

Honda RaaS Platform

Honda Robotics as a Service Platform Integrates Cloud and Robot Technology

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ABSTRACT

Honda Robotics as a Service Platform is a platform for the purpose of developing and operating robotics services.

In terms of development and operation for the purpose of establishing such services, past verification tests of delivery service using ASIMO identified issues for further work that required investigation relating to the network, the creation of testing environments, the development and operational environments, and the establishment and expansion of service.

Regarding each of the above issues, the Honda RaaS Platform can enhance the development and operation of robotics services by providing for a secure communication environment and expansion of the operating area by means of SIM, a scalable infrastructure environment using the Cloud, a development and debugging environment that is network accessible, an operational environment that enables remote monitoring, and an environment for establishment and expansion of service by API provision.

In addition to showing the architecture and interface of the Honda RaaS Platform, the concept of “collaboration of diverse talents all over the world” was also proven by case examples of a series of delivery services that create collaboration and coordination by multiple different robotics devices.

1. Introduction

Looking ahead to the year 2050 when Honda passes the centennial of its founding, the company formulated the 2030 Vision in 2017⁽¹⁾. This makes a statement, which is, “Serve people worldwide with the ‘joy of expanding their life’s potential’: Lead the advancement of mobility and enable people everywhere in the world to improve their daily lives.”

The Honda Robotics as a Service (RaaS) Platform was proposed in 2017 as a theme that would provide one means of realizing that vision in material form by taking steps to strengthen the company’s capability for creating solutions; not only in hardware, where Honda had for a long time boasted particular strengths in a wide range of Mono-zukuri (creating things, i.e. high-quality manufacturing), but also including Koto-zukuri (creating experiences) by means of software. The role this would play at Honda would be to aggregate the results of advanced research and development on various algorithms and applications within the company in reusable form, combined and organized to be of use to people worldwide. In doing so, it would heighten the value and importance of software throughout the company.

2. Robotics Vision

The history of robot development at Honda started in 1986 with research and development on bipedal walking (Fig. 1). Honda Robotics is the collective name for robotics technology produced from research on humanoid robots, exemplified by ASIMO, together with products for practical application. In parallel with that thrust, the development of ASIMO also involved the development of integrated control systems for the automation of reception desk and delivery service functions. The aim was to realize “a robot that can coexist with and assist people in society^{(2), (3)}.”



Fig. 1 Honda Robotics history

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In 2018, Honda announced a new vision of robotics that aimed to realize a “human-centered intelligent robotics society.” This was announced together with the concept of “3E,” which stands for “Empower, Experience, Empathy” (Fig. 2)⁽⁴⁾.

“Empower” in the 3E concept means that people and robotic devices work cooperatively in their respective areas of particular strength to provide people with an extra margin of capability in terms of their time, psychological state, and bodily state. People can then turn that extra capability in new directions to expand their own possibilities. “Experience” means that people experience entirely new things through robotics to enable them to grow. Robotic devices will also learn from people and grow in themselves to become better able to serve people. “Empathy” is a conceptual approach according to which robotic devices will care about people, empathize with them, and provide support for what people do.

It is clear, therefore, that “artificial intelligence that cooperates with people” will be a crucial factor in realizing the 3E concept.

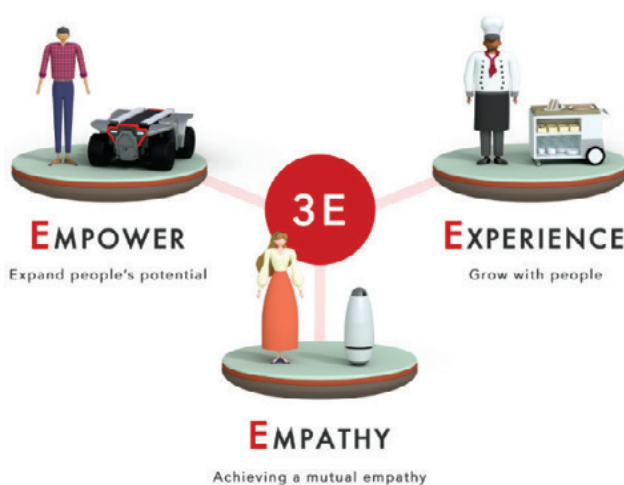


Fig. 2 3E concept

3. Robotics as a Service: RaaS

RaaS is generally considered to mean providing robotic functionality by means of the cloud. This approach seeks to have the burden of high-load processing taken on in the cloud environment so that the processing burden on the robot side can be lessened (off-loaded). Honda further reasons that making use of RaaS will bring the three main advantages shown below:

- (1) Increased efficiency in development and operation of common management for robots;
- (2) Flexible cost management according to robot operating circumstances; and
- (3) Continuous updating for new functions.

In (1), the basic functions for implementing robot management and operation are made common functions that are reusable. This enhances the efficiency of robot service development and operation.

In (2), RaaS makes it possible to charge according to the service used and so on, for example by calculating the cost just for the portion of a service that utilized a robot.

