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Moving Robots' Mind of Autonomous Decentralized FMS and Mind Change Control

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Abstract: This paper describes the control of the moving robots in an autonomous decentralized FMS by moving robots' mind change. In Autonomous Decentralized Flexible Manufacturing System where a lot of moving robots operate, there are problems of path interference. There is an existing method we have developed, called AAA used to evade from these interference problems. However, using this method, it is very difficult to grasp entirely the innumerable path interference situations that really occur. Therefore, to evade these unexpected situations flexibly, we propose the mind model which is the complicated expression of combinations from the three elements: Stimulation Vector, Unit and Load. Even if a same situation happens, moving robots take different actions when the mind is changed.

Keywords: Robot moving collision, FMS, AGV, path interference, mind

I. INTRODUCTION

Today; the actions of the robots are made by pre-decided control rules. When many robots try to perform complicated tasks, it is very difficult for them to cooperate with each other by using the pre-decided control rules.

On the other hand, human beings can perform such complicated tasks by an analyze based thinking. It is because the human beings have a mind that enables them to think by themselves [1].

Instead of using the pre-decided control rules, if we can provide a mind to the robots, they can cooperate themselves to perform complicated operations and will be able to adapt in every situation.

In Autonomous Decentralized Flexible Manufacturing System (AD-FMS), a lot of moving robots called Automated Guided Vehicles (AGVs) are operated [2-3]. In AD-FMS, AGVs move individually and have a high possibility to collide with each other.

In this paper, we propose the mind whose functions include mind change in order that AGVs do not collide. We will also present 6 models of AGVs mind, basic model, model of majority decision, model of mind that is hard to carry out mind change and other 3 models of mind that are easy to carry out mind change.

The effectiveness of these models are evaluated with production simulations in a AD-FMS virtual factory.

II. ELEMENTS OF MIND

It is said that mind is not constantly decided but changes ambiguously. And decision-making standards are different from each other.

Considering these factors, we propose the mind model which is the combination of three elements: Stimulation Vector, Unit and Load. The mind model can deal with mind change.

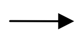

Fig.1 Stimulation vector

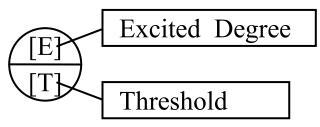

Fig.2 Unit

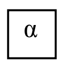

Fig.3 Load

The function of the Stimulation Vector shown in Fig.1 is to link between the Unit and the Load. If the stimulation signal is sent to the Stimulation Vector, the stimulation signal is either sent to the Unit or Load to indicate the arrow direction.

Fig.2 shows the schematic figure of the Unit which has the variable called Excited Degree [E] and the threshold value [T]. [E] of the Unit A is shown as A[E]. In the later sentences, Unit A is shown as just A. Similarly, [T] of A is shown as A[T]. [E] increases and decreases by various stimulations. If [E] exceeds [T], it is decreased to [T] and the Unit will send an output stimulation signal in the direction of the Stimulation Vector arrow. In this way, the Unit function will receive an input stimulation signal and send an output stimulation signal. When the [E] and [T] are equal, the Unit state is called Excited. Meanwhile, when [E] is lower than the [T], the Unit is said to be on Calm state. These two states can be changed and the change corresponds to mind change.

The Load shown in Fig. 3 has one numerical value plus or minus called Control Value. The Load is linked with the Unit by the Stimulation Vector following an arrow direction. If a stimulation signal is sent to the Load, [E] of the Unit is added or reduced by Control Value of the Load.

The mind change is expressed by the change of state of the Unit. Even if the same situation happens twice, AGVs can take different actions whether the mind has same state or not. The state of mind changes by sending a stimulation signal to Units or Loads from the result.

III. AGV WITH MIND

1. AD-FMS

Fig.4 shows the AD-FMS model. The AD-FMS consists of AGVs, machining centers that process parts, the parts warehouse that supplies many parts to machining centers and the products warehouse that stores finished parts. These correspond to agents.

2. Problems of AGV moving control

In the AD-FMS, when many AGVs operate, there are problems of path interference. There is an existing method we have developed called AAA used to evade from these interference problems by knowledge exchange [4-5]. Even if, this method is used, it is very difficult to grasp entirely the innumerable path interference situations that really occur. Therefore, to evade these unexpected situations flexibly, we use the mind model.

