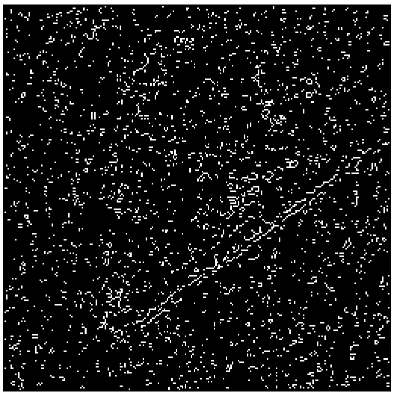

Figure 3. Edge detection on the first channel previously logarithmated.

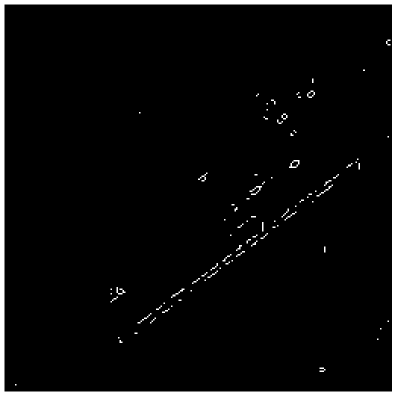

Figure 4. Edge detection on the filtered image.

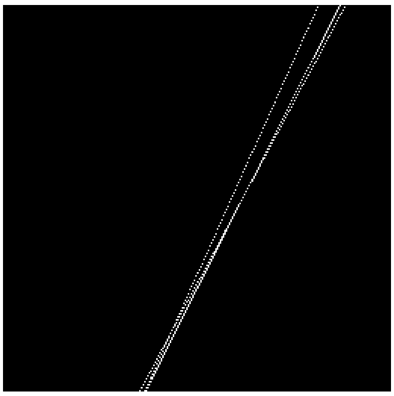

Figure 5. Reconstructed lines for the first channel.

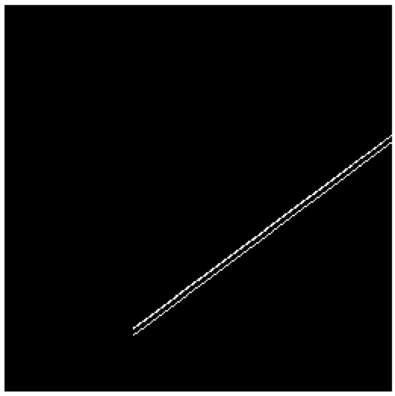

Figure 6. Reconstructed lines for the filtered image.

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