

Development and Styling Design of Airport Guide Robot System

Yoko SAITO¹ Takeshi KOSHIISHI²

ABSTRACT

In an effort to create “a robot that coexists and cooperates with people and performs useful functions in society,” the concept of a “Compass to Accompany” was formulated during the development of a robot system to provide a guide service inside an airport facility as one public space in which individuals are coming and going. A questionnaire was administered to airport staff and to families of Honda employees, and a design was brought to fruition that entails identifying a potential request while listening to a live voice. Thorough consideration was given to enhancements to driving mechanisms and to the feasibility of various types of sensors associated with advancements in development; mockups and prototypes were obtained; and reception and guide robots were realized as easy to talk to, functional designs.

Development efforts yielded an interface that guests can use without confusion and a feature capable of performing guided movement in the same manner as a human, even in an environment crowded with pedestrians, confirming the potential of offering a service consistent with this concept in an actual airport setting.

1. Background

1.1. Development Background of Honda Robotics

Honda has set forth its 2030 Vision to “serve people worldwide with the ‘joy of expanding their life’s potential,’” and as one such initiative has continued to make progress in the development of robots as typified by ASIMO⁽¹⁾. Moreover, in seeking to realize a robotics society that will further highlight the inherent greatness of human beings, Honda has looked at how robots can actually coexist with people and provide useful functions instead of merely serving as demonstrations.

Demand for robots capable of coexisting with people is growing due to interest in higher living standards and social environment changes, such as lifestyle shifts like telecommuting and teleconferencing that assume remote environments, and demand for services that do not rely on human facilitators. Robots are also expected to help fill the gap where labor shortages occur in fields such as delivery, cleaning, and guide services. In guide services in particular, multilingual capability is a key issue for

responding to people from diverse countries and regions, but it is a challenge in Japan to secure human resources capable of providing information in multiple languages. Personal information terminals such as smartphones have become widespread and the provision of information via multilingual map apps is progressing; however, a certain degree of media literacy is needed, and there are limits to services received on a personal device for addressing challenges involving movement such as exploration inside a facility.

The authors set out to realize a system that enables even users not familiar with a facility to navigate it without confusion, by linking existing services offered by the facility with a robot system.

1.2. Background and Overview of Airport Guide Robot Development

This development was done as a joint research effort with Narita International Airport Corporation concerning the use of robots in airports, with Narita International Airport (hereafter, Narita Airport) as the verification facility.

¹ Life Creation Center

² Design Center

Narita Airport is a public space facility that is planning and implementing the introduction of robots to revolutionize productivity by promoting innovation⁽²⁾. Images of robot utilization such as depicted in Fig. 1 were examined while searching for an advanced application that would address concerns of airport personnel, pedestrians, and facility management. As a result, guide service was selected as a challenging theme presenting many technical issues, as a case of utilizing autonomous navigation technology whereby a robot smoothly navigates an environment with many people. The reason for this selection is that compared with delivery and cleaning, guide service calls for the robot to navigate a crowded environment at the same speed as people and to smoothly avoid oncoming people and obstacles without stopping when detected. Through a process of discussing matters of this sort, the two research partners commenced development of an airport guide robot system.

Figure 2 shows the guide robot system standing by to receive pedestrians. The system comprises a robot home that serves to promote the presence of the robot guide service inside an expansive facility and is also the place where the robots reside, a reception robot inside that is responsible for interacting with guests and providing reception service, and one or more guide robots that

actually guide guests to the desired destinations while navigating the airport starting from the robot home. A cloud-based system called the management system⁽³⁾ coordinates and operates the robot home, reception robot, and guide robots.

Figure 3 shows the utilization flow of the robots by pedestrians. The reception robot displays a map to the destination and other information such as recommended shops on a touch-screen display, and provides detailed guidance in a cordial manner while interacting with the guest. Meanwhile, the guide robot refines and reduces the information to display to enhance maneuverability and efficiently guide the guest through spaces where people come and go. Although duties are divided between the reception robot and the guide robot, they are seamlessly linked in providing guide service to the guest.

