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Methods for Tele-Operation of Mobile Type Maintenance Robot

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This paper proposes a concept of a mobile type maintenance robot (MMR in shortly) that is controlled by the tele-operation for assuring the safety and health improvement of work forces. The main components of this system are the industrial robot, an image processing unit, vehicle and computers for tele-operation. Our focus is paid on a method that determine a pathway to move every places where troubles would occur. This method makes it possible that the MMR could arrive any place in the factory with three times of turns at most.

Additionally, turning radius of the vehicle is considered for correcting the pathway near the corners to make it possible that it arrives to the place accurately.

1. INTRODUCTION

The facilities are usually maintained at the same interval to secure the function of the production system. But as the some facilities are suddenly broken down, we should rush to there to recover the function. The almost maintenance work are enforced by maintenance men who should often wait to correspond the occurence the accident for a long time with do-nothing. Additionally, maintenance tasks require advanced technical knowledge and skillful behavior. So MMR by tele-operation is likely the most effective way from economical and technical points of view. Such a remote operation technology and an automation of maintenance tasks have been studied for a long time. As a results, many MMR have been developed for the maintenance. Conventional researches on the MMR have focused mainly to improve the dexterity of robots, and stability for walking by two legs. However other important problems have not been paid attention.

Therefore, this paper proposes a method that determines the route to approach any place where the maintenance tasks are required. The MMR is composed of a maintenance robot, a vehicle and an image processing equipment.

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Our method determines the route to move to the place where troubles have been occured, and plans a revised route after considering turning-radius of the vehicle.
Moreover, it minimize the frequency to make turn left and right on the way to go the target places.
Additionally, teleperation should be executed speedy and precisely.
Therefore, we also analyze coordinate transform system that have effect on the performance of the teleoperation, and clarify the suitable conditions for those factors.

2. PROPOSED METHOD

Maintenance robot should go any place in the production system since troubles might occur in various places. So, it is impossible to lay a fixed guides (magnet tape or cable) on the floor for the maintenance robot. In other words, the MMR could not use any guide. Therefore, a simple path should be planned whenever troubles happen.
By the way, almost vehicles easily stray off from their planned path when they move to oblique direction. Thus, we plan the path having no oblique direction, which is composed of only lengthwise and crosswise route.

2.1 Constraints

(1) The origin of coordinate system is the upper left corner of the floor. In this coordinate system, j-axis go down from the origin verticaly, and i-axis is horizontal.
(2) Floor is flat and the maintenance robot is able to move any direction.
(3) However, the robot moves along i and j axis, and it does not move to the oblique direction.
(4) The dimension of the layout of the factory is given beforehand.

2.1.1 Composition of maintenance robot

The system is composed of maintenance robot, control computers and monitor. They are connected by wireless LAN. (see Fig.1) .The wireless LAN is used to the communication between the maintenance robot and control computers. A joystick is attached to the control computer for remote operation. An operator manipulates the robot by viewing the working area through two monitors.

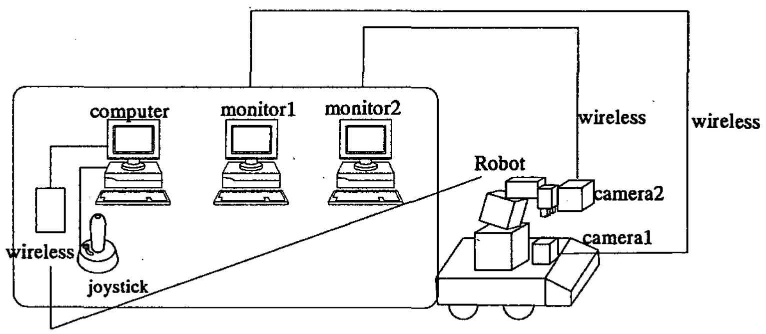

Fig. 1 MMR

2.2 Maintenance Work

After the arrival to the destination, the MMR starts the maintenance work. However, as the performance of robot is limited, so, the maintenance work is supposed as follows in this paper.

