A control method with pheromone information for a transport system

Imoto, Yoshitaka
Faculty of Engineering, Kyushu University

Tsuji, Yasutaka
Faculty of Engineering, Kyushu University

Kondo, Eiji
Faculty of Engineering, Kyushu University

出版情報：Artificial Life and Robotics. 16, pp.112-115, 2011-06. Springer
バージョン：
権利関係：

A Control Method with Pheromone Information for Transport System

Yoshitaka Imoto *1, Yasutaka Tsuji *2 and Eiji Kondo *2

*1 *Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan*
(Tel: 81-92-802-3167; Fax: 81-92-802-0001; imoto@zeus.mech.kyushu-u.ac.jp)

*2 *Faculty of Engineering, Kyushu University*

ABSTRACT

Since control methods of a transport system between processing machines are specialized for each layout of the system, it is difficult to design prompt schedules and control logic for recent complicated systems, especially in case of machine troubles or restructuring of system to modify the layout. In this paper, we propose a multi-agent transport control system which utilizes pheromone information. Each element of the system acts as an agent and estimates the appropriate path and time to drive out the products with information obtained by communication with other elements and pheromone information deposited on the track of products.

Keywords : Swarm Intelligence, Pheromone Information, Transport System

I. INTRODUCTION

Since control methods of a transport system between processing machines in manufacturing systems are specialized for each layout of the system, it is difficult to design prompt schedules and control logic of recent complicated systems, especially in emergent situations such as machine troubles or restructuring of the system to modify the layout[1].

On the other hand, in recent study in Information Transport System (ITS), pheromone model for prediction of traffic congestion has been proposed[2]. In the study, the pheromone model is used to make a short term prediction of the traffic congestion for frequent change.

In this paper, we propose a multi-agent transport control system which utilizes pheromone information. In the proposed system, the transport system consists of processing machines, buffers which temporally store products and drive them out in appropriate time, belt conveyors and turntables. Each element acts as an agent and estimates the appropriate path to drive out products with information obtained by communication with other elements and pheromone information deposited on the track of products. These two types of information are updated in different frequency. we examine validity and usefulness of the proposed method through simulation experiments.

II. RELATED STUDIES

Pheromone is a chemical material with which social insects, such as ants, communicate with each other indirectly through the environment. Ants deposit pheromones on their path when they find a food in their search. By using the pheromone information, other ants can find efficient path to the food. The deposited pheromone evaporates over time and old information loses their effect on the path selection gradually. In the engineering area, the mechanism is modeled as a *"pheromone model"* and utilized in many applications[3][4].

In the pheromone model, agents deposit the pheromone information onto the environment. The information decreases in its value gradually over time and is also updated by agents, so that the information goes along with the changes of the environment. Especially, in a recent study of the ITS (Information Transport System), pheromones are used to predict traffic congestions [2]. In the study, some information is used as the pheromone information, such as number of the braking and distance from other cars. The information enables short term prediction for frequent change of traffic congestion which can not be realized by long term prediction such as statistic.

On the other hand, there are some applications which utilize multi-agent control method for transport system. A multi-agent control method base on A*-algorithm is proposed in [4]. It considers a system in which products have priority to be transported, and reduce relocation of products in buffers. In [5], another multi-agent control method is introduced. It uses several types of virtual agent to find a path to the destination or to collect information.

In these studies, the controlled systems have only one processing machine as a destination and need some centralized control such as a server of virtual space, so that they are not enough in the case that the system contains several processing machines and several types of products or the scale of the system becomes larger.

In this paper, we propose a decentralized multi-agent transport control method for the system which contains several types of products and processing machines.

III. PROPOSED METHOD

1. Assumption of production system

The production system addressed in this work includes several kinds of processing machine and a transfer system, which consists of belt-conveyors, turntables and buffers. A belt-conveyor can carry a product in only one direction and a turntable can change a move direction of products. Buffers, located back and forth of a processing machine, can temporarily storage products. In this work, it is assumed that each element of the production system can communicate with each other elements connected to it.

