CHAPTER 6

CONCLUSIONS

This thesis addresses one of the emerging topics in Sonar Signal Processing, viz. improving the performance of the target classifier for noise sources in the ocean. The underlying classifier implemented is a multi-class SVM based classifier. The main challenges faced by underwater target classification systems are due to diverse noise sources that vary with time and location. The performance of underwater classifiers can be improved by selecting the most representative feature vector that characterizes the signals and also by setting the optimal parameters of the underlying classifier. Different procedures for feature extraction has been studied and implemented for generating the feature vector. Procedures for dynamic feature selection according to changing underwater environment, has also been implemented resulting in an improvement in the classifier performance. The optimal choice of the classifier parameters, kernel function and kernel function parameters has been found by meta-heuristic algorithms. Different meta-heuristic algorithms have been implemented for parameter tuning of the underlying classifier, which has shown to improve the classifier performance. A modified-SOS (m-SOS) algorithm is also proposed which has shown to give higher performance compared to other algorithms implemented. This chapter brings out the salient highlights of the work alongwith enlisting the scope and direction for future research in this area.
6.1 Highlights of the Thesis

Underwater target recognition has gained considerable significance due to its strategic as well as commercial importance. The composite and dynamic nature of the propagation medium imposed by the ocean makes underwater target recognition a very challenging task. The ocean, as a propagation medium consists of dynamically varying composite noise sources comprising of man-made noises such as noise due to shipping, natural noises due to environment such as wind, waves, currents and rains, and biological noises emanated by underwater living organisms, that establish a perpetual noise backdrop. Underwater target activity reflected by the acoustic activity of the targets of interest, are captured by hydrophones. However, the hydrophones receive an acoustic mixture of requisite signals embedded with the ocean noise. Individual targets of interest are identified from hydrophone captured acoustic mixture, through their characteristic signatures that are patterned by feature recognition algorithms, which are then provided to the classifier for classification into different classes. In this work, a support vector machine (SVM) based target classifier is used to distinguish between targets of 11 classes. The work reported in the thesis entitled Underwater Target Classifier with Improved Success Rate using Meta-Optimal Support Vector Machines addresses one of the emerging topics in Sonar Signal Processing, viz. improving the performance of an underwater target classifier for noise sources in the ocean which is achieved through carefully selected feature vector and also through optimising the classifier parameters. The following are the salient highlights of this thesis.

6.1.1 Need and Requirement of optimising the target classifier

The introductory chapter of the thesis throws light on the various noise sources in the ocean as well as the need and requirement of optimising
the target classifier. The chapter also highlights the applications of underwater target classification. The underlying principle of operation of the proposed classifier is also briefly introduced in this chapter.

### 6.1.2 Preparation of a State-of-the-art Literature

The development of a classifier involves extraction of target specific acoustic signatures using suitable feature extraction and feature selection algorithms and adoption of a suitable classifier for classification. The performance of the classifier is improved through optimisation of the classifier parameters. As prelude to the development of a classifier, a state-of-the-art literature survey has been prepared on various aspects such as the underwater acoustic environment, acoustic feature extraction techniques, and various classifiers such as the statistical classifiers, lazy learning algorithms, decision tree classifiers, neural network classifiers and support vector machines. Literature review has also been prepared on different optimization techniques that can be used for improving the classifier performance.

### 6.1.3 Feature Vector Based Classifier

The methodology suggested to be adopted for realizing the proposed classifier involves the formulation of the acoustic signature of the targets of interest using suitable feature extraction techniques. Various acoustic feature extraction schemes have been highlighted in the thesis. Cepstral based techniques have been found to give better classification performance. To reduce the dimensionality of the feature vector by removing redundant and irrelevant features, feature selection algorithms are used. A reduced but highly representative feature vector will lower the complexity of the classifier. Various feature selection algorithms have been attempted on the proposed classifier and their performance is analysed. The feature vectors of known targets are labelled according to their classes to create a knowledge
Chapter 6 Conclusions

base for the classifier. The classifier uses the labelled signals in the knowledge base to compare against the feature vector of an unknown signal, based on which the system performs the decision-making process.

