Toward Realization of Service Robots Working in Train Stations (A Study of a Sensor-Cloud System that Allows Autonomous Locomotion for Robots in Stations)



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Abstract
In recent years, demands for task automation of station services, which need to be done by humans, are increasing with the decrease in the productive-age population. In order to rationalize or automate these tasks such as passenger guidance, cleaning, security, and carrying goods, which involve movement, robot technology about autonomous locomotion is required. However it seems difficult to realize that with current robot technology alone. For this reason, prototypes of sensor-cloud systems have been developed and tested in model station with a prototype robot. Those systems are composed of sensors installed at stations and a cloud system, which gathers sensor data, and they provide station congestion information to robots As a result of our proof of concept test, the prototype robot has been successfully connected to a cloud system and avoided congestion on its path, planning with the help of congestion information provided by a sensor-cloud system.

●***Keywords*:** Robotics, Autonomous locomotion, Sensor-cloud system, Congestion avoidance

1. Introduction

Many tasks in stations rely on labor of humans, including the tasks of passenger guidance, cleaning, security patrols, and carrying goods. With the decline in the productive-age population in recent years, the burden placed on each individual is increasing for those tasks. Streamlining tasks has thus become a major issue for JR East to meet goals of maintaining and improving service levels. Expectations are rising for practical application of a variety of service robots along with the rapid technical advancement in recent years in ICT, especially in the areas of sensor technology and artificial intelligence. Multiple examples of practical use of communicating robots have emerged, and many examples of development of robots that move autonomously have been seen.

Such expectations for streamlining of station tasks and the rapid advance in robot technologies prompted the JR East Group to establish the limited liability partnership JRE Robotics Station in July 2017 so as to accelerate development and introduction of station service robots. The JR East Group will broadly gather station service robots and conduct proving tests in stations in order to put robots into use at an early stage.

At the Research and Development Center of JR East Group, we believe that a mechanism for the station to support autonomous locomotion of robots is needed in order to more safely and reasonably use robots that move autonomously in stations where there are many pedestrians. We are thus working on R&D for achieving that instead of just waiting for robot technology to advance to a practical level. This paper introduces efforts in that area.

2. R&D Overview

2.1 Station Cloud System

In order to safely use robots that move autonomously in stations where many pedestrians come and go, it is imperative that robots do not collide with pedestrians or obstruct their flow. Many current robots that move autonomously are equipped with functions to identify the surrounding environment and pedestrians by onboard sensors. However, the range of perception is limited, so there is risk of collision with pedestrians coming out of blind spots and of robots intruding into congested areas they cannot deal with and obstructing pedestrian flow. It is thus is difficult to utilize robots that move autonomously in stations by robot technology alone. Ways of avoiding those issues include making improvements to station facilities and setting up dedicated areas for robots, but station renovation entails large costs and imposes major restrictions on station operation, so this cannot be said to be advisable.

The authors thus studied a mechanism of supporting robots that move autonomously in terms of information. The mechanism considered was a system to identify pedestrian distribution and congestion in the station as a whole and transmit congestion information to robots (hereinafter, the “station cloud system”) by equipping station facilities with sensors to detect pedestrians and performing on a high-order server integrated processing of pedestrian data obtained by sensors (Fig. 1).

The following three methods are the three main types that already have track records in use at stations for sensing pedestrians. The first is identifying pedestrians by detecting the shape of people’s heads or bodies from overhead using infrared sensors. The second is identifying pedestrians from the shape of the entire or lower half of people’s bodies using video cameras sensors (video camera method). And the third is capturing pedestrians’ ankles by distance measuring sensors installed on the floor and identifying pedestrians from their movement (distance measuring method). By informing robots of pedestrian positions and congested areas through those sensing technologies, judgment can be made to keep robots away from pedestrians in blind spots and congested areas, thereby avoiding the aforementioned issues.

In order to verify feasibility of this station cloud system and effects of autonomous locomotion support for robots, we produced a prototype station service robot and station cloud system and tested the concept by connecting the two and performing running tests with the robot.

