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Robots' Action Control of Autonomous Decentralized FMS by Remorse Mind

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Abstract: This paper describes the control of moving robots in an autonomous decentralized flexible manufacturing system (FMS) by "changes in the mind" of the moving robots. In an autonomous decentralized FMS, many moving robots are operating, and path interference problems occurred. It is very difficult to grasp the innumerable path interference situations that really occur. Therefore, to avoid these unexpected situations flexibly, we used mind model. In this way, we could solve path interference problems. However, the previous mind model we proposed had problems while taking evasive action. Robots having the previous proposed mind model are inefficient in solving path interference problems. Therefore, we propose a new mind model that can allow robots to avoid path interference efficiently.

Keywords: Robot moving collision, FMS, AGV, Path interference, Mind

I. INTRODUCTION

Today, a robot's actions is made by determined control rules. Robots cannot do anything without determined controls. Therefore, robots needed to be adaptable and designed for all situations.

In this paper, the human mind is used as a model to solve this circumstance. Humans can cope with many situations and can modify their action by thinking for themselves. If we can provide a humanlike mind to robots, they will be able to perform complicated operations and will be able to adapt to every situation. In this research, we propose a mind model that allows robots to act flexibly.

II. AD-FMS

1. AD-FMS

In this paper, we adopt Autonomous Decentralized Flexible Manufacturing System (AD-FMS), an autonomous distributed system, as the production system of a virtual factory.

Figure.1 shows the AD-FMS model. In the AD-FMS, many moving robots called Automated Guided Vehicles (AGVs) are in use. AGVs carry parts and the completed product to the warehouse and a machining center (MC) [1].

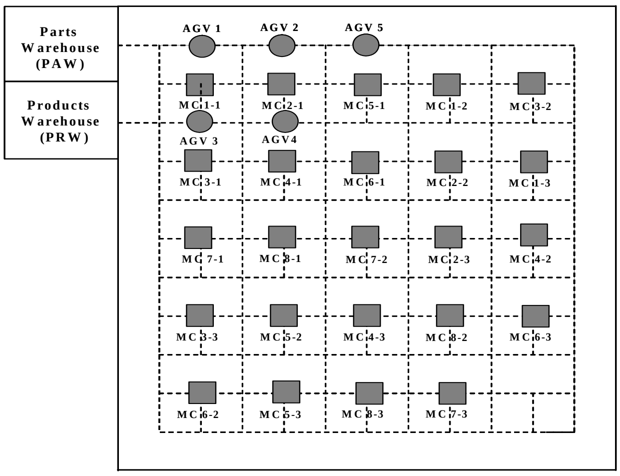

Fig.1 Autonomous decentralized FMS

2. Problems of AGV moving control

In the AD-FMS, path interference problems occur when many AGVs are in operation. There is an existing method we developed called Algorithm Avoid AGVs (AAA) which avoids these interference problems by knowledge exchange [2]-[4]. Even with this method, it is very difficult to identify the innumerable path interference situations that really occur. Therefore, to avoid these unexpected situations flexibly, we use the mind model.

III. REMORSE MIND

1. Element of mind

We proposed that the mind model is not static but changes ambiguously. The mind model is the combination of three elements: Stimulation Vector, Unit and Load.

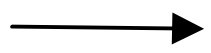

Fig.2 Stimulation vector

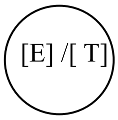

Fig.3 Unit

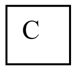

Fig.4 Load

The function of the Stimulation Vector shown in Fig.2 is to link the Unit and the Load. If the stimulation signal is sent to the Stimulation Vector, the stimulation signal is sent to either the Unit or Load to indicate the arrow direction.

Figure.3 shows the schematic figure of the Unit with the variables Excited Degree [E] and threshold value [T]. [E] of Unit A is shown as A[E]. Below, Unit A is shown as just A. Similarly, [T] of A is shown as A[T]. The increase or decrease of [E] depends on the value of stimulation. If [E] exceeds [T], [E] is decreased to [T] and its 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 [E] and [T] are equal, the Unit state is called "Excited". Meanwhile, when [E] is lower than [T], the Unit is said to be in a "Calm" state. These two states can be changed and the change corresponds to a mind change.

The Load shown in Fig.4 has one numerical value plus or minus called the control value. The Stimulation Vector links the Load with the Unit. If a stimulation signal is sent to the Load, [E] of the Unit is added or reduced by Control Value of the Load.

2. Basic mind model

Figure.5 shows the basic model of AGV that consists of three Stimulation Vectors, two Units (A,B), and a Load α with random negative numerical values.

