# Chapter 7.10
# Ethology-Based Approximate Adaptive Learning:
## A Near Set Approach

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## ABSTRACT

The problem considered in this chapter is how to use the observed behavior of organisms as a basis for machine learning. The proposed approach for machine learning combines near sets and ethology. It leads to novel forms of Q-learning algorithm that have practical applications in the controlling the behavior of machines, which learn to adapt to changing environments. Both traditional and new forms of adaptive learning theory and applications are considered in this chapter. A complete framework for an ethology-based approximate adaptive learning is established by using near sets.

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## INTRODUCTION

The problem considered in this paper is how learning by a machine can adapt its behaviour to changing environmental conditions to achieve a better result. The solution to this problem hearkens back to the work of ethologist Niko Tinbergen (1940, 1942, 1948, 1951, 1953, 1963), starting in the 1940s. Tinbergen (1953b) suggested that the behaviour of swarms of interacting organisms and their environment make swarms be seen as individual. Of course, the insight in Tinbergen's work augurs later by those who were interested in adaptive learning by societies of interacting machines. The work by Tinbergen and Konrad Lorenz (1981) led to the introduction of ethology, a comparative

science of behaviour. The basic idea in the proposed approach to adaptive learning is to look behaviour of an organism as episodic and to record observed behaviours ethograms. An ethogram is a tabular representation of observed behaviours. An ethogram is a tabular representation of observed behaviours during an episode. Let $s_i$, $a_i$, $r_i$ denote the i$^{th}$ state, action, reward, respectively. Reward $r_i$ results from performing action $a_i$, where $0 \leq i \leq n$ for some finite, positive integer $n$. Each episode consists of a finite state-action-reward sequence of the form $s_0 \xrightarrow{a_0, r_0} s_1 \xrightarrow{a_1, r_2} s_2 \bullet\bullet\bullet$ . In this chapter, adaptive learning itself is observed at the individual level as well as at the society level.

The fundamental of the proposed adaptive learning approach is the notion of perception. It was pointed out by Ewa Orłowska (1982) that an approximation space provides a formal framework for perception. This is especially important in establishing a formal basis what has come to be known as approximate adaptive learning (Lockery and Peters, 2008; Peters 2007d), which is the capstone of a new approach of machine learning based on ethology (Lockery, Peters 2007), which was based on earlier work on ethology and machine learning (see Peters 2005b; Peters, Henry, Ramanna, 2005a; Peters and Henry, 2005). It should also be noted that the solution to the ethology-based machine learning problem has been further aided by the recent introduction of near sets (see Peters 2007a, 2007b, 2007c, 2006e; Peters, Skowron, Stepaniuk 2006, 2007) and its applications (Anwar, Patnaik, 2008; Henry and Peters, 2007; Lockery and Peters 2007). A *near set* is a collection of objects that have matching descriptions to some degree. One set X is considered *near* another set X' in the case where there is at least one x in X with a description that matches the description of x' in X' (Peters, 2008a; Peters, 2008b; Peters and Wasilewski, 2008; Peters, 2007b, 2007e). Near sets can be looked as an extension of the original model for rough sets introduced by Zdzislaw Pawlak (1981) during the early 1980s.

The near set approach, the approximation of sets of behaviours of organisms, provides a basis for a biologically-inspired approach for approximate adaptive learning. Organism behaviour descriptions are stored in a form of short term memory called ethogram. An ethogram is a set of comprehensive descriptions of the characteristic behaviour patterns of a species. In this chapter, it focuses on learning by organisms such as E coli bacteria, silk moths, ants and tropical fish called glowlight tetra. Both the basic theory and sample applications of ethology-based study of approximate adaptive forms of machine learning are introduced. It introduces short-term and long-term memory models for biologically-inspired adaptive learning that is quite different from reinforcement learning (Sutton and Barto, 1998). In the observed behaviour of biological organisms, learning produces a durable modification of behaviour in response to information (e.g., intensity of perfume emitted by a female silk moth that leads to changing flight path of a male silk moth) acquired by an organism (Alcock, 1995). Hence, the term *adaptive* rather than *reinforcement* has been suggested to describe biologically-inspired learning by machines (Labella, 2007). The proposed approach of machine learning has many practical applications, such as target tracking by monocular vision systems, learning to recognize objects in sequences of images, and in studies of how learning by organisms can beneficially influence their environment.

## BACKGROUND

### Adaptive Behaviour by Machines

The proposed adaptive learning approach is a variant of the usual approach of adaptive behaviour in robotic systems, where the control of robotic behaviour relies on sensor values as a means of adapting to 'perceived' situations to accomplish a system goal. For example, in Salter (2006), a