The realization of these features will allow for offering guests a new form of guide service in Narita Airport, and the new experience of being guided to their destination by a robot. It will also create a new service in which robots continue to work in an environment where they coexist with people and supplement workforce shortages.

This paper introduces the concept and styling design of the guide robot system, and also discusses newly developed functionality and verification at Narita Airport.



Fig. 1 Image of robot utilization at airport

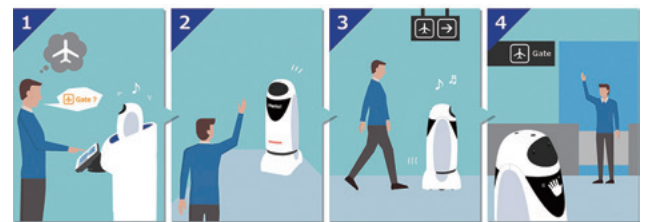


Fig. 3 Utilization flow of guide robot service

2. Concept

Studies were done to determine the appearance and gestures suitable for a robot that smoothly navigates a public space traversed by many people and provides guide service without provoking anxiety in people, and the desired feelings of guests receiving guide service was also examined. This resulted in the concept of a “Compass to Accompany” (Fig. 4).

“Accompany” indicates attention to maintaining a comfortable distance and being a reassuring presence, and “Compass” indicates a tool of unmatched accuracy showing the direction and route to a destination. The goal was to become a memorable presence that guests would want to meet again after encountering and receiving this guide service at the airport.

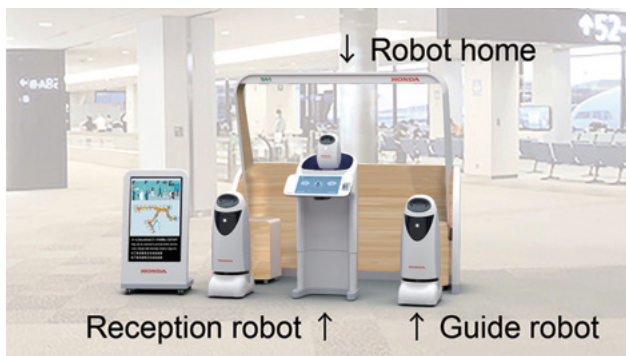


Fig. 2 Robot home, reception robot, and guide robot



Fig. 4 Development and styling design concept

3. Guide Robot Design

3.1. Design Process

Figure 5 shows the transition in the robot appearance design.

The initial design was an extremely simple one based on an omni-directional movement mechanism developed with the UNI-CUB⁽⁴⁾, and prioritized functionality [Fig. 5(a)].

Next, pseudo-models made of panels were brought into Narita Airport during a time when there were few people and compared with items such as luggage carts and baby strollers used in the airport, as shown in Fig. 6. It was determined that the optimal robot size, which would neither be lost among such items nor overpower them, was a total height of about 1100 mm. The drive mechanism changed to a ball drive that can respond evenly to input from various directions conceivable when operating among people, and which enabled minimization of the robot's floor projection footprint^{(5), (6)}. The design progressed to a body shape with a hexagonal cross section that would help stop continued rolling in the event that the robot tips over [Fig. 5(b)].

Refinement continued while performing operations testing with the prototype, and the robot was exhibited in April 2018 at the International Airport Expo, which was presented as a future form of airport services. The graphics were also changed and a dynamic exhibition under the name

P.A.T.H. Bot was performed at the Consumer Electronics Show (CES) held in Las Vegas in January 2019 [Fig. 5(c)]. While design did not elicit a negative response, it also did not leave a lasting impression. This was attributed to the fact that the robot had purposely been given an inorganic appearance to allay concerns that people might approach the guide robot owing to its novelty and thus interfere with guide operations. From the point of view of how a guest would feel when actually being guided by a robot at an airport, it was thought that a more lifelike design with the sense of an animating spirit within was desirable. Therefore, the design was modified to reflect an image common to both the design survey results described in Section 3.2. and the ASIMO design described in Section 3.3., elevating it to the Compass to Accompany concept.

