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Dynamic scheduling strategy of intelligent RGV

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Abstract: In the intelligent processing system, RGV can automatically guide the operation through the scheduling strategy. The problem of RGV allocation and scheduling is the core problem of the system operation. If the scheduling is reasonable, more processing efficiency can be obtained. In this paper, a set of RGV dynamic scheduling strategies and solving algorithms are developed for one process and two processes. For a process, the factors affecting the efficiency of the system are firstly judged. The RGV dynamic model is established with the minimum RGV moving total path as the target, and the greedy method is used as the solution algorithm. For the two processes, the rules for determining the CNC allocation scheme are first given. According to different distribution schemes, the optimal placement position of the two processes is given. The RGV dynamic scheduling model is established with the RGV moving total path as the target.

1. Introduction

RGV is an unmanned rail-guided vehicle system that integrates various high-tech technologies and is widely used in modern logistics systems. There is an intelligent processing system consisting of eight computer numerical control machine tools (CNC), one rail-type automatic guided vehicle (RGV), one RGV linear track, one feeding conveyor belt, and one feeding conveyor belt. RGV can automatically control the moving direction and distance according to the command, and comes with a robot arm, two mechanical grippers and material cleaning tanks, which can complete the tasks of loading and unloading and cleaning materials. The problem of allocation and scheduling of RGV in the processing system is the core problem of the system operation. If the scheduling is reasonable, more processing efficiency can be obtained. If it is unreasonable, the mechanical utilization rate of the system will be low.

2. Problem analysis

This paper mainly solves the RGV dynamic scheduling model and solving algorithm for one process and two processes.

2.1 One process

In the case of processing one process, since the same kind of workpiece loading and unloading, processing, and cleaning time are the same, consider making all CNC working times as much as possible within a certain period of time, and the moving time of the RGV trolley should be the shortest, that is, the single movement selection. The paths are currently the shortest, and the RGV dynamic scheduling scheme is implemented according to the shortest path principle.

2.2 Two process processing

The two processing steps must first consider the distribution problem of the CNC. The distribution of the CNC is determined according to the processing time ratio of the two processing steps. After determining the number of CNCs allocated to the two processing operations, it is necessary to consider how to arrange it. Considering the moving distance of RGV and the time of loading and unloading on both sides, the CNC corresponding to the processing procedure should

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consider how the RGV moves to maximize the system efficiency. Considering that the problem is more complicated, the general optimization model and algorithm are difficult to do. Simulation, determine the simulation rules with em_Plant for simulation.

2.3 Assumption

- 8 CNC working hours start from the same time;
- Assume that only feeding or cutting only is the same as loading and unloading;
- Assume that there are no two or more CNC failures at the same time;
- Assume that no other interference factors will occur except for the failure of the CNC;
- At the same position, ignore the arm movement time when loading and unloading the CNC on both sides.

3. Symbol Description

Table 1. Symbol Description

Symbol	Description	unit
T_α	One time of loading and unloading	s
T_β	Time required to process a material	s
L_i	The starting time of the i-th material loading	
U_i	The starting time of the i-th material blanking	
i	Number of material sequences processed by the machine	
j	CNC number	
Q_{RGV}	Where the RGV was when it received the order	
Q_j	The location of the CNC that issued the command	
C_j	CNC state set	

4. Model establishment and solution

4.1 One process

It is known that CNC processing time is the same for the same material, and RGV is the same for the same side CNC loading and unloading and cleaning. Therefore, within a certain working time, the shorter the total waiting time of the CNC, the higher the utilization rate of the CNC, and the more finished materials are processed. The problem of the shortest waiting time of the CNC can be converted into the shortest problem of the total path of the RGV trolley.

The starting time of material i is defined as L_i, the starting time of material i is U_i; Q_j is the location of the CNC that issued the demand instruction; Q_{RGV} is the location where RGV is requested, and Q_d is the location of the next working CNC of RGV; T_α is the time of one loading and unloading, T_β is the time required to process one material; $B_j(j=1,2,\cdots,8)$ represents the collection of CNC.

Define the remaining time of the i-th material for CNC machining with the number j as the machining time remaining for the CNC, denoted T_{ijw}, where j is the CNC number, j=1, 2,...,8; i is the intelligent machine tool Material processing serial number, i = 1, 2, ..., n.

