

An Introduction to Natural Computation

by Dana H Ballard, MIT Press, 1997. (price unknown) (xxii + 307 pages) ISBN 0 262 02420 9

On first inspection, “An Introduction to Natural Computation” appears to be a happy synthesis of at least three textbooks — An Introduction to Neural Networks, Reinforcement Learning and Genetic Algorithms. It performs this synthesis by assigning each of these modelling techniques to a different stage in the “life-cycle” of an organism. The first stage, developmental learning, occurs over the first few months or years of the organism’s life during which time it learns to extract useful invariants from the environment. Neural networks are introduced as ways of storing memories and classifying inputs, both useful for this stage of learning. The second stage, behavioural learning, is concerned with learning over the lifetime of an organism and is addressed by examining various reinforcement learning techniques. The last stage of learning, occurring over the longest time scale, is evolutionary learning where the architecture of the organism is modified over successive generations by changes to the genetic code. Both genetic algorithms and genetic programming are discussed in this context.

Each of these three approaches to modelling natural computation is important enough to deserve an introductory book of its own^{1,2,3}. Including three different approaches in one book has the benefit of providing a consistent framework for exploring the different learning techniques, and this is achieved very well. Another advantage, which we feel has not been exploited, is that by introducing three different approaches the book can evaluate and compare the relative merits of each approach. The obvious sacrifice is that the amount of detail devoted to each approach in this book is much smaller than in one of the more dedicated introductory books.

The text itself was perfectly coherent, although the merging of footnotes and references into a notes section at the end of each chapter was sometimes distracting. The problem of there just not being enough space in the book becomes evident in the first chapter, where every other paragraph contains a world of ideas. But it does provide an interesting perspective on natural computation, with the assertion that natural computation is about breaking the assumptions of complexity. The book is intended to be accessible to advanced undergraduates, and this is true, at least for the mathematically-confident. The mathematics and concepts underlying each technique are well laid out, with many examples spread throughout the book. The first section is solely devoted to introducing the main mathematical concepts needed for understanding the different models presented later in the book. Exercises are provided at the end of each chapter, making the book

ideally suited for teaching purposes. One minor criticism of the book as an introduction to the field is that there are not many references provided as starting points for further reading. More references to original works would also be beneficial for the reader.

Our main criticism of the book is that insufficient neurobiological information is given, despite the claim in the preface to stress “the computational task whilst at the same time staying near the neurobiology”. Our feeling is that the text wanders away from a brief discussion of the neurobiology at the start of each chapter, into the detailed mathematics of a relevant learning technique but usually does not return. As an example, topographic maps in visual cortical areas are briefly mentioned at the beginning of the section on developmental learning. Later in the section, competitive learning techniques, such as Kohonen learning, are introduced and shown that they can produce topographic maps of an input space. However the book then fails to return to the issue of how the maps produced by these learning techniques relate to topographic maps found in sensory cortical areas. Similarly, some of the learning techniques, such as the backpropagation algorithm for supervised learning of neural networks, are described without subsequently discussing whether they are biologically plausible.

As mentioned previously, another criticism of the book is that it does not devote much discussion to comparing and contrasting the three different approaches to learning introduced throughout the book. The summary chapter is far too brief (a mere three pages), especially to include such a fleeting glimpse of Marr as it does. More space could have been devoted to exploring the interactions between the different forms of learning. For example, the benefits of possible interactions between lifetime learning and evolutionary learning⁴ are only briefly mentioned during one of the questions at the end of the chapter on genetic algorithms. The book would also have benefited by spending some time comparing the performance of different learning techniques on the same problem. For instance, a modular genetic programming technique is shown to solve the parity problem but no mention is made of the difficulty of getting a supervised neural network to learn the same task.

In conclusion, we think that the book is suitable for advanced undergraduates and graduates new to the field. It provides a coherent framework within which to place the work they come across and has a sufficient explanation of specific modelling techniques. Our main criticism is that the book would benefit from spending more time exploring the relationships between the different techniques both to each other and to the underlying neurobiology.

Catherine Collin and Stephen Eglan

Centre for Cognitive Science

University of Edinburgh

2 Buccleuch Place

Edinburgh, EH8 9LW UK

tel: +44 131 650 4413

fax: +44 131 650 6626

email: cati,stephen@cns.ed.ac.uk

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