An algorithm to extract linear characteristics from SAR images

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Abstract. The analysis of images surveyed by remote sensing from space platforms are widely used in various sectors: in the field of industry, on the one hand the classification, on the other the singling out of lines or linear characteristics may prove to be useful to investigate the geologic and geographic conformation of the territory. The characteristics typically examined are essentially linear characteristics in areas representing pieces of land, where, because of the presence of components of noise (speckles), or the break caused by too low a contrast, you cannot easily locate rectilinear structures, such as roads, tracks, etc. For the visual interpretation of images geologists use their knowledge and experience to connect ideally lines and arcs which can be broken into a series of segments or tied one to the other; this suggests that the techniques of visual interpretation generally used by man can provide the rules to plan and develop automatic methods.
In particular, the results here reported have been achieved by implementing a “strong fitting” algorithm in a Matlab setting to extract characteristics based on the joined use of the Hough Transform (it may be considered a technique of robust fitting as the RLS (Reweighted Least Square) and Wavelet filters.

Keywords. SAR – Hough Transform – Wavelet – Robust fitting – Automated lineament detection.

1 The Hough Transform

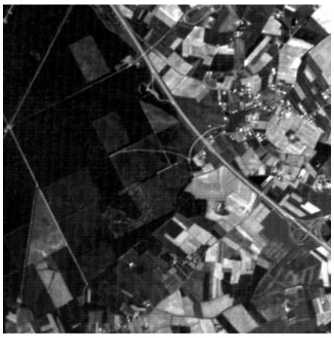
The Hough Transform (HT) is a robust estimator of multidiemnsional carateristichs in the images. The HT is not a proper regression method, however it is able to offer the estimate of regression parameters. It is possible to compare it with robust fitting techniques like RLS (Reweighted Least Square). The technique has been developed by Paul Hough on binarised images.

2 Filtering with 2D Wavelet (FWT 2D)

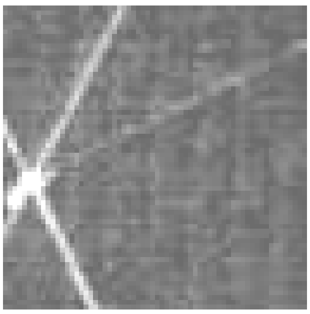
The Wavelet Transform it’s an instrument used in signal processing. It allows to decompose a n-dimensional signal in many different subsignal which represent the frequency of the input signal at different resolution levels.

3 Application of the HT-FWT2D. IFWT2D algorithm implemented in a Matlab setting

The starting image is the one in Picture1, relative to a place in Toulouse. For calculating reasons in the following research a small 64*64 pixel-sized subimage has been selected (Picture 2), where you may visually point out two “sure” rectilinear lines and two more lines, which, even if rectilinear, are not so easy to be singled out.



Picture 1 : A detail of the SAR Image of Toulouse



Picture 2 : A 64* 64 pixel subimage

Considering the two following reference systems, the values for θ , ρ corresponding to the four located lines may be inferred from Table 1

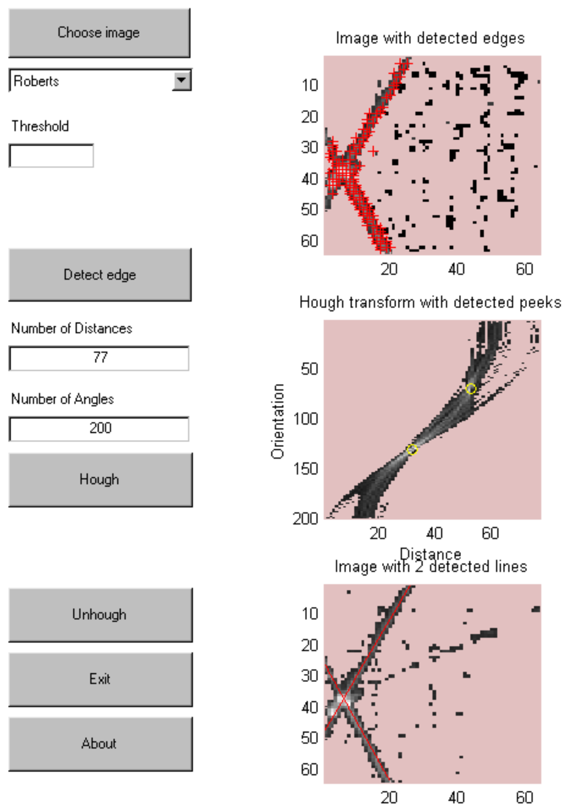
System 1: 0 < θ < 200 -------- 0 < ρ < 90
System 2 0 < θ < 200 -------- -45 < ρ < 45

