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The Study of Path Planning of Welding Manipulator Based on Improved QPSO

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***Abstract*—The welding path planning of manipulator is one of the key issues to improve efficiency in the industry. In allusion to the defects of particle swarm algorithm, enlightened by quantum mechanics, the quantum particle swarm algorithm is presented in this paper, expanding the search range of particles and retaining the good operability of particle swarm algorithm. Based on features of welding manipulator path planning, the welding spots passed by particles are weight-coded and the combination optimization problem is made continuous. Finally, an optimal welding path for the manipulator is worked out by using this algorithm.**

Keywords-Welding robot, path planning, quantum particle swarm algorithm, weight codes

I. INTRODUCTION

Welding is gradually becoming an important means of manufacturing industry, especially in the processing equipment manufacturing industry. The welding manipulator is widely used in industrial welding because of its good stability and security. On the purpose of improving the efficiency of welding robot, path planning of welding has become a key problem to be solved .

Nowadays, the mechanical hand path planning methods used in the industrial production line are mainly accomplished through teaching and playback[1] .Therefore, it is low in adaptability and of time-consuming, and makes the optimal pathunavailable during the welding process.In allusion to the defects of traditional industry path planning, the particle swarm optimization algorithm to solve this problem has been studied at home. Discrete particle swarm optimization, which was proposed by Kennedy, was utilized in the literature [4] for path planning. the improved algorithm was simple, yet it was not suitable for continuous optimization problems because it was liable to trap into local optimization. The k-center point method was used in literature [3] to perform clustering analysis of particle swarm optimization, which strengthened the exchange of information between the particles. In literature [4], the sub-population was divided and crossbred, retaining the diversity of particle swarm, And in the literature [5], the mixed application of hybrid particle swarm algorithm aimed at above defects was adopted.Enlightened by literatures [7] and [9], aimed at solving the problem of manipulator path planning, it is proposed in this paper a quantum particle swarm algorithm, encoding the welding spots passed by particles with the adoption of the weight code scheme [3].

II. PROBLEM DESCRIPTION AND MODEL ESTABLISHMENT

The welding process of manipulator can be described as: electrode holder starts from an initial position of the pads, and return the initial position after finishing assigned welding joints. Therefore, the welding path planning can be abstracted as a TSP problem, namely, for a pad with N solder joints, and for whichever initial point, we should select one of the shortest path to get every joint passed once and finally return initial position. Suppose a mechanical manipulator is allocated with n spots which are respectively $V = (v_1, v_2, v_3, \cdots, v_n)$, and the corresponding welding sequences for the spots are $T = (t_1, t_2, t_3, \cdots, t_n)$, and then we obtain the path length for welding:

$$D = \sum_{i=1}^{n-1} d(v_i, v_{i+1}) + d(v_1, v_{i+1}) \qquad (1)$$

The path’ s minimum value $D_{\min}$ shall be obtained, and $d(v_i, v_{i+1})$ is the distance from solder i to $i+1$. Also, all points must be in a loop, or cannot be adopted to solve the TSP problems.

III. QUANTUM PARTICLE SWARM ALGORITHM

A. THE STANDARD PARTICLE SWARM ALGORITHM

Particle swarm algorithm [6] was first raised by Kennedy and Eberhart in 1995. PSO originated from the study of birds of preying behavior and simulation of foraging behavior of clustered birds. In PSO algorithm, the purpose of finding the optimal solution will be achieved by continuous particles’search of optimum, which adopts the information provided by historically optimal solution of each particle itself and the global optimal historical best position.

The algorithm [2][5] is described as: Suppose there is a population $X = (X_1, X_2, X_3, \cdots, X_D)$ composed of n particles in a D dimension of search space, so the search position for the i-th particle in this space can be expressed as $X_i = (x_{i1}, x_{i2}, x_{i3}, \cdots x_{iD})^{\mathrm{T}}$,whose speed is $V_i = (V_{i1}, V_{i2}, V_{i3}, \cdots V_{iD})^{\mathrm{T}}$, then the best value for each individual particle is:

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$$P_{ibest} = (p_{i1}, p_{i2}, p_{i3}, \cdots, p_{id})^{\mathrm{T}} \qquad (2)$$

