Fifth International Workshop on Computational Intelligence & Applications
IEEE SMC Hiroshima Chapter, Hiroshima University, Japan, November 10, 11 & 12, 2009

Design Support of Transportation Routing for a Multi Layered Factory

Koji Nakagawa
Graduate School of Natural Science and Technology
Okayama University
3-1-1 Tsushima-Naka Kitaku, Okayama 700-8530
nakagawa@cntr.elec.okayama-u.ac.jp

Masami Konishi
Okayama University
konishi@elec.okayama-u.ac.jp

Abstract

Recently, it becomes important to improve transportation capability to attain high productivity in manufacturing. One of the necessary schemes to attain the purpose is that the floor layout is initially to be optimized. After the floor layout is determined, reasonable equipment position for transportation is decided. Then the design of the transportation route is to be determined. In this paper, design support system for transportation routing, based on agent method is proposed. To optimize the transportation route, the working space by the side of the equipment is to be prepared. Starting from given floor layout of a three layered factory, an appropriate transportation route is pursuit using Ant algorithm. To check the applicability of the proposed method, case studies are carried out under various constraints and objective functions, and its effects were verified.

1. Introduction

Recently, it becomes important to improve transportation capability to support high productivity in manufacturing. In the past, the floor layout has been treated as the optimized target in a factory to improve the productivity or to design a new factory. Many studies on the optimizations of the floor layout had been made, and basic technologies were developed.[1][2]. After the floor layout is optimized and the new equipment positions are decided, the transportation route is needed to be designed. In the design of transportation route, sizes and positions of the equipments are to be considered. In the route generation it is important to shorten the transportation time. However, transportation route is to be generated not only by the shortest route between equipments, but also preparing working space in a factory. This time, the multi layered factory is widely constructed in Japan for the reasons of saving factory space. Considering these factors, in this paper the design support system that derives the transportation route is developed. Here, the three layered factory is targeted. The proposed transportation route design support system can cope with the change in equipment positions. In addition, it can also cope with the change in transportation route due to the breakdown of equipments. In addition, this system is designed as the distributed autonomous system to enable handling of a large-scale transportation problem.

2. Statement of the problem

Figs.2 to 4 show the layouts of the three layered factory treated in this paper for the design of the transportation route. The first floor of factory is shown in Fig.2, the second floor is in Fig.3, and the third floor is in Fig.4 respectively. The number of equipments is set as 15, and they are set at each floor shown as in Figs.2 to 4. And, Table 1 shows the production process for each product. First of all, each product is transported from the entrance order first floor and manufactured according to the equipments which numbers are given in Table 1 and products are again transported to the exit on the first floor. Between floors on elevator is used for the movement of Automated Guided Vehicle (AGV). The transportation route is composed of nodes and arcs. In Fig.1, a node is defined as the black spot, and an arc is defined as the line between nodes. At the node, an AGV can change its direction or can stop. The arc is a road on which AGVs can run. Nodes are placed on the lattice in Figs.2 to 4 whose numbers are integers.

Table1. Production flow

Product No.	Flow of processing
1	3 → 1 → 2 → 5 → 8 → 6 → 7 → 11 → 14 → 12 → 13 → 15
2	3 → 1 → 4 → 5 → 8 → 9 → 10 → 11 → 14 → 12 → 13
3	3 → 1 → 4 → 8 → 6 → 7 → 11 → 14 → 12 → 13

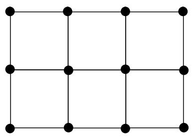

Figure 1. Nodes and arcs

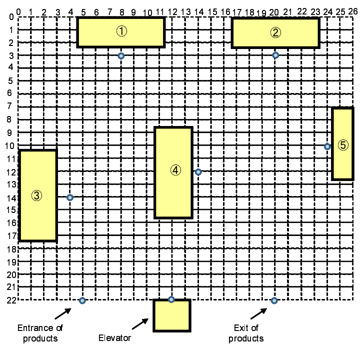

Figure 2. Equipment layout (first floor)

