Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 3, No. 1, 1999

Book Review

A Review of Self-Organization of Complex Systems: From Individual to Collective Dynamics. Edited by Frank Schweitzer. 1997. Gordon & Breach. 596 p. + xxiv.

A collected proceedings is like an X-ray crystallography. From the refraction patterns of the individual papers the reader is invited to infer the intellectual excitement of the event itself. This book consists of a selection of papers that were presented at the international conference "Self-Organization of Complex Structures: From Individual to Collective Dynamics," held in Berlin 24–28 September 1995. The conference attracted some 150 scientists from 15 countries. During the five days, 18 plenary talks, 34 talks in parallel sessions and 40 poster contributions were presented.

The Berlin conference continued the conference series, "Irreversible Processes and Self-Organization," begun in Rostok in 1977, continued in Berlin 1982, Kuhlungsborn 1985, and Rostok 1989; and "Models of Self-Organization and Complex Systems," Berlin 1990. The conference was similar to another, "From Individual to Collective Behavior in Social Insects," which was devoted to specific problems of organization in bee societies. Other recent conferences dealing with self-organization and complexity have concentrated on physical problems or the problems of artificial life. In contrast, the Berlin conference, as reflected in these proceedings, attempted to link the discussion of complex processes in the natural sciences, in particular physics and biology, to those in the life sciences, such as sociology, economics, or regional planning. The primary challenge was to reveal cross-links between the dynamic models used in these fields in order to find similarities upon which to base a common theory of self-organization and evolution of complexity.

The proceedings are divided into two parts, "Evolution of Complexity and Evolutionary Optimization," and "Biological and Ecological Dynamics, Socio-Economic Processes, Urban Structure Formation and Traffic Dynamics."

The first subsection of Part I is the "Evolution of Complexity." This section included papers largely by physicists at the highest levels of abstraction, both mathematical and philosophical. F.T. Arecchi attacked the prob-

1090-0578/99/0100-0119$16.00/0

lem of "Truth and Certitude in the Scientific Language," in a Popperian fashion, drawing upon the author's own published work in physics in adaptive measurement of dynamic systems, coming to the conclusion that "there is a non-linguisitic residue in the scientific operation which then precludes a Turing machine from acting as a creative scientist." J.S. Shiner, in "Self-Organization, Entropy and Order in Growing Systems," relates the normalized Landsberg entropy measure to Kaufman's NK networks in an informative discussion. Normalizing the measure by the maximum possible entropy of the system avoids the nonsensical result that larger systems (e.g., animals) are more entropic and less ordered than smaller ones, according to simple Shannon-Weaver entropy.

"Inherent Information Flow in Chaotic Systems," by G. Deco and B. Schurmann, proves that "A system can lose permanently information only if it has infinite information, and this is the case for deterministic chaos. In other words, the memory of the process is infinite." This startling proof goes against what I am guessing is the fairly widespread intuition of a chaotic process as a memoryless "random walk" of some variety.

"Information Processing in Evolutionary Systems," by N. Fenzl and W. Hofkirchner, reminds us that there is no information without some "self-organizing structure," which reflects a blurring of the subject-object dichotomoy.

The remaining papers in this subsection were produced using large amounts of CPU time: "A Note on Simulation and Dynamical Hierarchies," S. Rasmussen, N.A. Baas, C.L. Barnett and M.W. Olesen; "Fractal Evolution in Discretized Systems," S. Fussy, G. Grossing and H. Schwabl; "Interactive Structure Formation with Brownian Particles," L. Schimansky-Geier, F. Schweitzer and M. Mieth; "Fluctuation and Phase Space Structures of Agent-Resource Systems," I. Adjali; "Self-Organization of a Multi- Agent System in Pattern Formation." The titles describe the simulations performed.

The second subsection of Part I on "Evolutionary Optimization" begins with a paper by B. Andresen on "Global Opimization Using Ensembles," or the use of multiple walkers in establishing global convergence on a complicated manifold or state-space. Examples of ensembles include simulated annealing, genetic algorithms, and neural networks.

"Mixing of Thermodynamical and Biological Strategies in Optimization," by T. Asselmeyer and W. Ebeling, compares "brute force" thermodynamical search strategies with more flexible "biological" strategies. A mix is to be preferred. "Combinatorial Optimization Based on the Principles of Competing Processes," by J. Starke, explores the method of cost-oriented competing processes as a way of handling combinatorial optimization problems in a self-organizing manner. The advantage of this process compared to other parallel-processing approaches like Hopfield networks is that only valid solutions become outputs. "Explorations of Artificial Landscapes Based on Random Graphs," S. Kopp, C. Reidys, and P. Schuster, attacks highly specialized issues in the modeling of secondary structures in RNA.

The most provocatively-titled paper, by F.M. Dittes, "How Egoism Helps to Solve Global Problems," proposes a new optimization strategy for problems with many competing requirements, based on the simultaneous optimization of the standard objective function as well as of objective functions for the individual sites forming it, with a weight function realizing a balance between interests of different scales. The algorithm performs well in simulations. As an economist, I have to wonder where the weighting function is going to come from, however, if we're really talking about solving global problems.

