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An Improved Flower Pollination Algorithm for Global Numerical Optimization

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***Abstract*—A new bionic algorithm named as Flower Pollination algorithm (FPA) was proposed by Yang. FPA has some shortcomings, such as premature convergence, low precision, et al. So an improved flower pollination algorithm (IFPA) is proposed in this paper. IFPA combines three aspects: global pollination with quantum search mechanics, local pollination with DE/rand/1 mutation, and switch on dimensions. The experimental results show that IFPA can speed up convergence and improve accuracy.**

Keywords- DE mutation; improved flower pollination algorithm; quantum search mechanics

I. INTRODUCTION

The metaheuristics make few assumptions about their own search space, and have been applied in many aspects and achieved good results. Yang proposed a new metaheuristic algorithm: Flower pollination algorithm (FPA) in 2012[1]. It was inspired by the flower pollination process. The FPA uses pollen population to represent the solution, and solves the optimal solution by local pollination and global pollination. Compared with the other algorithms, the FPA has the virtues of strong searching ability, few parameters and simple structure. FPA has been successfully applied to many fields such as global optimization[2], multi-objective optimization[3], wireless sensor network[4], feature selection[5], parameter estimation[6], essential proteins identifying[7], data clustering[8], neural network training[9], flowshop scheduling[10], photovoltaic system[11], etc.

Although the basic FPA algorithm is very good in many aspects, it has slow convergence speed, low convergence accuracy, and difficulty to escape local optimum. So, the basic FPA needs be improved for complex problems. To balance the exploration and exploitation ability of FPA, an improved FPA called IFPA is proposed here. The improved algorithm uses quantum mechanics in the global pollination stage, and introduces the mutation strategy of the DE algorithm into the local pollination stage. In addition, the local and global pollination processes are carried out on dimensions.

The remaining structure of this paper is as follows. Section II briefly introduces FPA. Section III introduces IFPA. Section IV gives the simulation experiment and result analysis. Finally, Conclusions are drawn.

II. FLOWER POLLINATION ALGORITHM

FPA is based on treating flower pollination process in an idealized way, including the following 4 idealized rules [1]:

(1) Biological cross pollination is the process that pollinators make a global pollination in the mode of Levy flight;
(2) Flower constancy is proportional to the reproductive probability of the similarity of the double flowers;
(3) Abiological self pollination is regarded as a local pollination process;
(4) Local pollination and global pollination are switched by conversion probability $p \in [0, 1]$. Affected by physical location and wind and others, local pollination process will have a greater probability p in the whole pollination process.

FPA based on the above hypothesis is proposed. In FPA algorithm, there are two key parts: local and global pollination. At the global pollination stage, pollen is carried by insects and thus transmitted over a long distance to ensure optimum pollination. Therefore, Rule 1 is showed as follows:

$$X_i^{t+1} = X_i^t + \gamma L(\lambda)(X_i^t - G_*) \quad (1)$$

Among them, X_i^t is the ith solution vector of iterations t; γ is the scale factor controlling the moving step length; G^* is the best solution; $L(\lambda)$ is pollination intensity, essentially step length, randomly obtained by Levy distribution. The Levy distribution for $L(\lambda)>0$ is:

$$L \sim \frac{\lambda\Gamma(\lambda)\sin(\pi\lambda/2)}{\pi}\frac{1}{S^{1+\lambda}}, (S \gg S_0 \gg 0) \quad (2)$$

Among them, $\Gamma(\lambda)$ is standard gamma distribution and it is effective when the larger length s is larger than 0. Theoretically, $|S_0|>>0$. However, in practical applications, S_0 can even be small as 0.1. λ is distribution factor and set as 1.5.

Rule 2 and Rule 3 are expressed as:

$$X_i^{t+1} = X_i^t + \varepsilon(X_l^t - X_k^t) \quad (3)$$

Among them, X_l^t and X_k^t are randomly extracted from the all solutions and are used to simulate flower

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constancy. ε is a random parameter of 0 to 1. In this way, the local pollination process is exactly a local random walk process.

