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A hybrid genetic algorithm based on mutative scale chaos optimization strategy

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Abstract: In order to avoid such problems as low convergent speed and local optimal solution in simple genetic algorithms, a new hybrid genetic algorithm is proposed. In this algorithm, a mutative scale chaos optimization strategy is operated on the population after a genetic operation. And according to the searching process, the searching space of the optimal variables is gradually diminished and the regulating coefficient of the secondary searching process is gradually changed which will lead to the quick evolution of the population. The algorithm has such advantages as fast search, precise results and convenient using *etc*. The simulation results show that the performance of the method is better than that of simple genetic algorithms.

Key words: genetic algorithm; chaos; mutative scale; optimization

Chaotic phenomena exist in nonlinear systems extensively. Chaos does not mean merely confusion, but a series of phenomena with exquisite internal configuration. Chaotic motion is characterized by ergodicity, randomicity and "regularity" which can traverse all status according to its own "rule" without repetition within certain scope. Therefore, if chaotic variables are introduced into the optimization search, it is sure that more advantages will be brought to the optimization process than random search does.

On the basis of chaos optimization theory, the chaos genetic algorithm (CGA) which makes genetic algorithm (GA) and chaos optimization tactic as a whole was proposed in this paper. And based on the search mechanism of GA, mutative scale chaos optimization strategy was used to overcome problems in the convergence of speed and local minima of simple genetic algorithms (SGA). The results from a series simulation of several test functions were presented and show that CGA can provide better calculating performance than that of SGA. And the proposed method was confirmed to be effective and quite acceptable.

1 GA and mutative scale chaos optimization strategy

1.1 Characteristic of GA

GA can be defined as a self-organization, self-adaptation artificial intelligence technique which is a general and dominate independent optimization and search technique emulating the mechanism and process of natural evolution. In general, compared with traditional optimization strategy, GA has favorable concurrence and the capacity of simplicity and maneuverability as well as the property in common uses.

Although GA has many advantages as mentioned above, the fact that the main genetic operation is random and unsupervised iterating search process under certain occurring probability will inevitably bring the possibility of degeneration during the process of providing evolving chances to individuals in the population. At the same time, there are also other disadvantages of GA such as premature convergence and local minima, *etc*. To solve these problems and keep the good performance of GA, a variety of improved GA have been proposed recently. Based on the reasons mentioned above, a hybrid genetic algorithm based on mutative scale chaos optimization strategy was proposed in this paper.

1.2 Mutative scale chaos optimization strategy

The main characteristic of chaos is its extreme sensitivity dependent on the change of system initial states. The common chaotic optimization method is inefficacy when used in problems with big searching space in contrast with the condition when used in problems with small searching space. Mutative scale chaos optimization strategy proposed by the authors of reference [4] is, therefore, a necessity for handling these problems. The characteristic of the strategy is

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that the chaotic variable is used in the searching process after the linear mapping from the chaotic variable to the interval value of the optimal variables, and according to the searching process, the searching space of the optimal variables can be gradually reduced and the regulating coefficient of the secondary searching process can be gradually changed, which lead to the great improvement of the efficiency of the optimization. The method goes as follows.

The Logistic mapping is expressed by:

$$X_{n+1} = \mu x_n (1 - x_n) \qquad (1)$$

where μ is the control parameter; n = 0, 1, 2, ⋯. When μ is equal to 4, for any n initial values with slight difference (should not be the fix point of equation (1)), $x_n(0) \in [0,1]$, n chaotic variables with different trajectories can be obtained.

If the objective function is written as:

$$f^* = f(x_i^*) = \min f(x_i) \qquad (2)$$

where i = 1, 2, ⋯, n, $x_i \in [a_i, b_i]$, then the mutative scale chaos optimization procedure can be summarized as follows.

(1) The initialization of the algorithm: Let k denotes iterating mark of chaotic variable, and k' denotes the search mark, here k =1, k'=1, $x_i(k) = x_i(0)$, $x_i^* = x_i(0)$, $f^* = f(0)$, $a_i(k') = a_i$, $b_i(k') = b_i$.