So the objective function is as follows:

$$MIN=\sum_{i=1}^{n}\left|Q_j-Q_{RGV}\right|$$

The constraints are:

$$s.t.=\begin{cases}U_i-L_i\geq T_\beta\\ L_{i+1}>L_i\\ L_i,U_i,T_\alpha,T_\beta,T_{ijw}\geq 0\\ \prod_{i=1}^{n}B_j\times(\min T_{ijw})\leq T_{ijw}\end{cases}$$

Since the order of CNC machining is too much and the processing state of the material is constantly changing, it is difficult to derive a global optimal solution. Through analysis, the optimal solution may only exist in some better combinations, so it can be obtained by greedy method [1]-[2].

The idea of greedy law: every time you choose the current optimal point, if you do not meet the conditions, choose the second advantage again, and so on. According to the analysis, from the initial position, each step adopts the principle of proximity, and selects the shortest path in the CNC that needs to be loaded and unloaded. Every time you move to a CNC and complete the job, the status of all CNCs is updated, and the CNC position of the loading and unloading is determined next, and the approximate optimal solution of the shortest total path of the trolley movement can be obtained.

Algorithm steps:

Step1. Define the CNC idle state and the remaining time of the CNC that has completed clinker processing is 0;

Step2.RGV immediately updates the remaining working time of all CNCs when completing the loading and unloading of a CNC, and the remaining CNC working time of the completed is updated to T_β-T_α;

Step3. At this time, in all the CNCs with the remaining working time 0, the closest distance is selected, and when there are two or more identical shortest distances, the odd number CNC is preferred;

Step4.RGV moves to the selected CNC position, and the CNC is loaded and unloaded and cleaned;

Step 5. Repeat steps 2-5 until the shift time expires.

● Initial Strategy of RGV Scheduling

In the initial state, RGV is located between CNC1# and CNC2#, and this position is defined as 0, and the forward movement position is 1, 2, and 3, respectively. Because the time required for CNC1#, 3#, 5#, and 7# loading and unloading is less than CNC2#, 4#, 6#, and 8#, the CNC1# is first loaded, and the CNC2# is loaded; RGV continues to advance. For the same reason, the CNC3#, 4# are loaded, and continue to advance until all the CNCs are loaded, and the RGV is at the 8 position. Waiting for the signal of CNC1# here, looping back and forth.

Use matlab to implement the algorithm , and get the scheduling scheme as shown in the figure:

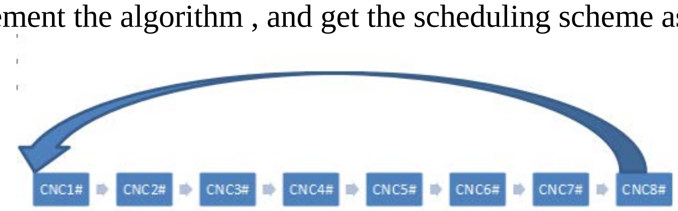

Figure 1: Preliminary scheduling plan

● Model test

The operating efficiency of the system can be defined as the number of processed materials per unit time. Here, the number of materials processed by the system per unit time is calculated, and the calculation results are as follows:

Table 2. Operational efficiency of the greedy law system

data	**Efficiency**
First set of data	45.375
Second set of data	42.125
Third set of data	45.750

● Improvement of RGV Scheduling Model

Through the calculation of the three groups, it is found that the processing time of a single CNC is much longer than the time of loading, unloading, moving and cleaning all the other CNCs. When one processing cycle is completed, RGV moves to the middle position of CNC7#, 8#, waiting for CNC# 1 When the processing is completed, the command issued by CNC1# is received, and the movement to the CNC#1 position is started. At this time, the intelligent system needs to wait for RGV to move for three unit time to enter the next production cycle. It takes too long to reduce the entire system. Mechanical utilization.

Therefore, the model is improved. According to the calculation, as long as the machining time of the first loading CNC is greater than the rest of the CNC loading and unloading and cleaning, RGV movement time, the RGV dynamic scheduling strategy of any path needs to wait for the CNC processing of the first loading. Will enter the next job cycle. Then the closer the RGV waits to the first CNC, the faster it will enter the next job cycle.

From this we conclude that the first time before the CNC is commanded, the RGV saves time when all the CNCs are finished and return to the initial position. Therefore, we have changed the scheduling scheme that satisfies the conditions as follows. According to this scheduling scheme, it is looped until it works for 8 hours.

