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An Effective Method for Dynamic Global Optimal Scheduling of RGV Based on Probability Function

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An Effective Method for Dynamic Global Optimal Scheduling of RGV Based on Probability Function

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Abstract. In this study, an effective dynamic scheduling strategy based on quasi-global optimizing search method is designed to plan the working sequence of RGV. By using '0-1' variable, the working state of CNC is simplified and the whole processing procedure could be simulated by Matlab. Also, probability function is applied to decide the scheduling sequences, thus avoiding local optimal solutions. Then, the dynamic global optimizing scheduling strategy is completed. Besides, the efficiency of the whole system is calculated and the corresponding results are compared with local optimizing scheduling. This dynamic scheduling strategy could improve the efficiency of the whole system during the processing materials.

1. Introduction

With the rapidly development of Industry4.0, Intelligent machining system is increasingly essential to manufacturing plant. It is mainly composed of eight Computer Number Controllers(CNC), a Rail Guide Vehicle(RGV), a RGV linear track and two feeding conveyor belts. RGV is a driverless smart car equipped with a mechanical arm, two mechanical claws and material cleaning groove. It could complete the loading and unloading and cleaning materials. It would not only save human resources largely but also accelerate the production speed. However, during the production, unreasonable scheduling of RGV would do damage to machines and slow down the production speed, causing the economic loss of factory. Therefore, it is of great value to make out feasible and efficient dynamic scheduling strategy [5-6].

Traditionally, local optimal scheduling strategy has been widely applied. Local optimal scheduling strategy is mainly based on greedy algorithm [1-2]. Greedy algorithm always makes the best decision in the present and must have no aftereffect, that is, the process before a certain state will not affect the later state, but only related to the current state. Due to the real time varying and complex production conditions, it usually could not meet the requirements of dynamic scheduling. Besides, local optimal strategy would decrease the production speed and could cause some financially loss. With the intensive development of industrial manufacturing, the demand for intelligent machining system has become increasingly urgent. The traditional local optimal scheduling method has difficulties to meet the high speed and efficient manufacturing demands. In recent years, some dynamic global optimal scheduling strategies [3-4] have already been used in many fields because its result approximates the global optimal solution, and has achieved good application effect.

Considering all the problems mentioned above, a dynamic global optimal scheduling strategy is designed. The strategy is mainly based on adaptive and global optimizing probability search method and uses Matlab to analyse the efficiency of the scheduling strategy. In the process, probability function determines whether the transport request is accepted or not, and the lower the transportation time cost, the more likely it is to be accepted. Besides, we compare results of our model with greedy algorithm and the corresponding efficiency is improved.

2. Design of dynamic scheduling Algorithm

Fig. 1 shows the procedure of the dynamic scheduling strategy. Firstly, we set the maximum number of searches and initiate the parameters. Besides, in order to adapt to the actual production demand, the whole procedure is set within 8 hours. Then, we check the working state of each CNC, and if there are more than one free CNCs, RGV will select one CNC machine randomly from the CNC set. However, if there's no CNC sending demand signal, it would wait until the appearance of signal. And the waiting time is recorded because it would have tremendous on the whole procedure. After that, according to the probability function, it would decide whether the CNC is chosen for the next processing. When the CNC is chosen, the processing time (including uploading, cleaning and loading time) is added up to the waiting time altogether. On the contrary, if the CNC is blocked by the probability function, it would reselect another CNC from the CNC set and repeat the whole procedure. Finally, when one CNC has been arranged for processing, RGV would consider planning for the next CNC until 8 hours are used up or reaching maximum number of searches.

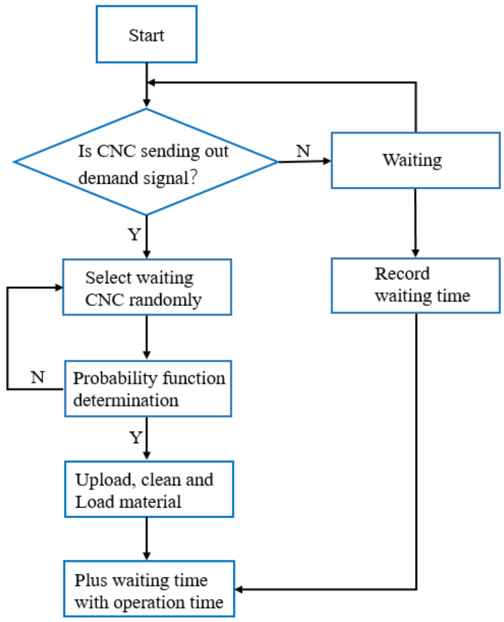

Figure 1. Flow chart of algorithm of dynamic scheduling Algorithm.

