

Chapter 10

Artificial Neural Systems for Robots

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ABSTRACT

This chapter reviews the use of neural systems in robotics, with particular emphasis on strongly biologically inspired neural networks and methods. As well as describing work at the research frontiers, the paper provides some historical background in order to clarify the motivations and scope of work in this field. There are two major sections that make up the bulk of the chapter: one surveying the application of artificial neural systems to robot control, and one describing the use of robots as tools in neuroscience. The former concentrates on biologically derived neural architectures and methods used to drive robot behaviours, and the latter introduces a closely related area of research where robotic models are used as tools to study neural mechanisms underlying the generation of adaptive behaviour in animals and humans.

INTRODUCTION

The idea of robots is rooted in the dreams and myths of old Europe and Ancient Greece in which mechanical men acted as either slaves or oppressors. Indeed the modern word ‘robot’ was introduced in Karel Čapek’s 1921 play *R.U.R.* (Rossum’s Universal Robots) which told of artificial men manufactured as a source of cheap labour on an

isolated island. This often dark and dystopian play was a world-wide smash hit capturing the popular imagination as well as sparking much intellectual debate (Horáková and Kelemen 2007). In the process it helped forge the predominant image of robots that now permeates our culture – that of life-like artificial creatures.

In fact this image refers to what we now call autonomous robots. In contrast to machines that perform precise repetitive tasks ad nauseam (e.g. robots used in manufacturing production lines),

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autonomous robots are required to behave in an appropriate way in a very broad range of circumstances. Like biological creatures, their behaviour must be self-generated, making use of sensory information to moderate their responses to the world. With these animal connotations, it is no surprise that when simple autonomous robots became a reality in the mid 20th century, researchers looked to natural nervous systems for inspiration as they developed their early control systems.

The huge advances in our understanding of real neural networks over the past few decades, coupled with our development of increasingly sophisticated artificial varieties, has led to significant growth in research on artificial neural systems in robotics. This chapter concentrates on the use of explicitly biologically inspired artificial neural networks in autonomous robotics, reviewing key applications and forms of neural system used. There are a variety of drives underlying such work, ranging from straightforward engineering motivations – the desire to build better, smarter machines – to purely scientific ones, particularly in the use of robots as tools to study mechanisms underlying the generation of adaptive behaviour in animals and humans. Often varying degrees of both these motivations are present in any particular project. This chapter will highlight work that falls at the two extremes of this spectrum, as well as much that rests in between.

The next section gives some historical background to the area in order to motivate the remainder of the chapter. Following that, there are two major sections that make up the bulk of the paper: one on the application of artificial neural systems to robot control, and one on the use of robots as tools in neuroscience. The chapter closes with a general discussion of prospects for such research. There is not enough space to give a comprehensive review of all major work in the area, instead we have concentrated on a few important topics that give a good overall flavour of research in the field. For more detailed coverage see e.g. Siciliano and Khatib (2008), Webb and Consi (2001), Ayers et al.

(2002), Bekey (2005), Bekey and Goldberg (1993) and Floreano and Mattiussi (2008).

HISTORY

Despite the construction of many ingenious mechanical automata over the centuries (including chess playing Turks and flatulent ducks (Wood 2003)), it was not until the 1930s that devices recognizable as robots (in the present day sense of the term) appeared. Early mobile robots, such as Thomas Ross's 'robot rat', completed in 1935, were designed for narrowly focused single behaviours (often maze running) and employed highly specific mechanisms to achieve their intended task (Cordeschi, 2002). These 'artificial animals' inspired what were probably the very first examples of more general mobile autonomous robots – W. Grey Walter's tortoises (Walter, 1950). These robots were also the first to employ an early form of neural network as their artificial nervous system. They were born out of the cybernetics movement, a highly interdisciplinary endeavour – drawing together pioneers of computing and modern neuroscience – which was the forerunner of much of contemporary AI and robotics, and the origin of artificial neural networks and evolutionary computing, as well as control and information theory (Boden, 2006; Husbands et al., 2008).

In 1949, Walter, a neurologist and cyberneticist based at the Burden Institute in Bristol, UK, who was also a world leader in EEG research, completed a pair of revolutionary machines he called 'tortoises'. The devices were three-wheeled and sported a protective 'shell' (see Figure 1). They had a light sensor, touch sensor, propulsion motor, steering motor, and an electronic valve (vacuum tube) based analogue 'nervous system'. Whereas earlier machines such as Ross's were constrained to run on rails, the tortoises could roam freely around their environment. Walter's intention was to show that, contrary to the prevailing opinion at the time,

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