Micro Variation Chaos Genetic Algorithm

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Abstract: The traditional genetic algorithm in the search of complex nonlinear problems, prone to early convergence and the late search fatigue and other issues. In view of these problems, the paper proposes the micro variation chaos genetic algorithm. Using the characteristics of chaos and randomness, the genetic algorithm is used to compensate for the slow evolution of the genetic algorithm and the difference of the genetic diversity. At the same time, the crossover operator, mutation operator and fitness function of genetic algorithm are improved, and the performance is improved. The simulation results show that the micro variation chaotic adaptive genetic algorithm is faster and more accurate than the conventional chaos genetic algorithm and genetic algorithm.

Key Words: genetic algorithm, premature convergence, search fatigue, crossover operator, mutation operator

1. INTRODUCTION

Genetic algorithm was first proposed in the 1960s by a University of Michigan professor of Holland America, which is a globally adaptive random search of intelligent optimization algorithm. Its main strategy is to simulate the Darwinian genetic and evolutionary mechanisms, namely: According to the "survival of the fittest, survival of the fittest" principle, the population best adapted to the environment gets the chance of survival of the individual, and can reproduce a large number of offspring. Different individuals mate each other's in populations. Which can get an individual with different phenotypes and fitness? Large fitness individual survival and reproduce next generation. After several generations of evolution, population is being stabilization, individual fitness in line with natural selection. As a new optimization algorithm, the strong robustness, randomness, good scalability and features a wide range of applications of genetic algorithm make it widely apply to various fields of science.

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As people's understanding and extensive use of genetic algorithm, it's inadequacy in the theory and applied technology is becoming increasingly obvious. Confronted with relatively larger scale or complex nonlinear problems, genetic algorithm cannot keep the diversity of colonies, which may lead to locally optimal solution in the initial search, evolution slowly in later stage and searching fatigue. This also makes the traditional genetic algorithm has some limitations.

Chaos refers manifested in deterministic systems in a similarly no rule and seemingly random phenomenon which is a widespread complex form of exercise and natural phenomena. Chaos seemingly chaotic, but it has an exquisite structure inside. As long as the moving track has a slight difference in the starting stage, the relationship between the trajectories will tend to disappear after a period of time. Chaotic motion not only has the randomness, but also within a certain range by its own laws without duplication through all the state, and has a strong sensitivity to the initial value changes. In accordance with its own laws of chaotic motion, the first phase of the chaotic search is the search for a large range, namely global search. A local search is carried out in the second phase of chaotic search process. By using the random and ergodic characteristics of chaos optimization algorithm, the chaotic optimization search is more likely

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to jump out of the local optimal solution, which also makes up for the defects of local search ability of genetic algorithm. Therefore, the unite of chaotic search and genetic algorithm can improve the local search ability of genetic algorithm and avoid the premature phenomenon of the algorithm in theory.

2. CHAOS GENETIC ALGORITHM

Many scholars have conducted researches about CGA. General way is that chaos optimization and genetic algorithm are solved independently, that is, at the end of the genetic algorithm, Algorithm add chaos chaotic disturbance to optimize it. This method is easy to operate; this text does not go into details. The following is the current chaos genetic algorithm to improve the mainstream method.

As an additional ingredient, the chaos genetic algorithm is added into genetic algorithm. For population initialization, in the Literature [1] Logistic mapping performance was analyzed and suitable as a Logistic mapping algorithm to generate the initial population of the genetic algorithm. Literature[2,3] analysis Logistic mapping, Cat mapping and Tent mapping comprehensively from ergodicity, the initial value of sensitivity and Lyapunov exponent three aspects and drawn Chaotic Cat has superior characteristics. Therefore it is more suitable for generating an initial value. Ergodicity and randomness of chaos can solve the problem of uneven distribution of the initial population to avoid search produces "premature" problem.

For the crossover, mutation operator of genetic algorithm, some scholars improve them with chaos characteristics. Titles [4] propose a chaotic cross, chaotic mutation argument. Chaos cross-way refers to that setting the initial value, after several Logistic map iterations to get. When individuals in groups have the best individuals, crossover operator selects. This practice slow down convergence rate, and prevent the rapid convergence and "premature" phenomenon. Chaos variation refers to that individual in an variation time will be mapped into (0,1) range of individual variation , and then use the Logistic mapping iterations, it will be remapped to the range of values of the individual to be an individual after mutation. Since the mutation has local search capability, and ergodicity of chaos may provide strong local search ability to mutation.

In addition to the above manner, some scholars have studied the ways the Chaos Optimization and Genetic Algorithm composite. Literature [5,6] propose that at the end of genetic manipulation, add chaotic disturbance in the population. Such operation may make added disturbances individuals' produces better than the previous individual, then speed up the searching speed, reducing the evolutionary algebra.