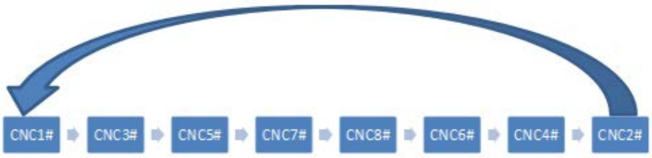

Figure 2: Improved RGV Scheduling Strategy

The operating efficiency of the system can be the number of materials processed by the system per unit time, or the average time required to produce one material. Here, the number of materials processed by the system per unit time is calculated, and the calculation results are as follows:

Table 3. System operation efficiency table before and after model improvement

data	Pre-improvement efficiency	Improved efficiency
First set of data	45.375	46.375
Second set of data	42.125	44.625
Third set of data	45.750	46.750

It can be seen from the table that after the improved algorithm, the operating efficiency of the three groups of systems is improved, so the improved model system is more efficient than the model before the improvement.

4.2 Two processes

● CNC quantity allocation

Since the first process and the second process are different in processing time, the tool should be installed in accordance with the time ratio of the two processes. The number of CNCs is evenly distributed when the time ratio is around 1, otherwise, a long time process is required to allocate a larger number of CNCs. The specific allocation rules are as follows:

Table 4. CNC allocation rule table

First process and second process time ratio	Number of CNCs in the first process	The number of CNC in the second process
(0.000,0.185]	1	7
(0.185,0.467]	2	6
(0.467,0.800]	3	5
(0.800,1.333]	4	4
(1.333,2.333]	5	3
(2.333,5.000]	6	2
(5.000,+∞)	7	1

(1) The distribution of two processes in accordance with one and seven units

One unit is allocated in a small amount of time, and seven units are allocated in a time-consuming process. Considering the moving distance of RGV and the waiting time of CNC, the process that takes less time is selected in CNC3#, 4#, 5#, 6#, taking into account the initial position of RGV, and then between 3# and 4#. Select, considering the difference between the loading and unloading time on both sides, if the first process takes less time, select CNC3#, otherwise select CNC4#.

(2) The distribution of the two processes in accordance with 2 and 6 units

Two units are allocated in a small amount of time, and six units are allocated in a time-consuming process. Considering the moving distance of RGV and the waiting time of CNC, if the first process takes less time, the first process is arranged in CNC1#, 6# or CNC2#, 5#. If the second process takes less time, then The second process is arranged in CNC3#, 8# or CNC4#, 7#.

(3) The distribution of the two processes in accordance with 3 and 5 units

Three units are allocated in a small amount of time, and five units are allocated in a time-consuming process. Considering the moving distance of the RGV and the waiting time of the CNC, if the first process takes less time, the first process is arranged in CNC2#, 3#, 5#, and if the second process takes less time, the second pass is taken. The process is arranged in CNC3#, 6#, 7#.

(4) The distribution of the two processes in accordance with 4 and 4 units

Taking into account the moving distance of RGV and the waiting time of the CNC, the first process arranges CNC1#, 2#, 7#, 8#, and the second process arranges CNC3#, 4#, 5#, 6#.

● Model establishment

The goal is to make the total path of RGV movement the shortest, and build the model as follows

$$MIN = \sum_{i=1}^{n} \left| Q_{j1} - Q_{RGV} \right| + \sum_{i=1}^{n} \left| Q_{j2} - Q_{RGV} \right|$$

The constraints are:

$$s.t. \begin{cases} L_{i1} + T_{\alpha} + T_{\beta 1} \le L_{i2} \\ U_{i1} - L_{i1} \ge T_{\beta 1} \\ U_{i2} - L_{i2} \ge T_{\beta 2} \\ L_{(i+1)1,2} - L_{i1,2} \ge T_{\alpha} + T_{\beta 1,,2} \\ L_{(i+1)1,2} > L_{i1,2} \\ \prod_{j=1}^{8} B_j \times (\min T_{ijw}) \le T_{ijw} \\ L_{i1}, L_{i2}, U_{i1}, U_{i2}, T_{\beta 1}, T_{\beta 2} \ge 0 \end{cases}$$

(1) The same material must be processed in the first process before the second process can be processed.

$$L_{i1} + T_{\alpha} + T_{\beta 1} \le L_{i2}$$

(2) The difference between the start time of feeding and the start time of loading in each process is greater than or equal to the processing time of the material in the process

$$U_{i1} - L_{i1} \ge T_{\beta 1}$$

$$U_{i2} - L_{i2} \ge T_{\beta 2}$$

(3) RGV can only perform one task in this process

$$L_{(i+1)1,2} - L_{i1,2} \ge T_{\alpha} + T_{\beta 1,,2}$$

(4) The same CNC can process another material only after processing one material.

