

Cellular Automata: Simulations Using Matlab

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Abstract—This paper presents a series of implementations of cellular automata rules using the Matlab programming environment. A cellular automaton is a decentralized computing model providing an excellent platform for performing complex computations with the help of only local information. Matlab is a numerical interactive computing environment and a high-level language with users coming from various backgrounds of engineering, science, and economics that enables performing computationally intensive tasks faster than with traditional programming languages (such as C, C++, and Fortran). Our objective has been to investigate and exploit the potential of Matlab, which is simple mathematical programming environment that does not require specific programming skills, regarding the understanding and the efficient simulation of complex patterns, arising in nature and across several scientific fields, captured by simple cellular automata structures. We have implemented several cellular automata rules from the recent literature; herein we present indicative cases of practical interest: the forest fire probabilistic rule, the sand pile rule, the ant rule, the traffic jam rule as well as the well-known "Game of Life". Our work indicates that Matlab is indeed an appropriate environment for developing simulations for cellular automata models.

Keywords—cellular automata; simulation; Matlab.

I. CELLULAR AUTOMATA

A cellular automaton (CA) is an idealization of a physical system in which space and time are discrete and the physical quantities take only a finite set of values. Informally, a cellular automaton is a lattice of cells, each of which may be in a predetermined number of discrete states (a formal definition can be found in [7]). A neighborhood relation is defined over this lattice, indicating for each cell which cells are considered to be its neighbors during state updates. Time is also discrete; in each time step, every cell updates its state using a transition rule that takes as input the states of all cells in its neighborhood (which usually includes the cell itself). All cells in the cellular automaton are synchronously updated. At time $t = 0$ the initial state of the cellular automaton must be defined; then repeated synchronous application of the transition function to all cells in the lattice will lead to the deterministic evolution of the cellular automaton over time. Many variations of this basic model exist; CA can be of arbitrary dimension, although one-dimensional and two-dimensional CA have received special attention in the literature. CA can be infinite or

finite. Finite CA can have periodic boundaries (e.g. the opposite ends of a one-dimensional finite CA are joined together so the whole forms a ring). Updates can be synchronous or asynchronous. Transition rules can be deterministic or stochastic. Many other variations exist; those mentioned above are some of the most typical ones.

The concept of cellular automata was initiated in the early 1950's by John Von Neumann and Stan Ulam [18]. Von Neumann was interested in their use for modelling self-reproduction and showed that a CA can be universal. He devised a CA, each cell of which has a state space of 29 states, and showed that it can execute any computable operation. However, Von Neumann rules, due to their complexity, were never implemented on a computer. Von Neumann's research raised a dichotomy in CA research. On one hand, it was proven that a decentralized machine can be designed to simulate any arbitrary function. On the other hand, this machine (CA) can become as complex as the function it is intended to simulate.

Cellular automata have received extensive academic study into their fundamental characteristics and capabilities and have been applied successfully to the modelling of natural phenomena and complex systems [1], [3], [4], [13], [17], [24], [23]. Based on the theoretical concept of universality, researchers have tried to develop simpler and more practical architectures of CA that can be used to model widely divergent application areas. In the 1970, the mathematician John Conway proposed the (now famous) Game of Life [10], which received widespread interest among researchers. Since the beginning of the 80's, Stephen Wolfram has studied in much detail a family of simple one-dimensional cellular automata rules (known as Wolfram rules [24]) and has showed that even these simplest rules are capable of exhibiting complex behavior. Other applications include, but are not limited to, theoretical biology [2], game theory [19], and non-equilibrium thermodynamics [15].

The rest of the paper is structured as follows: Section II includes a brief description of Matlab as well as main reasons that motivated us for using it in our simulations. Simulations are presented in Section III. Section IV includes conclusion and plans for future work on cellular automata simulations using Matlab.

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