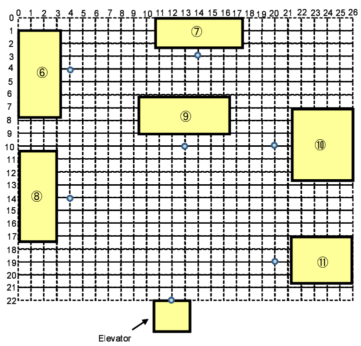

Figure 3. Equipment layout (second floor)

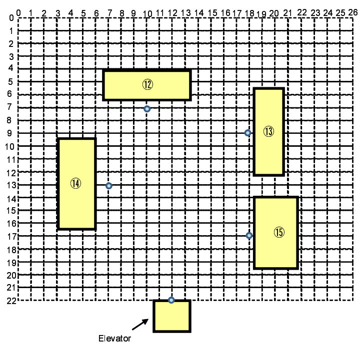

Figure 4. Equipment layout (third floor)

3. Route generation algorithm

In this system the Ant algorithm is used for route generation. This system is realized as the distributed autonomous system. When routes are generated, all connecting conditions shown in Tables 2 to 4 are fulfilled. The algorithm to generate transportation route is described as follows.

STEP1 Node setting

The node is set up in an integer coordinate.

STEP2 Judgment of prohibited node

The node to which an AGV cannot move is judged by equipment position and its size.

STEP3 Initial dissemination of pheromone

Pheromone is disseminated on nodes except the prohibited nodes.

STEP4 Generation of initial transportation route

The shortest route between equipments is generated by the Dijkstra method referring to Table 2.

STEP5 Pheromone dissemination

Pheromone is disseminated on all nodes and arcs on the generated route.

STEP6 Judgment of end of calculation

Go to STEP9, if the number of calculation reaches the predetermined number of calculations.
If not, go to STEP 7.

STEP7 Evaporation of pheromone

Amounts of pheromone on all nodes and arcs are deceased by a certain rate.

STEP8 Rerouting

A new candidate of route is generated randomly and return to STEP 5.

STEP9 Decision of transportation route

When the transportation route by which the best evaluation value is given, it is selected as the solution.

Here, Dijkstra method is one of the optimization techniques. Therefore, the initial route can be derived as the shortest route. And, Tables 2 to 4 show the matrices defining connecting relations between equipments. Satisfying the relations the transportation routes are to be constructed to carry products shown in Table 1.

Table2. Connecting relation between nodes(first floor)

	ENT	1	2	3	4	5	EXT	Elevator
ENT	1	0	0	1	0	0	0	0
1	0	1	1	0	1	0	0	0
2	0	0	1	0	0	1	0	0
3	1	0	0	1	0	0	0	0
4	0	0	0	0	1	1	0	1
5	0	0	0	0	0	1	0	1
EXT	1	0	0	0	0	0	1	0
Elevator	1	0	0	0	0	0	1	1

Table3. Connecting relation between nodes(second floor)

	6	7	8	9	10	11	Elevator
6	1	1	0	0	0	0	0
7	0	1	0	0	1	0	0
8	1	0	1	1	0	0	0
9	0	0	0	1	1	0	0
10	0	0	0	0	1	1	0
11	0	0	0	0	0	1	1
Elevator	0	0	1	0	0	0	1

Table4. Connecting relation between nodes(third floor)

	12	13	14	15	Elevator
12	1	1	0	0	0
13	0	1	0	1	0
14	1	0	1	0	0
15	0	0	0	1	1
Elevator	0	0	1	0	1

4. Design support system for route generation

Details of the design support system for transportation route will be described. First, the node is set up in the integer coordinates. Next, the prohibited nodes are determined from positions and size of equipments. Then, the transportation route is derived by design support system. In the following, the constraints and the objective function necessary for route generation, dissemination pattern of pheromone, and the distributed autonomous system will be stated.

4.1. Method for route generation

The transportation route is determined by using the Ant algorithm[3][4]. The Ant algorithm is a technique imitating the process when ants find out the appropriate route from their nest to food. First, ants moves randomly looking for their routes. And routes are gradually converge to one route referring pheromone information of other ants. In the Ant algorithm, pheromone information is used for route search and the solution with a better evaluation value is derived.

In the routing, the route is made through steps from STEP3 to STEP 9 of the route generation algorithm. The generated route by the Ant algorithm in the route between equipments reflecting condition of Tables 2 to 4. The route which has the best evaluation value in the generated routes is selected for the transportation route.

