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Research Article

Real-Time AGVs moving control of Autonomous decentralized FMS by mind change with deep learning

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ABSTRACT

This study describes the control method of Automated Guided Vehicles (AGV) movements by using a mind model in order to avoid AGVs interferences. The mind uses the two types of mind, the arrogant mind and the modest mind model. The interferences between AGVs are avoided by repeating the two types of mind changes, the arrogant mind and the modest mind. The mind model includes the deep learning system. By the mind including the deep learning, we can improve the decrease of the route interference time.

1. Introduction

We have developed the moving control of Automated Guided Vehicles (AGVs) in autonomous decentralized flexible manufacturing systems (AD-FMS). The AGVs have a minimum model of mind (MUM) [1]. However, in the past research, if the number of AGVs operating in FMS increases, it is difficult to express efficient mind changes. Because of it, it takes much time to avoid route interferences. As a result, production efficiency decreases. In order to solve the above-mentioned problems, we develop the new mind model including deep learning system. We call the model as Minimum Unit of Mind with Deep learning (MUMD). We compare the AGVs efficiencies of MUMD with the AGVs efficiencies of our developed two mind models, MUM, and MUMN by applying the three types of the mind models to FMS constructed in a computer. MUMN is including m a neural network into the MUM.

Autonomous Decentralized FMS

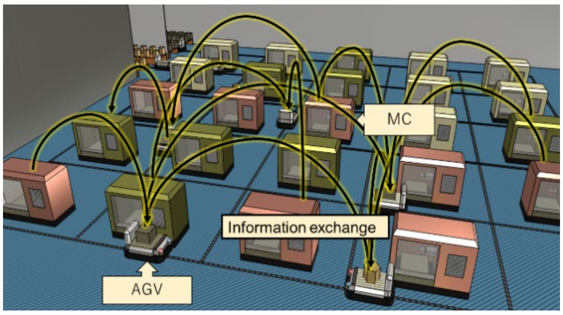

Fig.1 Example of AD-FMS

Fig.1 shows the example of AD-FMS. The factory floor is divided into a grid pattern where an AGV moves. The system of AD-FMS is carrying the parts to the warehouse or machining centers (MCs). The AD-FMS does not have a management system that controls the whole system. The agents (MCs, AGVs and Warehouses) which are the

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components of the AD-FMS exchange knowledge and determine the behavior of each agent.

3. AGV behaviors and its mind

AGVs autonomously decide their actions in the AD-FMS of this study. AGVs sometimes gets path interference between AGVs. To avoid the interferences, we adopted if-then rules in our past study. Even if we use the if-then rules, it is not easily find the if-then rules in the case of increasing the number of AGVs and changing the layouts of the factory. In order to solve this problem, we insert the MUM into AGV and realize autonomous AGV moving in order not to have AGVs interferences.

3.1. *Mind model and its problem*

The AGVs mind expresses two kinds of mind, the arrogant mind that takes action forcibly to approach the destination and the modest mind that takes action to give ways to other AGVs. To express the mind, we use MUM in Fig.2. A1 and A2 are units, X are the weights and arrows are called stimulus vectors. Units have thresholds and internal values. A unit whose internal value reaches the threshold is called excited. A unit whose internal value does not reach the threshold is called normal. By the amount of the signal input to the unit, MUM changes the mind to arrogant or modest frequently. We describe the internal functions of MUM. When the arrogant AGV has a path interference, A1 is increased by 1. Keeping the situation of the interference and being increased by 1, the A1 value becomes the threshold, and the AGV is changed to a modest one. When AGVs with a modest mind keep giving a way, the value of A2 is increased by 1. When the situation is repeated at optional times, A2 becomes excited and a signal is sent to a load. The received load decreases the values of units A1 and A2 by optional values. Owing to this, A1 and A2 are returned to normal and a modest mind is changed to an arrogant mind. In this way, AGV avoids the path interference by the change of mind.

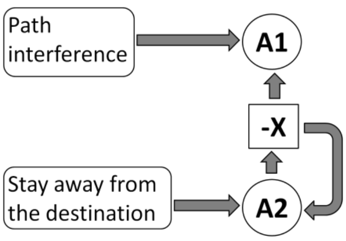

Fig.2 MUM model

The problem of MUM is that there are various patterns of path interferences in a large number of AGVs. Because of it, it takes time to solve route interferences.

