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Description Method of Required Motion Specification for Construction Modularized Robot

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ABSTRACT

The research and development of modularized robot are indispensable to successful introduction of robot into building construction, which includes a great many job types. As the first start of the modularized robot research, we previously presented a conceptual design framework, data collection and analysis techniques, and key technologies to be developed at the 9th ISARC. The purpose of this paper is to report a method of specifying the required motion specification for the design of the joint configuration of the modularized robot. This method is applied to the development of modularized robot associated with board application for ceiling, wall, and floor in construction finishing work. Additionally, a simulation system using computer graphics is developed in order to dynamically illustrate the motion trajectories of individual boards.

1. INTRODUCTION

For the robotization in building construction sites, we must solve new problems which include the unique characteristics of construction production systems. Therefore a concept of robot modularization is proposed as a reliable tool for solving these problems. Especially when a new modularized robot is developed in building construction sites, we have to specify joint configuration of modularized robot at the first step of the design. The purpose of this paper is to report a method of specifying the required motion specification for designing joint configuration of modularized robot. The method are to analyze the motion trajectories, which include points from the start positions of the work pieces to the final positions and the positions of obstacle. The positioning motion of modularized robot to place work pieces to the nearest point of the final position is analyzed. These motion trajectories and positioning motions are classified into the several motion elements. The required motion specifications are specified by these motion elements. And in this paper the method of specifying the required motion specifications is applied into the board application for ceiling, wall, and floor, since application task for backer and finish board is one of principal work in construction finish work.

2. DESCRIPTION METHOD OF REQUIRED MOTION SPECIFICATION FOR MODULARIZED ROBOT

Fig. 1 illustrates the process of the description method of the required motion specification for designing modularized robot. Firstly, a standard motion trajectory is defined based on four types of data as follows :

1) Overall design of robotic task system; fundamental system functions to complete a given task, basic size of modularized robot and peripheral machinery, and robotic task sequence.
2) Environmental conditions; overall layout, fundamental and robot coordinate system, working space for robot motions, and existence of obstacles.
3) Start position of the work piece located in the robot coordinate system.
4) Characteristics of the work piece such as weight, size and so on.

The standard motion trajectory means the simplest motion which is to move the work piece from a given start position to a previously determined goal without any collision between the work piece and obstacles.

Secondly, in order to prevent collision between individual work pieces and obstacles in the working space for robot movement and peripheral machinery, collision conditions are classified with the various factors related the final position of work piece, location of obstacles, modularized robot and peripheral machinery. Thirdly, the standard motion trajectory is judged if it can be applied without collision. If it can not, the standard motion trajectory is modified to various trajectory patterns in response to each classified condition. Fourthly, all motion trajectories of each work piece, which is moved and positioned as different working locations, are intensively enumerated. Fifthly the individual motion trajectories are divided into motion elements. Finally, a variety of the motion elements are classified into same types of the motion elements. The robotic range according to these individual types are determined base on the maximum motion quantity and area involved in each motion element. The required motion specification for designing robotic joint configuration is specified from the result of the data concerning the each motion range.

3. TASK SEQUENCE OF ROBOTIC BOARD APPLICATION SYSTEM

The presented description method is applied to boards applying for ceiling, wall, and floor in a construction finish work. Fig. 2 shows the standard motion trajectory for ceiling. The task sequence of the robotic board application system is described as follow:

1) The modularized robot is cooperatively operated with the automated vehicle for providing the required boards.
2) The vehicle follows behind the robot.
3) The robot lifts up a board one by one from the vehicle, and applies it to the final position.
4) When there is no board on the vehicle, it is automatically replaced with another vehicle which is already replenish with the boards.

4. ANALYSIS OF MOTION TRAJECTORIES AND POSITIONING MOTIONS FOR ROBOTIC BOARD APPLICATION

4.1 DEFINITION OF STANDARD MOTION TRAJECTORY FOR BOARD APPLICATION

The standard motion trajectory is defined under the follow conditions:

1) The fundamental measurements of the modularized robot and the board provision vehicle illustrate in Fig. 2.

