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Optimization of Waste Smoke Recovery Scheduling Strategy Based on Multi AGV

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Abstract. AGV is an important material handling equipment for flexible, lean and intelligent production of smart factory. Because of the high cost of AGV car and the congestion of vehicles in the system, this chapter studies the waste smoke recovery path planning and material handling task scheduling strategy of multi AGV system to improve the waste smoke recovery efficiency of AGV.

1. Problem Description and Modelling of Multi AGV Waste Smoke Recovery

In the smart factory, materials are transported according to the waste smoke recovery demand of each work area, and the AGV scheduling strategy meets the production of each production area. The planning path of AGV raw and auxiliary materials handling in smart factory needs to consider multiple interference factors. When building the handling model, it needs to consider the conflict of small workshops with multiple AGVs, the connection between AGV tasks, the AGV transportation distance and the interference between AGV and production environment. The handling strategy and path planning of AGV are not in line with the production situation, which may lead to material interruption in the production area, thus affecting the production interruption of the plant. Considering the complexity of multi AGV path planning in the plant workshop, the following assumptions are made:

(1) The initial position of AGV can be in any area of the smart factory, without considering factors such as avoidance, straight-line acceleration and deceleration, turning and deceleration, and walking at a constant speed.

(2) The number and working environment of AGV are known in multi AGV system, and the reaction time of AGV stop and start and the problem of AGV failure are ignored.

(3) A single AGV is only allowed to perform one handling task. AGV can handle multiple production materials, multiple handling modes and multiple handling businesses. This paper describes the planning of AGV path for the key logistics equipment in the smart factory workshop: V vehicles are equipped in the smart factory workshop to carry AGV by fork. There are n production areas in the handling task flow to complete the material transportation. A single AGV system produces P material transportation tasks. After the material loading, AGV carries the material from one production area to another. Build a mathematical model that AGV can perform the material handling task in the minimum cycle, as shown in formula (1) and formula (2):

$$f_{ij} = \min \max_{1 \le i \le V} \left\{ \sum_{j=1}^{P} X_{ij} T_{ij} \right\} \tag{1}$$

$$X_{ij} = \begin{cases} 1 & \text{The i-th AGV completes the j-th task} \\ 0 & \text{Other} \end{cases} \tag{2}$$

Equations (1) and (2) are constraints:

$$\sum_{i=1}^{V} X_{ij} = 1 \quad \forall j \tag{3}$$

$$\sum_{j=1}^{P} \sum_{i}^{V} X_{ij} = P \tag{4}$$

Where: f_{ij} is the time for completing all the handling tasks; T_{ij} is the time required for the *i*-th AGV to complete the *j*-th task; X_{ij} is the decision coefficient for the *i*-th AGV to perform the *j*-th task; formula (1) indicates the minimum total AGV operation time for performing all the material handling tasks; formula (3) indicates that a single AGV performs a single material handling task; formula (4) indicates that multiple AGVs perform all the tasks.

2. Waste Smoke Recovery Path Time Window

The reliability and effectiveness of the algorithm structure are reflected in the time window algorithm, which is very important for the accuracy of the access path of AGV. Therefore, we will discuss different definitions of time windows for various path situations.

A shown in Figure 1, the body length of AGV is set as *s*, and the uniform running speed is *a*. the handling tasks of a single AGV in a certain road section are divided into three types:

(1) AGV in straight line section

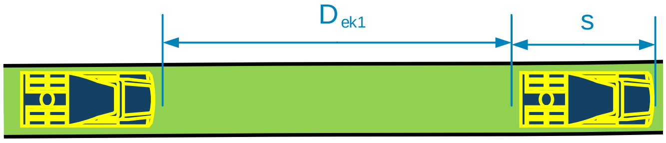

Figure 1. Straight Line Section

The calculation formula of AGV travel time in straight line section is as follows:

$$t_{straight} = \frac{D_{e_{k1}} + s}{a} \tag{5}$$

(2) AGV in curve section

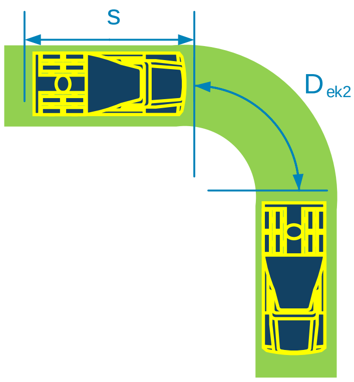

Figure 2. Curve Road Section

As shown in Figure 2, the calculation formula of AGV travel time in curve section is:

$$t_{curve}=\frac{\frac{\pi D_{e_{k1}}}{2}+s}{a}=\frac{\pi D_{e_{k1}}+2s}{2a} \tag{6}$$