Additional testing was conducted at the airport, and the fisheye cameras positioned on both sides of the body were changed to wide-angle cameras in a five-eye layout (two front, two upper, one rear) to enhance recognition accuracy. Also, the drive mechanism was changed from a ball drive to a differential two-wheel drive to enhance stability during travel. Although this drive system was unable to move directly to the side, which limited some expression during interactions, it made for easier handling and greater stability of behavior, and also increased the visual sense of reassurance [Fig. 5(d)].

3.2. Design Survey

A roundish design that focused on "a feeling of being accompanied (approachability)," a linear design that focused on "a compass (functionality)," and an intermediate design incorporating features of both were studied and full-scale mockups were created as appearance designs to convey the concept of a Compass to Accompany. In addition, a digital signage video to be displayed by the robot during guide service was created and steps were taken to enable checking on a PC screen.

Airport personnel and family members of Honda employees reviewed these designs and video, after which interviews and questionnaire surveys were conducted to ascertain whether the concept had been communicated as

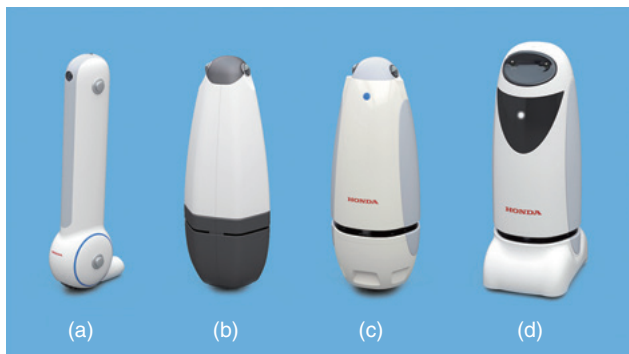


Fig. 5 Design process

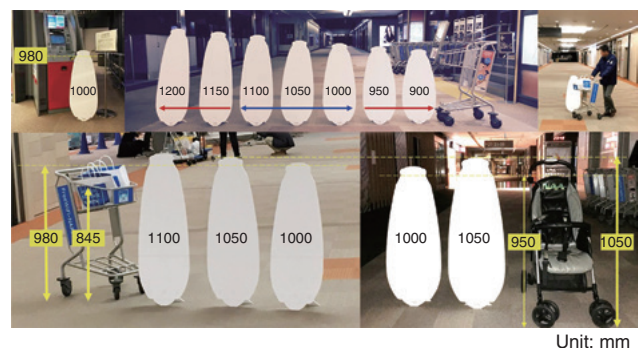


Fig. 6 Study of robot heights in Narita Airport

intended. The results showed that, as initially predicted, the design that focused on approachability was highly rated, but it gave the impression that the vital objective of providing accurate guidance to the destination could be a challenge. Responses indicated that the other designs did not have what people wished for in a guide robot, and it was found that none of the designs had achieved the concept.

It should also be noted that no difference was seen between responses given by children and those given by adults. It had been predicted that the more approachable design would score highly with children but this was not the case.

3.3. Shared Design Image with ASIMO

It is believed that the reason ASIMO has been able to maintain steady popularity over a 20-year period stems not from a playful design that has the goal of conveying approachability, but rather from its functionally straightforward and simple design⁽⁷⁾ in line with the concept of “harmony between being advanced and being people-friendly” (Fig. 7). The airport guide robot also has a simple and functional form like ASIMO. At the same time, the shape of its face, the slightly rounded body, the side pads suggesting arms, and the digital signage area were designed with the goal of conveying a sense of being not cold and unfeeling but alive. The exterior paint colors also use the same white and gray tones seen on ASIMO (Fig. 8). The

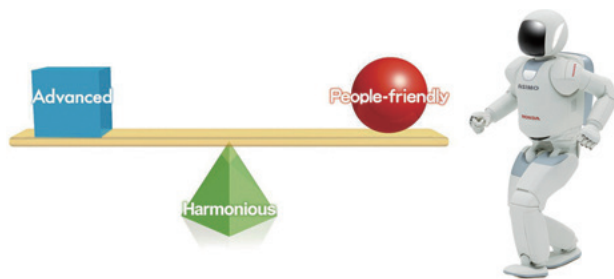


Fig. 7 ASIMO design concept



Fig. 8 Final design

result successfully embodies the concept of a Compass to Accompany with an approachable and functional design that is considered ideal for providing guide service at an airport.

