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Preface

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1 Introduction

Cellular automata, introduced by John von Neumann as a model of self-reproducing systems, represent a very powerful approach to the study of spatio-temporal systems where complex phenomena emerge from many simple local interactions. They are discrete, abstract computational systems that have been proved to be useful as general models of complexity as well as simplified representations of non-linear dynamics in a wide range of scientific areas. Through several decades already, cellular automata have generated a great deal of interest both in academia and industry attracting an increasing community of researchers working in different fields and dealing with theoretical aspects as well as with practical applications.

This special issue of the Journal of Natural Computing consists of extended and revised versions of selected papers presented at ACRI 2018, the 13th International Conference on Cellular Automata for Research and Industry, organized by the Department of Informatics, Systems and Communication of the "Università degli Studi di Milano-Bicocca", and held in Como, Italy, September 17–21, 2018. Since its first edition in 1994, the ACRI conference is focused on challenging problems and new research directions in Cellular Automata (CA). Its primary goal is to offer to both scientists and engineers in academia and industries an opportunity to establish international collaborations on Cellular Automata, to discuss their views on current trends and challenges in theory and applications of Cellular Automata, and to present state-of-the art solutions to various problems in areas such as: biology, computer science, chemistry, ecology, economy, engineering, geology, medicine, physics, and sociology. The previous editions of ACRI were held in Rende, Italy (1994), Milan, Italy (1996), Trieste, Italy (1998), Karlsruhe, Germany (2000), Geneva, Switzerland (2002), Amsterdam, The Netherlands (2004), Perpignan, France (2006), Yokohama, Japan (2008), Ascoli Piceno, Italy (2010), Santorini, Greece (2012), Krakow, Poland (2014), and Fez, Morocco (2016). The program of the conference in Como included the main conference track, three workshops on Asynchronous Cellular Automata, Crowds and Cellular Automata and Traffic and Cellular Automata

There were 51 submissions to the conference main track, 29 of which were selected by the Program Committee to be presented at the conference, together with two invited talks: by Raul Rechtman and Andreas Deutsch. The authors of 10 of these papers were invited to submit revised and extended versions to be considered for publication in this special issue. Each paper was carefully reviewed by two expert referees and finally 5 papers have been accepted for publication. The papers cover theoretical and algorithmic aspects of cellular automata, as well as applications to modeling of different kinds of complex systems and phenomena.

The contributions are listed below, following an order from more theoretical to more applied.

2 The papers

2.1 Umeo

The first paper, by Hiroshi Umeo, studies a classical problem in the theory of Cellular Automata (CAs), the Firing Squad Synchronization Problem (FSSP), on a model of fault tolerant CAs that may possibly contain some defective cells. The paper demonstrates that, under some constraints on the distribution of defective cells, any 1D cellular array of length n with p defective cell segments can be synchronized in $2n - 2 + p$ steps and the algorithm is implemented on a 1D cellular automaton with 164 states

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and 4792 transition rules. In addition, a cellular automaton with only 6 states and 935 transition rules for the 2D FSSP is given, that can synchronize any 2D rectangular array of size $m \times n$, including $O(mn)$ isolated defective zones, exactly in $2(m+n)-4$ steps.

2.2 Bagnoli et al.

The paper by Franco Bagnoli et al. presents an approach to the problem of controlling the behaviour of Probabilistic Cellular Automata, that are extended stochastic systems widely used for modelling phenomena in many disciplines, acting only on the boundary of a target region. In particular the authors are concerned with optimal control, which is rather demanding in computational terms, and they present also a less demanding suboptimal method as well as an example of optimal control with avoidance.

2.3 Daly et al.

Daly et al. propose a lattice-free approach for individual-based modelling of biological systems, focusing in particular on mechanisms that permit the coexistence of individuals of multiple types or species, even when these are engaged in competition. The proposed approach retrieves the same qualitative dynamics as the lattice-based approach. However, by facilitating a higher spatial heterogeneity and allowing for small spatial refuges to form and persist, the maintenance of coexistence is promoted in correspondence with experimental results. A directed movement mechanism allowing individuals of different species to pursue or flee from each other is also implemented. Simulations show that the effects on coexistence depend on the level of aggregation in the community: a high level of aggregation is advantageous for maintaining coexistence, whereas a low level of aggregation is disadvantageous. This agrees with experimental results, where pursuing and escaping behaviour has been observed to be advantageous only in certain circumstances.

2.4 Crociani et al.

The paper by Crociani et al. presents an algorithm to track the motion of a salient object using Cellular Automata. The paper takes inspiration from recent research on insect sensory motor system and it investigates the application of non conventional computer vision approaches to evaluate their effectiveness in fulfilling this task. The proposed system employs the Sobel operator to individual frames, performing further elaborations through a CA, with the aim of detecting and characterizing moving entities within the field of view to support collision avoidance from the perspective of the viewer.

2.5 Kirik et al.

Finally, the paper by Kirik et al. proposes an application of CAs to the simulation of pedestrian dynamics, in particular to the problem of correct simulation of movement of the people on the paths with angles. The shortest path strategy does not work in this case and gives unrealistic trajectories and increased evacuation time. The discrete-continuous pedestrian dynamics model is discussed, where angles from 90 to 180 degrees are considered, with “L”-, “Z”- and “U”-shaped geometries.

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