Dynamic Scheduling Strategy for Multiple AGVs based on 0-1 Planning Model

Bo Yang [1, *], Haoyu Wang [1], Xiangwen Tong [1], Wanghao Duan [2]

[1] Department of Energy and Mining Engineering, Shandong University of Science and Technology, Qingdao, China, 266590

[2] Department of Economics and Management, Shandong University of Science and Technology, Qingdao, China, 266590

* Corresponding author: yb868088@163.com

Abstract. The coordination of handling robots and AGVs can greatly improve the efficiency of unmanned warehouse picking operations and realize the automated management of warehouse logistics. The unreasonable scheduling scheme can lead to local congestion and collision of AGVs and reduce the picking efficiency of the unmanned warehouse. Therefore, this paper conducts an in-depth study on the scheduling mode of AGVs. When assigning orders, this paper designs an order-oriented double matching method, with the shortest total path length of AGV as the objective function, and establishes a 0-1 planning model to complete the matching of order-storage position nodes-AGV. The AGV searches and selects the nearest picking station node whose docking position is not full when it leaves the warehouse. In addition to the main order list, a workstation task list is created, and the workstation tasks are released by the picking stations, including return and recovery. In this paper, the default order and workstation tasks have the same priority, and the task selection order is the same as the release order. The 0-1 planning model is solved using a genetic algorithm to match the AGV with the order or station task that has the shortest path to completion.

Keywords: AGV scheduling, 0-1 planning, genetic algorithm.

1. Introduction

Automated Guided Vehicles, also known as mobile robots, are vehicles equipped with navigation devices that can travel along a planned path with safety protection and load shifting functions. And AGVs (Automated Guided Vehicles System) is usually composed of two parts: ground station system and vehicle control system. The vehicle control system receives instructions sent by the ground station system and makes the AGV automatically travel to the designated place according to the planned path to complete a series of operational tasks. With the rapid development of artificial intelligence, computer, microelectronics, automatic control, and other technologies, AGVs are more and more widely used in flexible manufacturing systems, three-dimensional warehousing, and logistics systems, intelligent inspection systems [1], which are mainly used in the automotive manufacturing industry, home appliance manufacturing, ports, airports, the tobacco industry, substations, chemical industry, etc. Chemical industry, etc.

2. AGV scheduling planning study

2.1. Model Establishment

For the planning and scheduling problem of handling robots, it requires that the walking path of a handling robot AGV is minimized if it is as busy as possible, and the Manhattan distance h_i between the starting point and the target point can be used to denote the length of the running path of the i-th AGV if the collision problem that may occur during the execution of the task by the AGV is not considered.

$$h_i = |n_x - g_x| + |n_y - g_y| \quad (1)$$

The main tasks of the handling robot AGV include three parts: outbound - back to the warehouse - recovery, and before performing the task must complete the matching of orders and AGVs. In this paper, we design an order-oriented double matching method, i.e., the order matches the storage node, and the storage node matches the handling robot AGV, and then complete the matching mode from order to AGV. The 0-1 planning function is designed, combining the idea of a greedy algorithm, introducing the concept of effective outbound quantity V and outbound efficiency value E. Under the condition of ensuring the order-storage nodes-AGV correspondence, the shortest inbound pickup path of AGVs is ensured and the number of outbound times required to complete each order is minimized.

$$V_{jk} = \begin{cases} C_{jk}, C_{jk} < I_k \\ I_k, C_{jk} \geq I_k \end{cases}, E_{ijk} = V_{jk}/h_{ij} \tag{2}$$

A 0-1 planning model is developed as follows. 0-1 decision variables are a_{ij} and b_{jk}. When a_{ij}=1, the i-th AGV matches the j-th storage node. When a_{ij}=0, the i-th AGV is not matched to the j-th storage node. When b_{jk}=1, the k-th order matches the j-th storage node. When b_{jk}=0, the k-th order is not matched to the j-th storage node.

