Book Review


The book under review is an important volume of the rapidly increasing Springer Complexity series. Since the main goal of complex system theory is to understand how interacting parts generate rich, unpredictable, emergent behavior, a paradigmatic illustration of the approach is to demonstrate how cognition and consciousness (both of them are dynamic in their nature) is generated from the interaction of different brain regions. This volume, edited by L. I. Perlovsky and R. Kozma, grew up from a series of lectures presented at the World Congress of Computational Intelligence in Vancouver, BC, Canada, in summer 2006.

Part I is about “Neurodynamics of Cognition and Consciousness,” and it contains reviews from major players of the field. The papers are carefully selected, and what makes the book particularly exciting is that the authors have partially overlapping, but still very original views.

The importance of the analysis of dynamic patterns of neurons and cell assemblies was emphasized by A. K. Katchalsky (who died at the Tel-Aviv airport in 1972 from a terrorist act). Neurodynamics has two intellectual sources. First, the theory and applications of dynamic system itself had a massive influence on brain theory. The emerging nonlinear science adopted such keywords as oscillations and fluctuations, bifurcations and phase transitions, chaos, nonconvergent attractors, strange attractors and fractals, morphogenesis, bi- and multistability, just to mention some of them. Second, experimental methods have been developed to monitor spatio-temporal phenomena at different levels of neural organization: from single cells by microelectrode techniques, from neural networks by using multielectrode techniques, and from neural centers and the whole brain by applying brain imaging methods.

W. Freeman, a prominent pioneer of neurodynamics, was motivated by Katchalsky’s theoretical concepts, and developed EEG methods to record and interpret neural spatio-temporal patterns. In the introductory paper of Part I, he showed the importance of phase transition phenomena between different dynamical regimes.

A somewhat different approach, namely, “complementary neuro-science,” was suggested by another eminent scientist, S. Kelso, and his co-worker, E. Tognoli. Complementarity principles were suggested by the pioneers of quantum physics, most famously by N. Bohr. In the present paper, complementarity is related to metastability, which here means balance between independence of, and coupling between, components. While there are slight differences in Freeman’s and Kelso’s attitudes and methods, both approaches could be interpreted as excellent applications of the theory of nonlinear dynamics.

Brain is certainly a prototype of hierarchical dynamical systems. While the reductionist research strategy helped to uncover many details of the cellular and neural network level organization of the individual brain regions, the perspective of complex systems raises questions and occasionally offers answers for the neural and computational organizational principles. Concerning neural organization, theories—for the emergence of global neurocognitive states (Bressler) and context-dependent intelligence (Levine)—were offered as a consequence of interaction among different brain regions. The former is based on transitions between synchronized and desynchronized states, while the latter gives a dynamic model for rule selection. In terms of computational perspective, a dynamic logic framework is being elaborated to explain mechanisms of the mind, also in cultural context (Perlovsky); intelligence is being replicated by learning from our own brain mechanisms (Werbos); and intentional behavioral generation is explained by integrating the theory of phase transitions with hierarchical models of large population of neurons (Kozma). I feel that early cybernetics could have received some more credit. Cybernetics, an optimistic, ambitious movement (led by such legendary pioneers as W. McCulloch and N. Wiener) hoped to understand human knowledge based on a logical theory of brain, and to build computers motivated by the brain—computer metaphor (“Design for a Brain,” as the title of a book “Design for a Brain” by another legendary cybernetician, R. Ashby, suggests). AI strongly attacked cybernetics, and the search for mechanisms was replaced by writing programs based on heuristic principles to implement specific functions. This attitude has survived in some communities. However, many of us believe that the actual biological substrate is very important to construct intelligence. If I should choose the single most important difference between the organization principles of the brain and computers, I would vote for the synaptic organization of neural networks, which has a fundamental role in the implementation of neural functioning. In the same period when traditional AI developed, and brain modeling was not fashionable (and supportable), J. Eccles worked on and understood the physiological mechanism of excitatory and inhibitory synaptic transmission and their interplay in neural networks. Synaptic modifiability makes us ready to learn and at the same time be susceptible to epilepsy.

Part II, “Cognitive Computing for Sensory Perception,” is somewhat more eclectical than Part I, but it still gives excellent examples for the application of the general neurodynamic principles.

New algorithms for shape and object recognition are offered by adopting dynamic models instead of the classical static ones. Face recognition, artificial olfactory systems, developments of the concept of computations with attractors, models of synaptic transmission, and memory are important illustrations of these principles.

The book, as a well-edited whole, offers a coherent perspective and contains many remarkable details. I recommend it to anyone who would like to learn more about the field.