Two Improved Particle Swarm Optimization Algorithms for Electromagnetic Device Optimization

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Abstract — Two improved particle swarm optimization (PSO) algorithms have been introduced in this paper. Enlightened by the phenomenon of mutation and disaster in the biology evolution procession, a population disappearance particle swarm optimization was proposed. Simulation results of Schaffer's f6 function show that it can easily find the global optimum solution. The other improved PSO was designed with allied strategy formed in the evolutionary process of human society. Its superiority has been verified by applied to optimize the Rastrigin function. The two improved PSO algorithms have been used for the optimal design of electromagnetic relay and the simulation results have verified the validation of them.

I. INTRODUCTION

Particle swarm optimization (PSO) is an optimization algorithm based on swarm intelligence developed by Kennedy and Eberhart in 1995[1]. Particle swarm optimization algorithm has become a new research hot point [2]-[3]. Its principle could be described by the flight velocity and the new position of particle for the next fitness evaluation in the dth dimensional subspace.

$$v_{id}^{k+1} = wv_{id}^{k} + c_1 r_1 \left(p_{id} - x_{id}^{k}\right) + c_2 r_2 \left(p_{gd} - x_{id}^{k}\right) \qquad (1)$$

$$z_{id}^{k+1} = z_{id}^{k} + x_{id}^{k+1} \qquad (2)$$

Where, i = 1, ..., n and n is the size of the swarm, Here w is an inertia weight determining how much of the particle's previous velocity is observed. p_{id} is the personal best position found by the ith particle and p_{gd} is the record of the former best position of the whole swarm[4].

II. THE TWO IMPROVED PARTICLE SWARM ALGORITHMS

A. Population disappearance PSO

The chief principle of the population disappearance PSO could be described as follows:

Step.1: Initialize every particle swarm randomly. All particles are divided into several sub-swarms in the same size. Evaluate the adaptive value of each particle by computing the objective function. Find the best position of each particle and each sub-swarm. Comparing and sorting all the current best positions, and finding the optimum position of the whole swarm;

Step.2: Update the velocity and position according to SPSO algorithm. Comparing and updating the best position of each particle and each sub-swarm.

Step.3: Comparing and updating the optimum position of the whole swarm after every L generations. Sorting all particles based on their adaptive values in every sub-swarm. Sorting all sub-swarms based on their historical best adaptive values. The last part of each sub-swarm's particles disappeared and the same number of new particles generated randomly in the problem space added to each sub-swarm to maintain the swarm size. Exchange the historical best positions of the adjacent sub-swarms as shown in Fig. 1.

Step.4: If the terminate conditions was met, end the algorithm, or continue the computation.

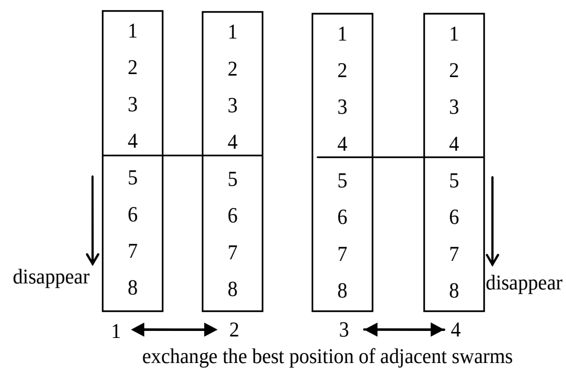

Fig. 1. Operational method of population disappearance PSO

B. PSO with Allied Strategy

PSO with allied strategy decreases the gene similarity by the allied strategy and protects the individual fitness through the crossover strategy. This improved PSO has the same step.1, step.2 and step.4 with the population disappearance PSO. Here, the difference in the Step.3 could be stated as: The last part of each sub-swarm's particles disappeared and the same number of new particles generated by the first half part of the adjacent sub-swarms' particles in the problem space added to each sub-swarm to maintain the swarm size. The allied strategy was realized by the genetic cross operator of the adjacent sub-swarms. The sequence of the allied strategy was shown in Fig. 2.

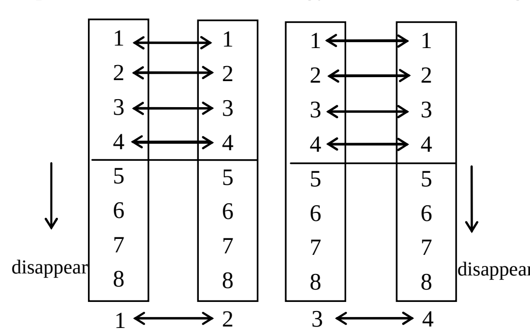

Fig. 2. Allied strategy in adjacent sub-swarms

III. Simulation for Benchmark Testing

Here, the PSO with allied strategy (MPSO-1) was tested by the Rastrigin function and the population disappearance PSO algorithm (MPSO-2) tested by the Schaffer's f6 function. Test results are shown respectively in Table I and Table Ⅱ.

