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Path Planning of Intelligent Inspection Robot for Power Plant Based on Hybrid Particle Swarm Optimization

Wenyue Chen

School of Control and Computer Engineering, North China Electric Power University, Beijing 102206, China.

Abstract

This paper briefly introduces the transformation direction of power plants and the development trend of introducing intelligent inspection robots. Considering that the hybrid particle swarm optimization algorithm has strong global search capability and the premature phenomenon is not serious, the algorithm is used to solve the path planning problem of mobile robots.The simulation results obtained from the coordinates of the power plant equipment to be inspected in the abstract model are compared with the results of other algorithms to verify the advantages of the hybrid particle swarm algorithm. Provide a reference for the actual use of intelligent inspection robots in power plants.

Keywords

Intelligent inspection robot, Power plant, Path plan.

1. Introduction

1.1 Smart power generation

In the context of energy transformation, China has put forward the concept of intelligent power generation. The core is the transformation revolution of power generation technology under the background of the fourth industrial revolution[1]. At this stage, smart power generation already has certain basic conditions. Most power plants have supporting facilities for automatic control systems, monitoring information systems and management information systems, but the goal of intelligence has not yet been fully achieved. Intelligent power generation is a multi-disciplinary high-tech field[2]. It is not just a simple realization of automation, digitization and informationization, but should form a deeper combination and application form[3].

1.2 The necessity of using intelligent inspection robot

In the construction and improvement of intelligent power plants, the use of intelligent inspection robots is one of the general development requirements. The current situation of China's power system is wide range, large passenger volume, and multiple voltage levels[4], The power plant is the core link of the power system, and the operation safety of power plant equipment is the prerequisite for ensuring the safety of the entire power system[5]. Therefore, an automatic, efficient and reliable power plant equipment inspection system is very necessary. Compared with the old manual inspection, the use of intelligent inspection robots can effectively improve the standardization and authenticity, and effectively guarantee the safe operation of power plant equipment.

2. Intelligent inspection robot and path planning technology

2.1 Intelligent Inspection Robot

The intelligent inspection robot can use multiple technologies such as multi-sensor flexible fusion technology, steam leakage early warning technology, intelligent inspection point system construction

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technology, fire warning technology, intelligent integrated operation and maintenance management technology and other technologies[6], apply AI to the power production process.

In power plants, there are various types of equipment and items to be inspected, such as: Boiler and steam turbine inspection, technically required to adapt to the complex terrain and equipment operating conditions on site[7], combined with temperature detection, sound vibration monitoring and other functions. High-voltage switch room inspection, using video information and multi-sensor fusion technology to monitor key equipment in real time[8], operate high-risk key parts, ensure personnel safety and reduce accidents. Inspection of coal conveying corridors[9] to detect coal accumulation powder, dust concentration of corridors, temperature of cables, motors, reducers. Prevent accidents such as belt deviation, coal leakage, coal powder spontaneous combustion, corridor fires, and improve the safety level of important coal transportation systems[10].

The intelligent inspection robot integrates a variety of sensors, and uses infrared temperature measurement, meter recognition, vibration measurement, voice recognition and other functions as needed[11]. The inspection results are uploaded to the data center, and an integrated management and control platform is established to meet the requirements of timely, accurate and intelligent.

2.2 Intelligent algorithm path planning technology

Path planning is one of the core problems in the work of intelligent inspection robots in power plants[12]. The classic TSP can be used for preliminary simulation testing of intelligent algorithms used for path planning background. In this paper, hybrid particle swarm optimization is used to plan the path, and the simulation results are compared with the results of ant colony algorithm and genetic algorithm. If the actual operation is finally considered, the specific situation of the power plant and the difference between the TSP model can be adjusted to adapt to the site environment.

