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Chapter XIV

Once More Unto the Breach: Towards Artificial Homeostasis

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ABSTRACT

The field of biologically inspired computing has generated many novel, interesting and useful computational systems. None of these systems alone is capable of approaching the level of behaviour for which the artificial intelligence and robotics communities strive. We suggest that it is now time to move on to integrating a number of these approaches in a biologically justifiable way. To this end we present a conceptual framework that integrates artificial neural networks, artificial immune systems and a novel artificial endocrine system. The natural counterparts of these three components are usually assumed to be the principal actors in maintaining homeostasis within biological systems. This chapter proposes a system that promises to capitalise on the self-organising properties of these artificial systems to yield artificially homeostatic systems. The components develop in a common environment and interact in ways that draw heavily on their biological counterparts for inspiration. A case study is presented, in which aspects of the nervous and endocrine systems are exploited to create a simple robot controller. Mechanisms for the moderation of system growth using an artificial immune system are also presented.

INTRODUCTION

The practice of drawing inspiration from biological systems for implementation in computing has a long and reasonably successful history. There remains, however, a wide gulf between the capabilities of computer systems and their biological counterparts. The variety of biological systems that have provided models is enormous, as is the ingenuity of many implementations. Implementations range from hardware systems such as artificial retinas and neurons (Mead, 1989; Perrinet & Samuelides, 2002), through software implementations of neural networks (Grossberg; McClelland & Rumelhart, 1986), genetic algorithms (Holland, 1975), artificial immune systems (deCastro & Timmis, 2002), cellular automata (Tommassini, Capcarrere et al., 1999) and a host of other techniques. Whilst each of these systems is undoubtedly extremely valuable in its own right, none has led to the type of behaviour that really warrants anything approaching the famous *Turing Test,* or is capable of lifelike, long-term autonomous operation.

In this chapter we present a way forward that we believe represents an opportunity for biologically inspired computing in the current mould to break new ground in terms of generating complex, adaptive, autonomous and crucially: *self-organising* computational behaviour. We believe that all these properties are required for the implementation of systems capable of generating the type of behaviour sought by researchers in fields such as robotics, artificial intelligence and operating system design. With this in mind we wish to focus on one of the most impressive abilities of living organisms: their ability to ensure a reasonably stable internal state despite wildly changing external environmental factors. This property, often termed homeostasis, is a major contributor to an organism's autonomy, and is the biological embodiment of the type of behaviour described above.

The investigation of animal behaviour by biologists has taken many forms (Aylett, 1999), but the basic goal has been to understand the ways in which animals achieve this ongoing autonomy of the individual. Of these approaches, the one that arguably most directly reflects the interest in ongoing autonomy of a homeostatic nature is the dynamical systems approach. This considers the state of the individual in some state space that represents the state of the organism at any time. Homeostasis in such a state space is usually assumed to mean an orbit about some attractor that represents the "normal" condition for the organism. Clearly the presence of "attractive" values for particular variables will often lead to this type of cyclic path through state space, but should probably not be considered an immediate goal when constructing autonomous systems. This is for several reasons:

- The definition of such state spaces is fraught with problems such as: "*What variables should be included?" and "How should behavioral attributes be represented?"*;
- The presence (or absence) of cyclical behaviour is often dependent on external factors such as the rising and setting of the sun. Thus, we need to define a set of circumstances under which a particular cyclic path will occur. Due to the unconstrained nature of the environment in which most workers wish their systems to operate, this is intractable;
- Once there are a significant number of interacting variables and control systems it is extremely hard to "design in" such cycles and to verify their presence and

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