510

Control of Complex Systems: An Intrinsically Derived or Imposed Process?

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Review by
M. T. Turvey *and* B. Kay

Oliver G. Selfridge is senior scientist at GTE Labs in Waltham, Massachusetts. ■ *The other two editors are associated with the Department of Computer and Information Science at the University of Massachusetts—Amherst. Edwina L. Rissland, assistant professor, is author of the chapter "A.I. and the Learning of Mathematics: A Tutorial Sampling" in E. A. Silver's* Teaching and Learning Mathematics Problem Solving: Multiple Research Perspectives. ■ *Michael A. Arbib, professor, is author of* Brains, Machines, and Mathematics. ■ *M. T. Turvey is professor of psychology at the University of Connecticut. A past recipient of APA's Early Career Award, he is coauthor with P. Kugler and J. A. S. Kelso of the chapter "On the Control and Coordination of Naturally Developing Systems" in Kelso and J. E. Clark's* The Development of Movement Control and Coordination. ■ *B. Kay is research assistant at Haskins Laboratories in New Haven, Connecticut. He is interested in motor coordination, perception, and qualitative dynamics.*

How is it that complex systems exhibit qualitatively coherent and very successful behavior? The paradigmatic instance of this problem is provided, of course, by biological systems, from the "simple" unicellular organisms up to and including the most complex social structures of humans and other species. This volume (a collection of papers from the NATO Advanced Research Institute held in Moretonhampstead, Devon, in 1981) contains a variety of insights into the vexing problem of complex systems, a problem of considerable interest to contemporary science.

The book is well organized, with theoretical issues prefacing a wide range of applications. Moray gives an excellent definition and taxonomy of ill-defined systems (those whose state matrices or transition matrices are probabilistic or time-varying) that is roughly agreed upon by all of the participating authors. There is some confusion, however, about whether the observer, that is, the scientist, is a part of that definition. Some authors propose that if *we* cannot understand a complex system it is thereby ill-defined. Other authors rightly contend that this observer-centered definition is vacuous, preferring a definition in terms of system characteristics in and of themselves.

A major theoretical dichotomy emerges from the contributions: control of ill-defined systems wrought through symbolic processes versus control arising from principles of self-organization. The most widely held view, not surprisingly, given the zeitgeist, is that control is largely computational/representational: The coherent behavior of ill-defined systems originates in symbol strings (representations) and their manipulations (computations). The less widely held view (Yates, Selfridge) questions the legitimacy of explaining coherent systemic activity through imposed control structures, preferring to believe that the sought-after explanation must be couched mainly, if not solely, in terms of dynamical principles of self-organization. According to the less popular view, dynamics—broadly conceived as the complementation of mechanics and nonlinear, nonequilibrium thermodynamics (Haken, 1977; Iberall, 1977; Prigogine, 1980)—is the significant mode of description for explaining complex behaviors, including language. The more popular view does recognize the dynamic mode along with the symbolic mode but tends to suppress its importance. Unfortunately, Howard Pattee's many informed discussions (e.g., Pattee, 1972, 1973, 1977) of this particular issue of the discrete, symbolic and the continuous, dynamical modes of description receive little mention in the text. His thoughts would have usefully rounded out the debate.

Another major difference of opinion exists with regard to the necessity of error in adaptive control. In most of adaptive control theory (be it of ill- or well-defined systems), deviations from the desired states of affairs, or goals, are the most crucial data for the control strategies. Several of the present articles question this assumption (Selfridge, Minsky, Boden, Yates) and derive reasonable control principles without needing any optimization procedures. Some confusion exists among the articles as to whether goals are defined by the controller a priori or whether they are observed a posteriori by us, the observers. Clearly, intentionality is an issue that calls out for clarification in this domain, and I believe that the philosophical analyses of Dennett (1971) or Searle (1983) might have provided a steadying influence.

Concepts deserving careful attention abound in the applications section of the book. Motor skills (Shaffer, Whiting, Arbib), language acquisition and adaptation (Gleitman and Wanner, Lavorel), and development and evolution (Brainerd, Churcher, Boden, Holland) are the three applied fields that are sampled. Unfortunately, the first two topics are somewhat underrepresented. And the promise of a dynamical explanation of language is not fulfilled by either of the two language chapters, both of which present control as a matter of computations over representations. The dynamic perspective is conspicuously absent in the motor skills chapters, also. In comparison, the chapters concerning development and evolution contain elements of both sides of the debate, although their emphasis is still roughly within the computational/representational domain. As Boden points out, little has been said anywhere of how the control structures posited by the theorists come about—that is, how they are acquired in the first place (a problem that Pattee has sought to define in a physically consistent fashion). Artificial intelligence algorithms always seem very arbitrary, but Holland claims that useful algorithms can be gleaned from nature, echoing a similar claim made by the dynamicists.

There is some common ground to be found among all of the entries, in addition to agreement on the nature of the problem. There is hardly any disagreement with the current realization that action is necessary for perceptual development, and vice versa. There is also a common blind spot, namely, the issue of how the control of ill-defined systems can be sustained over different contexts. Although this issue is raised in the introductory chapter, it is never mentioned again. The issue of how a system is controlled within one context is challenging; but how adaptive systems shift from behaving successfully in one context to behaving successfully in others is not a separate issue, since many of the same control principles must carry over. An understanding of the similarities of control processes across domains is crucial, but it has not been addressed here.

The present selection is broad enough to render a good picture of the contemporary state of complex systems theory. It seems to be a vibrant state, given the depth of the concepts considered and the extent to which they are in debate. Nevertheless, it is very apparent that the understanding of such systems is still in its infancy. At root, the debate lies at a fairly fundamental level, with the overarching approach (symbolic or dynamic or a complementarity of the two) largely undecided. A broader treatment of this field would be hard to imagine, and *Adaptive Control of Ill-Defined Systems* promises to be a useful companion volume to *Self-Organizing Systems: The Emergence of Order* (edited by Yates), in which leading physicists, algebraic topologists, and qualitative dynamicists tackle the same issues.

References

Dennett, D. C. (1971). Intentional systems. *The Journal of Philosophy, 118*, 87–106.

Haken, H. (1977). *Synergetics: An introduction*. Heidelberg, Federal Republic of Germany: Springer-Verlag.

Iberall, A. S. (1977). A field and circuit thermodynamics for integrative physiology: I. Introduction to general notions. *American Journal of Physiology: Regulatory, Integrative, & Comparative Physiology, 2*, R171–R180.

Pattee, H. H. (1972). Laws and constraints, symbols and language. In C. H. Waddington (Ed.), *Towards a theoret[illegible] biology* (Vol. 4, pp. 248–258). Chica[illegible] Aldine.

Pattee, H. H. (1973). Physical problem[illegible] the origin of natural controls. In A. Locker (Ed.), *Biogenesis, evolution, homeostasis* (pp. 41–49). Heidelberg Federal Republic of Germany: Spring[illegible] Verlag.

Pattee, H. H. (1977). Dynamic and linguistic modes of complex systems. *International Journal of General Syste[illegible] 3*, 259–266.

Prigogine, I. (1980). *From being to becoming: Time and complexity in the physical sciences*. San Francisco: Freeman.

Searle, J. (1983). *Intentionality*. Cambri[illegible] England: Cambridge University Press

Yates, F. E. (Ed.). (1984). *Self-organizin[illegible] systems: The emergence of order*. New York: Plenum Press.