Artificial Intelligence and Technologies of Arm-type and Mobile Robots in Industry

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Abstract

In recent years, labor shortage has become a serious issue in industrial fields. Various technologies including robot and information processing system to realize flexible work like humans are effective solutions to this issue. Artificial intelligence technology of arm-type robots equipped with 3D sensors and force sensors has been applied in the manufacturing field to cope with different intelligent and highly precise tasks in Mitsubishi Electric. In addition, various technologies to expand the scope of application to the service field, as well as to realize highly functional delivery with mobile robots is under development. Furthermore, IoT technology is also being used for easy and quick on-site implementation and efficient operation. This paper introduces these initiatives with actual examples.

Keywords: Industry, Arm-type robot, Service, Mobile robot, Artificial intelligence, IoT, 3D sensor, Force sensor

1. Introduction

In recent years, the decline in the working population is accelerating worldwide as the birthrate declines and the population ages and labor shortage has become a serious issue in industrial fields. Many intelligent technologies including robot system and information processing system to realize flexible work like humans are effective solutions to this issue, because there is a serious shortage of skilled and experienced workers. Based on these ideas, Mitsubishi electric corp. has developed the intelligent technologies of arm-type robots equipped with 3D sensors and force sensors in the manufacturing field to cope with intelligent and highly precise tasks [1], [2], [3]. By combining artificial intelligent (AI) technology with these technologies, we have developed technologies such as automatic parameter adjustment technology to achieve optimum motion adjustment quickly, and technology for safe operation by determining abnormal conditions [4].

To spread various applications with intelligent robots, we have developed the teaching-less robot system using intuitive I/F technology to facilitate teaching operations that previously required a high level of expertise and skilled experience. This system includes technologies to generate optimum routes and movements, interference checking algorithm with the surrounding area, and series of technologies for bin picking of random stacked objects using 3D sensor.

There is a growing demand for automation of transport operations not only in factories, but also in various facilities such as logistics, public buildings, commercial facilities, and hospitals. For this reason, multiple technologies to expand the scope of application to the service field, as well as to realize highly functional transportation with mobile robots is under development. In addition, as a future technology that will further expand the scope of robot applications, we are also developing technologies for remote robot operation by humans for non-standardized tasks and troubleshooting. Specifically, we have been developing technologies to convert force information, into visual information that is easily recognized by humans, to decompose summary instructions into robot actions, and to operate multiple types of robots with a common interface.

Furthermore, the increase in the number of target devices monitored in real time with advancement of communication technology and the increase in computer capacity have led to remarkable progress in 3D simulation technology. These technologies are also being used for easy and quick on-site implementation and efficient operation. In this paper, these initiatives with actual examples are described.

2. Teaching-less Robot System

2.1. *Overview of the system*

The use of machines and robots in mass production is increasing due to a shrinking labor force caused by an aging population and declining birth rate. However, there are still challenges in implementing robots in certain production lines, such as those involved in making "Bento" boxes and ready-made dishes. These lines require expertise and time-consuming adjustments due to the soft and irregular shapes of the food products and frequent menu changes. We have developed a teaching-less robot system that utilizes technology and research data accumulated over the years [5]. This system includes arm robots, controllers, 3D vision sensors, force sensors, a tablet PC and a master PC for control. Task assignments can be easily inputted using a tablet PC and 3D sensor camera. The 3D sensor camera senses the area around the arm robot, allowing for static environment recognition and accurate measurement of spaces. 2D vision sensors installed on the production line detect the conditions of the items moving on the line. Task assignments can be set using voice and touch inputs, and the movement path of the arm robot is displayed using augmented reality. This teaching-less robot system eliminates the need for expert knowledge and time-consuming programming, as it automatically generates optimum movements based on assigned start and endpoints. Autonomous programs generate various approaches to determine the optimum and fastest speed for movements with reducing the need for test runs and saving time. The 3D sensors monitor the production area and ensure smooth workflow. The sensors identify slanted "Bento" boxes, allowing the robot to determine their position and add ingredients accordingly. These technologies not only control the arm robot but also facilitate the expansion of production lines with multiple robots.

2.2. *Surrounding Environment Modeling*

In order to acquire the 3D model of the robot's surrounding environment, we have used our original simultaneous localization and mapping (SLAM) method which use only an inexpensive camera (Fig. 1). This camera can be used for interference detection during path generation and displayed on the operation teaching device. We have achieved processing time by simplifying 3D models and reducing data size (approximately 60% reduction).