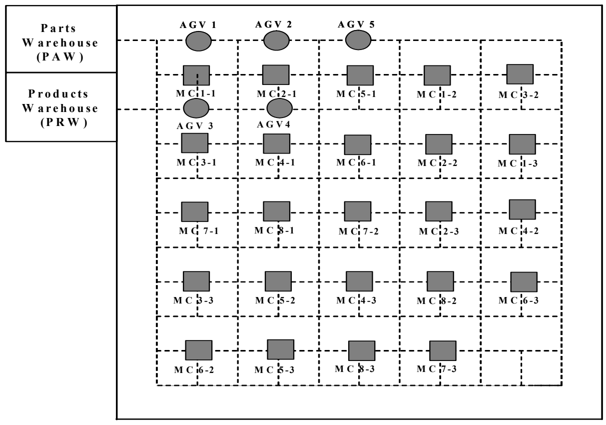

Fig.4 Model of AD-FMS

3. Basic models of AGVs' mind

Fig.5 shows the basic model of AGVs' mind (model (1)) that consists of 3 Stimulation Vectors, 2 Units (A,B) and a Load α with random numerical values of minus.

Fig.6 shows the work of model (1). In AD-FMS environment, AGVs can grasp each other's positions by exchanging their information [4-5].

When a certain AGV-1 gets closer to the other AGV, the information for possibility of the path interference is input into A of the mind. Then, the model (1) of AGV-1 outputs one of the following actions by the two states of its A, Calm and Excited. In this way, AGVs mind can also be divided into arrogant and modest states by the states of A.

Calm : Go to the destination
→ Arrogant AGV
Excited : Make way for other AGV
→ Modest AGV

When the arrogant AGV and the modest AGV gets closer, the arrogant AGV forces to go ahead. At the same time, the modest AGV clears the path so that the arrogant AGV can pass.

When the two arrogant AGVs get closer and path interference occurs, AGVs stimulate their individual mind by sending A the signal to increase A[E]. A gets Excited when A[E] reaches to A[T]. As a result, one of the AGVs becomes modest and both AGVs can evade path interference.

On the other hand, when the two modest AGVs get closer and try to make mutual concession of the path, AGVs stimulate their individual mind by sending B the signal to increase B[E]. B gets Excited when B[E] reaches to B[T] and sends a signal to α. α sends A and B the stimulations that decrease A[E] and B[E] by random integers from 1 to A[T] and from 1 to B[T]. As a result, A and B become Calm together and one of the AGVs becomes arrogant.

In this way, as for A, the state of A changes (Excited ⇔ Calm) by the action result (path interference or mutual concessions). This change corresponds to mind change. In addition, it can be said that the model (1) can express two states of mind, arrogant and modest.

When many AGVs get closer, AGVs evade path interference by repeating the mind change.

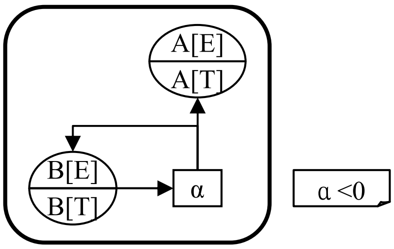

Fig.5 Basic model of AGVs' mind

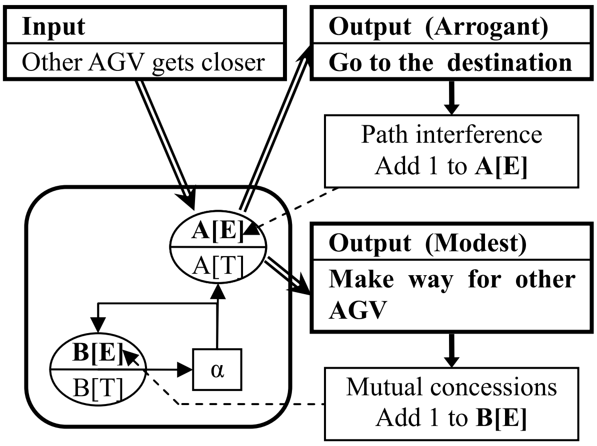

Fig.6 Work of model (1)

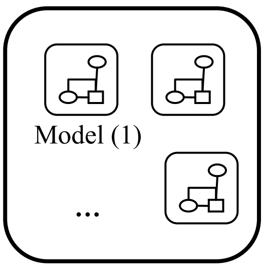

Fig.7 Model (2)

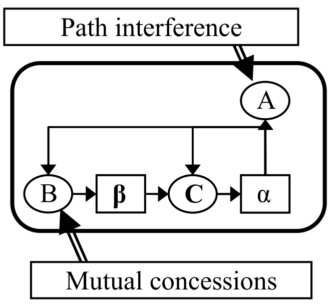

Fig.8 Model (3)