θ	ρ (Syst. 1)	ρ (Syst. 2)
129	30	-26
69	50	23
29	71	9
74	56	30

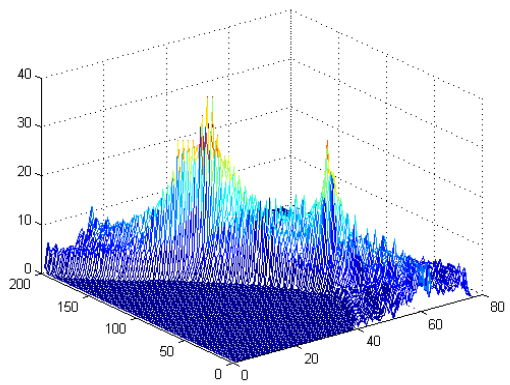
Table 1 : Visual singling out of the rectilinear lines

Specifically, the following steps have been implemented in a Matlab setting:

- Loading the subimage and converting it into a range of greys values
- Converting the image into the binary system (red lines in Picture 3), using a search algorithm for relative maxima through Roberts's approximation of the derivative (the threshold is automatically set up by the algorithm itself (edge.m function)) so as to determine the set of pixels to be converted. (Notice that the binarization causes a heavy loss of information in the image)
- Applying the HT (The calculation has been carried out by means of the ht1.m MATLAB script) to the binarized image. In this case you have to increase the value of the accumulator by one unit at a time (Pictures 3 – 4 and Table 2)
- Applying the HT (The calculation has been carried out by means of the ht2.m MATLAB script) to the original image in 256 tones of grey (Pictures 3 - 4 and Table 2). In this case you have to increase the accumulator by the value corresponding to the examined pixel.(Remember that the result of the HT may be interpreted as a two-dimensional histogram where you use a quantization of the intervals θ , ρ ; this means that you may index every single value produced by this quantization(θ , ρ) with whole numbers i, j)
- Selecting some cells of the accumulator which show the greatest peaks and tracing (HT inverse transformation) the corresponding straight lines (Pictures 3 – 4 and Table 2)



Picture 3: The HT to the image of Picture 2 (Binarization- Singling out the peaks- Tracing linear segments-)



Picture 4: Accumulator (spatial representation- internal system) of the HT(binarized image)

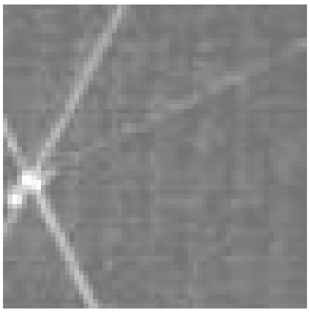
Binarized image Internal System 1 Binarized image System 2			Binarized image System 2		Image 256 grey levels System 2	
θ	ρ	Param	θ	ρ	θ	ρ
130	33	30	130	-27	130	-27
70	52	24	70	24	70	23
54	11	18	54	-10	29	10
					76	31
					141	54
					52	-10
					9	-13

Table 2: Parameters of the straight lines and local maxima singled out by the HT algorithm (in the two reference systems) for the SAR image (binarized – 256 tones of grey)

As you may notice in Table 2 the application of the HT to the binarized image really restores two of the visually recognizable straight lines, but it adds one of uncertain origin. The presence of this "unreliable" straight line is probably due to the fact that the HT algorithm, singling out the local maxima in the accumulator, produces some spurious ones, besides the points really corresponding to the straight lines in the examined image, because the sinusoids corresponding to points which do not have any geometric relations interact in the converted domain by wrongly locating straight lines among distinct linear elements.
The application of the HT to the image in 256 tones of grey, instead, restores a greater number of straight lines, though including all the four straight lines recognizable with the naked eye too. This is due to the fact that the algorithm is applied to an image containing a greater quantity of information (256 tones of grey), compared to the case of the binarized image.
The pre-filtering of the SAR image through the WT intends to remove the presence of spurious straight lines recognized by mistake and probably due to the component of noise.

• Applying the HT to the image rebuilt with the inverse transformed Wavelet.
The calculation has been carried out by means of the iwt.m MATLAB script.

