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ROLE OF CELLULAR AUTOMATA IN BUDDING FIELDS OF COMPUTER SCIENCE

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ABSTRACT

The cellular automaton is a discrete dynamical system composed of very simple, uniformly interconnected cells. The cellular automata play important role in neural network, data mining, compression, cryptography, random number generation, parallel computers, data clustering, visualization and rule discovery in data classification, modeling and simulation. In this paper, we will discuss the current use of cellular automata in emerging fields of computer science.

Keywords: Cellular automata, learning automata, uniform learning automata, regular and irregular learning automata.

I. Cellular automata

Cellular Automata is a mathematic model to the system in which number of simple components cooperates to produce complex patterns. In fact, a cellular automaton is discrete dynamical system and communication between its cells is limited which is based on local interaction. CA composes of lattice of cells and set of rules [2][3]. Each square is called cell with each cell having two states that are black and white colors. The rules of cellular automaton determine how the states changes [2].

The notion of cellular automata originated in the 1940s with the work of Stanislaw Ulam and John von Neumann on self-reproducing machines. The study of cellular automata has continued in more recent times with such scientists as Stephen Wolfram, John Holland, and Christopher Langton, and is central to the emerging science of complexity [4, 5]. Two remarkable features of cellular automata are the surprisingly complex patterns that they can exhibit based upon simple rules, and their ability to model many natural biological and physical systems [6].

II. Cellular automata characters

Cellular automata, as a reinforcement learning has the following characters [2]:

1. Cellular automata is discrete space.
2. Time goes discrete.
3. Each cells consists of a number of limited state. All the cells are in the same position.
5. All the cells are updated at the same time.
6. The rule in each site depends on the value of the site around its neighbors.

7. The rule for new value of each site just depends on value of limited number of previous states.

III. Cellular learning automata

Cellular Automata is only unable to solve most of the problems collectively [2][7].

Regarding the weakness of Cellular Automata with combination of two recent models (Learning Automata and Cellular Automata), a new model called Cellular Learning Automata was created [2]. It's a powerful mathematical model for many decentralized problems and phenomena. The main idea of CLA, which is a subclass of stochastic CA, is using Learning Automata to adjust the state transition probability of stochastic CA. A CLA is a CA in which Learning Automaton one or more than one is assigned to every cell [2].

There is a rule that CLA operates under it. Those rules and the actions that are selected by the neighbors' LA determine reinforcement signal to LA resided in each cell. According to those rules and the previous states of neighbors, new transaction of dataset will give reward or penalty. Giving penalty or reward will update CLA structure [2].

Uniform learning automata

A Cellular Learning Automata is called uniform if all cells are the same neighbor function, rule, Learning Automat, otherwise Learning Automata called non-uniform [7][2].

Regular learning automata

A Cellular Learning Automata is called regular if all cells (active cell and its neighbors) have the regular order. Regular order means, a one-dimensional or two-dimensional orders that is used by Von Neumann and Moore. Regular Learning Automata has used different applications so far. But some applications need model with no limitation of a regular lattice such as subsequence mining. Because in such network, nodes are completely point random and could not be considered a regular structure for that. This type of Automata is called irregular cellular learning automata [2].

Irregular learning automata

Irregular cellular learning automata are a kind of CLA with only irregularity of the main different. ICLA doesn't have a restriction of lattice cells. ICLA is an undirected graph in which each vertex shows a cell which is resided with learning automata [2].

IV. Role of Cellular automata in data mining

Cellular automata play important role in data mining. Cellular learning automata is used for mining customer behavior in shopping activity, data clustering, visualization and rule discovery in data classification,

Andrew Vande Moere, Justin J. Clayden, and Andy Dong in his paper titled data clustering and visulazation using cellular automata ants presented two new features of the cellular ant method: color (data clustering) and shape size negotiation. It combines ant-based data mining algorithms with cellular automata insights, or data scaling with data clustering to derive an approach that is capable of representing multidimensional datasets. The resulting diagrams are visually similar to those of ant-based data mining clustering approaches [8].

M. R. Aghaebrahimi, S. H. Zahiri, and M. Amiri proposed new data miner based on the learning automata for rule discovery in data classification task in his paper. The proposed algorithm, named LA-miner, searches the solution space (rule space in our case), to find the optimum rule sets in order to minimize the number of miss-classified data points. The performance of the LA-miner is tested on three well known benchmarks and compared with Ant-miner and CNZ [9]. The comparative results show that the recognition score of LA-miner is comparable (sometimes better than) Ant-miner and CNZ for both training and testing phases. Furthermore, the average numbers of rules obtained by LA-miner is less than the other two data miners [9].

V. Role of cellular Automata in neural network

The concept of cellular automata arose in the very beginnings of the digital computation era, around the 1920s and 1930s, when two mathematicians - Alan Turing and John von Neumann - pursued the idea that machines would be self-reproducible, i.e. they would be able to generate infinity of diverse patterns that could be indefinitely perpetuated [11]. Cellular automata and neural networks empirical models designed to simulate and predict urban land use changes are generally based on the utilization of statistical techniques to reckon the land use change probabilities. In contrast to these methods, artificial neural networks arise as an alternative to assess such probabilities by means of non-parametric approaches. This work introduces a simulation experiment on urban land use change in which a supervised back propagation neural network has been employed in the parameterization of the simulation model. The thereof estimated spatial land use transition probabilities feed a cellular automaton (CA) simulation model, based on stochastic transition rules. The model has been tested in a medium-sized town in the Midwest of São Paulo State, *Piracicaba*. A series of simulation outputs for the case study town in the period 1985-1999 were produced and statistical validation tests were then conducted for the best results, upon basis of a multiple resolution fitting procedure [10].