3. Results and discussion

3.1 Establishment of quasi-global optimal model

Fig.2 shows the layout of RGV-CNC workshops during one shift. Usually, the whole procedure includes moving RGV to the specified CNC, loading, cleaning and unloading materials. It is obvious that the relationship between RGV and CNC is quite complex. The workshop has three shift every 24 hours and each shift lasts for 8 hours. Besides, the speed of RGV is non-uniform, meaning that the more moving units the RGV has, the faster the average speed will be. Without reasonable RGV dynamic scheduling strategy, the whole processing procedure could cost more time and the producing efficiency would decrease, which could cause great economical loss to the company finally.

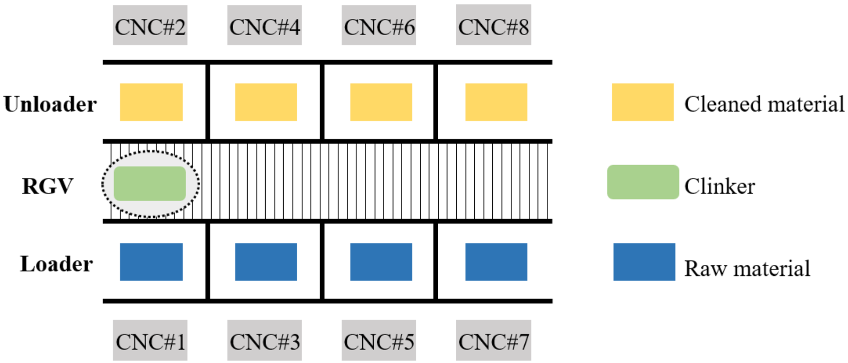

Figure 2. Layout of RGV-CNC workshop.

In order to show the working state of CNCs more conveniently and intuitively, we use "0-1" variable to represent the loading and unloading requirements of the two groups of CNC, and "0" is used to represent the demand signal of CNC, which required the overall operation process of "uploading - loading" or "uploading - cleaning - loading", and "1" is used to indicate that CNC was working without the need for loading, unloading and cleaning materials. As is shown in Fig.1, in a certain moment, No. 1, 3, 5 and 6 CNC are in working state and no operation is required. No. 2, 3, 7 and 8 CNC send out demand signals and require loading and unloading

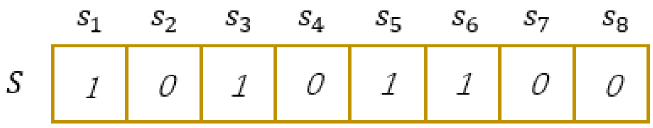

Figure 3. Working state of CNCs in a certain moment.

Considering the time of each shift is fixed (8 hours), we set the maximum amount of finished materials produced in a shift as the goal of establishing a dynamic scheduling model. In the procedure, RGV processing sequence not only determines the current state of CNC but also the imminent state of CNC. The imminent state of CNC would affect the next demand processing of RGV in turn. Therefore, the state of CNC is a function of prior state of CNC, RGV processing sequence and time.

During a shift, due to the non-uniform speed of RGV, it is not easy to determine the influence of the RGV processing order on the total production. Thus, in the first step, we base our model on the local optimal solution of the dynamic scheduling strategy. If RGV receives multiple demand signals in the idle time, we first calculate the complete operation time in all possible strategies. It includes the time for moving RGV, uploading, cleaning and loading materials. Then, RGV would select the strategy with the shortest operation time. That is to say, when selecting the next CNC machine, RGV would only consider the next operation and ignore the impact on the next few operations. By making the most favourable choice for the current moment, RGV could only obtain the local optimal solution. Besides, we also set a parameter to describe the efficiency of dynamic scheduling. The efficiency parameter is mainly composed of two parts. One part is the actual output of processing products and the other part is the maximum output which is calculated in the case of 8 CNC continuous operation. The system efficiency is achieved by dividing the two parts. And the results are shown in the Table 1.

Table 1. The results of local optimal solution.

