Optimized Growth Models of Cucumber Using The Species Compete-Die out (SCD) Algorithms

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ABSTRACT

Inspired by the phenomena of evolution in nature and society, this paper put forward a new model for evolutionary algorithms to conquer its limitation of premature convergence. Then the model is used to optimize the parameters of model of crop in greenhouse and compared the result to that of the simple Evolutionary Algorithms under the same situation. Finally it is convinced that the new model is superior in stability and astringency.

Categories and Subject Descriptors

C.4 [PERFORMANCE OF SYSTEMS]: *Modeling techniques*

General Terms

Algorithms.

Keywords

Species Compete-Die out Algorithms, Evolutionary Algorithms, premature convergence, optimization

1. INTRODUCTION

The optimal control problem in greenhouse is a kind of non-linear, multi-variable problem which makes most optimization methods, such as Gauss-Newton, Simulated Annealing and simple Evolutionary Computation, are not suit to solve such hard problem. In previously study Evolutionary Algorithms (EA) or Genetic Algorithms (GA) was used to solve such problem. But there is inherent limitation to EA or GA, which makes it easily for the solution to fall into premature convergence. In fact, the basic cause of such convergence of EA or EA comes from the explicit fact that selection pressure makes high fitness individuals reproduce quickly and thus supplant low-fitness individual, some of which may be more promising, but not yet fully exploited. To overcome such insufficiency, we put forward the Species Compete-Die out (SCD) algorithms model for evolutionary computation.

Based on the thought of Niche, the SCD model simulates the rule in nature and society that it is the force of combination of independent evolution in every species and overall competition among all species that makes the history continually advance. In addition, SCD model can adaptively adjust mutation step which can improve the performance of local search and accelerate convergence efficiency. Generally the SCD can get the global solution, which indicates that the new model is apparently superior to simple EA in stability and astringency.

2. THE RESPIRATION MODEL OF CUCUMBER IN GREENHOUSE

The growth models of cucumber in greenhouse include the submodels of photosynthesis, respiration, etc. In this paper we only use SCD on the respiration submodels. Now we begin to analyze respiration by the analysis of maintain respiration and growth respiration. Maintain respiration can be described by:

$$RM = RM(T_o) \times Q_{10}^{(Tav-To)/10}$$

$$RM(T_o) = mc_{lv} \times W_{lv} + mc_{st} \times W_{st} + mc_{rt} \times W_{rt} + mc_{so} \times W_{so}$$

where Q_{10} is the respiration coefficient, T_{av} is the daily average temperature, T_o is the standard temperature which equals 25^o,

$RM(T_0)$ is the ratio of maintain respiration when the temperature is 25^o, mc_{lv}, mc_{st}, $mc_{rt,}$, mc_{so} are separately the maintain respiration coefficients of leaf, stem, root and storage organ, W_{lv}, W_{st}, W_{rt}, W_{so} are the corresponding weigh of biomass of such organs. Growth respiration is calculated as follows:

$$AAR = CR_{lv} \times CP_{lv} + CR_{st} \times CP_{st} + CR_{rt} \times CP_{rt} + CR_{so} \times CP_{so}$$
$$EGR = 1/AAR$$

where AAR is the average amount of assimilation needed by the synthesis of unit biomass, EGR is the efficiency of growth respiration of the whole plant, CR_{lv}, CR_{st}, CR_{rt}, CR_{so} are separately the amount of assimilation needed by the synthesis of biomass of leaf、stem、root and spike, CP_{lv}, CP_{st}, CP_{rt}, CP_{so} are the distribution coefficient of biomass of such organs.

3. THE SPICES COMPETE-DIE OUT ALGORITHMS MODEL

3.1 The Evolutionary Phenomena in Nature and Society

At the very beginning of evolution our ancestors all lived within their tribe and the competition and evolution was taken place only in the inner so every tribe can develop independently, the result of which was that the development between groups was rather uneven. Then, in order to take the limit resources in the nature, the strong spices used to commit aggression against the weak. These phenomena resulted to the fact that some tribe generally died out, some were assimilated, while some were getting more and more stronger, which made the whole human history advancing continually. Also, animals have the same history as human being.

It is rather important for the ancient men to be left an unattached space to develop themselves before they attend the competition of the whole society. Once they have no opportunity to grow fully, some of which, whose fitness are usually lower, will die out easily. In this case, the nature will lose many categories and the diversity can not be maintained availably.

3.2 The Spices Compete-Die Out Algorithms Model

Inspired by the evolutionary phenomena and the hierarchical fair competition in nature and society, we propose the SPICES COMPETE-DIE OUT algorithms model (SCD) for Evolutionary Algorithms. Simple Evolutionary Algorithms often results in premature convergence or just arriving local optimal solution. The main reason is that the selection pressure often makes the high-fitness individuals reproduce largely then result to a high proportion of individuals with similar genes. But they are not surely the best in the whole space of the research.