The objective function is:

$$max\sum_{i=1}^{20}\sum_{j=1}^{n} E_{jk}a_{ij} \tag{3}$$

The constraints are:

$$s.t.\begin{cases} \sum_{i=1}^{20} a_{ij} \leq 1 \\ \sum_{j=1}^{n} a_{ij} = 1 \\ \sum_{k=1}^{20} b_{jk} \leq 1 \\ \sum_{j=1}^{n} b_{jk} = 1 \\ \sum_{i=1}^{20} a_{ij} = \sum_{k=1}^{20} b_{jk} \\ \sum_{j=1}^{148} c_{jk}b_{jk} > 0 \\ a_{ij} = 0,1 \quad b_{jk} = 0,1 \end{cases} \tag{4}$$

After assigning the orders, we enter the outbound process. According to the actual scenario, we assume that the number of docking positions at each picking station node b=3, and the dwell time t_0 =2, i.e. the time for the AGV to move two units of distance, and establish a 0-1 planning model as follows. 0-1 decision variable is s_{ip}. When s_{ip} =1, the i-th AGV matches the p-the picking station. When s_{ip} =0, the i-th AGV does not match the p-th picking station.

The objective function is:

$$min\sum_{p=1}^{18}\sum_{i=1}^{20} s_{ip}h_{ip} \tag{5}$$

The constraints are:

$$s.t.\begin{cases} \sum_{i=1}^{20} s_{ip} \leq 3 \\ \sum_{p=1}^{18} s_{ip} = 1 \\ s_{ip} = 0,1 \end{cases} \tag{6}$$

If the i-th AGV completes the order task, the system will issue the order in order of order ID, considering the task demand of picking station back to storage and pallet recovery, it is necessary to establish a station task list when the picking station completes its picking task, it will release a station

task, the priority of station task and main order in this paper is the same. At this time for the dynamic matching stage of the order, the AGV not only needs to go to the storage node to execute the outbound task but also needs to go to the picking station node to complete the return to storage and pallet recovery tasks.

Assuming that there are *n* AGVs that have completed the current order task at the same time, the master order list and the workstation task list will select the first n orders in the list for assignment in the order of ID, respectively, to establish a 0-1 planning model, and for each AGV that has completed the current task, design the planning model as follows. 0-1 decision variable is a_j. When a_j=1, AGV matches to the *j*-th picking station. When a_j=0, AGV does not match the *j*-th picking station.

The objective function is:

$$max\sum_{j=1}^{148} E_{jk}a_j \tag{7}$$

The constraints are:

$$s.t.\begin{cases} \sum_{j=1}^{148} a_j = 1 \\ \sum_{j=1}^{148} b_{jk} = 1 \\ a_{ij} = \sum_{k=1}^{n} b_{jk} \\ \sum_{j=1}^{148} c_{jk}b_{jk} > 0 \\ a_j = 0,1 \end{cases} \tag{8}$$

Further judgment:

$$min\sum_{j=1}^{148} h_j a_j,\ min\{hp1,\ hp2,\ldots,\ hpn\} \tag{9}$$

The AGV will choose the task with the shortest distance to perform, where h_j denotes the distance between the cart and the *j*-th storage node. h_p indicates the distance of the AGV from each picking station node.

If multiple AGVs receive the same main order or workstation task at the same time, they will receive the order tasks in order according to the AGV number, and the AGVs that have not received the task will be deferred to complete the subsequent tasks, and this planning equation is also applicable to the order assignment of the AGVs that have completed the workstation task.

If the main order of an AGV is not completed, the system will not select a new order and the AGV must continue to complete the current unfinished order and select the most appropriate storage node according to the SKU corresponding to the order. The design planning model is as follows.

The objective function is:

$$max\sum_{j=1}^{148} E_{jk}a_j \tag{10}$$

The constraints are:

$$s.t.\begin{cases} \sum_{j=1}^{148} a_j = 1 \\ \sum_{j=1}^{148} c_j a_j > 0 \end{cases} \tag{11}$$

If the AGV is assigned to a station task, it must first pick up the pallet from the picking station corresponding to the task. If it is assigned to a returned task, the AGV must return to the node where the pallet was stored before it left the warehouse according to the pallet number.