3.2. *MUMN*

MUMN is the model of the mind that was developed in order to achieve more efficient mind changes by using a neural network for MUM and to change the mind according to the AD-FMS floor situations. Fig. 3 shows the model of MUMN.

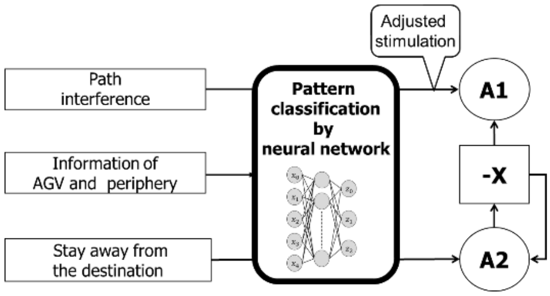

Fig.3 Model of MUMN

3.3. *MUMD*

We explain how MUMD gives the good influences to the production of AD-FMS by increasing the number of intermediate layers of MUMN. Fig.4 shows the MUMD.

MUMD adjusts the amount of stimulus sent to A1 and A2 by a deep learning system after receiving an information such as how close or how far they are from the destinations and how many AGVs are in the surrounding areas. The model is shown in the diagram below.

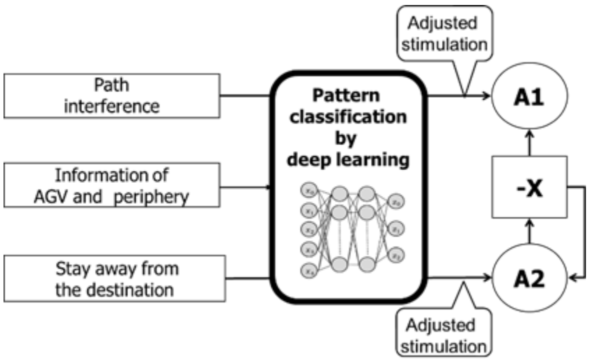

Fig.4 MUMD model

4. Inside information of MUMD

4.1. *Input information of deep learning*

The input information of the deep learning is the following five.
x_0: bias (always 1)
x_1: Destination
x_2: Distance from the destination
x_3: Number of other AGVs which are moving around the destination
x_4: Number of other AGVs numbers which go away from the destination

4.2. *How to create teacher signals*

x_1: The destination is the sum of the X and Y coordinates of the AGV destination.
x_2: The distance to the destination is the absolute value of the difference between the coordinates of the destination (X, Y) of the AGV and into current position (X ', Y'), as shown in equation (1).

Distance to destination = | X - X'| + | Y - Y' | (1)

x_3: The number of other AGVs within the range of bold line as shown in Fig. 5. We call the AGVs as neighbor AGVs.

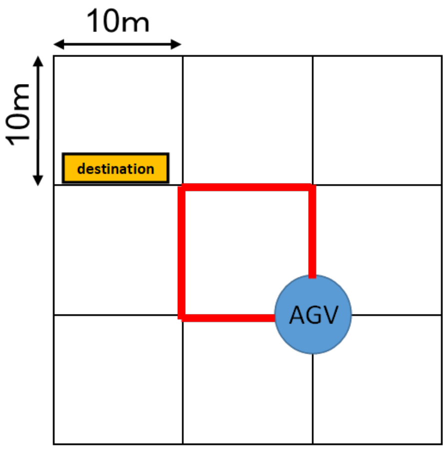

Fig.5 Other neighbor AGVs

x_4: The number of other AGVs which moves from the destinations. The AGVs take the bold line of Fig. 6 and we call the AGVs as not neighbor AGVs.

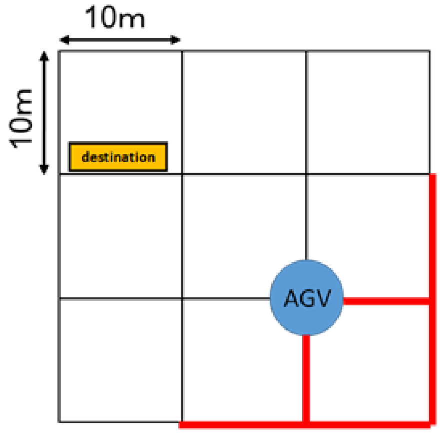

Fig.6 Not neighbor AGV

4.3. *Output information of deep learning*

The output information of the deep learning has the following three patterns. The input and output relationships are shown in Fig. 7.
z_0: Pattern to move to the destination with an arrogant mind ①
z_1: Pattern of giving way with a modest mind ②
z_2: neutral pattern ③