"Frustration and Clustering in Biological Networks," by H. Bersini, explores the tendency of many different kinds of networks, ecological, Boolean, Hopfield, neural networks and others, to form self-organizing oscillatory clusters, and addresses the issue of optimality of such clustering. "Cortical Functionality Emergence," by H.-O. Carmesin, models the emergence of cortical functions from generalized networks. "Emergence of Functionality and Biological Clock in 'Fast' Proteins," W. Klonowski, advances the negentropic hypothesis that some very short-lived proteins' usefulness is in fact determined by their limited lifetimes, as these proteins are the products of disequilibrium states and are designed to reach extinction when the cell reaches equilibrium.

Part II begins with the subsection "Biological and Ecological Dynamics." E. Ben- Jacob and I. Cohen explore the fractal growth and response patterns of bacterial colonies to different environmental conditions. "Self-Regulation of Plants," by K.-W. Wirtz examines optimization of leaf area under different soil nitrogen concentrations for a population of birch trees.

"Aperiodic Patterns in the Cell-Nutrient Substrate System," A.B. Medvinsky et al., explores using a cellular automata approach to the origin of spatial structures resulting from a combination of diffusion and local kinetics; following in the tradition of Turing's solution to this problem. A similar approach is taken by D. Drasdo in "Different Growth Regimes Found in a Monte Carlo Model of Growing Tissue Cell Population." In this case stochastic local interaction rules are specified for a lattice model, which is able to reproduce observed characteristics of growing tissue cell populations.

"Classification of Terrestrial Ecosystems with Complexity Measures," H. Lange, M. Hauhs and C. Romahn, uses symbolic dynamics representations of ecosystems to generate measures of metric entropy and metric complexity. In this view an ecosystem acts as a filter in its abiotic environment by extracting information from irreversible input fluxes. Not surprisingly, the reconstruction of finite state machines from observed precipitation and run-off data for two well-documented ecosystems failed.

"Temporal Self-Organization in Generic Ecosystem Models," M. Bussenschutt and C. Pahl-Wostl, performed a number of ecosystem simulations. I.M. Janosi and I. Scheuring, in "Possible Role of Mobility in Natural Selection," show that in simulations a mobile species is able to squeeze out less mobile competitors from an entire lattice of connected local habitats, as often observed in world history. E. Steffen and H. Malchow, "Chaotic Dynamics in a Simulation Model of a Plankton Community," is also based on Turing's nonequilibrium reaction-diffusion patterns in biomorphogenesis. This model includes phyto- and zooplankton biomasses, a nutrient level, predation by fish, growth rates, grazing rates, a competition coefficient, respiration and mortality rates.

The second subsection of the second part, "Dynamics of Socio-Economics Processes," is probably of special interest to readers of this journal. "Self-Organization in Social Systems: The Process of Integration," begins with a qualitative review of the importance of information in nature and social life. H.C. Harton and B. Latané explore the dynamics of cultural self-organization as a cultural "game of life," with local interaction rules of clustering, correlation, consolidation, and continuing diversity, all without once using the word "meme." Latané's social impact model is extended by K. Kacperski and J.A. Holyst in a cellular automata model of opinion clustering around a leader in cases of external impact on the group. Parameters included the strength of the leader and the "social temperature."

T. Brenner simulates the "VID" (variation-imitation-decision) model to describe the interaction between decision makers when exchanging information. Brenner makes the unfortunate assumption that decision makers have no social influence on each other, leaving the results with a singular lack of credibility. F. Liebl writes on the management of strategic issues by corporations, which he defines as "discontinuities in the (social-psychological) environment." This paper, one of the few non-mathematical papers in the volume, reads like a *Harvard Business Review* article, and can be summarized as giving the following advice to management: "Remain aware of your surroundings and be flexible." W. Ebeling reviews the now-familiar envelop function of development dynamics. This paper reminds us that some of the empirical regularities that emerge from a dynamic systems perspective, such as life cycles of products and firms, or the strong correlations of firm growth rates with size across industries, are extremely powerful and are not derivable from classical or neoclassical economic theory.

G. Silverberg, "Is there Evolution after Economics?" reviews similar results in evolutionary economics in a simulation model with "boundedly rational" agents which reproduces some of these effects. M. Grothe, makes the unsupported assertion that the degree of coordination of a socio-economic system is a function of the degree of long-run competitiveness and short-run cooperativeness of agents.

T.C. Dandridge and B. Johannisson make some general remarks about self-organization among business establishments, in different larger contexts such as business incubators, franchising systems, cooperatives, science parks, and so on. V. Ahrens discusses planning and control in self-organized production systems, without a mathematical model or empirical results. S. Guriev and M. Shakhova consider "Self- Organization of Trade Networks in an Economy with Imperfect Infrastructure," in a model with consumers, producers, and traders acting in a distributed model for a homogeneous good. While infrastructure is a concern in Russia currently, this paper is too abstract to provide useful policy guidelines.

