APPLYING THE MODIFIED FRACTAL SIGNATURE METHOD TO IMAGE CLASSIFICATION: SOME PRELIMINARY RESULTS FOR ISAR RADAR IMAGES

(Scientific area of interest: 'Image Classification')

C. Pandis, A. Malamou, P. Stefaneas and P. Frangos

National Technical University of Athens
9, Iroon Polytechniou Str., GR 157 73, Zografou, Athens, Greece
Tel. +30 210 772 1869, E-mail: petros@math.ntua.gr

Abstract

The Modified Fractal Signature (MFS) method uses the 'blanket' technique to provide useful information for image classification. It has been used in [1] and [2] in order to provide classification results for document analysis purposes [1] and biomedical image classification [2]. It is based on the calculation of the volume of a 'blanket', corresponding to the image to be classified, and then on the calculation of the corresponding fractal signature (MFS) of the image. We present here some preliminary results concerning the application of MFS method to the classification of Inverse Synthetic Aperture Radar (ISAR) images. In these results it is clearly seen that the focusing of the ISAR radar image clearly correlates with the value of MFS signature.

1. INTRODUCTION

MFS method has been introduced by Y. Tang et. al. for the purpose of document analysis, classification and pattern recognition [1]. N. Ampilova et. al. applied similar methods for biomedical image classification [2]. This method includes fractal analysis [3,4] of surfaces and uses a 'blanket' technique [1,2], which is explicitly provided in Section 2, below. The concept in this technique is that different classes of images yield different values of fractal signature (MFS) and fractal dimension, upon which classification of different types of images is possible. In particular, in this paper we are interested for the classification of ISAR radar images, and, in particular, for discrimination of 'focused' or 'unfocused' ISAR images [5]. In [5], the criterion for image focusing is based on the 'image entropy', while in the present the criterion of fractal signature value is investigated.

2. MATHEMATICAL FORMULATION OF THE PROBLEM

The 'blanket' (MFS) method [1,2], as implemented by our research group in this paper, is summarized as following: initially, the whole image is divided into several non-overlapping sub-images and the fractal signature is calculated for each sub-image, as explained below (the overall fractal signature of the initial image will be calculated ultimately by summation of the corresponding values of the sub-images, as it will be explained below). Subsequently, each sub-image is converted to a gray – level function g(x,y) [1].

According to [1] and [2], the covering blanket is defined by its upper surface $u_\delta(x,y)$ and its lower surface $b_\delta(x,y)$. Initially, δ=0 and $u_0(x,y)$ = $b_0(x,y)$ = g(x,y). For δ=1,2,… we have the following iterative formulae:

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

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

Subsequently, the volume of the 'blanket' is calculated

$$\mathrm{Vol}_\delta = \sum_{(x,y)} \left(u_\delta(x,y) - b_\delta(x,y)\right) \quad (2)$$

Furthermore, the fractal signature A_δ is calculated by

$$A_\delta = \frac{\mathrm{Vol}_\delta}{2\delta} \quad (3)$$

or

$$A_\delta = \frac{Vol_\delta - Vol_{\delta-1}}{2} \quad (4)$$

(see also Fig. 1)

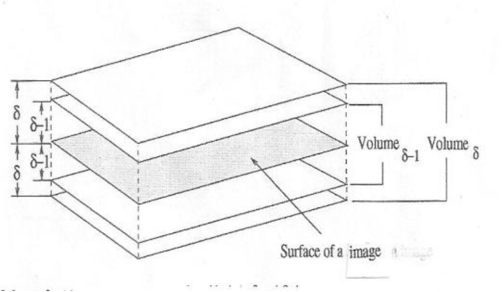


Fig. 1. Volumes of the 'blanket' involved in our proposed algorithm for fractal signature calculation [1]

Finally, concerning the calculation of the corresponding fractal dimension D, the following formula is used [1]

$$A_\delta \approx \beta \delta^{2-D} \quad (5)$$

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

$$D \approx 2 - \frac{\log_2 A_{\delta_1} - \log_2 A_{\delta_2}}{\log_2 \delta_1 - \log_2 \delta_2}, \ \delta=1,2,\ldots \quad (6)$$

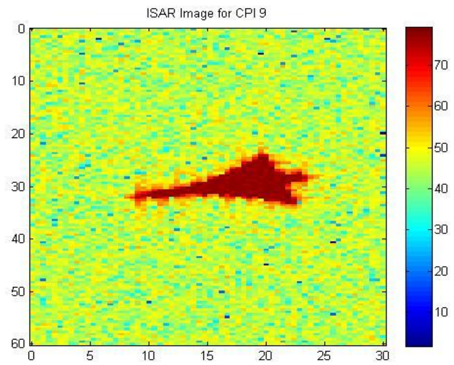
3. PRELIMINARY NUMERICAL RESULTS

In this paper our simulations of the proposed algorithm concern ISAR radar images of the authors' previous research [5], see Fig. 2 below [similarly, in the near future, our research group will investigate, in a similar fashion, classification issues of direct Synthetic Aperture Radar (SAR) images [6]].