Shift	The optimal strategy	Output	Efficiency
1	$1 \to 2 \to 3 \to 4 \to 5 \to 6 \to 7 \to 8 \to 1 \to 2 \ldots$	355	95.2%
2	$1 \to 2 \to 3 \to 4 \to 5 \to 6 \to 7 \to 8 \to 1 \to 2 \ldots$	337	89.3%
3	$1 \to 2 \to 3 \to 4 \to 5 \to 6 \to 7 \to 8 \to 1 \to 2 \ldots$	366	91.0%

3.2 Improved global optimal model

Results of local optimal solution are not necessarily the best solution because it only focus on the choice which is best for the current moment. Thus, we improve the judgement and selection process of RGV on the basis of local optimal solution. When RGV receive the demand signal from CNC, it would calculate the overall processing time of each CNC and put them into the CNC set. Instead of choosing the CNC with shortest operation time, RGV would select one CNC from the CNC set and accept it according to the probability function. The probability function includes two parts. In the first part, the operation time of each CNC from the CNC set is calculated and is divided by the whole operation time of CNC in the set. Then we subtract the part with 1 and acquire the probability parameter (as shown in formula 1).

$$P(k) = 1 - \frac{T_{operate}(t_{ik})}{\sum_{k=1}^{8} T_{operate}(t_{ik})} \tag{1}$$

When determining whether to accept the selected CNC or not, the system would generate a random number ranging from 0 to 1. Then we compare the probability parameter with the random number and choose whether to accept it or not. The smaller the probability parameter is, the less operation time the CNC would cost, which means that the possibility of acception is greater. And the corresponding results of global optimal solution is shown in table 2. From the table, we could conclude that the system efficiency has been improved to some extent.

Table 2. The results of global optimal solution.

Shift	The optimal strategy	Output	Efficiency	Gains
1	1 → 2 → 3 → 5 → 8 → 7 → 6 → 4 → 1	371	98.9%	3.7%
2	1 → 2 → 3 → 4 → 7 → 8 → 6 → 5 → 1	358	94.9%	5.6%
3	1 → 2 → 3 → 6 → 7 → 8 → 5 → 4 → 1	371	92.2%	1.2%

In order to show the results of global optimal solution more clearly, we depict the material gantt chart of Shift 1. As is shown in Fig.4, the scheduling sequence of RGV and total consuming time of each material is displayed intuitively. The horizontal axis represents the processing time, and the vertical axis represents the number of processing material. The number in the middle of article column means the number of CNC. For instance, the No.5 processing material is processed by CNC#8 at the time of 331s and ends at 886s. Besides, the RGV loads the No.4 material on the CNC#5 at the time of 275s. After that, it loads the No.5 material on the CNC#8 at the time of 404s.

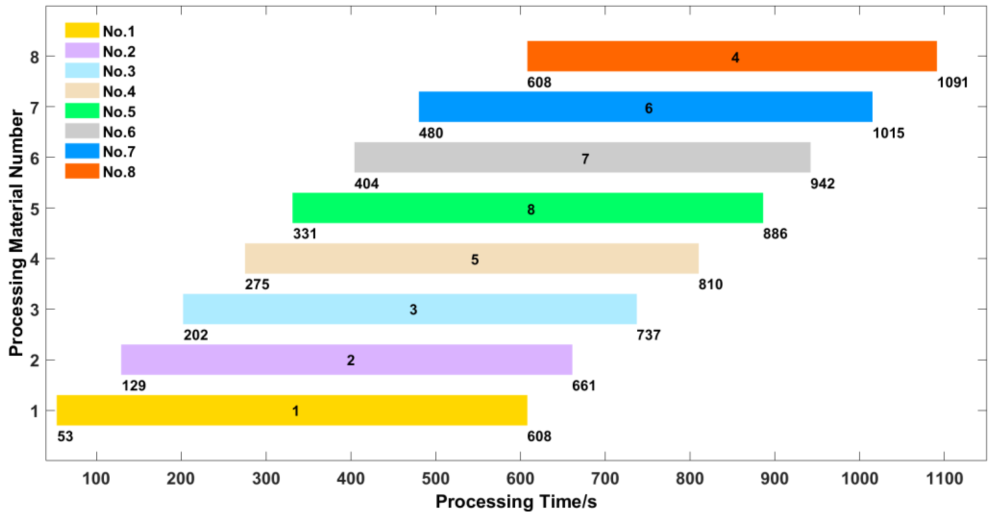

Figure 4. Material Gantt Chart.

4. Conclusion

In this paper, we proposed an effective dynamic scheduling strategy based on adaptive and global optimizing probability search method. In the process, ‘0-1’ variable is used to represent the state of CNC, and the simulation scheduling model is established. Also, in order to avoid the results of local optimal scheduling strategy, the probability function is introduced to decide whether the demand signal would be accepted. By using this system, the real-time optimal processing scheduling of RGV is realized, which could provide financial support for processing manufacture.

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