3.4. Digital Signage Design

A study was done to investigate the optimal signage displays while providing guide service to guests in an airport. At a time when no pedestrians were present in the airport, a simulated experience was conducted in which a Honda employee assuming the role of a guest followed an existing remote-control robot equipped with a small monitor that displayed digital signage information, as shown in Fig. 9. The results revealed the following.

- When there are many displayed contents, the guest focuses on the screen and does not monitor their surroundings, which can be dangerous.
- When much information is displayed, the guest slows down in order to understand it.
- Displays are needed not only for the guest being guided but also for others around the robot.

This led to a digital signage policy of conveying only the information needed at a given point in time, in a simple display. The information was organized in line with the following three perspectives, and digital signage display areas were provided on the front and rear sides of the robot body, as shown in Fig. 10. The front side displays information for the guest being guided and others around the robot, while the rear side displays information for the guest walking behind the robot.

- At the start of guidance: Displays the destination using graphics based on pictograms in use at the airport.
- En route to destination: Turning directions, cautions, stopping
- Acknowledging other parties: Greetings and attentiveness

In addition to the above, when the design survey described in Section 3.2. was conducted, universal design



Fig. 9 Simulated experience of temporary guide robot

proponents at Narita Airport shared important insights, pointing out that for individuals with impaired color vision, displays such as blue text on a white background have lower contrast, making them a challenge to distinguish, and white or yellow on a black background is best for achieving the highest contrast. The displays were changed to luminescent white on a black screen to enhance distinguishability for both older individuals with deteriorating eyesight and persons with impaired color vision, and digital signage was created to express information such as the standby state, greetings, guidance in progress, and arrival at the destination.



Fig. 10 Guide robot signage displays

4. Reception Robot Design

Consideration was given to what approach would best enable people to use the airport guide service naturally and without confusion. It is usually considered ideal for people to receive help from people, but there are also cases where, due to human nature, people may hesitate to avail themselves of services due to worries about language differences or because there is a crowd at the guide service counter and it looks busy. On the other hand, while it may seem reasonable to completely automate reception, lack of familiarity may give rise to anxiety about usage, and there are scenarios in which this approach may fall short as a guide service. The method shown in Fig. 11 where the guest is provided with not only a screen interface but also the physical presence of a robot seemed to be an effective way to attract people and impart a greater sense of reassurance.

As a presence that invites guests into the extraordinary and enjoyable world of air travel, the reception robot's appearance was designed to achieve commonality with the guide robot, and referenced the proportions of familiar and long-favored symbols of welcome and good fortune. These objects include Daruma dolls (traditional round dolls depicting the Bodhidharma), maneki-neko ("beckoning cat") figures, and Fukusuke dolls (male figure bowing from a kneeling position). The robot responds to guests with motions such as bowing (a), tilting (b), and looking back over its shoulder (c). In addition, a large 19.5-inch touch-screen display is used as a visual aid to increase the guest's comprehension by displaying details about the destination. The robot and touch-screen part use an electric lift device⁽⁶⁾ to enable comfortable access by various people, including very tall individuals and those using a wheelchair.

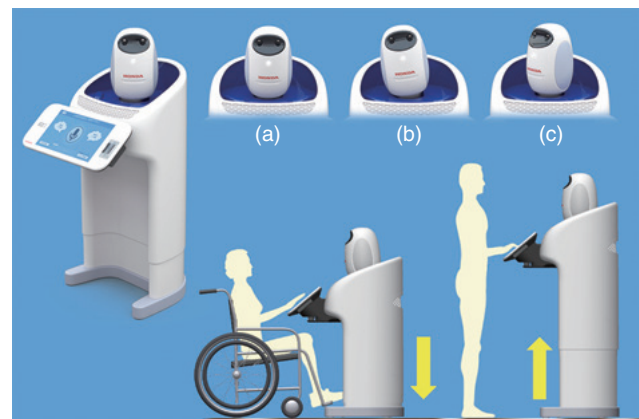


Fig. 11 Reception robot design

5. Interaction Design

5.1. Flute Sound and Body Movements

As a non-humanoid robot using human language in a strange manner when providing reception service may engender a sense of unnaturalness, it was assumed that it might be effective to attract guests by means of non-linguistic sounds and physical movements. Airports are typically loud, with public announcements and miscellaneous bustling noise, and thus in an attempt to cut through that noise and reach people's ears, the sound produced by the robot was created as that of a ryuteki "dragon flute" of traditional Japanese court music as a motif.