Table.1. The maintenance work

Motion	Typical maintenance work	Required force
push	button, flopper, cover	1.0kg or less
turning	screw turned by motor screw driver	1.0kgcm or less
insertion	circuit board,electric parts. hold up	1.0kg or less.

2.3 Route Planning

The MMR goes back to a specific place and waits a call of maintenance works.

After the call, the maintenance robot moves to the called destination along a planned simple path. This pathway is determined by the following procedure.

2.3.1 Partitioning of the floor

Vehicle of the MMR easily goes off from the planned pathway as it moves to the oblique direction. Therefore, we plan a simple path that is composed of only lengthwise and crosswise route with a rectangular turning.

This method aims also to minimize the number of turn. In order to make straight segment of the path, the floor is divided some rectangular regions virtually considering the lay out of facilities. Thereby, the partitioning is conducted so that the number of machines in each region should be less than two.

This constraint makes it possible that the maintenance robot could move to the destination within three times of turns.

The partitioning is excursed by following procedure.

① Make horizontal line which meet at lower side of facility. These lines satisfy eq. (1).

$$\sum_{i=1}^{NI} TI(i,j) > 0$$
$$\sum_{i=1}^{N} TI(i,j+1) = 0 \qquad (1)$$

② Make vertical lines which contact the right side of facilities. These lines satisfy eq. (2).

$$\sum_{j=1}^{NJ} TI(i,j) > 0$$
$$\sum_{j=1}^{N} TI(i+1,j) = 0 \quad (2)$$

③ Delete unnecessary line

Procedure ① and ② could make some lines that divide excessively a region including only one facility. Such lines are deleted. For example, both line X1 and X2 in Fig.2, have divided region that have only one facility at most. Such partitioning is not necessary. So, both line X1 and X2 are deleted.

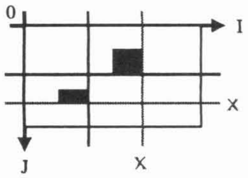

Fig.2 delete unnecessary line

2.3.2 Determination of the route

Next, we determine a path from the waiting place to the destination through some regions.

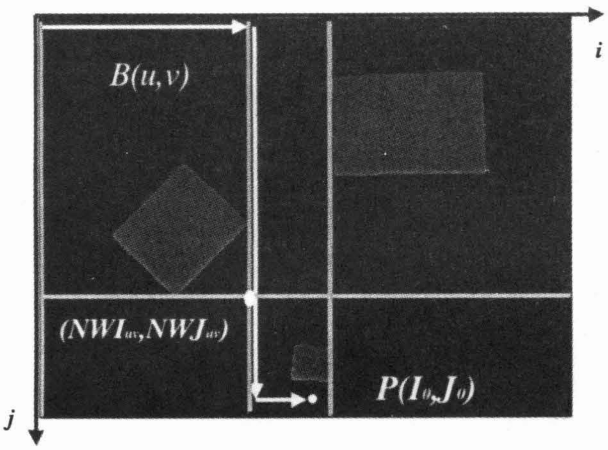

Fig.3 the method of determination of the route

It is assumed that a targeted point (Goal point) is $P(I_0,J_0)$ and (start point) is $B(u,v)$

Additionally, a symbol (NWI_{uv} NWJ_{uv}) is used to represent an upper left corner of the region wherein the target point is marked.

Direction of the MMR sets to parallel to i-axis.

① It goes straight along i axis until it reach to NWI_{uv}

② Make turn $\frac{\pi}{2}$ right and go straight downwards.

③ Stop temporally at NWJ_{uv} on the vertical line.

④ Start again to go down to J_0 .

⑤ Make turn left $\frac{\pi}{2}$

⑥ Go straight along horizontal line until it reach I_0

This procedure makes it possible that the MMR could move to the destination place with three times of turns at most.

