An Adaptive Genetic Algorithm based on Population Diversity strategy

Chen Lin
College of Computer science, Yangtze University, Jingzhou Hubei, 434023, China
(chan_@sohu.com)

Abstract-- *Genetic Algorithms are adaptive methods which may be used to solve search and optimization problems. Three basic operations in Genetic Algorithms are selection, crossover and mutation, an important problem using Genetic Algorithms is the premature convergence in local optimum. This paper presents an adaptive genetic algorithm which adjusts probability of mutation dynamicly based on average square deviation of population fitness value that shows the population diversity to solve premature problem. Compared Analysis shows the proposed adaptive Genetic Algorithm is efficient to avoid premature.*

Keywords-- *Genetic Algorithms, population diversity, mutation*

Ⅰ. Introduction

The Genetic Algorithms (GAs) are proposed based on Darwin's principle of survival of the fittest by professor J.H.Halland in 1975 to solve larger scale combination optimization problem. It can jump out local search space to achieve optimal solutions in global space. In Genetic Algorithms, it process a population of individuals which represent search space solutions, each individual is candidate solution and population including all individuals are examinated Simultaneously, and quality of population are improved gradually, at last the best solution or secondary solutions are achieved by repeating employing three GA operations: selection, crossover and mutation. GA are theoretically and empirically proven to provide robust search capabilities in complex spaces, offering a valid approach to problems requiring efficient and effective search[1,2].

An important problem in usage of GA is premature convergence; the search may trap in a local optimum before the global optimum is found. Premature convergence can be blamed on[3]: the loss of critical alleles due to selection, the schemata disruption due to crossover, and the parameter setting such as mutation rate, crossover rate and population size. Mainly, all these issues produces two effects which cause the problem[4]: the lack of diversity in the population and a disproportionate exploitation or exploration relationship; e.g., adequate balance between a broad search and a sufficient refinement is not established.

In order to solve the premature problem, some tools are needed to monitor the genetic process. In fact, there are several strategies for maintaining population diversity and a good exploitation or exploration relationship, such as modified selection and crossover operators, or optimization of control parameters studies, and so on.

In general, the three GA operations all influence population diversity varying in degrees. The selection operation reduces the diversity of population, the crossover operation does not decrease the diversity of population, and the mutation operation can advance the diversity.

Many investigations have been attempted to find optimal mutation probability because this probability can improve diversity of population. Shen[5] proposes an adaptive GA to improve diversity of population by adjust operation parameter based on fitness function; Liu[6] proposed novel mutation operator strategy using direction character to determine the mutation probability and positions adaptively; in [7], fuzzy strategy is proposed by using mean square deviation of group fitness and population generation as the criteria of premature convergence. These methods have well ideas, and can solve partial real problem such as design of industrial controller, TSP problem and so on.

This paper adopts adaptive idea to adjust mutation probability dynamicly based on average square deviation of fitness for multi-peak function search problems, aim to overcome premature problems.

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Ⅱ.Design of Adaptive Genetic Algorithm

A. Basic Ideas

As described above, the mutation operation can advance the diversity of population. In standard GA, the genetic operator is fixed or does not change during the GA executing. At the last procedure of GA, all individuals may get the same values, this will make the algorithm be limited in a local space and can not achieve global optimal solutions. In general, average square deviation of population (for short as ASD) describe the specific differences of population, bigger the ASD value, bigger the specific differences. When the ASD becomes smaller or less, it shows that many individuals are becoming as the same, so the mutation probability should be increased to advance the diversity of population for getting global optimal solutions. The adaptive idea in this paper is to adjust mutation probability dynamicly based on ASD during the GA executing, this algorithm is named as modified GA or MGA.

B. Evaluation Indicators

Definition 1: average fitness is the fitness accumulation of all individual fitness, described as:

$$f_v = \frac{1}{N}\sum_{i=1}^{N} fit(x_t^i)$$

Where the f_v is the average fitness of the t th generation, N is the number of population, and the $fit0$ is the evaluation function, x_t^i expresses the individual x^i in t th generation .

Definition 2: In the t th generation, the average square deviation of population ASD is described as:

$$ASD_t = \frac{1}{N}\sqrt{\sum_{i=i}^{N}\left(fit_t^i - f_v\right)^2}$$

In the formula above, the ASD_t is the average square deviation of population in the t th generation which indicates the population difference or diversity, its less value expresses that the population diversity is becoming less, so the mutation probability will be increased dynamicly based on this value for next generation. The fit_t^i is the fitness value of the individual i in the t th generation.

C. Design of MGA

1) Real number coding is adopted to present real population change in function optimization procedure.

2) Selection operator: hybrid selection methods. At first, the fixed number best individuals are selected into next generation directly, then Monte Carlo method is used to select remaining individuals. In theory, the individuals with better fitness may be selected into next generation more than one times. In each generation, the number of individual is fixed.

3) Crossover operator: a adaptive method is used which is named as RGA. In crossover procedure, two individuals are selected who have the most remote distance. this method avoids consanguineous marriage and optimize next generation. Then two individuals with the most remote distance in remaining individuals are selected to complete crossover procedure, until remaining individuals are empty. After finishing crossover, the same number individuals are generated. The number of population is fixed.

