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Preface

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Cellular automata are discrete systems where dynamics are governed by simple local rules of interaction between discrete elements that are applied in parallel throughout the entire system. The local interaction and simplicity of rules allow cellular automata to serve as useful models for a variety of physical systems. In this issue the behavioral properties and complexity of cellular automata are studied from the perspective of computational universality and reversibility, the complexity of global synchronisation in both deterministic and stochastic settings, group theory, and the emergence of life.

This special issue of Natural Computing is devoted to the 22nd International Workshop on Cellular Automata and Discrete Complex Systems (AUTOMATA 2016), and includes extended versions of a selection of papers presented at the conference. The AUTOMATA series has been running yearly since 1995, most frequently taking place in Europe but also making visits to Japan, South America, and North America. AUTOMATA provides a forum for researchers working on fundamental aspects of cellular automata and related discrete complex systems. A non-exhaustive list of the topics of interest to AUTOMATA include: dynamics, topology, ergodicity, algebra, algorithms, complexity, emergence, formal language processing, symbolic dynamics, parallelism, distributed systems, timing schemes, phenomenology, modeling and applications.

The papers in this special issue include regular and invited contributions from AUTOMATA 2016 that have been extended and improved, and have went through a thorough review process independent from AUTOMATA 2016.

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The paper "A Universal Non-Conservative Reversible Elementary Triangular Partitioned Cellular Automaton That Shows Complex Behavior" by Kenichi Morita gives an 8-state triangular partitioned cellular automaton with a very simple form of update rule that is both isotropic and reversible. An analysis of the interaction/collisions between the various patterns that appear in this cellular automaton are given and it is shown how switch gates and inverse switch gates can be simulated by these interactions. Switch gates and inverse switch gates simulate Fredkin gates and so it follows that this cellular automaton is computationally universal.

The paper "Remarks on the cellular automaton global synchronisation problem: deterministic vs. stochastic models" by Nazim Fatès investigates the problem of finding a cellular automaton where regardless of the initial condition the cellular automaton evolves to a homogeneous blinking state. The paper studies the problem for one-dimensional cellular automata on periodic boundary conditions. For the stochastic case rules are given where the average synchronisation time to the blinking state occurs in time quadratic in the number of cells. For the deterministic case it is shown that reducing the problem to SAT allows the use of SAT solvers to find rules that synchronise a large set of initial conditions.

The article "Cellular Automata and Finite Groups" by Alonso Castillo-Ramirez and Maximilien Gadouleau studies the algebraic properties of cellular automata over a finite group. It is shown that the structure of the group of invertible cellular automata may be expressed as wreath products and in a related result a new lower bound on the number of aperiodic configurations is given. This article ends with a study of the minimal size of generating sets for the set of cellular automata over a finite group.

The paper "Cellular Automata on Group Sets and the Uniform Curtis–Hedlund–Lyndon Theorem" by Simon Wacker generalizes some well-known results to a more general setting. It is known that a cellular automaton is reversible if and only if it is bijective, and here this result is extended to functions on a left homogenous G-space. G-equivariance properties of such functions are used to prove a variant of the standard Curtis–Hedlund–Lyndon theorem which can thus be applied to the wide variety of topologies that are obtainable as a left homogenous G-space, including spheres, Euclidean spaces, hyperbolic spaces, uniform tilings, and vertex-transitive graphs. This work thus brings many cellular automata results to a new level of generality.

The essay "Waiting for the rapture: What can we do with computers to (hopefully) witness the emergence of life?", by Tommaso Toffoli, is about how to look for a cellular automaton rule in which life emerges. It discusses what sorts of rules to consider, and argues for reversible rules that exhibit something analogous to chemistry that can support non-brittle higher-order structures and even provide significant support for a reproductive cycle. It also discusses how to detect when some sort of life has emerged. Specifically, life can be detected by the accompanying evolutionary development of more and more life forms, identifiable as runaway emergence. Life itself can be detected, in its most general form, as any process that converts negentropy into preservation of identity. This is an opinion piece rather than a technical paper, and it brings up a large number of intriguing observations and opinions.

The 22nd edition of AUTOMATA was held at the University of Zurich, Switzerland, June 15–17, 2016. We would like to thank all those whose hard work, advice, and participation made AUTOMATA 2016 possible. We extend our gratitude to Joost Kok, Grzegorz Rozenberg and the Springer staff for their assistance in putting together this special issue. Finally, we thank the authors who submitted to this special issue and the reviewers for their time and effort.