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Facility Layout Linked with Scheduling Problem by Genetic Algorithm and Tabu Search

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SYNOPSIS

In this paper, we propose a method to solve simultaneously facility layout problem and scheduling problem. About a initial random layout planning, the production scheduling and the transportation scheduling of AGV are obtained by using priority rules. From the obtained transportation scheduling, the critical transportation and the closeness rating are obtained. Facility layout is renewed by the combined procedure of genetic algorithm and tabu search in order to reduce the material handling cost. By using this renewed facility layout, the production scheduling and the transportation scheduling of AGV are also revised until no further improvement is possible.

1. INTRODUCTION

In order to obtain the sub-optimal facility layout solution and the sub-optimal scheduling which include both the production scheduling and the transportation scheduling simultaneously, we propose a method which is consisted of the facility layout method by genetic algorithm and tabu search and the scheduling method considering not only production time but also transportation time[1]. Transportation time is affected by AGV(Automated Guided Vehicle) routing layout. In this paper, the loop routing layout which has the two types of the movement of parts , the uni-directional movement and the multi-directional movement is used. And the three traffic control patterns for AGV are also used in this paper. In the following sections, first we describe the travel distances and the travel times of the loop routing layouts. Then we describe the algorithm which solve simultaneously the facility layout problem and the scheduling problem. Finally we discuss the experimental results of the facility layout cost and the flow time with regard to the AGV traffic control pattern, the priority rules and the AGV movement direction.

2. TRASPORTATION BY AGV AND FACILITY LAYOUT

2.1 Travel Distance and Travel Time

Transportation between stations in which facilities are installed are done by AGV and the facility M_i is allocated at the station ST_i ,where i=1,2,$\cdots$,N_S ,and ST_0 and M_0 show the warehouse. And each station has APC(Automatic Pallet Changer) with pallet pool. Parts for processing are carried out from the automated warehouse which has the function of

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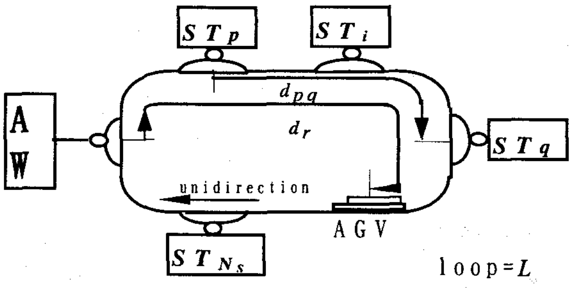

Fig.1 Loop routing Layout(uni-direction).

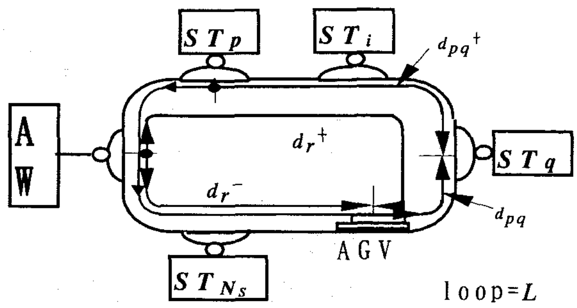

Fig.2 Loop routing layout(multi-direction).

the waiting station at the same time and the parts are stored in this warehouse after processing. At each station, the bypass is provided for the purpose of getting ahead and avoiding collision of AGV. The distance between station ST_i and ST_j is shown by d_{ij} which is an element of the distance matrix $\boldsymbol{D}$, where $i,j=0,1,\cdots,Ns$.

The travel distance from the pick-up station to the delivery station is varied by the AGV routing layout and the traffic control pattern. The travel distances can be expressed as the following equations, and the average speed through the accelerated period, the constant speed period and the decelerated period is used as the AGV speed. By this average speed, the travel time can be calculated .

In the loop routing layout, the length of this loop is set as L and two kinds of AGV routing direction, the uni-direction and the multi-direction, are utilized in this paper, which are shown in Fig. 1 and Fig. 2. So the clockwise routing direction is defined as the plus direction and the anti-clockwise route is defined as the minus direction as a matter of convenience and these distances are denoted as d^+ and d^- respectively. And stations are allocated in numerical order. The travel distance of each transportation direction can be calculated as follows[2].

