Development for Industrial Robotics Applications

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Factory automation is currently expected to improve productivity, quality and/or safety in the production industry, especially for functions depending on workers. This report introduces IHI's R&D activities to allow industrial robots to work in bin picking, payload handling, assembly, and similar operations. The R&D activities integrate IHI's advanced technologies; such as sensing and measurement technology, control technology, and mechanics technology, to automate operations not possible for conventional robots.

1. Introduction

In the past, factory production lines were automated for mass production, and many industrial robots and specialized machines were introduced. Recently, flexible manufacturing systems, such as the cell production system (unlike in the line production method, an entire product is assembled by one worker), are being introduced in an increasing number of production sites in order to deal with differentiation of products and to meet diversified needs. However, many of the tasks in flexible manufacturing systems rely heavily on workers because the number of parts to be handled is larger so the time and costs required to switch product types on robots and specialized machines is greater.

Recently, because of the decrease in the working population due to Japan's aging society with a falling birth rate, there are expectations that tasks which rely heavily on workers will be automated by using industrial robots in combination with sensing technology and production know-how.

With "intelligence" as their motto, industrial equipment manufacturers are focusing on developing technology that will automate tasks that are currently performed by humans, but the types of tasks that have so far been automated are very limited.

In order to automate factories of IHI group companies and/or customers (present and potential), IHI is also conducting research and development for the development of a new system that combines IHI's hard-earned innovations, such as (1) advanced sensing technology, (2) control technology, and (3) mechanics technology with industrial robots, for the purpose of making it possible for these robots to perform tasks that have yet to be automated and that rely heavily on human workers.

This paper introduces the concept of a system in which industrial robots are applied to (1) picking work, (2) medium payload handling work, (3) assembly work, etc. and also introduces the research and development of such a system.

2. Bin picking robotics using 3D object recognition

At production sites, parts in bins are arranged and transferred by workers. Parts such as bolts are stored in bins, and it is easy for humans to handle several types of parts at a time. However, it is extremely difficult for robots to measure parts in bins with a sensor, recognize individual parts, and take them out.

IHI is developing bin picking robotics using its own proprietary 3D object recognition technology [(1)].

The main feature of this system is that unlike conventional systems that use cameras (2.5-dimensional or stereo vision), this system is not affected by ambient light because it adopts lasers as the three-dimensional measurement method. In addition, this system is highly compatible with 3D CAD systems and facilitates switching product types when used with 3D CAD data, providing enhanced usability.

Figure 1 shows the configuration of the entire system (**-(a)**)and how parts are picked (**-(b)**), and **Table 1**

shows the basic specifications of the system. Generally, handling parts in bins requires complicated recognition processing of a large amount of three-dimensional measurement data, and therefore, the operation cannot be completed within a time required for practical use. However, the system shown in **Fig. 1** is able to execute measurement, transfer, inspection and arrangement in only 12 seconds.

Further efforts will be made to improve the speed and stability of 3D object recognition processing in order to automate the cell production system and other flexible manufacturing systems.

3. Medium payload handling

Currently, medium-weight objects (50 to 200kg) are handled mainly by workers or by operating a crane. Many production sites are expected to be automated because automation provides improved safety and productivity. However, because objects to be handled are generally large and heavy, it is difficult to measure and position them, causing a delay in automation with robots.

IHI developed a system that can load and unload engine blocks, etc. of around 60 kg onto and off of pallets, and automatically transfer them to the inspection process when necessary.

Figure 2 shows the appearance of the system (**-(a)**) and the result of 3D object recognition (**-(b)**). The combination of the hand eye method, in which a camera is installed in the robot's hand, and 3D object recognition technology allows a robot to recognize workpieces even if they are not perfectly aligned or if the pallets onto which the workpieces are loaded have a manufacturing tolerance. In addition, the adoption of a hand tool equipped with a floating mechanism for grasping a workpiece from above enables smooth depalletizing (unloading of workpieces from pallets) and palletizing (loading of workpieces onto pallets) even if workpieces are tightly arranged in a pallet.

