Evolution versus Design: Controlling Autonomous Robots

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Abstract

This paper sets out and justifies a methodology for the development of the control systems, or 'cognitive architectures', of autonomous mobile robots. It will be argued that the design by hand of such control systems becomes prohibitively difficult as complexity increases.

The alternative approach of artificial evolution is presented. It is argued that the most useful basic building blocks for an evolved cognitive architecture are adaptive noise tolerant neural networks rather than programs. These networks may be recurrent, and should operate in real time. Evolution should be incremental, using an extended and modified version of genetic algorithms.

Time constraints mean that architecture evaluations must be largely done in simulation. Results from a simulation are presented. The pitfalls of simulations compared with reality is discussed, together with the importance of incorporating noise.

1 Introduction

This paper sets out and justifies a methodology for the development of the control systems, or 'cognitive architectures', of autonomous mobile robots intended for use in unstructured or dynamic environments. Such robots will require active perception and will be behaviour-based. Although behaviour-based approaches to robot control appear to be far more promising than traditional model-based functional decomposition methods, it will be argued that the design of such control systems is still prohibitively difficult. A methodology based on the alternative approach of artificial evolution is presented. The advantages of such a scheme over design by hand are described.

The methodology is further illuminated by describing its application to the development of the cognitive architecture of a mobile autonomous robot engaged in a series of increasingly complex tasks. The robot is equipped with low resolution sensing devices and is required to act in uncertain environments. It is argued, in this case, that the most useful basic building blocks for an evolved cognitive architecture are adaptive noise tolerant neural networks.

Relevant work by others will be discussed. There have recently independently been suggestions of different but related evolutionary approaches. In particular during the preparation of this paper Brooks proposed using Evolutionary Programming techniques [8]; and Beer and Gallagher reported on the use of dynamical neural networks [5]. These methods will be compared with ours.

Artificial evolution requires the evaluation of a great number of candidate control systems. Time constraints mean that many of these evaluations must be done in simulation. The requirements of such a simulation system are discussed.

2 Interesting robots are too difficult to design

Traditional approaches to the development of autonomous robot control systems have made only modest progress, with fragile and computationally very expensive methods. A large part of the blame for this can be laid at the feet of an implicit assumption of functional decomposition — in the terms of the themes of this conference, the assumption that perception, planning and action could be analysed independently of each other. This failure has led to recent work at MIT which bases robot control architectures instead around *behavioural decomposition*[6, 7]. Such work rejects the traditional AI approach which manipulates symbolic representations of the world, and places more emphasis on 'knowing how' to do things rather than 'knowing that' the world is in a given state. Viewpoints sympathetic to such an approach can be seen in, e.g., [22, 4, 10, 2].

Such a subsumption-style cognitive architecture for

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