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Book Review: *Brownian Agents and Active Particles*

Brownian Agents and Active Particles. F. Schweitzer, Springer, Berlin, 2003.

In 1905 Karl Pearson submitted a question to *Nature* requesting the solution to the problem of a walker who takes a number of equidistant steps, but who rotates through a random angle after each step. He wanted to know the probability of being a given distance from the origin after a prescribed number of steps. Lord Rayleigh recognized the problem to be mathematically equivalent to one he had considered some years earlier concerning the sum of N isoperiodic vibrations, all of unit amplitude and each with a random phase. He immediately wrote down the form of the solution as a two-dimensional Gaussian distribution in the radial variable. In this way was the theory of random walks ushered into science.

It was not realized at the time but on the continent a young Albert Einstein was publishing an equally remarkable paper on the theory of diffusion; a theory describing the diffusing particle by a Gaussian distribution. It would require a few years, but eventually random walks would form the simplest description of the phenomenon of diffusion. This process would later become known as Brownian motion, due to Einstein's speculation that diffusion might be related to the observations of the botanist Robert Brown.

In the 100 years since the introduction of random walks and its utilization in the description of physical processes, such models have been generalized to incorporate increasingly complex mechanisms. One kind of modeling implements probabilities and transitions in the phase space for the systems of interest. A complementary method uses the equation of motion for the dynamical variable. These two techniques enable the modeler to incorporate the system's internal forces, no matter how complex, into a dynamical description (stochastic differential equation; Langevin equation) in which the influence of the environment is treated as a stochastic force related to an internal dissipation. At first such models were kept relatively simple, since it was the interpretation of analytic solutions that provided insight into complex phenomena. However, as the computer became more accessible, an alternate approach, simulation, became available to the modeler and significant insight into complex physical phenomena could be obtained without analytic solutions. This alternative to theory and experiment, for many, is the third pillar supporting the nascent science of complexity.

The success of simulating Langevin and Fokker–Planck equation models of physical phenomena has lead to their application in the social and life sciences as well. Frank Schweitzer in his book *Brownian Agents and Active Particles* shows how even the complex phenomena from the social and life sciences are captured using relatively simple simulation models. At the heart of this approach is the idea that complex phenomena need not have complex descriptions, which has been the mantra of nonlinear dynamics systems theory for the past two decades. The strategy of agent-based modeling is to replace the featureless physical particles of diffusion with entities that have internal structure (Brownian agents). The behavior of the interacting units is encapsulated in simple programs that constitute self-contained interacting modules. Schweitzer does his modeling with restraint in order to distinguish between those properties in the model that are assumed and those that emerge by means of the nonlinear interactions.

Schweitzer's book is not for the mathematically faint of heart. The applications of Brownian agents to complex phenomena require a minimal level of understanding of multi-dimensional differential equations having both deterministic and stochastic components. However, he successfully reviews the necessary background material, so that one can follow the generalization from the physical diffusion of Brownian particles using Langevin and Fokker–Planck equations to the more general motion of Brownian agents.

The book follows a strategy of incrementally increasing the complexity of the phenomena being addressed using the Brownian agent strategy. The book starts from active agents requiring the external input of energy that can be stored and converted to motion, to moving agents that can react to signals in the environment, to the adaptive self-organization of networks for tracking and the trail formation of ants, to human trail formation in social systems, to complex search and optimization problems to econophysics and rumors. In each of these areas the author introduces the mathematical modeling assumptions necessary to capture the interactions of interest. Then employing a combination of asymptotic analysis, numerical simulation using a variety of parameter values and phase space plots separating regions of stability and instability, the author discusses the phenomena under study and relates the analysis to the existing literature.

There are very few books available today that provide both an overview of a new area of research, but contain sufficient technical detail to enable the reader to implement the methods in their own area of investigation. This is such a book. The author has argued convincingly, primarily through simulation, that Brownian agents are a viable, and perhaps even unique, way to explore the rich dynamics of complex adaptive systems. This book would be a valuable reference for anyone doing research into the properties of complex phenomena.

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