(2) Mapping the chaotic variable $x_i(k)$ to the interval value of the optimal variables:

$$y_i(k) = a_i(k') + x_i(k)\,(b_i(k') - a_i(k')) \qquad (3)$$

(3) Use chaotic variables to search: if $f(y_i(k)) < f^*$, then $f^* = f(y_i(k))$, $x_i^* = y_i(k)$; otherwise continue.

(4) $k := k+1$, $x_i(k) := 4\,x_i(k)\,(1 - x_i(k))$.

(5) Execute steps (2)-(4) repeatedly, until f^* preserves fixedness in some tolerance after some steps, then go to the following steps.

(6) Using equations (4), (5) to reduce the casting area of chaotic variables:

$$a_i(k'+1) = y_i^* - \gamma(b_i(k') - a_i(k')) \qquad (4)$$

$$b_i(k'+1) = y_i^* + \gamma(b_i(k') - a_i(k')) \qquad (5)$$

If $a_i(k'+1) < a_i(k')$, then $a_i(k'+1) = a_i(k')$;

If $b_i(k'+1) > b_i(k')$, then $b_i(k'+1) = b_i(k')$;

thereinto adjustable modulus $\gamma \in (0, 0.5)$, y_i^* is the current best solution.

(7) Reducing treatment to x^* is given as:

$$x_i^* = \frac{y_i^* - a_i(k'+1)}{b_i(k'+1) - a_i(k'+1)} \qquad (6)$$

(8) Equation (7) is used to determine the new chaotic variable $y_i(k)$, then repeat the process (2)-(4) to execute the chaotic search, until f^* preserves fixedness in some tolerance after some steps, then go to the following steps.

$$y_i(k) = (1-\alpha)x_i^* + \alpha x_i(k),\ 0<\alpha<1 \qquad (7)$$

(9) $k' := k'+1$, diminish α, and repeat the steps (6)-(8).

(10) Repeat step (9) several times, and stop the calculation, then y_i^* is the optimal variable, and f^* is the optimal solution.

1.3 The combination of chaos optimization algorithm and GA

In GA, after a genetic operation of selection, crossover and mutation to the population, the max and average value of its fitness are improved apparently. As to the problem described in equation (2), because the optimal solution corresponds to the lowest situation of system's power, the power of adjacent area is also lower comparatively, if the chaotic search algorithm is used to the individuals with high fitness value at the same time, the search speed, as well as the property of GA will be improved greatly. Based on the above mentioned, reference [5] presented a hybrid genetic algorithm, and the results are acceptable. In this paper, in order to improve the property of GA, a model combining mutative scale chaos optimization strategy and GA is given (**figure 1**). Steps of the algorithm are given as follows.

(1) Input the initial data: analyze the given problem and obtain the radical feature information.

(2) Specify the required parameter of GA: the population size M = 10; the crossover probability p_c= 0.8; the mutative probability p_m=0.15.

(3) Generate the initial population and encode it. Certain encoding scheme is chosen to generate the genetic coding of the initial population (decimal codes are used in this paper). Every genetic coding is a certain individual that represents a solution of the optimization problem. The main job of GA is to simulate the natural selection process which starts from the above mentioned initial population, gains an excellent population and individuals which satisfies the conditions of the optimized problem at last.

(4) Compute the values of the objective function (fitness values of individuals). Compute the fitness value of every individual in population by the rule of coding, the bigger the objective function value, the bigger the corresponding fitness value, the more it can

fit to environment. So the fitness value can be used in selection during the evolution process of a population.

