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★**Control and optimization of multiscale process systems.**

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This book is concerned with a class of multiscale process systems. The motivation stems from industry, especially the chemical industry. As the authors point out, the book aims to achieve the following objectives.

1. It intends to present a framework for the design of real-time control systems, in which integrated process models, model reductions, feedback control laws, and surface measurement techniques to regulate material microstructure in multiscales are taken into consideration.
2. It develops methods for the efficient solution of optimization tasks when the cost functions and equality constraints involve multiscale process models.
3. It deals with control and optimization problems featuring coupled macroscopic and microscopic phenomena.

The book contains 7 chapters. After an introductory chapter, the following subjects are covered.

- Multiscale modeling. One main challenge is the integration of various time scales. As the authors argue, for example, in the gas phase the processes of heat/mass transport can be modeled as continua. When the microstructure of the surface is studied, events such as atom adsorption, desorption, and migration have to be considered and the continuum hypothesis is no longer valid. Partial differential equation (PDE) techniques are no longer adequate. Microscopic simulation techniques should be used instead.
- Kinetic Monte Carlo simulation. Accompanying the multiscale modeling, Monte Carlo techniques provide a way to obtain unbiased realizations of the random processes involved, which is consistent with the equation satisfied by the transition density, most commonly known as the "master equation" in the chemical engineering literature, as the Fokker-Planck equation in statistical mechanics, and as the Kolmogorov forward equations in probability theory.

  In the book, there are detailed descriptions of how the Monte Carlo simulation can be conducted. It appears that the methods based on multiscale modeling can be related to the singularly perturbed Markov processes [R. Z. Khasʹminskiĭ and G. G. Yin, SIAM J. Math. Anal. **35** (2004), no. 6, 1534–1560; MR2083789 (2005h:60245); G. G. Yin and Q. Zhang, *Continuous-time Markov chains and applications*, Springer, New York, 1998; MR1488963 (2000a:60142); and references therein], where reduction of computation complexity can be achieved by means of decomposition, aggregation, and averaging.
- To control material miscrostructure in multiscale systems, it is essential to be able to solve the master equation efficiently. For systems arising in applications, the dimension of the master equation can be huge. It is thus virtually impossible to solve the master equation directly.

One of the ideas in the book is to use kinetic Monte Carlo methods to find the solution to the master equation. The rationale appears to be to use certain average properties to design feedback controls leading to desired performance.

- Stochastic PDEs. These are not exactly like the setup in, for example, [J. B. Walsh, in *École d'été de probabilités de Saint-Flour, XIV—1984*, 265–439, Lecture Notes in Math., 1180, Springer, Berlin, 1986; MR0876085 (88a:60114); P. L. Chow, *Stochastic partial differential equations*, Chapman & Hall/CRC, Boca Raton, FL, 2007; MR2295103 (2008d:35243); and references therein], but they are closely related. Here the stochastic PDE means a PDE perturbed by a random noise, e.g., the following equation describes the evolution of the surface of a thin film:
$$\frac{\partial h}{\partial t} = c + c_0 h + c_1 \frac{\partial h}{\partial x} + \cdots + c_w \frac{\partial^w h}{\partial x^w} + \xi(x,t),$$
where $x \in [0,\pi]$, t is the time, $h(x,t)$ is the height of the surface position x at time t, $\xi(x,t)$ is the noise assumed to be Gaussian, and c and c_i are the prederivative coefficients. Several problems discussed here include moment analysis of the solutions, parameter for nonlinear equations, and kinetic Monte Carlo methods.
- Based on the stochastic PDE models given above, model-based controllers are given. Computationally efficient multivariate predictive control algorithms are suggested.
- The authors go on to treat optimization of multiscale process systems. The emphasis is on the efficient solution of optimization problems when the cost and equality constraints display multiscale structure. Several optimization methods are presented. Then the optimization techniques are extended to dynamic optimization problems.

The book is well prepared, and contains many interesting applications. People working in the area of process control, and/or in the area of stochastic PDEs, and/or in multiscale modeling, analysis and simulation may find it a good source of problems to work on.

Reviewed by *George Yin*