Although pollination activities can take place in random local and global ranges, compared with flowers that are relatively distant, adjacent flowers are more prone to local pollination. Therefore, the conversion probability p is used to balance local and global pollination. In general, when p is equal to 0.8, a better application result will be achieved[12].

III. IMPROVED FLOWER POLLINATION ALGORITHM

FPA also encounters some problems,like to other swarm intelligence algorithms. For example, FPA falls into local optimization and is with slower convergence rate in later evolution. Therefore, to improve the search performance of FPA, an improved flower pollination algorithm was proposed. The idea of IFPA is given from the following three aspects:

A. Global pollination with quantum search mechanics

Sun et al.[13] believe that each particle in the particle swarm optimization system has a quantum behavior, and can be represented by a wave function, so a quantum-behaved search mechanism is proposed. Lu et al. [14] introduced the search mechanism to basic FPA and proposed a quantum-behaved flower pollination algorithm(QFPA). QFPA has a good global search ability, however, there are too many parameters to control. Here, a new attractor G^* is introduced to quantum search mechanics, and the global pollination is represented mathematically as following formulas:

$$X_i^{t+1} = G_* \pm \alpha |C^t - X_i^t| \ln(1/U_i^t) \quad (4)$$

$$C^t = \left(\frac{1}{M}\sum_{i=1}^{M} x_{i,1}^t, \frac{1}{M}\sum_{i=1}^{M} x_{i,2}^t, \dots, \frac{1}{M}\sum_{i=1}^{M} x_{i,d}^t\right) \quad (5)$$

Where, parameter α is known as the adjustment coefficient, G^* is the current optimal solution, C^t is known as the mean positions of all particles, U_i^t is a random vector uniformly distributed over (0, 1), M is the population size.

B. Local pollination with DE mutation

In the process of local pollination, as shown in equation 3, pollen Xi is only affected by randomly selected pollen X_k, and searches in the neighborhood of X_i. This kind of search ability is limited, which limits the global search ability of FPA. Therefore, FPA has some disadvantages such as falling into local optimum and slow convergence speed. The DE/rand/1 mutation in DE makes the algorithm have good global search performance and is used widely. Therefore, to enhance the local pollination process and increase local pollen random walk, DE/rand/1 mutation is introduced to the local pollination, and the local pollination is represented mathematically as following formulas:

$$X_i^{t+1} = X_a^t + F(X_b^t - X_c^t) \quad (6)$$

Among them, $i \neq a \neq b \neq c$. F is zoom factor.

C. Switch on dimensions

In the basic FPA, the local and global pollination processes are carried out on the whole pollen, as shown in equation 1 and equation 3, which is conducive to the fast convergence of the algorithm, but not conducive to the fine search of the algorithm. Especially for complex problems, it is easy to sink into the local optimum. To overcome this disadvantage, local pollination or global pollination is carried on dimensions by switching probability p, as shown in the following formula:

$$x_{ij}^{t+1} = x_{aj}^t + F\left(x_{bj}^t - x_{cj}^t\right) \quad (rand<p) \quad (7)$$

$$X_{ij}^{t+1} = G_{j*} \pm \alpha\left|C_j^t - X_{ij}^t\right| \ln(1/U_{ij}^t) \quad (rand \geq p) \quad (8)$$

The steps of the IFPA can be shown in table I.

TABLE I. THE IFPA FLOWCHART.

