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REALIZATION OF A TRI-VALUED PROGRAMMABLE CELLULAR AUTOMATA WITH TERNARY OPTICAL COMPUTER

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Abstract. A TPCA (tri-valued programmable cellular automata) is proposed in this paper. Implemented based on TOC (Ternary Optical Computer) the TPCA has three advantages over other automata, that is the high programmability, the parallelism of computing and the tri-valued logic implementation. The programmability means that the transformation rules of each cell in CA can be modified at will and be any functions both linear and nonlinear. The parallelism comes from the advantage of optical computing and it can guarantee that CA even with very large-scale can be constructed in parallel and efficient. And the tri-valued implementation would make the CA be more flexible and complex than the counterparts in binary. Combining the characteristics of TOC, the TPCA is discussed in detail. Studied results show that the time complexity has nothing to do with the number of the cells in CA and it is just related to the complexity of the transformation functions. This means that it would be easy to construct more powerful and complicated CA and be widely used in many other fields.

Key words. Cellular Automata, Ternary Optical Computer, Parallel Computing, and Tri-valued Logic.

1. Introduction

Cellular automaton (CA) was put forward by J.von Neumann and Stanislaw Ulam in Mid-20th century, it is a discrete model that consists of a regular grid of cells, each in one of a finite number of states. Since the setup of the CA theory, much attention has been focused on it. Because of the diversity of its statuses and the simplicity of the forms of the transformation rules, CA has been widely studied and applied in considerable fields with varieties of purposes, say in parallel computing model, traffic simulation model, encryption system [1], Built-In Self-Test [2] and so on. Though all these researches and applications are interesting, there is a limitation in common, that is the transformation rules applied to the cells of CA are invariable in the whole transformation process. This would make that the application of CA just suit to be used in the relatively limited and simple areas.

In order to solve more complicated problems, it need to make the cells of CA change following with different rules and the transformation rules can be arbitrary. For example, when construct an adaptive feedback control system, it is needed to modify the transformation rule based on the result of the pre-step. The other problem is the computational speed. Because of the characteristics of CA, it is possible to compute large-scale CA in parallel.

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In 2000, Prof. Yi Jin from Shanghai University proposed the framework of TOC [3][5][6]. Since then, much research has done and many breakthroughs of TOC have been obtained which include the architecture of TOC, the theory of encoding and decoding, Principles of MSD adder in TOC[4] and decrease-radix design principle[10] and so on. Based on all these researches, especially the tri-valued logic optical computing system [7][8][9], a method that can be used to design highly controllable tri-valued cellular automata (TPCA) is put forward. Combined with the characteristics of CA and optical computing of TOC, the TPCA proposed not only can be used to do computation in parallel, but also can be reconfigured and programmable according to the users' requirements.

The paper is organized as follows: After a brief introduction of TPCA, the following section gives a brief review of the basic concepts the TOC computing platform and the theory of CA. Section 3 discusses the implementation of the computing parallelism and programmability of TPCA in detail. Section 4 is the experiment and results and section 5 is the analysis and conclusion remark.

2. Basic Concepts

2.1. Ternary Optical Computer. TOC is an opto-electronic hybrid parallel computer. Built based on the ternary number system, the TOC expresses the processed information with three states of light, that is the dark state, the vertical polarized state and horizontal polarized state. In the implementation, liquid crystal devices (LCD) together with polarizers are used as the optical encoder, processor and decoder. Where the encoder is mainly used to encode the natural light into the three operable states available in the TOC. The processor is mainly used to process the user's request and output the results. And the decoder is to try to decode the computation results from the unreadable format into more easily understandable format. They all belong to the optical operation components. Besides these components, the control of the rotation of polarizers, the synchronization of different components and the storage to the processed results are all implemented on an embedded system, and human machine interface, the monitor and display of the results are implemented on a host.

In 2008, Dr. Junyong Yan et al. discovered the decrease-radix design principle [10]. In this principle, they put forward a normative method that can be use to reconstruct any kinds of calculate unit in TOC with the 18 kinds of basic units. This is a very important discovery. Following the principle together with the optical computing characteristics of TOC, a new complex CA that can be used to do the computation in parallel is put forward which means it will be very promising in the complex applications of CAs.

2.2. Cellular Automata. In the 1950s, John Von Neumann [11][12] firstly introduced some kinds of CAs which are discrete dynamical systems with simple construction and complex and variable behaviors. In order to study the CA by mathematical tools, many researchers have used the symbol vector (L_d, S, N, f) to describe CA. Where L expresses the space of cells and d is the number of the dimension of the space. All of the possible states of one cell consist of the set of S. N is an arrangement of the neighboring cells, such as the $N = (s_{p_1}, s_{p_2}, \cdots, s_{p_{|N|}})$, where the p is the index of neighboring cell,s_{p_1} means the state of the neighboring cell which is indexed by p_1,and the $|N|$ is the number of elements in N. The symbol f is the transformation function which determines the next state of some