APPLICATION OF AN AUTOFOCUSING ALGORITHM FOR SAR IMAGE QUALITY IMPROVEMENT AND APPLICATION OF THE MODIFIED FRACTAL SIGNATURE (MFS) METHOD FOR SAR IMAGE CLASSIFICATION FOR THE CASE OF REAL RADAR DATA

A. Malamou, C. Pandis, A. Karakasiliotis, P. Stefaneas, D. Kodokostas and P. Frangos

National Technical University of Athens
9, Iroon Polytechniou Str., GR 157 73, Zografou, Athens, Greece
Tel. +30 210 772 3694, Fax. +30 210 772 2281, E-mail : pfrangos@central.ntua.gr

Abstract

In the first part of this paper, the application of an autofocusing algorithm is presented for the case of real field radar data, provided to us by SET 163 Working Group. This algorithm is named 'CPI-split-algorithm', where CPI stands for 'Coherent Processing Interval'. Numerical results presented in this paper show the effectiveness of the proposed autofocusing algorithm for SAR image enhancement.

In the second part of this paper the Modified Fractal Signature (MFS) method is presented. This method uses the 'blanket' technique to provide useful information for SAR image classification. The MFS method is applied in real field data provided to us by SET 163 Working Group (comparison of a 'town' area, 'suburban' area and 'sea' area). In these results it is clearly seen that the type of area can be distinguished by the value of MFS signature for the real data.

1. INTRODUCTION

Synthetic aperture radar (SAR) can perform with high image resolution at long range, regardless the weather conditions. It is a radio frequency (RF) sensor and has been widely used as a tool for long-range imaging. The range-Doppler information collected by the SAR antenna leads to the synthesis of the SAR image of the target with high resolution [1], [2]. The targets of observation can be either stationary or moving ground objects. Moving targets are usually monitored as they are of great interest. However the reconstruction of the image of a moving target using SAR data is difficult because the obtained SAR image is usually degraded by defocus, distortion or displacement due to target movement. In this paper the post processing CPI-split autofocusing algorithm [3] is applied to the case of real field data of a moving ship (airborne SAR), provided to us by SET 163 Working Group (see acknowledgement below for more details), in order to obtain a focused SAR image of a moving target.

Moreover, in this paper, the Modified Fractal Signature (MFS) is applied in real SAR radar images. This technique has already been used for document analysis, classification and pattern recognition [5], [6]. In this paper is applied in the classification of SAR radar images and in particular in the discrimination of a real SAR radar image ('Oslo Fjord') to 'town' area, 'suburban' area and 'sea' area.

2. APPLICATION OF AN AUTOFOCUSING ALGORITHM FOR SAR IMAGE QUALITY IMPROVEMENT FOR THE CASE OF REAL RADAR DATA

In this section we incorporate the post processing CPI-split autofocusing algorithm (briefly named "CPI-split auto-focusing") recently introduced by our research group [3], [4] in the case of real field radar data. This algorithm has already been tested for simulated data in the cases of SAR and ISAR geometry [3], [4]. The application of our proposed algorithm produced excellent focusing of SAR and ISAR images for several cases of moving targets [3], [4].

The real field radar data, which are examined here, were provided to us by SET 163 Working Group (see the 'Acknowledgement' below for more details). This radar transmits linear frequency modulated waveform (LFM), whereas in our simulation scenarios [3], [4] the radar antenna is assumed to emit Stepped Frequency (SF) pulses. These raw radar data yield ultimately (after appropriate SAR signal processing) a moving ship target, which is being imaged by the SAR radar. In Fig. 1 three SAR images of consecutive CPI's are presented.