4. Hand guiding system

Assembly and handling of workpieces with complicated shapes requires precise positioning. To fully automate such tasks, expensive sensors and advanced and complicated controls are needed. In addition, there are still many problems to solve, for example, it may be impossible to measure some parts of a workpiece

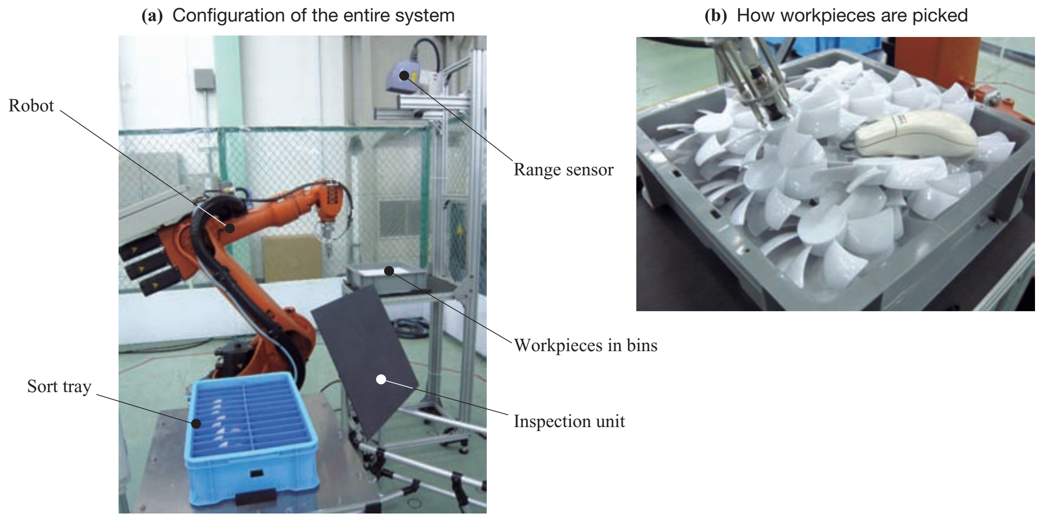
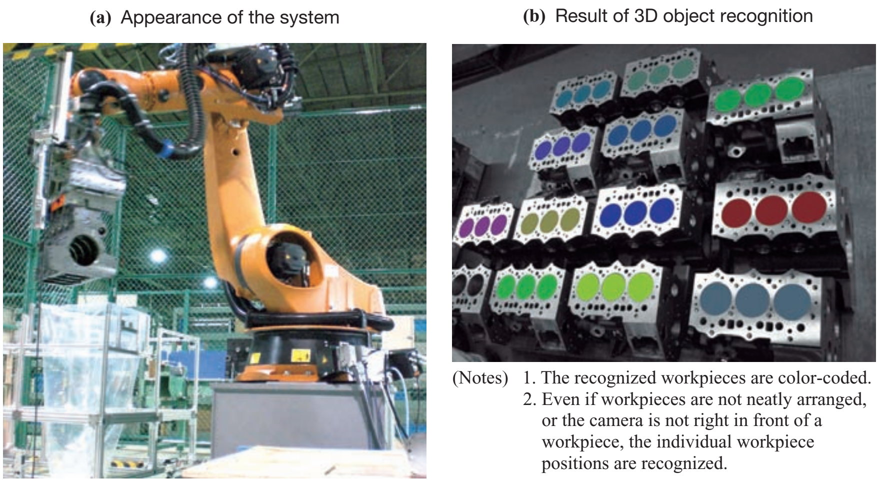


Fig. 1 Bin picking robotics using 3D object recognition

Table 1 Specifications of bin picking robotics

Items		Specifications
Measurement *1	Method	Three-dimensional measurement using lasers
	Distance	500 to 1 000 mm
	Range	250 × 250 to 500 × 500 mm
	Time	Depending on the measurement range
Recognition	Method	Recognition of three-dimensional shapes by comparison with three-dimensional data
	Processing time	Depending on the situation *2
Target object		Parts, etc.*3 (min. 50 × 50 mm or so)
Basic configuration		Control unit, robot*4, robot controller, hand*4, and range sensor

(Notes) *1: These specifications are for the system shown in **Fig. 1**. The specifications vary depending on the type of sensor.
*2: The recognition time varies depending on the shape, quantity, and location of workpieces.
*3: Workpieces may not be measured or recognized depending on the surface material.
*4: The specifications of the robot and hand vary depending on the type of workpiece.



(Notes) 1. The recognized workpieces are color-coded.
2. Even if workpieces are not neatly arranged, or the camera is not right in front of a workpiece, the individual workpiece positions are recognized.

Fig. 2 Medium payload handling robot

to be positioned depending on its shape, and even if automation is successful, "minor stoppage" (equipment does not fail but temporarily stops due to minor abnormalities, though it can be restored in a short time) occurs frequently, preventing the utilization ratio from increasing.

One possible solution to address these problems is to classify tasks into those that robots are suited for and those that humans are suited for so that robots and humans can work cooperatively.

ISO 10218-1 (JIS B 8433-1: 2007), revised in 2006, specifies new safety standards and guidelines that industrial robots must satisfy, and permits cooperative operations between robots and humans if robots have met the requirements. **Table 2** shows the requirements for cooperative operations.