So in this new model, before the start of evolution all individuals are divided into some species according to the fitness of individual. At the initial several generations, evolution only takes place in the inner of species, not between the species, which can provide every individual some opportunity to develop fully without outer disturbance. After several generations of inner evolution, the competition between different species begin, which can finally result in to the evolution and development of the whole species. The structure of the new model is showed as figure 1.

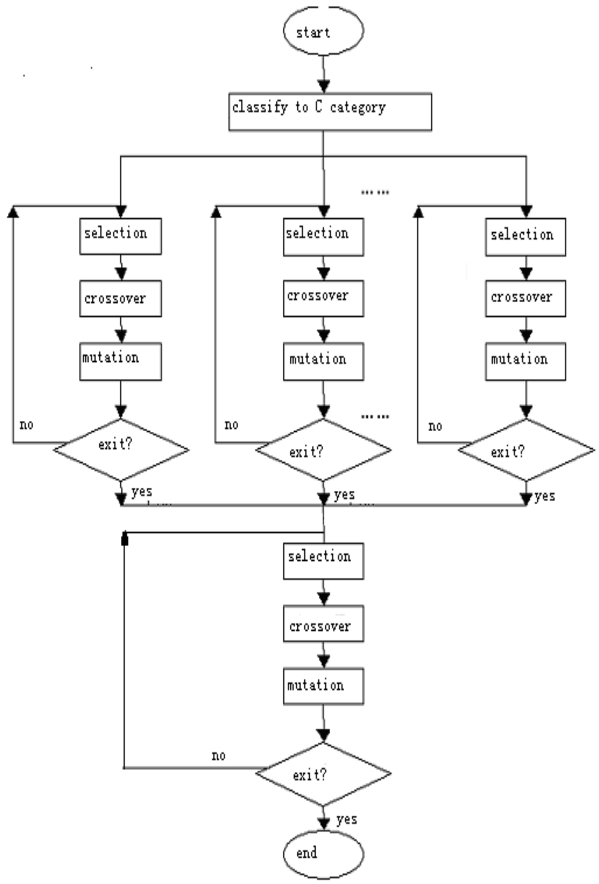

Figure 1: Structure of the SCD Model

It is very important for individuals to evolve independently in the inner species because unattached development can ensure those excellent genotype with different level of fitness can develop well and be inherited fully, which can protect the apparent low-fitness but promising individual and maintain the diversity of revolution. Then the unlimited expand of some good genotype at the beginning of evolution can be effectively avoided, so can the premature convergence.

The way of classification at the very beginning of evolution is based on the hierarchical fair competition often seen in societal and biological systems. According to the original fitness, all individuals are divided into a number of species to have unattached development. Such a kind of hierarchical fair competition can effectively protect individuals with different level of fitness in one population and maintain the diversity of individuals.

In Evolutionary Algorithms the choice of selection strategy is rather important. In the new model we employ two different strategies. When the evolution is happened in the inner species we choose the Ranking Selection, which can gives more selective pressure towards the optimum when the fitness of the population are similar. When the whole species all take part in the competition and evolution, we choose the Conservation the Best

Strategy and the μ＋λ Selection Strategy. The combination of the two strategies can avoid being destroyed by the operator of crossover and mutation and thus can save the excellent genotype to maintain the diversity through out the whole finding of the solution.

In this model we put forward the adjustment of the mutation step, which is called local fine-tuning. In order to save the excellent genotype locating in the promising area or next to the global solution, we can reduce the mutation step when searching in the promising area to improve the final global solution. The method is as follows:

$$\sigma'_{ik} = \begin{cases} \sigma_{ik} + b[1 - r\cdot(1 - \frac{F(V_i)}{F_{\max}})^{\lambda}] & rnd(2) = 0 \\ \sigma_{ik} - a[1 - r\cdot(1 - \frac{F(V_i)}{F_{\max}})^{\lambda}] & rnd(2) = 1 \end{cases}$$

where σ_{ik} is the kth mutating local of the individual V_i, $[U_{\min}^{(k)}, U_{\max}^{(k)}]$ is the range of σ_{ik}, $a = \sigma_{ik} - U_{\min}^{(k)}$, $b = U_{\max}^{(k)} - \sigma_{ik}$, r is a stochastic numeral between zero and one, λ is a parameter between two and five, $F(V_i)$ is the fitness of V_i and $F_{\max}$ is the maximal fitness.

4. THE VALIDATION AND ANALYSIS OF SCD ON THE FOREGOING MODEL

We used the SCD model and simple EA ten times on the foregoing model of cucumber in greenhouse to optimize the thirteen parameters of Q_{10}, mc_{lv}, mc_{st}, mc_{rt}, mc_{so}, CR_{lv}, CR_{st}, CR_{rt}, CR_{so}, CP_{lv}, CP_{st}, CP_{rt} and CP_{so}. The tested result of SCD and simple EA are listed in Table 1. In this table, "mean" is the tested average value of ten times, "SD" is indicated to Standard Difference. The maximum generation of SCD and simple EA in our test is 200 generations.

