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David P. Rosin

# Dynamics of Complex Autonomous Boolean Networks

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# Dynamics Of Complex Autonomous Boolean Networks

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**Katherine Toh**



## **Dynamics Of Complex Autonomous Boolean Networks Springer Theses:**

**Dynamics of Complex Autonomous Boolean Networks** David P. Rosin, 2014-12-31 This thesis focuses on the dynamics of autonomous Boolean networks on the basis of Boolean logic functions in continuous time without external clocking These networks are realized with integrated circuits on an electronic chip as a field programmable gate array FPGA with roughly 100 000 logic gates offering an extremely flexible model system It allows fast and cheap design cycles and large networks with arbitrary topologies and coupling delays The author presents pioneering results on theoretical modeling experimental realization and selected applications In this regard three classes of novel dynamic behavior are investigated i Chaotic Boolean networks are proposed as high speed physical random number generators with high bit rates ii Networks of periodic Boolean oscillators are home to long living transient chimera states i e novel patterns of coexisting domains of spatially coherent synchronized and incoherent desynchronized dynamics iii Excitable networks exhibit cluster synchronization and can be used as fast artificial Boolean neurons whose spiking patterns can be controlled This work presents the first experimental platform for large complex networks which will facilitate exciting future developments

*Discrete-Time and Discrete-Space Dynamical Systems* Kuize Zhang, Lijun Zhang, Lihua Xie, 2019-08-06 Discrete Time and Discrete Space Dynamical Systems provides a systematic characterization of the similarities and differences of several types of discrete time and discrete space dynamical systems including Boolean control networks nondeterministic finite transition systems finite automata labelled Petri nets and cellular automata The book s perspective is primarily based on topological properties though it also employs semitensor product and graph theoretic methods where appropriate It presents a series of fundamental results invertibility observability detectability reversibility etc with applications to systems biology Academic researchers with backgrounds in applied mathematics engineering or computer science and practising engineers working with discrete time and discrete space systems will find this book a helpful source of new understanding for this increasingly important class of systems The basic results to be found within are of fundamental importance for further study of related problems such as automated synthesis and safety control in cyber physical systems using formal methods Performing Math Andrew Fiss, 2020-11-13 Performing Math tells the history of expectations for math communication and the conversations about math hatred and math anxiety that occurred in response Focusing on nineteenth century American colleges this book analyzes foundational tools and techniques of math communication the textbooks that supported reading aloud the burnings that mimicked pedagogical speech the blackboards that accompanied oral presentations the plays that proclaimed performers identities as math students and the written tests that redefined student performance Math communication and math anxiety went hand in hand as new rules for oral communication at the blackboard inspired student revolt and as frameworks for testing student performance inspired performance anxiety With unusual primary sources from over a dozen educational archives Performing Math argues for a new performance oriented history of American math

education one that can explain contemporary math attitudes and provide a way forward to reframing the problem of math anxiety

**Reservoir Computing** Kohei Nakajima, Ingo Fischer, 2021-08-05 This book is the first comprehensive book about reservoir computing RC RC is a powerful and broadly applicable computational framework based on recurrent neural networks Its advantages lie in small training data set requirements fast training inherent memory and high flexibility for various hardware implementations It originated from computational neuroscience and machine learning but has in recent years spread dramatically and has been introduced into a wide variety of fields including complex systems science physics material science biological science quantum machine learning optical communication systems and robotics Reviewing the current state of the art and providing a concise guide to the field this book introduces readers to its basic concepts theory techniques physical implementations and applications The book is sub structured into two major parts theory and physical implementations Both parts consist of a compilation of chapters authored by leading experts in their respective fields The first part is devoted to theoretical developments of RC extending the framework from the conventional recurrent neural network context to a more general dynamical systems context With this broadened perspective RC is not restricted to the area of machine learning but is being connected to a much wider class of systems The second part of the book focuses on the utilization of physical dynamical systems as reservoirs a framework referred to as physical reservoir computing A variety of physical systems and substrates have already been suggested and used for the implementation of reservoir computing Among these physical systems which cover a wide range of spatial and temporal scales are mechanical and optical systems nanomaterials spintronics and quantum many body systems This book offers a valuable resource for researchers Ph D students and experts alike and practitioners working in the field of machine learning artificial intelligence robotics neuromorphic computing complex systems and physics

