Pattern Formation and Lattice Gas Automata

Anna T. Lawniczak
Raymond Kapral
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Pattern Formation and Lattice Gas Automata

Anna T. Lawniczak
Raymond Kapral
Editors
The Fields Institute
for Research in Mathematical Sciences

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Preface

Lattice-gas automata are fully discrete models that employ a simplified molecular dynamics consisting of propagation and collision events. If the basic conservation laws and symmetries are preserved this dynamics can lead to the Navier-Stokes equations of hydrodynamics. The introduction of such lattice-gas models in 1986 (Frisch et al. [1986], d'Humieres et al. [1987]) prompted a great deal of research (Doolen [1990]) on moderate Reynolds number hydrodynamic flows since these models provide a computational scheme that is stable and can be applied easily to complicated geometries.

The most recent developments in the field have taken the research far beyond the original goal of simulating hydrodynamic flows. Current work has focused on further development of these models and their applications to diverse physical problems. These include: the development of more elaborate models to restore the Galilean invariance that is destroyed by the lattice symmetries, studies of the statistical mechanics of lattice-gas models, extensions to multi-phase systems where phase separation and flows in porous media can be studied, the construction of lattice-gas models for chemically reacting systems, as well as applications to a variety of other physical problems.

Many of these newer developments utilize lattice-gas descriptions that differ radically from the original hydrodynamic lattice-gas models; for example, the models for phase separation often lack semi-detailed balance and reactive models intended to describe reaction-diffusion phenomena need not conserve momentum. It has also been recognized that fluctuations which naturally arise in lattice-gas models can be exploited to obtain a deeper level of description of the system. The study of such fluctuations and their correlations forms the basis for the investigations of the statistical mechanics of these models. However, these fluctuations are often a source of difficulty in lattice-gas simulations of the Navier-Stokes equations since considerable averaging is required to obtain smooth velocity fields.

Lattice-gas automata have also inspired the development and investigation of other classes of discrete models, the most well-studied of which is the lattice-Boltzmann model. While this model falls into the category of finite-difference schemes, the philosophy of its construction is different; it is based on physical considerations rather than pure discretisation of macroscopic partial differential equations describing physical phenomena. The use of the lattice-Boltzmann model
has allowed the study of a broad class of systems that would have been difficult by other means.

This conference on Pattern Formation and Lattice-Gas Automata had as its aim the review of these diverse recent developments in the field. The sessions were organized around the following themes: theory and development of lattice-gas and lattice-Boltzmann methods and their applications to hydrodynamics, multi-phase flows, flows through porous media, reaction-diffusion systems, pattern formation phenomena, and phase separation processes. Various aspects of the statistical analyses of these methods were discussed with emphasis on fluctuations and correlations, as well as computational prospects including development of dedicated hardware.

It was clear from the discussions at the meeting that lattice-gas automata continue to be developed in radically new ways, have been applied in many different fields and contexts, and will continue to inspire controversy. Their greatest utility may lie in fields quite different from their original application to hydrodynamic flows.

It remains for us to thank the other members of the organizing committee: Jean-Pierre Boon, Gary Doolen and Daniel Rothman. We gratefully acknowledge NATO for their support under the NATO Advanced Research Workshop program and the Fields Institute for Research in Mathematical Sciences for providing support and for hosting the conference. We also express our appreciation to B. Lawniczak for his help in the organization of the meeting and to Gary Doolen for providing the list of abstracts.

References

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Pattern Formation and Lattice Gas Automata
Anna T. Lawniczak and Raymond Kapral, Editors

This book is the Proceedings of the Fields Institute Conference/NATO Advanced Research Workshop held in June 1993. The articles review the diverse recent progress in the theory and development of lattice-gas and lattice Boltzmann methods and their applications to hydrodynamics, multi-phase flows, flows through porous media, reaction-diffusion systems, pattern formation phenomena, and phase separation processes. Discussed here are various aspects of the statistical analysis of these methods, with emphasis on fluctuations and correlations, as well as computational prospects including development of dedicated hardware.

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