Basing on the above, this article proposes that after the selection operation, adds chaos practices into the same group. This effectively reduces the number of same individuals in the cross-operating groups. It also reduces the unnecessary crossover operations, greatly enhances global search capabilities, and improves search efficiency. In addition, the paper also has been improved Crossover operators, mutation operator and a fitness function, so that it can be better adapt to the search of the law, and make up for shortcomings of traditional genetic algorithm.

3. ALGORITHM IMPLEMENTATION

3.1 Coding

This selection of the encoding scheme is real coding [7]. Compared with the conventional binary encoding, the length of the chromosome and the solution vector is same. One gene corresponding to a component. Real coding can express great domain, the domain-wide increase is not like binary coded requiring to the expense of accuracy. Choose binary encoding also avoid consuming bring computing code.

3.2 Fitness function

Chaos Genetic Algorithm does not require the external environment that all optimization criteria and judgments are drawn based on the fitness function. So choosing the right fitness function determines the algorithm to optimize efficiently. Classical genetic algorithm fitness function selects directly the objective function. This choice is able to directly show the extent of optimization variables adaptation, however, it cannot avoid some defects, such as: in the search early, prominent individuals can not limit the search into the local optimal solution; in the latter part of the search, the possibility of continue to dive reduce, which leads to the search fall into local optima. In this paper, the

fitness function improved. When there is a prominent individual that is not conducive to the evolution of the population in the population, the individual's fitness value artificially reduced to not competitive, so unfavorable individual is 'destroy'. When the individual is not so prominent that influences population evolution, the fitness function changes associated with the evolution of algebraic index, this would resolve the problem of weak late stage of evolution.

$$F=\begin{cases} f-f_{\min}+\dfrac{1}{1+e^{-t}}(f_{\max}-f_{\min}) & \dfrac{f-\overline{f}}{\overline{f}-f_{\min}}<k \\ \dfrac{f}{1+e^{t}} & \dfrac{f-\overline{f}}{\overline{f}-f_{\min}}\geq k \end{cases} \quad (1)$$

Wherein, is the size of the improved fitness, is the objective function value, respectively belong to the objective function maximum, minimum, is average objective function value, is the evolution algebra, according to different environments have different values.

3.3 Choice

Traditional genetic algorithm using roulette wheel selection, which is simple and easy to extract individuals with high fitness. But this approach has its drawbacks that highlight individual groups easily lead to make searching local optimal solution, and because individuals with high genetic fitness remain to the next generation more, during the crossover operation, two of the same individuals prone to unwanted crossover operation, which reduces the efficiency of the search. Based on the roulette selection, this paper proposes a "roulette + micro variation." The so-called "micro-variations" refers to the small probability of variation after an individual copy. Variation way is to add chaotic disturbance. Doing so, to a certain extent, not only reduces the 'premature', but also reduces the probability of a cross between the same individuals. Set $P_m^{'}$ =0.001， α_1 is random number generated by the system. δ is manually set the degradation factor $X_n=(x_1,x_2,...,x_i)$, $n=1,2,...,Size$ ($Size$ is the population size). $X_n^{'}$ is variability after individual. a,b are respectively, individual maximum value, minimum value. Chaotic disturbance factor is $\beta=(\beta_1,\ \beta_{,2},...,\beta_i,...,\beta_L)$ (L is individual length) is determined by the following equation.

$$\alpha_{n+1}=4\cdot\alpha_n(1-\alpha_n),\quad n=1,2,3...$$

$$\beta_i=(a-b)\cdot\alpha_n$$

$$X_n^{'}=(1-\delta)\cdot X_n+\delta\cdot\beta_i$$

3.4 Crossover

This article based documents [8, 9] proposes adaptive crossover both relating evolution algebraic and the fitness value of the corresponding generation. With the increase of evolutionary generation, reducing demand for global search algorithms, so crossover increases gradually with algebraic decreasing. On the other hand, when individual fitness which participants in the cross operation is larger than the contemporary average, indicating that the individual has a reserved value, so adaptive crossover will also increase with individual fitness function value getting small, and quickly sought to help search the optimal solution. This paper proposes an adaptive crossover as follows.

$$P_c=\begin{cases} P_{c\min}-\dfrac{P_{c\max}-P_{c\min}}{1+e^{-t}}\cdot\dfrac{f-\overline{f}}{f_{\max}-\overline{f}} & f\geq\overline{f} \\ P_{c\max} & f<\overline{f} \end{cases} \quad (2)$$

Supposing $P_{c\max}=0.8$， $P_{c\min}=0.5$ .Since the interleaving is performed by two adjacent individual mutually. Therefore, in the formula (5) $f=\max(f_n,f_{n+1})$ .the Cross-way are follow.

$$\begin{aligned} X_n^{'}&=\gamma\cdot X_n+(1-\gamma)\cdot X_{n+1} \\ X_{n+1}^{'}&=\gamma\cdot X_{n+1}+(1-\gamma)\cdot X_n \end{aligned} \quad (3)$$

Wherein, γ between the random number $(0,1)$ is generated by the system.