Each element of the transfer system sets the machines as candidate destinations, which perform next process to a product on it, and can obtain useful information of the candidates to transport the product through the communication between the elements. When a production system is large, amounts of information sent and stored are also huge. In this work, therefore, the each element sends only information of the next destinations, i.e. next machines in downstream, and the communication between them is executed on periodic interval.

Each element of the transport system can obtain information of candidate destinations, which may be a little past, but they do not have a current status of its neighbor element. In order to estimate the local information of neighbor element, each turntable counts number of products which have moved in each direction as trail of a product move. We call this number as *"pheromone"*. The pheromone is evaporated and the effect of the past information decreases gradually as the natural pheromones.

With these kinds of information, we construct the method which determines the optimal path for the situation on each element by considering the whole of the system. As the information is obtained by communication between neighbor elements or an element and a product, the control can be decentralized. Thus, it is expected that the transport changes flexibly for the change of the system.

2. Information about the path to the candidate destinations

In the communication, the following three types of parameters (estimations) are used,

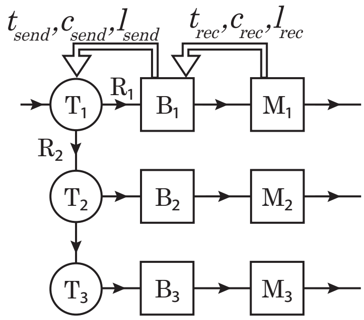

Figure 1: Flow of information

t : waiting/moving time to next element
c : vacant capability of a buffer
l : completion time of next processing

Processing machines send their own information to the elements which connected to them in the upstream side. Each element receives the information and sends the information added with its own status value to the upstream side, but the information is not sent to the processing machines in upstream side.

Each element receives three parameters t_{rec}, c_{rec} and l_{rec} from its downstream side, then sends t_{send}, c_{send}, l_{send} to its upstream side. When sending these parameters, each parameter is updated as Eqs.(1)-(3).

$$t_{send} = \max(t_{own}, t_{rec}) \tag{1}$$
$$c_{send} = \min(c_{own}, c_{rec}) \tag{2}$$
$$l_{send} = l_{own} + l_{rec} \tag{3}$$

t_{own} , c_{own} , l_{own} are parameters of the element. t_{own} is the process time in the processing the machine or time interval from input to output on the buffer. The element sends bigger one of t_{own} and t_{rec}. c_{own} is value of empty space in the buffer. The element sends smaller one of c_{own} and c_{rec}. l_{own} is the time for process completion on the destination. The element adds l_{own} to l_{rec} and sends it to the upstream side. By using these parameters, the evaluate function of the path is defined as:

$$E = c_{send}^{\alpha}/(at_{send} + bl_{send})^{\beta}. \tag{4}$$

Here α , β , a , b are weighting coefficients.

3. Pheromone information

The pheromone information is deposited when a product is transported from an element to the next element, in the direction of the next element. The large value of the information implies the congestion and the direction is avoided to transport. The pheromone increases with constant value $\triangle\phi$ for a product. The deposited pheromone evaporates and decreases its effect on path selection. The

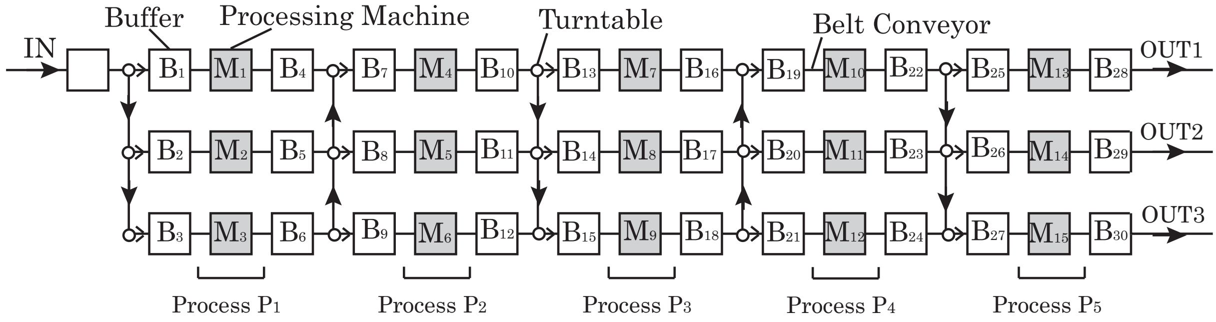

Figure 2: Layout of the production system

pheromone $\phi(s)$ on time s evaporates in time period $\triangle s$ as given in the Eq.(5). Here, ρ is evaporative rate.

