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Development of Industrial Robot System with 5th Generation Mobile Communication System

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Abstract: We experimented the configuration of a 5th generation mobile communication system (5G) for factory automation (FA) systems consisting of industrial robots and three-dimensional measurement sensors. We examined the configuration of system components, on the basis of which we developed an experimental FA system. In addition, we confirmed that the need for communication lines is eliminated as 5G greatly reduces the production preparation time when rearranging the parts of the developed FA system.

Keywords: industrial robot, three-dimensional sensor, FA system, the 5th generation mobile communication system.

1. INTRODUCTION

Industrial robots are mainly used at the factory automation (FA) site for improvement of productivity. Although industrial robots are efficient at simple repetitive work, program and equipment modifications are often complicated, and are time consuming working processes. In addition, since specialized skills are required for the operation of industrial robots, therefore the workers required for changes in setup must also be highly skilled. In other words, although the current industrial robots improve productivity, their introduction and modifications require a great amount of labor and cost [1].

Therefore, in this research, with the aim of reducing production preparation time (leading time) of industrial systems with robots, we developed a system using the 5th generation mobile communication system (5G). 5G has features such as low communication delay, large communication capacity, and simultaneous multiple connections. In addition, its use eliminates the need for wiring of communication lines between devices. Therefore, it is possible to reduce the number of person-hours for introducing new equipment and for carrying out maintenance tasks such as replacement of faulty equipment. In addition, several sensors and devices can be connected simultaneously with low communication delay, and the preparation time for new system introduction and layout changes can be shortened.

First, we constructed a test machine simulating a product transfer system in which an industrial robot and a three-dimensional (3D) sensor communicate over 5G. In this construction, we verified what kinds of FA device communication configurations are possible using 5G. Furthermore, an industrial robot system was developed based on these verifications, and it was verified whether the preparation time required for relocation of industrial robots could be shortened.

2. WIRELESS INDUSTRIAL ROBOT SYSTEMS

2.1 Overview of general industrial robot systems

Fig. 1 shows the configuration of a typical industrial robot and controller. Fig. 1(a) shows how to connect one industrial robot and robot controller. In general, by using a user interface terminal called a teaching pendant, it is possible to program the robot operation on the controller. Moreover, programmable logic controller (PLC) is connected to the robot controller to interlock the industrial robot with the external device. Fig. 1(b) shows the configuration when using multiple industrial robots. In this configuration, a control panel is used to control and supply power to multiple industrial robots. The control panel stores several PLC's and power supply circuits, and the PLC's are programmed according to combinations of signals from various sensors and operations of each industrial robot. In a typical industrial robot system, all components are connected using dedicated lines, and predetermined operations are repeatedly executed according to the program stored in the robot controller and PLC. The work of changing this program is called "teaching of industrial robots". When a 3D measurement sensor is used to measure an object, 3D

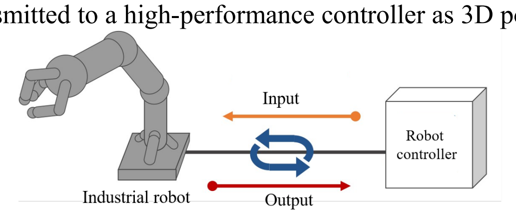
CAD data of the object and actual measurement data are registered in advance in the controller dedicated to the sensor. This automatically detects the position and orientation of the object. Furthermore, in order to operate the detected object using the industrial robot, the relative positions of the industrial robot, FA devices, and the 3D measurement sensor are registered in advance. In general, 3D measurement sensors are also fixed and operated like the industrial robots and FA equipment.

