Optimization Algorithm of Fireworks Explosion Based on Genetic Algorithm

Dandan Wang and Kai Yang

ABSTRACT

Fireworks algorithm is proposed in recent years, which has a strong ability to solve optimization problems. In this paper, a new algorithm, GA-FWA (Genetic Algorithm Based Fireworks Algorithm), is proposed by combining Genetic Algorithm with Fireworks Algorithm. The GA-FWA can improve the explosion radius of Fireworks Algorithm and add the crossover and mutation operation of Genetic Algorithm into Fireworks Algorithm. A large number of experiments show that the genetic algorithm based on the fireworks explosion optimization algorithm can greatly improve the search efficiency, avoid falling into the local optimal value, and improve the optimization accuracy and stability.

INTRODUCTION

Fireworks algorithm is a kind of parallel explosive search method by introducing random factors and selection strategy, which is developed into an optimization algorithm with strong optimization ability in recent years. Fireworks algorithm by simulating the behavior of fireworks explosion in the air to establish the corresponding mathematical model [1]. Genetic algorithm is a global, simulated biological evolution process search optimal solution method. Genetic algorithm uses the idea of biological genetics and evolution to study the principle of biological evolution of "survival of the fittest, survival of the fittest", so as to evolve a better and better approximate solution [2,3]. There are many similarities between genetic algorithm and fireworks algorithm. For example, the two algorithms initialize the population randomly, and search the population randomly through the fitness of the population.

Dandan Wang, Kai Yang. University of Science and Technology Liaoning, DC 114051, China.
individual, and evaluate the quality of the individual. Therefore, in order to solve the
problem that genetic algorithm is easy to "precocity", we combine genetic algorithm
with fireworks algorithm and propose a new algorithm--GA-FWA. This algorithm
can effectively avoid the optimization process into the local optimal problem, and
can improve the optimization accuracy and speed, find the global optimal value.

At present, the improved Fireworks Algorithm and Fireworks Algorithm have
been applied to many practical problems, such as solving equations [4], NMF
calculation [5], multi-objective search of swarm robot [6], power system
reconstruction [7] and so on.

ORIGINAL FIREWORKS ALGORITHM

The standard fireworks algorithm (FWA) is to generate a certain number of
fireworks in the search space through fireworks, and the fireworks exploded with a
certain number of sparks. In the generated sparks, several fireworks (sparks) with
good fitness value are selected through selection strategy to continue to explode. Let
the fireworks fill the entire search space[8]. Repeating the fireworks explosion and
the selection process, the global optimal value can be searched more quickly, and the
search efficiency is improved, meanwhile the problem of getting into local optimal
is avoided.

The number of sparks produced by each fireworks explosion in the fireworks
algorithm:

\[ S_i = m \cdot \frac{Y_{\max} - f(x_i) + \varepsilon}{\sum_{i=1}^{N} (Y_{\max} - f(x_i)) + \varepsilon} \]  \hspace{1cm} (1)

In the formula (1), \( S_i \) is the number of sparks generated by the \( i \)-th fireworks; \( m \)
is a constant to limit the total number of sparks produced; \( Y_{\max} \) represents the fitness
of the largest and the worst individuals in the current population; \( f(X_i) \) is the fitness
of individual \( X_i \); \( \varepsilon \) represents a minimal constant to avoid zero in the fraction.

The first \( i \) (\( i=1, 2, 3,.., n \)) fireworks explosion radius:

\[ A_i = \hat{A} \cdot \frac{f(x_i) - Y_{\min} + \varepsilon}{\sum_{i=1}^{N} (f(x_i) - Y_{\min}) + \varepsilon} \]  \hspace{1cm} (2)

In the formula (2), \( A_i \) is the range of the explosion of the \( i \)-th fireworks, that is,
the spark of the explosion will randomly shift in this range, but cannot exceed this
range; \( \hat{A} \) is a constant, representing the maximum explosion amplitude; parameter
$Y_{\text{min}}$ represents the fitness of the smallest and best individuals in the current population; $f(X_i)$ and parameter $\varepsilon$ represent the same meaning as formula (1).

The distance between any two individuals in the algorithm is measured by Euclidean distance:

$$R(x_i) = \sum_{j=1}^{k} d(x_i, x_j) = \sum_{j=1}^{k} \|x_i - x_j\|$$  

(3)

In the formula (3), $d(X_i, X_j)$ represents the Euclidean distance between any two individuals $X_i$ and $X_j$; $R(X_i)$ represents the sum of the distance between the individual $X_i$ and the other individual; $j \in K$ means that the jth position belongs to the set $K$; the set $K$ is the set of locations of sparks.

Individuals choose to use roulette way, the probability of each individual being chosen with $p(X_i)$, that is:

$$p(x_i) = \frac{R(x_i)}{\sum_{j=x} R(x_j)}$$  

(4)

From formula (4) we can see that the greater the distance of fireworks or sparks, the greater the probability of being selected. So that we can avoid falling into the local optimal, find the global optimal value. Selecting sparks with large distance can increase the diversity of the population and improve the accuracy of global search.

**GA-FWA ALGORITHM**

**Improvement of Explosion Radius**

In the formula (2), $f(X_i)$ is the fitness of the individual $X_i$; the parameter $Y_{\text{min}}$ represents the fitness of the smallest and best individuals in the current population. So bring the best fireworks from the explosion into the formula (2):

$$A_i = \hat{A} \cdot \frac{\varepsilon}{\sum_{i=1}^{n} (f(x_i) - Y_{\text{min}}) + \varepsilon}$$  

(5)

From formula (1), we know that the smaller the fitness value, the more sparks will be produced when the fireworks explode. At the same time, according to formula (5), the smaller the fitness value is, the more close the explosion radius of fireworks is to zero, which is equivalent to the almost unchanged position of sparks produced after a fireworks explosion. However, when the next round of fireworks
explodes, according to formula (4), these fireworks and sparks will be almost entirely discarded in the next round of iterations. So these sparks are worthless, and these fireworks not only increase the computation of the algorithm but also reduce the search opportunities, wasting a lot of time.

