A novel plant growth simulation algorithm and its application

Jun Lu, Yueguang Li

Gansu political science and law institute, Lanzhou, gansu, 730070, China

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Abstract . This paper proposes a novel plant growth simulation algorithm. Through the optimization experimental of testing on the standard function, the results show that the novel plant growth simulation algorithm has reliable convergence, high convergence rate and solution precision.

1. Introduction

The optimization process of function problem is from one initial state to the attractor in the feasible region of space [1]. When the function has a unique optimal solution, equivalent to only one attractor in the space of feasible region, at this time the whole feasible region of space is the domain of attraction of the attractor, in order to solve this problem, branch bound method [2], cutting plane method [3], Monte2carlo stochastic method and a series of local or greedy algorithm are effective, they can obtain the global optimal solution [4]. However, the complex function problem has multiple global or local optimal solutions in the feasible region, which means that the space exists multiple attractors, and the optimization process evolution to which attractor depends on the initial fall in which space of feasible region, this feature causes the algorithm into a local minimum point and can not be the fundamental of the global optimal solution [5].

Aiming at this problem how to jump out of a local minimum point, in recent years, the category of bionic algorithm achieved attract people's attention achievements, its success lies in the algorithms the imitation of nature in different biomes for environment adaptive optimization model, set up random, positive feedback, coordination model. In many of the bionic model, essential to simulate animal and insect, for some plant natural optimization model, such as phototropism dynamic mechanism, have not given sufficient attention. Rush J J Ki and Turin et al. Plant growth and plant morphogenesis model of Linden Mayer and Proulx Sen Covic et al. The growth of branch model is mainly aimed at the field of computer graphics, fractal problems, the plant growth dynamics mechanism applied to solve function problems, there is no related research.

2. The plant growth simulation algorithm

Plant growth simulation algorithm (PGSA) is an evolutionary computation technique through simulating the growth processes in plants, which is based on the principles of plant phototropism growth [6]. The algorithm has a good prospect in the application due to requiring a simple on the parameters. It has gradually been applied in the field of engineering by many scholars [7]. PGSA sets up several basic conception: root、trunk、branch、growth point and light source. The root of a plant expresses initial solution; the trunk and branch correspond to the search domain of possible solutions; the selected growth point expresses the base of next searching process and the light source represents the global optimal solution. The key point of PGSA is selecting one growth point to erupt into branch, and ensuring the branch growing toward the light source.

Plants can be viewed as a system, which composes of a large number of branches and nodes. It must be as soon as possible to strive for breeding more branches and leaves for earning more surface areas, which can obtain the greatest possible sunlight. The form of grammar that simulates the plant description analysis and development had been established since linguistics was introduced into the biological, which based on a simple rewrite rules and branching rules, this is called L-system. Formal description of plant growth can be carried out as the following:

1. The section of the site grow new branches which first emerged in a number of stems is called the growth node.

2. Most of the new branches have grown updated branches, and the process repeated on the old and new branches.

3. Different branches in the tree have similarities with each other, and the entire plant has self-similar structure.

The Branching model of plant growth is improved according to L-system combined with computer graphics and fractal theory, the plant, as the form of plant growth characteristics, can be described as follow: Supposed branches of plant growth occurred in the two-dimensional plane, Each branch growing in units length every time, or rotating a certain angle α , Starting from the node of trunk or branches, The growth process were repeated through rewriting the rules of branches of plant growth in the two dimensional plane.

It was proved by biological experiments that a new branch that is able to grow depends on its morphactin concentration when the plant has more than one node. The node which has larger value of morpheme concentration has more growth opportunities than the smaller one, morphactin concentration are not pre-assigned to the nodes, but formed according to their location information which we call that plant showed the feature of plant's Phototropism. After the node has been formed, morphactin concentration will be readjusted according to changing in the environment of a new growth node else.

We could describe the characteristics of plant growth in term of the mathematical view basis on plant growth analysis of the above. Suppose the length of tree trunk is T, the length of branch is L, there are W growing nodes $S_T = (S_{T1}, S_{T2}, ..., S_{TW})$ in the trunk, morphactin concentration of those nodes is $P_T = (P_{T1}, P_{T2}, ..., P_{TW})$ respectively. There are q growth nodes $S_T = (S_{T1}, S_{T2}, ..., S_{Tq})$ in the branch. Morphactin concentration of those nodes is $P_T = (P_{T1}, P_{T2}, ..., Pq)$ respectively. The morphactin concentration which grown in the trunk and branch is calculated as follows:

$$P_{Ti} = \frac{f(x_0) - f(S_{Ti})}{\sum_i^W (f(x_0) - f(S_{Ti})) + \sum_j^q (f(x_0) - f(x_{Tq}))} \qquad (1)$$

Where x_0 represents the root of plant (the initial node), $f(*)$ is the information function of the node in the environment, The smaller value of the function as possible shows the better environment where the node located, it will help to grow new branch.