In the dynamic matching phase, the exit scenario of AGVs is different from the initial phase, where each cart is not required to match the picking station node, and assuming that there are *n* carts ready to exit from the storage node, the planning model is modified as follows.

The 0-1 decision variable is s_{ip}. The objective function is (5). The constraints are:

$$s.t.\begin{cases}\sum_{i=1}^{20} s_{ip} \le 3 \\ s_{ip} b_p \ne 3 \\ \sum_{p=1}^{18} s_{ip} = 1 \\ s_{ip} = 0,1\end{cases} \tag{12}$$

Dynamic matching will continue until all orders and station tasks are completed, at which time all picking stations are idle, and then this dispatching is completed. The overall workflow of the AGV is analyzed and its working logic is summarized in Table.1.

Table 1. AGV Work Behavior Logic

Orders	Pallets	Whether the pallet is empty or not	AGV Behavior
√	√	√	Empty pallet recycling
√	√	×	Return to/out of storage
√	×		Pick-up/pick-up of pallets at workstations
×	√	√	×
×	√	×	×
×	×		Allocate orders

The order distribution strategy designed in this paper is non-stop, and the AGV will be in working motion until all order tasks are completed. If the possible failure of the AGV is not considered, the time efficiency of unmanned warehouse storage and transportation can be ensured to the maximum extent.

2.2. Solving by genetic algorithm

A nonlinear function appears in the objective function as nonlinear integer programming, and this paper uses a genetic algorithm to solve the problem, which is an efficient, parallel, and global search method.

i. Chromosome coding

In this paper, chromosomes are coded for 18∗148 0-1 variables.

ii. The initialized population is generated randomly with n individuals satisfying the coding and constraint conditions to form the initial population, denoted as $G = \{g_1, g_2, g_3, \ldots, g_n\}$.

iii. Genetic manipulation

Step 1. select

In this paper, the best individual retention scheme is adopted, using a roulette wheel selection strategy. First, we find the current chromosome fitness value *fit*(*i*), and then sum the fitness values of all chromosomes $sumfit = \sum_{i=1}^{18} fit(i)$, calculate the selection probability of chromosome $p(i)=fit(i)/sumfit$; calculate the cumulative probability of each chromosome $p_s(i)=\sum(fit(i)/sumfit)$, [0,1] which produces a random number. The first chromosome is selected if $p_s(i)<r$, otherwise the first chromosome satisfying $p_s(i\text{-}1)< r< p_s(i)$ is selected.

Step 2. crossover

A heuristic crossover operator is used. Set the crossover probability p_c, generate two individuals randomly in the parent population, and then generate a random number p in the interval (0,1). If $p > p_c$, the parent chromosomes do not crossover, and vice versa, the chromosomes crossover. During the crossover, a random crossover points *k*, (1*kn*) is determined, then after fragment *k*, the parent chromosome is crossed, and before *k* the chromosome remains unchanged. This crossover method

means that only the part of chromosome *n-k* is changed and fragment *k* is retained, which can inherit the good genes of the parent and also reflects the idea of population evolution.

Step3. variation

A single-segment variation method is used. Let the mutation probability of the population be p_m, then generate a random number *p*' in the interval (0,1), if *p*'> p_m, the parent chromosome does not mutate and no new individual is produced, and vice versa, the chromosome mutates. Generate a random integer *f*(1*fn*) indicating that the *f*-th segment of the chromosome undergoes mutation. The *f*-th segment of the chromosome is recoded to produce a new chromosome by replacing the original chromosome segment.

iv. Termination guidelines

The maximum number of iterations is set to 50, and the cycle is terminated when the maximum number of generations is reached.

3. Conclusion

The model restores the whole process of scheduling the handling robot AGV and realizes the simulation calculation of unmanned warehouse transportation and goods sorting.

The optimization model is built using the 0-1 planning method, and the numerical solution of the planning result is easily obtained.

The AGV dispatching model established in this paper restores the whole process of AGV dispatching, which can effectively determine the total path length of AGVs and make targeted improvements to various aspects of AGV dispatching, which has certain significance for modern unmanned warehouse logistics dispatching problems.

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