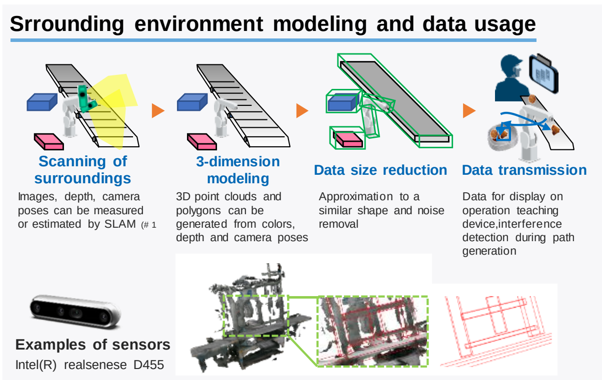

Fig. 1. Surrounding Environment Modeling

2.3. *Intuitive UI for easy robot teaching*

We have developed the intuitive user interface (UI) system which use tablet-touching and voice-controlled operation to realize easy teaching operation of robots. Various specifications such as the workpiece sizes and positions can be confirmed beforehand by checking the simulated movies using the augmented reality (AR) technology. After the motion instruction is completed, the robot's motion can be confirmed in advance on a tablet PC, thus ensuring the safety of the operator (Fig. 2).

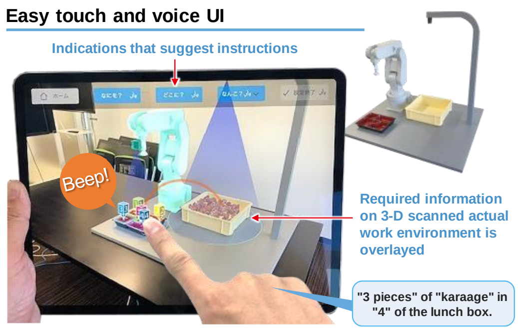

Fig. 2. Intuitive UI for easy robot teaching

2.4. *Automatic Generation of Optimum Path*

We have developed the automatic calculation method which generate optimum path without interfering to peripheral equipment by simply specifying start and end points. It can derive the avoidance route that minimizes the operating time by considering the amount of movement of each joint and allowable torque (Fig. 3).

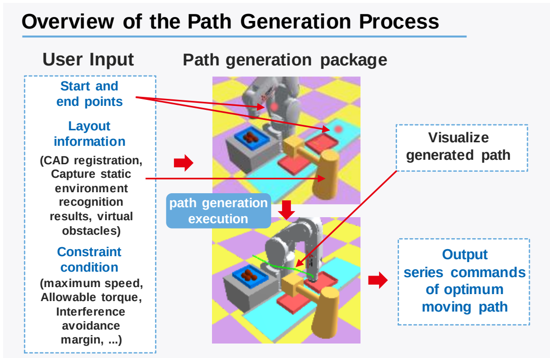

Fig. 3. Automatic Generation of Optimum Path

2.5. *Irregular Shape Object Recognition*

To packing food objects using random bin-picking method with 3D sensor, each object is distinguished according to segmented region, and each grasping position is estimated with high accuracy at high-speed using the deep learning (DL) based AI algorithm (Fig. 4).

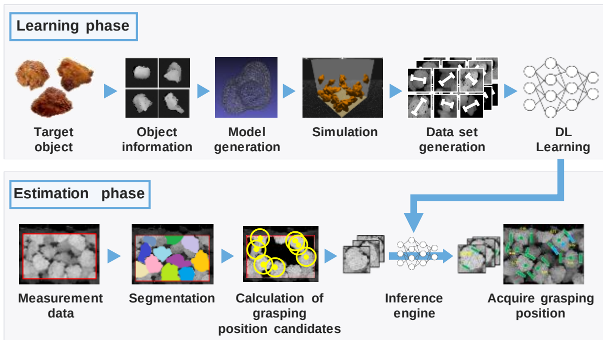

Fig. 4. Irregular Shape Object Recognition

Prior learning of the DL network for determining optimum grasping position according to the shape of each object is operated. Then this algorithm calculates segmented region of each object using the trained DL network.

3. Robot Technologies in Service Field

3.1. *Mobile Robots for Transportation*

The demand for the Autonomous Mobile Robot (AMR) is increasing due to the decrease in the working population and the increase in demand for various types of transport (factories, distribution warehouses, commercial facilities, hospitals etc.). To meet these demands, we have been developing the system that can be redesigned to variation of transport configurations. We have also developed the series of technologies to enable robots to run safely and autonomously in response to changes in facility rules and conditions through the control system that controls multiple robots. In addition to these technologies, we have also realized autonomous vertical and horizontal movement in coordination with facilities such as elevators and access control systems [6], [7] (Fig. 5).

We have been also conducting actual experiments with mobile robots in various situations (e.g., transporting books in reading rooms, making announcements while moving, and transporting items in backyards) as a field test of mobile robots that can coexist with people (Fig. 6).

