Wavelet Transformation and Signal Discrimination for HRR Radar Target Recognition

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Abstract. This paper explores the use of wavelets to improve the selection of discriminant features in the target recognition problem using High Range Resolution (HRR) radar signals in an air to air scenario. We show that there is statistically no difference between four different wavelet families in extracting discriminatory features. Since similar results can be obtained from any of the four wavelet families and wavelets within the families, the simplest wavelet (Haar) should be used. We further show that a simple box classifier can be constructed from the extracted features and that any feature that classifies four or less training signals can be removed from the classifier without a statistically significant difference in the classifier performance. We use the box classifier to select the 128 most salient pseudo range bins and then apply the wavelet transform to this reduced set of bins. We show that by iteratively applying this approach, classifier performance is improved. The number of times the feature reduction and transformation can be performed while producing improved classifier performance is small and the transformed features are shown to quickly cause the performance to approach an asymptote.

Key Words: rough sets, wavelets, automatic target recognition, high range resolution radar, feature selection

1. Introduction

Most of the work in HRR target recognition has been done by or sponsored by the military. The approaches taken by various researchers as summarized by [8] appear to ignore the benefits that can be gained by proper transformations of the input signal. The wavelet transform is a new tool which has been used in image compression and more recently in target recognition. When wavelet transforms are used for image compression the most important goal is to minimize the loss of information. In ATR the most important objective is to be able to separate the various target classes [7]. Some researchers have explored the use of wavelets to provide a richer feature space [2], [3], [4], [7], [9], [12], [13]. However there is little evidence of widespread use of this technique. Mitchell himself explored transformations but he limited the analysis to an autoregressive approach to clean up (remove low information data) from the signature.
Famili states that preprocessing the data “...conditions the input data to allow easier subsequent feature extraction and increased resolution.” [5]. In the past, engineers have used transforms such as the Fourier transform to move the signal from a time base to a frequency base [14]. Although this is useful for some applications, target recognition of HRR signals improved only a little under this transform. Wavelets bring a new tool to HRR signals classification. The benefits of using wavelets, according to Strang, are related to a local character of those transformations “...new transforms are much more local. An event stays connected to the time when it occurs. ...a time-frequency description” [11]. Researchers that have used wavelets for target recognition (especially for HRR) have found that the original feature space can be augmented by the wavelet coefficients and will yield a smaller set of more robust features in the final classifier [9], [13]. In addition to computational savings [4], investigators have also found that wavelet methods can improve radar performance (Pcc) [12], [13]. However, as pointed out by Stirman [13] even with improvement in Pcc there can be a bias of the wavelets toward one or two classes to the detriment of others.

In considering wavelets for ATR, serious consideration must be given to the selection of a wavelet family and a wavelet in the family. Lu explored this issue in the context of image coders [15]. In his paper, Lu compared two wavelets, one from the Biorthogonal family (B97) and the other from the Daubechies family (D8). Using two different metrics, Lu observed a slight advantage of the B97 versus the D8. In this paper, using the criterion of improving the probability of correct classification (Pcc), we show that there is no statistical advantage of one family (out of four) over any other family. Any difference in performance which can be observed in a particular application is due to the statistical nature of normal variations in the data. Stirman, using wavelets for ATR, explored the use of different wavelets from the Daubechies family, and found that results were similar among the three wavelets [13]. In this paper we show that here is no statistical advantage of one wavelet in a family over another in the same family, thus generalizing Stirman’s observation.

Once the input data is transformed, the process of feature selection for the given type of classifier must begin. A very popular approach uses a quadratic classifier [8]. The quadratic classifier uses statistics of the signal to be classified and compares them to the statistics of a template for the various target classes. This method is fraught with problems since it uses the entire signal and thus tries to match noise to noise. In an effort to get around this problem, Mitchell [8] uses an autoregressive filter to remove noise and then uses the filter to help select important range bins for classification. It is not the purpose of this paper to explore the development of a classifier. However, in order to have a means to test the usefulness of the data transforms, we must have a classifier to test the performance. In order to reduce the problem of the quadratic classifier, we have chosen to use the simple generalized box classifier [1], [10] from which to evaluate results. Our main objective was to determine which, if any, family of wavelets provided the best feature set for a classifier. A secondary objective was to determine if further wavelet transformations would produce even better classification results. This required the use of a method for down selecting features from which