2) The boards are sucked by the vacuum pads attached to the end effector module of the robot.
3) No obstacle exists during the boards transferred from the start position to the final position.
4) The start position of the board in the robotic coordinate system is shown in Fig.2.
5) The size of the board used in robotic board application are 1820*910*9 mm and 12 mm as the backer board of ceiling and wall, 600*300*9 mm as the finish board of ceiling, and 900*600*2 mm and 3 mm as the finish board of floor. The maximum weight of these boards is less than 15 kg.

Fig.2 shows the standard motion trajectory which satisfies 1)~5) conditions for ceiling board application.

4.2 MODIFICATIONS OF STANDARD MOTION TRAJECTORY IN RESPONSE TO COLLISION CONDITIONS

The standard motion trajectory has to be modified in response to the conditions of existing the obstacles within the robotic working space. In order to prevent collision between individual work pieces and obstacles in working space for robot movement and peripheral machinery, collision conditions are classified with the various factors related the final position of work piece, location of obstacles (column, wall, etc.), the modularized robot and the prevision vehicle. The standard motion trajectory is judged if it can be applied without collision. If it can not, the standard motion trajectory is modified to various trajectory patterns in response to the collision condition. For example Fig. 3 shows it is impossible to apply the board to the final point P_6 by the standard motion trajectory. So the standard motion trajectory is modified that the whole modularized robot moves along Y-axis in the robot coordinate system after the board is moved to the point P_3 in Fig. 3. Fig. 4 shows the all motion trajectories for the ceiling board application. The quantities of motion in Fig. 4 are found during the checks of collision between the obstacles and the board using computer graphics. Fig. 5 shows the example of the motion trajectories using computer graphics. As the result of these analysis the motion trajectories for board application are specified 13 patterns for ceiling, 6 for wall , 8 for floor.

4.3 ANALYSIS OF POSITIONING MOTION FOR BOARD APPLICATION

The positioning motion of the ceiling board is analyzed in Fig. 5. The qualitative motion pattern, with regard to the positioning motion for ceiling board, is common to the wall board and floor.

5. REQUIRED MOTION SPECIFICATION FOR JOINT CONFIGURATION OF MODULED ROBOT

All motion trajectories with regard to every work piece, which a modularized robot must handle in given task, are divided and classified into the same types of the motion elements. The typical types of the motion elements are described as follows:
1) The motion of one dimension along X-axis in the robot coordinate system.
2) The motion of one dimension along Y-axis in the robot coordinate system.
3) The motion of one dimension along Z-axis in the robot coordinate system.
4) The motion of two dimensions on XY-plane in the robot coordinate system.
5) The motion of two dimensions on YZ-plane in the robot coordinate system.
6) The motion of two dimensions on XZ-plane in the robot coordinate system.
7) The motion of three dimensions in the robot coordinate system.
8) The rotation motion of X-axis in the work piece coordinate system.
9) The rotation motion of Y-axis in the work piece coordinate system.

10) The rotation motion of Z-axis in the work piece coordinate system.

Regarding the robotic board application, the individual motion trajectories according to all types of bucker and finish boards for ceiling, wall, and floor, are classified into each kind of the motion element. Fig. 7 groups all motion elements together by the type of the classified motion. Fig. 7 includes data of motion quantity and area concerning each motion element. The maximum quantities and areas within the same classified motion are associated with the required motion specifications. Table 1 and Table 2 show the required motion specification for arm-module and wrist-module, respectively. Both the tables include the individual required motion specifications for ceiling, wall, and floor board applying. These specifications are useful to design joint configuration for arm- and wrist-modules consisting of a modularized robot.

6. CONCLUSION

The proposed method of specifying the required motion specification is essential to design the joint configuration with regard to the arm- and wrist-module involved in a modularized robot. These specifications are defined from the result of analyzing all motion trajectories and positioning motions for completing the given tasks. This method was applied to determining the specifications associated with a modularized robot which applied several kinds of the bucker and finish board for ceiling, wall, and floor by performing a variety of motion trajectories and positioning motions. All motion trajectories and positioning motions for the board application were classified into the same types of the motion elements. The required motion specifications regarding the arm- and wrist-module of the modularized robot were defined base on the maximum quantities and areas within each type of the motion element.