(3) AGV in mixed section

There are two AGVs competing for resources in the same road section. The relevant time window of the road section can be determined by confirming the time point they enter. As shown in Figure 3, AGV_2 on the road e_{k3} and AGV_1 on the road e_{k1} compete for the road e_{k4} section. 1#AGV passes the intersection first. Suppose that the time t_{2k4}^{in} point for entering the road section is e_{k4}, the time t_{2k3}^{out} point for 2#AGV to leave the road section is e_{k3}, and the time t_{1k4}^{out} point for 1#AGV to leave the road section is e_{k4}, then:

$$t_{2k4}^{in}=\max\left\{t_{1k4}^{out},t_{2k3}^{out}\right\} \tag{7}$$

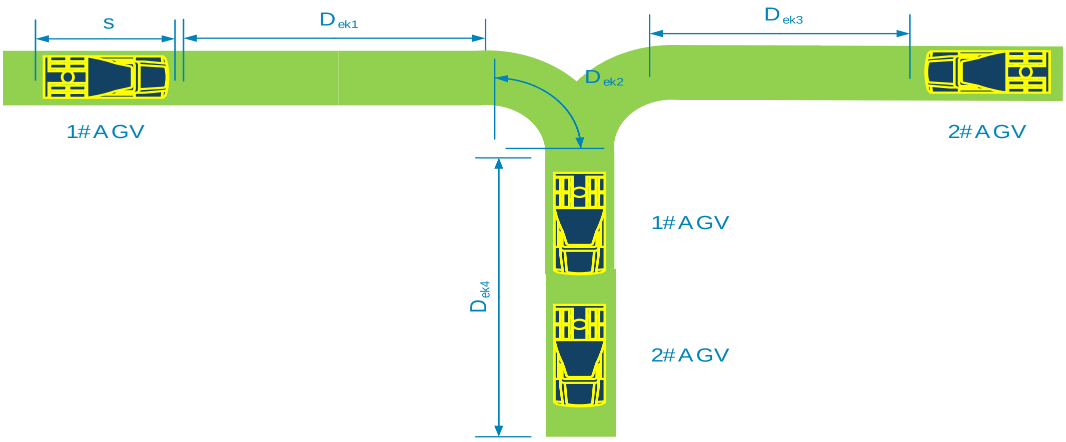

Figure 3. Two AGVs Compete for the Same Section

3. Optimization of Particle Swarm Optimization Algorithm for AGV Scheduling

With $P_i=(p_{i1},p_{i2},\cdots,p_{iD})$, $i=1,2,\cdots,n$, the i-th particle is searched for the current optimal spatial position, and the individual particle p_{best} of the basic particle swarm algorithm is searched until now. The optimal position is represented by $P_g=(p_{g1}, p_{g2}\cdots, p_{gD})$, which is the g_{best} global extremum, and each particle updates the spatial position and velocity in real time with reference to P_g and P_i.

$$\mathrm{v}_{id}(k+1)=w\mathrm{v}_{id}(k)+c_1r_1(p_{id}(k)-x_{id}(k))+c_2r_2(p_{gd}(k)-x_{gd}(k)) \tag{8}$$

$$x_{id}(k+1)=x_{id}(k)+\mathrm{v}_{id}(k+1) \tag{9}$$

$$i=1,2,\cdots,\mathrm{n} \quad d=1,2,\cdots,\mathrm{D}$$

In the formula, $w\geq 0$ is inertia. r_1 and r_2 are arbitrary numbers between [0, 1], The normal number learning factors c_1 and c_2. It is difficult to find the local optimal solution, thus losing the opportunity to find the global optimal solution. If the whole particle swarm will converge to P_g quickly, then P_g is a local optimal value.

