Mathematics and Computer Sciences

From Animals to Animats: Proceedings of the First International Conference on Simulation of Adaptive Behavior. Jean-Arcady Meyer and Stewart W. Wilson, eds. 551 pp. The MIT Press, 1991. $55.

The study of artificial intelligence has lately undergone a change of emphasis, which might be described as a shift from book learning to street smarts. For three decades AI aimed to simulate such intellectual activities as playing games, planning strategies, solving problems and understanding stories. This traditional approach to AI has not been abandoned, but a quite different kind of study has grown up beside it. In the alternative scheme the most characteristic expression of intelligence is not game playing or theorem proving but merely surviving in a hostile or indifferent world. The practitioners of the new techniques argue that simulating human cognition is far too ambitious a goal for the present state of the art. Before taking on the human mind, they suggest, one ought to understand the mental world of the cockroach and the frog and the lobster.

One thing the new approach to AI does not yet have is a settled name. Some workers in the field speak of "computational neuroethology"; others favor "simulation of adaptive behavior." But perhaps the label that will stick is "animat," a word formed on the model of "laundromat" and signifying a simulated animal or an animal-like robot. The title given to the volume under review should help to advance the case for calling the new field "animat studies." The volume records the proceedings of the first major scientific meeting on the new area of research, held in Paris in September of 1990.

Whatever the new field is called, it can be defined as the intersection of several other pursuits. There are contributions from conventional neuroscience and behavioral science, which serve as a necessary reality check; when you set out to build an artificial frog, it is helpful to know something about the anatomy and behavior of real frogs. Another important thread is the study of artificial neural networks, which is a renaissance field in its own right. The traditional approach to AI emphasizes symbolic computation, where the basic objects of thought are concepts, words, propositions and the like. These abstractions have little bearing on the life of an insect or an amphibian, and so the simulation of such animals must focus on more tangible entities such as nerve impulses and neural connections. In other words, where traditional AI simulates the mind, animat studies simulate the brain. As a matter of fact, animat models generally go beyond the brain to include the sensory and motor apparatus of the peripheral nervous system.

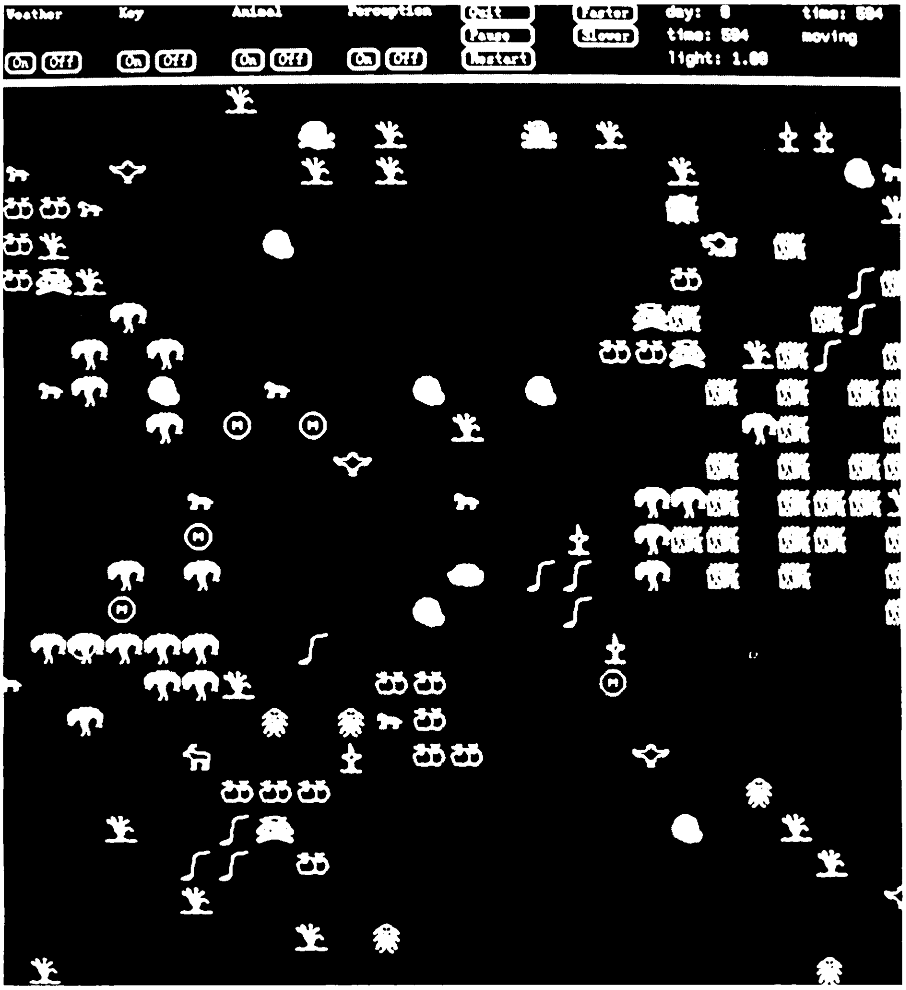
Robotics is another discipline that has been recruited to the animat camp. After all, robot-builders have much experience in making mechanical contraptions that roam around under their own power and guidance; the robot-makers just haven't been thinking of these devices as simulated animals. Yet another tributary to the animat stream is the field of study called artificial life, which is just as young and stylish as work on animats. Artificial life is generally concerned less with the behavior of individual organisms than with the evolution of whole populations and with grand questions such as the origin of life, but there are large areas of common interest with the animat community.