2.4 A Method For Controlling The Mobile Maintenance Robot Considering Its Turning-radius

This MMR does not require any guide (magnetic tape or cable) to move the targeted place. It should be keep in mind that the mobile maintenance robot has a turning-radius. That is, its turning-radius should be considered so that the MMR could start an action to make turn before the virtual turning point. By the way, the MMR could receive a signal " make turn radius". So, turning angle of the MMR is controlled by changing the time of $\frac{\pi}{2}$ the signal " make turn ".

We assume that the relation between the time of the signal " make turn " and turning angle has been examined previously. The travel to the targeted place becomes possible by above mentioned these commands. Minimum turning radius R is taken into consideration when it make a turn, and the route for right turn or left turn is different by the distance between the targeted point and turning point.

(1) Case of d>R.

This case assumes that distance (d) from the turning point to the targeted point is longer than turning radius R of the MMR. In this case, the mobile maintenance robot has enough space to approach the start points of turning action with the radius R. In this case, the path way considering turning radius is shown in Fig.4.

(2) Case of d<R.

In this case, the MMR does not have enough distance. The MMR should start the action to make turn earlier than the case (1). The locus of this turning action is shown in Fig.5. Geometrically, the distance h from turning point to the start point of turning action is given by the eq. (3).

$$h = \sqrt{R^2 - (R + d)^2} + R \tag{3}$$

Additionally, the distance k from turning point to the inflection point is given by the eq. (4).

$$K = \frac{\sqrt{R^2 - (R+d)^2} + R}{2} \tag{4}$$

And, the following equation gives position (i、 j) of inflection point on the actual pathway, when the coordinate of the goal site is (i_0、 j_0).

$$i = i_0 - \frac{R + d}{2}$$

$$j = j_0 - k \tag{5}$$

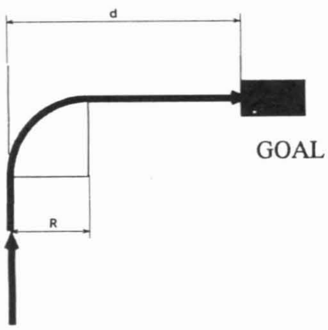

Fig.4 The case of d>R

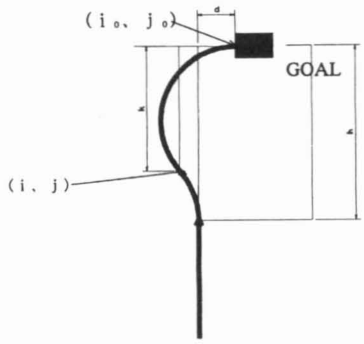

Fig.5 The case of d<R

The MMR is able to make turn actually by using above mentioned pathway.

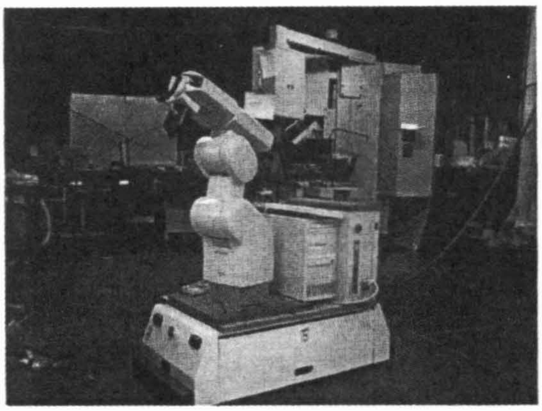

Fig.6 The mobile maintenance robot

3. APPLICATION EXAMPLE

Fig.6 shows the MMR developed by using the proposed method. It is composed of an industrial robot, AGV and computer.[4][5] The validity of the proposed method was examined actually by using this mobile maintenance robot. But the limitation of space, the detail of this example is eliminated.

4. CONCLUSION

This research proposed a method for designing MMR and determines the route to approach any place where the maintenance tasks would be required.

First, by make horizontal line which meets at lower side and right side of facilities. In order to partitioning the floor.

A rule set is proposed for making the path way from waiting place to every targeted places. This method enables the MMR to move to the target place within three times of turn on the way.

Moreover, a method for correcting initial path way so that MMR could arrive the target place accurately considering its turning radius.

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