$$L_{(i+1)1,2} > L_{i1,2}$$

(5) RGV waiting time is less than or equal to the remaining time of CNC machining

$$\prod_{j=1}^{8} B_j \times (\min T_{ijw}) \le T_{ijw}$$

(6) All time parameters are non-negative

$$L_{i1}\ L_{i1}, L_{i2}, U_{i1}, U_{i2}, T_{\beta 1}, T_{\beta 2} \geq 0$$

● Scheduling algorithm

Step1: Define the status of the RGV and the status of the CNC.

When RGV is unloaded, it is recorded as 0 state, and when RGV is loaded with material, it is recorded as 1 state. When the CNC is idling in the first process, it is recorded as 1 state. When there is material on the CNC, it is recorded as 0 state. When the CNC is idling in the second process, it is recorded as 0* state. When there is material on the CNC, it is recorded. It is 1* status.

Table 5. CNC Status Table

	No load	Material
First set of data	1	0
Second set of data	1*	0*

Step2: Determine the initial state of RGV

RGV initial state is 0

Step3: Specify the type of signal received by the different states RGV

When the RGV is in the 0 state, it can accept the signal from the CNC with the status 0 or 1 or 1*. The RGV is in the 1 state and can accept the signal from the CNC with the status 0 or 0*.

Step4: Update rules for RGV and CNC

When the RGV is in the 0 state, the status is 0 or the status of the CNC service is updated. When the RGV is in the 1 state, the status is 0. The CNC service status is updated (the CNC service in the status 1* state includes loading and unloading) And cleaning)

Step5: RGV movement rules

Table 6. RGV Movement Rule Table

0→0	feasible
0→1	feasible
0→0*	Infeasible
0→1*	feasible
1→0	Infeasible
1→1	Infeasible
1→0*	feasible
1→1*	Infeasible

Table 7. RGV algorithm rules

RGC status	CNC status	Path	Is it feasible	Is RGV updated	Is the CNC updated
0	0	0→0	feasible	Y	N
	1	0→1	feasible	N	Y
	0*	0→0*	Infeasible		
	1*	0→1*	feasible	N	Y
1	0	1→0	Infeasible		
	1	1→1	Infeasible		
	0*	1→0*	feasible	N	Y
	1*	1→1*	Infeasible		

Step6: Path selection

When the RGV receives multiple instructions, according to the "nearby" principle, select the position closest to the RGV to perform the task. If the two CNC positions of the RGV to the signal are the same, the above-mentioned blanking takes less priority.

- Practical verification of the model

Calculate the hourly efficiency of the three sets of data separately.

From the results of the obtained effect rate, it can be seen that the efficiency of the three sets of data is high, so the model has strong practicability.

- Algorithm validation

For the first group of data, the ratio of the first process to the second process time is 1.06. According to the above table, the number of the first process and the second process CNC is four.

For the second group of data, the ratio of the first process to the second process time is 0.56. According to the above table, the first process is 3 sets, and the second process is 5 sets.

For the third group of data, the processing time ratio of the first process to the second process is 2.5. According to the above table, the first process is 6 sets, and the second process is 2 sets.

The effectiveness of the algorithm is verified by using the algorithm to successfully obtain the scheduling scheme of three sets of data.

5. Model evaluation

5.1 Advantages of the model

1) Establish dynamic mobilization model, give dynamic mobilization algorithm, successfully obtain RGV scheduling scheme, further improve the model algorithm, compare the working efficiency of the two schemes, and make the scheduling scheme better.

2) Using simulation algorithms to establish simulation rules to make complex dynamic scheduling problems more visual.

3) The applicability of the model is strong, and the model algorithm is applicable to the case of no failure and failure or interference.

5.2 Shortcomings of the model

1) The obtained transfer scheme is not a global optimal solution, but a local optimal solution.

2) The improved model of one process is only applicable when the processing time is much longer than other working processes and RGV moving speed.

5.3 Promotion of the model

The dynamic scheduling algorithm of this paper can be used for multi-machine mold electrode scheduling problems, bus scheduling problems, port cargo transportation problems and other types of dynamic scheduling problems.

The simulation rule algorithm used can be used to deal with transportation, vehicle detection, mechanical operation and other fields.

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