4) Mutation operator. In popular GA, the mutation probability is fixed during all the evolution procedure. This paper proposes a adaptive method to adjust mutation probability dynamicly based on the ASD value. When the ASD decreasing, mutation probability will be increased to advance the population diversity. The relationship between mutation probability and ASD is given following:

$$p_m = M_a * (1 + \frac{f_{\max} - ASD_t}{f_{\max} + ASD_t})$$

M_a is mutation probability fixed, $f_{\max}$ is the largest fitness in current generation. In this formula, dynamic mutation probability p_m is related with fixed mutation probability M_a and ASD_t. In direct, when ASD_t value decreases, the p_m will increases dynamicly. The effect of dynamic mutation probability will be showed in next section.

Ⅲ.Simulation Analysis

A. Simulation Function

Two functions are used to simulate the proposed methods.

$f1$:Rosenbrock function

$$\min \ f1(x,y) = 100\,(x^2 - y)^2 + (1 - x)^2$$
$$-2048 \le x, y \le 2048$$

$f2$:Shube function

$$\min \ f2(x,y) = \sum_{i=1}^{5} i\cos((i+1)x + i) \times \sum_{i=1}^{5} i\cos((i+1)y + i) + 0.5(x + 1.42513)^2 + (y + 0.80032)^2$$
$$-10 \le x, y \le 10$$

$f1$ is a no quadratic function with single peak. But it is a morbid function. Because there is a long narrow deep gorge in $y = x^2$, it is difficult to find minimum value. In the GA procedure, algorithm may step into local space. There is a minimum value 0 in (1,1) . $f2$ has a Maximum value 1 in (0,0) ,but it may step into local space easily.

B. Simulation Results

During simulating, crossover probability is set as 0.75, the fixed mutation probability is 0.01, in our proposed MGA, mutation probability will be adjusted dynamicly based on this fixed probability. Number of population is 100, iteration number is 600, and 4% best individuals will be selected into next generation in selection operation.

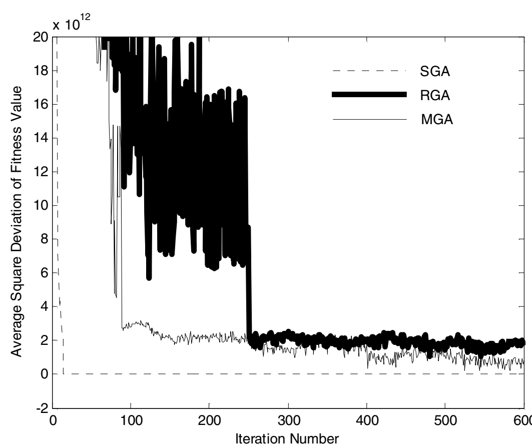

Fig1: ASD value about function f1

SGA is standard GA, RGA adopts the most remote distance crossover strategy, our proposed GA is named as MGA.

Fig1 and fig2 are the ASD values in difference iteration number. In fig1, SGA is premature, RGA and MGA all avoid premature convergence and step to the global minimum value, and our MGA has fast convergence rate compared with RGA and also avoids premature. In fig2, RGA and MGA have similar convergence rate, and SGA has a violent shock around a minimum value.

