An improvement Adaptive Genetic Algorithm

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Abstract. In order to solve the premature convergence and local optimization and improve the global optimum and fast convergence, a new adaptive genetic algorithm is presented in this paper. It is based on the evaluation of population diversity and calculation of fitness value. The experimental result shows that the algorithm is clearly improved in aspects of convergent speed and stability and gets the desired results.

Keywords: genetic algorithm; population diversity; population entropy; crossover; mutation

1. Introduction

Genetic algorithms are global stochastic optimization techniques which imitate the natural selection and evolutionary mechanisms in biosphere [1]. It is originally created by the U.S university of Michigan professor Holland and his students who are inspired by the biological simulation technology. The genetic algorithms have many characteristics such as global search, internal parallelism, simple and universal, robust strongly, and fast convergence etc. They are suit for solving the search complex problems in the system. As the rapid development of the genetic algorithms, they are widely used in many fields to solve the optimization problems. In this paper, after studying the main flow of the genetic algorithm and the traditional improved algorithms, we propose an improved suggestion for the important parameters that could influence the performance of genetic algorithm.

2. The Basic Process of the Genetic Algorithm

2.1. The main steps of genetic algorithm:
  1） determine the program of coding and generate initial population;
  2） assess the fitness function;
  3） to determine whether meet the terminating condition;
  4） according to the selection strategy to execute the selected operation;
  5） according to the crossover probability to execute the crossover operation;
  6） according to the mutation probability to execute the mutation operation;
  7） return to the third step(3) .

2.2. The basic process of the genetic algorithm shown in Fig1:

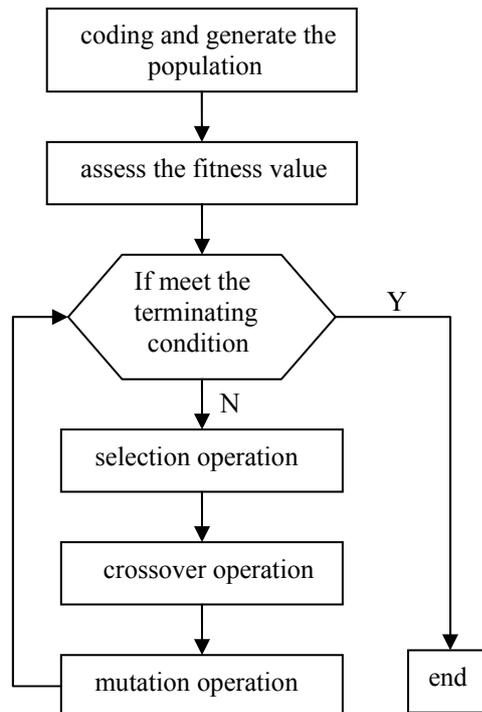[+]   Corresponding author.   *E-mail address*: zyc_hd@sina.com

Figure1.The flow chart of genetic algorithm

3. The Important Parameters in the Genetic Algorithm

The behavior and property of the genetic algorithm mostly depend on the selection and identify of crossover probability and the mutation probability [2].In the following, we will illustrate the prone problems in the Standard genetic algorithm (SGA) and Adaptive genetic algorithm (AGA) by introducing the related concepts and the defects in the two algorithms.

3.1. The concepts of the basic operations in genetic algorithms:

1） Selection: According to computing the fitness value of each individual, this operation uses a selection strategy (such as roulette wheel selection) to select the superior individuals from the parents population to inherit to the next generation. It is similar to the survival of fitness principle in the nature (That is, the individuals who have larger fitness will contribute more to the next generation).

2） Crossover: Crossover operation is the most important operation in genetic algorithm[3].In this operation, we will compute a crossover probability to compare with the given crossover value to choose the individuals will participate the crossover ,then paired with them and exchange part of chromosomes of them using a crossover strategy (such as single crossover).

3） Mutation: In this operation, we will use a certain mutation probability to select genes to participate mutation. Then to exchange the gene value to its allele. The mutation operation will provide the opportunity for the new individuals.

