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# EDITORIAL

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This special journal issue of *Advances in Complex Systems* presents a collection of papers describing current research delivered by recognized researchers actively working in various corners of the field of modeling of complex systems by cellular automata and related methods. All included papers are self-contained and present the latest developments in the areas where the authors work. Hence, all papers can be read independently, but it is strongly recommended to study the issue as a whole to get a general overview of the various methods and techniques from the field. The main aim of this special issue is to provide researchers from neighboring fields with sufficient information and vital examples of how to design models in complex systems. The whole issue is organized in such a way that common features occurring repeatedly in most models of complex systems are highlighted.

*Keywords*: Complex systems; cellular automata; modeling.

During the development of various models of natural phenomena observed within diverse fields expressing complex behavior — where those models were developed by researchers having completely different backgrounds — a set of unifying features repeatedly occurring within those models of complex systems has emerged. From a certain perspective, one could say that those common features represent an alphabet for the design of new models of complex phenomena in other fields as well — and not necessarily using cellular automata as the computational method. This observation automatically leads us to the main purpose of this special issue: to show the “Lego blocks” of the game so that everybody can apply them in their own field and build new “buildings.”

Eight researchers each present ongoing research work in their fields of interest. Each paper provides self-contained information and can be studied independently of the others, but it is recommended to spend some extra time studying the various

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approaches to handling complexity within all of the papers. This will provide one with a deeper understanding of complexity in general and help to build a sense of complex systems and their modeling overall.

We would like to direct the reader's attention to those common features occurring repeatedly in most of the models of complex systems presented here. In order to recognize those common features easily, an explicit list of them is provided in this editorial. It is worth emphasizing one important fact: those who study all the papers in this issue — and not only those close to their own field — will benefit much more. A well-known principle observed within complex systems work says that the whole is more than a mere sum of the parts. The very same principle works for this special issue. Those who spend their time reading the whole issue will get not only an overview of possible applications of complexity, but also a better sense of complexity.

Special attention should be given to the following "Lego blocks": self-organization (1), emergence (1, 2, 7), topology of CAs (1, 4), swarm intelligence (1, 8), predictability and genetic programming (2, 3). It is worth thinking about the topology — mesh, meshless, or networked — of CAs playing the key role in problem solutions. The way of viewing the problem is different for each application. There are computational problem solving methods (1–4, 8), theoretical predictions (5, 6), and typical computational models (6, 7). Usually, there are combinations of several of the above mentioned "blocks" in each paper. This means that one has the freedom to use the best available tools in order to achieve the goal; there are no limits to the reader's creativity. But what is necessary to stress is the fact that nature — especially when working with biological processes — shows unbeatable creativity. Hence, careful studies of nature and its ways of problem solving might serve as our best teacher.

(1) The paper by A. Rodrigues, A. Grushin and J. A. Reggia presents research in the field of swarm intelligence with a special focus on self-organization and emergence. Solutions are achieved through local component interactions without any central control. It is extremely difficult to design swarms having the desired control functions and this work proposes new layered, hierarchical controlling of swarm components that facilitates a greater flexibility in design.
(2) A. Hauptman and M. Sipper demonstrate how the emergence of chess endgame complex strategies using the genetic programming (GP) technique works. GP is often used in complex simulations — and, hence, in CAs as well — to find the best rule or strategy. This paper teaches us how to work with genetic programming and what people might expect from it.
(3) Z. Pan, J. A. Reggia and D. Gao present an extremely efficient technique for finding CA rules performing self-replication of structures based on a unique modification of genetic programming using different trees for data structures and for rule encoding. This leads to an extreme speed-up of search for new rules performing self-replication of structures, and makes it possible to generate

families of replicators and systematically study their properties for the first time.

(4) C. Darabos, M. Giacombini and M. Tomassini study performance and robustness of collective tasks of networked CAs tested on both density classification and synchronization tasks. They demonstrate the crucial influence of topology — such as random graphs, Small Worlds, and/or scale-free graphs — on the solution of problems.

(5) L. Gonzales presents a theoretical, unified approach allowing extremely efficient comparison of occurrence probabilities within complex stochastic Boolean systems. The theoretical results enable rapid determination of all the binary strings with probabilities less than or equal to (or greater than or equal to) the probability of any fixed binary string. The approach is based on use of the intrinsic ordering graph, which enables ordering those probabilities without the necessity of evaluating them on what is, in general, a computationally intractable task.

(6) D. Hiebeler uses statistical methods to make predictions of CA behavior for stochastic rules updated asynchronously. He studies voter models computationally and stochastically using a pair approximation moment-closure method leading to a system of differential equations predicting the behavior of the system.

(7) J. L. Guisado, F. Jiménez–Morales and F. Fernández de Vega present a CA simulation of laser behavior, and its parallel implementation for computer clusters. The global physical laser response emerges from local interactions of photons operating at the lowest model level where photons are emitted by stimulated emission of excited electrons. Electrons are excited by pumping energy from outside. Modeled collective behavior of photon populations creates different laser modes: steady-state, oscillatory, or possibly chaotic, which are observed experimentally.

(8) J. Kennedy presents the particle swarm algorithm, which is a problem-solving method based on social-psychological principles. The particle swarm is used for optimization of problems through the interactions of topologically connected particles with one another and mutual sharing of knowledge about a problem space. The population tends to converge towards robust problem solutions as individuals discover and share better problem solutions.

We conclude with the following about the preparation of this issue. This issue is the result of intensive discussions between the editor and the contributors. The authors present their work in a way which is tractable for non-specialists.

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