The melody is performed while the reception robot is in operation and as guide robots provide guide service, and simple body movements like shaking or rotating are used to stir the imagination of observers. Every effort is taken to help ensure that the guest remains the focus.

5.2. Ways of Making an Impression

In an attempt to casually convey a sense of Japan to foreign visitors at the airport, a traditional Japanese pattern called Asanoha, in use since the ancient Heian Period, was applied over the ventilation area on the rear side of the guide robot and on the speaker portion of the reception robot, as shown in Fig. 12.



Fig. 12 Japanese traditional pattern, Asanoha

6. System Configuration and Features

6.1. Overall System Configuration

The guide robot system comprises a robot home, a reception robot, one or more guide robots, a management system, and information provided in real time by the airport (Fig. 13).

The robot home is positioned as a place for the reception robot and guide robots to reside. To make the robot home stand out amid the busyness of the airport, a tall structure is put in place as a landmark to attract the attention of pedestrians who, having taken notice, see a digital signboard explaining the functions of the robots. After a guide robot finishes guiding a guest, it returns to the robot home, charges its battery with a dedicated charger, and prepares for the next guide operation. The guide robot details are presented in Section 6.2.

The management system⁽³⁾ is responsible for operation management to execute efficient guide service with multiple robots of various types cooperating with one another. As the goal is to not be bound by the limitations of the robots' movement range or infrastructure construction, a server-free configuration that uses Cloud services and the Internet of Things (IoT) to communicate was employed.

Real-time information provided by the airport is used while searching for the destination. As a result, the information provided uses the same maps and names as those provided by other guide services in the airport, such as face-to-face guidance at Information Centers and digital information boards. This also enables guests to check the latest flight information, including when changes occur in flight schedules or boarding gate numbers, which spares them rush and confusion.

The reception robot has the functions of searching for a destination and displaying a map and route according to

the needs of the guest, and uploading to the management system the information needed to guide the guest to the destination. This robot is the first point of contact for guests using the guide service, and the goal was to create an interface that can be used without confusion. The details are described in “Development of Reception Robot for Airport Guidance”⁽⁸⁾.

6.2. Guide Robot Features and Functions

The role of the guide robot is to perform the function of leading a guest to a destination and then to return to its original position after doing so. As the goal is to navigate smoothly even in crowded conditions, a feature of the robot is that when it detects someone passing by or an obstruction ahead, it selects a smooth path and proceeds without stopping, in a manner similar to that of a person.

Figure 14 shows the hardware configuration, and Table 1 lists the main specifications. The environmental conditions in the airport and other considerations that formed the basis for this configuration and the specification settings are described below.

- (1) As described in Section 3.1., the total height of the robot is set to a value that enables easy recognition by people in the area, even in an environment crowded with people and carts, but also so as not to be intimidating in size.
- (2) The footprint of the robot is set to a size that does not interfere with the progress of people in the area and enables smooth path planning. The wheel layout uses two driving wheels with motors and four driven wheels (double-row omni-wheel).
- (3) A low center of gravity is used so that the robot will not lose balance and tip over even if it comes in contact with an obstacle or structure. For this reason, components whose placement is not restricted for functional reasons

