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Foreword

The present issue of the Journal is devoted to theoretical aspects and numerical experiments of Lattice Gas Automata (LGA), a new field in Statistical Physics which connects with theoretical physics, computational physics and dedicated machine technology. The bronze age was in 1985 when the pioneering studies established theoretically and computationally the feasibility of simulating fluid dynamics via a microscopic approach based on a new paradigm: a fictitious oversimplified microworld is constructed as an automaton universe based not on a realistic description of interacting particles (as in Molecular Dynamics), but merely on the laws of symmetry and of invariance of macroscopic physics. At the time, most of the effort was invested into lattice gas hydrodynamics through theoretical developments recovering Navier Stokes equations, simulations showing wakes and eddy formation, and hardware elaboration of dedicated computers. As already noticeable in 1989, the field of lattice gas automata had by now flourished into a broad range of theoretical studies and applications: statistical mechanical theories had gone deeper into the basics of lattice gases and models had been proposed for a wide variety of phenomena. The concomitant consequence was the sophistication of the new models and of the methods developed for their implementation. A typical example is the pseudo three-dimensional model elaborations in the race to high Reynolds numbers. As a result the present situation is considerably less monolithic: the field has been branching out into more specialized subareas, such as statistical mechanics of LGA's, 3-D models for high Reynolds numbers and the transition to turbulence, multi-species and multi-phase models for low Reynolds number complex flows (with or without surface tension), boundary layers, lattice Boltzmann approach to turbulence, thermal LGA's, reactive systems. Nevertheless the common paradigmatic basis still keeps the LGA community conceptually—if not operationally—unified. On the other hand it is to be recognized that some of the work performed via the LGA approach on a specific topic now often addresses to the given topic audience as much as to the LGA experts. This dual situation is quite common in Statistical Physics and is examplified by such questions as: How good are LGA models for real systems? How well

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can one trust the prediction of a new effect obtained from the LGA approach? Can LGA's meet the needs for solving practical problems? Although no clearcut answers can yet be given to these questions, most papers in the present issue do contain—explicitly or implicitly—a partial answer contributing positively to our evaluation of the perspectives.

Topics range from fundamental statistical physics to simulations of phenomena for well posed practical problems. As to the applicability of those studies in the latter category labeled "applied science" (e.g. multi-phase flow through porous media), there is still a long way to go before LGA codes can become operational for industrial needs. Yet the research investment in LGA methods by some well established large companies is indicative of the potentialities for future applications.

Schematically the present status of major LGA poles can be depicted as follows:

Statistical mechanics

Hydrodynamic Eqs. Reaction-Diffusion Eqs.

Complex flows Complex fluids Reactive systems

Most of the systems considered within the frame of this scheme are nonthermal fluids in the incompressible limit. Recent developments have shown that multi-speed models incorporating correct temperature fluctuations possess actual thermodynamic states. The model complexity presently imposes operational restriction to two-dimensional thermal LGA's. On the other hand recent versions of the pseudo-four-dimensional algorithms have proved remarkably efficient for the implementation of 3-D LGA flows at moderately high Reynolds numbers on workstations. Furthermore, 3-D simulations on the transition to turbulence—despite intrinsic periodic boundary conditions—are now amenable to configurations where analysis can be performed along the same lines as for actual laboratory experiments. Considerable progress should be expected in the near future. The same conclusions apply to the classes of LGA's concerning multi-species reaction-diffusion systems and multi-phase flows at low Reynolds number in complex geometries. Considerable progress has also been accomplished on the theoretical side in particular in unraveling the existence and the effects of local and global invariants and in general for a deeper understanding of the statistical mechanics of LGA's. From there we expect that new convergences should emerge from the various paths taken along the presently somewhat diversified LGA excursions.

Landmarks in the still young history of Lattice Gas Automata were the international meetings held in 1986 (Santa Fe), 1989 (Los Alamos), and 1991 (Nice). Most of the articles in the present issue arose from presentations given during the Nato Advanced Research Workshop: Lattice Gas Automata, Theory, Implementation, Simulations (Nice, France; June 25-28, 1991) steered by the following scientific committee: J. P. Boon (University of Brussels), G. D. Doolen (Los Alamos National Laboratory), M. H. Ernst (Rijksuniversiteit Utrecht), J. L. Lebowitz (Rutgers University). The workshop was sponsored by the Nato Special Programme on Chaos, Order, and Patterns, and by DRET (France). It took place at the pleasant site of the Observatoire de Nice whose kind hospitality is gratefully acknowledged. Conference management was provided by Nadia Sardo (University of Brussels), Christiane Cazneuve and Marie-Claude Pophillat (Observatoire de Nice).

The workshop in Nice took place in the summer of 1991 and this date was not a coincidence: for it provided the opportunity to close the meeting with a special celebration in honor of our colleague and friend, Michel Hénon, on the occasion of his 60th birthday. We have the pleasure to dedicate the present volume to Michel.

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