Maritime Radar Target Detection
Using Neural Networks
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Abstract—In this paper two neural network based maritime radar target detection systems are presented: one is based on a Back-Propagation (BP) network and the other on the combination of a Principal Component Analysis (PCA) network and a BP network. Using maritime radar images as inputs, both systems include a pre-processing stage, a BP network classification stage and a post-processing stage. In the PCA + BP network system, an extra PCA network is used for compacting test patterns. Experimental results show that: (a) for the BP network based system, the overall detection rate is 95.3%; (b) for the PCA + BP network based system, the same overall detection rate can be reached with a reduced number of false-alarms; (c) as the number of components of compacted data from the PCA network is reduced, the overall detection rate is maintained at nearly the same level; and (d) compared with a conventional mean-level constant false-alarm rate detector, the two neural network based systems can provide higher overall detection rates while maintain lower number of false-alarms.

I. INTRODUCTION

RADAR applications include numerous military purposes, earth mapping, crop, forest and flood disaster assessments, topographic studies for water resources and minerals, ocean surface surveillance and others[1]. In performing maritime patrol, airborne surveillance radar is used for detecting seaborne targets. Since sea represents a dynamic and highly variable environment, it is generally difficult to describe the radar response of sea clutter with a high level of confidence or precision[2,3,4,5]. Maritime patrol radar target detection is a difficult task due to: (a) a wide variation in sea clutter echo levels; (b) sea clutter echo levels are in many cases stronger than that of target echoes; (c) a wide variation in target echo levels; and (d) target echoes are a function of numerous known and unknown parameters. Conventionally, in a parametric approach, target detection is based on the presumption that the background echoes conform to Rayleigh, lognormal, Weibull or K distributions[1]. Numerous adaptive detection processes are based on these distribution assumptions[6,7]. Their detection performance will suffer great degradation when the assumed echo distributions differ significantly from the real situation. In a nonparametric approach, the background return has unknown (and potentially varying) distributions, target detection is based on forming a test variable whose statistics (in the no-signal case) are independent of the distribution of the input interference[1]. The Mean-Level (ML) or cell-averaging) constant false-alarm rate (CFAR) detector is a simple detector used by most radar signal processors. However, its response to spiky sea clutter can be poor.

Target detection using radar images can be performed on the pixel gray level values representing either the magnitude or squared magnitude of radar echoes. Various image processing methods have been used in radar target detection[8,9]. For maritime patrol radar images, variations in the appearances of targets, sea clutter and land clutter make target detection a very difficult task.

Recently, a number of researchers have explored artificial intelligence based approaches, such as neural networks and expert systems, for automatic target detection applications[10,11,12,13]. In particular, neural networks can learn to establish internal representations for selected training patterns so that they can be used as intelligent classifiers. The widely used Back-Propagation (BP) network is such an example. However, the success of the neural network approach is related to the complexity of patterns to be classified. For maritime patrol radar images, target pattern complexity is a function of the variations of targets and the environment mentioned earlier.

This paper focuses on the neural network based approach for automatic maritime target detection using radar images. The organization of this paper is as follows. Section II explores the representation of target patterns which establishes a basis for the neural network based detection approach. Two neural network based detection systems, a BP network based system and a combined Principal Component Analysis (PCA) network and BP network based system, are presented in section III. In section IV, the PCA method is discussed. Based on extracting the eigenvectors of the input correlation matrix to construct a compact form of input patterns, the PCA technique can be used to improve detection performance and processing speed. The PCA method can also be implemented using neural networks. Simulation results and performance evaluation are presented in section V. Finally, conclusions and a perspective for further development are presented in section VI.

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are used for classification without the need of establishing classification models. PCA is used to compact test data for classification. Experiments show that the two neural network based systems outperform a conventional mean-level CFAR detection algorithm which is used widely in radar signal processing. With the addition of PCA, system performance is improved in terms of the number of false-alarms and speed processing.

Adaptivity to many known and unknown factors are the critical factors in successful target detection. To improve the detection performance, further studies could be expected in the followings: (a) the appearance of targets change with respect to many known and unknown factors such as shape, sizes, sea clutter states, land clutter states, target echo levels, etc., target pattern representation can be established in more detail relating to these factors; (b) neural network approach can be used based on the detailed target representation; and (c) an expert system can be added to perform target detection based on target and non target descriptions established as a set of rules.

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REFERENCES