Chapter 1

Introduction

Classification is the process to orderly separate a group of similar patterns into classes according to structure or characteristics common to each class. Various classification models have been developed, which can be broadly divided into two classes of algorithms. The first class of algorithms include decision trees [70], rough sets [58, 61] and rule induction [83], while the second class includes algorithms that model a natural process. Examples of these are the artificial neural network that models the biological neural network in the brain [6], evolutionary computation techniques that model the natural evolution of organisms [1] and swarm intelligence that models the behavior of a structured collection of interacting organisms to solve a global objective [47]. The modeling of natural processes has also proven to be successful in classification problems, optimisation problems, control, pattern matching and data mining. These computational techniques are usually trained with negative and positive examples that have been pre-classified according to a specific concept or rule. This training method is known as supervised learning and the trained model must be able to correctly predict or classify any pattern not seen before. Classification models have also been developed using unsupervised learning algorithms where the training process consists of automatically discovering similar patterns in data without relying on an external teacher [51].

Recently, artificial immune systems (AIS) have been developed as an alternative classification algorithm. An AIS is modeled after the natural immune system (NIS) to detect foreign patterns in a non-biological environment. The NIS has the ability to not only learn valid patterns and recognise foreign patterns (or anomalies), but also has the ability to memorise general foreign pattern structures [56, 63]. Contrary to standard classification algorithms, the AIS can be trained on positive patterns alone. After training on positive patterns, the artificial immune system can detect or distinguish negative patterns from the positive patterns. The AIS can thus be used as a classification algorithm where one class (the positive patterns) is separated from all other classes (the negative patterns).

The AIS has mostly been used in anomaly pattern detection where detectors are trained with negative selection using a set of positive patterns [16, 28, 29, 37, 39, 40, 49, 50, 74, 75]. The detectors are randomly initialised or constructed from a genetic library [38]. The patterns represented by the trained detectors can also be used as training data for other classification algorithms [16]. The detectors can also be trained with a training set of positive and negative patterns [38, 64].

The AIS proposed in this thesis uses a set of mature artificial lymphocytes (ALCs) to detect negative patterns. An ALC in the AIS becomes mature after the ALC has been trained on a set of positive patterns. This set must represent a good distribution of positive patterns or a complete representation of positive patterns. The ALCs can be trained with negative or positive selection. The ALCs with poor detection of negative patterns need to be distinguished from the ALCs with a good detection of negative patterns. It is important to distinguish between these types of ALCs to remove the ALCs with poor detection of negative examples from the set of ALCs, i.e. to guarantee an optimal set of ALCs with a high probability to detect negative patterns. This dissertation has as its main objective to develop an AIS where an optimal initial set of ALCs are evolved using a genetic algorithm (GA). The goal of the GA is to evolve individual ALCs with the least overlap with existing ALCs in the set and with the maximum space coverage of possible negative examples. The GA was chosen as optimisation method since the GA guarantees local optimum solutions. With each new ALC that must be added to the set of existing ALCs, the least overlap restriction forces the GA to explore different regions in the search space that are not yet covered by the existing set of ALCs. These evolved ALCs are then trained using positive or negative selection, and it is determined how well the trained set of ALCs perform on a number of classification problems. As a sub-objective, the dissertation proposes a method to dynamically determine the status of an ALC, which can be annihilated, mature or memory. The status of an ALC is determined based on the number of negative patterns detected, the space covered by the ALC and the number of patterns presented to the ALC to classify. The status of an ALC indicates the detection performance of the ALC. Annihilated ALCs are poor detectors and are removed from the ALC set.

The rest of the dissertation is organised as follows:

- *Chapter 2* introduces the natural immune system and explains how the natural immune system protects the body against viruses, bacteria and any pathogenic material that can damage the body. The different types of lymphocytes and the life cycle of a lymphocyte are discussed.
- *Chapter 3* gives an overview of evolutionary computation. The chapter presents the different recombination operators, selection methods and also gives a summary of the different evolutionary computation (EC) paradigms. Sufficient background on EC is provided only to support the development of the approach to evolve a set of ALCs.
- *Chapter 4* gives background on existing artificial immune system models or models that originated from ideas from immunology. Applications of the artificial immune system are also discussed.
- *Chapter 5* explains how artificial lymphocytes cover the non-self space and how their receptors are initialised. The training of an artificial lymphocyte is explained. The requirements for classifying a non-self pattern are also presented, and the hit ratio function is introduced. The three status types that artificial lymphocytes can assume in the artificial lymphocyte's life cycle are prioritised into low, medium and high. The life counter threshold function, that determines an artificial lymphocyte's state, is presented and explained.
- *Chapter 6* explains how one of the evolutionary computation paradigms (as discussed in chapter 3) will be used in the proposed genetic artificial immune system (GAIS) to evolve an initial set of ALCs.
- *Chapter 7* presents experimental results to illustrate and to discuss the behavior of GAIS on different classification problems which were collected from the UCI Machine Learning Repository [7]. The influence of the GAIS parameters on its performance is also investigated.
- *Chapter 8* concludes this dissertation and presents ideas relating to possible future work.
- *Appendix A* lists the publications derived from this dissertation.
- *Appendix B* lists and defines the symbols used throughout this dissertation.
- *Appendix C* lists and defines the abbreviations used throughout this dissertation.

- *Appendix D* lists and defines the main terms used throughout this dissertation.