

A Brief History of Cellular Automata

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Cellular automata are simple models of computation which exhibit fascinatingly complex behavior. They have captured the attention of several generations of researchers, leading to an extensive body of work. Here we trace a history of cellular automata from their beginnings with von Neumann to the present day. The emphasis is mainly on topics closer to computer science and mathematics rather than physics, biology or other applications. The work should be of interest to both new entrants into the field as well as researchers working on particular aspects of cellular automata.

Categories and Subject Descriptors: F.1.1 [**Computation by abstract devices**]: Models of Computation; K.2 [**Computing Milieux**]: History of Computing

General Terms: Theory

Additional Key Words and Phrases: Cellular automata, cellular space, homogeneous structures, systolic arrays, tessellation automata

1. INTRODUCTION

Cellular automata were originally proposed by John von Neumann as formal models of self-reproducing organisms. The structure studied was mostly on one- and two-dimensional infinite grids, though higher dimensions were also considered. Computation universality and other computation-theoretic questions were considered important. See Burks [1970] for a collection of essays on important problems on cellular automata during this period. Later, physicists and biologists began to study cellular automata for the purpose of modeling in their respective domains. In the present era, cellular automata are being studied from many widely different angles, and the relationship of these

structures to existing problems are being constantly sought and discovered.

Next, we would like to clarify the purpose of this survey as compared to other related work. There is an excellent survey of CA by A.R. Smith III [Smith III 1976]. However, it is more than twenty years old. There are also two other surveys [Vollmar 1977; Aladyev 1974] which are quite old. Currently, it is perhaps quite impossible to survey the whole of CA research. There is a good survey on computation theoretic aspects of CA by Culik II et al. [1990]. There are also books on CA [Garzon 1995; Chaudhuri et al. 1997; Wolfram 1986] which cover specific topics of CA research. In this survey we try to cover the major questions asked about CA as opposed to the use of CA in

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CONTENTS

1. Introduction
2. Classical
 - 2.1 Beginnings
 - 2.2 Variants of Cellular Automata
 - 2.3 Biological Connection
 - 2.4 Fault-Tolerant Computing
 - 2.5 Language and Pattern Recognition
 - 2.6 Invertibility, Surjectivity and Garden of Eden
3. CA Games
 - 3.1 Firing Squad Problem
 - 3.2 Game of Life
 - 3.3 $\sigma(\sigma^+)$ -Game
4. Modern Research
 - 4.1 Empirical Study
 - 4.2 Classification of CA
 - 4.3 Limit Sets and Fractal Properties
 - 4.4 Dynamics of CA
 - 4.5 Computational Complexity
 - 4.6 Finite CA and its Applications
5. Conclusion

modeling of natural phenomena. We focus on topics which are closer to computer science and mathematics rather than physics or other applications. We believe that such a survey has not been previously attempted, and will prove to be useful to both fresh entrants into this field and to experts working on particular aspects of CA. However, we would like to point out that any review of CA is bound to be incomplete. We have been motivated in choosing topics based on our knowledge and interest. The aforementioned surveys by A.R. Smith III and Culik II et al. have helped us greatly in preparing this work. The bibliography associated with this article is not comprehensive, though we believe that there are sufficient links to almost all aspects of CA. Additional bibliographies can be found in the books mentioned above. An online bibliography on CA is also available at

<http://alife.santafe.edu/alife/topics/cas/ca-faq/ca-faq.bib>

At this point we would like to make a few remarks on the problem of trying to write a history of any scientific topic. A chronological ordering of ideas is difficult to adhere to, since an idea may be introduced at some point in time, is pursued vigorously for a while, and may

disappear from the literature for quite some time, only to be taken up again at a later point. There is almost no final statement on any idea. A thematic grouping of topics is possible and is mostly used. However, in such an approach one might have to include work from different decades under the same group, and this presents its own problems. The scientific temper varies across time, which leads to a distinct difference in the approach to a problem. So even though the topic may be the same, the method and questions may vary considerably. In this paper we try to take a chronological view of work done in the area of cellular automata over the past forty years, and we order the topics based upon their first appearance in the literature. We have divided the work into three broad categories.

—*Classical*: The themes which were more or less influenced by the initial work of von Neumann.

—*Modern*: The themes which were influenced by the work of Wolfram on one hand, and by developments of other branches of computer science on the other hand. In this part we restrict ourselves to topics closer to computer science than physics.

—*Games*: Apart from the Game of Life and σ -game we have also included the Firing Squad problem in this section. The problem formulation of the Firing Squad problem has more of the flavor of a game than a synchronization problem. Also, this problem somehow does not fit into any of the above two classes.

In the rest of the article we abbreviate both cellular automata and cellular automaton by CA. We consider different varieties of CA, but the exact structure meant will always be clear from the context.