This paper improves the original particle swarm optimization algorithm:

(1) V_{id} adjustment

It is necessary to adjust the particle swarm of the individual extreme P_{id}:

$$P_r=(p_{r1},p_{r2},\cdots,p_{rD}) \qquad r=1,2,\cdots,\mathrm{n} \tag{10}$$

Among them $P_{rj} = (p_{1j} + p_{2j} + \cdots + p_{nj}) / n \quad j = 1, 2, \cdots, D$

The updated particle speed is updated to:

$$v_{id}(k+1) = wv_{id}(k) + c_1 r_1 (p_{rd}(k) - x_{id}(k)) + c_2 r_2 (p_{gd}(k) - x_{id}(k)) \tag{11}$$

(2) P_{id} adjustment

In the evolution of the species of the t-th generation, a random number r in the range [0, 1] is generated, and R_i is obtained according to $R_i=t/G_{max}$. When $r>R_i$, randomly generate a single particle, mark the optimal spatial position of this particle as P_{rnd}, replace P_{gd} in equation (11), adjust the particle velocity in real time according to formula (12); Otherwise, according to formula (11)) to update.

$$v_{id}(k+1) = wv_{id}(k) + c_1 r_1 (p_{rd}(k) - x_{id}(k)) + c_2 r_2 (p_{md}(k) - x_{id}(k)) \tag{12}$$

In the formula: P_{rnd} is randomly generated from P_i of non-local particles and is not P_g, G_{max} is the largest algebra of evolution, and t is the current evolutionary algebra.

4. Implementation of AGV Scheduling Particle Swarm Optimization Algorithm

The scheduling of the tasks received by each AGV and the scheduling of each AGV handling task are two key points for the AGV system to optimize the handling tasks. The AGV scheduling strategy is a complex process of multiple interference factors. In this paper, the particle swarm algorithm of AGV scheduling strategy is designed by multi-bit spatial representation of vector particles. The flow is shown in Figure 4.

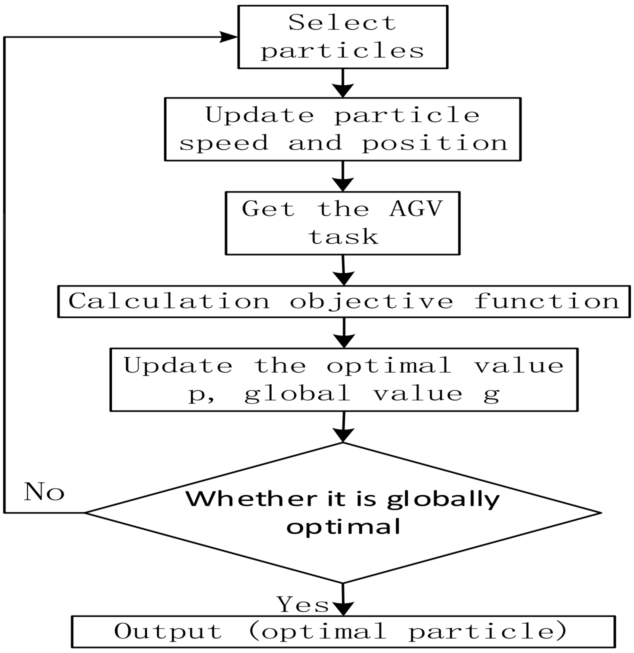

Figure 4. Implementing Flow Chart of Improved Particle Swarm Optimization Algorithm

4.1. Encoding and Decoding of Particle Swarm Optimization

The handling tasks of AGV in this paper include assignment and ordering problems. Therefore, the paper uses 3D vector representation when completing particle swarm coding. See Table 5.1:

Table 1. Representation of the First Particle

Task Number	1	2	3	4	5	…	Z
Task Assignment	z_{i1}	z_{i1}	z_{i1}	z_{i1}	z_{i1}	…	z_{iN}
Task Order	d_{i1}	d_{i1}	d_{i1}	d_{i1}	d_{i1}	…	d_{iN}