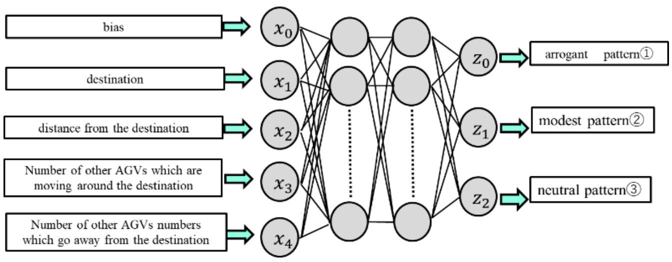

Fig.7 Internal information of MUMD

4.4. *Effect of MUMD*

The MUMD receives the output patterns and sends the stimulations, as shown in Table 1, to the units A1 and A2.

Table.1 Stimulation of each pattern

	A1	A2
arrogant pattern 【1】	1	4
modest pattern 【2】	4	1
neutral patter 【3】	2	2

First, we explain the actions of each pattern in Table.1.

When the pattern 【1】 that moves with an arrogant mind is output, the stimulus to A1 gets reduced and the stimulus to A2 gets increased. Because of this, MUMD can keep an arrogant mind long.

Second, when the pattern 【2】 that moves with a modest mind is output, the stimulus to A1 gets increased and the stimulus to A2 gets reduced. Because of this, MUMD can keep a modest mind long.

Third, when pattern 【3】 is output, the amount of stimulus sent to A1 and A2 keeps equal. Because of this, MUMD can keep a neutral pattern between pattern 【1】 and pattern 【2】.

5. Application Simulations and their results

By using the AD-FMS layout as shown in Fig. 8, the virtual production simulations with the three minds types, the conventional MUM, MUMN and MUMD, were carried out. Every simulation includes ten AGVs. The simulations for 8 hours AD-FMS operations were carried out 10 times each. As a result, Table 2 was acquired. It shows the comparisons of production outputs, the average operation rates of AGVs, the time of route interference for each AGV and the MC average operating rates.

From the table, the followings are found, MUMD improved the production outputs by 2.1%, AGV operation rate by 1.3% and MC operation rate by 1.9%, compared with MUM. MUMD decreased the production outputs by 0.9%, the AGV operation rate by 0.5% and the MC operation rate by 0.9%, compared with MUMN. MUMD reduced route interference time by 5.6%, compared with MUM. MUMD reduced route interference time by 3.0%, compared with MUMN. The reason MUMD is excellent is that MUMD can send appropriate stimulations to the AGVs minds and can give mind changes that strongly adapt the production situations. The production outputs and MC operating rate were not high. This is why the modest mind AGVs that need to avoid interferences increased and they had to choose detours for destinations.

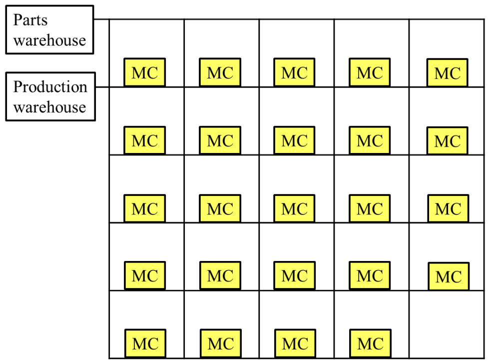

Fig.8 AD-FMS

6. Conclusions

From the application simulation results, it was found that the route interference times of the proposed MUMD was shorter than those of MUMN. The study of our deep learning is to classify mind patterns by using 3 outputs and 4 inputs for each mind model. As our future study, we will develop AGVs that change their minds more flexibly by changing hyper parameters such as the numbers of input information, output information and the units of the middle layer.

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Table.2 Simulation results

	outputs(num)	occupancy rate(%)	path interference time(sec)	occupancy rate of MC(%)
MUM	264.1	62.024	10880.2	35.581
MUMN	272.3	63.146	10613.9	36.586
MUMD	269.8	62.831	10306.8	36.244

Authors Introduction

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He received his B.S, M.S and PhD from Nagoya Institute of Technology. After joining Toyota Industrial Corporation and Wakayama Univ., he works for Gifu Univ. He is currently Specially-appointed Professor, Honorary Professor of Gifu University and the fellow of the Japan Society of Mechanical Engineers.

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