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Bellomo, Nicola

Modeling complex living systems. A kinetic theory and stochastic game approach. (English)

Modeling and Simulation in Science, Engineering and Technology. Boston, MA: Birkhäuser. xii, 220 p. EUR 54.90/net; SFR 95.00; £ 42.00; $ 69.95 (2008). ISBN 978-0-8176-4510-6/hbk

This nicely written book promotes the idea that the methods employed for modeling living systems may significantly differ from the techniques used for analyzing the inert matter. Dynamics of the large system of individuals, acting in quite organized manner and possessing certain intelligent abilities, cannot be adequately described by using traditional methods of mathematical kinetic theory which treats elements of inert matter within the framework of classical or quantum mechanics. Therefore, it is suggested to model complex systems arising in life sciences describing them as constituted by a large number of interacting "active particles," whose physical state includes, in addition to variables accounting for mechanical and geometrical properties, a variable "activity" characterizing each specific leaving system. Necessity to properly model the living world calls for a new mathematical methodology which is being developed in the book. The introductory chapter provides a brief overview of main definitions, scaling techniques, and principal methods in the kinetic theory. In particular, discrete velocity models of classical kinetic theory, description of the microscopic state and microscopic interactions and preliminary ideas on the use of kinetic theory methods for the modeling in applied sciences are discussed here. The main body of the book is divided logically into two parts. The first part focuses on methodological issues and derivation of general mathematical frameworks that are further used for modeling of particular systems arising in applied sciences, whereas different models and applications are collected in the second part. Novel mathematical approaches to modeling living systems are developed in Chapters 2-4. Two types of evolution equations for a one-particle distribution function over the microscopic state of a system involving a large number of interacting active particles corresponding to short and long range interactions are derived in Chapter 2. These equations are regarded as a general mathematical framework and include, under suitable assumptions, classical Boltzmann and Vlasov equations. Techniques for modeling mixtures with mixed-type long or short range interactions and proliferative events that generate active particles in a population different from the one to which the interacting pairs belong are developed in Chapter 3. Chapter 4 is concerned with the modeling of systems possessing a macroscopic state that attains a finite number of states rather than a continuous one. All applications in Chapters 5-8 are presented with a similar layout that includes phenomenological interpretation of the original system, derivation of the appropriate mathematical model within the mathematical kinetic theory using active particles approach, simulations, study of the sensitivity of the model with respect to parameters, critical assessment of the model, and discussion of its possible improvements. The selection of models primarily reflects the personal experience of the author, which by no means excludes eventual applications to other complex systems. Chapter 5 addresses modeling aspects of social competition of individuals whose microscopic states correspond to their social collocation. The models are spatially homogeneous, and attention is focused on their predictive ability. In Chapter 6, a new approach where a car-driver system is considered as an active particle is applied to the traffic problem, traditionally viewed within the framework of inert matter. Immune competition between the cells of the immune system and those of an aggressive invasive guest is modeled in Chapter 7. The case where the number of populations varies in time is examined, and the case where a new cell is generated in a different, possibly new population, as a result of interaction of two particles that belong to different populations is also explored. Chapter 8 focuses on the dynamics of crowds in closed domains, with a constant number of particles, and in the presence of attractive and repulsive forces acting between active particles. The case of transition from normal to panic behavior, which significantly modifies the evolution of the system is studied, and then even more complex situation with swarms, where the domain containing active particles evolves in time is considered. The final Chapter 9 summarizes the methodological aspects discussed in the book. It starts with the overview of models that refer to the mathematical frameworks designed in Chapters 2-4 and proceeds with a critical analysis of the techniques focusing on mathematical difficulties that arise in modeling of living systems. Suggestions for further research are given and methodological aspects regarding multiscale modeling which requires proper matching of microscopic and macroscopic sub-models are addressed. One should note that no special skills in the methods of mathematical kinetic theory are required since presentation of all mathematical techniques employed in the book is self-contained. This text, carefully written by a well-known expert, explains broad and profound applications of a new approach to modeling of nonlinear complex systems not only in the natural sciences, but also in the systems describing social, ecological, and economic phenomena. It is a very useful reference for anyone interested in mathematical modeling of complex

Svitlana P. Rogovchenko (Famagusta)

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Classification :
- ∗91-02 Research exposition (Social and behavioral sciences)
- 00A71 Theory of mathematical modeling
- 82-02 Research monographs (statistical mechanics)
- 91A15 Stochastic games
- 91A80 Applications of game theory
- 92-02 Research monographs (appl. to natural sciences)