KERNEL REGRESSION-BASED BACKGROUND PREDICTING METHOD FOR TARGET DETECTION IN SAR IMAGE

Gu Yanfeng, Liu Xing, Han Jinlong, Zhang Ye

School of Electronics and Information Technique, Harbin Institute of Technology

1. INTRODUCTION

Target detection and automatic target recognition in SAR imagery are attached importance to increasingly these years. In SAR imagery, complicated background clutters affect the performance of the conventional CFAR algorithm seriously. Therefore, effective approach to restrain the background clutters will be greatly helpful to CFAR detection. Classical parametric image processing methods rely on a specific model of the signal of interest and seek to compute the parameters of this model in the presence of noise. In contrast to the parametric methods, nonparametric methods rely on the data itself to dictate the structure of the model [1]. With the relatively recent emergence of machine learning methods, kernel methods have become well-known and used frequently for pattern detection and discrimination problems [2]. In this letter, we propose a small target detecting algorithm in SAR imagery, which predicts the background clutter using 2D kernel regression to eliminate correlative background and get remaining image which only consists of noise and targets, then uses CFAR detecting algorithm to process the remaining image.

2. METHODOLOYY

2.1 2D Kernel Regression

Kernel regression in 2-D [3]:
The form of 2-D (2-dimension) KR is

$$y_i = z(x_i) + \varepsilon_i, \quad i = 1, \cdots\cdots, P \tag{1}$$

where x_i is a vector of 2x1, y_i is image pixel gray, $z(x_i)$ is regression function, ε_i is a random error or interference that is decorrelated with x_i, and P is the total number of pixels. Generally, suppose ε_i be normal variable with zero mean. Thus, the local expansion of the regression function $z(x_i)$ is as follows

$$z(x_i) = \beta_0 + \beta_1^T (x_i - x) + \beta_2^T vech\{(x_i - x)(x_i - x)^T\} + \cdots \tag{2}$$

where $vech(\cdot)$ denotes vector processing manner for symmetrical matrix. For example, for a 2x2 symmetrical matrix,

$$vech\left(\begin{bmatrix} a & b \\ b & d \end{bmatrix}\right) = [a \;\; b \;\; d]^T \tag{3}$$

And $\beta_0 = z(x)$ is the pixel value of interest, and the β_1 and β_2 are

$$\beta_1 = \nabla z(x) = \left[\frac{\partial z(x)}{\partial x_1}, \frac{\partial z(x)}{\partial x_2}\right]^T \tag{4}$$

$$\beta_2 = \frac{1}{2}\left[\frac{\partial^2 z(x)}{\partial x_1^2}, 2\frac{\partial^2 z(x)}{\partial x_1 x_2}, \frac{\partial^2 z(x)}{\partial x_2^2}\right]^T \tag{5}$$

As in the case of univariate data, the $\{\beta_n\}$ are computed from the following optimization problem:

$$\min_{\{\beta_n\}} \sum_{i=1}^{P} [y_i - \beta_0 - \beta_1^T (x_i - x) - \beta_2^T vech\{(x_i - x)(x_i - x)^T\} - \cdots]^2 \cdot K_H(x_i - x) \tag{6}$$

with

$$K_H(t) = \frac{K(H^{-1}t)}{\det(H)} \tag{7}$$

where K is the 2-D realization of the kernel function, and H is the 2x2 smoothing matrix. It is also possible to express (6) in a matrix form as a weighted least-squares optimization problem.

After $\{\beta_n\}$ are obtained by solving the optimization problem, KR-based background prediction can be performed on the image.

2.2 2D Kernel Regression

Detecting algorithm using kernel regression-based background prediction: the steps for the anomaly detection are as follows.

(i) Set the hollow window size. The window consists of two regions, the inner and outer window regions, as shown in Fig.1. The window size varies with resolution and the type of target of interest [4].

(ii) Select the kernel function, estimate the parameters and the smoothing matrix. In this paper, we use the popular Gaussian RBF as the kernel function defined as

$$K(x,y) = \exp(-\frac{\|x-y\|^2}{\sigma^2}) \tag{8}$$

(iii) Predict the background using kernel regression; subtract the predicting image from the original image and get the remaining image.

(iv) Use the CFAR detector [5] to process the remaining image.

3. PAGE TITLE SECTION

We tested our algorithm on a real SAR image to make a comparison with conventional CFAR detecting algorithm. To get better predicting results, we set the size of the guard window $N = 30$, and the width of outer area $M = 4$..

The ROC curves comparing the proposed algorithm and the two-parameter CFAR detecting algorithm are shown in Fig.1. To get a clearer comparing result, the probability of detection is defined as the ratio of the detected target pixel number and the whole target pixel number. And the detecting algorithm using kernel regression-based background prediction greatly outperforms the conventional two-parameter CFAR detecting algorithm throughout the curve.

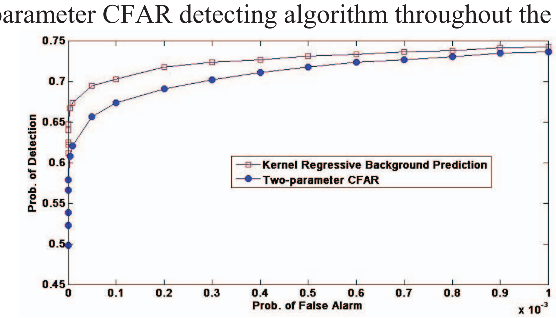

Fig.1. ROC curve comparing detecting algorithm using kernel regressive background prediction and conventional CFAR detecting algorithm

4. CONCLUSION

In this paper, a KR-based background prediction method is proposed for small target detection in SAR imagery. In the proposed method, 2D KR is firstly performed to predict the background clutters in SAR imagery. Then, the predicted background clutters are removed from the original SAR imagery, and a new image is obtained, in which, there are only target and noise. The conventional CFAR algorithm is performed on the new clean image finally. The experiment results indicated the proposed algorithm can greatly improve the performance of the conventional CFAR algorithm.

5. REFERENCES

[1] M. P. Wand and M. C. Jones, Kernel Smoothing, ser. Monographs on Statistics and Applied Probability. New York: Chapman & Hall, 1995

[2] P. Yee and S. Haykin, “Pattern classification as an ill-posed, inverse problem: a regularization approach”, in Proc. IEEE Int. Conf. Acoustics, Speech, Signal Processing, April, 1993, vol. 1, pp. 597–600

[3] H.Takeda, P.Milanfar, “Kernel Regression for Image Processing and Reconstruction”, IEEE Trans. on Image Processing, February, 2007, 16 (2), pp. 349-365

[4] Amit Banerjee, Philippe Burlina, and Chris Diehl, “A Support Vector Method for Anomaly Detection in Hyperspectral Imagery”, IEEE Trans. On GRS, August, 2006, vol. 44, pp.2282-2290

[5] Novak L M, Halversen S D, Owirka G J, et al. “Effects of Polarization and Resolution on SAR ATR”, IEEE Trans on AES, January, 1997, 33(1), pp.102-115