2.2 Teaching less pick and place system

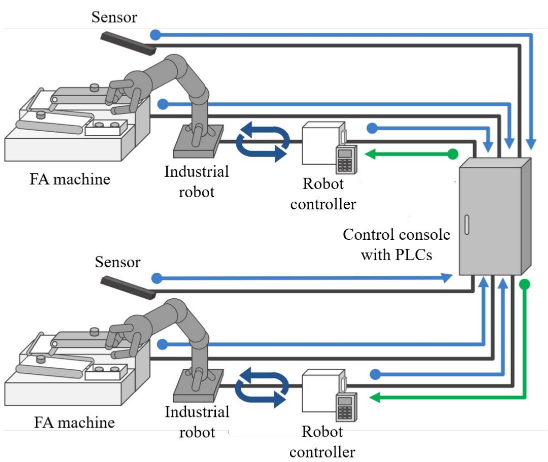
When relocating the industrial robots and other FA devices, it is necessary to teach the industrial robot again and calibrate the 3D measurement sensor, and this further increases production preparation time. Therefore, in order to minimize the increase in preparation time due to the relocation of 3D measurement sensors, industrial robots, and FA equipment, we constructed a system that does not require re-teaching. In this system, signal transfer of all devices and automatic generation of path planning are executed using a personal computer equipped with an autonomous trajectory generation function, making re-calibration and re-teaching of industrial robots unnecessary [2].
In this system, first, 3D position information of the environment measured by a 3D measurement sensor is transmitted to a high-performance controller as 3D point cloud data sets (PCD's). Next, the PC controller detects the position and orientation of the object, and automatically generates an operation plan for grasping the object, transporting it to a specific position, and releasing it so that it does not touch the surrounding obstacles. Motion commands are sent to the robot controller, and after the industrial robot starts operating, the operational status is fed back to the PC controller, where it is monitored.

2.3 Placement of sensors and industrial robots

This system primarily consists of a movable industrial robot, a movable 3D measurement sensor, 5G communication terminals mounted on them, a belt conveyor, and a PC controller. It also consists of an antenna that transmits and receives 5G signals and its control device. Several combinations of these arrangements and connections can be considered, however in this research we have configured as shown in Fig. 2. Casters are attached to the belt conveyors, industrial robots, and 3D sensors and their relative positions can be easily changed.

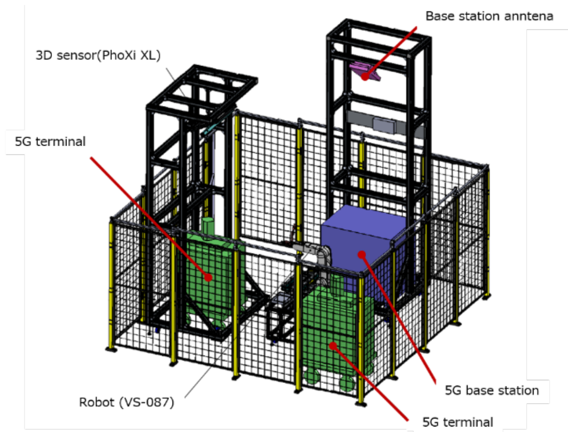


(a) Industrial robot and its controller.

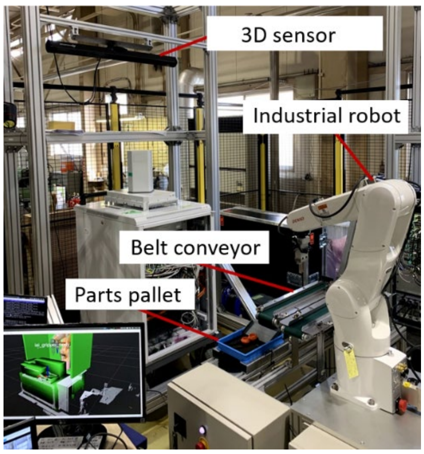


(b) Configuration of a system that interlocks and controls multiple sensors and robots.

Fig. 1. General configuration of industrial robots.



(a) Overview of a CAD model.



(b) Overview of developed system

Fig. 2. Developed experimental system.

3. EXPERIMENTAL SYSTEM

3.1 Industrial robot

We used the vertical articulated robot, VS087 (Denso) with six axes as the industrial robot. The robot's operation commands are generated by the PC controller sequentially and transmitted to the robot controller over TCP/IP. The industrial robot is controlled by the sequential operation commands through b-CAP slave mode [3].

A parallel chuck gripper RCP4-GRSML (IAI) [4] was adopted as a gripper for the target. This gripper has a mechanism for opening and closing two claws, and it is possible to grip the target object by holding it or by opening the claw from the inside of the hole of the object.

3.2 3D measurement sensor

PhoXi 3D Scanner XL (Photoneo) [5] was adopted as a sensor for third-order measurement of workspace of industrial robots. It is equipped with a projector system that emits a class 3R laser and is connected to a personal computer via a GigE network. In addition, the Photoneo localization SDK [6] was used to detect the object. The position and orientation of the detected object in the robot coordinate system are acquired by registering in advance the CAD data of the object and the relative positions of the sensor and robot. In addition, based on the acquired information of the position and orientation of the target object, the industrial robot automatically generates and executes an operation of holding the target object and inserting it into the component loading position of the belt conveyor.