All of these subdisciplines (and more) were amply represented at the Paris animat meeting. The proceedings volume includes 62 papers in 10 broad categories. To convey a sense of the breadth of topics covered, I shall mention one paper from each of these sections.

In an introductory section, Stewart W. Wilson (co-editor of the proceedings) gives the history and the intellectual context of "The Animat Path to AI." He is explicit about the ultimate goal: "We hope to reach human intelligence 'from below,' instead of piecemeal through high-level competencies as in Standard AI."

Dave Cliff's article, "The Computational Hoverfly: A Study in Computational Neuroethology," argues strenuously for the importance of including peripheral nervous activity in animat models. Indeed, he stresses the value of closed-loop models, where motor outputs act on an environment, which then acts on sensory inputs. All of this is illustrated through the example of a simulated hoverfly, which controls its flight based on visual cues.

In a section on animats' internal maps and models of the world, Michael A. Arbib and Alberto Cobas describe how *Rana computatrix*, a simulated frog, goes about tracking the motion of a simulated fly and deciding when to snap at it. In a section dealing with motivation and emotion, Jür-



A random simulated environment by Toby Tyrrell and John Mayhew. From *From Animals to Animats*.

gen Schmidhuber takes up the subject of curiosity and boredom, which might seem to reintroduce the cognitive states of traditional AI (or for that matter the affective states of traditional psychology); but Schmidhuber's approach is to build a low-level neural network from which curiosity and boredom emerge spontaneously.

Pattie Maes discusses motivation and decision-making in a different context, with a simulated creature whose repertoire of behaviors includes eating, drinking, sleeping, fighting, fleeing and exploring. In order to force the organism to choose a single action at each moment, the neural network is wired so that competing behaviors inhibit one another. This strategy has an unexpected consequence. Confronting a hostile conspecific, the creature's impulses to fight and to flee may be equally balanced, in which case they are both suppressed; as a result, the organism may well respond to a threat by deciding to eat or sleep. This peculiarity of the simulation is not necessarily a failure of realism; analogous phenomena are known to ethologists and psychologists as displacement behavior.

The section on learning includes articles that focus on biology as much as computer science. For example, James M. Williams and P. J. B. Slater investigate song learning in chaffinches with studies carried out both in the field and through computer simulations.

Among all the papers in the collection, my personal favorite is "The Dynamics of Collective Sorting: Robot-like Ants and Ant-like Robots," by J. L. Deneubourg and five colleagues, which appears in a section on collective behavior. Deneubourg and his co-workers observe that ants can readily sort eggs, larvae and pupae into separate caches, even though no central authority directs the sorting process. The investigators duplicate this behavior with some remarkably simple simulated ants, following a remarkably simple algorithm. "Sorting is achieved without requiring either external heterogeneities (e.g., temperature or humidity), hierarchical decision-making, communication between the individuals or any global representation of the environment. We also stress that the ants/robots have only very local information about the environment and a very short-term memory, and furthermore move randomly, no oriented movement being necessary. They can't see far off nor move directly towards objects or piles of objects."

Ants turn up again in a section on the evolution of behavior, where Robert J. Collins and David R. Jefferson give an account of AntFarm, a simulated colony in which the foraging strategies of worker ants are subject to evolution through natural selection. Their main concern is finding a suitable representation for genetic and behavior information—a computational equivalent of DNA.

In a section giving details of several specific animat projects, Rodney A. Brooks describes the current state of an elaborate six-legged robot named Attila, which is to be a "creature" capable of long-term autonomous survival. And in the final section, on animats in education, Jim Donnett and Tim Smithers present a low-tech version of the same idea in "Lego Vehicles: A Technology for Studying Intelligent Systems."

Critics of traditional AI have long expressed scorn and annoyance at its supposed failure to fulfill the grand promise of creating machines of humanlike intelligence. The proponents of AI have responded with surly defensiveness, protesting the practical importance of their work. There is a hazard that the same cycle of expectations and disappointments will arise in animat studies, but I hope not. For the time being, the modelers of animal behavior are clearly having fun with their creations, and fun is a stimulus to further learning that ought to be carefully nurtured.

The second international conference on the simulation of adaptive behavior will be held this December in Hawaii. May the playful spirit of the field survive at least that long.—*Brian Hayes*

An Eye for Fractals: A Graphic and Photographic Essay by Michael McGuire. Michael McGuire. x + 165 pp. Addison-Wesley, 1991. $29.95.

This beautifully produced book—a small "coffee-table volume"—is an artistic tour de force by Michael McGuire, who wrote it, typeset it, generated the fractal images, photographed the many gorgeous natural images, and designed the layout. In a warmly enthusiastic foreword, Benoit Mandelbrot, the father of fractal geometry, says that fractal graphics "made people dream." McGuire demonstrates this with beauty, elegance and charm. As Mandelbrot says, "Enjoy it."

McGuire introduces fractals to us not by way of mathematical transformations, but by an appeal to visual intuition and to the patterns he presents in his beautifully selected and photographed landscapes and other subjects: "There is... a kinkiness about aspens, a ropiness about pahoehoe lava, a swirliness about kelp, and a 'somethingness' about ferns that wants a common name, a common language. Such a language is *fractal geometry.* Let's see what it is about."

With smooth plausibility and the simplest lines of argument, the author introduces the key concepts of fractal geometry, iteration, self-similarity, fractal dimension, replacement rules, collage, nonlinearity in the real line and the complex plane, attractors and chaos. All seem natural, elementary and inevitable as he presents them. The gifted physicist-printer-photographer has synthesized mathematics and visual