Versatile Mobile Robot System Realizing Contactless and Manpower-saving Solutions

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1. Introduction

In recent years, the market for service robots has been expanding with the acceleration of digital transformation (DX: transforming people's lives for the better by the spread of advanced digital technology). In particular, as the birthrate declines and the workforce shrinks, the demand for robots is increasing as a way of resolving the labor shortage and reducing the workload of essential workers to help create a sustainable society. In addition, the demand for mobile telepresence robots that enable non-face-to-face contact is increasing due to the novel coronavirus pandemic (Covid-19).

Therefore, we are developing a versatile mobile robot system with a telepresence function to realize contactless and manpower-saving solutions.

2. Concept

To date, robots that perform routine tasks, such as autonomous mobile robots that transport objects in factories, have been the mainstream, but in order to realize contactless and manpower-saving solutions, robots must be able to not only perform routine tasks but also respond according to the situation as humans do, including in emergencies.

Therefore, we are developing a versatile mobile robot with a telepresence function. This robot can perform routine tasks autonomously and, depending on the situation, can be operated remotely (telepresence) by human intervention to perform non-routine tasks, thereby enabling versatile use. As example applications, in this section we consider "use in a hotel to support peak times" to save manpower in hotel operations, and a "remote use in non-face-to-face work equivalent to face-to-face work regardless of time and space."

2.1 Hotel support

In a hotel, each employee typically handles a wide variety of tasks, and the busiest tasks differ depending on the time of day and situation, so employees dynamically switch between tasks depending on the peak. Therefore, even if robots, etc. are used to improve the efficiency of a single routine task, it is unlikely that enough manpower can be saved. Therefore, robots are designed to support the tasks of employees depending on the time of day and situation as follows:

(1) Transport guests' baggage to their room at check-in.
(2) Direct guests to restaurants during breakfast/dinner hours.
(3) In restaurants, help serve and clean up by moving between tables and kitchens and by carrying dishes.
(4) Patrol the facility at night and contact the hotel staff upon finding a fallen person, garbage or lost item.
(5) Deliver amenities and sheets for cleaning guest rooms at night to the linen room on each floor.
(6) Search the relevant area if a child or item becomes lost, and notify the hotel staff of the result.
(7) In a disaster, move to a branching point and guide the evacuation along the appropriate route.

Such abilities would improve efficiency during the busiest hours according to the situation, and help save manpower.

2.2 Remote robot operation

Currently, remote work, in which workers can do their tasks anywhere by using e-mail and phone, is spreading. However, many types of local work are difficult to do remotely, making it necessary to come to the office. In such cases, or where there are spatial or physical constraints, etc., the fact that only limited types of work can be done is a problem.

The following types of non-face-to-face remote work can be realized by remotely controlling a robot that acts on behalf of a worker who is working remotely at home:

(1) When receiving visitors, the person in charge remotely guides them to the work site via a video call. The work continues in a coordinated manner.
(2) If equipment in the building malfunctions, move close to the equipment and remotely check it with a camera.
(3) Robots can complement non-verbal communication such as gestures, thus facilitating dialogue.

This will enable workers who cannot come to the office due to spatial or physical constraints to handle a wider range of tasks, and thus help to alleviate the labor shortage.

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3. Feasibility Verification by PoC

When developing the versatile mobile robot system to implement the concept described in Section 2, it is necessary to increase customer acceptance and technical feasibility in order to encourage commercialization and expansion. To increase customer acceptance, it is important to consider not only the actual needs that customers are already aware of, but also their potential needs that they have not yet noticed. Therefore, the cycle of proof-of-concept (PoC) design, construction, evaluation, and verification based on customer feedback is repeated to clarify potential needs.

As the first phase of PoC, we have developed a versatile mobile robot system that can set tableware, which is one type of hotel support, in cooperation with our arm-type collaborative robot MELFA ASSISTA (1). This PoC is intended to verify the technical feasibility and to identify customer requirements for moving objects through dialogue with customers.

The PoC scenario is as follows.

(1) A versatile mobile robot moves from its home position to a tableware receiving position when a remote operator instructs it to start serving dishes.
(2) An on-site worker puts a tray with tableware on the shelf of the robot.
(3) The robot moves to the handover position of MELFA ASSISTA, which arranges the dishes. After handing over the tray, the robot returns to its home position. Figure 1 shows how the tray is handed over.

When communication is needed, such as when the on-site worker informs the remote operator that the robot has started delivering tableware, the remote operator and the on-site worker can make a video call via the robot.

Our demonstration confirmed that the following functions are technically feasible in this scenario; the detailed functions of the versatile mobile robot system are described in Section 4 below.

(i) The robot can move autonomously to a designated location remotely.
(ii) The movement of the robot can be controlled while checking the camera image of the area in front of the robot, which is taken from a remote location.
(iii) A video call allows the remote operator and tableware dispenser to communicate.
(iv) Autonomous movement, remote control and video call can be switched seamlessly.