VI. Role of Automata in compression of XML documents

Extensible Markup Language(XML) is a standard meta language used to describe a class of data objects, called XML documents and to specify how they are to be processed by computer programs. XML is rapidly becoming a standard for the creation and parsing of documents. However, a significant disadvantage is document size, which is a consequence of verbosity arising from markup information [1]. It is commonly observed that non-standardized text formats for describing equivalent data are significantly shorter. Theoretically, therefore, one should be able to compress XML documents down to the same size as the compressed versions of their non-standard counterparts. XML documents have their structure specified by document type definition which specify the syntax of the documents [1].

The use of syntax in the compression of program files is not new. Cameron has used Context Free Grammars (CFG) for compressing programs [13]. However Hariharan Subramanian and Priti Shankar presented in his paper titled Compressing XML Documents Using Recursive Finite State Automata a scheme for the compression of XML documents where the underlying arithmetic model for the compression of tags is a finite state automata generated directly from the DTD of the document. They propose scheme for automatically generating compressors for XML documents from Document Type Definition(DTD) specifications. Their algorithm is a lossless adaptive algorithm where the model used for compression and decompression is generated automatically from the DTD, and is used in conjunction with an arithmetic compressor to produce a compressed version of the document [1]. The structure of the model mirrors the syntactic specification of the document. Their compression scheme is on-line, that is, it can compress the document as it is being read. They have implemented the compressor generator, and provide the results of experiments on some large XML databases whose DTD's are specified. They note that the average compression is better than that of XMLPPM, the only other on-line tool we are aware of. The tool is able to compress massive documents where XMLPPM failed to work as it ran out of memory. The main appeal of this technique is the fact that the underlying model is so simple and yet so effective [1]

VII. Role of cellular automata in Cryptography and Random Number Generation

Cellular automata can serve as a source of random numbers that are used for encrypting messages, running simulations, and other purposes [14].

The configurations of a succession of cellular automata generations can be used as a random sequence [15]. One-dimensional cellular automata are normally used for this purpose. Sarkar cites several specific applications that have been proposed for cellular automata generated random numbers, including private key cryptosystems, public key cryptosystems, and hash functions [15].

Wolfram [16][17][14] further reveals that the random number generator used for large integers in his Mathematica system is based upon the elementary cellular automata known as Rule 30. Wolfram states that this particular cellular automata type is used as a random number generator due to the fact that it has the interesting and useful property of being chaotic [18][14].

VIII. Role of cellular automata in Parallel Computers

Some cellular automata have the property of universal computation, which means that in principle they can perform arbitrary computations [14]. According to Wolfram [19], this property may be of more than theoretical interest, and might allow cellular automata to form an architectural model for building practical parallel-processing computers. The homogeneity of cellular automata (one of their basic property of cellular automata) would permit cellular automata to be readily implemented using integrated circuits. For example, it might be possible to fabricate on a single silicon chip one-dimensional, computationally-universal cellular automata with about a million cells and a time step of about a billionth of a second. The homogeneous, one-dimensional structure of the cellular automata would make finding defects relatively simple [14].

However, Wolfram [19] also points out that programming a cellular automata computer would require a radically new programming approach. He suggests that new programming technologies focus initially on problem domains for which cellular automata are inherently suitable, such as image processing [14].

IX. Role of automata in Modeling and Simulation

Cellular automata, as implemented on computers can be used to model a wide variety of complex biological and physical systems [16]. Although many natural systems- for example, turbulence in fluids or the formation of snowflakes—can be analyzed using traditional mathematical models such as differential equations, cellular automata often provide a simpler tool that preserves the essence of the process by which complex natural patterns emerge [18]. According to Wolfram [19], cellular automata are inherently more efficient at analyzing many natural systems than traditional computational methods because the mechanisms found in most natural systems are closer to those of cellular automata than to those of conventional computation [14].

The complex global patterns and behavior of an array of cellular automata emerge from the simple laws built into the individual cells. Thus, cellular automata are especially suitable for modeling any system that is composed of simple components, where the global behavior of the system is dependent upon the behavior and local interactions of the individual components [14]. The following are some specific examples of biological and physical systems that have been effectively modeled using cellular automata [14][19][20]:

- Gas behavior. (A gas is composed of individual molecules, the behavior of which is dependent on neighboring molecules.)
- Ferromagnetism. (A magnetic material consists of a network of nodes, where the magnetic state of each node—that is, the direction of electron spin—depends on the state of the neighboring nodes.)
- Forest fire propagation.
- Urban development.
- Turbulence in fluids.
- Immunology and biological ageing.
- The flow of electricity in a power grid.
- Crystallization.

X. Artificial Life

The field of artificial life attempts to model biological life or even to create an artificial form of life on a computer. One of the primary purposes of this pursuit is to determine how complex systems, such as life forms, can emerge in a universe where the increase of entropy is one of the most fundamental laws. Artificial life is possibly the best-known application of cellular automata [21][22].

Cellular automata are an ideal tool for the computer modeling of life because they are analogous to life in fundamental ways. Namely, cellular automata are based on simple rules from which complex life-like behavior—including self-reproduction—can emerge given the right conditions (such as an appropriate lambda value), just as life appears to have emerged from relatively simple molecules with evolution pushing the molecular precursors of living systems toward the right conditions where complexity could emerge [21][14].

XI. Conclusion

Cellular automata can be used for compression of XML document, neural network, data mining, cryptography, random number generation, parallel computers, data clustering, visualization and rule discovery in data classification, modeling and simulation. Cellular automata and neural networks empirical models designed to simulate and predict urban land use changes are generally based on the utilization of statistical techniques to reckon the land use change probabilities. The main use for cellular automata, however, is to model physical and biological systems. Cellular automata can often serve as simpler tools for modeling systems than traditional mathematical methods.

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