Improved flower pollination algorithm
Set algorithm parameters α, F,M, p and T;
Initialize pollen population. X_i (i=1,2,…,M);
Calculate the current optimal population solution G^*;
while $t<T$
for i=1:M
for j=1:d
if rand<p
$x_{ij}^{t+1} = x_{aj}^t + F\left(x_{bj}^t - x_{cj}^t\right)$
else
if rand>0.5
$x_{ij}^{t+1} = G_{j*} + \alpha\left\|c_j^t - x_{ij}^t\right\| \ln(1/u_{ij}^t)$
else
$x_{ij}^{t+1} = G_{j*} - \alpha\left\|c_j^t - x_{ij}^t\right\| \ln(1/u_{ij}^t)$
end if
end if
end for
Evaluate and update population
end for
Calculate the optimal solution G_* of the current population
end while
Output the optimal solution

IV. SIMULATION

A. Test function

To test the performance of IFPA, This paper selects eight common test functions. The specific information of the eight functions is shown in Table II. The optimal values of function F1~F7 are 0,for F8 are -1.0316.

TABLE II. THE RELATED INFORMATION OF TEST FUNCTION

Benchmark test functions	**Dim.**	**Range**
$F1(x) = \sum_{i=1}^{d} x_i^2$	30	[-100 100]
$F2(x) = \sum_{i=1}^{d} \|x_i\| + \prod_{i=1}^{d} \|x_i\|$	30	[-10 10]
$F3(x) = \sum_{i=1}^{d} (ix_i)^4 + \text{random}[0,1)$	30	[-1.28 1.28]
$F4(x) = \sum_{i=1}^{d-1} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2]$	30	[-30 30]
$F5(x) = \frac{1}{4000}\sum_{i=1}^{d} x_i^2 - \prod_{i=1}^{d} \cos\left(\frac{x_i}{\sqrt{2}}\right) + 1$	30	[-600 600]
$F6(x) = -20e^{-0.2\sqrt{\frac{1}{d}\sum_{i=1}^{d} x_i^2}} - e^{\frac{1}{d}\sum_{i=1}^{d}\cos(2\pi x_i)+20+e}$	30	[-32 32]
$F7(x) = \frac{sin^2\sqrt{x_i^2 + x_2^2} - 0.5}{[1 + 0.001(x_i^2 + x_2^2)^2]} + 0.5$	2	[-100 100]
$F8(x) = \left(4 - 2.1x_1^2 + \frac{x_1^4}{3}\right)x_1^2 + x_1x_2 - (4 - 4x_2^2)x_2^2$	2	[-5 5]

B. Test result and performance analysis

Four comparison algorithms are used in the test results. They are flower pollination algorithm(FPA) [1], quantum-behaved flower pollination algorithm(QFPA) [13], differential evolution algorithm (DE)[15], and improved flower pollination algorithm (IFPA). For each one, 20 independent runs are carried out with M= 80 and T=5000. In FPA and QFPA, the switching probability p=0.8, and λ=1.5, for IFPA, p is set to 0.9, F is set to 0.5, and α drops from 1 to 0.1,for DE, 0.5 for F and CR=0.9.