ACKNOWLEDGMENT

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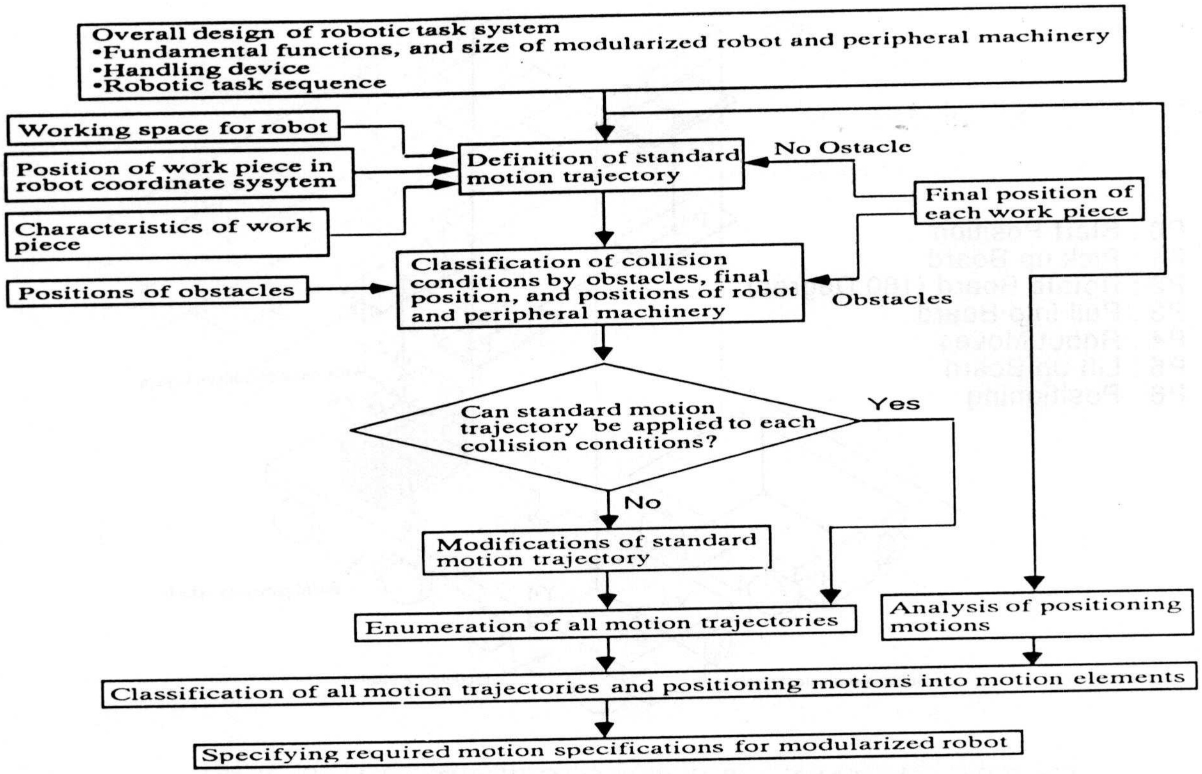


