AGV with Mind and its production simulation for autonomous decentralized FMS

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Abstract

This study controls Automated Guided Vehicle (AGV) moving by using a mind model in order to avoid AGVs’ interference. The mind model can avoid the interference by repeating the two types of mind changes. By applying the mind to several FMSs, the production simulations were carried out. As a result, AGV could avoid the interference flexibly even if the shape of the production floor was changed, and it is ascertained that the mind model could control the AGV actions.

*Keywords:* Autonomous Decentralized FMS, AGV control, AGV mind, Production simulation

1. Introduction

We have developed an autonomous decentralized FMS factory. We need to avoid collisions among AGVs when we use the autonomous decentralized FMS. Although some rules to avoid collisions are considered, these rules are not enough to control when many AGVs are used. Therefore, we try to control the behavior of AGVs by using a mind model. In this study, we apply AGV with the mind model to plural FMSs and examine whether AGVs can avoid the path interferences flexibly even if the shape of the production floor is changed. Moreover we examine the influence on production efficiency.

2. Mechanism of autonomous decentralized FMS

2.1. Overview of autonomous decentralized FMS

Fig.1 illustrates an autonomous decentralized FMS factory scheme. As Fig.1 shows, the factory floor is divided into grid patterns and AGVs are moving along these lines to carry parts to the warehouse and machining centers. The autonomous decentralized FMS does not have a management mechanism to integrate the entire system, such as machining centers, AGV, product warehouse and parts warehouse. Each agent that configures the system autonomously determines the act by recognizing the purpose of the system by cooperating and negotiating to other agents.

2.2. Model of mind and behavior of AGVs

In autonomous decentralized FMS, each AGV determines the behavior autonomously. Therefore, AGVs often cause path interferences. In our previous studies, we used control rules to avoid path interferences. However, in the control rules, it was not able flexibly to adapt the environmental changes including the changes of the number of AGVs and the changes of the shape of production floor.

Therefore, in this study, we apply the AGV mind to solve the problem and realize the autonomous movement control not to produce path interferences of AGVs. AGVs’ mind is expressed two kinds of an arrogant mind...
and a modest mind. Specifically, (1) AGV with an arrogant mind takes the action forcibly to approach the destination. (2) AGV with a modest mind takes the action to make way for other AGVs.

AGVs take three actions by changing the two kinds of mind.

- If AGV with an arrogant mind and AGV with a modest mind run on the same line at the same time, AGV with a modest mind takes the action to give way and AGV with an arrogant mind takes the action to approach the destination forcibly.
- If the two AGVs with an arrogant mind run on the same line at the same time, one of the AGVs changes its mind to a modest mind and gives way for the other AGV.
- If the two AGVs with modest mind run on the same line at the same time, one of the AGVs changes its mind to an arrogant mind and the other gives way for the AGV just changed to an arrogant mind.

We use the mind model as shown in Fig.2 to express the mind. In the study, we call it Minimum Unit of Mind (MUM). In Fig.2, A1 and A2 is a unit, X is a load, and an arrow is a stimulation vector. The threshold is determined by the unit. When the internal value reaches the threshold, we call the mind situation as excited and if it does not reach, normal.

The functions of each component of MUM are as follows.

- Unit: When a signal is sent to the unit, it sends a signal to the direction of the arrow when excited, and it is not sent when normal.
- Load: Load has the function to change the internal value of the unit. When the signal is sent to the load, the value of unit is decreased by the value of X.
- Stimulation vector: Stimulation vector is a line connecting the load and the unit. It gives a signal to the load or unit when the signal comes.

When A1 keeps exited, we call a arrogant mind, and when normal, we call a modest mind.

Next, we describe the internal functions of MUM by the following ① to ③.

① When the AGV with an arrogant mind encounters a path interference, the value of A1 is increased by 1. Keeping the situation of the interference, the value of A1 will increase and soon becomes the threshold value. As soon as the value becomes the threshold value, the AGV mind is changed to a modest mind.

② When AGV with a modest mind keeps giving way, the value of A2 is increased by 1. When the situation is repeated an optional time and A2 becomes exited, the signal is sent to a load.

③ The load received the signal from A2 decreases the value of units A1 and A2 by an optional value. Because of this, A1 and A2 return to normal and AGV with a modest mind is changed to AGV with an arrogant mind.

In this way, by changing minds from arrogant to modest or from modest to arrogant repeating ① to ③, the mind change is realized.

3. Target production line

We performed the production simulations of autonomous decentralized FMS using the production floors of two different shapes.

One is the integrated production floor that parts warehouse and products warehouse are next to each other as shown in Fig.3 and are contiguous with one production floor.

The other is the split production floor shown Fig.4 that the floor of Fig.3 is split into the production floor connected parts warehouse and production floor connected products warehouse. AGVs come and go between the two floors.