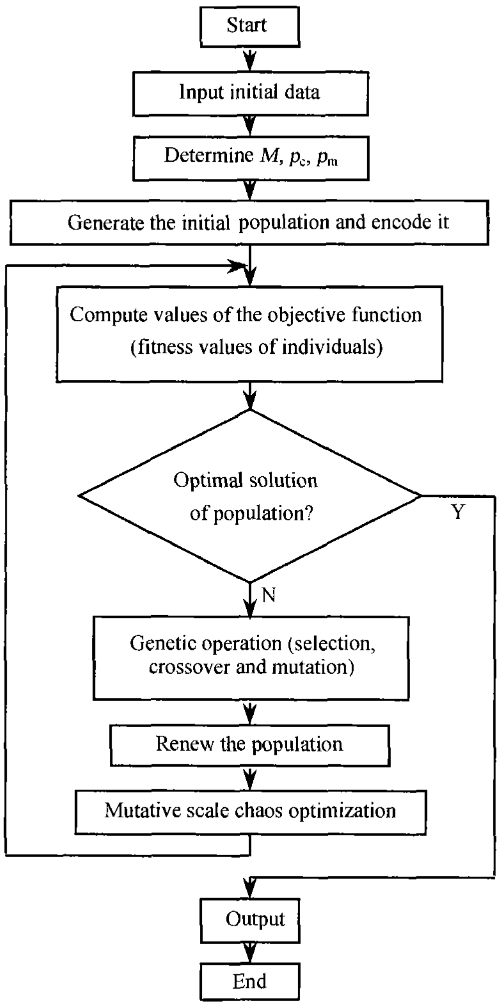

Figure 1 Model of mutative scale chaos genetic algorithm.

(5) Genetic operation (selection, crossover and mutation). In order to improve the global and local search abilities, a proportional selection strategy is used in this paper, as the same time an arithmetical crossover and a Guass mutation strategy are also used to fulfill the crossover and mutation operation.

(6) Mutative scale chaos optimization strategy is used in the chaotic search for the individuals with high fitness value, which lead to the evolution of population and improvement of search speed.

To the new generation, iterate the process of evaluation, selection, crossover and mutation to improve the fitness value of the optimal individual and the average fitness value of the population, until they are no longer increased or the fitness value of the optimal individual reaches the given limits which represents the end of the algorithm.

2 Examples of the Algorithm

In order to verify the property of the chaos genetic algorithm, we use it in the follow four test functions, at the same time a comparison between chaos genetic algorithm and SGA is given, the result is shown in **table 1**, where the optimal target is to obtain the global minima of every test function, and the ratio of convergence to the global optimal solution is obtained by executing every program 50 times randomly, the convergent condition is $|f-f^*|\le 0.002$, where f^* is the global optimal solution.

Table 1 Comparison of MSCGA and SGA

Test functions	Global optimal point	Global Optimal solution	Optimization method	Ratio of convergence to Global optimal solution / %	Iterative numbers of feasible solution before obtaining Global optimal solution
F_1	(1, 1)	0	MSCGA	100	1996
			SGA	69	4025
F_2	(0, 0)	0	MSCGA	100	1081
			SGA	58	3192
F_3	(0, 0)	0	MSCGA	100	837
			SGA	100	616
F_4	(−0.0898, 0.7126)	−1.031628	MSCGA	100	2224
	(0.0898, −0.7126)		SGA	21	5488

$F_1=100(x_1^2-x_2)^2+(1-x_2)^2$, $x_i\in[-2.048,2.048]$;

$F_2=\sum_{i=1}^{3}x_i^2$, $x_i\in[-5.12,5.12]$;

$F_3=0.5+\frac{\sin^2\sqrt{x_1^2+x_2^2}-0.5}{[1+0.001(x_1^2+x_2^2)]^2}$, $x_i\in[-100,100]$;

$F_4=(4-2.1x_1^2+\frac{x_1^4}{3})x_1^2+x_1x_2+(-4+4x_2^2)x_2^2$,

$x_1\in[-3,3]$, $x_2\in[-2,2]$.

As shown in table 1, when using chaos genetic algorithm, every test function mentioned above converges to the global optimal solution by 100%, but on the contrary, when using SGA, almost every test function except F_3 can not converge to the global optimal solution by 100%; in the searching times' view, the iterative numbers of feasible solution of MSCGA is far less than that of SGA (except F_3). This, in turn, save the program's routine time greatly. On all accounts, MSCGA is quite promising in optimal computation, moreover, it has better synthetic performance than that of SGA.

3 Conclusions

(1) By making use of the chaotic variable's own regularity and characteristic, the mutative scale chaos optimization strategy can diminish the search space gradually during the optimal process, which can avoid the local optimal solution easily. This increases the efficiency as well as the precision of optimization.

(2) The strategy which introduces the chaos optimization tactic into GA on condition that the search mechanism of GA holds the line can lead to the quick evolution of the population and improve the performance of SGA greatly.

(3) This strategy has many advantages, such as the fast search, the precise results, the convenient using. The simulation results show that the performance of this method is better than that of simple genetic algorithm. It also shows that the proposed method is quite promising.

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