*Boolean Systems* Serban E. Vlad, 2023-01-06 The Boolean functions may be iterated either asynchronously when their coordinates are computed independently of each other or synchronously when their coordinates are computed at the same time In *Boolean Systems Topics in Asynchronicity* a book addressed to mathematicians and computer scientists interested in Boolean systems and their use in modelling author Serban E Vlad presents a consistent and original mathematical theory of the discrete time Boolean asynchronous systems The purpose of the book is to set forth the concepts of such a theory resulting from the synchronous Boolean system theory and mostly from the synchronous real system theory by analogy and to indicate the way in which known synchronous deterministic concepts generate new asynchronous nondeterministic concepts The reader will be introduced to the dependence on the initial conditions periodicity path connectedness topological transitivity and chaos A property of major importance is invariance which is present in five versions In relation to it the reader will study the maximal invariant subsets the minimal invariant supersets the minimal invariant subsets connectedness separation the basins of attraction and attractors The stability of the systems and their time reversal symmetry end the topics that refer to the systems without input

The rest of the book is concerned with input systems The most consistent chapters of this part of the book refer to the fundamental operating mode and to the combinational systems systems without feedback The chapter Wires Gates and Flip Flops presents a variety of applications The first appendix addresses the issue of continuous time and the second one sketches the important theory of Daizhan Cheng which is put in relation to asynchronicity The third appendix is a bridge between asynchronicity and the symbolic dynamics of Douglas Lind and Brian Marcus Presents a consistent and original theory of the discrete time Boolean asynchronous systems which are useful for mathematicians and computer scientists interested in Boolean Networks dynamical systems and modeling Studies the flows and equations of evolution nullclines dependence on initial conditions periodicity path connectedness topological transitivity chaos nonwandering points invariance connectedness and separation as well as the basins of attraction attractors stability and time reversal symmetry Explains the fundamental operating mode of the input systems and the combinational systems systems without feedback Includes a chapter of applications of the Boolean systems and their modeling techniques Makes use of the unbounded delay model of computation of the Boolean functions

*Computational Methods for Understanding Complexity: The Use of Formal Methods in Biology* David A. Rosenblueth, 2016-11-21 The complexity of living organisms surpasses our unaided abilities of analysis Hence computational and mathematical methods are necessary for increasing our understanding of biological systems At the same time there has been a phenomenal recent progress allowing the application of novel formal methods to new domains This progress has spurred a conspicuous optimism in computational biology This optimism in turn has promoted a rapid increase in collaboration between specialists of biology with specialists of computer science Through sheer complexity however many important biological problems are at present intractable and it is not clear whether we will ever be able to solve such problems We are in the process of learning what kind of model and what kind of analysis and synthesis techniques to use for a particular problem Some existing formalisms have been readily used in biological problems others have been adapted to biological needs and still others have been especially developed for biological systems This Research Topic has examples of cases 1 employing existing methods 2 adapting methods to biology and 3 developing new methods We can also see discrete and Boolean models and the use of both simulators and model checkers Synthesis is exemplified by manual and by machine learning methods We hope that the articles collected in this Research Topic will stimulate new research

*Art and Complexity* J. Casti, A. Karlqvist, 2003-02-19 This title is the result of a one week workshop sponsored by the Swedish research agency FRN on the interface between complexity and art Among others it includes discussions on whether good art is complex art how artists see the term complex and what poets try to convey in word about complex behavior in nature

**Advances in Artificial Life** ,2005      **Computer & Control Abstracts** ,1996      **Electrical & Electronics Abstracts** ,1997      *Mathematical Reviews* ,1993      *Dynamics of Boolean Networks* Florian Greil, 2009

**Analysis and Control of Boolean Networks** Daizhan Cheng, Hongsheng Qi, Zhiqiang Li, 2010-11-23 Analysis and

Control of Boolean Networks presents a systematic new approach to the investigation of Boolean control networks. The fundamental tool in this approach is a novel matrix product called the semi tensor product STP. Using the STP a logical function can be expressed as a conventional discrete time linear system. In the light of this linear expression certain major issues concerning Boolean network topology, fixed points, cycles, transient times and basins of attractors can be easily revealed by a set of formulae. This framework renders the state space approach to dynamic control systems applicable to Boolean control networks. The bilinear systemic representation of a Boolean control network makes it possible to investigate basic control problems including controllability, observability, stabilization, disturbance decoupling etc.