(1) uni-direction transportation

a)GCT: if $p \leqq q$, $d = L$, (1)
otherwise, $d = 2L$ (2)

b)GCSD: if $p \leqq q$, $d = d_{pq}$, (3)
otherwise, $d = L - d_{pq}$ (4)

c)FTCT: if $p \leqq q$ and $0 \leqq d_r \leqq d_{0p}$,
$d = d_{0p} - d_r + d_{pq}$ (5)
if $p \leqq q$ and $d_{0p} < d_r < L$,
$d = L + d_{0q} - d_r$ (6)
if $p > q$ and $0 \leqq d_r \leqq d_{0p}$,
$d = L + d_{0q} - d_r$ (7)
if $p > q$ and $d_{0p} < d_r < L$,
$d = 2L + d_{0q} - d_r$ (8)

(2) multi-direction transportation

a)GCT:

$$d = \min\{d^{+}_{0p}, d^{-}_{0p}\}+\min\{d^{+}_{pq}, d^{-}_{pq}\} +\min\{d^{+}_{q0}, d^{-}_{q0}\} \tag{9}$$

b)GCSD:

$$d = \min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{10}$$

c)FTCT :

if $p \leqq q$ and $0 \leqq d^{+}_{r} \leqq d^{+}_{0p}$,

$$d = \min\{ d^{+}_{0p} - d^{+}_{r}, d^{-}_{0p} + d^{+}_{r} \}+ \min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{11}$$

if $p \leqq q$ and $d^{+}_{0p} < d^{+}_{r} \leqq d^{+}_{0q}$,

$$d = \min\{ d^{+}_{r} - d^{+}_{0p}, L - d^{+}_{r} + d^{+}_{0p} \}+\min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{12}$$

if $p \leqq q$ and $d^{+}_{0q} < d^{+}_{r} < L$,

$$d = \min\{L + d^{+}_{0p} - d^{+}_{r}, d^{+}_{r} - d^{+}_{0p} \}+\min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{13}$$

if $p > q$ and $0 < d^{+}_{r} < d^{+}_{0p}$,

$$d = \min\{ d^{+}_{0p} - d^{+}_{0p}, d^{+}_{0p} + d^{+}_{r} \}+\min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{14}$$

if $p > q$ and $d^{+}_{0p} < d^{+}_{r} < L$,

$$d = \min\{ d^{+}_{r} - d^{+}_{0p}, L + d^{+}_{0p} - d^{+}_{r} \}+\min\{ d^{+}_{pq}, d^{-}_{pq} \} \tag{15}$$

2.2 AGV Traffic Control

AGV traffic control is classified into three types, viz. the ground calling type(GCT), the ground calling & specifying the destination type(GCSD) and the from-to calling type(FTCT). In GCT type, AGV starts from the waiting station by the transportation requirement and comes back to the same waiting station after carrying. In GCSD, AGV moves to the station according to the beforehand stored route in the AGV onboard computer and is waiting at the station until the next transportation requirement is received. The waiting station is not installed at the case of FTCT and the from-to transportation requirement is accepted at the random station.

3. ALGORITHM

3.1 Scheduling Problem

A set of machines performs technologically ordered operations of each member of a set of jobs. Each operation has a fixed duration, no machine can perform more than one operation at a time, and once an operation has begun it may not be interrupted. The objective is to minimize the make-span, or the flow time.

N jobs are to be assigned to N_S machines and p_{ij} expresses the number of machine which is utilized by the job i at the j'th process and it is the component of the process sequencing matrix : $\boldsymbol{P}=\{p_{ij}\}$, and the processing time matrix is denoted as $\boldsymbol{T}=\{t_{ij}\}$,where $i=1,2,\cdots,N$, $j=1,2,\cdots,n_i$.

Firstly, by using these matrices, the production scheduling is planned considering the transportation time, and the job sequence is decided . The job sequence at each machine is expressed by the sequence matrix $\boldsymbol{W}=\{w_{uv}\}$, where w_{uv} means the v-th job number at the machine M_u , $u=1,2,\cdots,N_S$ and $v=1,2,\cdots,n_u$. In this paper, the priority rules of FCFS(First Come First Service), DD(Due Date), SPT (Shortest Processing Time) and CR(Critical Ratio,i.e. the smallest ratio of due date to processing time) are adopted and the production scheduling is obtained, and the transportation scheduling is also calculated by the above mentioned distances of equations (1)-(15).