Table 3 reports the results achieved after the application of the HT algorithm to the filtered and rebuilt image (Picture 5)



Picture 5: Rebuilt image Inverse Wavelet Transform (IWT2D)

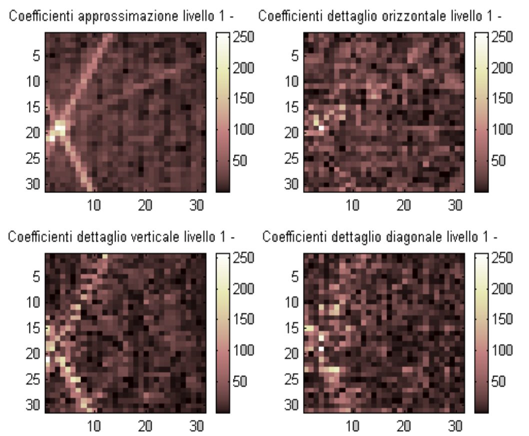
Image 256 grey levels	System 2
θ	ρ
130	-27
70	23
29	10
76	32
141	54
52	-10

Table 3: Parameters of straight lines singled out by the HT algoriyhm in the rebuilt image.

Notice that the original image and the rebuilt one are "almost" the same: this means the reconstruction mistake is substantially null and so you may not think of achieving a very different qualitative result by applying the HT to the IWT 2D of the image, in comparison with the direct application of the HT to the original image.
However, notice (compare Table 2 to Table 3), in this case, a straight line less is singled out, compared to the case of the application of the algorithm to the original image in 256 tones of grey. This circumstance points out that the total application of the WT, even though it does not lose in the resolution on the whole (rebuilding phase), it allows you to remove some components of noise (speckles)

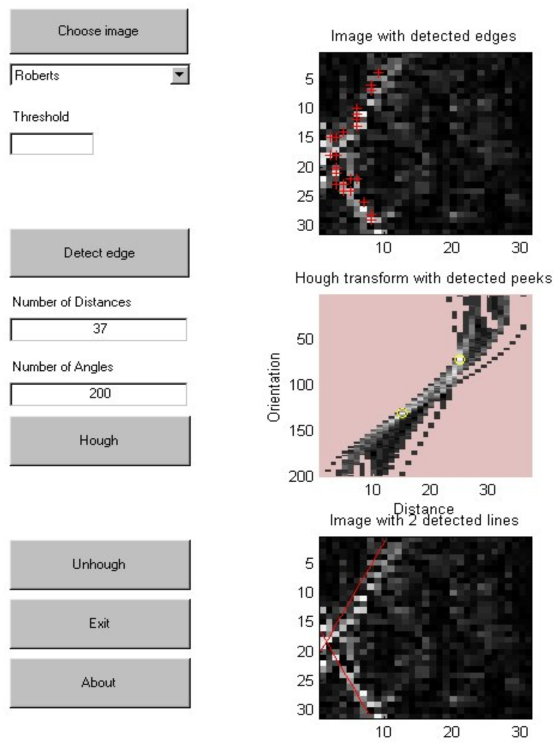
• Applying the Hough Tranform to the subimages (approximation, horizontal - vertical - diagonal) provided by the two-dimensional Wavelet Transform in a SAR image.

The calculation has been carried out by means of the fwt.m MATLAB script.
The filters used here characterize the kind of transformation. The Daubechies 2 has been used in the analysis and the decomposition has reached the third level. As an undersampling is carried out in every decomposition , the converted images have got halved dimensions and consequently the definition becomes rougher. Therefore, in the case under examination, only the first level has been reached (Picture 6).



Picture 6: Decomposition according to the WT at the first level of the SAR image

In particular, you may not carry out a direct comparison between the results offered by the HT applied directly to the image and the ones offered by the application to the subimages, as every subimage has got halved dimensions compared to the original image, because of the undersampling operation of the FWT 2D algorithm. The application only allows you to see if some linear details may really be better located.
The approach based on the application of the HT to the subimage of approximation, cannot bring any advantages, because the analysis is carried out on an undersampled low frequency component of the original image. In the specific case you may notice that (as expected) the application of the HT to each one of the three possible subimages (horizontal - vertical - diagonal), produces real advantages only in the case of the vertical detailed subimage (Picture 7) and "partially" in the diagonal detailed one. This is due to the fact that the rectilinear lines in the original image are mainly of vertical and diagonal kinds. The advantages of the application are here more evident, if you consider the binarized images.



Picture 7: HT application to the vertical detailed image of the SAR image.

Particularly, the application of the HT to the subimages does not seem to produce a big advantage as you may single out the same linear lines recognizable with the application of the HT to the original image. This circumstance is due to the fact that in the starting SAR image a very limited number of linear lines are actually present.

4 Conclusions

The use of the "robust fitting HT" transformation has proved to be a powerful means of singling out linear characteristics inside images (in both the binarized version and the one in 256 tones of grey).
The use of FWT and its inverse transformed IWT allows you to reduce some components of noise (speckles) without significantly altering the structure of the original image.
In the presence of complex images (a high number of rectilinear lines with different gradients) the integration of the HT-FWT algorithm applied to the three subimages seems to permit a considerable improvement in the singling out of linear lines.

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