3.2. The defects of the Standard Genetic Algorithm (SGA) and Adaptive Genetic Algorithm (AGA):

● The local search ability of the Standard Genetic Algorithm is bad and this algorithm's convergence speed is slow. One important reason of this is the algorithm's crossover probability and mutation probability are predetermined and fixed. Optimization of complex functions could not be based on the current status of population and individuals to dynamically adjust its probability. Then the population becomes premature and falls in local convergence early. At the biological view, although this algorithm considers the population's adaptation ability to the environment, it neglects the population's adaptation ability following the change of environment. The adaptability of the individual is bad.

● Based on computing the individual fitness, in the adaptive genetic algorithm, crossover probability and mutation probability are adjusted linearly between average fitness value and changing fitness value. When the fitness value is closer to the maximum value, the crossover probability and mutation probability become smaller. When the fitness value closes to or equal to the maximum fitness value, the crossover probability and mutation probability close to or equal to zero[4]. Adaptive Genetic Algorithm is suit for the later evolution not for the early stage. Some superior individuals almost stay the state of unchanged and others in the population are eliminated, then, speed up the convergence speed of the population. But the population is difficult to converge to the global optimal solution, culminating in the phenomenon of premature convergence [5].

4. The Improvement of Important Parameter in Genetic Algorithms

In order to ensure the global convergence of genetic algorithm, maintaining diversity of population is the first. On the other hand, in order to accelerate the convergence speed, it is necessary to make the population relatively rapid shift to the optimal state. This will reduce the population diversity. To avoid the algorithm easily traps into local optimum early and find optimal solutions rapidly in the same time and to prevent premature convergence of genetic algorithms are difficult. Currently the control of genetic algorithm parameter settings still lacks of a reasonable theory to guide. Parameter selection in Standard Genetic Algorithm and the Adaptive Genetic Algorithm make the phenomenon of early maturity and local optimization problem appear, a major reason is the premature loss of population diversity. The following method is proposed to improve the phenomenon.

4.1. Evaluation of population diversity

Usually the size of population is determined, the greater the diversity of population is ,the population more likely to produce better generation; while the smaller population diversity is ,then population continues convergent in individuals, the more prone to premature convergence[2]. Evaluation of population entropy is an indicator of population diversity.

Definition of population entropy [1]: We set p(t) is the tth generation population, population size is N.

According to the different types of individuals into m parts $P_1(t), P_2(t)....P_m(t)$, obviously, $\bigcup_{i=1}^{m} p_i(t) = p(t)$ .And

for $\forall i, j \in \{1,2...m\}$ there are $P_i(t) \bigcap P_j(t) = \emptyset$ .Set $k_1, k_2......k_m$ are the size of $P_1(t), P_2(t)...... P_m(t)$,so

$\sum_{i=1}^{m} k_i = N$ .Delimit the value of population entropy of the t generation is $E_i = -\sum_{i=1}^{m} p_i \log p_i$,where $p_i = k_i / N$.

From the above definition, when the individuals in the population are different from each other, that is m=N, the value of entropy achieves the maximum $E_{max} = \log N$ .When the individuals in the population are all the same, the value of entropy achieve the minimum $E_{min} = 0$. The more types of individual population have, the more evenly distributed, the greater the entropy is. In the process of algorithm runs, the value of population entropy will change with the changing of the diversity of population. By comparison of the value of current population entropy and the maximum value, we can measure the diversity of contemporary populations. Set $a = E_t / E_{max}$, and $a \in [0,1]$.

The value of a is larger, the number of different individuals in the current population is greater. The diversity of population is larger, on the contrary, the population diversity is smaller. When the population diversity is higher, that is a is larger, the ability of population to search the better individuals is greater. You should improve the crossover probability and decrease the mutation probability. When the population diversity is lower, that is a is smaller, the ability of population to search the better individuals is weaker. Therefore, the mutation probability should be increased to enhance population diversity, then avoid the phenomenon of local optimization occurs[6].

