Collaborative R&D and Mutual Utilization of Construction Robotics in the Construction RX Consortium

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Abstract

The Construction RX Consortium was established to promote increased productivity and attractiveness of the Japanese construction industry as a whole. The Construction RX Consortium has established 12 subcommittees and stimulates various technology developments for mutual utilization. The automatic material delivery system subcommittee developed an automated transport system. The project is currently in the trial stage.

Keywords –

Construction robot; IoT tools; Collaborative R&D; Mutual utilization; Automation; Material Delivery; BIM

1 Introduction

In the construction industry in Japan, given the social background of the decreasing working population due to the aging of workers, securing future workers and realizing work style reforms have become urgent issues [1]. Under such circumstances, general contractors have promoted the development of construction support and construction management tools utilizing construction robots and IoT. However, it is inefficient for each company to conduct them individually because of the often-generated excessive development costs. Furthermore, the increased number of robot types and IoT tools is a factor that hinders the productivity improvement of cooperating companies who are actually utilizing the technology. The purpose of this research is to introduce overseas the outline of the joint development and mutual utilization efforts of the “Construction RX Consortium (hereafter RX Consortium)” established under this background, and to provide an overview of the development of an automatic material transport system.

2 Research method

This research adopted the case study research method. The target is an automatic material transportation system, which is one of the subcommittees of the Construction RX Consortium. The analysis method is to conduct trials at the five actual sites shown below.

Table 1. Trial list

No.	Building use	Trial year
1	Warehouse	2023
2	Hospital	2022
3	Office	2022
4	Office	2022
5	Office	2022

3 Overview of The Construction RX Consortium

The RX Consortium is a voluntary organization comprising general contractors and various companies supporting the construction industry. It was established with 16 companies in September 2021, and as of December 2023, the number of member companies is 242, of which 29 are regular members [2].

3.1 Aims and Objectives of the Construction RX Consortium

The RX Consortium aims to reduce the cost of technology development of construction robots and IoT tools, shorten the development period, accelerate their popularization by cost range reduction, and promote their introduction by cooperating companies. In addition, the goal is to improve the construction industry’s productivity comprehensively and improve the work-life balance and workers’ treatment. It is worth noting that the RX Consortium clearly distinguishes the areas of cooperation and competition so as not to hinder healthy competition. In other words, the members collaborate in the development of construction tools that everyone can mutually utilize. Nonetheless, they position which kind of construction can be made by employing them as a competition area.

3.2 The Construction RX Consortium Organization and Activities

The RX Consortium encompasses regular members (general contractors above a determined size with their own R&D organization) and cooperating members. As shown in Figure 1, the organization of the RX Consortium consists of a general meeting, a board of directors, a steering committee to promote and support daily activities, and subcommittees for actual joint development and mutual use. The themes addressed in the subcommittees are discussed internally and decided by the executive committee. In principle, each member may enter the subcommittee if a member wishes to participate based on the member's own free will. However, the subcommittee discusses the division of roles and the burden of costs, establishing a contract to conduct the R&D activities. The main role of the RX Consortium is the establishment of the subcommittee. The concrete activities are in charge of the participating members of the subcommittee. In the subcommittee, besides the members who carry out the technology developments at their expense, the members who contribute without bearing the development costs by feeding back the results of the field trials are also allowed to participate. The mechanism that enables participation in the subcommittee is relatively simple, in line with the purpose of the RX Consortium to contribute widely to the construction industry [3].

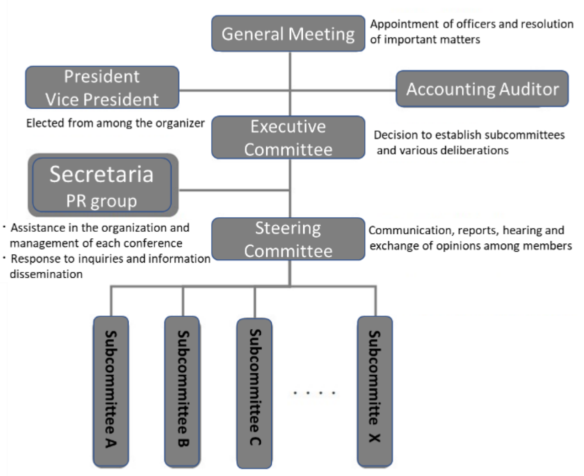

Figure 1. Organization

4 Subcommittee Activities

The RX Consortium currently has 12 subcommittees as listed in Table 2. The initiatives of one subcommittee in the table are reported in the next section.