3. Hybrid particle swarm optimization algorithm for planning the path of intelligent inspection robot

3.1 Problem Description

The intelligent inspection robot is a mobile robot used in the actual operation of the power plant[13]. The purpose of optimizing the planned path is to design the most reasonable movement path for the mobile robot. The technical support required is: robotics map construction technology, positioning technology and path search technology[14]. The first is to model the scene, according to the working environment of the power plant and the requirements of the inspection equipment in the work of the intelligent inspection robot, determine the coordinates of the map model positioning navigation. Then, according to the coordinate position, conduct intelligent algorithm planning path simulation test.

3.2 Hybrid particle swarm optimization

The traditional particle swarm optimization algorithm uses individual extremum and group extremum to complete the extremum optimization. Although the principle is simple and convenient to operate, and can quickly converge, while the population converges and concentrates as the number of iterations increases, the difference between the particles is getting smaller and smaller, which is likely to be limited to the local optimal solution and cannot jump out.

The genetic algorithm is inspired by the natural selection and evolution of biology. It proposes a highly parallel, random, and adaptive global optimization probability search algorithm. It does not rely on gradients during optimization, and has strong robustness and global search capabilities. But there is also the defect of immature convergence, that is, all the individuals in the group gradually tend to the same state in the iterative loop and the evolution is slow or even stagnant. Generally, when the scale is large, only approximate solutions can be obtained.

The hybrid particle swarm optimization algorithm used in this paper does not continue to use the traditional particle swarm optimization algorithm to track the extreme value to update the particle position. Instead, combined with genetic algorithms, it introduces crossover and mutation operations,

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and finds the optimal solution through the crossover of individual extreme values and population extreme values of particles plus the operation of particle mutation[15].

3.3 Hybrid particle swarm algorithm flow

The flow of the hybrid particle swarm algorithm is shown in Figure 1, the specific steps are as follows[15].

