Chapter 9

The Integration and Control of Behaviour: Insights from Neuroscience and AI

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Abstract

Clues to the way behaviour is integrated and controlled in the human mind have emerged from cognitive psychology and neuroscience. The picture that is emerging mirrors solutions (driven primarily by engineering concerns) to similar problems in the rather different domains of mobile robotics and intelligent agents in artificial intelligence (AI). This chapter looks in detail at the relationship between a psychological theory of willed and automatic control of behaviour, the Norman and Shallice framework, and three types of engineering-based theory in AI. As well as being a promising basis for a large-scale model of cognition, the Norman and Shallice framework presents an interesting example both of apparent theoretical convergence between AI and empirical psychology, and of the way in which theoretical work in both fields can benefit from interaction between them.
Introduction

Building a computationally specified theory of a human-level mind is an ambitious goal. How can the cognitive disciplines—artificial intelligence (AI) and cognitive psychology—contribute to such an undertaking? Both psychology and AI have tended to study small areas of cognition and work with theories of single empirical phenomena. In a full-scale cognitive theory, two related issues must be addressed, those of integration (how are numerous cognitive theories or models organised into a coherent whole, rather than descending into behavioural chaos?) and control (how are these modules to be coordinated by an overall goal?).

Within cognitive psychology, few theories have emerged that attempt to deal with this breadth of human cognitive function. One that does is the framework proposed by Norman and Shallice (1986). In the context of the research goal mentioned above, this theory is interesting for a number of reasons.

First, it takes the form of a layered architecture. There is a strong parallel with certain forms of layered agent architecture that have been developed within AI, although the rationale for the architectures and the scientific tradition from which they have emerged are different.

Second, the elements of the Norman and Shallice framework relate closely to analogous theories or models in AI. For example, the middle layer of the framework is similar to AI models of action selection. Thus, there is potential for useful cross-fertilisation of ideas between comparable theories in the two disciplines.

Finally, the various elements of the Norman and Shallice framework are now sufficiently well specified that computational implementations have been produced for the major components of the framework.

The next section discusses the first of these points—the correspondence between the three levels of control in the Norman and Shallice framework and a class of AI agent models. It begins by introducing the framework and the empirical phenomena on which it is predicated. The framework and its rationale are then compared with a group of three-layer architectures in AI that are motivated largely on engineering grounds. We then move on to examining the internal operation of the main elements of the Norman and Shallice model. The middle layer of the framework is compared with an action selection model in AI. The upper level is compared with an agent architecture model from AI—the Domino model. Finally, the “Discussion” section notes some connections with other approaches in the literature, reviews the work that has been done toward a computational implementation of the Norman and Shallice framework, and discusses the future prospects for the general architecture identified in the chapter.
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