Evolving Cellular Automata Based Associative Memory for Pattern Recognition

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Abstract. This paper reports a Cellular Automata (CA) model for pattern recognition. The special class of CA, referred to as GMACA (Generalized Multiple Attractor Cellular Automata), is employed to design the CA based associative memory for pattern recognition. The desired GMACA are evolved through the implementation of genetic algorithm (GA). An efficient scheme to ensure fast convergence of GA is also reported. Experimental results confirm the fact that the GMACA based pattern recognizer is more powerful than the Hopfield network for memorizing arbitrary patterns.

Keywords: Cellular Automata, Genetic Algorithm, Pattern Recognition.

1 Introduction

Pattern recognition is the study as to how the machines can learn to distinguish patterns of interest from their background. The training enables a machine to learn/store the patterns and recognize them with reasonable certainty even from a noisy environment. The performance of pattern recognition depends on the depth of training. In conventional approach of recognition, the machine compares the given input pattern with each of the stored patterns and identifies the closest match. The search requires the time proportionate to the number of patterns learnt/stored. Obviously, with the growth of the number of patterns stored, the recognition process becomes too slow.

The Associative Memory provides the solution to the problem where the time to recognize a pattern is independent of the number of patterns stored. In such a design, the entire state space gets divided into some pivotal points (a,b,c of Fig.1). The states close to a pivotal point get associated with that specific point. Identification of a noisy pattern (original pattern distorted due to noise) amounts to traversing the transient path (Fig.1) from the given noisy pattern to the closest pivotal point learnt. As a result, the process of recognition becomes independent of the number of patterns learnt/stored.
In the above background, since early 80’s the model of associative memory has attracted considerable interests among the researchers [1]. Both sparsely connected machine (Cellular Automata) and densely connected network (Neural Net) [1,2] have been explored to solve this problem. The seminal work of Hopfield [3] made a breakthrough by modeling a recurrent, asynchronous, neural net as an associative memory system. However, the complex structure of neural net model has partially restricted its application. Search for alternative model around the simple structure of Cellular Automata (CA) continued [4].

![Fig. 1. Model of associative memory with 3 pivotal points](image)

The design of CA based associative memory has so far mostly concentrated around uniform CA [2,4] with same rule applied to each of the CA cells. Some works on non-uniform CA has also been reported in [5]. But none reported the evolution of CA to a general purpose pattern recognizer although it has been able to recognize some patterns [2,6]. In this paper, we propose the evolution of associative memory for pattern recognition with more general class of CA referred to as GMACA. This specific class of CA displays very encouraging result in pattern recognition. The memorizing capacity of such a class of CA, as established in this paper, can be found to be better than that of Hopfield Network.

The genetic algorithm (GA) has been employed to arrive at the desired GMACA configurations. An innovative scheme to identify the initial population, which significantly improves the GA convergence rate, has been also reported.

In order to present the underlying principle of CA based model for pattern recognition, in Section II we introduce an overview on Cellular Automata. GMACA based associative memory and its application for pattern recognition is next outlined in Section III. Application of genetic algorithm to evolve CA based associative memory is subsequently presented in Section IV. In Section V, we report the experimental observations that establish the CA as an efficient pattern recognizer. A comparative study with Neural Net model has been also reported in this section.