3.2 Facility Layout Problem

Facility layout problem can be so described as to find the optimal assignment of N_S facilities to N_S stations in order to minimize a sum of distances multiplied by the flow between facilities. In the facility layout problem in which N_S facilities are assigned to N_S available stations, $s(i)$ denotes the facility which is assigned to station ST_i , and also $S = \{s(1),s(2),...,s(N_S)\}$ denotes the assignment vector of the facility layout. In this paper, we use the total closeness rating which consisted of the closeness rating of processing and the closeness rating of transportation instead of the flow between facilities. The objective function of facility layout can be expressed in the following equation (16), where d_{ij} is the distance between stations ST_i and ST_j and $TCR_{s(i)s(j)}$ is the total closeness rating between facilities $s(i)$ and $s(j)$.

$$f(S)=(1/2)\sum_{i=1}^{N_S}\sum_{j=1}^{N_S} d_{ij} TCR_{s(i)s(j)} \qquad (16)$$

$TCR_{s(i)s(j)}$ consists of the closeness rating of processing and the closeness rating of transportation. The former closeness rating is defined as the number of transportation obtained from the technologically determined processing sequence. And the latter is defined as the number of the transportation of AGV which has no waiting time until the beginning of the next process after the transportation of a job.

For searching the optimal or sub-optimal facility layout solution , Genetic algorithm[3] (hereinafter abbreviated as GA) and tabu search are adopted in our procedure.

GA is one of the random search method based on the mechanics of natural genetics and natural selection by reproduction, crossover and mutation , and in this algorithm the change of generation is repeated and the individuals which have the higher fitness are increased and finally the sub-optimal solution is obtained among these individuals.

When GA is applied simply to the facility layout problem, the probability for the infeasible solution to be derived may be high because of the occurrence of individuals which have the lethal gene, that is, the infeasible solutions of the facility layout problem. So, the coding method to convert to the string of chromosome is used to make the application of GA to the facility layout problem possible.

(1)Make the facility standard list in which suffixes of the notations showing the facilities are arranged in alphabetical order .
(2)Convert the ordinary number from the beginning of the facility standard list to the string of the chromosome ,where the element of the facility standard list is eliminated if it has been already coded.
(3)Make the genetic operation such as crossover and mutation to these strings.
(4)After the genetic operation, transform strings to the allocation vectors inversely.

GA searches the solution widely among the population of solutions and extends the search space by generating new generation. But in GA, there is a possibility of the premature convergence. Therefore, in our proposed procedure to determine the facility layout, the approach in which both GA and tabu search are combined together is used, where the solution by GA is used as the initial solution for tabu search.

Tabu search was introduced by Glover[4] as a technique to overcome local optimum solution. This search is characterized by forbidding some search direction(move) at a present iteration in order to avoid cycling, but to be able to escape from a local optimal point. Tabu size is a parameter which means the length of a tabu list. Scorin-kapov[5] experimentally obtained the results about tabu size that if it is too small, cycling will occur and conversely if it is too big, it will restrict the search enough to skip better local minima of the objective function value space. Therefore the half of the number of facility $N_S/2$ is used as the tabu size in this paper.

3.3 Proposed Algorithm To Solve The Problem Combined Scheduling and Facility Layout

The optimal or sub-optimal of scheduling problem and facility layout problem are resolved simultaneously by the following procedure for a given process sequencing matrix, a given processing time matrix, a given distance matrix and a given closeness rating matrix.

Step 1. Determine an initial layout vector S_i randomly and its cost C_i . And calculate closeness rating of transportation from process sequencing matrix.
Step 2. Set the optimal layout vector $S^*=S_i$, the minimum cost $C^*=C_i$ and the minimum flow time $ft^*=\infty$. And set tabu size $ts=N_S/2$.
Step 3. Calculate transportation time between every two facilities of a given layout vector S_i based on the equations(1)-(15).
Step 4. Determine production scheduling and transportation scheduling by one of priority rules and obtain the maximum flow time ft_i among flow time of every jobs.
Step 5. If $ft_i<ft^*$, set $ft^*=ft_i$, $S^*=S_i$ and $C^*=C_i$, then go to Step6. Otherwise, go to Step 10.
Step 6. From the obtained scheduling, determine the closeness rating of transportation.
Step 7. Calculate the total closeness rating from the closeness rating of processing and that of transportation.
Step 8. Apply GA to layout vector S_i and select a best solution S_j among alternatives by GA. Furthermore, apply the tabu search with tabu size ts to S_j and obtain a best solution S_k and its cost C_k. And set $S_i=S_k$, $C_i=C_k$ and put S_i into the tabu list.
Step 9. If $C_i < C^*$, go to Step 3 for iteration. Otherwise, go to Step 10.
Step 10. Finish this procedure and S^* and C^* are obtained as the optimal layout vector and the minimum cost respectively.

