

Cell-production Parts Layout by Virtual Factory System using Reinforcement Learning and MTM

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Abstract: For a cell production system to use a part rack for production environment, the quality of efficiency of the production time varies according to the part placement of the part rack. To solve this problem, we developed Virtual Assembly Cell-production System (VACS) which evaluates the movement distance of operators and decides part placement. In this study, we suggest a new VACS which evaluates not only movement distance of the operators but also up-and-down motion to get parts on the rack. In this VACS, by part placement decision, I adopt reinforcement learning and adopt the MTM as a work evaluation of the up-and-down motion of the rack in this reinforcement learning.

Keywords: Cell-Production, Virtual Factory, Reinforcement Learning, Method-Time Measurement

1 INTRODUCTION

The parts picking up operation which uses a rack in a cell production system has the problem with different production efficiency by the part locations of the rack. To solve this problem, we developed Virtual Assembly Cell-production System(VACS) which optimizes part placement, and visualizes the work process to an operator. ^[1]

VACS is the system which integrates a virtual production system with a part placement decision system. In the part placement decision system, we decide the most suitable combination of rack and parts. In the virtual production system, we make a shop floor of the cell production by 3DCG, and we visualize the installation process of the production parts based on the combination of the most suitable rack - parts which were decided by a part placement decision system. Thus, we realize the visualized work production, but, VACS decided part placement is based on movement distance. We should add the degree of difficulty of the movement of the operator to evaluate. Therefore, this paper proposes new VACS with reinforcement learning. And we apply this VACS to the assembly cell product line of the PC and inspect the effectiveness.

2 VACS

2.1 VACS

VACS consists of two systems of a part placement decision system and the virtual production system as shown

in Fig.1. First, VACS makes the shop floor by the reinforcement learning in a virtual production system. Next, VACS decides the most suitable placement of a part and the rack in a part placement decision system, Finally VACS makes a virtual shop floor by acquiring the most suitable placement by a virtual production system again.

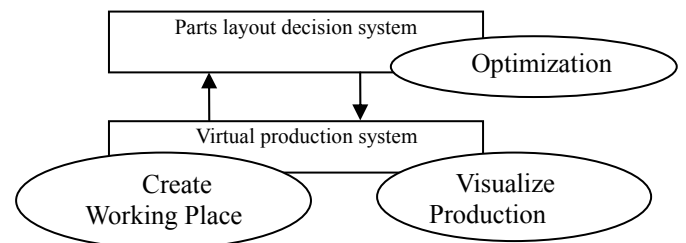


Fig.1 VACS

2.2 Part placement decision system

The part placement decision system uses reinforcement learning based on the workshop which is received from virtual production system, and decides part placement of the cell production. The decision corresponds to the movement distance of the operator and the evaluation of the degree of difficulty of the up and down movement.

In this study, we use Profit Sharing as reinforcement learning. In order to update the value of Profit Sharing, the walk movement that an operator moves between racks, and the work degree of difficulty of the up and down movement when an operator takes a part are

converted to time value by MTM, and VACS uses this time. We call this time an operating time. The time is decided by conditions such as the weight and height and the part of the operator.

The part placement decision system consists of two modules, namely, the condition making module and the learning module. The condition making module performs reading with various information files, and compiles the data to enable it to learn in a learning module. The learning module performs the pre-decided number of learning times and decides the most suitable part placement by Profit Sharing.

2.3 Condition making module

The condition making module sets a production condition and a learning initial condition of Profit Sharing through the following steps.

Step3-1: Reading of the configuration file

By using the initial conditions, the conditions about production are decided. Reading setting information and decide a condition about the production. The initial conditions are as follows.

- Width of the workshop
- Depth of the workshop
- The size of cart and rack
- The number of the steps of the rack
- Highest step height of the rack
- The lowest step height of the rack
- The learning times number
- Learning rate
- Height of the operator

Step3-2: Read the parts information of the part.

Parts information necessary for product is acquired. The part information to read in this STEP are as follows.

- Part name
- Size of the part
- Ease of grasping the part
- Weight of the part

The size of the part data gives 0 or 1, The part which can be held with one hand is 0. The part which is held with both hands is 1. Ease of grasping the part is given as 1~3, which are used as analysis of the up and down movement in movement analysis. As the numbers increase, the degree of difficulty of the grasp rises, and operating times increase. The weight is in kg unit and is used as the analysis of the up-and-down motion.

Step3-3: Setting of the condition of the workshop

The rectangular of the depth and the width that are read in STEP3-1 becomes rectangular. After reading the workshop information, the size of rack parts, carts, and coordinates are set. Fig.2. shows the example of the workshop using this information.