3.3 Belt conveyor system

The belt conveyor shown in Fig. 3 was developed to perform automatic repetitive operation. The industrial robot holds and lifts the object from the component pallet and places it at the component loading position of the belt conveyor. Subsequently, due to the reaction of the infrared switch attached to the input position, the conveyance by the belt conveyor starts and then automatically stops after operation for a fixed period. Since this belt conveyor operates without an external signal input, it has no 5G communication function.

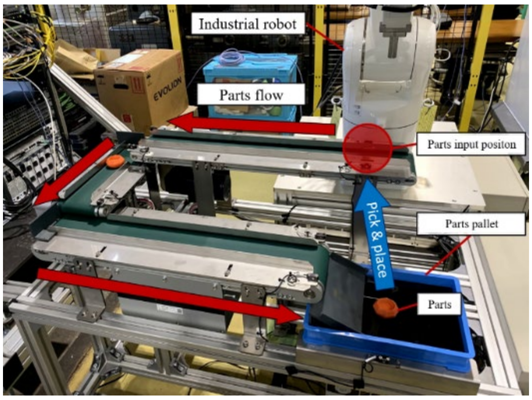


Fig. 3. Developed experimental belt conveyor.

3.4 Automatic generation of robot motion plans

The robot middleware ROS (Robot Operating System) [7] was used for robot motion generation, sensing and visualization of sensed data. Moreover, in this study, STOMP planner [8] was adopted as a motion planner for robots to perform motion planning without collision with obstacles. This provides a function to generate the motion of an industrial robot that transports avoiding obstacles. Furthermore, RViz (ROS visualization), a 3D visualization tool for ROS, was used to visualize robot states and sensor information. Fig. 4 shows the state of the robot in operation in the system, the measurement results from the 3D measurement sensor, and the visualization of the obstacle information based on the CAD model of the belt conveyor and the rack. In this figure, the area represented by the white point cloud is the PCD's acquired by the three-dimensional sensor, and the green areas represent obstacles. With such visualization, it is possible to monitor the measurement results of the 3D sensor and the operation plan of the industrial robot.

4. 5G SYSTEM

4.1 Overview of 5G communication equipment

5G realizes high-speed, large-capacity communication using 3.6 GHz to 6 GHz or 28 GHz band [9]. Although the communication speed in the 3.6 GHz to 6 GHz band is about 200 Mbps, the amount of propagation

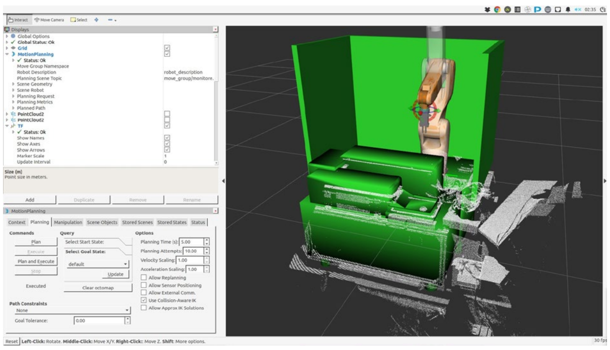


Fig. 4. Visualizing of the system.

