CHAPTER 1
INTRODUCTION

This chapter provides an introduction to this thesis. It begins with the background of the work then provides the objectives of the study followed by chapter wise organization of the thesis.

1.1 Background

Steganography is a method of hiding secret information into innocent looking cover media such as digital images, videos, audios and texts in such a way that existence of message is not visible [1]. It is derived from Greek words ‘Steganos’ and ‘Graphy’ meaning covered and writing respectively. The cover file with secret message hidden in it is referred as ‘stego’ file. Among the various media types the digital images are mostly used for communication as they contain redundant bits and are most widely used on internet. Steganography apart from having positive applications such as smart identity cards which holds individuals confidential information, circulating secret data of a company, medical imaging systems etc. has also been found to be utilized by anti-social elements for terrorist activities [2]. The modern steganography algorithms are extremely secure which makes it difficult to visually detect any changes in the stego file. However, statistical properties of the cover images are modified through these steganography algorithms, which can be exploited to detect steganography. This process of identifying these statistical changes is known as steganalysis which is an extremely challenging task and demands in-depth computational analysis.

Steganalysis has been broadly studied under two categories; specific and blind steganalysis [3]. Aim of specific steganalysis is to detect information hidden in a carrier by having prior knowledge of underlying steganography algorithm. This makes it very accurate but at the same time it is not capable of detecting new steganography algorithms. To overcome this shortcoming blind steganalysis has been
introduced which aims to detect any known or unknown steganography algorithms. This study applies machine learning, pattern recognition and image processing to detect presence or absence of hidden information in images. The blind image steganalysis involves two steps i) Feature Extraction and ii) Classification. The feature space constructed by extracting features from different domains (spatial and transform) is an important process that determines the performance of a classification algorithm. Classification is a technique in machine learning that develops a model with training data samples which helps predict class (stego or cover) of test data samples.

A large number of high dimensional features such as Markov [4], Cartesian Calibrated Pevný [5], Subtractive Pixel Adjacency Matrix [6], Cartesian-calibrated Features (CF*) [7] etc. have been generated from different domains (spatial and transform) to improve the performance of various classification algorithms such as Fisher Linear Discriminant [8], Support Vector Machines [9,10,11,12], Neural networks [13] etc. for steganalysis.

The issue with high-dimensional feature spaces is that the volume of space increases at a very fast pace with the increase in number of features. This makes the data sparse and the sparseness further increases exponentially with addition of extra features given a fixed number of data sample sizes. This makes it difficult for the classifier to estimate accurate decision boundaries [14]. This problem caused due to high dimensional feature space and small data samples is referred as “Curse of dimensionality”.

To achieve optimal classification accuracy and avoid overfitting of data it is generally believed that the size of training samples should be at least ten to twenty times that of number of features [15]. However, with the increase of input dimension and large size of the training sample the complexity of classifying algorithm also increases. The effect of “Curse of dimensionality” can be avoided by reducing the dimensions of feature space with techniques like feature selection prior to building a classification model.
The aim of feature selection [16] methods is to identify relevant and significant subset of features from the original feature set, which improves the prediction capability of a classification algorithm and reduces its computational complexity. The subset is generated through various search strategies and optimality of selected feature subset is measured using evaluation criteria [17]. Feature selection methods based on different evaluation criteria can be discussed under the following three categories a) Filter [18] b) Wrapper [19] and c) Hybrid [20]. A filter approach works independently of a classifier to reduce the feature set. It ranks the features in order of descending values of the evaluation criterion. The features corresponding to the higher ranks are considered more beneficial for further computation. On the other hand, in a wrapper approach a classifier is used to assess the effectiveness of the feature subset. The set of features giving maximum accuracy are considered to be the optimal feature subset.

The filter approach is not dependent on the classifier hence it is hard to estimate the performance of the selected subset until a classifier model is generated. Wrapper approach has a drawback of having high computational complexity. To overcome these shortcomings and to reduce computational cost through reduction of dimensionality various researchers have proposed hybrid models [20, 21, 22]. The hybrid models are developed by combination of filter and wrapper approaches. These have been found to be more effective and efficient as they incorporate advantages of both filter and wrapper approaches. In a hybrid model, the filter approach contributes by removing irrelevant and redundant features without much overhead of computation cost which helps in speeding up the search process of wrapper approach. This helps in overall reduction of computational complexity of the classification algorithm. Hybrid approach has been designed in this thesis for blind image steganalysis.