TABLE III. SIMULATION RESULTS

Fun.	Method	Best	Worst	Mean	Std
F_1	FPA	35.08	91.78	50.47	13.30
	QFPA	2.058e-5	4.298e-4	1.520e-4	1.119e-4
	DE	5.994e-74	2.089e-71	4.319e-72	5.331e-72
	IFPA	***6.903e-94***	***9.409e-90***	***9.324e-91***	***2.140e-90***
F_2	FPA	11.94	41.67	22.26	6.473
	QFPA	2.179e-4	2.488e-2	2.993e-3	6.526e-3
	DE	5.599e-37	6.425e-35	1.937e-35	1.634e-35
	IFPA	***3.862e-49***	***1.527e-44***	***1.001e-45***	***3.372e-45***
F_3	FPA	0.0243	0.0638	0.0466	0.0116
	QFPA	0.0051	0.0269	0.0163	0.0054
	DE	1.551e-3	4.106e-3	2.643e-3	6.658e-4
	IFPA	***1.237e-3***	***4.096e-3***	***2.613e-3***	***5.979e-4***
F_4	FPA	999.9	3118	1615	610.1
	QFPA	28.94	288.3	81.26	57.86
	DE	4.293e-21	3.986	0.1993	0.8914
	IFPA	***1.391e-24***	***3.250e-7***	***1.625e-8***	***7.267e-8***
F_5	FPA	1.240	1.809	1.427	0.1487
	QFPA	0.0012	0.3032	0.0469	0.0753
	DE	***0***	0.0073	3.698e-4	0.0016
	IFPA	***0***	***0***	***0***	***0***
F_6	FPA	8.270	15.62	11.22	1.872
	QFPA	0.0053	2.543	0.9373	0.7863
	DE	***4.4409e-15***	***4.4409e-15***	***4.4409e-15***	***0***
	IFPA	***4.4409e-15***	***4.4409e-15***	***4.4409e-15***	***0***
F_7	FPA	5.043e-7	2.700 e-4	9.025e-5	9.495e-5
	QFPA	4.658e-10	1.634e-5	1.527e-6	3.825e-6
	DE	***0***	***0***	***0***	***0***
	IFPA	***0***	***0***	***0***	***0***
F_8	FPA	***-1.0316***	***-1.0316***	***-1.0316***	***0***
	QFPA	***-1.0316***	***-1.0316***	***-1.0316***	***0***
	DE	***-1.0316***	***-1.0316***	***-1.0316***	***0***
	IFPA	***-1.0316***	***-1.0316***	***-1.0316***	***0***

The simulation results are shown in Table III. In table III, the optimal fitness value, worst fitness value, mean fitness value and standard deviation are presented. The better results are bold and italicized. From Table III, IFPA can find the optimal solution for F5,F7, and F8. For other functions, the optimal fitness values and mean fitness values of IFPA are best among those of other three algorithms. On the other hand, the standard deviation of IFPA is smaller than the other three algorithms.

The evolution curves of F_1 and F_5 test functions under the four algorithms are shown in Figs. 1 and 2. From the trend of these two figures, as the number of iterations increases, the basic FPA will appear early stagnation.DE is a good algorithm for most problems. But for some problems as F5, DE appears early stagnation too. However, IFPA significantly improves the search accuracy and convergence performance for the eight problems. Especially in the later iteration of the algorithm, IFPA still has a continuous optimization effect. That shows IFPA algorithm has a good global search ability, can effectively escape local extremum and avoid premature convergence.

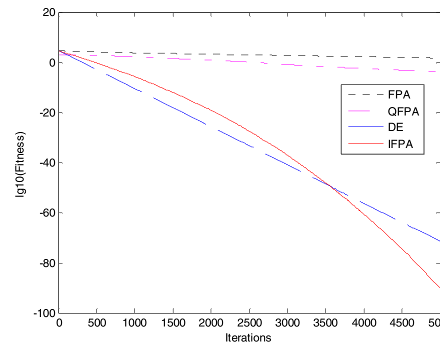

Figure 1. Convergence curve of function F_1

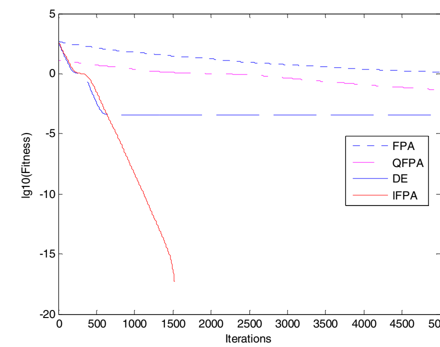

Figure 2. Convergence curve of function F_5

V. CONCLUSIONS

The basic FPA has some disadvantages, such as low optimization accuracy and slow convergence speed. In this paper, to overcome the shortcomings, an IFPA is proposed in three aspects: global pollination with quantum search mechanics, local pollination with DE mutation, and switch on dimensions. Eight test functions are used to test with other algorithms. Simulation results of comparison show that the proposed IFPA is better than the other algorithms used in the tests.

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