The last subsection of Part II, "Urban Structure Formation and Traffic Dynamics," begins with a "Sim-City"-type paper by W. Weidlich, "From Fast to Slow Structures in the Evolution of Urban and Regional Settlement Structures," which establishes the usefulness of the "slaving principle," when fast processes take place on the local micro level of building sites, where the local traffic infrastructure of streets and subways is constructed, while slow processes take place on the regional macro level, including the slow evolution of whole settlements, like villages, towns and cities, which can be considered as population agglomerations of different size, density and composition. The reader is presented with a beautiful assortment of 3-D topologies created by the simulations. However, until "dynamical empirical regularities" can be established in some large data sets, these results are less than compelling. The same remark can be applied to "Regional Dynamic Processes in the Economy," by K. Brandt.

F. Schweitzer and J. Steinbrink, in "Urban Cluster Growth: Analysis and Computer Simulations of Urban Aggregations," do attempt to model stylized empirical facts of urban agglomerations using a reaction-diffusion approach. Both empirically and in simulation, the rank-size distribution of urban clusters approaches a power law. It is comforting to see simulation results compared with empirical results.

R. White and G. Engelen perhaps go the furthest toward integrating regional economics with the sciences of chaos and complexity in "Multi-Scale Spatial Modeling of Self-Organizing Urban Systems," This article surveys the "Sim-City" cellular automata approach to urban modeling, with a nice discussion of the parallels to the "edge of chaos" and fractals. In this paper I read the most compelling rationale for the use of the term "fractal" in describing human organizations, namely, that in this sense the self-organizing system or organization contains a model of itself at some scale, which may be—probably is—erroneous to some degree.

J. Portugali and I. Benenson explore the effects of local and global forces in a self-organizing city, with particular attention to the interaction of members of different ethnic or racial groups. Given somewhat hopeful assumptions about the long-run ability of members of different groups to form a "common culture," the authors find that, in simulations, early tendencies toward segregation give way in the long run to "neutrals," and presumably, peace.

J. Lobo and R.E. Schuler consider the straight-forward economics question: "In a random environment, is there an optimal number of cooperating elements that results, on average, in maximum group output?" However, as they assume minimal structure and no foresight on the part of the elements (i.e., a one-period memory) their model of a "trial-and-error economy" is far removed from reality, and is derivatively related to Kaufmann's NK networks.

J. Kropp and G. Petschel-Held apply Kohenen self-organizing feature maps to the reduction of dimensionality of descriptors of German cities, showing that a 34- dimensional data array can be mapped into a 4-dimensional subspace with minimal topological distorion by Kohenen's learning neural network method. The authors suggest that, "with the implementation of valuable databases," the method offers a promising road toward qualitative description and prototyping of complex systems.

"Self-Organization Phenomena in Pedestrian Crowds," by D. Helbing and P. Molnar, joins the raft of papers on queuing and swarming, implementing simulation models of pedestrians at intersections and passing through narrow passages, and comes to the following conclusions: lanes develop of pedestrians who walk in the same direction; the walking direction at narrow passages undergoes oscillatory change; and roundabout traffic forms spontaneously at crossings. These self-organized patterns arise from nonlinear interactions of pedestrians following a simple social force model at the individual level. While the authors do not present empirical support for these findings, they ring so true to experience as to be unassailable.

K. Nagel, S. Rasmussen and C.L. Barrett, "Network Traffic as Self-Organized Critical Phenomena," reach the paradoxical conclusion as a result of their simulations of the collective behavior of "simple adaptive agents," that traffic management, while it may indeed make traffic more efficient, may also make traffic more variable and unpredictable, by driving the system closer to capacity and "self-organized criticality." The introduction of a traffic management system can actually produce a more unpredictable traffic dynamics. The authors write that this happens because the traffic management system moves traffic from more congested to less congested roads and thus as a whole forces the transportation system into the critical regime where small perturbations have a large influence on the microscopic dynamics. At lower traffic densities, variations of travel time are maximized, flow is maximized, but travel time is near minimal levels. Since air pollution as well as serious accidents are maximal where acceleration and deceleration are maximal, the critical regime, in addition to its noncontrollability, produces other highly undesirable side effects.

While not quite an *Ur*-document on the order of some of the early Santa Fe proceedings, "Self-Organization of Complex Structures" is a valuable proceedings volume. It accomplishes its purpose of bringing together multiple perspectives and making the reader draw inferences about commonalities. Most of the work is by physicists and is at a high level of mathematical and computational sophistication. It is perhaps reasonable to quibble that many of the papers produce yet another virutoso simulation, without reference to empirical results. A few papers compared simulation results with empirical results; and indeed, a new standard seems to be emerging that this be done of any simulation. In this way, researchers may indeed be led to meaningful generalities linking classes of generating structures and the output distributions they produce. The day-to-day practice of science requires the formulation and testing of falsifiable hypotheses. Making one's favorite assumptions about agent behaviors, and then embedding them in a simulation model which exists apart from the real world, is not much different from the enervating practices of mathematical economics and psychology, where assumptions are made and results "proved" about economic systems or human psychology. The sciences of complexity would be well-advised to avoid this pitfall.

Elliott Middleton
Department of Finance
Metropolitan State University
Minneapolis, MN 55403-1897
elliott@maroon.tc.umn.edu