And the best position of the swarm can be expressed as:

$$P_{gbest} = (P_{g1}, P_{g2}, P_{g3}, \cdots, P_{gd})^{\mathrm{T}} \qquad (3)$$

At each iteration, the optimal particle swarm updates its own location through individual and group optimums. The ways of updating are as follows:

$$V_{id}^{k+1} = \omega V_{id}^{k} + c_1 r_1 (P_{id}^{k} - X_{id}^{k}) + c_2 r_2 (P_{gd}^{k} - X_{id}^{k}) \qquad (4)$$

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \qquad (5)$$

Among them, ω is the inertia weight , k is the iteration, c_1, c_2 are the acceleration factors and r_1, r_2 are random numbers between [0,1]. At the same time we will also set the particles'position and speed range in order to prevent the particles from searching blindly.

B. QUANTUM PARTICLE SWARM ALGORITHM

The standard particle swarm algorithm is simple, and the operation is easy, but it lacks of variation mechanism, which results in a slow speed of convergence and the low precision of search. In 2004, inspired by quantum mechanics, Sun Jun proposed a new PSO algorithm model. That model is based on the DELTA potential, putting forward the particle swarm optimization algorithm based on quantum behavior [8].

The probability function of particle's being a certain point can be obtained by the adoption of quantum particle swarm algorithm, by using the wave function describes the state of particles and solving Schrodinger equation. And then the optimal iterative equation can be abstracted by Monte Carlo randomly[9] .

(1) m_{best} represents the average optimal position of all particles in the population, i.e:

$$m_{best} = (\frac{1}{k}\sum_{i=1}^{k} P_{i1}, \cdots, \frac{1}{k}\sum_{i=1}^{k} P_{iD}) \qquad (6)$$

(2) P_{id} means optimal value of individual particle , i.e.:

$$p_i(t) = \omega P_{id} + (1-\omega) P_{gd} \qquad (7)$$

(3)The final iteration equation for total particle swarm optimization is:

$$X_{id}(t+1) = P_{id} \pm \frac{L}{2}\ln(\frac{1}{u}) \qquad (8)$$

Among them, L is determined by the following formulas:

$$L(t+1) = 2\beta \left| m_{best} - X(t) \right| \qquad (9)$$

Among them, u, w are the random numbers of the [0,1], t is the number of iterations, and $p_i(t)$ represents the current best position of the i-th particle, while β is the algorithm expansion coefficient.

C. PARTICLE WEIGHT CODE

In order to make the particle swarm algorithm available, we use the weighted coding method in literature [3] to encode the particles, then TSP problems of combinatorial optimization will be turned into continuous optimization problems. The coding scheme is: using n-dimensional vector to represent the planning problems allocated with N welding spots, and among the position vectors, each of vectors successively represents the weight of each solder joint. The order of size of weight represents the sequence in welding path. The spots with lower weight will be passed first. Suppose there are 4 spots which will passed by a welding manipulator, then we can obtain all the weight vectors of these welding spots that will be passed by a certain particle, which is shown in Table1.

Table1. Weight encoding of solder joints

Number	1	2	3	4
Weight	0.215	0.355	0.23	0.2

According to the rules of weight code, the sequence of welding is determined by the weight of spots while passed by the certain particle. Therefore, we can obtain the welding sequence of 4 spots: 4-1-3-2.In this way, we can get the solution of welding distance of the particle by passing sequence.

D. FITNESS FUNCTION

In order to facilitate the judgment of results, the target function is used as the fitness function. The smaller the fitness function is, the better the result is.

$$fit(x) = \sum_{i=1}^{n-1} d(v_i, v_{i+1}) + d(v_1, v_{i+1}) \qquad (4)$$

Attention: $d(v_i, v_{i+1})$ is the distance from i-th to the i+1-th solder joint.

IV. THE ALGORITHM STEPS

Step 1: For algorithm parameters of particle swarm optimization (population size, number of iterations and so on), we randomly generate initial particle swarm and the each dimension of position vector of each particle ,Each randomly between real [0,1].

Step 2: According to the weight of each particle, calculate the fitness value of each particle, and compare the particles , fitness values to determine the individual optimum P_{id} and the population P_{gd} of initial population.

Step 3: We can get m_{best} according to the initial population's P_{id} and P_{gd} , and updates the particles through the formulas (8)and (9) ,then work out the Welding distance computation corresponding to each particle'path .

