Its up-to-date handling of the complete process of creating real-world AI systems is perhaps most relevant to those new to applied AI from related fields, although it assumes some knowledge of computational terminology. The book is suitable for use as a reference guide for all involved in any aspect of AI and its plethora of relevant bibliography will prove useful. However, its plausibility as a text-book for students is questionable especially due to its high price. One consolation for those willing to pay this substantial cost is that its outlook on AI will last well into the next century as it is printed on acid-free paper!

Reviewed by Rashmi Pandya, University of Exeter, Exeter, UK

Neural networks and fuzzy systems: A dynamical systems approach to machine intelligence by Bart Kosko, Prentice Hall, Englewood Cliffs, NJ, 1992, pp 449, £24.96, ISBN 0-13-612334.

The traditional standpoint of artificial intelligence is that real-world concepts can be structurally disassembled into crisp predicates to be treated by first-order logic. Whereas this assumption works quite well in reasoning with simple artificial objects, problems arise with real-world (say, biological) concepts, where uncertainty, imprecision, and noise come into play. Such words as "warmth", "democracy" or "ferocity" resist being described by rigid logical structures. Among the technologies invented to address these issues, Fuzzy-Set Theory (FST) and the philosophy of Artificial Neural Networks (ANN) in particular attract the attention of researchers worldwide.

In FST, each object is associated with a real number $\mu/\varepsilon[0,1]$ understood as the degree of truth of the proposition that the object is a positive instance of some concept. Reasoning is then carried out by applying simple rules for truth propagation along a sequence of fuzzy propositions. Even though fuzziness was invented by Zadeh in 1965, it has raised interest among practitioners only after the recent commercial success of the first fuzzy-logic applications in control systems.

The reason for this delay is probably the common western belief that the only salient grounding for intelligence is in Aristotelian logic. Yet, binary logic suffers from flaws that were pointed out as early as two and a half millennia ago in the form of the familiar Greek paradoxes. In his book *Neural Networks and Fuzzy Systems*, Bart Kosko shows that these paradoxes disappear when the concepts are defined in terms of fuzzy sets. What poses problems is proper definition of truth degrees because their manual setting is somewhat arbitrary and can lead to poor performance in reasoning tasks.

ANNs encode knowledge in terms of synaptic weights between neurons. Importantly, their behaviour is usually robust against small changes in the weights. The major strength of ANN, however, is the ability to *learn* proper weights from examples, often without any prior knowledge about the concept to be acquired. On the other hand, people with an artificial-intelligence background complain that ANNs lack the ability to explain their conclusions in terms of explicit lines of inference.

What the two paradigms share is that dealing with uncertainty and truth grading are intrinsic to them. Bart Kosko deserves credit for being one of the pioneers in the endeavours to combine the learning ability of ANN with the computational simplicity of FST.

The book consists of two major parts. One of them presents, with remarkable erudition, artificial neural networks as gradient systems. The author focuses primarily on the dynamic aspects of neuronal membranes and synapses, and describes the relevant processes by stochastic differential equation. Then, the well-known backpropagation learning algorithm is presented as a stochastic-approximation task. Attention is given to the problems of convergence and stability of feedforward and feedback systems.

The second part examines fuzziness and adaptive fuzzy expert systems. In the author's view, the crucial step for a deeper understanding of the reasoning with *fuzzy adaptive maps*, a concept that unifies the fuzzy-set and neural-network perspectives, is the geometric interpretation of fuzzy sets as points in unit hypercubes. The underlying theory is explained in great detail, and many interesting aspects are analysed, among them the entropy of fuzzy sets and probability as a special case of fuzziness.

The utility of fuzzy adaptive maps is demonstrated on the familiar control problems of backing up a truck, and truck-and-trailer, to a loading dock in a parking lot. The same methodology is then demonstrated on the tasks of real-time target tracking and signal processing.

The book is accompanied by neural-network and fuzzy-system software to enable the reader to develop practical experience with the relevant theoretical frameworks. Moreover, the author suggests to the reader many interesting problems for further consideration. Each of the individual chapters is followed by an extensive list of related literature.

Neural Networks and Fuzzy Systems is conceived of as an advanced reading, and certainly is not addressed to newcomers. The author's ambition to present his ideas in precise mathematical terms entails a highly technical style that makes the text difficult for readers without the necessary background. However, graduate students and researchers from respective fields should not fail to include the book in their library.

Reviewed by Miroslav Kubat, Institute of Systems Science, Johannes Kepler University in Linz, Austria

First steps in modal logic by Sally Popkorn, Cambridge University Press, 1994, pp 314, £25.00, ISBN 0-521-46482-X.

If someone wants to teach themselves the basics of modal logic, three textbooks come immediately to mind. By Hughes and Cresswell there is *An introduction to Modal Logic*, and the later *A Companion to Modal Logic*; and by Chellas, *Modal Logic, an Introduction*. The most recent of these (the second Hughes and Cresswell book) was published in 1984. Given that modal logic is a rapidly maturing discipline, both in scope of its application and understanding of its foundations, it is not too surprising that a fourth introductory text has now been written which effectively complements and updates the earlier texts.

Just to recapitulate a little to set the scene, in certain contexts it has been thought valuable to enrich the language of classical logic with modalities, initially in an attempt to study the informal modalities which are used in natural language. The first to be introduced is usually $\Box$. Possible reading of $\Box\phi$ include "ϕ is necessary", "ϕ is obligatory", or "ϕ is known". The different readings suggest different semantics and proof systems. There is a close analogy between $\Box$ and universal quantification in predicate logic. However, whereas in predicate logic quantification is over variables, $\forall$x.P(x) for example being read as "for all values of x, P(x) is true", in modal logic the quantification is implicitly over contexts. So we may alternatively gloss $\Box\phi$ as "in all possible contexts ϕ is true", or "in all possible situations ϕ must be acted upon", or possibly "ϕ is true and always will be true" if the modality is used in a tense logic.

A dual statement, $\neg\Box\neg\phi$, is of sufficient importance that an additional symbol is introduced as an abbreviation: $\Diamond$. Readings of $\Diamond\phi$ include "ϕ is possible", "ϕ is permissible" and "ϕ will be true at least once". This modality has an analogy with existential quantification $\exists$; "there is a possible context in which ϕ is true", or "there is a possible situation in which ϕ is acted upon".

Having defined the basic modalities, it is then necessary to say how new statements may be derived from a logical theory which includes modal statements. Additional axioms to those of classical logic are required to enable interactions between the modalities to be modelled. For example, in a logic of knowledge and belief (where $\Box\phi$ is read as "ϕ is known"), it is usual to include the axiom: $\Box\phi \Rightarrow \Diamond\phi$. This accounts for consistency of knowledge; if the equivalent $\neg\Box\neg\phi$ is substituted for $\Diamond\phi$, this axiom can be read as "if ϕ is known, then $\neg\phi$ cannot be known".

As mentioned earlier, modal logic has been used as a basis for tense, or temporal, logics. To be sufficiently expressive, two different forms of the $\Box$ modality need to be introduced. $[+]\phi$ is usually associated with the above reading of "is and always will be", whilst $[-]\phi$ corresponds to "is and