Fig. 1 Process of Description Method of Required Motion Specification

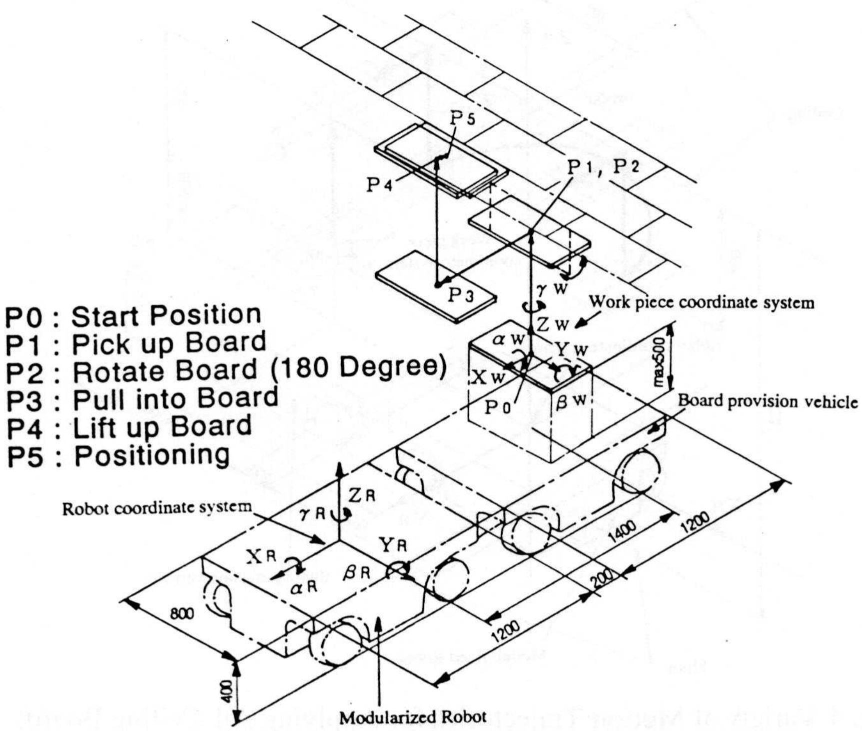


Fig. 2 Standard Motion Trajectory for Ceiling Board Application

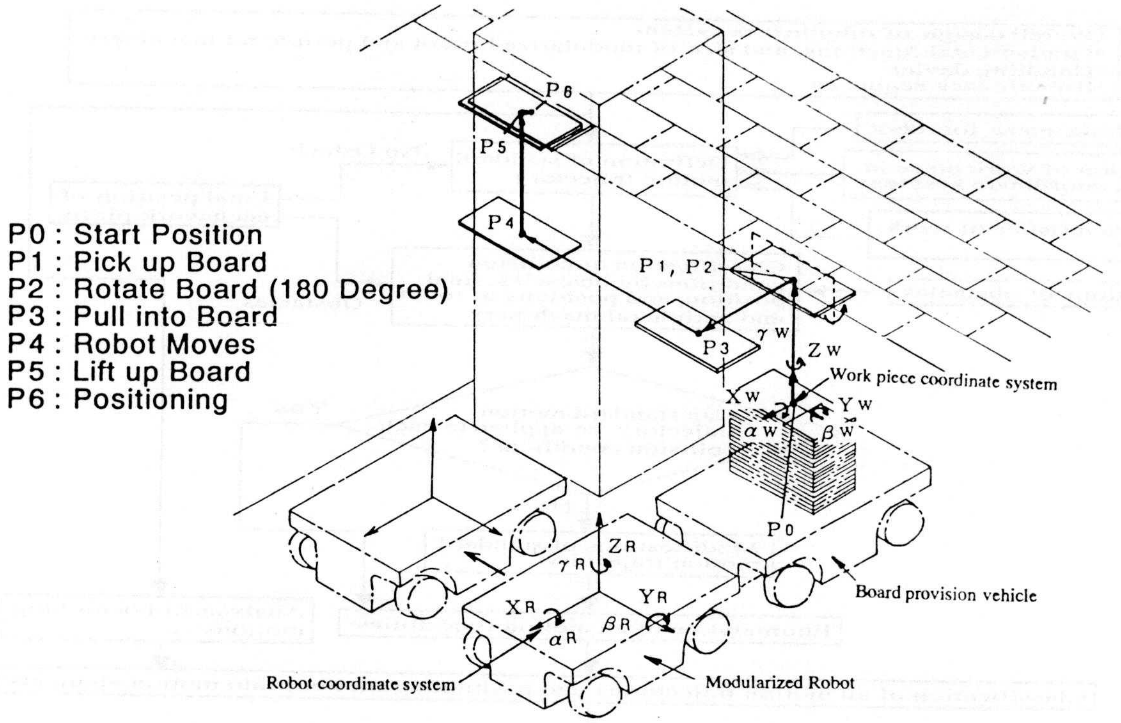


Fig. 3 Example of Motion Trajectory for Ceiling Board Application

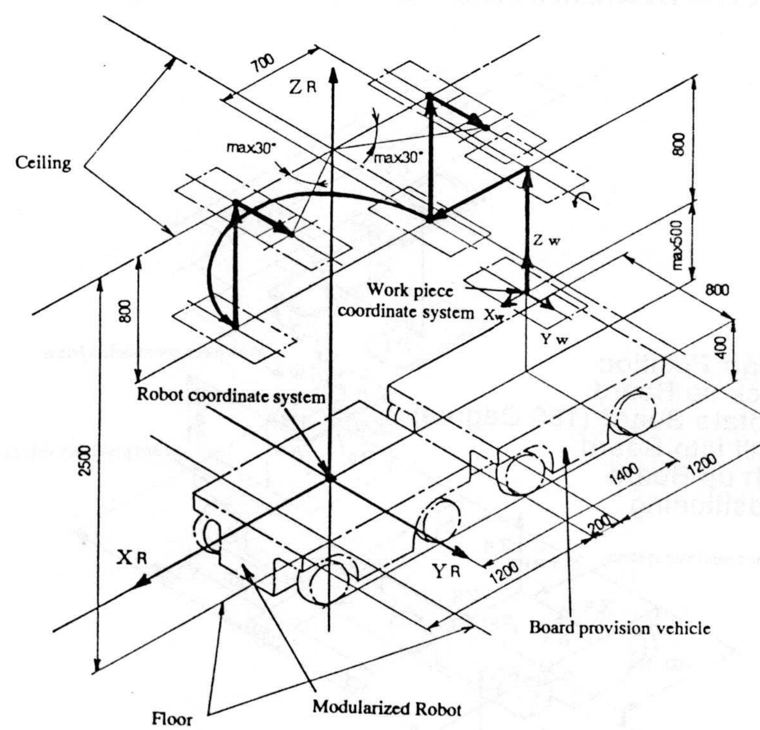


Fig. 4 Variety of Motion Trajectories for Applying All Ceiling Boards

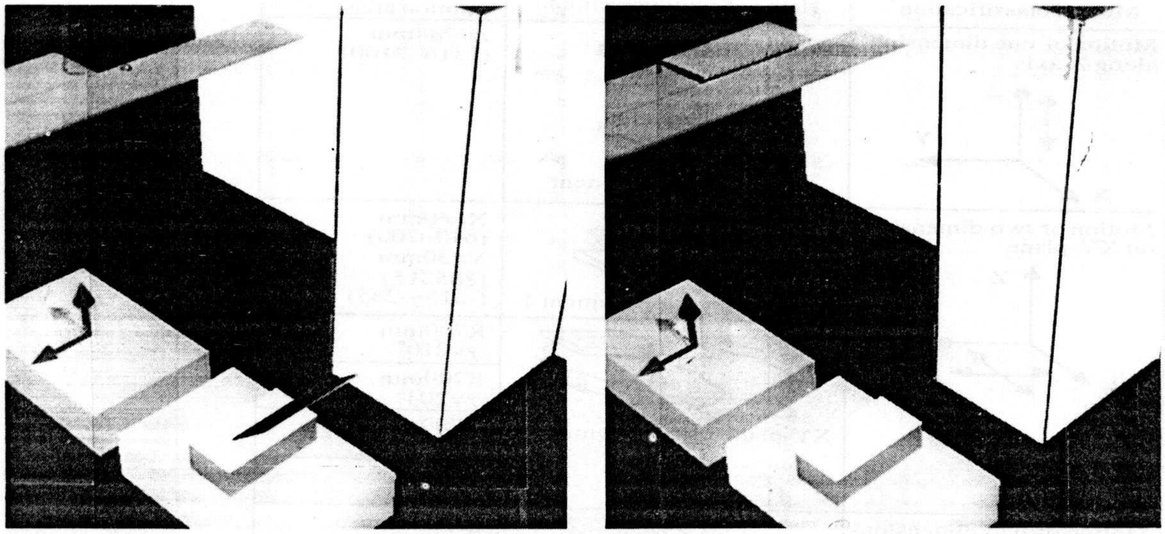


Fig. 5 Example of Motion Trajectory Using Computer Graphics

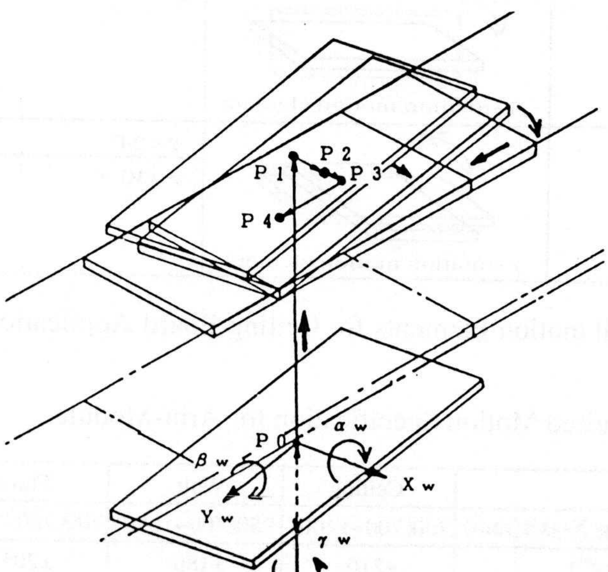


Fig. 6 Positioning Motion for Ceiling Board Application

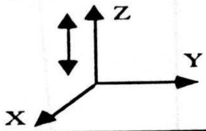
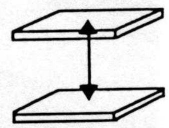
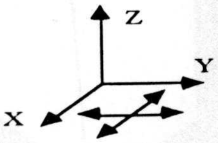