This versatile mobile robot system is exhibited at XCenter (2), a venue which exhibits DX and smart city-themed solutions. Discussions with customers are currently underway.

Furthermore, while collecting knowledge from the first PoC, we are considering external demonstrations with customers for operations such as transporting baggage between floors at hotels. Movement between floors is assumed to be done by elevator linkage using Ville-feuille (3).

4. Details of the Versatile Mobile Robot System

This section describes the details of the versatile mobile robot system developed in the first PoC.

4.1 System architecture

The versatile mobile robot system consists of ceiling cameras, infrastructure positioning devices equipped with Ultra Wide Band (UWB), a robot, a remote-control terminal held by the robot operator, and a server unit that controls these devices, which communicate with each other via 5G

Versatile mobile robot   MELFA ASSISTA

Fig. 1 Cooperative working between the versatile mobile robot and MELFA ASSISTA (fifth-generation mobile communication system), Long-Term Evolution (LTE), and Wi-Fi *[1]. Figure 2 shows the system architecture. In this study, the server unit, which includes camera processing, sensor processing, bird's-eye view image creation processing, mobility control processing, and applications for robot operation, was configured on-site; part or all of it could also be constructed in a cloud server.

In the effective range from where ceiling cameras and UWB infrastructure positioning devices are installed, the robot can drive autonomously even in areas where there is no pre-built map information or where the layout changes frequently.

4.2 Functions provided

The versatile mobile robot system has a remote control function, an autonomous driving function, and a remote video call function, which can be executed by a remote control terminal.

4.2.1 Autonomous driving

In autonomous driving, the remote operator sets the waypoints and destination of the robot on the bird's-eye view image, and then the robot sets the driving route and moves. If there is an obstacle on the movement path, the robot generates an avoidance path and then moves while avoiding the obstacle. Figure 3 shows the operation display for autonomous driving.

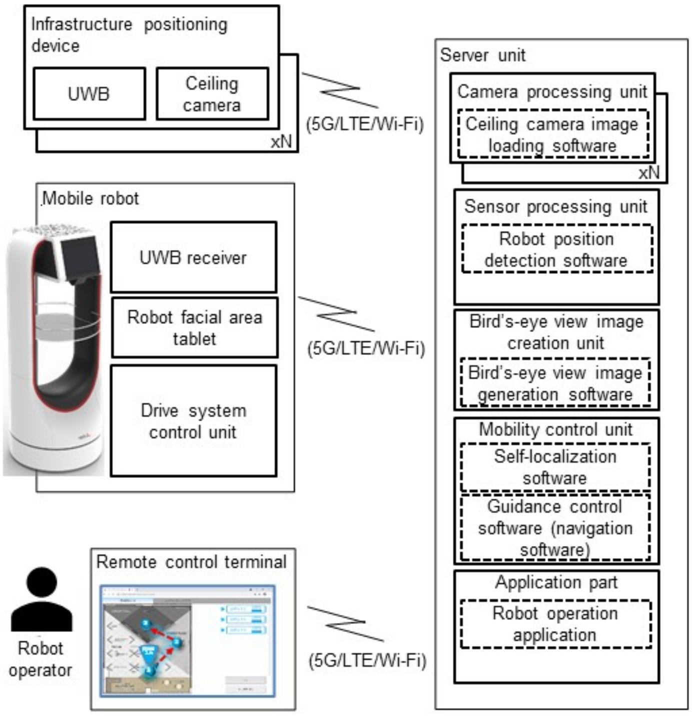

Fig. 2 System architecture

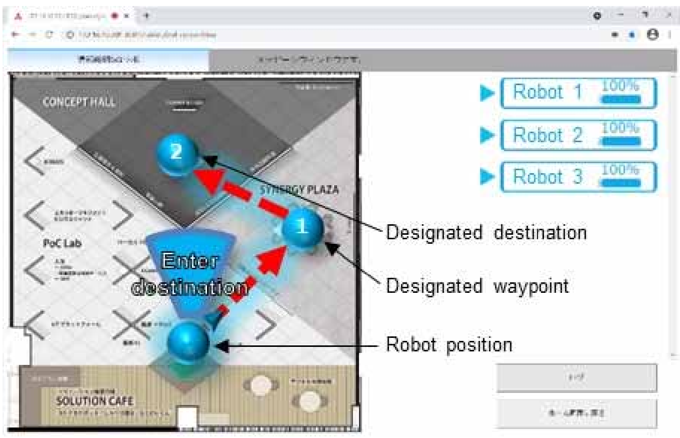

Fig. 3 Operation display of autonomous driving

[1] Wi-Fi is a registered trademark of the Wi-Fi Alliance.

4.2.2 Remote control

Remote control is performed by switching between two movement operation modes as necessary while watching the image of the camera capturing the area in front of the robot.