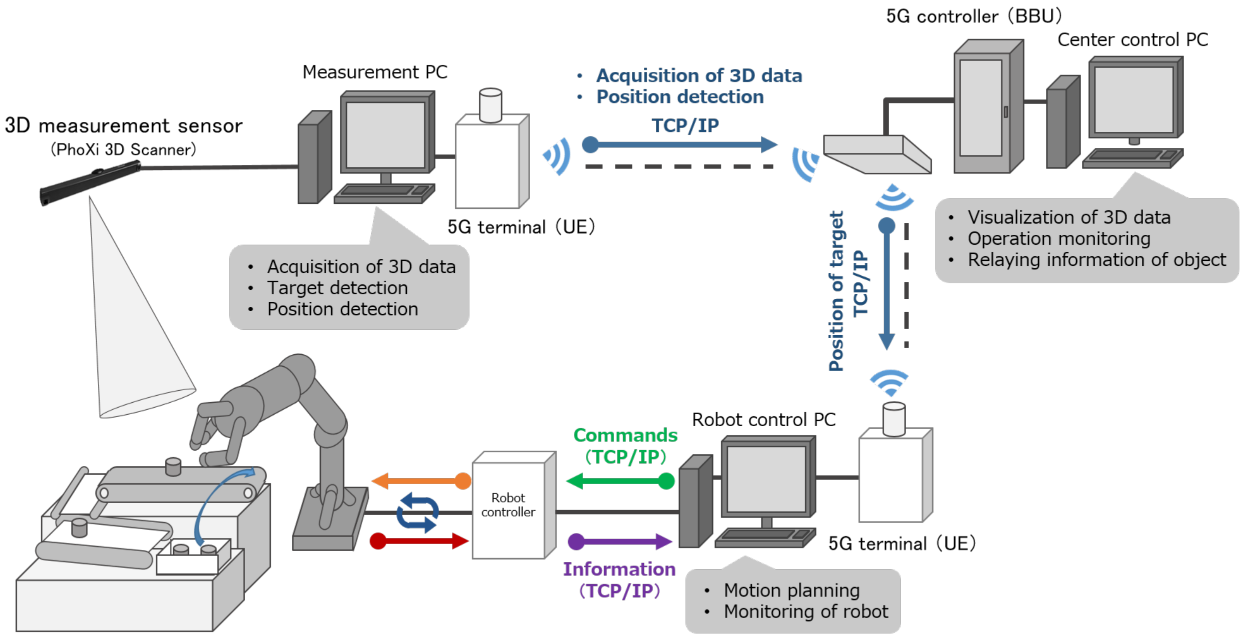


Fig. 5. Signal communication of developed system.

attenuation is small, and it is not easily affected by shielding from trees or utility poles. In the 28 GHz band, large capacity communication of 1 Gbps is possible if it is a visible area, but the propagation attenuation is large and it is susceptible to shielding effects from trees and utility poles. In this study, we assumed that the equipment was installed in an area where the prospect is good and used 28 GHz communication.

4.2 5G communication of FA equipment

An overview of the communication of each device in the system constructed in this study is shown in Fig. 5. Data from the 3D measurement sensor is sent to the measurement PC as PCD's. The measurement PC receives the PCD's and detects the position and orientation of the object. The information of PCD's and the position and orientation of the object is sent over TCP/IP. After that, those data are transmitted over 5G from user equipment (UE) to base band unit (BBU), PCD's are received by the center control PC connected to BBU, and 3D measured data is visualized. This function is used to monitor the operating status of the system. Subsequently, the position and orientation of the object are output from the center control PC, transmitted from the BBU to UE connected to the industrial robot, and received by the robot control PC. This PC automatically generates a motion plan of the robot for gripping, transporting and releasing the target object.

5. EXPERIMENT AND RESULT

5.1 Operation experiments

First, in the system constructed in this research, it was confirmed that the position and orientation of the target can be detected by analyzing the 3D data acquired by the 3D measurement sensor. Furthermore, it was confirmed that the measurement data was transmitted by 5G to a high-performance computer connected to BBU and visualized. It was also confirmed that the target parts were gripped and transported by the belt conveyor. These experiments show that 5G can control the constructed industrial robot system.

5.2 Replacement of FA equipment

The relative positional relationship between the industrial robot, the belt conveyor, and the 3D measurement sensor was changed, and it was confirmed that the pick-and-place operation was possible without teaching. Fig. 6 shows the behavior of the industrial robot before and after relocation. In this system, wiring work for signal lines was not required, so it was confirmed that the work of changing the robot layout could be completed in about 10 min. In addition, after relocation, it was confirmed that it was possible to resume the work of the industrial robot immediately by the teaching less function that this system has.

(a) Before layout change.

(b) After layout change.

Fig. 6 Robot movement before and after layout changes.

6. CONCLUSION

In this research, we constructed a testing FA machine of pick-and-place system in which industrial robot and 3D sensor communicate over 5G for product transport. In this construction, we verified using 5G what kind of FA device communication configuration is possible. Furthermore, after verifying these system configurations, we compared the preparation times required for relocation of industrial robots. As a result of verification, we showed that an industrial robot can be controlled using 5G, and this system configuration is shortens production preparation time due to relocation and improves flexibility of equipment layout.

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