Figure.6 shows the work of the basic mind model. In AD-FMS environment, AGVs can determine each other's positions by exchanging their information[4]-[5].When one AGV-1 gets closer to the other AGV, the possibility for the path interference is input into the mind of A. Subsequently, the mind outputs one of the two actions by the two states of its A, Calm and Excited.

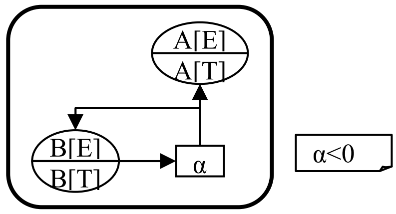

Fig.5 Basic mind model of AGVs

We call the mind with state A Calm as arrogant and that of state A Exited as modest.

When the arrogant AGV and the modest AGV gets closer, the arrogant AGV forces itself ahead, while simultaneously, 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] equals A[T]. As a result, one of the AGVs becomes modest and both AGVs can avoid path interference.

In contrast, when the two modest AGVs get closer and try to mutually concede the path, AGVs stimulate their individual minds by sending B the signal to increase B[E]. B gets Excited when B[E] equals B[T] and sends a signal to α. Load α sends a stimulation to Units A and B to decrease A[E] and B[E] by random integers from 1 to A[T] and from 1 to B[T]. As a result, Unit A becomes Calm and the AGV with its Unit A becomes arrogant.

In this way, as for Unit A, the state of A changes (Excited ⇔ Calm) by path interference or mutual concessions. This change corresponds to a mind change. The mind whose state of A is Calm behaves like an arrogant AGV and the mind whose state of A is Excited behaves like a modest AGV.

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

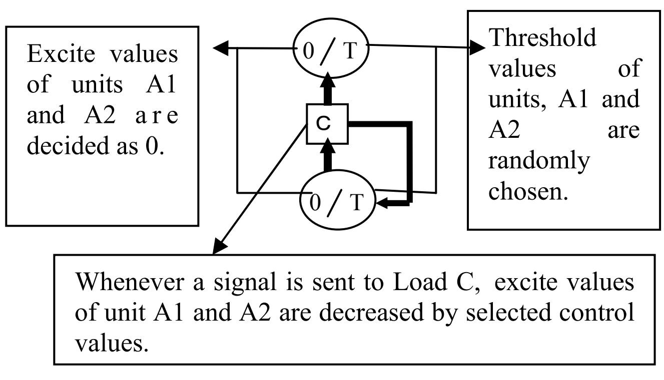

Fig.6 Work of basic mind model

3. Problems of a basic mind model

The number of path interferences is reduced to 0 by the mind we developed before [5]. However, the basic mind model has other problems when taking evasive action.

We know that the number of bad evasions is the same as the number of a good evasions. This means that AGVs with a basic mind inefficiently avoid path interference inefficiently. Table.1 shows the number of the both evasive actions.

Table.1 Date of evasion

Good evasion	Bad evasion
33	32

Good evasion means that the AGV that is far from the goal gives way to the AGV that is close to the goal.

Bad evasion means that the AGV that is close to the goal gives way to the AGV that is far from the goal.

Thus, we focus on AGVs evasive actions. We propose the new mind model that can increase the number of good evasions.

4. Remorse mind

Figure.7 shows the new mind model. We call it the "remorse mind". We propose that this remorse mind can control the tendency of mind change by estimating its own situation. We call this action "Remorse" like human remorse.

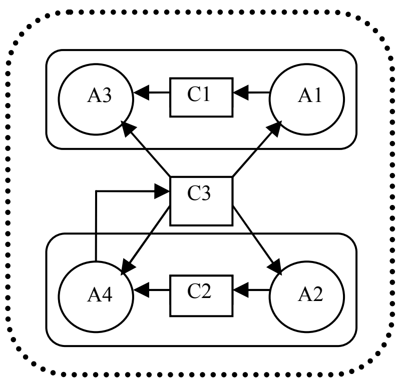

Fig.7 Model of remorse mind

5. Constructive features of remorse mind

We will explain constructive features of the remorse mind, which has three Loads and four Units. The control value of one Load is minus. The others are plus. Figure.8 shows the structure of the remorse mind. We show that the remorse mind consists of the structure of a basic mind model, which is defined as a core structure that a certain structure has the same structure inside.