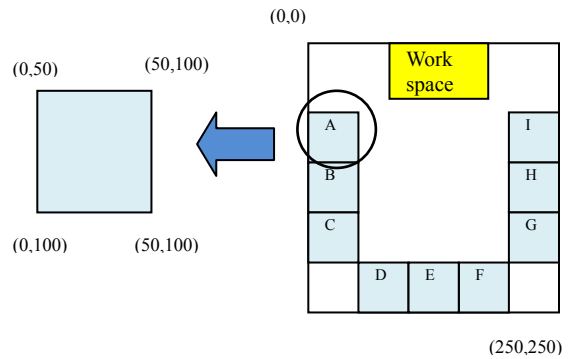


Fig.2 coordinate data

Step3-4: Read order data.

The order data describes the kind of products, outputs, necessary parts information, and the number of the parts. We show an example of order data in Table.1. Table.1 indicates the kind of PC to produce, needed parts and, number of products. For example, in PC 1, one case, one power supply, one motherboard, one unit of CPU, and two memory. Furthermore, a person of order wants to produce PC 1 20.

Table.1 example of order data

Product name	PC1	PC2	...
Case	1	1	
Power	1	1	
Mother board	1	1	
CPU	1	1	
Memory	2	4	
⋮			
Number of products	20	17	

Step3-5: Give the pair of all available placement possibility place - parts an initial value.

This step gives all placement places and pair of the part initial values. The values are the standards which judge the superiority of the state that the part is put is in the part placement. The values are used in later roulette choice.

First, make a table of the values. In the part placement place, the number of L1 - Ln, parts is referred to as part placement possibility place m point, part n unit X1 - Xm, and the table of the value expresses with value ω(Li,Xj). ω(Li,Xj) expresses it how superior it is to place part Xj in the part placement possibility place Li. The table of values of (a number of the parts) × (part placement

possibility place) is shown in Table.2.

Table.2 Values and racks relations

	A	B	C	...
1	$\omega(A,1)$	$\omega(B,1)$	$\omega(C,1)$...
2	$\omega(A,2)$	$\omega(B,2)$	$\omega(C,2)$...
⋮

A, B... Rack names 1, 2... parts

Step3-6: Calculate the distance of work table and the distance between two points between each placement place.

The step calculates the distance between each necessary part placement for analysis of the walk movement. The distance between two points are calculated using a Pythagorean formula. For example, (X_A, Y_A) is the coordinate of place A, and (X_B, Y_B) is the coordinate of place B. The distance between two points is calculated with the following formula.

$$z = \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2} \tag{1}$$

The distance between the two points for all part placement possibility places can be calculated using the above method. In the case where the part placement possibility place to $L_i - L_n$, the distance between $pL_i - L_j$ ($0 \leq i, j \leq n$) is expressed as $D(L_i, L_j)$. The distance between each part placement possibility place that is calculated above is used in the analysis of the walk movement.

2.4 Learning module

The learning module is carried by using Profit Sharing in the following Step.

Step4-1: Make the initial value of the standard value.

For an acquired operating time, the initial value of the standard value to determine whether VACS gives a reward or not is set. As the initial value, the average time value acquired after random parts arrangements is adopted.

Step4-2: Performing part placement based on value (using roulette choice).

The step puts a part using the roulette selection based on the following equation.

$$p(a | s) = \frac{\omega(s, a)}{\sum \omega(s, b)} \tag{2}$$

S: placement place a: The part which is chosen
b: The number of total parts

The roulette choice is a method to choose an action according to the ratio of the value. By this method, we calculate the chosen probability of the part in the part placement possibility place and decide the placement

sequentially at each placement place.

Step4-3: Using the MTM method and analyzing it.

The step analyzes the picking up operations by the MTM method. The step divides the operations into two operations top and bottom movement and walk movement to move between racks. Fig.3 shows that an operator moves to the front of the rack for the up and down operations. STEP4-3, calculates each up and down time which are needed for produce all products.

Step4-4: Compare the working hour with the conventional smallest working hour.

This step compares the working time taken with the smallest working time of the work simulation. Replace the smallest working time and memorize part placement as the most suitable part placement.

Step4-5: Update the value of each placement.

The step, updates the value of each placement possibility place, by using the following equation.

$$\omega(s, a) \leftarrow \omega(s, a) + \gamma(T - t + 1)r \tag{3}$$

s: placement place a: parts γ : discount rate
r: Reward T: The number of the total parts
t: Part place decision order

Step4-6: Repeat Step4-2 - Step4-5.

As shown in Fig.3, Step4-2 ~ Step4-5 are repeated. The part placement whose working time is the smallest become the solutions.