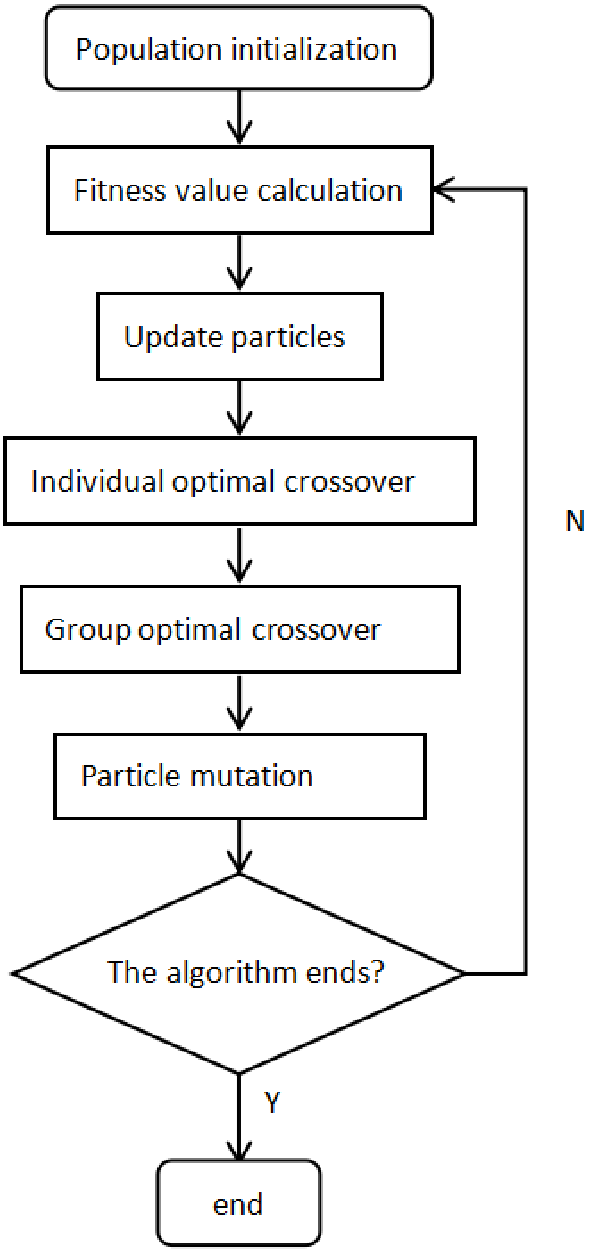

Figure 1. Flow chart of hybrid particle swarm optimization

The population initialization module randomly generates the initial particle swarm population. The fitness value calculation module calculates the fitness value of individual particle swarms. Update the particle module, update the individual optimal particle and the group optimal particle according to the fitness value calculation. The individual optimal cross module performs cross operation on the individual and individual optimal particles to obtain new particles. Group optimal cross module, the individual and group optimal particles are cross-operated to obtain new particles. Particle mutation module, particle mutation operation. Determine whether the end condition is met, exit if it is satisfied, and return to fitness value calculation to continue the iterative loop if not.

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3.4 The concrete realization of hybrid particle swarm optimization in this paper

Individual particle coding. The algorithm in this paper uses integer coding, that is, each particle is expressed as a sequential number that traverses all the power plant equipment to be detected.

Calculation of fitness value. The fitness value selected by the algorithm in this paper is the total length of the path that the intelligent inspection robot traverses all the detection points from the starting point and then returns to the starting point. The formula is

$$fitness\ (i) = \sum_{i,i=1}^{n} path_{i,j} \tag{1}$$

Cross operation. The algorithm in this paper adopts the integer cross method, randomly selects two cross positions, and crosses the individual, the individual extremum and the group extremum separately. The new particles obtained are the new traversal paths. If there are duplicate numbers in the generated new particles, replace them with numbers that have not appeared. In addition, the operation of keeping only excellent individuals is added here, that is, the new particle will participate in the subsequent loop only when the fitness value of the new particle is better than the fitness value of the old particle.

Mutation operation. The algorithm used in this paper adopts the two-digit mutation method within the individual particles, selects two mutation positions, and exchanges the serial numbers of these two positions to obtain new particles. This step also adds the operation of keeping only better individuals.

The condition to determine whether the loop ends. This paper uses the loop algebra judgment method, if the current iteration number is less than the termination algebra, continue to loop. Otherwise, exit the loop.

4. Case Analysis

4.1 Coordinates determined in the abstract model

The coordinates of the 34 power plant equipment to be inspected abstracted by the modeling selected in this paper are shown in Table 1.

Table 1. Equipment coordinates in power plant model

j	(U_j,V_j)	j	(U_j,V_j)	j	(U_j,V_j)	j	(U_j,V_j)
1	(3.64,2.68)	11	(2.37,1.02)	21	(3.33,2.44)	31	(3.68,1.42)
2	(4.18,1.76)	12	(3.43,2.09)	22	(2.94,0.76)	32	(4.03,1.16)
3	(3.71,2.60)	13	(3.54,0.70)	23	(3.39,1.36)	33	(3.47,0.70)
4	(2.77,1.50)	14	(3.51,1.62)	24	(3.49,2.46)	34	(1.30,1.69)
5	(1.33,3.30)	15	(3.44,0.80)	25	(2.78,1.17)		
6	(4.20,2.96)	16	(3.24,2.77)	26	(3.14,0.45)		
7	(4.39,3.43)	17	(2.38,2.32)	27	(4.31,3.21)		
8	(3.92,1.82)	18	(2.56,2.24)	28	(3.72,2.32)		
9	(4.26,1.07)	19	(3.01,2.03)	29	(4.06,1.63)		
10	(2.55,1.64)	20	(2.79,2.51)	30	(3.78,1.79)		

4.2 Matlab programming simulation results

The parameters of the hybrid particle swarm optimization algorithm used in this paper: the number of iterations is 200, and the population size is 1000. Equipment location coordinates are shown in Figure 2. One of the iteration process is shown in Figure 3.