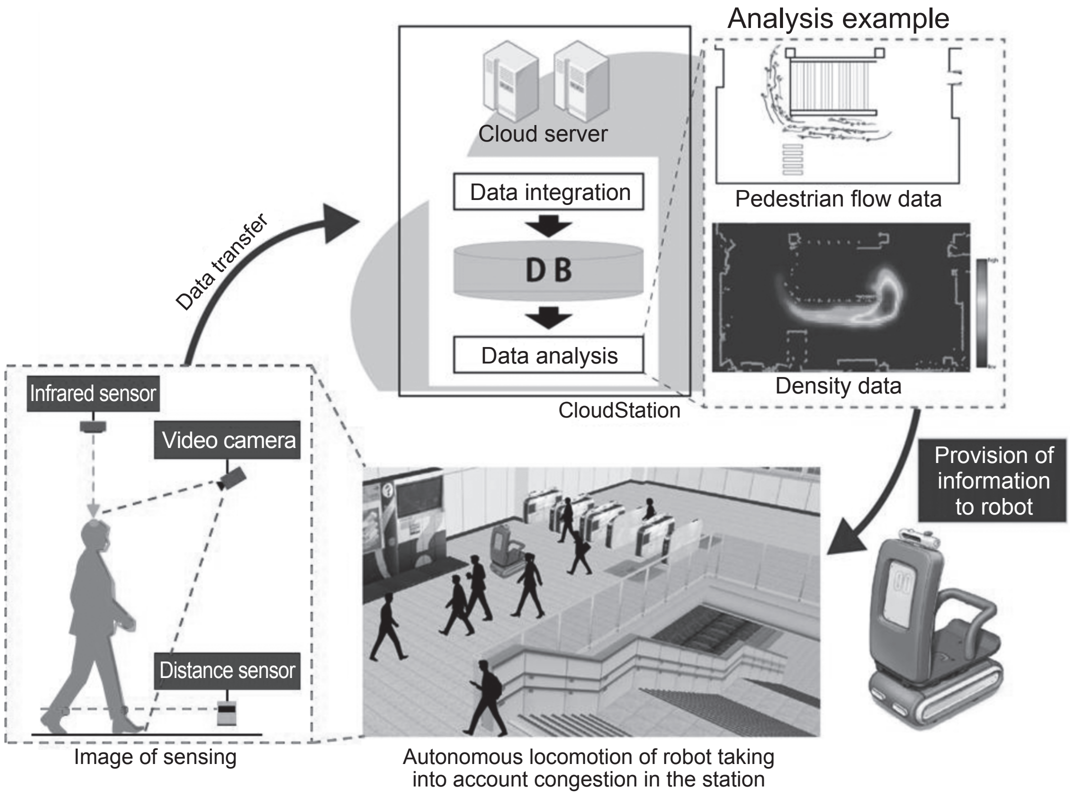

Fig. 1 Station Cloud System Supporting Station Service Robots

2.2 Station Cloud System Prototyping and Installation

Selection of the sensing method was made when prototyping the station cloud system. The infrared method is promising as a candidate for future implementation due to its ease of installation at stations and high accuracy/stability in detecting pedestrians, but the sensing range is narrow, so it is used mainly for counting the number of pedestrians passing. As it is difficult to identify areas of congestion in the station as a whole, this was thus not employed in the proving tests due to the purpose of those tests being to confirm the concept of the system. The video camera and distance measuring methods have broad sensing ranges, and they were employed because they can easily reproduce result in the tests this time.

A system using the two methods selected was installed in JR East's “Smart Station Lab”, which simulates station spaces. Sensor mounting design was done so blind spots were not created, and six distance measuring sensors and three video cameras were placed as shown in Fig. 2.

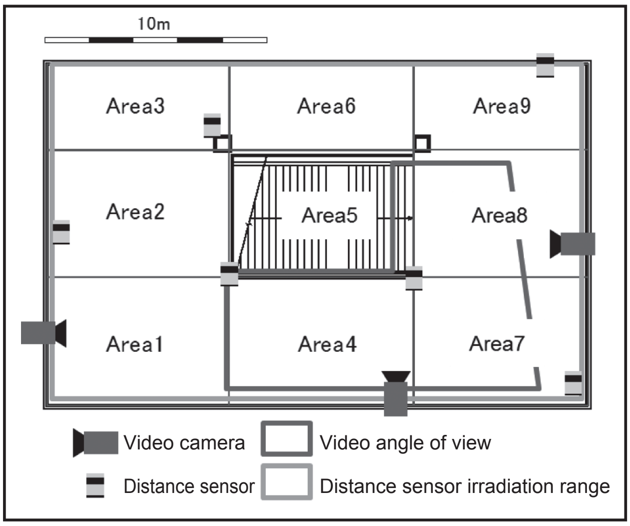

Fig. 2 Schematic of Sensors Installed in Concourse of Smart Station Lab

2.3 Station Service Robot Prototype

A station service robot prototype was produced for testing. The robot was equipped with functions to detect the shape of its surroundings and to detect pedestrians in its direction of travel. It was also given functions to automatically plan routes to destinations, move autonomously, and avoid collisions with obstacles and pedestrians (Fig. 3).