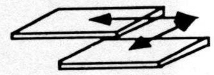
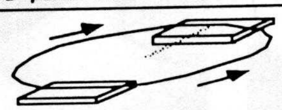
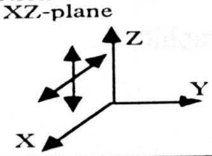
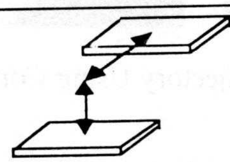
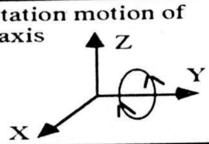
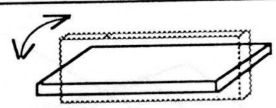
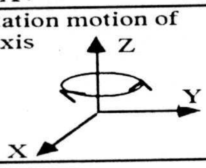
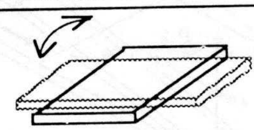
Motion classification	Neme of motion element	Quantity of motion (motion area)
Motion of one dimension along Z-axis 	 Z-axis motion element	Z=784mm (1316~2100)
Motion of two dimensions on XY-plane 	 XY-plane motion element 1	X=60mm (640~700) Y=30mm (285315) (-315~-285)
	 XY-plane motion element 2	R700mm γ=210°
		R700mm γ=204°
		R700mm γ=180°
		R700mm γ=30.5°
Motion of two dimensions on XZ-plane 	 XZ-plane motion element	X=700mm (-1400~-700) Z=404mm (0~404)
Rotation motion of Y-axis 	 β -rotation motion element	β =180°
Rotation motion of Z-axis 	 γ -rotation motion element	γ =24°
		γ =30.5°

Fig. 7 Group of All motion Elements for Ceiling Board Application

Table 1 Required Motion Specification for Arm-Module

	Ceiling	Wall	Floor
Straight line motion along X-axis(mm)	700(700~1400)	950(700~1650)	700(700~1400)
Rotation motion of Z-axis(°)	±210	±180	±205
Straight line motion along Z-axis(mm)	2100(0~2100)	1600(0~1600)	850(-400~450)

*X-axis, Z-axis:Robot coordinate system

Table 2 Required Motion Specification for Wrist-Module

	Ceiling	Wall	Floor
Rotation motion of Y-axis(°)	±90	±90	±5
Rotation motion of Z-axis(°)	±16	±90	±25

*Y-axis, Z-axis:Work piece coordinate system