Step 4: Compare the fitness value obtained in last step with the determined optimal route of initial particle adaptation, and update every particle's historical best position P_{id} and optimal location P_{gd} of total population.

Step 5: Judge whether the output meet termination condition, if it does, output the optimal value, if it does not, returns **Step 2.**

E. Example analysis

Example analysis is provided in order to test the performance of QPSO algorithm for welding robot path planning: we randomly select 30 points as solder joints for welding robots and the joint distribution is shown in figure 1:

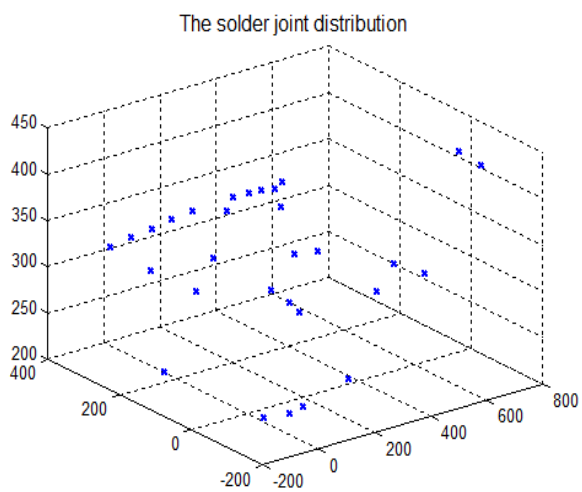

Fig 1. The distribution map of solder joints

Assigning the population size is 100, the termination generation is 200, the crossover probability is 0.9, and mutation probability is 0.05, the optimal welding path can be obtained by GUI simulation platform which programed by Matlab. The optimal welding path is shown in Figure 2; the optimal iteration number and the fitness value change are shown in Figure 3:

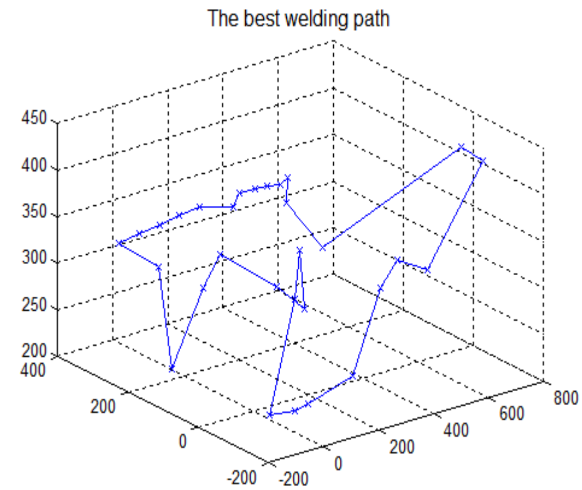

Fig 2.The optimal welding path of solder joint

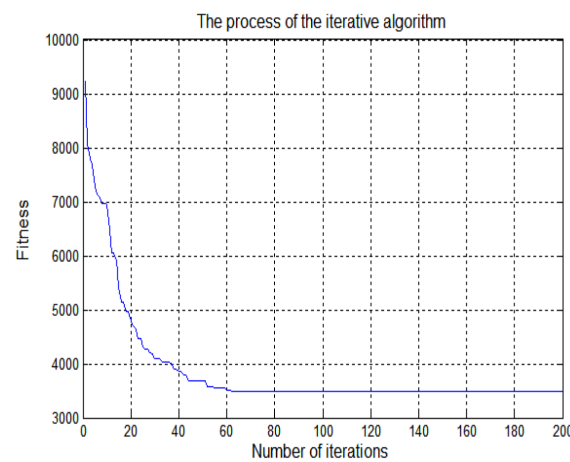

Fig 3. The process of the Particle iteration

For a given spot, the problem of welding path planning is properly solved by using QPSO combined with the particle weight code.

V. Conclusions

Aiming at the path planning problem for manipulators, this paper proposes a particle swarm algorithm with quantum behavior. particles.T In addition, Based on features of welding manipulator path planning,the algorithm is improved by performing the weight code of particles in this paper,transforming TSP into the continuous optimization problem and the algorithm expands the search scope of the particles to the whole feasible solution space.Finally, an optimal welding path for the manipulator is worked out by Matlab. The test results indicate that the algorithm is efficient and feasible in solving TSP problems.

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