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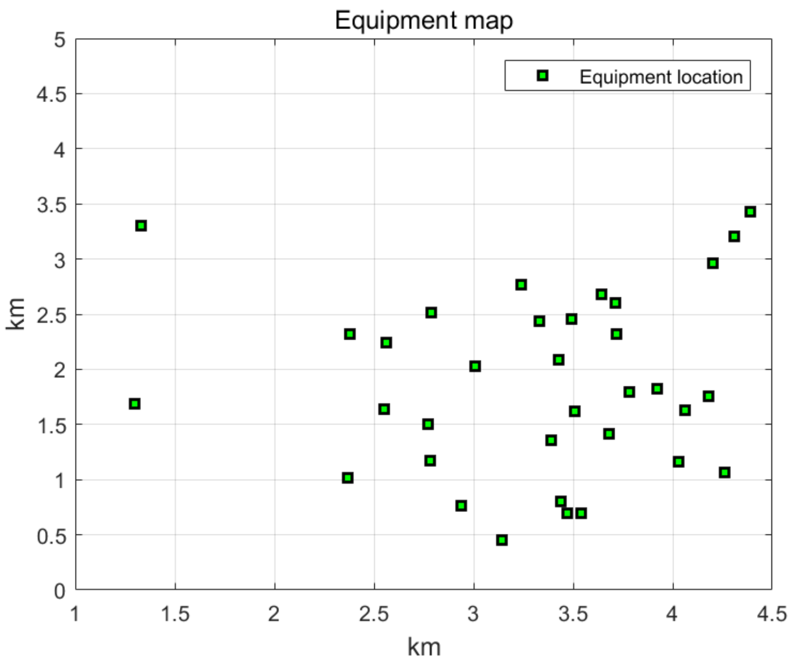

Figure 2. Equipment location coordinates map

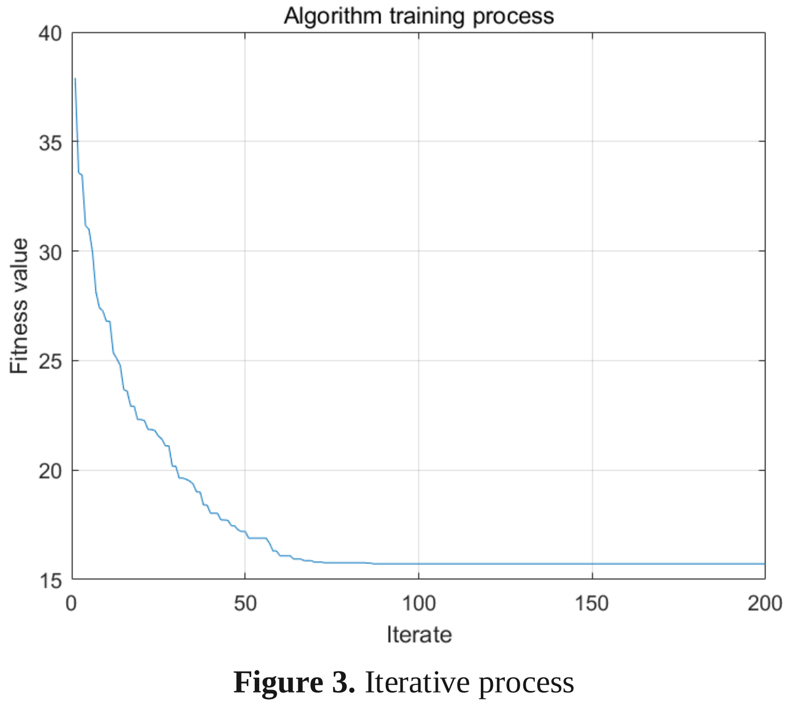

Figure 3. Iterative process

Table 2 lists the shortest path length values obtained during the 10 times of optimization. The average value of 10 simulation results, that is, the average value of the shortest path length obtained by the algorithm is 16.0483.