4.2. Constraints

Here, the constraining condition is described. First, the decision variable is defined by $x_{i,j}$ and given in Equation (1).

$$x_{i,j} = \begin{cases} 1 : nodes\ \ i\ \ and\ \ j\ \ are\ \ connected \\ 0 : otherwise \end{cases} \tag{1}$$

Let, N is a set of nodes to which an AGV can move, and N_p is a set of prohibited nodes. And, n_s^e is the node for equipment e that is the starting point. Moreover, n_g^e is also the node for equipment e that is the arrival point. The constraints stated above are presented as follows.

$$x_{i,k} = 0 \quad (i \in N, k \in N_p) \tag{2}$$

$$x_{n_s^e,i} = 1 \quad (i \in N) \tag{3}$$

$$x_{i,n_g^e} = 1 \quad (i \in N) \tag{4}$$

Equation (2) means the prohibited node is not to be used for transportation. And, Equation (3) and (4) mean that both start point and end point must be involved in the transportation route between equipments. Moreover, the state of the transportation route which has the intersection with any arc is automatically avoided.

4.3. Objective function

In the Ant algorithm, the adjacent node j of node i is stochastically chosen, such that a high evaluation value of Equation (5) is attained.

$$s_{i,j} = aE_{i,j} + bP_{i,j} + cRi, j \tag{5}$$

The first term of the right hand side of Eq.(5) is the item representing the distance between equipments on the transportation route. And the second term is that related to the pheromone information. Moreover, the third term is the number of curves involved in the generated route. a, b, and c are weights for these three items respectively. If these weights are adjusted, priorities for working space or that for transportation time can be regulated.

The objective function that is the evaluation of the generated route is shown in Equation (6). Here, r_t is a node involving the starting and the arrival points on the generated route. And T_t is the route length of the generated route. This term is related directly to the transportation time.

$$\sum_{r_t \in N} \sum_{t=0} s_{r_t, r_{t+1}} + T_t \rightarrow min \quad (r_t, r_{t+1} \in N) \qquad (6)$$

The generated route with best evaluation value of the objective function becomes selected as the transportation route.

4.4. Dissemination pattern of pheromone

Dissemination of pheromone differs between initial routing and rerouting.

In the initial routing, dissemination of the pheromone is made as shown in Fig.5. In Fig.5, the pheromone is widely disseminated on the route derived by Dijkstra method. On the node next to the adjacent node of the initial route, pheromone is disseminated.

In the rerouting, there are two kinds of dissemination of the pheromone. One is the dissemination of the pheromone on the nodes of the generated route, and the other is the dissemination of the pheromone on the surround nodes of the generated route. For example, when one route as shown in Fig.6 is made, the pheromone is disseminated on nodes #85 and #112. And, the pheromone is also disseminated on the nodes around the straight line connecting nodes #85 and #112 as shown in Fig.7. The pheromone will be disseminated on nodes #98 and #99 in this case.

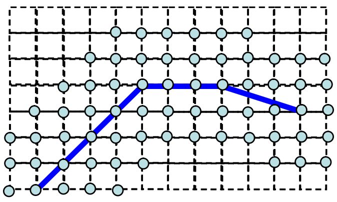

Figure 5. Dissemination by initial routing

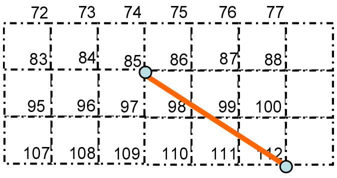

Figure 6. Dissemination pattern (1)

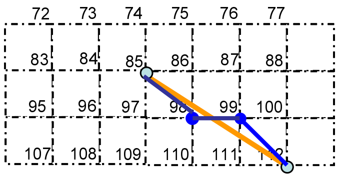

Figure 7. Dissemination pattern (2)

4.5. Distributed autonomous system

This system uses the distributed autonomous system. Transportation route is locally generated by the connection relations between equipments from Tables 2 to 4. When the route is generated, the search area is restricted as shown in Fig.8. The restriction of the search area is decided by the start position and the goal position. For example, area1 is set as shown in Fig.8. And, if there is a prohibition node in the outer circumference of the restricted search area, the search area is expanded. For example, area2 is expanded as indicated in Fig.8.