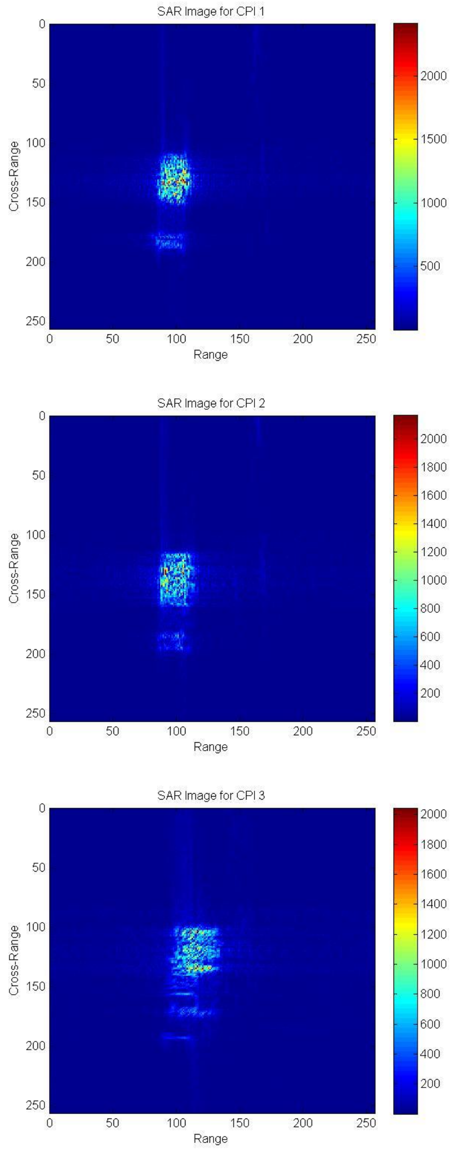


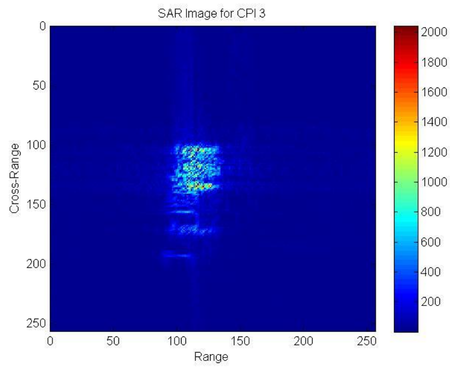
Figure 1. SAR images for three CPI's (real radar data provided by 'SET 163 Working Group')

In order to compare the quality of the above SAR images, the entropy value of each image is computed [3], [4]. In Table 1 the entropy values for the three SAR images presented above are listed. The CPI-split autofocusing algorithm is employed in the CPI which entropy value exceeds a threshold that represents an acceptable SAR image quality [3]. The images with entropy values below the entropy threshold are called "focused" images, while the images with entropy values over the threshold are called "unfocused". We have applied the autofocusing algorithm to the previously presented SAR images for four CPIs. As seen in Table 1, the 3rd CPI has the greater entropy value and therefore is the "unfocused" CPI. The entropy threshold was set to 7.5.

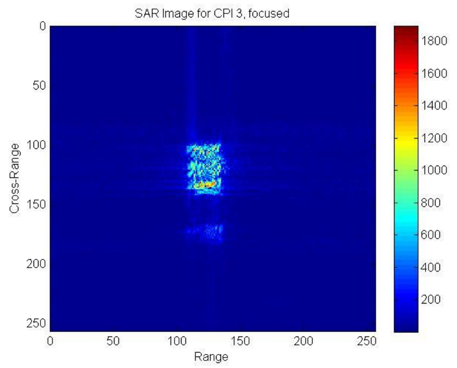
Table 1. Entropy values

SAR Image	Entropy	Minimum Entropy Combination
1st CPI	7.1409	
2nd CPI	7.3497	
3rd CPI, unfocused	7.6694	
3rd CPI, focused	7.3948	stage 3, segment 2, combination 3 [3]

In Fig. 2 the SAR images for the 3rd CPI are presented, before and after the application of the autofocusing algorithm.



2a)



2b)

Figure 2. SAR image before (a) and after (b) the application of the proposed autofocusing algorithm.

The SAR image for the 3rd CPI after the application of the autofocusing algorithm is clearly more focused than the SAR image before the application of the autofocusing algorithm. This result is also validated by the entropy values presented in Table 1. The entropy value of the SAR image (3rd CPI) before the application of the autofocusing algorithm is greater than the entropy value of the SAR image (3rd CPI) after the application of the autofocusing algorithm. Moreover the entropy value of the 'focused' image is within the acceptable entropy values (below the entropy threshold).

The real-field data results presented above show that the proposed algorithm is effective in producing focused SAR images. Based on SAR image entropy minimization criterion, the proposed algorithm neglects data leading to ISAR images of poor quality and uses only data leading to ISAR images of superior quality. The simulations results verify the adaptiveness of the autofocusing procedure to different SAR imaging conditions.

3. APPLICATION OF THE MODIFIED FRACTAL SIGNATURE (MFS) METHOD TO SAR IMAGE CLASSIFICATION

In this section the implementation of the 'blanket' (MFS) method [5], [6] is described. Initially, the SAR image is converted to a gray – level function g(x,y). Subsequently the whole SAR image is divided into several non-overlapping sub-images and the fractal signature is calculated for each sub-image. The overall fractal signature of the initial image is calculated ultimately by summation of the corresponding values of the sub-images [5]. In addition in order to compute the fractal dimension, we need to measure the area of the gray level surface.

In the blanket technique, all points of the three dimensional space at distance δ from the gray level surface g(x,y) are considered. These points construct a "blanket" of thickness 2δ covering the initial surface. The covering blanket is defined by its upper surface $u_\delta(x,y)$ and its lower surface $b_\delta(x,y)$ as it is presented in Fig. 3.

