LEAF CELLULAR AUTOMATA

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ABSTRACT

We have developed bio-system derived algorithm: Leaf Cellular Automata(LCA). LCA are one form of cellular automata. LCA are reffered to activity of a leaf. LCA have four layers: the "CO_2 Layer", the "Stoma Layer", the "Starch Layer" and the "Water Layer". In order to evaluate this optimization algorithm, we used a pattern matching problem.

Key Word: Optimization, Bio-system derived algorithm

1. Introduction

Many problems in the field of agricultural engineering involve the optimization of operating systems, such as drainage and irrigation systems, crop scheduling, and handling and blending materials. Problems that deal with optimizing operating systems and fitting quantitative models ultimately make use of adaptive search procedures or optimization techniques. There are many search techniques, including exhaustive techniques (random walk), calculus-based techniques (gradient methods), partial knowledge techniques (heuristic methods, production rule systems), stochastic techniques (simulated annealing), and biosystem-derived algorithms (Genetic Algorithm, Immune System Algorithm). In realistic systems, the interactions between the parameters are not generally amenable to analytical treatment, and the researcher must resort to appropriate search techniques. Recently, the Genetic Algorithm and neural networks have received attention, due to their ability to locate very good approximate solutions in extremely large search spaces with a reasonable amount of computational effort. This study introduces a biosystem-derived algorithm called Leaf Cellular Automata (LCA).

2. Cellular Automata (CA)

It is often difficult to describe complex systems analytically using many elaborate equations. Even if successful to a certain extent, it is often impractical. Cellular automata (CA) are one possible method to describe such complex systems. For example, turbulence is an extremely complex phenomenon that cannot be described by analytical equations in general. On the other hand, CA can simulate turbulence as collisions of particles involving phenomena that simply follow Newton's laws. CA have the following characteristics:

1. *Cell Spacing*: The space of CA is divided into many cells in n dimensional space. In two-dimensional space, a cell often takes the shape of a square. In three-dimensional space, it becomes a cube.
2. *Parallel Processing*: CA make use of parallel processing. The state of individual cells changes or remains unchanged simultaneously depending on conditions over the entire CA space.
3. *Local Relationship*: Processing of CA is local. When the state of a cell is updated, only the states of the 8 neighboring cells - 4 cells adjacent to corners and 4 cells adjacent to sides – affect the next state of the cell.
4. *Uniform Law*: Every cell is updated according to a uniform law. A simple theory decides the next state of a cell.

3. Leaf Cellular Automata

Leaf Cellular Automata are one form of cellular automata and are estimation engines that make use of the rules of the photosynthetic pathways. LCA are derived from interaction of substances on a leaf.

3.1 The structure of Leaf Cellular Automata

Leaf Cellular Automata consist of 4 layers: the "CO_2 Layer", the "Stoma Layer", the "Starch Layer" and the "Wather Layer". These four layers overlap and have close relationship (Fig. 1).

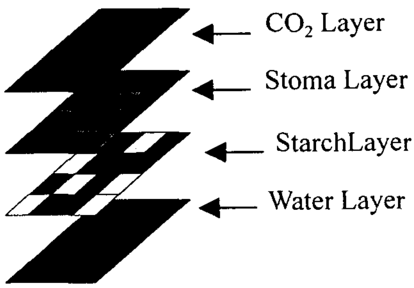

Fig. 1 The structure of LCA

3.1.1 CO_2 Layer

The CO_2 layer represents consentrations of CO_2. Concentrations of CO_2 on the layer change randomly.

3.1.2 Stoma Layer

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This layer represents open degrees of stomata. The open degree s of stomata are affected by the water layer.

3.1.3 Starch Layer

The starch layer represents a quantity of starch. Quantities depends on the CO_2 Layer and the stoma layer. In LCA, This layer represents a solution.

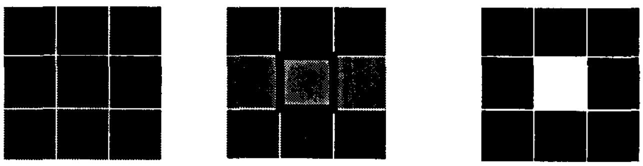
3.1.4 Water Layer

The water layer represents a quantity of water in a leaf. The water layer plays an important role in order to be LCA as an optimization algorithm. This layer affects the stoma layer.

3.2 Procedures

3.2.1 Photosynthesis

The quantity of Starch on the Starch layer is decided by the product of the open rate of a stoma and the sum of CO2 concentration around the cell.(Moore neighborhood). First, LCA calculates the sum of CO2 concentrations of these cells. Then LCA multiplies this sum by the open degree of the cell. This is the quantity of starch on the starch layer. If this quantity exceeds a certain threshold, the value of the stoma layer is 1. If not 0.



CO2 Layer Starch Layer Starch Layer

Fig. 2

3.2.2 Copying the best starch layer in the new water layer

The water layer takes a key role of LCA as an optimization algorithm. Quantites of the water layer are reflected in open degrees of the stoma layer. When the solution becomes better than the best solution that has ever produced, the water layer is recorded as a good layer and used in next calculation, too. If the solution is not renewed for some period, the following procedure carry out at the water layer.