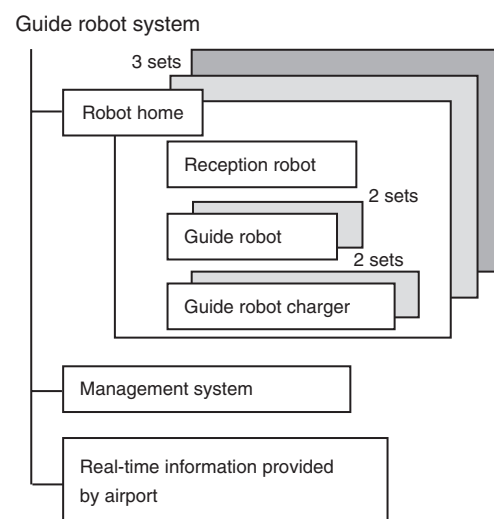


Fig. 13 Guide robot system architecture

Table 1 Guide robot specifications

Height [mm]	1080
Footprint [mm]	410 (Width) x 510 (Depth)
Height of center of gravity [mm]	300
Weight [kg]	33
Speed [m/s]	Max. 1.11 (4 km/h)
Acceleration [m/s ²]	Max. 1.67 (6 km/h/s)
Slewing angle speed [deg/s]	Max. 90
Braking distance [mm]	350 or less
Allowable difference in height [mm]	Max. 5

are situated in the lower portion of the robot.

- (4) Navigation speed, acceleration, slewing angle speed, and braking distance are set so as to enable movements similar to those made by people.
- (5) The difference in flooring levels that the robot should be able to negotiate is set so as to leave some margin from the greatest level difference it can actually negotiate. The robot is equipped with suspension to buffer the electronic components from impact while the robot negotiates differences in flooring levels. The greatest level difference in the airport is 3 mm in places where there is a change in the type of floor surface (e.g., short pile carpet, linoleum, decorative tile). The robot is

configured not to proceed when there is a large level difference such as a staircase.

- (6) As described in Section 3.1., a five-eye camera layout is used. The front cameras detect people and objects, the upper cameras enable the robot to recognize its location by extracting characteristics of the ceiling above, and the rear camera is used to recognize the guest (follower) being guided.
- (7) In order to fulfill the requirements outlined in Section 3.4., two short focus projectors are mounted on the robot for front display and rear display.
- (8) The robot uses a laser rangefinder (LRF) to detect people and objects ahead and to recognize its own position. The LRF is positioned at a height that enables detection of people and structures inside the airport.

A feature of the guide robot's autonomous navigation is its ability to navigate while providing guidance under crowded conditions like a person would. In order to quantify this feature, a target level was established to indicate the degree of crowdedness that the guide robot can navigate. Using definitions of service levels⁽⁹⁾ as an index of crowded conditions, "a state in which pedestrians have limited freedom to choose their own travel speeds or overtake others" was set as the target level. The reason for selecting this level is that it presented the greatest challenge of all likely service levels for the autonomous navigation of a guide robot in the crowded environment of an airport. Below this level there are fewer people in the airport and the robot could navigate easily, and at higher levels of congestion the robot would lose all freedom of path planning, and thus the challenge of path planning would decrease.

Examples of issues that a crowded environment raises for the guide robot functions of follower recognition, localization, and obstacle (people) avoidance, and measures for addressing those issues are as follows:

- (1) For follower recognition, the guide robot continues to perform recognition even when follower occlusion occurs due to other pedestrians intervening between the follower and the guide robot under crowded conditions, and maintains a distance that is comfortable for the follower. The details of this function are covered in "Research of Robust Follower Recognition Function for Airport Guide Robot"⁽¹⁰⁾.
- (2) For localization, even when the guide robot cannot obtain information about structures in the area through one sensor under crowded conditions, the guide robot combines information obtained from various sensors (LRF, cameras, inertial sensors) to avoid losing track of its position⁽¹¹⁾.
- (3) For obstacle (people) avoidance, the guide robot is equipped with learning capability that uses the avoidance actions of people as training data, so that the robot does not make clumsy maneuvers when people do not behave as expected under crowded conditions, and chooses a smooth evasion path just as a person would⁽¹²⁾.

