Chapter 1
Stochastic Learning–Based Weak Estimation and its Applications

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ABSTRACT

Although the field of Artificial Intelligence (AI) has been researched for more than five decades, researchers, scientists and practitioners are constantly seeking superior methods that are applicable for increasingly difficult problems. In this chapter, our aim is to consider knowledge-based novel and intelligent cybernetic approaches for problems in which the environment (or medium) is time-varying. While problems of this sort can be approached from various perspectives, including those that appropriately model the time-varying nature of the environment, in this chapter, we shall concentrate on using new estimation or "training" methods. The new methods that we propose are based on the principles of stochastic learning, and are referred to as the Stochastic Learning Weak Estimators (SLWE). An empirical analysis on synthetic data shows the advantages of the scheme for non-stationary distributions, which is where we claim to advance the state-of-the-art. We also examine how these new methods can be applicable to learning and intelligent systems, and to Pattern Recognition (PR). The chapter briefly reports conclusive results that demonstrate the superiority of the SLWE in two applications, namely in PR and data compression. The application in PR involves artificial data and real-life news reports from the Canadian Broadcasting Corporation (CBC). We also demonstrate its applicabilty in data compression, where the underlying distribution of the files being compressed is, again, modeled as being non-stationary. The superiority of the SLWE in both these cases is demonstrated.

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INTRODUCTION

Artificial Intelligence (AI) is the sub-field of computer science that deals with the intelligent behaviour of machines. Researchers who work in AI attempt to create intelligent machines or design algorithms that will help the machine make intelligent decisions. Although the field of AI has matured over the last five decades, researchers, scientists and practitioners are expanding their horizons by seeking superior methods, namely for those applicable for increasingly difficult problems. In this chapter, our aim is to consider knowledge-based novel and intelligent cybernetic approaches for problems in which the environment (or medium) is time-varying. To achieve this, in the larger context of this book, our chapter deals with enhancing AI by techniques generally used within the overall field of "Cybernetics".

The Webster's dictionary defines "Cybernetics" as "the science of communication and control theory that is concerned especially with the comparative study of automatic control systems (as the nervous system, the brain and mechanical-electrical communication systems)". The word "Cybernetics" itself has its etymological origins in the Greek root *kybernan* meaning "to steer" or "to govern". Typically, as explained in the *Encyclopaedia Britannica*, "Cybernetics is associated with models in which a monitor compares what is happening to a system at various sampling times with some standard of what should be happening, and a controller adjusts the system's behaviour accordingly". Modern cybernetics is an interdisciplinary field, which philosophically encompasses an ensemble of areas including neuroscience, computer science, cognition, control systems and electrical networks. In this context, we mention that a fundamental tool used in cybernetics is the so-called Learning Automaton (LA). The aim of this chapter is to show how we can use LA-based estimation methods to investigate, model and solve problems which are inherently difficult because they are, as mentioned, time-varying.

What is a "Learning Automaton"? What is "Learning" all about? How are LA related to the general field of "Cybernetics"? The linguistic meaning of "automaton" is "a self-operating machine or a mechanism that responds to a sequence of instructions in a certain way, so as to achieve a certain goal. The automaton either responds to a pre-determined set of rules, or adapts to the environmental dynamics in which it operates. The latter types of automata are pertinent to tools used in this chapter, and are termed as "adaptive automata". The term "learning" in Psychology means the act of acquiring knowledge and modifying one's behavior based on the experience gained. Thus, in our case, the adaptive automata we study in this chapter, adapts to the responses from the Environment through a series of interactions with it. It then attempts to learn the best action from a set of possible actions that are offered to it by the random Environment in which it operates. The Automaton, thus, acts as a decision maker to arrive at the best action.

Every statistical problem involves a fundamental issue, namely that of estimation. Since the problem involves random variables, decisions or predictions related to the problem are in some way dependent on the practitioner obtaining reliable estimates on the parameters that characterize the underlying random variable. These estimates are computed from the observations of the random variable itself. Thus, if a problem can be modeled using a random variable which is normally (Gaussian) distributed, the underlying statistical problem involves estimating the mean and the variance. Put in a nut-shell, *in this chapter, we shall review a new family of estimation methods that are based on the primitive cybernetic tool, the LA. Further, we shall demonstrate that these estimates are powerful when the medium or environment is non-stationary.* We shall also demonstrate its applicability in two real-life application domains.

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