Neural networks and animal behavior

Magnus Enquist & Stefano Ghirlanda. Monographs in behavior and ecology, Princeton University Press, 2005. 253 pages.

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Simulation with neural networks, or artificial neuron nets, is perhaps the most common type of learning in computers. During the learning process the networks can be trained by a genetic algorithm. This can be seen as self-learning in machines - a popular science fiction topic, such as in the movies *Terminator* or *Matrix*. More seriously, computation intelligence methods (cellular automata, genetic algorithms and neural networks) are becoming popular in ethology and behavioral ecology. Still they are not yet common, and few biologists have formal training in these methods. Thus Enquist and Ghirlanda's book on neural networks and their applications in animal behavioral models comes in very handy. The book contains a subject-oriented introduction to neural networks. It is easy to follow, well structured, and I believe that it will appeal to a wide variety of behavioral scientists. It focuses on networks as a means to understand animal behavior, rather than black-box simulators of behavior. The introduction to neural networks aims to give an understanding of what they actually do, rather than an account of all technical details that a beginner might need to look up before making his/her own networks.

The book contains six chapters. It starts with introductions to the two topics of the book; neural networks and animal behavior. Enquist and Ghirlanda present numerous examples where neural networks have been used to investigate animal behavior. In many of the examples, the networks are designed to mimic the actual neural machinery. This is normally only possible for relatively *simple* behavior, for example behavior that would be labeled neuroethology. As the authors point out, there are fewer examples of cognitive processes in animals with complex brains. At the end of each chapter there is a summary and a list of references.

In chapter 1, the authors discuss "Tinbergian" levels on which animal behavior can be explained. They continue with various approaches to behavioral modeling, such as operational models, black box models and physiological models. The chapter ends with a historical overview of the development of neural networks. The authors introduce the *behavior map* to describe the motivational processing that changes incoming signals into behavior.

The next chapter, (chapter 2) is a technical and theoretical explanation of neural networks. It starts very basically and goes through topics of increasing complexity. The authors suggest that many readers should skip this chapter but I found it pedagogic and relatively easy to follow, compared with more technical books on the subject (e.g., Haykin 1999). This chapter explains the common *perceptrons* (the oldest and best known neural network) and feed forward networks as well as recurrent networks that can simulate time delay. Furthermore, learning rules, i.e. different methods to update weights, are explained here. The chapter ends with examples of how C code can be used to implement networks in the computer.

Chapter 3 starts with a description of some mechanisms of behavior and then goes on with an account of how neural network models can be constructed. The chapter treats processes such as stimuli perception, motor control, simple decision making and motivation.

The following chapter (chapter 4) treats learning from two view points: in real animals and in neural networks. Learning and developmental phenomena such as imprinting, ontogeny and conditioning are discussed together with neural networks terms such as Hebbian learning, reinforcement and back propagation. The authors also discuss neural networks in the context of various learning processes and animal learning theory.

Chapter 5 discusses neural networks and evolution. Some parts of this chapter are a bit tentative, but it also contains interesting parts. Neural networks are compared to more common theoretical approaches to adaptive behavior, such as optimization theory and game theory. The authors point out some evolutionary questions that are especially well suited for neural network analyses. These include the evolution of camouflage and mimicry, adoption of unrelated young (requires opposite solutions to very similar stimuli), coevolution between signal senders and receivers and evolution of signals. The book concludes with chapter 6 which contains a summary of the book and some suggestions for future work.

What is then my general impression of the book? The authors make an admirable effort in explaining how neural networks work, both mathematically and as "behavioral simulators". To describe what goes on in a neural network mathematically is almost impossible for large networks that are designed to solve complex

problems. This makes the book pedagogical but by necessity also focused on networks that fit problems within classic ethology rather than behavior ecology; examples from neuroethology and learning psychology dominate. A citation from chapter 5 illustrates this 'The advantages that neural networks enjoy over similar or even formally equivalent models stem from their interpretation as models of nervous systems rather than black-box models of abstract cognitive process'. Another citation may also serve to illustrate the emphasis: 'The understanding of motor control in terms of neural networks is perhaps the best developed field of neural network research'. Motor control is a suitable topic for neural network modeling but it is probably of more interest to neuroethologists than to behavioral ecologists.

For an evolutionary trained ecologist (such as most readers of the ISBE newsletter) the ethological approach may give novel insights, which, in my view, makes the book interesting. Experienced behavioral scientists may also learn new things, or rediscover facts they had forgotten. However, I am not sure that I always agree with the authors about the explanatory power neural networks will have for real nervous processes. For example, they suggest that the use of neural networks makes it possible to give internal factors that govern learning a concrete interpretation. To me this is fine, as long as one is aware that neural networks are just simulators of processes that may be very different in real brains. In neural networks memory is located in connection weights, and the learning process depends on changes of these weights. The fact that it is easier to define memory and learning in neural networks than in real animals does not mean that they may offer a realistic interpretation of memory and learning, only that they can be used to model these entities.

There are a number of details on the construction and training of neural networks that are either not included or not treated in depth. This does not mean that the authors have missed to include these. Rather, the book is intended to give an understanding of how neural networks can be used for behavioral modeling, not as a dictionary for network building. Thus the book can be a goldmine for behavioral scientist that already have some knowledge of neural nets, but newcomers to this field will probably need to look up details before they can build their own networks. For example, biases are not mentioned in the book. Biases are net inputs to a layer that will increase the capacity of many networks. Inexperienced network builders may also ask questions about transfer functions, the number of neurons, training method (batch or sequential), etc. The learning rule that probably will appeal most strongly to behavioral ecologists, inserting the weights in a genetic algorithm, is not really treated in depth. More details on genetic algorithms in neural networks can be found for example in Kamo et al. (1998) and Brodin and Haas (2006).

In conclusion I find this book very useful for behavioral scientists that want to model animal behavior, but beginners will probably need additional technical advice on the encoding of the networks, which is available on numerous websites or in some software that has neural network toolboxes. The authors mention Matlab, which I think has a very pedagogic explanation of neural networks fundamentals. For readers that have access to this software I recommend typing the command nnd4db at the prompt to see how easy it can be to understand a neural network.

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