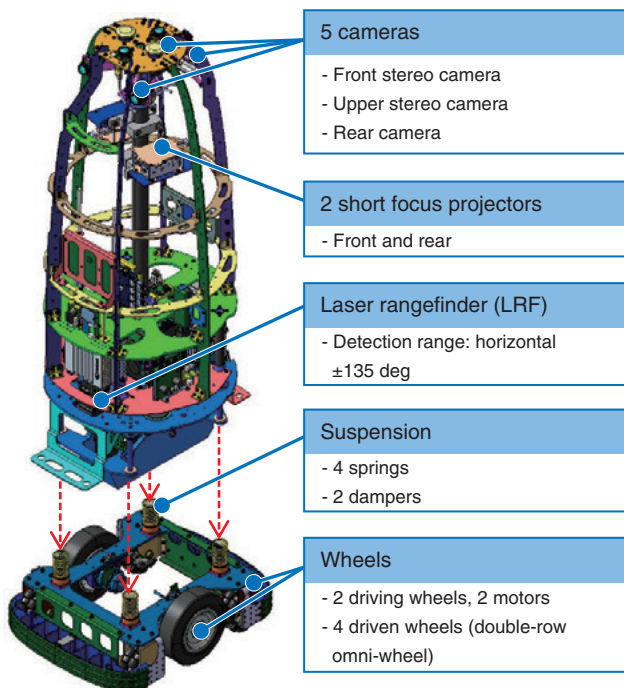


Fig. 14 Hardware configuration of guide robot

7. Verification of Feasibility

It was envisioned that the service verification would be performed over a period of three consecutive months (excluding holidays), with an operating time of eight hours between 9:00 a.m. and 5:00 p.m., using the entire area of one floor that could be traveled without the use of stairs or elevators. In addition, to increase opportunities to provide service to guests, it was decided to install robot homes in three locations on the floor. Given these factors, it was anticipated that the number of guests who would experience the guide service during the verification period would be 4500 or more parties for route guidance by the reception robots and 1000 or more parties that would be led to their destinations by a guide robot. Furthermore, some 20000 pedestrians visiting the airport each day might observe the reception and guide robots working in coexistence with people.

To investigate whether service verification would be feasible under the anticipated conditions described above, a guide robot system consisting of a reception robot, a guide robot, and a management system that linked the two was operated in Narita Airport with pedestrians coming and going, and a mock trial was conducted of the robot utilization flow shown in Fig. 3. Figure 15 depicts a developer playing the role of a guest during verification of the service.

Meanwhile, on the assumption that this configuration would be insufficient to provide service to guests in general, a trained, dedicated staff member was deployed to provide a thorough operation. In other words, it was decided to handle the following items with people during verification of the service, and these items were identified as issues for complete automation in the future.

- Shore up functionality of the reception interface at the robot home.

Automate responses to questions from guests who do not understand the digital signboard, display of service wait time during busy periods, and explanation of how to use the touch screen.



Fig. 15 On-site simulation at Narita Airport

- Simplify the work of dedicated staff.
Automate or digitize daily routine work such as charging guide robot batteries, understanding when to check and maintain the consumables of both robot types, record keeping, etc.
- Expand functionality of guide robot body surface.
Add an interaction interface so that the guide robot can respond to inquiries from the guest being guided as well as other pedestrians in the area while navigating.

8. Conclusion

Development of a new robot system is useful not only to Honda but also to its joint research partner Narita Airport, and a new form of robot service that can fulfill an active role at airports was designed while recognizing the need to create satisfaction for pedestrians. The concept of a Compass to Accompany was established, and on that basis a reception robot and guide robot with approachable and functional designs were created.

An airport guide robot system was constructed with a management system that links these two types of robots, and the system feasibility was verified in Narita Airport amidst pedestrian traffic.

As a result, knowledge necessary to have advanced robots that fulfill a role at an airport offer continuing service was gained.

9. Afterword

Public facilities such as airports and service facilities such as restaurants are striving on a daily basis to technically address issues related to workforce reduction and enhancement of efficiency across a wide range of operations. Under these circumstances, robotics technology has become all the more important due to changes in our living situations, and a landscape in which robots perform work and have a natural role to fulfill is fast becoming a reality.

There are many challenges to realize autonomous navigation robots actually working while coexisting with people. However, what is needed to achieve this is not repeated demonstrations, but rather to identify issues arising from actual use of robots in the field and the achievement of social acknowledgment by repeatedly verifying measures to address those issues.

Going forward, the knowledge gained from this development effort will be utilized in continuing initiatives to achieve the Honda goal of realizing a robotics society that will further highlight the inherent greatness of human beings.

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■ Author ■



Yoko SAITO



Takeshi KOSHIISHI