Table 2. Subcommittee list

No	Subcommittee Name	Principal Company	Number of Regular Members	Number of Cooperative Members
1	Automatic material delivery system	Takenaka	18	14
2	tower crane remote control	Takenaka	10	6
3	Workplace Waste Management Technology	Takenaka	12	5
4	Concrete construction efficiency	Shimizu	14	7
5	Sumidashi Robot	Takenaka	16	9
6	Illuminance measuring robot	Kajima	7	17
7	Production BIM	Kajima	22	19
	Equipment Subcommittee		13	14
8	interoperable technology	Shimizu	12	4
9	Use of commercially available tools	Kajima		
	WG1 drone		17	16
	WG2 vital sensor		12	12
	WG3 assist suit		12	8
10	Airflow measuring robot	Kajima	4	13
11	Safety belt non-use detection system using AI	Shimizu	10	10
12	Efficient reinforcement inspection using ICT technology	Obayashi	11	7

5 Subcommittee on Automatic Material Delivery Systems

5.1 Overview of the Subcommittee

In construction work, the delivery of various materials in the required time at the needed place without delay is very important to process control. The delivery of materials within a construction site is an ancillary task for construction workers, and by automating it, they can spend more time working on core tasks that require higher skills. Therefore, the RX Consortium has set up a subcommittee on "Automatic Material Delivery System" and is working on developing such a system.

As of March 2023, 18 construction companies and 14 cooperating companies have participated in the subcommittee. Each general contractor has started activities to realize the practical application of the automatic material delivery system by flexibly linking systems, robots, and delivery equipment developed so far, enabling robots to be used at any construction site of any construction company through repeated development, trial, and feedback among members.

5.2 Overview of the system

Figure 2 shows an overview of the Automatic Material Delivery System, which is positioned as the core system of this subcommittee. This system consists of an "Automatic delivery management system (JHS App)", which handles material delivery reservations and adjustments, delivery instructions, and collection of results, and a "Construction robot platform (RPF)", which receives instructions from the system and generates delivery routes for various robots in conjunction with BIM to perform operation control and condition management.

It works in conjunction with the construction elevator and elevator shutter to realize a series of automatic deliveries by sequentially instructing robot groups and construction elevators based on a planned delivery list. From partial to full automation, various systems and delivery robots can be flexibly combined depending on the purposes and needs. At the construction site, the material unloaded from the truck is horizontally transported to the construction elevator and loaded. Then, the construction elevator vertically transports them to the work floor. On the work floor, another robot unloads the materials from the elevator and distributes them to the workplace.

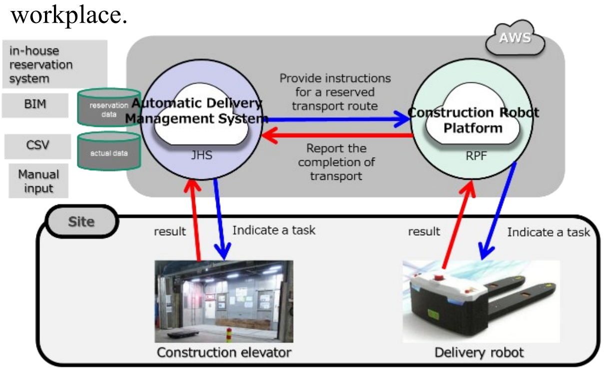

Figure 2. Automatic Material Delivery System.

5.2.1 Automatic delivery management system (JHS application)

The JHS App inputs delivery reservation information (i.e., material name, packing form, delivery destination floor yard, scheduled start and end dates, delivery means on a delivery route, etc.) for each material to be delivered. As shown in the left screen of Figure 3, the input information is listed and can be viewed for each day/delivery means, and the reservation can be adjusted. The JHS App links the construction autonomous driving elevator and the RPF described later by API. By sending the delivery reservation information from the JHS App, the work order is given to the construction elevator and the delivery robot, and the vehicle is automatically delivered. In addition, as shown in the right screen of Figure 3, the instructions to the worker are also possible through the smart device. When the delivery is completed, the actual information is automatically collected, and the status of the material can be checked on the screen in real-time.

