The Coevolution of Antibodies for Concept Learning

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Abstract. We present a novel approach to concept learning in which a coevolutionary genetic algorithm is applied to the construction of an immune system whose antibodies can discriminate between examples and counter-examples of a given concept. This approach is more general than traditional symbolic approaches to concept learning and can be applied in situations where preclassified training examples are not necessarily available. An experimental study is described in which a coevolutionary immune system adapts itself to one of the standard machine learning data sets. The resulting immune system concept description and a description produced by a traditional symbolic concept learner are compared and contrasted.

1 Introduction

Concept learning is a task that has been extensively studied by researchers in the field of machine learning. Much of this work has been in the area of inductive learning from examples using symbolic representation languages such as predicate calculus [5] and decision trees [9]. In most of the previous efforts to apply evolutionary computation to concept learning, binary-string representations have been evolved with a genetic algorithm and mapped into some form of symbolic representation for evaluation, such as propositional logic. For some examples of this approach, see [4, 1, 3]. In the work described here, we take a different approach by experimenting with a biologically inspired representation in which concept descriptions are evolved using a model of the immune system. For other approaches to evolving models of the immune system, see the pioneering work of Forrest et al. [2].

The motivation behind applying a model of the immune system to concept learning lies in its highly developed ability to discriminate between self and non-self. In biological immune systems, this consists of the discrimination between the vast array of molecules that are an integral part of the body of an organism and foreign molecules that left unchecked could result in disease or death. In the research described here, we apply the immune system's power of discrimination to the problem of differentiating between examples and counter-examples of a given concept. An advantage of this approach over the traditional symbolic approaches to concept learning is its generality. We believe that evolved computational models of the immune system could be successfully applied to a wide variety of discrimination problems that do not necessarily lend themselves to the supervised learning methodology typically used by symbolic concept learning systems. A controller for an autonomous vehicle, for example, may need to learn to discriminate between navigable terrain and a variety of hazards based on input from a noisy sensor array. Constructing a set of preclassified training examples that adequately covers the modalities of this task would probably not be practical. An evolutionary immune system could learn the necessary concepts by adapting instead to a simple reinforcement signal that captures the ability of the autonomous vehicle to move safely through its environment.

2 A Brief Overview of the Immune System

The purpose of an organism's immune system is to protect it against infection. This is accomplished by recognizing the molecular signature of microbes or viruses that attack its body, and once identified, eliminating the foreign molecules in a variety of ways. The immune system consists of two interrelated components: an innate defense component and an adaptive component. Here we will focus on the adaptive component, which is responsible for acquired immunity.

Molecules capable of stimulating an acquired immune response are called *antigens*. When the immune system is working properly, only foreign molecules will produce a response. There are a number of ways antigens are recognized, depending on whether the foreign molecule is inside or outside a cell boundary. It is the job of *antibodies*—protein molecules displayed on the surface of a type of white blood cell produced in the bone marrow called a B-lymphocyte or B-cell for short—to recognize antigens that are located outside a cell boundary. Recognition by a B-cell occurs when one of its antibodies comes into contact with an antigen of complementary shape. Although all the antibodies on an individual B-cell have the same three-dimensional shape, the human body, for example, has about 10 trillion of these cells and they collectively have the potential of recognizing about 100 million distinct antigens at any one time.

One should realize that the immune system is quite complex and is the focus of much current research. Although we have only provided a brief and somewhat simplistic overview of one of its processes here, this description should be sufficient for an understanding of the rest of this paper. For more details concerning the workings of the immune system, see, for example, [10].

3 Coevolving Antibodies for Concept Learning

As in previous evolutionary computation models of the vertebrate immune system (cf. [2]), our model is limited to the interaction between B-cells and antigens. This model is applied to concept learning from preclassified positive and negative