According to [9,10], we use the following method to calculate the explosion radius:

$$r = \left( \frac{T - t}{T} \right)^k (r_{\text{initial}} - r_{\text{end}}) + r_{\text{end}}$$  \hspace{1cm} (6)

In the formula (6), $T$ is the maximum number of iterations; $t$ is the current number of iterations; $r_{\text{initial}}$ is the maximum radius of the initial fireworks explosion, $r_{\text{initial}} = \alpha \ast (X_{\text{max}} - X_{\text{min}})$, $X_{\text{max}}$ is the position of the farthest sparks produced by a fireworks explosion; $X_{\text{min}}$ is the position of the nearest sparks produced by a fireworks explosion; the range of $\alpha$ [0.05 , 0.3 ]; $r_{\text{end}}$ is the maximum radius of the last fireworks explosion; The explosion radius $r$ of fireworks decreases with the number of iterations; and $k$ is the parameter that controls the decreasing trend of $r$. Through a large number of repeated experiments, when the value of $k$ is 7, the experimental results are the best.

**Fusion of Genetic Algorithms**

In order to avoid the problem of "precocity", ZHENG et al. [11] proposed an algorithm combining FA and differential evolution (DE). Although the algorithm is unique in controlling the scope of explosion radius, the method of generating sparks in fireworks explosion and the method of selecting next-generation fireworks, the algorithm still has the problem of low search efficiency. In this paper, genetic algorithm and fireworks algorithm are combined. The crossover and mutation operation of genetic algorithm is added to the fireworks algorithm, and the explosion radius of the fireworks algorithm is improved, which makes the fireworks algorithm based on genetic algorithm not only in the optimization accuracy but also in the optimization speed. The specific implementation steps of the fireworks algorithm based on genetic algorithm are as follows:

Step1: Initialize n populations and determine the number of fireworks.

Step2: Calculate the number of sparks produced by each fireworks explosion according to formula (1) and the explosion radius of each fireworks explosion according to formula (2).

Step3: Selection of new fireworks and sparks. Select n fireworks or sparks with the best fitness for next operation.

Step4: The fitness values and the displacement data of the newly selected n fireworks are rounded and binary encoded for the n fitness values. Then two data are randomly selected from these n populations, one as father and the other as mother, to
realize the crossover and mutation operation of the population. The position of crossover and mutation is also produced randomly by the system, which can not only increase the diversity of the population, but also increase the search range. After the crossover mutation operation, the fitness values of n populations are decoded and transformed into decimal data.

Step 5: Exploding the decoded population as a new generation of fireworks. The size of the explosion radius linearly decreases with the number of iterations.

Step 6: Repeat steps 3-5 until termination conditions are met.

Step 7: Output the optimal value and output the operation time.

The flow chart of fireworks optimization algorithm based on genetic algorithm is shown in Figure 1.

EXPERIMENT

PSO (Particle Swarm Optimization) is a kind of swarm intelligence algorithm which simulates the process of birds searching for food. Particle Swarm Optimization (PSO) does not need gradient information and has few parameters, so it is very suitable for solving optimization problems [12,13].

In this paper, compared the improved fireworks algorithm with the standard particle swarm algorithm. The number of fireworks is set at 5, optimization dimension 30, the number of iterations 3000 in the experiment. In the particle swarm algorithm, the size of particle population is 60, optimization dimension is 30, the number of iterations is 3000. Through Matlab simulation experiments, through a large number of experimental tests, draw the TABLE I conclusions:

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>function</th>
<th>dimension</th>
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<th>iteration</th>
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In order to further prove the genetic algorithm based on the fireworks algorithm optimization effect is better. The paper also compared the five sets of data: the original fireworks algorithm, the improved explosion radius fireworks algorithm, the fireworks algorithm with cross operation, the fitness value improvement based on the genetic algorithm, the fitness value and GA-FWA. In order to compare each other, the longitudinal coordinate of the graph is expressed by the logarithmic value of fitness. The experimental data are as follows: the number of fireworks is n=5, the dimension of the problem is d=30, the total number of iterations is T=30000. In this paper, four functions are tested. The experiment result is like Figure 1-4.

The experimental results show that the genetic algorithm based on the fireworks algorithm is superior to other optimization algorithms in the optimization effect and convergence performance. By adding the crossover and mutation strategy of genetic algorithm to the fireworks algorithm, the problem that the genetic algorithm runs slowly and is easy to fall into the local optimum is solved. At the same time, the
cross mutation strategy increases the population diversity of the fireworks algorithm, which makes the algorithm can quickly find the optimal fitness value, and with a shorter time, improve the search speed. Experiments show that the algorithm is superior to other algorithms in the accuracy of fitness value and search speed.

CONCLUSION

In this paper, a fireworks algorithm based on genetic algorithm is proposed. The algorithm makes good use of the advantages of genetic algorithm and fireworks algorithm. The crossover and mutation operation of genetic algorithm is added to the fireworks algorithm, which increases the diversity of the population and improves the precision of optimization. At the same time, the explosion radius of the fireworks algorithm is improved to decrease linearly with the increase of the number of iterations, so that the algorithm can avoid falling into the local optimal value effectively and find the global optimal value. The optimization of the explosion radius also makes the fireworks produced by each explosion is a useful individual, will not produce worthless sparks, greatly improving the search efficiency.

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REFERENCES