**Dynamics and Evolution of Random Boolean Networks** Tamara Mihaljev, 2008 *A Study of Visualization Approaches and Fractal Dimension Classification of Certain Boolean Networks* Gretchen Boxdorfer, 2021 Boolean Networks provide a simple yet effective approach to the analysis of many complex dynamical systems. And yet this approach is not currently utilized as widely as possible in various fields. Whether due to lack of knowledge about Boolean Networks or lack of proper modeling software, researchers outside of mathematics may not be able to use this tool that could potentially help with solutions in their own field of knowledge. The main goal of this thesis is to explain the basics of Cellular Automata and Boolean Networks in a way that requires little mathematical background, making the concepts of these topics accessible to many. Recognizing that visual aides and key to deeper understanding of these concepts we provide a brief overview of some of the currently available visualization software as well as explore some potential additions and propose some possible modifications to these visualization approaches. Furthermore we outline the basics of fractals and fractal dimensions and explore how Boolean Networks may be thought of within this framework. We detail the calculation of fractal dimensions of certain Boolean Networks and examine the correlation between fractal dimension and some aspects of the network dynamics. Specifically we explore the relationship between fractal dimensions and Wolfram's 4 classes of Elementary Cellular Automata behavior. Our findings match and complement previous work on the topic and are an indication that fractal dimensions are a meaningful measure of network dynamics, the implication of this being that it may be possible to quantify complex networks using simple measures. The goal is to improve communication surrounding the discourse of Boolean Networks and their utility both among non mathematicians and between mathematicians and others. Some applications for Boolean Networks are detailed including suggested modeling software and use of new findings for these fields.

**Probabilistic Boolean Networks** Ilya Shmulevich, Edward R. Dougherty, 2010-01-21 The first comprehensive treatment of probabilistic Boolean networks unifying different strands of current research and addressing emerging issues.

**Dynamics of Random Boolean Networks Governed by a Generalization of Rule 22 of Elementary Cellular Automata** Gary L. Beck, 2006 [Dynamics and Classification of Heterogeneous Boolean Networks with Two Totalistic Rules](#) Katherine Toh, 2019 Boolean Networks are being used to analyze models in biology, economics, social sciences and many other areas. These models simplify reality by

assuming that each element in the network can take on only two possible values such as ON and OFF The node evolution is governed by its interaction with other nodes in its neighborhood which is described mathematically by a Boolean function or rule For simplicity reasons many models assume that all nodes follow the same Boolean rule However real networks often use more than one Boolean rule and therefore are heterogeneous networks Heterogeneous networks have not yet been studied in depth only specific cases have been looked at This research looks at 64 generalized totalistic rules and analyzes the behavior of heterogeneous Boolean networks in which a certain proportion of the nodes in the network update based on one totalistic rule and the rest of the nodes updated based on a second totalistic rule Totalistic rules consider only how many nodes in a neighborhood are ON or OFF and not the placement of those nodes within the neighborhood Bifurcation diagrams are used to visualize the behavior of these networks using mathematical tools such as mean field approximations The findings show that it can be predicted which of these networks will have a certain stable long term evolution and which will not The findings of this analysis provide insights into the dynamics of these networks letting us predict the likely behavior of some real networks that can be modeled this way

**Autonomous Dynamic Reconfiguration in Multi-Agent Systems** Markus Hannebauer, 2014-03-12 High communication efforts and poor problem solving results due to restricted overview are two central issues in collaborative problem solving This work addresses these issues by introducing the processes of agent melting and agent splitting that enable individual problem solving agents to continually and autonomously reconfigure and adapt themselves to the particular problem to be solved The author provides a sound theoretical foundation of collaborative problem solving itself and introduces various new design concepts and techniques to improve its quality and efficiency such as the multi phase agreement finding protocol for external problem solving the composable belief desire intention agent architecture and the distribution aware constraint specification architecture for internal problem solving The practical relevance and applicability of the concepts and techniques provided are demonstrated by using medical appointment scheduling as a case study

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