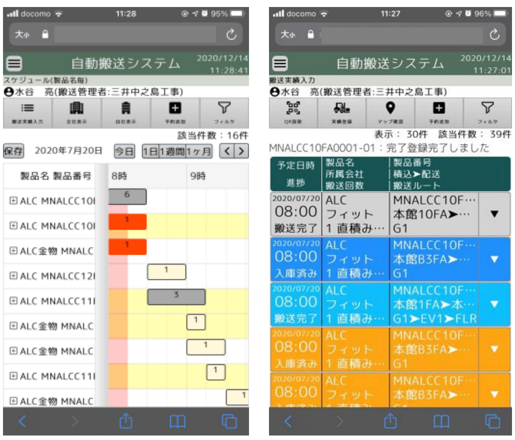

Figure 3. Example of the JHS App screen

5.2.2 Construction Robot Platform (RPF)

Traditionally, in the operation of construction robots in buildings under construction, it has been a problem that it is necessary to specify the range of operation by teaching in advance in the field, magnetic tape, two-dimensional code, etc., requiring many man-hours for maintenance and operation management due to the increased number of robots in operation and the advancement of functions [4]. To solve this problem, we developed RPF. An overview of RPF is shown in Figure 4. As shown in Figure 5, RPF uses BIM data as map information to set the movement and operating range of the robot on the cloud, enabling the robot to run autonomously. In addition, it is also possible to remotely monitor the condition of the construction robot, such as the battery and abnormality, on the cloud. It is also possible to manage a wide variety of robots, such as marking robots, cleaning robots, and delivery robots.

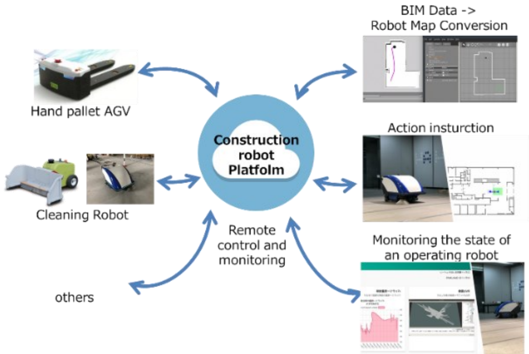

Figure 4. Construction Robot Platform

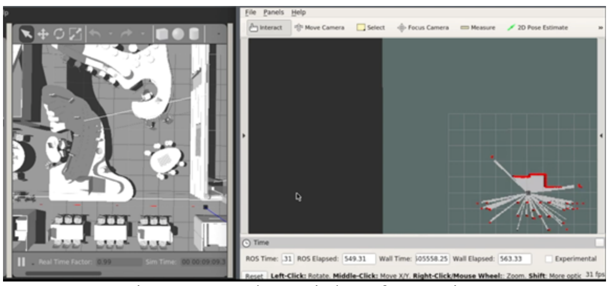

Figure 5. Robot Right-of-Way in BIM

In the automatic delivery system, the route from the delivery source to the delivery destination is set beforehand, and it is simulated using BIM data for all materials to be delivered automatically. In the automatic delivery execution, the delivery route information is transmitted to the robot based on the conveyance reservation information from the JHS App to instruct execution. The RPF monitors the operation status of the delivery robot in real-time. The delivery performance information, such as the completion of delivery, can be fed back to the JHS App in real-time.

5.2.3 Delivery robot (Automatic hand pallet)

The specifications of the developed automatic hand pallet are shown in Table 1. The appearance is shown in Figure 6. A 2D LiDAR and stereo camera are added to the upper part of the rear housing of the main body. The 2D LiDAR detects objects in the rear range of 180 degrees and serves to grasp their position. The stereo camera is used to detect the position of the pallet. A PC for hand pallet control and a pocket WiFi are stored inside the housing and communicate with the RPF on the cloud.

The automatic hand pallet autonomously drives the route set by matching the self-driving map generated from the BIM with the point cloud data acquired by the 2D LiDAR and performing self-position estimation. When loading the pallet, it moves forward while grasping the shape of the pallet using a stereo camera, and drawl into the lower part of the pallet. When there is an obstacle that was not in the map acquired in advance, the 2D LiDAR detects it, detours around it, and runs autonomously to the destination [5].

Table 3. Specification of Automatic hand palettes

Dimensions	1,420mm×750mm×450mm
Self-weight	170kg
Carrying capacity	1,000kg
Running speed	Min42m/min, Max60m/min
Operating time	6h (battery)
Filling lifting dimensions	105-175mm

Figure 6. Automatic hand pallet

5.3 Trial at construction site

The developed system was tested at several construction sites. We confirmed that it is possible to automatically deliver materials to designated locations based on delivery instructions from the JHS App. In the future, we will conduct repeated trials at the general contractors participating in the subcommittee and assess the effects. We will also develop an operational system and aim to put it into practical use.

Figure 7. Trial at construction site

6 Conclusion

In addition to the subcommittee activities, the RX Consortium carries out various initiatives to promote information sharing and mutual technology utilization among members, such as holding exhibitions and introducing technologies and services by member companies. The number of members has also increased faster than initially expected, and a wide range of industries, such as insurance companies, trading companies, and consulting companies, are participating. The environment for incorporating technologies and services useful for the construction industry is becoming better. Through these activities, we hope to improve the productivity and attractiveness of the construction industry.

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