In the first movement operation mode, ClicktoDrive, the destination of the robot is designated by touching the desired location on the remote control terminal, which is effective when the robot moves to a distant place. Figure 4 shows the operation display of ClicktoDrive. The cross-shaped area is where the robot can move based on information from Light Detection And Ranging (LiDAR: a device that measures the distance to an object using light); when the operator touches any point in the area, a marker is displayed at that point and the robot moves to it.

In the second movement operation mode, DirectDrive, the robot moves according to the movement amount, direction, or rotation specified on the operation display, which is effective for fine-tuning the position. Figure 5 shows the operation display of DirectDrive. When the operator touches the arrow indicating forward or backward, or the arrow indicating rotation, the robot moves accordingly.

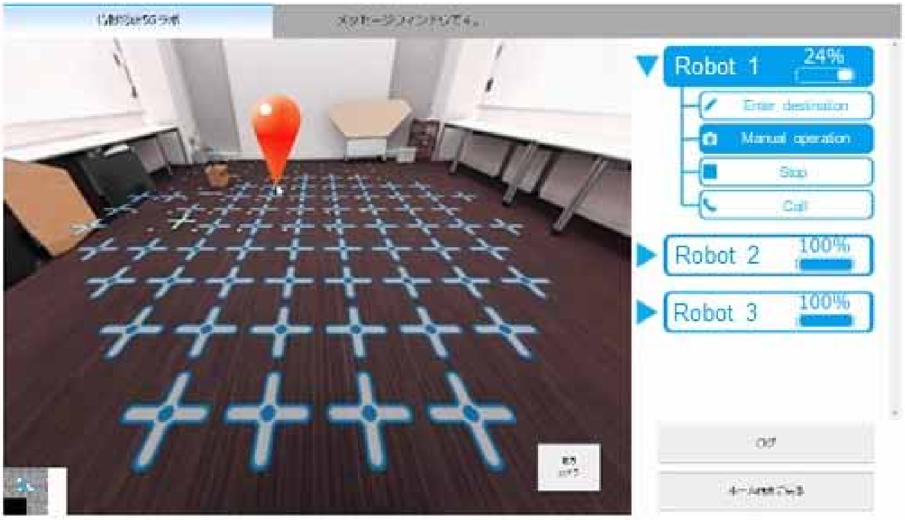

Fig. 4 Operation display of ClicktoDrive mode

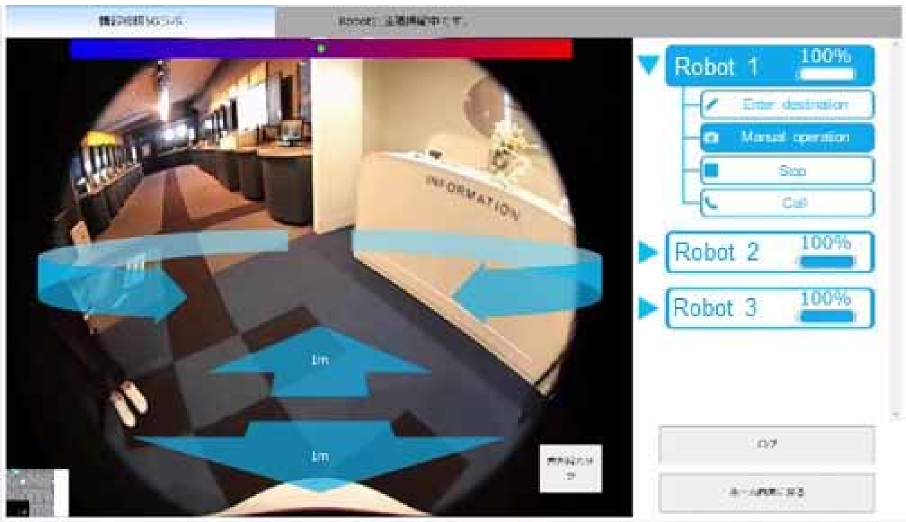

Fig. 5 Operation display of DirectDrive mode

Fig. 6 Situation of remote video call

4.2.3 Remote video call

Remote video call enables video calls between the remote control terminal and the robot. On the robot side, the camera image of the remote control terminal is displayed on the tablet installed in the robot's face area, and on the remote control terminal side, the image of that camera is displayed. Figure 6 shows the situation of a remote video call.

The video call can be made from either the remote operator or the robot side, and can be used by the remote operator to call the site, or by the person on site to contact the remote operator.

5. Conclusion

This paper described our development of a versatile mobile robot system that offers contactless, manpower-saving solutions, as well as our first PoC of the system for the two applications of tableware serving and remote communication.

Currently, we are verifying and validating the first PoC, and will repeat the cycle of PoC design, build, evaluation, and validation by utilizing the knowledge obtained. This will result in solutions that are popular with customers and lead to the expansion of our robot business.

References

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