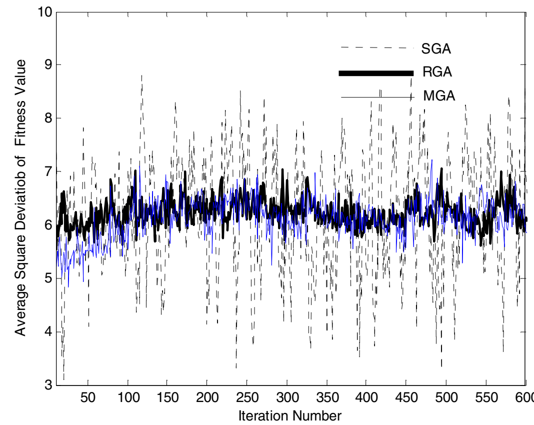

Fig2: ASD value about function f2

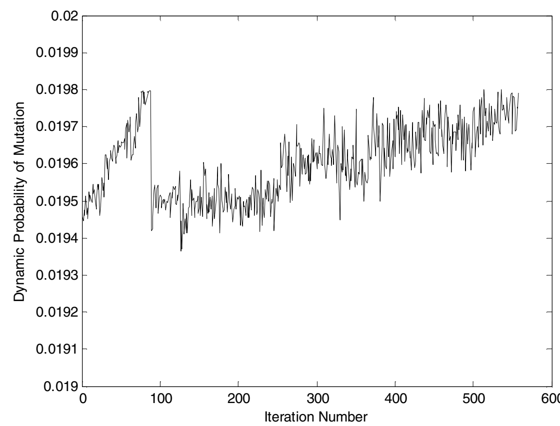

Fig3: dynamic mutation probability of function f1

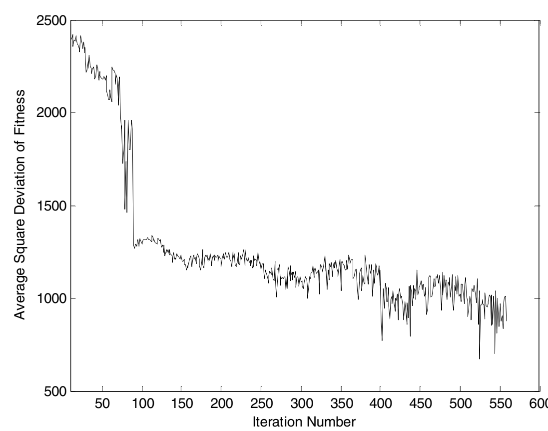

Fig 4: ASD value of MGA about function f1

Fig 3 and fig4 show that mutation probability change with the current ASD value. When the ASD values in fig4 decrease which means the individual similarity are being increased, the mutation probability p_m in fig 3 will be increased based on dynamic formula in section 2.

Fig5 and fig6 also show the change of p_m with current ASD value.

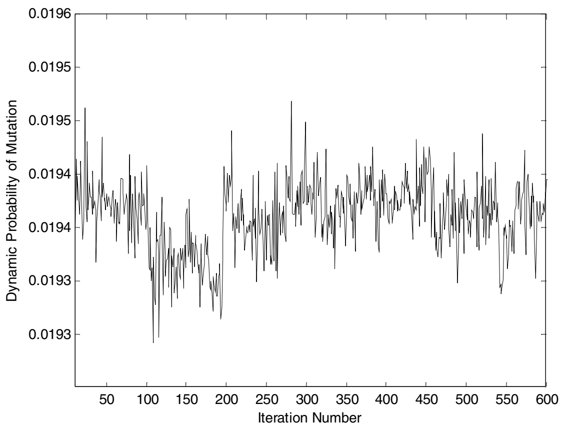

Fig5: dynamic mutation probability of function f2

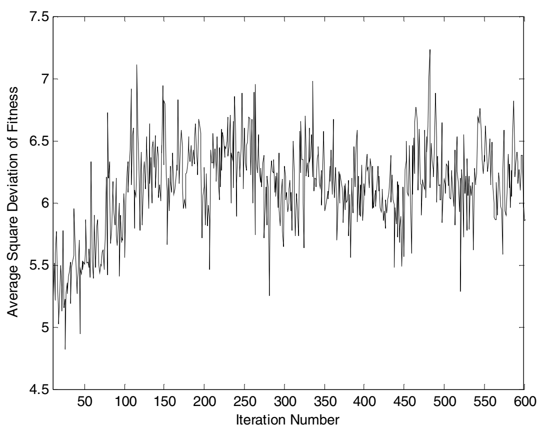

Fig 6: ASD value of MGA about function f2

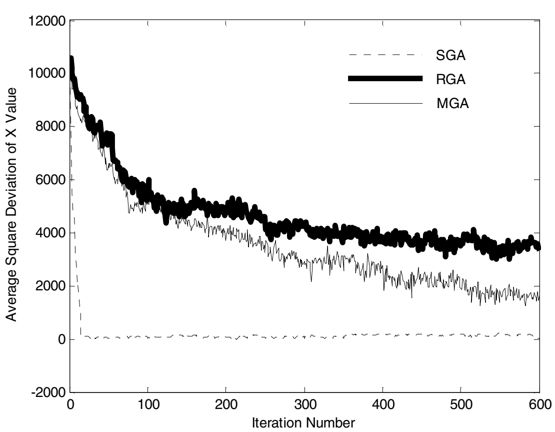

Fig7: ASD value of X value about function f1

Fig7 and fig8 expresses ASD value of axis about function f1. From a long view of the matter, the solution (x,y) value about f1 will convergence on a most optimal solution. At the same time, proposed MGA can convergences faster than the RGA.

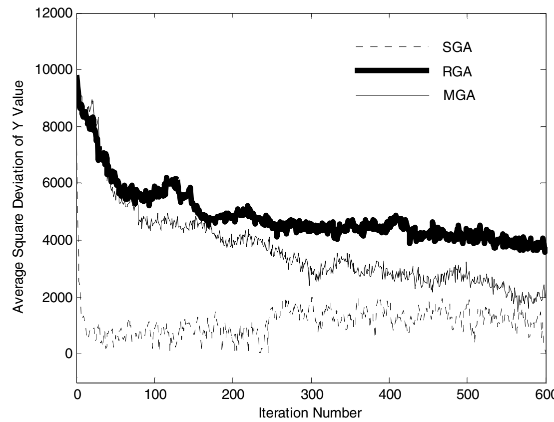

Fig8: ASD value of Y value about function f1

Ⅳ. Conclusions

This paper has proposed an adaptive GA which adjusts mutation probability dynamicly based on average square deviation of fitness in each generation. Simulation results show that this proposed GA can avoid premature and can find a most optimal solution in global search space.

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