$$\phi(s+\triangle s) = (1-\rho)\phi(s) \tag{5}$$

By using these two types of information, next element of the transport is selected for each product p_k. The best element $e_k^{(opt)}$ is determined, which can perform the next process to p_k and have small value of the pheromone information ϕ and large value of the evaluate function E. If the candidate elements have several destinations, they are evaluated as the weighted sum of the evaluation function E (see Eq.(7)). The optimal element to transport is determined as shown in the followings.

$$e_k^{(opt)} = e_i, i = \arg\min_{j \in D}(\phi_j^{\gamma}/E_{k,j}) \tag{6}$$

$$E_{k,j} = \sum_{m \in S} E_m c_m \delta_{k,m} / \sum_{m \in S} c_m \delta_{k,m} \tag{7}$$

$$\delta_{k,m} = \begin{cases} 1 & (p_k \text{ can be processed}) \\ 0 & (p_k \text{ can not be processed}) \end{cases} \tag{8}$$

D is the set of possible elements where p_k can be transported. S is the set of path including element j. $\delta_{k,m}$ is 1 when the destination element e_m of the path can process the product p_k, otherwise $\delta_{k,m}$ is 0.

In Fig.1, M_1-M_3 represent processing machines and they are set as candidate destinations for B_1-B_3 and T_1-T_3. For example, M_1 sends the information about its self such as process time t to B_1. B_1 also sends the information updated as in Eqs.(1)-(3) to T_1. In the same way, T_1 gets information about the path to M_2 and information about the path to M_3. The products on T_1 are transported based on the information and pheromone. If the product p_k on T_1 can be processed on both M_2 and M_3, the evaluation of the direction R_2 is calculated as weighted sum of evaluation of the path to M_2 and that of the path to M_3. Finally, the product is transported to the optimal direction and the pheromone information is deposited on the direction.

4. Collision avoidance

In the system which contains some confluent point, collisions must be considered. In this study, as the considered system is constructed by belt-conveyors, it is difficult to avoid collisions by adjacent avoidance. For the problem, we put a buffer in the upstream side of each confluent point and make them communicate with each other to transport elements one by one in order of input. Therefore, the system in Fig.2 assumes that the each of buffers B_4-B_6, B_{10}-B_{12}, B_{16}-B_{18} and B_{22}-B_{24} can communicate and determine the time of output.

IV. SIMULATION EXPERIMENT

We examine validity and usefulness of the proposed method through simulation experiments. The parameters β , γ are varied to examine the effectiveness of the proposed information. α is fixed.

In the simulation experiments, we use the layout shown as Fig.2. $M_i(i = 1, ..., 15)$ represent processing machines, $B_i(i = 1, ..., 30)$ represent buffers and lines between them are belt conveyors. Products are carried into the system from IN with constant interval, performed each process $P_i(i = 1, ...5)$ on processing machines M_1-M_{15}, and finally output from $OUT1$-$OUT3$. The system has several processing machines of same type. For example, process P_1 is processed in M_1-M_3, but each processing machine has difference in process time as shown in Table 1. The maximum capability of the buffers is 20. The type of products is only one type. Products are carried into the system for every 30 steps. The number of the products is 200. The time from the output of the 50th product to the output of the 150th product is measured, and the value is defined as $T_{(est)}$. The work rate w is calculated as the ratio of working time of the processing machines to the $T_{(est)}$. The results of the experiments are shown in Table 2, Table 3 and Table 4.

Table 2 shows the work rate of each processing machine in the condition of $\alpha = 1.0$, $\beta = 1.0$, $\gamma = 1.0$. Table 3 and Table 4 show $T_{(est)}$ in each condition. In each experiment, $a = 1.0$, $b = 0.01$.