![Fig.3 Integrated production floor](image-url)
We carried out the production simulation by using these two kinds of production floors and compared the production outputs and the number of path interferences of AGVs.

The initial internal value of MUM unit A1, A2 is 0 and the threshold values are chosen as random. Therefore, all AGVs keep arrogant minds for the first time.

4. Simulation results

We investigated parameters changing number of AGVs and simulation times in each integrated production floor and split production floor.

Condition 1(number of AGV: 5 units, simulation time: 8 hours)
Condition 2(number of AGV: 5 units, simulation time: 40 hours)
Condition 3(number of AGV: 8 units, simulation time: 8 hours)

Table.1, 2, 3 and Fig.5, 6 are the acquired number of production outputs and the acquired number of path interferences in each condition.

Table.1. Simulation result of condition 1

<table>
<thead>
<tr>
<th></th>
<th>Production Outputs</th>
<th>Number of path interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td>186</td>
<td>769.6</td>
</tr>
<tr>
<td>Split production floor</td>
<td>134.6</td>
<td>911.8</td>
</tr>
</tbody>
</table>

Table.2. Simulation result of condition 2

<table>
<thead>
<tr>
<th></th>
<th>Production Outputs</th>
<th>Number of path interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td>971</td>
<td>3190.8</td>
</tr>
<tr>
<td>Split production floor</td>
<td>712.2</td>
<td>3752</td>
</tr>
</tbody>
</table>

Table.3. Simulation result of condition 3

<table>
<thead>
<tr>
<th></th>
<th>Production Outputs</th>
<th>Number of path interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Split production floor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.5 shows that the integrated production floor acquired more production outputs than the split production floor in any conditions. In condition 1 and 2, the production outputs are proportional at simulation time. In condition 1 and 3, condition 3 manufactured more production outputs than condition 1. Therefore, the more number of AGVs becomes, the more production outputs.

Fig.6 shows that the split production floor gets more path interferences than the integrated production floor in any conditions. Comparing condition 1 and condition 2, 3, it is proved that the more simulation time and the number of AGVs, the more the path interferences. The split production floor gets much more path interferences than the integrated production floor in condition 3.

Table.4, 5, 6 indicate the percentage of each places (periphery of parts warehouse, products warehouse and the route connecting two floors) in the total places caused path interference in each condition. Fig.7, 8, 9 are the plots of path interference places of the split production floor.
Table 4. Path interference place of condition 1

<table>
<thead>
<tr>
<th></th>
<th>Parts warehouse</th>
<th>Products warehouse</th>
<th>Route connecting two floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td>21%</td>
<td>8.4%</td>
<td>-</td>
</tr>
<tr>
<td>Split production floor</td>
<td>12.7%</td>
<td>3%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Table 5. Path interference place of condition 2

<table>
<thead>
<tr>
<th></th>
<th>Parts warehouse</th>
<th>Products warehouse</th>
<th>Route connecting two floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td>17.2%</td>
<td>10%</td>
<td>-</td>
</tr>
<tr>
<td>Split production floor</td>
<td>8%</td>
<td>4.5%</td>
<td>43.3%</td>
</tr>
</tbody>
</table>

Table 6. Path interference place of condition 3

<table>
<thead>
<tr>
<th></th>
<th>Parts warehouse</th>
<th>Products warehouse</th>
<th>Route connecting two floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated production floor</td>
<td>19.3%</td>
<td>5.6%</td>
<td>-</td>
</tr>
<tr>
<td>Split production floor</td>
<td>11.2%</td>
<td>1.7%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Fig. 7 Path interference place of condition 1

Fig. 8 Path interference place of condition 2

Fig. 9 Path interference place of condition 3

Table 4, 5 and 6 shows that the split production floor has much more path interferences on route connecting two floors. For this reason, it is assumed that the path interferences increase in the split production floor. As a result, it is assumed that the integrated production floor has more production outputs than the split production floor. Comparing condition 1 and condition 2, 3, the path interference percentage increased a little in condition 2 and the path interference percentage much increased in condition 3 on the route connecting two floors. From Table 4, 5 and 6, it is assumed that the reason for condition 3 acquired much path interferences on the route connecting two floors than condition 1 or 2. From this, the number of AGVs have a great influence on congestion of the route connecting two floors in split production floor.

5. Conclusions

With AGV minds, even if a different shape production floor is adopted, AGV was able to avoid path interferences flexibly in autonomous decentralized FMS. In the split production floor, AGV was crowded very much near the route connecting two floor. However, it was able to finish the simulation without freezing and it is ascertained that the results of the production simulation becomes proper. Therefore, we were able to control actions of AGVs by using AGV mind.