Table 2. 10 shortest path values

1	2	3	4	5
15.8585	16.1261	16.6579	15.9844	16.4849
6	7	8	9	10
15.8585	16.0676	15.7196	15.7196	16.0059

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4.3 Compare with other intelligent algorithms

The iterative process of simulated annealing (SA) algorithm is shown in Figure 4. The shortest path length of the final optimization result is 17.5392.

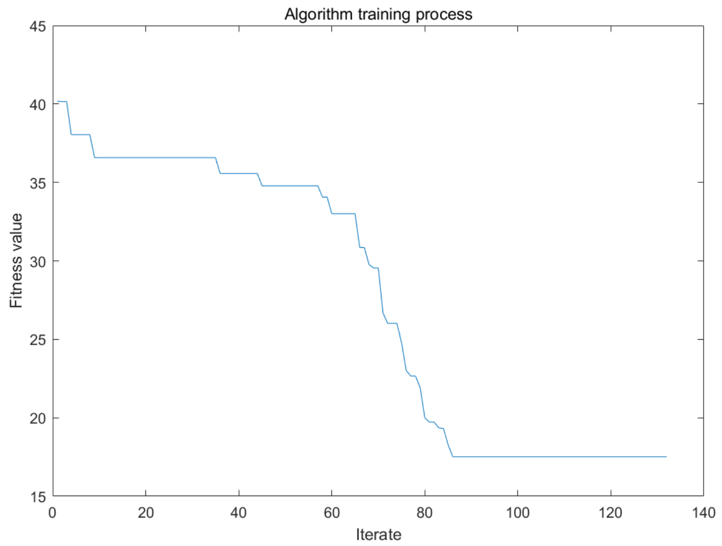

Figure 4. Iterative process(SA)

The iterative process of genetic algorithm (GA) is shown in Figure 5. The shortest path length of the final optimization result is 16.4834.

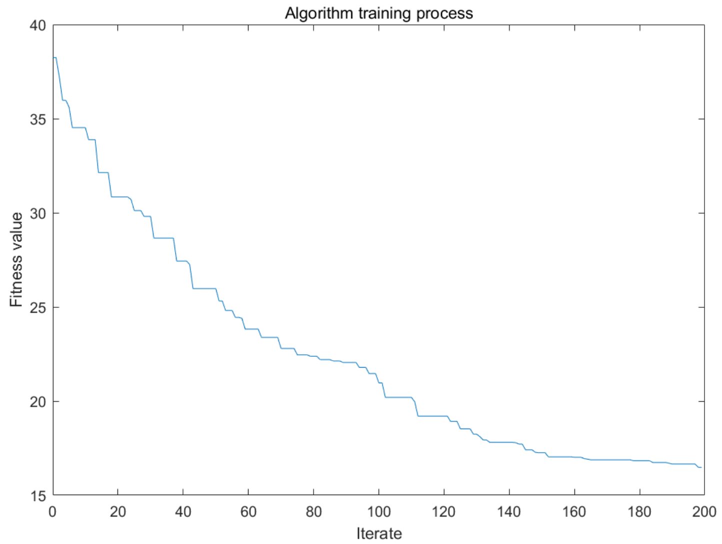

Figure 5. Iterative process(GA)

It can be easily known from the comparison that the hybrid particle swarm optimization algorithm used in this paper has a faster convergence speed, iterative process curve is more stable, and the fitness value of the optimization result, that is, the total path length is smaller. Therefore, the effect is best.

5. Conclusion

In the context of "Made in China 2025", one of the development strategy elements of power plants is the introduction of high-tech products represented by artificial intelligence technology[16]. Intelligent inspection robots can create results for power companies in terms of economic benefits, safe production, and intelligent construction. Path planning technology is a basic and critical part.

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This paper verifies the feasibility and advantages of the hybrid particle swarm optimization algorithm in the path optimization problem, which can provide important reference value for the actual application scenarios[17] of inspecting power plant equipment.

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