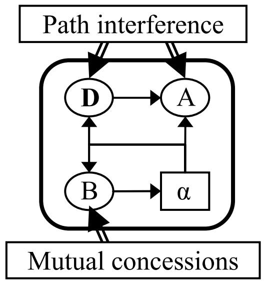

Fig.9 Model (4)

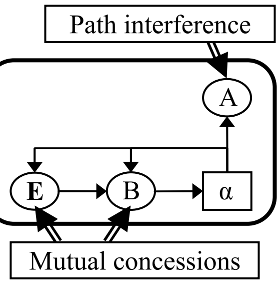

Fig.10 Model (5)

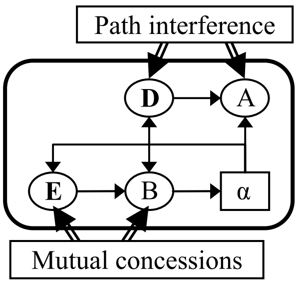

Fig.11 Model (6)

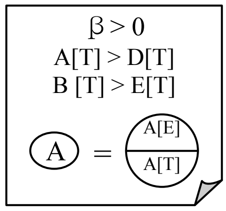

Fig.12 Condition and formulas of the models

4. More complicated models

To express various personalities of AGVs, it is necessary to increase the number of internal elements of the model of mind (1). We will present 5 more complicated models of mind (model (2)-(6)).

Fig.7 shows the model (2). Inside this model, there are a few model (1) and the state of mind is decided by majority decisions.

Fig.8 shows the model (3). It is the model that adds C and β between B and α of model (1). β takes random positive integers from 1 to C(T). The process that A gets Excited is similar to model (1). We will explain the process that A gets calm. When β gets Excited, C is stimulated. When C gets Excited, α is stimulated. As a result, α changes all states of A, B and C from Excited to Calm. It can be said that model (2) is harder to change mind than model (1).

Fig.9, 10 and 11 show the model (4), (5) and (6) respectively. These models are those who add D and E to the model (1).

In case of model (4), when path interference occurs, A[E] and D[E] increase. Because when A[T] > D[T], D becomes Excited faster than A and D sends A the signal to increase A[E]. Therefore, it can be said that the model (4) is easy to become modest because A is easier to get Excited than model (1).

Table 1. The simulation results

Item \ Model	(1)	(2)	(3)	(4)	(5)	(6)	Random
Volume of Production	256.6	256.1	253.6	257.9	258.3	257.9	143.3
Average Efficiency	25.79	25.7	25.44	25.84	25.92	25.92	14.79
Path Interference	1108	1113	1116	851	1110	891	11985

In model (5), when AGVs try to make mutual concession of the path, E gives B simulations. Because of it, the model (5) is easy to become arrogant. That means A is easier to get Calm than model (1).

Model (6) has the characteristics of both models (4) and (5).

Let's pay attention to the numerical values of A[T] and D[T]. The smaller they are, the more easily A gets Excited. That is the mind easily becomes modest. On the other hand, the larger they are, the more difficult mind becomes modest. Similarly, let's pay attention to numerical values of B[T], C[T] and E[T]. The smaller they are, the more easily A gets Calm. That is the mind easily becomes arrogant.

Various characters can be expressed by combining the above-mentioned features. For instance, when a certain model of mind has small values for A[T] and B[T], this model expresses the mind that are easy to change mind.

Fig.12 shows the condition and formulas of the models.

IV. SIMULATION RESULTS

In this paper, we applied all of mind models (model (1)-(6)) that we have presented to AGVs in AD-FMS which is built on a computer and carried out simulations. In addition, to compare the various conditions of the models, the simulation with the condition that randomly changes mind states were also carried out.

Table 1 shows the simulations results (the volume of production, average efficiency of machining centers, and the number of path interference).The results of model (2)-(6) are compared with that of model (1).

The results shown in table.1 reveal that the state of a mind changes randomly, the volume of production and average efficiency of machining centers fell remarkably, and the number of path interference increased 10 times than that of model (1). Therefore, it can be said that moving control with a mind change is effective.

Both the volume of production and the average efficiency of machining centers of model (4)-(6) were slightly better than that of model (1). The models can reduce time spent for evading path interference because these models are easy to change their states. Moreover, number of path interference of model (4) and (6) could be reduced 20% more than that of model (1).

V. CONCLUSIONS

In this paper, we proposed the various mind models of AGVs that can flexibly evade unexpected path interference situations not using the pre-decided control rules. Comparing the proposed mind model with the basic mind model, we could obtain the better result that reduced the number of path interference by 23.2%.

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