From formula (1), the value of morphactin concentration in every node depends on relative position of the relative to the initial root and the location of the environmental information, the mechanism consistent with the formation of the morphactin concentration in the plant cell. We can deduced from formula (1) as follows:

$$\sum_{i=1}^{T}\sum_{j=1}^{q}\left(P_{Ti}+P_{Tj}\right)=1 \tag{2}$$

We can produce random number in the interval [0, 1]. The random number must fall within one of the state space $\left(P_1, P_2, ..., P_{T+q}\right)$, where the corresponding node will have a prior right to grow new branch. The value of morphactin concentration in all nodes will change after the new branch has grown up. Computation formula of the value of morphactin concentration in other nodes will add the relevant node on the new branch, and remove the grown node, which basis on formula (1). The process will be repeated until there is no new branches growing.

3. The analysis of simulation

In order to verify the effectiveness of the algorithm, this paper takes 5 benchmark functions as an example to calculate, compared with reference [8], literatures [9], literatures [10] and literatures [11].

$$f_1=\sum_{i=1}^{n}x_i^2$$

$$f_2=\sum_{i=1}^{n}\left(\sum_{j=1}^{i}x_i^2\right)$$

$$f_3=\sum_{i=1}^{n-1}\left(100\left(x_{i+1}^2-x_i^2\right)+\left(1-x_i\right)^2\right)$$

$$f_4=\frac{1}{4000}\sum_{i=1}^{n}x_i^2-\prod_{i=1}^{n}\cos\left(\frac{x_i}{\sqrt{i}}\right)+1$$

$$f_5=-20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2}\right)-\exp\left(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i)\right)+20+\exp(1)$$

In the experiment, the algorithm parameter settings are as follows. For functions f1 - f5, the population size is 20, the number of iterations is 50, the scope of the search for [-10, 10], dimension N=10. The final testing results of the algorithm using the average value of the independent operation of 20 times. It can be seen, the convergence speed and convergence accuracy of the algorithm is better than AFSA and SAFSA, the expected effect is reached for novel plant growth simulation algorithm.

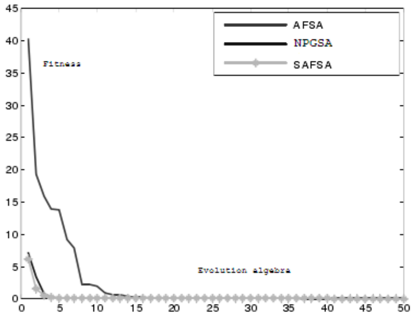

Fig.1 Fitness of the evolutionary curve of f1

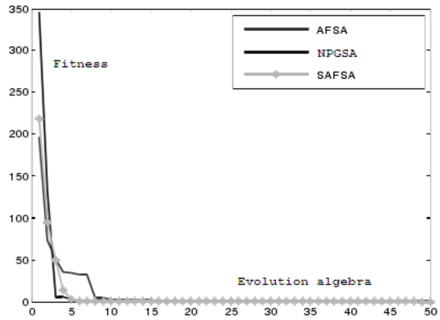

Fig.2 Fitness of the evolutionary curve of f2

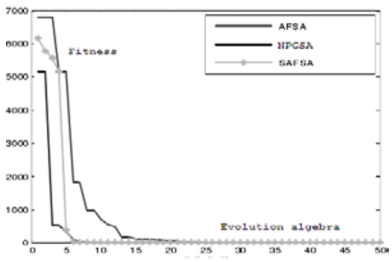

Fig.3 Fitness of the evolutionary curve of f3

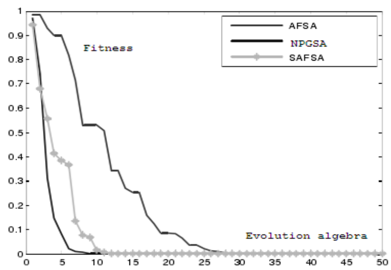

Fig.4 Fitness of the evolutionary curve of f4

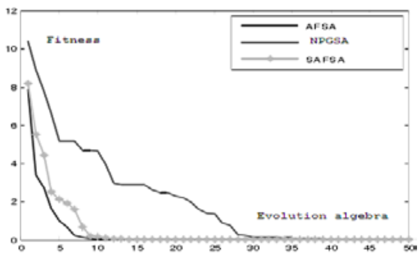

Fig.5 Fitness of the evolutionary curve of f5

4. Conclusions

This paper presents an improved plant growth algorithm and verifies through five test functions, the experimental results show that this method is practical, simple and easy to understand.

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