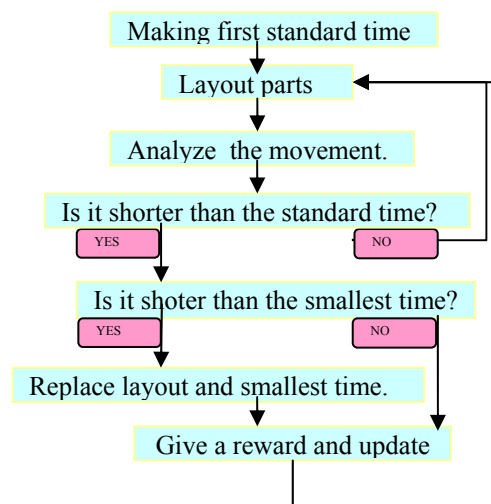


Fig.3 flow of Optimization system

2.5 Virtual production system

The virtual production system makes the shop floor and realizes the visualization of the working process by 3DCG. The virtual production system makes the shop floor including racks and the working table top to use in a part placement decision system. Based on placement decided by a part placement decision system, part on the rack of the shop floor is put. Finally, we input a work process and express a work process with an animation.

3 Application example of VACS

We performed the most suitable placement of the PC part and in the workshop such as Fig.4 using VACS. The simulation performs unevenness by learning ten times to consider it and does the thing which we bought with a little time with the most suitable placement. In addition, we tried it before learning at random to confirm the effect by the learning. As a result, the shortest result, as in Table.3 is adopted as the most suitable placement because there were the fewest the fifth learning results. It was fewer than 141,804, and an effective result was provided. In addition a method of VACS using the reinforcement learning was able to confirm its effectiveness, VACS at minimum time when a value located it before 112,912, learning at random in time for part placement decision using VACS. In addition, we set up a part in a virtual production system and made a virtual shop floor such as in Fig.5 based on the most suitable placement and realized to see the work.

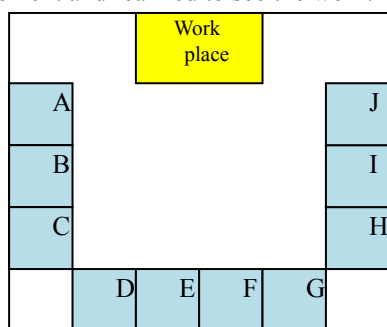


Fig.4 Rack locations

Table .3 Simulation results

Before learning average	181753
Before learning minimum	141804

	1st	2nd	3rd	4th	5th
First standard time	181831	183021	182568	181856	182311
Last standard time	124967	119213	121258	121517	117508
Result time	113227	114726	115559	114917	112912
Update number	38955	52072	42708	33335	60450

	6th	7th	8th	9th	10th
First standard time	182319	182210	182480	181168	181633
Last standard time	119620	119292	117863	117554	118919
Result time	114613	114062	114143	115401	113203
Update number	23407	20029	105376	100089	70012

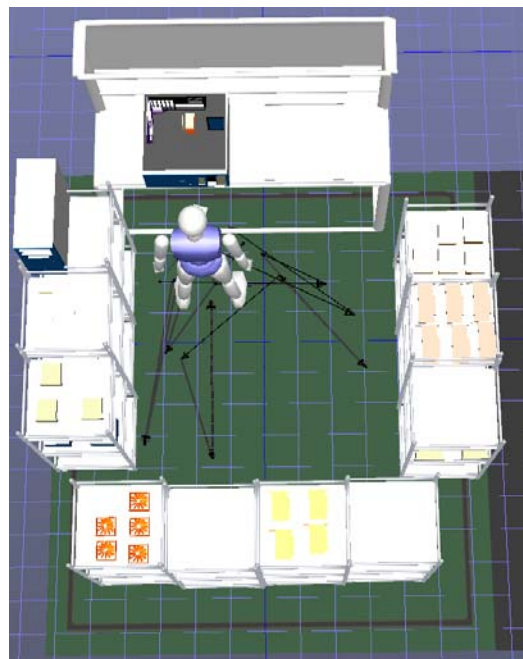


Fig.5 Result of VACS

4 CONCLUSION

VACS, which we suggested reduced the level in the time that the part acquisition took in comparison with random placement from a result for simulation, provided good results. It was shown to be effective for optimization of the part placement of the cell production. In addition, we were able to incorporate the evaluation of the movement analysis using the MTM method in learning by Profit Sharing.

We were able to do part placement of part placement layout decision systems and confirming parts layout by virtual production system by visualizing. In this way, we were able to build VACS where a part placement layout decision system and a virtual production system are linked to each other.

REFERENCES

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