3.2.3 Averaging the water layer

It looks good that copying the stoma layer that has produced the temporary best solution. But it is dangerous to insist the "temporary" best solution. Because that solution may lead us to local minima. Therefore we need to give up to insist the "temporary" solution after some period. LCA uses following procedure. First the water layer is copied from the stoma that produced the temporary best solution. Then if the water layer is not renewed for a while, each quantity of cell is averaged little by little as step passes. So LCA can try little different water layer from the temporary best layer.

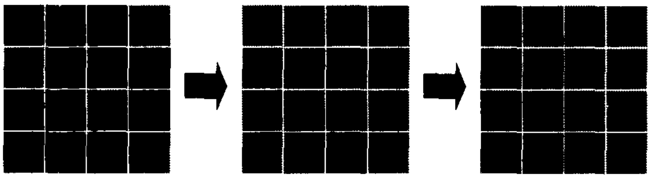


Fig. 3 Changing the water layer

4. Pattern Matching Problem

In order to evaluate the ability of LCA, we used the pattern matching problem. This problem is to estimate an orginal pattern by an error.

4.1 Exercise

In order to evaluate ability of LCA, we used the pattern matching problem. The aim of this problem is to match a pattern to an goal pattern. LCA estimates a goal pattern from this error. We tried three cell-size of this problem: 8×8, 16×16 and 32×32.

4.2 Result and Discussion

Figure 4, 5 and 6 show the error of LCA and of random search at 1000-iteration-calculation. In every cell- sizes(N), the average errors of LCA are lower than random search. The difference between LCA and random search is the biggest 10.47 in cell-size 32. So we can say that the difference is bigger, as the cell-size become bigger. Sandard deviations of errors in LCA are bigger than in random search. LCA trends to have a scattering solution.

5. Conclusion

LCA could search better pattern than random search in the pattern matching problem. But we can not say that the differences between them is not satisfied level. We need more idea that derived from the procedure in a leaf.

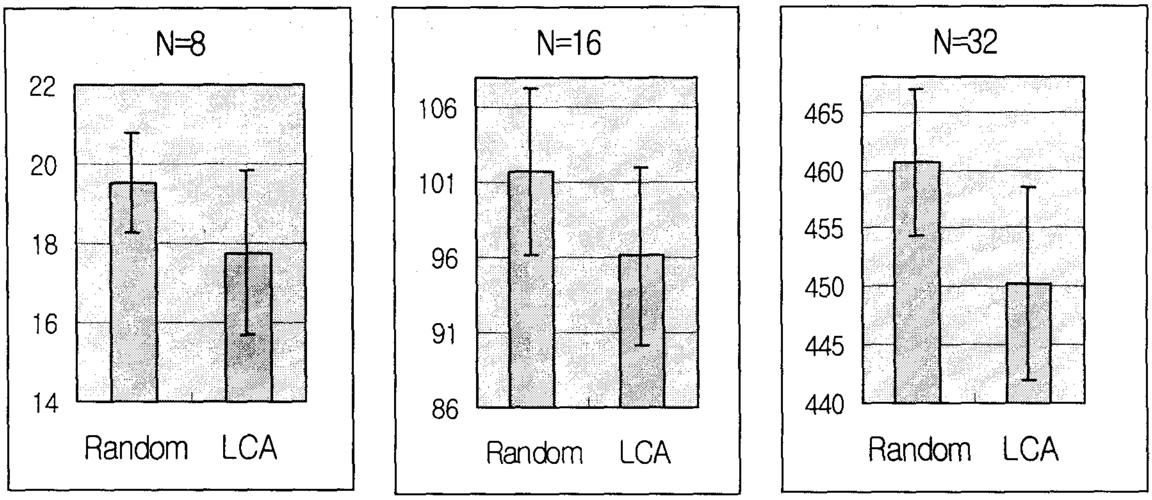


Fig. 4. The Average of Error at 1000-iteration

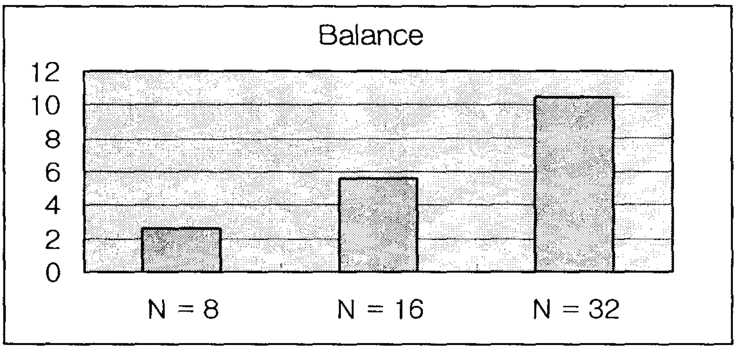


Fig. 5 The balance between LCA and randm search

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