In the Table, D is the number of particle groups, $i\in[1,M]$, M is the number of AGVs in the smart factory site, Z is the number of material handling tasks; the first dimension is the AGV handling task, Z is the number of handling tasks; the second dimension It is the sorting of material handling tasks. The size of the $D_{i(1\text{-}Z)}$ value is unlocked, and the tasks belonging to the same path are queued to complete the whole column of the particle vector. The third dimension is automatically received by the upper system of the multi-AGV material handling task. The particle group is given upper and lower limits: $Z_{i(1\text{-}N)}\in[1,M+1]$, and the complete $INT(z_{ij})$ is obtained in the $[1,M]$ constant, which corresponds to the ordering of the AGV. Therefore, when the algorithm is initialized, the range of values of each dimension of the particle vector is known, and the range of feasible solutions to some extent has been given in the particle swarm optimization algorithm.

4.2. Constraint Conditions and Objective Function Settings of Particle Swarm Optimization

The AGV system of this paper determines that the total number of tasks performed by the number of tasks is at least the objective function. The handling cycle of each task z consists of two parts. Each AGV takes a fixed delivery period, and the AGV assignment task is more uniform, so it arrives from the current position. The time of the starting station and the time at which the task start station reaches the target station determine the period of the AGV handling task.

The start is based on the single-particle coding. In each group of the execution task queue, the displacement and velocity calculations are completed, and the obtained particle space position is analyzed. The first dimension is the execution task number of the AGV application; the second dimension is the task order obtained by decoding; the third dimension is the acquisition task number and the corresponding AGV. The total running time of all AGV tasks is the total operating cycle of the AGV system. Finally, the total time of all AGV operations is compared, and the shortest solution of the AGV system is selected, and the AGV time is relatively average as the objective function of the iteration.

4.3. Analysis of AGV Waste Smoke Recycling Business

Assume that the AGV of the smart factory waste smoke recovery system has 12 sets of AGVs of the same specification. Selecting a certain cycle, the AGV system tasks include 10 empty waste pipe recycling tasks, 10 machine waste recycling tasks, and AGV system tasks total 20 the task of recycling AGV waste smoke at a certain time is shown in Table 2:

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Table 2. Task Data Table for AGV Jobs at a Time

No.	Start address	Aims address	Issued time	Start time	End Time	Task status
1	YPP08	8345	17:27:00	17:29:00	17:37:03	End
2	YPP07	8345	17:27:40	17:29:35	17:37:16	End
3	ZBE04	8345	17:32:30	17:37:21	17:42:19	End
4	8314	YPP07	17:39:50	17:41:41		Doing
5	8323	ZBE04	17:45:10	17:46:54		Doing
6	8334	YPP08	17:46:40	17:48:59		Doing
7	ZBE09	8345	17:52:00	17:57:02		Doing
8	8333	ZBE09	18:04:30	18:06:11		Doing
9	ZJG04	8345	18:06:45	18:08:41		Doing
10	8323	YPP02	18:09:45	18:12:20		Doing
11	ZBG03	8345	18:14:30	18:15:34		Doing
12	8333	ZBE11	18:20:00	18:23:39		Doing
13	8314	ZBG08	18:20:40	18:23:20		Doing
14	ZJG04	8345	18:21:15	18:23:19		Doing
15	ZJE06	8345	18:26:15	18:27:25		New
16	8333	YPP11	18:30:10	18:31:19		New
17	8323	YPP03	18:31:40	18:32:00		New
18	ZBF02	8345	18:32:40			New
19	8334	ZJF07	18:36:10			New
20	ZBG08	8345	19:40:10			New

Set the particle swarm initial condition: the operation precision of 0.5, the population number of particles D=40, the total number of AGVs M=12, the total number of task schedules Z=22, the maximum number of iterations G_{max}=200, the inertia weight w=0.6, the learning factor c_1=2, c_2=2, particle coding uses a three-dimensional vector group.

5. Conclusions

The total waste smoke recovery task performs an improved particle swarm optimization algorithm with a minimum running time as an objective function. Under the condition of ensuring the time point, the queued waiting task is dynamically pre-allocated to the AGV of the normal execution task, and the algorithm does not have to be in the task transformation. After recalculation, the algorithm cycle is compressed. After the system releases a new task or completes the task, it determines the location and quantity of the material handling task, and assigns the material handling task again based on the improved particle algorithm.

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