3.5 Mutation

Being similar to the above principle, this paper presents an adaptive mutation operator that is also associated not only with the evolution generations, but also individual variation fitness. With the increase of algebra, in order to prevent the search fall into the local optimal solution, this paper design adaptive mutation operator which increases with algebra until the maximum. And when variation individual fitness is greater than the average level, one increases the mutation operator, otherwise reduced. This increases the diversity of individuals and avoids the phenomenon of post-search fatigue, which is conducive to finding the optimal solution as quickly as possible.

$$P_m = \begin{cases} P_{m\max} - \dfrac{P_{m\max} - P_{m\min}}{1+e^t} \cdot \dfrac{f - \overline{f}}{f_{m\max} - \overline{f}} & f \geq \overline{f} \\ P_{m\max} & f < \overline{f} \end{cases} \quad (4)$$

Supposing $P_{m\max} = 0.05, P_{m\min} = 0.001$,Variation way is that

$$x_i^{'} = (\frac{a-b}{2}) + (a-b) \cdot (\varphi - 0.5) \quad (5)$$

Among them, φ is system generated random number between $(0,1)$, $x_i^{'}$ is the mutated gene.

3.6 Chaos perturbation

After the selection, crossover and mutation operation, the better individuals of the population are retained, and the individuals with low fitness are added to the chaos, so that the population is not easy to fall into local optimal solution. The addition method of chaotic perturbation is shown in the following formula:

$$\begin{cases} \alpha_{n+1} = 4 \cdot \alpha_n (1 - \alpha_n) \\ X_n^{'} = X_n \cdot \eta + \alpha_{n+1} \cdot (a - X_n) \cdot (1 - \eta) \end{cases} \quad (6)$$

Among them, η is system generated random number between $(0,1)$.

3.7 End criterion

Towards the end of the search, the gap of social adaptation degree between maximum and average values also continues to close. At the same time, spreads the advantages and near distance will also continue to close, so the chaos genetic algorithm termination criterion is

$$\begin{cases} f_{\max} - \overline{f} \leq k \\ x_{ibest} - \overline{x} \leq g \end{cases} \quad (7)$$

Among them, k , g are set according to the different needs of different values, x_{ibest} , $\overline{x}$ are the largest factor and the average factor.

4 SIMULATION ANALYSES

Using chaos genetic algorithm to test the effectiveness of the three test optimization algorithm, compared with the traditional genetic algorithm and the general chaos genetic algorithm from the two aspects of the evolutionary algebra and computational accuracy of the algorithm, Paper gets table 1.Among them, the evolution algebra and the accuracy of each algorithm are 30 times after the calculation of the average value.

Function 1 is

$$F_1 = 80 - (x_1 - 2)^2 - x_2^2, 0 \leq x_1 \leq 4, -4 \leq x_2 \leq 4 .$$

The function is single peak function, the maximum point generated in the (2, 0), the peak value is 80. This function is used to measurement algorithm convergence speed. Such as in Figure 1.

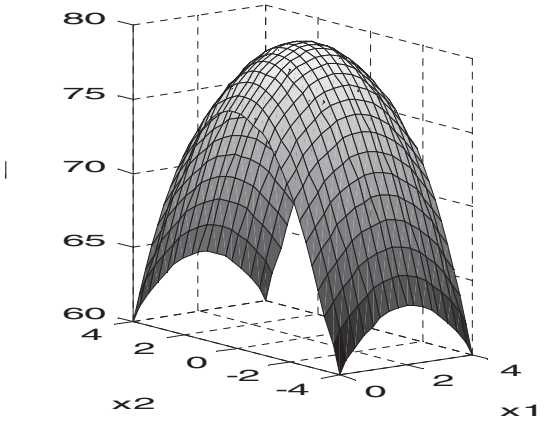

Fig 1. Function 1

Function 2 is

$$F_2 = 100(x_1^2 - x_2)^2 + (1 - x_1)^2, -2.048 \leq x_i \leq 2.048, i = 1,2$$

The function is difficult to minimization of pathological function and its extreme points is (1,1), minimum value is 0. This function can be used to test whether algorithms can overcome and prevent premature phenomena in the evolutionary. Figure 2 (for easy viewing, Z axis relationship 1000 times).