4. COMPUTATIONAL RESULTS

The sample problems in which AGV routing layout of loop type has N_S=7 stations and the number of job N=5 are used. The scheduling and facility layout were planned by using three AGV traffic control pattern ,GCT,GCSD,FTCT and four scheduling priority rules, FCFS, SPT, DUEDATE, CR in order to investigate the effect of these factors to the flow time of the obtained scheduling of sample problems. And in GA, the generation change is set up at 10 and the probability of mutation is set at 5%, and in tabu search, the maximum iteration is set at 10. The speed of AGV is set up at 10 m/min in every traffic pattern.

Fig.3 shows the results of the layout cost and the flow time of DD priority rule and GCT traffic control pattern. These values of the initial layout by pseudo-random number are 28.83 and 72 respectively. These values are decreased with the repetition of the procedure and finally converge to the best solution after 5 iterations. In the change of the layout cost, the vertical reduction shows the effect of tabu search which improves the layout solution introduced by GA. Furthermore, in Fig.4 the improvement ratios of GA and tabu search in this case are shown and the improvement ratio of tabu search exceeds that of GA in every repetition. From these results, it is clarified that the combined approach of the wide rage search of GA and the narrow range search of tabu search is more efficient than the independent approach of these search methods.

The effect of the priority rules in scheduling is shown in Fig.5. The minimum flow time of both AGV uni-direction and multi-direction loop routing layouts is obtained in FCFS and also the minimum layout costs are also obtained in FCFS. Therefore FCFS performs the best among these four priority rules in this case. And in every priority rules, both the layout cost and the flow time of the multi-direction AGV transportation are superior than those of the uni-direction AGV transportation.

Furthermore, from the comparison of the layout costs and the flow time of the AGV control patterns using GCT,GCSD and FTCT, the values of GCSD perform the best among these three AGV control patterns.

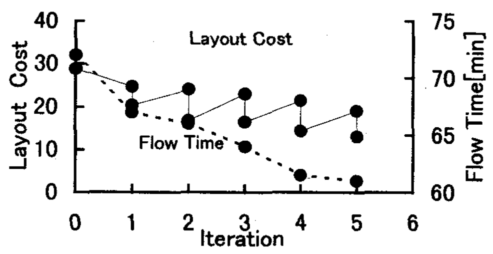

Fig.3 Layout cost and flow time versus iteration.

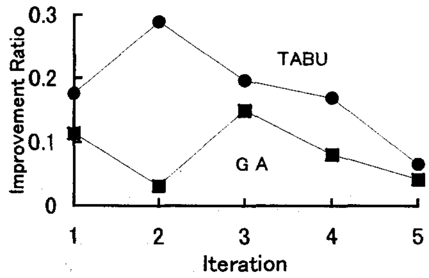

Fig.4 Improvement ratio of layout cost by GA and tabu search.

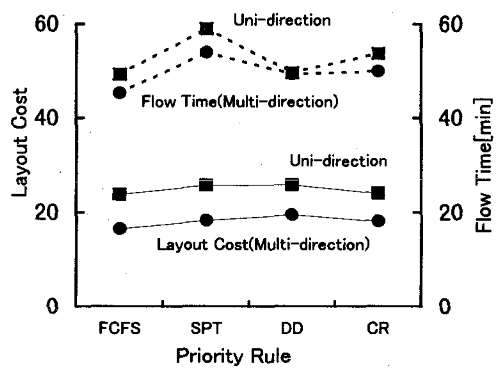

Fig.5 Effect of priority rules.

5. CONCLUSIONS

In this paper, we proposed the method to make the scheduling plan and the facility layout plan simultaneously in the case of the AGV loop routing layout. In making the facility layout plan, the procedure combined genetic algorithm and tabu search is employed. The computational results show the effectiveness of the proposed scheduling and facility layout method.

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