6.1.4 SVM Based Multi-class Classifier

Once the feature vector has been extracted and the knowledge base is created, a suitable classifier needs to be identified to do the final classification task. In this work an SVM based classifier, which can learn non-linear decision surfaces efficiently, is adopted. SVMs are relatively easy to implement and very robust due to its sound theoretical background. They also have the advantage of creating a model with minimized Vapnik–Chervonenkis (VC) dimension, resulting in a low expected probability of error and thus good generalization performance. SVM’s were originally proposed as binary classifiers, but were later extended to solve multi-class problems by decomposing the multi-class problem into simple binary classification problems. Two popular approaches of solving multi-class problems are, one-against-one approach and one-against-all approach. In this work a multi-class SVM based target classifier for classifying 11 classes of acoustic targets is developed using one-against-all approach.

6.1.5 Parameter Optimisation of the classifier

The algorithmic parameters of the classifier impact its performance. Particularly, for an SVM based classifier, which is acclaimed for its high generalization capabilities, setting the right kernel parameters is a very determining factor in the classifier performance. Hence, attempting to set the right classifier parameters results in its performance improvement. Since, the underwater environment is highly dynamic in nature with changing channel properties, dynamic selection of algorithmic parameters, kernel and kernel parameters are required. Optimization algorithms are resorted to, for
scanning the parameter space to determine the most suitable set of parameters. In this work, parameter optimization is attempted using five meta-heuristic algorithms, namely GA, BAT, WOA, SFS and SOS. Though all the optimization algorithms have shown to improve the performance of a multi-class SVM based classifier, SOS algorithm exhibited superior performance improvement over others. A modification to SOS algorithm is also proposed which is called \( m \)-SOS (modified-SOS) algorithm. The \( m \)-SOS algorithm has shown to better improve the performance of the classifier in selecting the optimal parameter setting for the underlying classification task.

6.2 Future Scope for Research

The work presented in this thesis has a significant role to play in view of its practical applications. This work also has substantial scope for further research for improving the overall system performance. Some of the possible proposals for future work in this area are enlisted below.

6.2.1 Expansion of Knowledge Base

The proposed prototype system for identifying the noise sources in the ocean works on a simulated environment with a limited data set. By expanding the knowledge base, more training data can be obtained. A well trained classifier will certainly yield better performance in actual environment. Attempts were made to obtain more data from the Indian seas, but could not succeed to the expectations, and so could be taken up as a separate major project in collaboration with appropriate funding agencies.

6.2.2 Hardware Implementation

The proposed SVM based classifier works on a simulated environment and the modules have been developed in Matlab. The hardware
version of the system can be developed using high-end Digital Signal Processors, and FPGA systems.

6.2.3 Augmentation of Feature Vector

The performance of the classifier can be improved by augmenting the feature vector used, with higher order features such as bispectrum and trispectrum which are based on third and fourth order statistics respectively. However, as the order increases, the computational complexity and storage requirement also increases, which necessitates the requirement of efficient hardware systems for their implementation.

Most feature extraction techniques based on cepstral analysis are based on auditory models of human ear. Developing a feature extraction technique based on the auditory model of marine mammals may result in better signature features for underwater targets. Incorporation of features motivated by auditory models of marine mammals may also be worked up on.

6.2.4 Incorporating Meta-meta optimal SVMs

Meta-optimization refers to employing an optimization algorithm to optimize the parameters of another algorithm. In this work, we are employing different meta-heuristic algorithms to optimize the parameters of SVM. Meta-meta-optimization can be resorted to, for optimizing the parameters of the meta-heuristic algorithm which is optimizing the parameters of the SVM classifier. Parameter free algorithms such as Teaching Learning Based Optimisation (TLBO) can be attempted as the top level algorithm for meta-meta-optimization, for optimising the parameters of the meta-heuristic algorithm which is optimising the parameters of underlying SVM based classifier.
6.3 Summary

An attempt has been made in this chapter to bring out the salient highlights of the work carried out for the implementation of an underwater target classifier with improved success rate using meta-optimal SVMs. A discussion on the scope and directions for future research works in this area has also been presented.