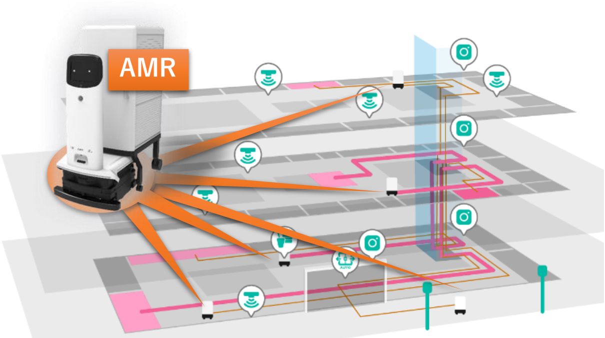

Fig. 5. Integrated Control System for AMR

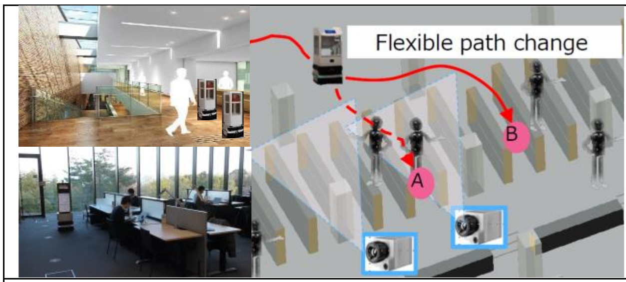

Fig. 6. Field Test image of AMR

3.2. *Remote Robotics for Dexterous Operation*

The technologies for remotely operating robots are useful for individual operations in non-standardized tasks and for troubleshooting operations in automated tasks. Force-haptic information is often important in these tasks, but feedback of these information to the operator typically requires a complex operation system. We proposed the “Visual Haptics” architecture that converts force-haptics information into visual ones that are easily precepted by humans (Fig. 7). The cognitive process in this method utilizes visual and force-haptic cross modalities. We have showed its effectiveness through quantitative experiments [8].

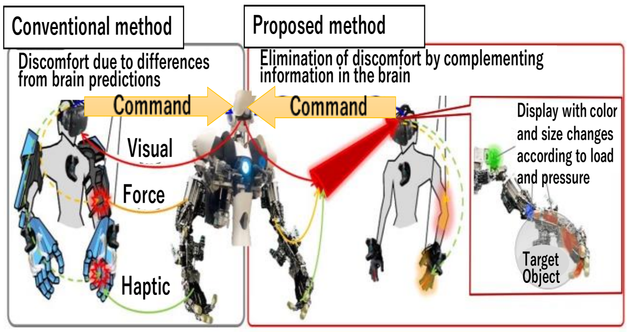

Fig. 7. Visual Haptics” architecture

Furthermore, we have showed its effectiveness in various situations through demonstration systems [9] (Fig. 8).

Fig. 8. Operation Test Scene

4. IoT Platforms for Data Integration

Mitsubishi Electric is ready to provide the digital transformation (DX) services including multiple IoT platforms that organically connect data from facilities, equipment, mobile applications functioning in various fields such as manufacturing, logistics, business facilities, hospitals, etc., with the aim of contributing to area value enhancement and advanced operational management. The various data collected in these distributed platforms can be used to accelerate the creation of new value-added products and seamless indoor/outdoor services (Fig. 9).

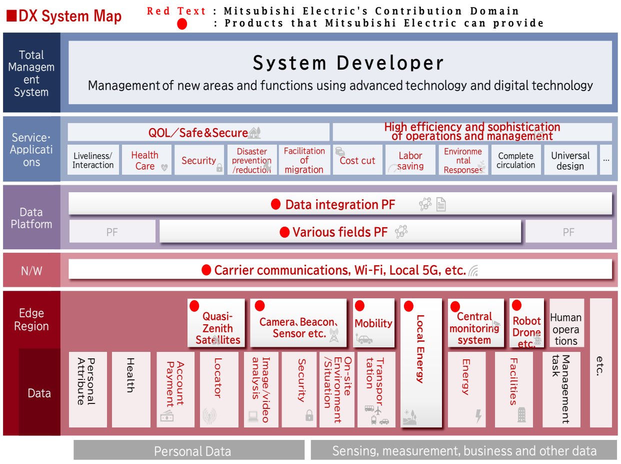

Fig. 9. DX System including IoT Platforms

5. Conclusion

At the first in this paper, the teaching-less robot system was described, which is using intuitive I/F, optimum routes and movements generation, interference checking algorithm and series technologies for 3D random bin picking. At the second, as the robot technologies in service field, the system that realize the flexible and safety control of multiple AMR and the remote robotic technologies for dexterous operations are showed with actual examples. At the last, the integrated IoT platforms for connecting data from facilities, equipment and mobile applications functioning in various fields is described. Various solutions using these initiatives will be provided in the near future.

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Authors Introduction

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He received B.E. and M.E. from the Dept. of Precision Engineering, Kyoto University in 1991 and 1993 respectively. In 1993, he joined Mitsubishi Electric Corp., where he has been engaged in the research and development of 2-D and 3D object recognition system and AI technology for industrial robots at mainly Advanced Technology R&D Center. He received the Ph.D. degree in 2007. He has been concurrently serving as a visiting professor at the Graduate School of System Informatics, Kobe University since 2019.He is a member of the RSJ.