Table 1: Process time t of each processing machine for a product

	M_1	M_2	M_3	M_4	M_5	M_6
P	P_1			P_2		
t	60	50	35	80	50	40
	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}
P	P_3			P_4		
t	50	30	25	50	40	40
	M_{13}	M_{14}	M_{15}			
P	P_5					
t	30	25	20			

Table 2: Work rate w for each processing machine ($\alpha = 1.0$, $\beta = 1.0$, $\gamma = 1.0$)

	M_1	M_4	M_7	M_{10}	M_{13}
w	0.419	0.780	0.156	0.487	0.117
	M_2	M_5	M_8	M_{11}	M_{14}
w	0.378	0.466	0.268	0.339	0.204
	M_3	M_6	M_9	M_{12}	M_{15}
w	0.335	0.293	0.396	0.189	0.209

The transport was finished properly except in some conditions. In the case that pheromone information has no effect ($\gamma = 0.0$) or little effect($\gamma = 0.1, 0.2$), products are transported to the buffer over its capability and the transport was not finished properly. Thus, it is considered that the pheromone information plays important role in path selection. On the other hand, the transport is also not finished properly, where the effect of the pheromone information is bigger ($\gamma = 2.0$). γ has to be adjusted to proper value. The small or the big effect of the time information also results in overflow of the buffers($\beta = 0.1$, 10.0). As $T_{(est)}$ changes remarkably for the change of β, it is considered that the information about waiting/moving time t has a great influence on the utility.

In the experiments, the input time of products is constant, so that the work rate should be improved if the input time is controlled properly. However, considering some loss of time to transport products from the buffers to the machines, the work rate of M_4 is nearly bound to improve. Thus, the unbalance of work rates between processing machines needs to be improved. For example, the work rate of M_6 is less than that of M_4 and M_5. It is caused by a lack of the information about products which is processed in M_1 and M_2. Although some of the information about the products processed in M_1 and M_2 is given as waiting/processing time t and capability of the buffer c, which improve the unbalance in the condition of bigger β, additional introduction of some new information is needed.

Table 3: Process time for 100 products ($\alpha = 1.0$, $\gamma = 1.0$)

β	0.1	0.5	1.0	1.5	2.0	3.0
$T_{(est)}$	–	4615	4366	4239	4208	3927
β	5.0	10.0				
$T_{(est)}$	3765	–				

Table 4: Process time for 100 products ($\alpha = 1.0$, $\beta = 1.0$)

γ	0.0	0.1	0.2	0.5	1.0	1.5	2.0
$T_{(est)}$	–	–	–	4424	4366	4351	–

V. CONCLUSIONS

In this paper, we have proposed the multi-agent transport control system which utilizes pheromone information and examined validity and usefulness of the proposed method through simulation experiments. As a result of the experiments, although there is some unbalance in work rates, the proposed method can transport products properly in some conditions. For future works, we need to improve the work rate by controlling the input time of product, adjust some parameters and introduce new information such as pheromone of distanced elements.

ACKNOWLEDGMENT

This work has been supported in part by *a financial aid for Encouragement of Young Scientists* of *Faculty of Engineering, Kyushu University*(2009).

REFERENCES

[1] K. Uchiyama, T. Yoshikawa, K. Uchimura and Z. Hu: Construction of transport control system using congestion index, *IEICE Technical Report*, ITS 105(166), pp.23-28, (2005), (in Japanese).

[2] Y. Ando, Y. Fukazawa, O. Masutani, H. Iwasaki and S. Honiden: Performance of pheromone model for predicting traffic congestion, *AAMAS '06 Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems* , Vol.3, No.1, pp.1-16 (2006).

[3] M. Dorigo and T. Stützle: *Ant Colony Optimization*, The MIT Press, (2004).

[4] T. Seidel, J. Hartwig, R.L.Sanders and D. Helbing: An Agent-Based Approach to Self-organized Production, *Swarm intelligence*, Springer, pp.219-252 (2008).

[5] P. Valckenaers and T. Holvoet: The environment: An essential abstraction for managing complexity in MAS-based manufacturing, *In Lecture notes in computer science*, Springer Verlag, (2006).