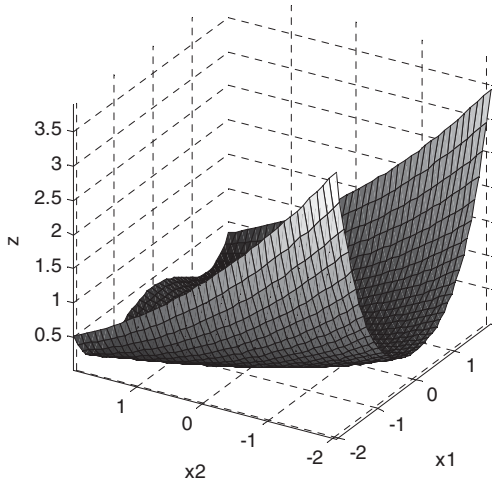

Fig 2. Function 2

Function 3 is

$$F_3 = 0.5 - \frac{\sin^2\sqrt{x_1^2 + x_2^2} - 0.5}{(1 + 0.001(x_1^2 + x_2^2))^2}, -4 \le x_i \le 4, i = 1,2 .$$

The function is with a large number of local optimal solution of multi peak function. This function is intended to investigate whether the algorithm can overcome the "premature" phenomenon. As shown in Figure 3.

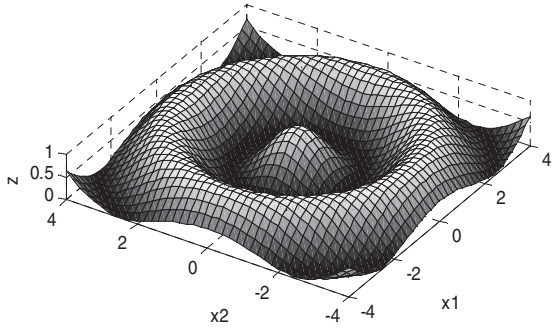

Fig 3. Function 3

Table 1 The optimal solution of all functions

	Algorithm	GA	CGA	MVCGA
Function 1	EA①	594	97	23
	MD②	831	318	2
	Solution	x_1=1.9895 x_2=0.0440	x_1=1.9895 x_2=0.0440	x_1=2.0013 x_2=0.0007
Function 2	EA	1085	286	42
	MD	1365	541	2
	Solution	x_1=1.0194 x_2=1.0218	x_1=0.9978 x_2=0.9960	x_1=0.9988 x_2=0.9988
Function 3	EA	242	30	11
	MD	237	58	1
	Solution	x_1=0.0421 x_2=0.0158	x_1=0.0145 x_2=0.0116	x_1=-0.0067 x_2=0.0025

Note:①Evolutionary Algebra: EA; ②Maximum difference: MD.

Table 2 The algebraic radio and error radio

	Algorithm	GA	CGA	MVCGA
Function 1	Algebraic ratio	25.8	4.2	1
	Error ratio	e_1=8.07 e_2=62.8	e_1=2.69 e_2=17.28	e_1=1 e_2=1
Function 2	Algebraic ratio	26.4	6.8	1
	Error ratio	e_1=16.1 e_2=18.1	e_1=1.83 e_2=3.33	e_1=1 e_2=1
Function 3	Algebraic ratio	22	2.7	1
	Error ratio	e_1=6.28 e_2=6.32	e_1=2.16 e_2=4.64	e_1=1 e_2=1

For Table 1, the error rate of each algorithm for each function is calculated, and the evolution algebra of each algorithm is used to improve the ratio of the evolution algebra of micro variation chaotic genetic algorithm. Table 2 can be obtained. And ratio error is to point improved chaotic genetic algorithm as a benchmark, each algorithm relative to the benchmark rates. Evolution algebra ratio is same to this point. (In order to comparison gap between the errors)

It can be found in the simulation process:

(1) The smaller the evolutionary algebra of the same algorithm, the greater the error of the calculation results.

(2) Stability of searching for genetic algorithm and chaos genetic algorithm is bad. Between two runs, the algebraic difference of the evolution is between large and small. The biggest difference can be explained by the ability of the global search and local search of genetic algorithm and chaos genetic algorithm, and the improved chaos genetic algorithm proposed by this title is Superior to above two.

(3) By comparing the data in the table, the evolutionary rate of chaos genetic algorithm is obviously faster than the traditional genetic algorithm. This paper proposes an improved genetic algorithm based on chaos genetic algorithm Again greatly improve. Therefore, this paper proposes an improved chaotic genetic algorithm which has the advantages of fast searching speed.

(4) The optimal solutions of the three algorithms are compared with the optimal solution of the function. It can be seen that the error of the chaotic genetic algorithm is less than that of the traditional genetic algorithm, and the improved chaos genetic algorithm has higher accuracy than the previous one.

5 CONCLUSIONS

This paper proposes a micro variation chaos adaptive genetic algorithm, which is based on the genetic algorithm, and improves the crossover operator, mutation operator and fitness function. The results show that the improved chaos genetic algorithm can not only accelerate the speed of optimization, but also improve the accuracy of the algorithm.

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