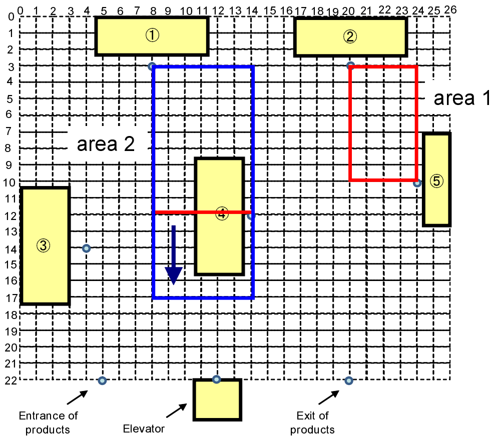

Figure 8. Local area

5. Numerical experiment

Starting from result 1 of Figs.9 to 11, the weight a is enlarged and the result 2 was obtained as shown in Fig.12. In the result of Fig.9, it is able to secure a space for workshop, because the route is brought close to equipments. On the other hand, the transportation distance between equipments becomes long. Contrary to Fig.9, the result of Fig.12 is derived by enlargement of the term of the pheromone information. Here, result 2 shows only the result of first floor. This is why the initial transportation route and the term of

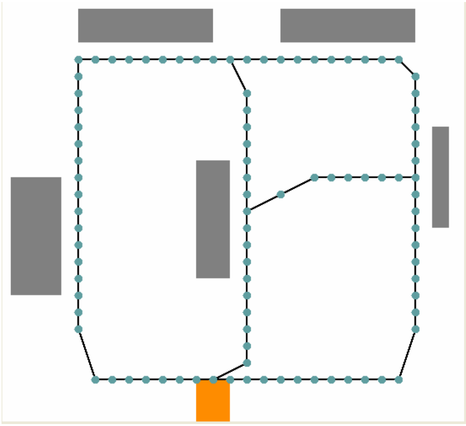

Figure 9. Result1(first floor)

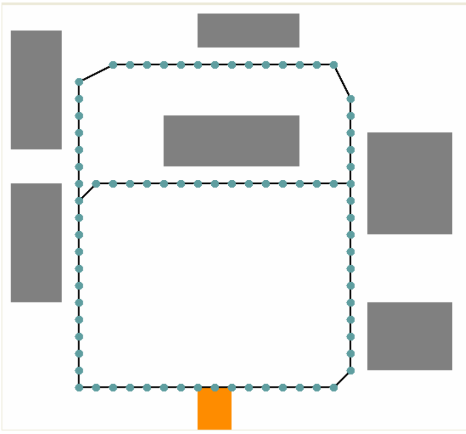

Figure 10. Result1(second floor)

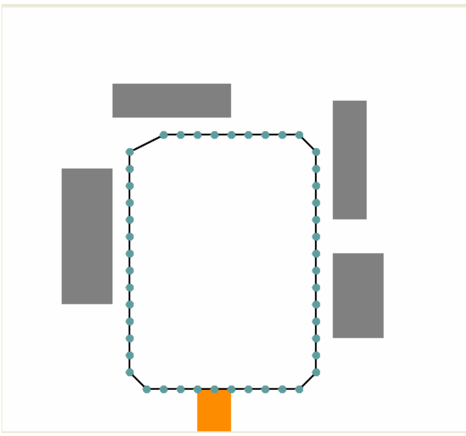

Figure 11. Result1(third floor)

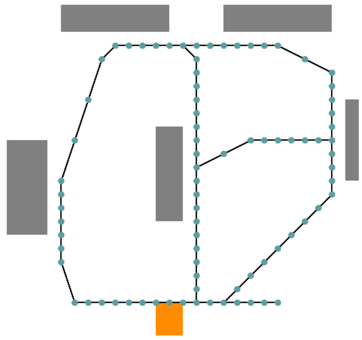

Figure 12. Result2 (first floor)

