extensions" to a command-based system which is shown by Greenberg to be open to redesign to further empower the user.

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Neurons and symbols—the stuff that mind is made of by I. Aleksander and H. Morton, Chapman & Hall, UK, 1993, pp 256, £24.95, ISBN, 0-412-46090-4.

Heated symbols-versus-neurons debates were common in the latter half of the 1980s and their rhetoric and conviction live on. Strong polar views on matters such as representation, computation, and relative value to cognitive science continue, but there is now also an accumulating body of work concerned with hybrid models and equivalence relations. Proponents of symbolic methods have a great deal of theory to support their formalism whereas connectionism is a relatively under-developed science. It is the imbalance in science's understanding of these two subjects which drives many to gain a better understanding of artificial neural systems, and which makes *Neurons and symbols* a timely volume containing a useful common analysis of both formalisms.

The book presents a new analysis of both neural and symbolic systems in terms of automata theory and then applies this perspective to the main themes in the modern history of artificial intelligence and cognitive science. Throughout the history the authors review major issues of contention between the connectionist and symbolic camps and with the benefit of their automaton perspective and hindsight make useful observations concerning earlier positions and theoretical predictions.

The role of symbolic and sub-symbolic models of cognition is examined through the development of AI covering such topics as natural language, problem solving and vision. Along side this the role of automata theory (synchronized, asynchronous, non-deterministic, etc.) applied to connectionism is considered as a key to understanding computational possibilities in cognitive science with the need for learning continually stressed. There follows an absorbing summary of the great neurons *versus* symbols debate of the mid 1980s. Repeated reference to the impoverished nature of symbolic learning may well be justified but the omission of any counter argument, like a reference to Newell's later work on Soar, seems a little out of hand.

In early chapters we gain an analytical understanding of the micro behaviour of simple neurons which gives insight into a great deal of macro behaviour in neuronal-models, for example there is a clear description of the attractor phenomenon. A light and interesting analysis of a general neural unit, unassuming mathematically, leads on to matters of cognition with artificial neural system problem solving. Goal, state and action representations are outlined for a neural state machine.

The analysis presented is a type of equivalence relation between symbolic and neural automata which leaves the reader considering all processes as automata but with the questions, are these symbolic or neural, are they describing an abstraction of both the symbolic and neural or is their view reductionist? (but never the less useful). Igor Aleksander and Helen Morton are able to present these interesting and important ideas by having an abstract and broad view of computation which leads them to a summary of emergent artificial neural system properties with respect to cognitive science and allows them to consider, for example, vision and internal representation, lesions to a neural state machine model, internal state-learning and abstract scaling up.

The book concludes with a straightforward summation of the neural state machine model (NSMM) using the devices of simplicity and freely admitted speculation to demonstrate and explain the role and potential of an automaton-like neural system in cognitive science, with evidence that the NSMM is well suited to dealing with the symbols in current neural models. The examples can be readily absorbed and important points of detail are described step-by-step.

Neurons and Symbols is both a useful historical account for the student and interested reader of the stormy relationship between connectionists and symbolists in recent AI and cognitive science, together with a computationally and mathematically sound theorizing of a particular analysis, the Neural State Machine Model which addresses much of the historical concerns of connectionism. With such an analysis the practitioner may usefully and rationally discuss the merits of neurons for a symbolic model and consider how the symbols might be captured in a connectionist model. The virtue of patience is needed to work through the more sophisticated examples, never the less the verbal, as opposed to the mathematical, explanation of these processes, which until recently were considered by many as diametrically opposed, is very welcome in a subject rich in technical camouflage.

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