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Cellular Automata

12th International Conference on Cellular Automata for Research and Industry, ACRI 2016
Fez, Morocco, September 5–8, 2016
Proceedings

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Preface

This volume contains a collection of original papers covering a variety of theoretical results and applications of cellular automata, that were selected for presentation at the 12th International Conference on Cellular Automata for Research and Industry - ACRI 2016, held in Fez, Morocco, September 5–8, 2016. The conference was organized by the University of Perpignan, IMAGES_Espace-Dev, the UMR 228 IRD UM UG UR "Espace pour le Développement", and the AGH University of Science and Technology of Kraków, Poland, in association with the International Systems Theory Network located in Morocco and represented by the University Moulay Ismail of Méknès. Its primary goal was to bring together researchers from a large variety of scientific fields in order to enforce international collaborations on cellular automata research as well as spread knowledge between experts in several scientific areas: pure and applied mathematics, computer science, physics, biology, and mathematical systems theory.

Cellular automata represent a very powerful approach to the study of spatio-temporal systems where complex phenomena are built up out of many simple local interactions. They are discrete, abstract computational systems that have proved useful both as general models of complexity and as simplified representations of non-linear dynamics in a wide range of scientific areas. In the last few decades, cellular automata have generated a great deal of interest both in academia and industry as they are attracting an increasing community of researchers working in different fields and dealing with theoretical aspects as well as practical applications.

The ACRI conference series was first organized in Italy, namely, ACRI 1994 in Rende, ACRI 1996 in Milan, ACRI 1998 in Trieste and followed by ACRI 2000 in Karlsruhe (Germany), ACRI 2002 in Geneva (Switzerland), ACRI 2004 in Amsterdam (The Netherlands), ACRI 2006 in Perpignan (France), ACRI 2008 in Yokohama (Japan), ACRI 2010 in Ascoli Piceno (Italy), ACRI 2012 on Santorini Island (Greece), and ACRI 2016 in Kraków (Poland).

From the start, ACRI conferences have constituted interesting biennial scientific meetings for researchers and innovation managers in academia and industry. They are dedicated to the expression and discussion of viewpoints on current and future trends, challenges, and state-of-the-art solutions to various problems in the fields of physics, biology, chemistry, communication, theoretical computer science, ecology, economy, geology, engineering, medicine, sociology, traffic control, etc.

This 12th ACRI conference aimed at widening the classical topics to include other areas related to or extending cellular automata. This offered a larger community the opportunity to discuss their work in various related fields such as: complex networks, lattice gas and lattice Boltzmann models, bio-inspired computing, agent-based models, etc.

This volume contains invited contributions and accepted papers from the main track and from the three organized workshops. We would like first to take this opportunity to express our sincere thanks to the invited speakers who kindly accepted our invitation to

give plenary lectures at ACRI 2016: Anna Lawniczak from Ghelph University, Canada; Bastien Chopard from the University of Geneva, Switzerland; Bernard De Baets from Ghent University, Belgium; and Laurent Lefèvre from INP Grenoble, ESISAR, France. We regret that Raul Rechtman, from the National Autonomous University of Mexico, had to cancel his talk.

The submission and refereeing process was supported by the EasyChair conference management system. Each submission was reviewed by at least three referees and finally 45 articles were selected for oral presentation at the conference, from a total of 60 submissions. We express our gratitude to the Program Committee members for their excellent work in making this selection. We also thank the additional external reviewers for their careful evaluation. All these efforts were the basis for the success of ACRI 2016.

The whole book is divided into two parts. The first part deals with theoretical and computational aspects and the second one with applications derived from physical, biological, environmental, and other systems. Each part is partitioned into sections containing a number of papers arranged in alphabetical order. The first part is organized according to three topics: (1) Cellular Automata Theory and Implementation (2) Cellular Automata Dynamics and Synchronization (3) Asynchronous Cellular Automata and Asynchronous Discrete Models - ACA. The second part of the volume contains three topics: (4) Modelling and Simulation with Cellular Automata (5) Crowds, Traffic, and Cellular Automata – CT&CA (6) Agent-Based Simulation and Cellular Automata – ABS&CA.

The contributions from topics (3), (5), and (6) were selected within the organized workshops ACA, CT&CA, and ABS&CA respectively. On this occasion, we would like to express our sincere thanks to the workshop chairs for their very good and valuable work, specifically Stefania Bandini, Andreas Schadschneider, and Katsuhiro Nishinari for the workshop on Traffic, Crowds, and CA; Alberto Dennunzio, Nazim Fates, and Enrico Formenti for the workshop on Asynchronous Cellular Automata and Asynchronous Discrete Models; and Andreas Pyka, Giuseppe Vizzari, and Jarosław Wąs for the workshop on Agent-Based Simulation and CA.

It should be stressed that the realization of this conference would have been impossible without the help and continuous encouragement of a number of people, especially the members of Steering Committee who strongly supported the organization of ACRI 2016 in Fez, Morocco.

Many people contributed to the success of ACRI 2016 and to the accomplishment of this volume. Our first acknowledgement is to all the scientists that submitted their work, and to all Program Committee members and reviewers for their precious collaboration.

In particular, we would like to express our gratitude to the International Organizing Committee for their excellent work, as well as to the Local Organizing Committee from Morocco for their help with local logistics. A special mention goes to Franco Bagnoli, Abdelhaq El Jai, and Yves Maurissen for their strong involvement during the organization of this conference.