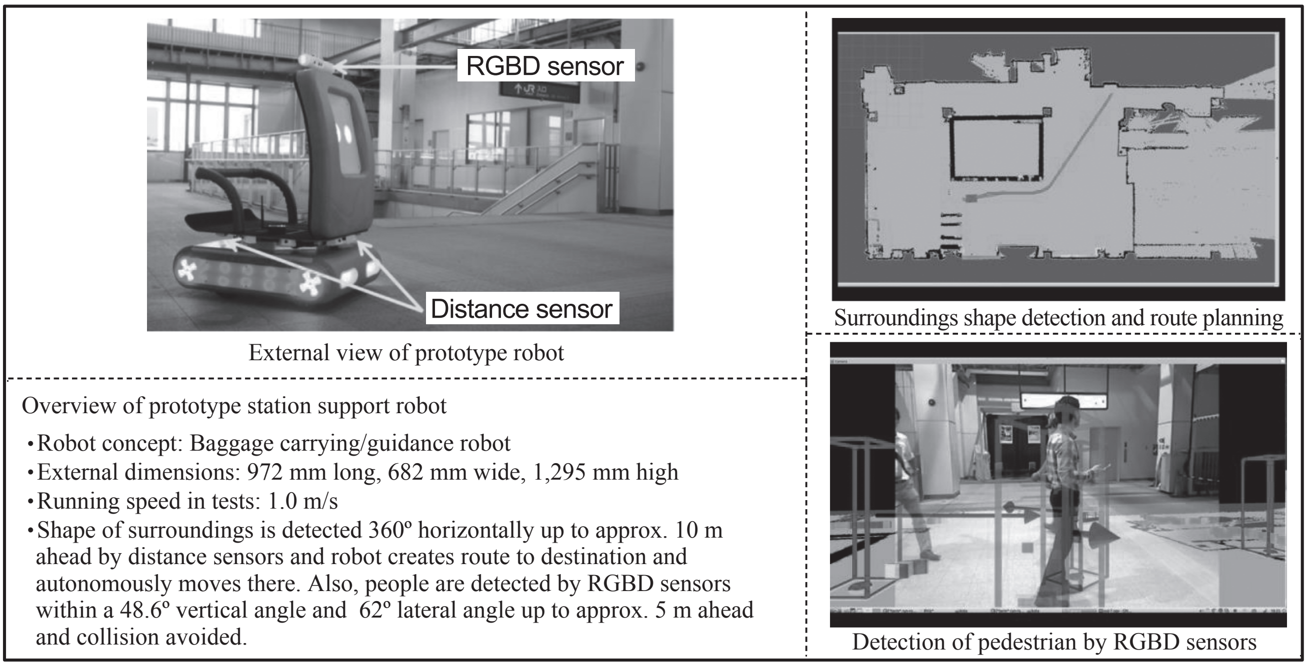

Fig. 3 Prototype of Station Support Robot Used in Tests

3. Proving Tests

3.1 Overview of Tests

For the proof of concept tests on reasonableness of route planning by a robot connected to the station could system, we performed running tests for a robot under the following conditions at the Smart Station Lab (Fig. 4).

- · Robot autonomously selects a route to the destination provided and moves there.
- · Pedestrians pass on the shortest route from departure point to destination point.
- · Robot is informed of congestion from the station cloud system.
- · Robot has function to change its route depending on congestion.

3.2 Test Results

The tests covered in 3.1, above, were repeated with the robot departure and destination points and route taken by pedestrians varied. Results for the most prominent differences between when the robot received or did not receive notice of congestion from the station cloud server are shown in Fig. 5. When the prototype robot was run without being connected to the station cloud server, it obstructed pedestrian flow around Area 3; but when it was connected and received notice of congestion, it changed the travel route as expected and was able to avoid pedestrians and reach the destination.

With the station cloud system prototyped and installed at the Smart Station Lab this time, an approx. 2 second information lag occurred between sensors detecting pedestrians and that being integrated and delivered to the robot as congestion information for the station as a whole. From those results, we see issues occurring such as being unable to react to pedestrians suddenly coming out of blind spots while the robot is running. We thus need to study in the future ways of reducing information delay and a method of linking the station cloud server and robots taking into account the effects of delay in congestion information

Fig. 4 Running Test

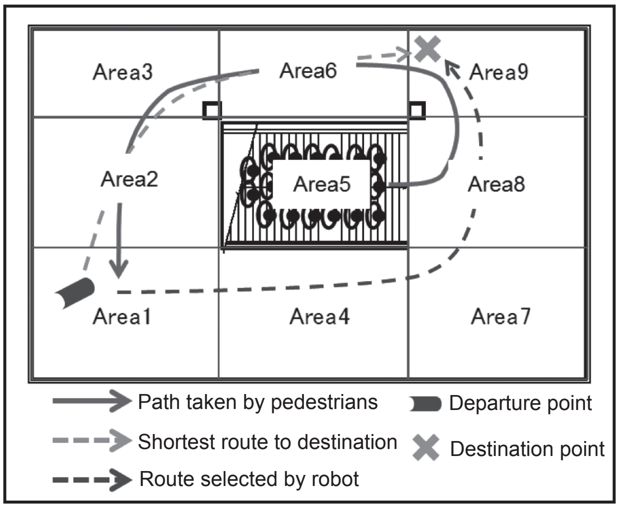

Fig. 5 Robot route change due to notification of congestion information

4. Conclusion

This paper introduced the station cloud server, which supports autonomous locomotion of station service robots. We were able to show that making the environment where robots are utilized to be more intelligent is an important key to accelerating and putting into practical use robots for which expectations on their ability to streamline tasks in stations is heightening. In the future, we will put efforts into advancing and generalizing the results demonstrated in this paper for putting the system into practical use. Furthermore, in order to be able to use various robot safely in stations, we will put efforts into systemizing rules for using robots in stations and aim to create spaces where humans and robots coexists to maintain and improve service quality.