TABLE I
TEST RESULTS OF MPSO-1

algorithm	testing times	average value of the optimum solutions	convergence rate
SPSO	100	4.49E-7	90%
MPSO-1	100	1.07E-8	98%

TABLE Ⅱ
TEST RESULTS OF MPSO-2

algorithm	testing times	average value of the optimum solutions	convergence rate
SPSO	100	0.99475	72%
MPSO-2	100	0.99963	82%

IV. Optimum Design of the Electromagnetic Relay

SPSO, MPSO-1 and MPSO-2 have been used to the optimum design of the electromagnetic relay. The structure of the electromagnetic relay was shown in Fig. 3. After sifting out the design variables that influence largely the optimization results of the relay and inducting the main constraint condition of the system, the final optimization object function which using volume of the relay as optimization object has been established. The bound for objective function have been established by the temperature rise limit and the cooperation of the attraction force and mechanical spring force. Equation (3) is the optimum design model of the electromagnetic relay. The simulation results were shown in Fig. 4.

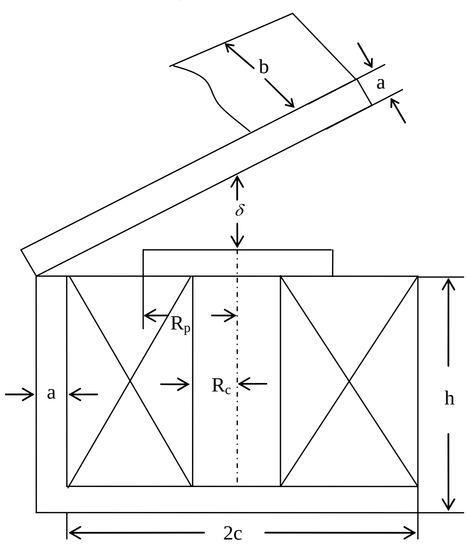

Fig. 3. Structure of the electromagnetic relay

$$\min V = \pi\left(\frac{\delta_0}{x_1}\right)^3 \cdot \left[x_3 x_2^2 + \frac{(x_4^2-1)(x_4^2+x_5)}{2x_4^2}\right] + x_5\cdot\left(3x_2 + \pi\cdot\frac{x_5}{x_2} + x_3 + x_4\right) \quad (3)$$

$s.t.$

$$F_0 = \frac{1}{2}(IN)^2\cdot\mu_0\pi\cdot\frac{2x_2\left(x_2-\sqrt{x_2^2-1}\right)}{x_1^2} > F_{f0}$$

$$F_1 = \frac{1}{2}(IN)^2\cdot\mu_0\pi\cdot\left(\frac{\delta_0}{\delta_1}\right)^2\cdot\frac{2x_2\left(x_2-\sqrt{x_2^2-1}\right)}{x_1^2} > F_{f1}$$

$$\tau = (K_N IN)^2\cdot\frac{\rho_\tau}{2K_T k_{tc}\delta_0^2}\cdot\frac{(x_2^2-1)\cdot x_1^2}{(x_2+k_\beta)(x_2-1)\cdot x_3^2} < \tau_m \quad x_i > 0, i = 1,2,\cdots,5$$

$$x_1 = \frac{\delta_0}{R_c},\ x_2 = \frac{c}{R_c},\ x_3 = \frac{h}{R_c},\ x_4 = \frac{R_p}{R_c},\ x_5 = \frac{A_e}{A_c}.$$

A_e is the sectional area of the yoke, and A_c denotes the cross sectional area of the iron-core.

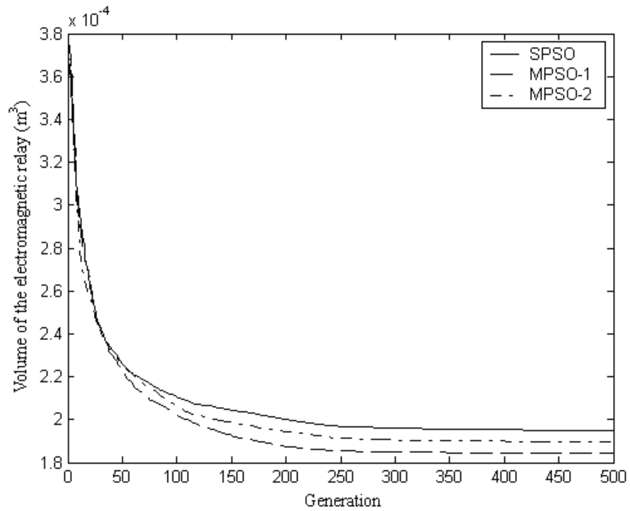

Fig.4. Comparison of performance of the SPSO、MPSO-1、MPSO-2

V. Conclusion

Both the population disappearance PSO and the PSO with allied strategy have better convergence rate than the SPSO. The MPSO-1 is more suitable to optimize the Rastrigin function and the MPSO-2 is suitable to optimize the Schaffer's f6 function. The results of optimum design for the electromagnetic relay in Fig. 4 have revealed that the two improved PSO can not only heighten particle diversity and avoid premature problem, but also maintain the characteristic of fast speed search to get global optimum. The MPSO-1 has the best performance for the optimization of the electromagnetic relay. In a word, test results show that the two improved algorithms are feasible and efficient.

VI. References

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