Finally, the organization of ACRI 2016 was made possible thanks to the financial support of the international Systems Theory Network, the Academy of Science and Technology in Morocco, the laboratory “ESPACE pour le Développement”, UMR 228 IRD UM UG UR, the Institute of Research and Development-IRD, specifically the “Département Dynamiques Internes et de Surface des Continents” - DISCO, the University Moulay Ismal and the Science Faculty of Méknès, and other institutions and local authorities.

July 2016

Samira El Yacoubi
Jarosław Wąs
Stefania Bandini

Organization

ACRI 2016 was organized by the University of Perpignan and the UMR ESPACE-DEV associated with the Systems Theory Network, in Fez, Morocco.

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Invited Talks

Discrete Numerical Methods for Biomedical Applications

Bastien Chopard

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Abstract. Numerical modeling and simulations are becoming a central approach to better understand physiological processes involving several scales and the interaction of different physical, biological or chemical phenomena. Numerical models such as lattice Boltzmann models coupled with discrete/continuous a Lagrangian descriptions of particles offer a powerful and flexible method to describe and simulate such processes. In this presentation, we will present such an approach for the case of thrombosis in cerebral aneurysms and for the description of platelet adhesion and aggregations.

New Directions in the Classification and Identification of Cellular Automata

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Abstract. Catalyzed by the emergence of modern computers, cellular automata (CAs) became a full-fledged research domain in the eighties of the previous century. The relevant literature is of a dichotomous nature in the sense that studies either focus on the spatio-temporal dynamics that is evolved by CAs, while others merely use the CA paradigm to build a model for a given biological, natural or physical process. It goes without saying that a profound understanding of CA dynamics is a prerequisite for building realistic, identifiable CA-based models, though this is not straightforward due the fact that a CA is discrete in all its senses.

In an attempt to quantify CA behaviour in a meaningful and reproducible way, several so-called behavioural measures have been proposed during the last two decades. Here, we show how Lyapunov exponents and Boolean derivatives can be used to get a complete picture of CA dynamics in the sense that they not only make it possible to unravel the nature of a given CA, but also allow for assessing the effect of changing model design parameters on the CA behavior. Finally, we introduce the so-called Lyapunov profile of a CA, which may be understood as the counterpart of the Lyapunov spectrum of a smooth dynamical system. These profiles capture the spreading properties of a set of defects, as well as the exponential accumulation rates of defects within this set.

In a second part, we focus on 1D CAs and the space-time diagrams they evolve. We present a novel approach to the automated classification of 1D CAs according to Wolfram's classification scheme by relying on texture features grasping the diagrams' nature, followed by nearest neighbor classification. Finally, we consider the identification of 1D CAs in the context of spatially and/or temporally incomplete space-time diagrams. We formulate the identification problem as an optimization problem and present a genetic algorithm variant with individuals of variable length, corresponding to different neighborhood radii. Connections between the dynamical properties of CAs and the performance of the algorithm are explored.

Cognitive Agents Learning to Cross a Cellular Automaton Based Highway

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Abstract. Research in swarm robotics has shown that, for carrying out some tasks (e.g., target or source search, task allocation, exploration, mapping, cooperative transportation, unmanned aerial vehicle (UAV) controlling, post-disaster relief), it may be more efficient, reliable and economical to employ a large number (hundreds or thousands) of very simple robots than to employ a small number of sophisticated ones. For the development of swarms of autonomous robots, which may require them to learn how to accomplish some tasks in unknown dynamically changing environments, it is important to study the process of learning through observation and repetition.

Since individual robots in a swarm are usually architecturally minimal with limited computational capabilities, it is important that, in a swarm of robots, the implemented learning algorithms are not computationally demanding. In the microscopic modeling of swarm of robots, individual robots may be identified as cognitive agents capable of performing cognitive acts; i.e. a sequence of the following activities: (1) Perceiving information in both the environment and that which is provided by other agents (2) Reasoning about this information using existing knowledge; (3) Judging the obtained information using existing knowledge; (4) Responding to other cognitive agents or to the external environment, as it may be required; (5) Learning; i.e. changing (and hopefully augmenting) the existing knowledge if the newly acquired information allows it.

In this talk a simple example of a minimal cognitive agent that could be used as a virtual experimental platform to explore agent ability to learn will be identified and discussed. We will discuss the model of cognitive agents learning to cross a CA based highway. As the emphasis is on minimal storage and logical primitives, the formal methods of computational intelligence and established algorithms such as reinforcement learning algorithms are not used in this example. Instead, inspired by biomimicry, simple learning algorithm based on an observational social learning principle, i.e. each agent learns from observing the outcomes of the behaviours of other agents, is designed and its performance is investigated. We discuss the effects of the agents different decision-making cognitive processes, the effects of the agents knowledge base accumulation through observation and repetition and the effects of other model parameters on the agents success of learning to cross a CA based highway.

Some Control Problems for Distributed Parameter Systems

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Abstract. Modern control theory emerged in the late 50s and since then successfully addressed many theoretical and application problems related with the online observation and control of finite dimensional dynamical systems. Later on, from the late 60s, some system theorist (mainly applied mathematicians) were getting involved in the analysis and control of spatially distributed dynamical systems, also termed as distributed parameters or infinite dimensional systems, whose dynamics is usually described with sets state partial differential equations. From then, many problems were solved, especially those related to classical control problems for linear distributed parameter systems. However very challenging questions arise specifically for spatially distributed systems.

In this talk we will review briefly the traditional settings for distributed parameters control systems and some important questions related to the control and observation of these systems. Then we will present some control problems related to the spatial distribution of these systems for which cellular automata like approaches could be relevant.

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