Table 1. Tested Result of SCD and Simple EA

Parameters		Q_{10}	mc_{lv}	mc_{st}	mc_{rt}	mc_{so}	CR_{lv}	CR_{st}	CR_{rt}	CR_{so}	CP_{lv}	CP_{st}	CP_{rt}	CP_{so}
theoretic value		1.4	0.015	0.015	0.010	0.010	1.326	1.326	1.326	1.462	1.587	1.587	1.587	1.612
SCD	mean	1.3986007	0.0149856	0.0150230	0.0100426	0.0100207	1.3260199	1.3260090	1.3260010	1.4619912	1.5869818	1.5869980	1.5879969	1.6120039
	SD	0.0089206	0.0000391	0.0000519	0.0001742	0.0001000	0.0000640	0.0000346	0.0000087	0.0000200	0.0000360	0.0000100	0.0033200	0.0000150
Simple EA	mean	1.3604547	0.0145217	0.0152878	0.0096868	0.0094856	101238491	1.3083851	1.2408637	1.3781168	1.4927832	1.5314730	1.4176641	1.4728118
	SD	0.1191753	0.0012248	0.0011270	0.0022633	0.0024986	0.1270549	0.0590408	0.1674405	0.1694855	0.1736569	0.0951257	0.3188920	0.2686154

From the table we can conclude that the SCD is superior to simple EA in stability because the final Standard Difference of each parameter in SCD is far less than that of simple EA. In our tests when simple EA evolved at the fortieth generation, the fitness couldn't, in fact, be improved, which indicated that the arithmetic was in stagnation and probably in premature convergence of local optimum. On the other hand, the spending time of simple EA was about fifty-eight seconds, while the SCD about two hundred and ten seconds, which could be explained by the fact that SCD has introduced some complex operator such as the classification according to the fitness and the local fine-tuning. Actually the SCD model has better convergence efficiency and stability on the cost of more time spending. The convergence of SCD is showed as figure 2 and simple EA figure 3.

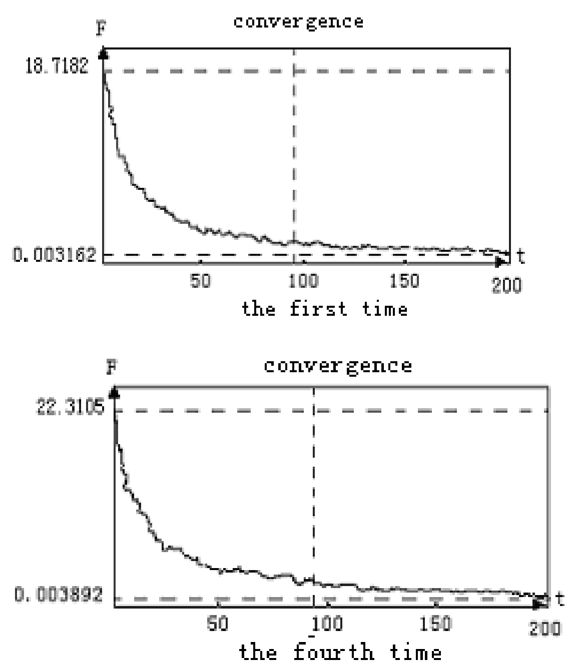

Figure 2: Convergence of SCD

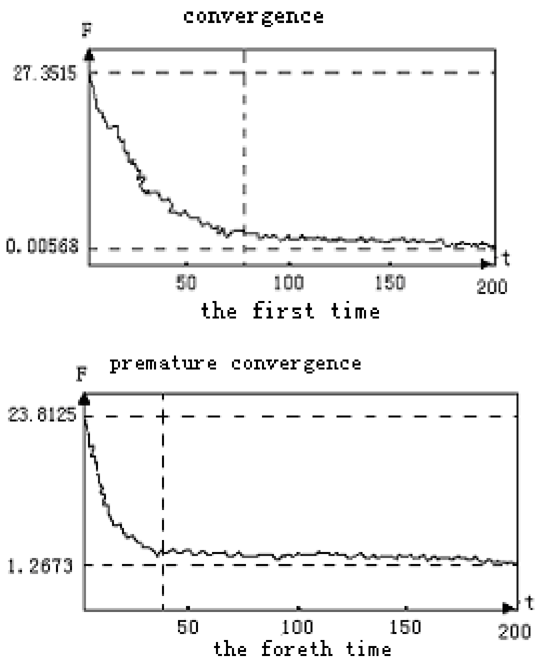

Figure 3: Convergence of Simple EA

5. CONCLUSIONS

We have explained our SCD model and applied it to optimize some parameters of the growth model of cucumber. Validation of the present model has been demonstrated by comparison with simple EA. The results exhibit that it has considerable advantages in stability and convergence to resolve optimal problem in greenhouse.

6. ACKNOWLEDGMENTS

The authors are particularly grateful to STCSM for providing SSTDF Project 03DZ19303 and thanks to Shanghai Key Lab of Protected Horticultural Technology for their help during this project.

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