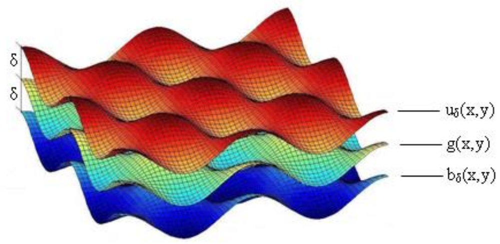


Figure 3. 'Blanket' of thickness 2δ defined by its upper $u_\delta(x,y)$ and lower $b_\delta(x,y)$ surface

The algorithm used to compute the upper and lower surface includes the following steps. Initially, the iteration δ equals zero (δ=0), the gray-level function equals the upper and lower surfaces, namely: $u_0(x,y) = b_0(x,y) = g(x,y)$. For iteration δ=1,2,… the blanket surfaces are calculated through the following iterative formulae

$$u_\delta(x,y) = \max\{u_{\delta-1}(x,y)+1, \quad \max_{|(m,n)-(x,y|\le 1} u_{\delta-1}(m,n)\} \quad (1)$$

$$b_\delta(x,y) = \min\{b_{\delta-1}(x,y)-1, \quad \min_{|(m,n)-(x,y|\le 1} b_{\delta-1}(m,n)\}$$

Subsequently, the volume of the 'blanket' is calculated from $u_\delta(x,y)$ and $b_\delta(x,y)$ by:

$$Vol_\delta = \sum_{(x,y)} (u_\delta(x,y) - b_\delta(x,y)) \quad (2)$$

Furthermore, the fractal signature Aδ is calculated by :

$$A_\delta = \frac{Vol_\delta}{2\delta} \text{ or } A_\delta = \frac{Vol_\delta - Vol_{\delta-1}}{2} \quad (3)$$

Finally, concerning the calculation of the corresponding fractal dimension D, the following formula is used [5]:

$$A_\delta \approx \beta \delta^{2-D} \quad (4)$$

where β is a constant, from which the fractal dimension can be calculated from successive fractal signature values as following:

$$D \approx 2 - \frac{\log_2 A_{\delta_1} - \log_2 A_{\delta_2}}{\log_2 \delta_1 - \log_2 \delta_2} \quad (5)$$

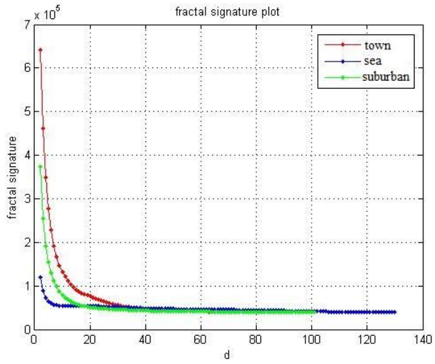
where δ=1,2,… e.t.c.

Subsequently, the application of the MFS method to Synthetic Aperture Radar (SAR) images from real radar data (SAR image of 'Oslo fjord') provided to us by SET 163 Working Group is presented. The SAR image examined here is shown in Fig. 4. Three sub images were obtained from the initial SAR image: the first includes a 'town' area, the second a 'suburban' area and the third a 'sea' area.

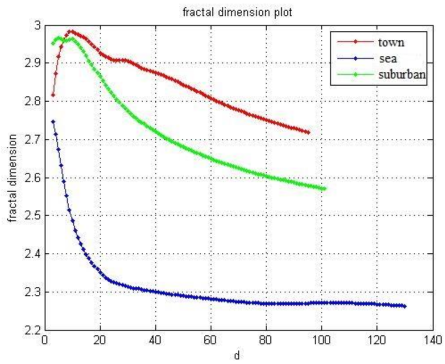
Figure 4. SAR image of 'Oslo fjord'
(provided by 'SET 163 Working Group')

In Fig. 5, the fractal signature Aδ as a function of iteration δ and the fractal dimension D as a function of iteration δ for the cases of three sub images: 'town' area, 'suburban' area and 'sea' area are presented.

It appears that the proposed algorithm provides interesting characterization results for the cases of 'town' area, 'suburban' area and 'sea' area.



5a)



5b)

Figure 5. (a) fractal signature A_δ as a function of iteration δ, (b) fractal dimension D as a function of iteration δ for the cases of 'town' area, 'suburban' area and 'sea' area.

4. CONCLUSION

In this paper, the 'CPI-split autofocusing algorithm' is incorporated for the case of real field radar data. The real-field data results presented above show that the proposed algorithm is effective in producing focused SAR images. The simulations results verify the adaptiveness of the autofocusing procedure to different SAR imaging conditions.

Furthermore, an iterative MFS technique [5], [6] is applied aiming in SAR radar image characterization (real data). As confirmed by the results presented above, the proposed algorithm provides interesting characterization results. It is apparent that the criteria of 'fractal signature' and 'fractal dimension' for SAR image characterization work in a satisfactory way. The type of area can be distinguished by the value of 'fractal signature' and 'fractal dimension' for the real field radar data.

Acknowledgments

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