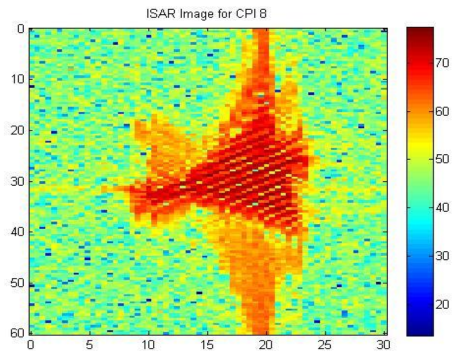
As well expected, the image of Fig. 2(a) is characterized from small value of entropy, as opposed to the image of Fig. 2(b) [5]. In the present study, the criterion of fractal signature and fractal dimension will be used instead. Fig. 3, below, shows the fractal signature A_δ as a function of iteration δ for the cases of the 'focused' and the 'unfocused' image of Fig. 2.

From the results of Fig. 3 above, through the use of Eq. (6) above, the following results of Fig. 4 for the corresponding fractal dimension are derived.

From the numerical results of Figs. 3,4 above, it is apparent that the criteria of 'fractal signature' and 'fractal dimension' for ISAR image characterization work in a satisfactory way for the above simulations (besides to the criterion of entropy values, examined in [5] and [6]). Furthermore, from the first simulations presented above, we can provide here some preliminary remarks, as following. First, it appears that conclusions about image characterization follow for small values of iteration δ. Furthermore, for the particular case of Fig. 3, above, note that information about image characterization is lost for number of iteration δ=13. Finally, we easily can understand that, for large number of iterations (δ), the proposed algorithm of Eq. (1) appears to select the ±1 values of the previous iteration, so that the value of fractal signature equals, in this limit, the number of the pixels of the image. This final statement can be very easily proved from Eq. (4), where, in the current simulations, this situation occurred for δ=148 ('focused' case) and δ=129 ('unfocused' case).



(a)



(b)

Fig. 2. ISAR images used in the present simulations, (a) 'focused' ISAR image of airplane, (b) corresponding 'unfocused' image [5]

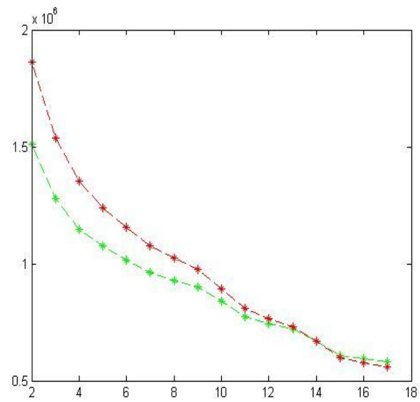


Fig. 3. Fractal signature Aδ as a function of iteration δ for the cases of the 'focused' and the 'unfocused' image of Fig. 2 (red = unfocused, green=focused).

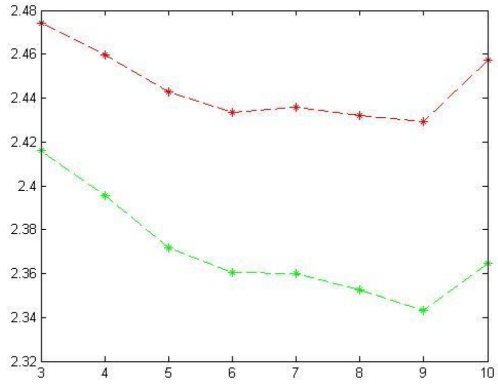


Fig. 4. Fractal dimension D as a function of iteration δ for the cases of the 'focused' and the 'unfocused' image of Fig. 2 (red = unfocused, green=focused)

4. CONCLUSION – Future Work

In this paper we applied an iterative MFS technique [1,2] for ISAR radar image characterization. It appears that for small values of iteration δ the proposed algorithm provides interesting characterization results. In the near future, our research group will also examine the behavior of direct SAR images, as well, further comparisons with the entropy value criterion, and other fractal image characterization methods, such as 'Regny spectrum' method, as well [2].

Acknowledgements

The authors would like to acknowledge very interesting relative discussions with Professors N. Ampilova and I. Soloviev, St. Petersburg State University, Russia, which initiated this research.

This research has been co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES:Reinforcement of the interdisciplinary and / or inter-institutional research and innovation.

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