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Book Review: *Evolution, Games, and Learning*

Evolution, Games, and Learning: Models for Adaptation in Machines and Nature. Proceedings of the Fifth Annual International Conference of the Center for Nonlinear Studies, Los Alamos, May 20–24, 1985. Doyne Farmer, Alan Lapedes, Norman Packard, and Burton Wendroff, eds., North-Holland, Amsterdam, 1986.

This volume consists of 27 articles, most of which are based on lectures presented at the Los Alamos conference of the title. The central theme, as stated in the introduction by Doyne Farmer and Norman Packard, is the exploration of how complex adaptive behavior may emerge from the nonlinear interaction of many components that individually do not display such behavior. The unifying approach employed by most of the contributors is nonlinear dynamics, and the method of analysis numerical simulation.

The previous decade has seen an increasing number of physicists, especially those in the condensed matter community, aiming toward synthesis rather than reduction. While this in some sense has always been the underlying theme of condensed matter physics, the choice of problems represented in this volume (such as evolution, the brain, and computing machines), coupled with the approach described in the previous paragraph, result in what Farmer and Packard, drawing a parallel with the evolution of rock music, call "new wave science." I agree with them, although others, less sanguine about these new directions, might suggest "punk physics" as more appropriate. The articles in this book represent, perhaps, a new field, and one which is far from mature, which makes them to my mind all the more exciting.

The book is loosely structured, with groups of lectures falling into several categories, including evolution, pattern recognition, the immune system, neural networks, and several assorted topics: ant colonies, game theory applied to machine learning and nuclear arms races, and definitions of "complexity." As a bonus, the book includes a previously unpublished paper of Stan Ulam, in whose memory the conference was held. Coauthored with R. Schrandt, the paper discusses numerical simulation of evolutionary processes and compares the growth and survival rates of species using asexual and bisexual reproduction. In a short but revealing dedication, G.-C. Rota reports a discussion with Ulam on the foundations

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of the AI problem, and Stephen Wolfram concludes the volume by discussing possible ways of engineering "complexity" using cellular automata, which are used as well by several other authors in the volume.

Because of the diversity of topics and authors, the quality is uneven, some papers being clear and interesting, others less so. Perhaps surprisingly, considering that the book is a conference proceedings, it can be read with considerable profit by those with no previous contact with the area; in fact, several articles can serve as excellent brief introductions to their fields. Special mention in this respect should be made of John Denker's article on neural networks, John Holland's article on classifier systems (parallel, rule-based systems capable of adaptation and learning), the article by Farmer, Packard, and Perelson on the immune system (in which the similarity with Holland's classifier system is stressed), and the articles by Schuster and Farmer, Kauffman, and Packard on molecular evolution. An important article by Sejnowski, Kienker, and Hinton on learning and recognizing symmetry using Boltzmann learning algorithms contains both an introductory part and progresses to a rather technical finish. Other articles in the volume, such as that of Lee *et al.* on machine learning, Baird on pattern recognition in the rabbit olfactory bulb, Kirby and Conrad on neuronal dynamics, Hoffman *et al.* on an unorthodox neural network model, and Mycielski on algorithms with purported predictive power, are more appropriate for those who have some familiarity with the topics under discussion.

While the book conveys a sense of excitement over new approaches to old problems, a strong dose of caution is still in order: all of these models (and others that do not appear in the volume) are not yet close to the degree of sophistication and complexity of the systems they attempt to model, and it is still far from clear whether they ever will. This applies as well to other approaches not represented in the book, such as those that borrow concepts from the statistical mechanics of disordered systems. I believe the problem becomes worse when one attempts to model even some small aspect of psychological or political systems, as do some of the later articles in the book. On a more modest level, there is good reason for optimism; many of the articles present genuinely interesting approaches or models that exhibit nontrivial adaptive behavior, and there do appear to be real opportunities for engineering complexity as defined in the book. For those interested in these problems from the physicist's perspective, this is a good volume to acquire.

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