1.2 Objectives of the thesis

The aim of this thesis is to select most relevant features from a set of high dimensional features and simultaneously enhance the performance of a classifier to
discriminate images as ‘stego’ or ‘cover’ with reduced computational complexity. The objectives of this thesis are as follows.

- To design a filter feature selection method for identifying a subset of relevant features for image steganalysis through ensemble of univariate and multivariate filter approaches.
- To find out variations that can be done on heuristic wrapper approaches for enhancing the detection capability of blind image steganalyzer.
- To design hybrid models for reducing computational complexity of wrapper approaches by incremental combination of filter approach with modified wrapper approach.
- To analyze the effectiveness of spatial and transform domain features selected through hybrid models in detecting secret information hidden by various known and unknown steganography algorithms.

1.3 Chapter Organization

Chapters 2 focus on review of various available literatures in the area of Steganography, Steganalysis and Feature Selection methods. An overview of two steganalysis techniques, specific and blind is provided with emphasis on blind image steganalysis. In depth study on different features extracted in literature for blind image steganalysis has been presented. The literature survey reveals the gap areas of feature selection methods through intense study of filter, wrapper and hybrid feature selection methods.

Chapter 3 describes the proposed methodology used for achieving the research objectives of this thesis. This involves three stages; Feature Extraction, Feature Selection and Classification. To develop an efficient method features from spatial as well as transform domain are extracted. A two phase novel feature selection method to select significant subset of features for efficiently classifying images as ‘stego’ or ‘cover’ is proposed. Exploratory analysis of data was done using Data visualization and Histogram analysis. In data visualization the datasets are investigated for linearity and nonlinearity through grouped scatter plots. This leads to selection of Support
Vector Machine as appropriate classifier for blind image steganalysis. The strength of steganography algorithms is analyzed by Visual analysis and Histogram analysis.

Chapter 4 provides detailed description of different univariate and multivariate filter feature selection algorithms. The comparative analysis of classification accuracies of these algorithms then becomes the basis of selecting one univariate and one multivariate algorithm in Phase I. A univariate filter algorithm is able to capture all relevant features; however it does not take relationships among features into consideration. To ensure inclusion of all important features in the final subset, ranking criteria is defined by ensemble of both univariate and multivariate algorithms. In further analysis the deterioration in performance of classifier without feature selection exhibits the effectiveness of the proposed methodology.

Chapter 5 presents and proposes variations of heuristic wrapper approaches namely Particle Swarm Optimization (PSO), Discrete Firefly Algorithm (DFA) and Bird Swarm Algorithm (BSA) for effective utilization in blind image steganalysis. These modified wrapper approaches constitute Phase II of proposed hybrid models. This transits towards our second objective of this thesis. The proposed wrapper approaches display an improvement in classifier’s prediction abilities with reduced number of features but with high computational complexity. To overcome this shortcoming of wrapper approaches Phase I and Phase II are combined to design a hybrid model. This model is capable of reducing computation time and at the same time increasing classifier’s accuracy which successfully meets the third objective of present work. Comparison of results based on various parameters of classification accuracy, reduction in number of features and computation time is performed with five heuristic wrapper approaches and ten filter approaches to ascertain the effectiveness of proposed novel approach. This is further verified with 2-tailed statistical t-test.

Chapter 6 presents an intense analysis of features from transform and spatial domain used for experiments in our thesis. The relevance of different type of features selected by all three proposed hybrid models is analyzed for different steganography
algorithms. The efficiency of each feature set in detecting a particular steganography algorithm is deliberated. A thorough inspection of features from hybrid models for four steganography algorithms helps in understanding influence of each feature on steganalysis. A detailed description of the features common in feature subsets selected by proposed hybrid models provides further insight. The significant feature set selected by all three hybrid models tested on an extended dataset and an unknown steganography algorithm establishes that these models are capable of achieving higher classification accuracy with less number of features.

Chapter 7 finally presents the conclusion of the thesis and suggests future scope in the application of blind image steganalysis.