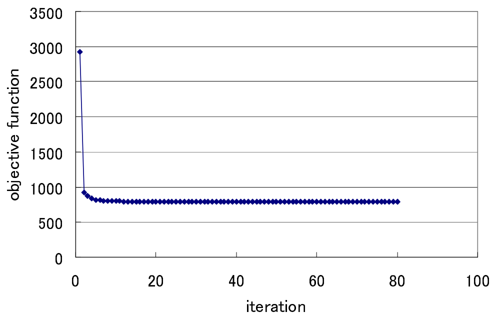

Figure 13. Transition of evaluation

transportation time influences the result of Fig.12, and in this case, the transportation distance becomes short. However, the space of the workshop is not enlarged. In a word, it is necessary to adjust weights according to the purpose, in the generation of the transportation route. When wide work space is necessary, we adjust the weight to obtain the result like Fig.9, and when it is necessary only to shorten the transportation distance, decrease weight b to obtain the result such as shown in Fig.12.

The value of objective function of result 1 is shown in Fig.13. Initial value is value derived by Dijkstra method. The value of objective function converge to its best value.

This system can flexibly cope with the equipment position. Moreover, it can be said that the best route is made avoiding the prohibition node if the prohibition node is specified. In a word, it is possible to cope with flexibly by specifying the prohibition node in such case when the passage prohibition is induced by the accident and by the breakdown of the route such as given by result 3 in Fig.14.

Production flow of product 1 on generated route is shown in Fig.15. And, transition nodes are shown in Fig.16. As the result, it is confirmed that the generated route can be used for operation in a multi layered factory.

In this paper, the proposed system treated a small scale problem. The reason is that it is necessary to confirm the validity of the system. However, to reveal the applicability of the proposed system, it is necessary to treat a large scale problem. This is left for the future works.

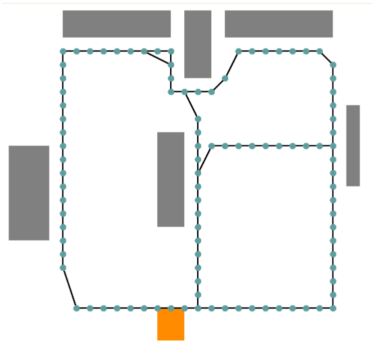

Figure 14. Result3 (first floor)

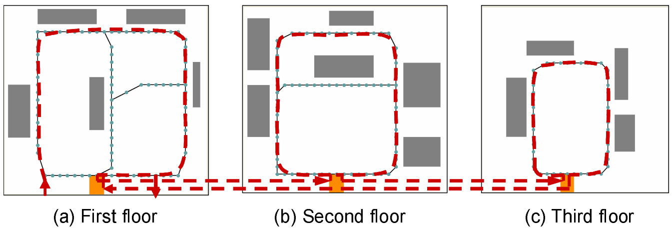

Figure 15. Result4

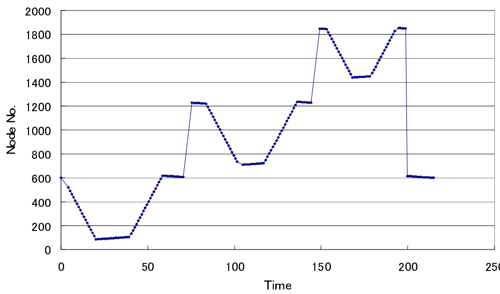

Figure 16. Result4 (transition node)

6. Conclusions

In this paper the system that generates transportation route for the floor layout of a three layered factory is described. The results of the transportation route design support system showed that the transportation route corresponding to the purpose can be generated by changing the weights of the objective function. The developed transportation route support system can make the transportation route flexibly for the change in the position of equipments and the breakdown of transportation route. As the future work, it is necessary to unity the transportation route support system and the transportation control system.

References

[1] Hiroaki Hujikawa,Introduction to multilayer floor factory layout: Kogyo Chosakai pablishing, 2005

[2] Yamada, Irohara, Hujikawa, Design Methodology for the Facility Layout Problem to Consider the Aisle Structure and Intra-Department Material Flow: Japan Industrial Management Association, Vol.55, No.3, pp.111-120, 2004

[3] Kawamura, Collective Serch Algorithm with pheromone Communication for Vehicle Routing Problems, Interigent Autonomous System, IOS Press, p.p.587-594, 1998

[4] Dorigo, Ant System: Optimization by a Cology of co-operative Agents, IEEE Tras. On SMC, Vol.26, No.2, p.p.29-41, 1996