IHI developed a hand guiding system that complies with ISO 10218-1: 2006 in order to enable cooperative operations between industrial robots and humans.[(2)]

Figure 3 shows the configuration of the system (**-(a)**) and the appearance of the system (**-(b)**). This system can be operated in manual and automatic modes, and the robot performs tasks that can be performed based on teaching-playback and sensing. The worker, while being assisted by the robot, performs tasks that cannot be performed based on teaching or sensing, offering the advantages of using industrial robots as more than a mere power assist system.

In order to apply the system to a wider range of tasks, IHI will perform various tests to evaluate and improve this hand guiding system.

Table 2 Collaborative operation requirements in ISO 10218-1

Requirements	Section	Titles
Mandatory requirements	5.10.1	General
Requirements, at least one of which needs to be met	5.10.2	Stop
	5.10.3	Hand guiding
	5.10.4	Speed and position monitoring
	5.10.5	Power and force limiting by inherent design
	5.10.6	Power and force limiting by control system

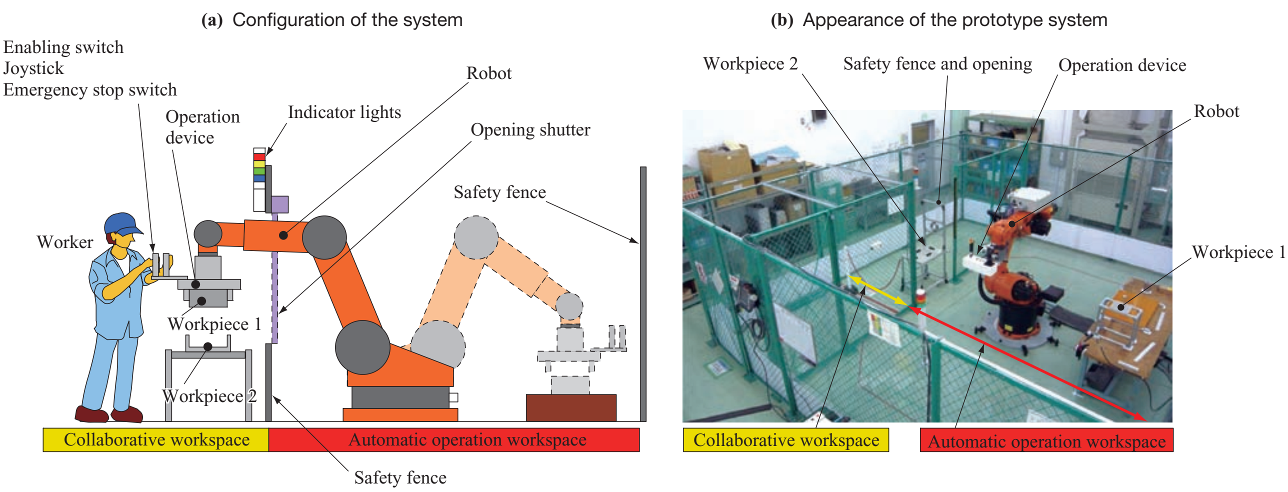


Fig. 3 Concept of hand guiding system

5. Cell production robots

In order to meet diversified market needs, the cell production system has been adopted in various fields because it is suitable for flexible manufacturing systems where various types of products are manufactured according to demand. At the same time, it has become difficult to secure workers at production sites, and therefore, automation that utilizes the advantages of the cell production system is increasingly required. However, because the cell production system requires many more types of tasks and parts, there is a need to make design changes or prepare special jigs for automation, and the tact time becomes longer, making it difficult to take advantage of the benefits of automation.

IHI is developing assembly robots by making robots more intelligent so that they can be made to function in multi-product assembly work that has yet to be automated. These assembly robots can operate in the same cell production system work environments as human workers. Therefore, the existing workbenches, jigs, and dedicated automatic equipment currently used by workers can be used as is.

Figure 4 shows the cell production robot in the prototype system. The intelligence technology for flexible manufacturing systems that this prototype employs is a force control that enables assembly with an accuracy of a few micrometers and a visual sensor that enables the robot to correct misaligned parts and screw holes. This technology has eliminated the need for dedicated aligners and jigs used for the accurate positioning of parts. In addition, the tact time is almost the same as that needed for workers.

6. Cooperative handling

At production sites, tasks that require handling various types of parts are performed mainly by workers. When handling workpieces of different sizes, robots need to change tools, but people can handle them by using both hands with dexterity.