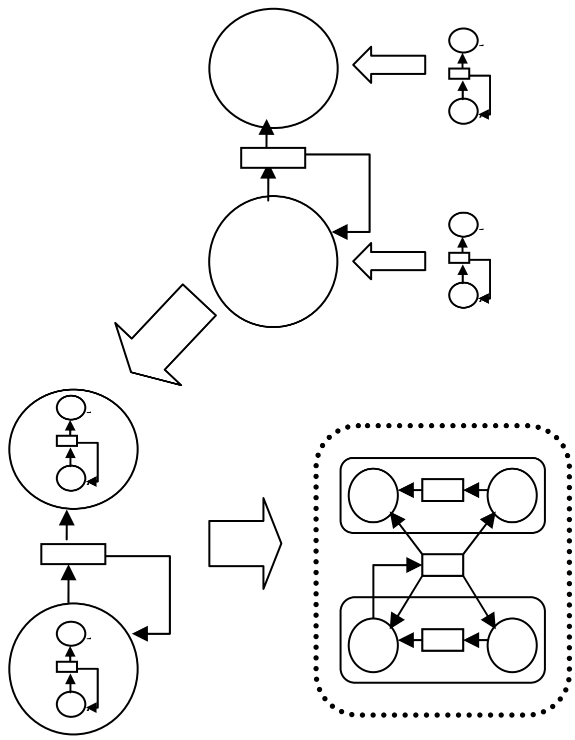

Fig.8 Structure of remorse mind

6. Functional features of remorse mind

AGVs with a remorse mind can evaluate their own situation by referring to their distance to the Goal. AGVs always have information on both their current position and the goal. This information is always being refreshed. AGVs can calculate the distance to the goal based on this information.

AGVs with remorse mind can control the control value [X] and [Y] by the distance to the goal point. If AGVs get closer to the goal, the remorse mind tends to become arrogant. Then, [X] becomes higher than [Y]. If AGVs are far from the goal, the remorse mind tends to become modest (Fig.9). Then, [Y] becomes higher than [X]. Figure.10 shows the remorse mind that tends to be arrogant.

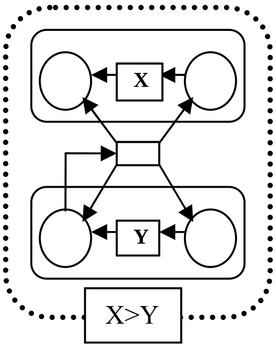

Fig.9 Tend to be modest

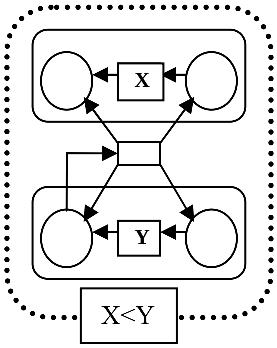

Fig.10 Tend to be arrogant

IV. SIMULATION EXPERIMENTS

In this paper, we applied the remorse mind to AGVs in an AD-FMS that was computer modeled and on which production simulations were performed.

In addition, to compare the conditions of the remorse mind with the condition of the basic mind model, the simulations of the basic mind model were performed.

Figure.11 shows the layout of the AD-FMS factory.

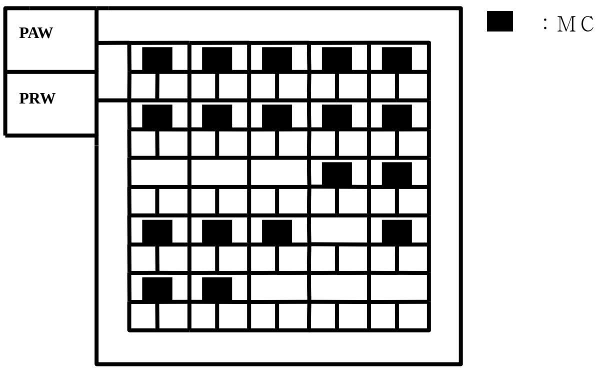

Fig.11 Layout of simulation

V. SIMULATION RESULTS

Table.2 shows the simulations results (the volume of production, average efficiency of machining centers, and the number of good and bad evasions).

The results shown in Table.2 reveal that the number of good evasions is increased and the number of bad evasions is decreased significantly. Therefore, one can say that AGVs that have the remorse mind can efficiently avoid path interferences rather than AGVs that have the basic mind model..

Table.2 The Simulation Results

	Outputs	Average Efficiency	Good evasion	Bad evasion
Basic mind	266	29.9	33	32
Remorse mind	268	30.0	42	5

Both the volumes of production and the average efficiency of machining centers of the remorse mind were better than those of the basic mind model.

VI. CONCLUSIONS

In this paper, we proposed the remorse mind model of AGVs that can efficiently avoid path interference situations better than the basic mind model. Comparing the proposed remorse mind model with the basic mind model, we were able to obtain better results that reduced the number of bad avoids by 15.6%.

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