4.2. The improvement of parameters in genetic algorithm

With the concept of population entropy, we will adjust the crossover probability and mutation probability by two steps:

1）The first step: According to the diversity of contemporary populations (ie, population entropy) to determine probability ranges:

$$\begin{cases} p_{c1}(t) = p_{c1} + \dfrac{(p_{c2} - p_{c1})}{2} * a_t \\ p_{c2}(t) = p_{c2} - \dfrac{(p_{c2} - p_{c1})}{2} * (1 - a_t) \end{cases}$$

Where, p_{c1}, p_{c2} are the range of the initial crossover probability and $p_{c2} > p_{c1}$; a_t is the tth population diversity. $p_{c1}(t), p_{c2}(t)$ are the range of crossover probability in tth generation population. In the above equation, a_t is larger, the crossover probability is larger. In the contrary, it is smaller.

$$\begin{cases} p_{m1}(t) = p_{m1} + \dfrac{(p_{m2} - p_{m1})}{2} * (1 - a_t) \\ p_{m2}(t) = p_{m2} - \dfrac{(p_{m2} - p_{m1})}{2} * a_t \end{cases}$$

Where, p_{m1}, p_{m2}, is the range of initial mutation probability, and $p_{m2} > p_{m1}$; a_t is the tth population diversity $p_{m1}(t), p_{m2}(t)$ .are the range of mutation probability in tth generation population. With the above equation, a_t is larger, the mutation probability is smaller. In the contrary, it is larger.

2） The second step: According to the determining of the range and the fitness value, we will determine the value of crossover and mutation probability.

$$p_c = \begin{cases} \dfrac{p_{c1}(t)(f_{avg} - f') + p_{c2}(t)(f' - f_{min})}{f_{avg} - f_{min}} & f' < f_{avg} \\ \dfrac{p_{c2}(t)(f_{avg} - f') + p_{c3}(t)(f' - f_{avg})}{f_{max} - f_{avg}} & f' \geq f_{avg} \end{cases}$$

$$p_m = \begin{cases} \dfrac{p_{m1}(t)(f_{avg} - f) + p_{m2}(t)(f - f_{min})}{f_{avg} - f_{min}} & f < f_{avg} \\ \dfrac{p_{m2}(t)(f_{avg} - f) + p_{m3}(t)(f - f_{avg})}{f_{max} - f_{avg}} & f \geq f_{avg} \end{cases}$$

Where, f_{max} represents the maximum value of the population, f_{avg} represents the average value of every generation population [7], f_{min} represents the minimum value of the population, f' represents the larger value in the two individuals to cross, f represents the fitness value of the individual to mutate; $p_{c1}(t), p_{c2}(t)$ represents respectively the upper and lower limits of the crossover probability after the adjusting in the first step. $p_{c3}(t)$ is a constant, and $p_{c3}(t) < p_{c1}(t) < 1$; $p_{m1}(t), p_{m2}(t)$ is the upper and lower limits of the mutation probability after the adjusting in the first step. $p_{m3}(t)$ is a constant, and $p_{m3}(t) < p_{m1}(t) < 1$.

5. The Experimental Result

Here we give one function to compute the genetic algorithms (Standard Genetic Algorithm (SGA), Adaptive Genetic Algorithm(AGA) and the algorithm in this paper(TAGA)) maximum value and the results show in the Table 1:
The function:

$$f_1(x) = \sum_{i=1}^{4} x_i, \qquad -2.56 < x_i < 2.56$$

TABLE I.   comparison for the average evolution generation of genetic algorithms to the specified function

	SGA	AGA	TAGA
19.20	8	5.1	1
19.37	11	7.2	1.6
19.556	26	12.4	3.3
19.60	135	47.4	3.4
19.66	165	67.8	7.8

6. Conclusion

In this paper, by the evaluation of population diversity, we improve the determination about the operation probability of the genetic algorithm and adjust them by two steps. So that it can be better to control the crossover and mutation probability according to the status of the current population and make them can change with the change of fitness value. Also we can be able to make the largest fitness value of individual in the population not equals zero. This can improve the superior individuals' crossover probability and

mutation probability and makes them not always in a state of near stagnation. This method can make the algorithm to jump out of the local optimal solution and overcome the premature shortcomings and avoid the premature convergence phenomenon occurs because of the loss of population diversity. The experimental result shows that the algorithm is improved.

7.　References

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