In general, one large robot that fits the largest workpiece is used when handling workpieces of different sizes. IHI is developing a new system based on the idea that using two or more robots that fit smaller workpieces provides enhanced versatility.

Figure 5 shows the cooperative handling robots. One large workpiece is handled by two or more robots and two or more small workpieces are handled individually by robots, providing a shorter tact time than when one large size robot is used.

In addition, because a large workpiece is handled by two or more robots, the load can be distributed. Therefore, the size of the hand can be reduced, the structure of the hand can be simplified, and more types

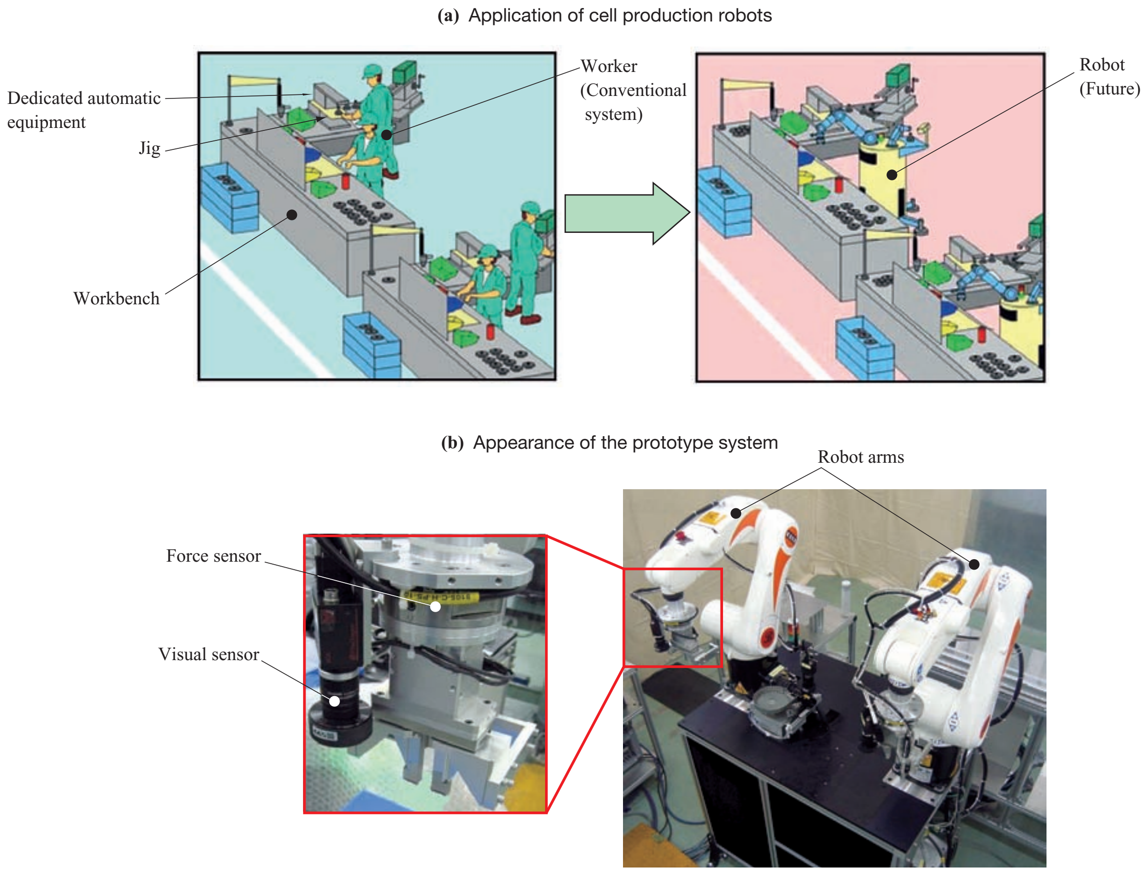


Fig. 4 Cell production robot system

Fig. 5 Cooperative handling robots

of workpieces can be handled with just one type of hand. Moreover, because the robot and its hand are smaller, it is easier to keep them from interfering with workpieces as they approach the workpieces, offering the advantages of storing parts in bins. Furthermore, the holding positions can easily be changed by changing the robot's program, facilitating the addition of workpiece types.

7. Conclusion

This report has introduced the concept of a system in which industrial robots were applied to picking work, medium payload handling work, assembly work, etc. by combining IHI's hard-earned innovations, such as advanced sensing technology, control technology, and mechanics technology with industrial robots, and has also introduced the research and development of such a system.

It is becoming possible to apply industrial robots to tasks that cannot easily be automated and thus rely heavily on human workers. In addition, robots work long hours and handle heavy objects without getting tired or making mistakes, leading to improved quality.

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