In (3), the software in the robot and in the cloud can be updated continuously so it is kept up to date. This makes it possible to respond flexibly with robotic services that address customer needs and requests.

4. Concept of Honda RaaS Platform

Having a multiplicity of different, human-centered robots cooperate and coordinate is a crucial factor in realizing the Robotics Vision. The capability to seamlessly link together systems and robots that are not just from Honda but also from various development partners is key. Honda announced its RaaS Platform Concept at CES 2019 as the base system for realization of the “human-centered intelligent robotics society” that is the Robotics Vision as well as of the 3E concept and cooperative intelligence (CI)⁽⁵⁾.

The Honda RaaS Platform is intended to ease the development and operation of robotic services. It does this by providing data accumulation and sharing, communication control, state transition management, cooperation among robots, and other such common functions by means of an interface, which is the application programming interface (API), or as a software development kit (SDK) (Fig. 3).

The Honda RaaS Platform also involves the concept of “collaboration of diverse talents all over the world.” This concept aims to realize services that a single robot cannot provide by linking together robots and systems that have various different roles and functions and causing them to work together cooperatively. In other words, the goal that should be aimed for is to work together with various robot manufacturers, service integrators, and so on to cultivate platforms while also building arrangements to enable mass production of robotic services by large numbers of people⁽⁵⁾⁻⁽⁸⁾.

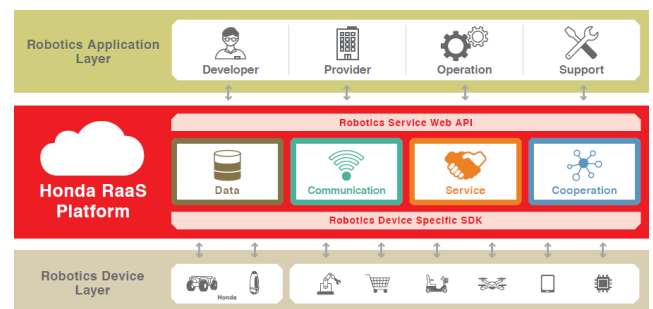


Fig. 3 Honda RaaS Platform conceptual diagram

Issues for enhancement of the network will be addressed by implementing cellular communications using SIMs provided for the robots by the Honda RaaS Platform, following the approach in item (1) above, so that they can also communicate in other than the WiFi domain. This will enable the robots to connect with the network in various locations both indoors and outdoors, allowing the operating area to expand. The SIM information for each robot will also be used to implement device authentication, and the ability to communicate over cellular circuits, without passing through the Internet, means that secure communication between robots and the cloud can be established. Secure communication on the Honda RaaS Platform is capable of covering both WiFi communication and cellular communication by SIM. In the case of WiFi, security is enhanced when communicating over the Internet by using security tokens issued by the Honda RaaS Platform that are needed for authentication.

Issues for enhancement related to the creation of testing environments were addressed by the approach in item (2) to provide an infrastructure environment that uses a cloud environment to enable the increase of dynamic computational resources and distribution of loads (i.e. is scalable) according to processing capability. If a web browser is available, then it will also be possible to access the web GUI of the Honda RaaS Platform from any terminal and easily carry out registration and management of the robots at each center without having to log on individually to each server.

Issues for enhancement of the development environment were addressed by the approach in item (3), which makes it possible to conduct quick and continuous development and modification by making newly developed software available over the network in a form usable by the robots. The developers will also be able to log on to a robot remotely by means of its SIM from any terminal. This will allow them to change its configuration and access the robot's log for debugging.

Issues for enhancement of the operational environment were addressed by the approach in item (4), which allows operators to remotely check and monitor the robot's

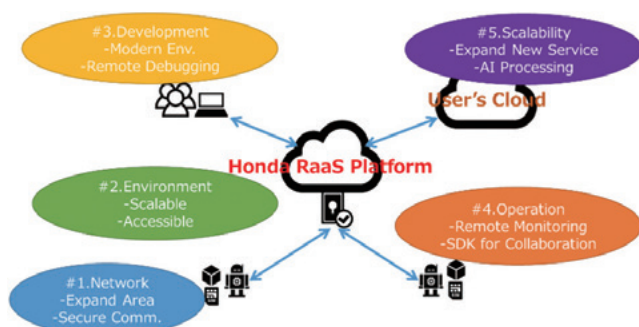


Fig. 6 Approach of Honda RaaS Platform

operating circumstances from a remote location, thereby enabling efficient batch monitoring. The operational environment can also be linked with various external systems by means of Web API and SDK.

Issues for enhancement with regard to the costs of establishing services were addressed by the approach in item (5), whereby the Web API provided by the Honda RaaS Platform is used to link together the cloud environment of the user (hereafter, User's Cloud) and the system, allowing expansion of robotic service functionality. In this way, the core functions provided by the Honda RaaS Platform can be augmented by developing new functions, expanding existing services, and so on. This also makes it possible for high-load processing, such as machine learning, AI processing, and other processing that cuts across multiple systems to be off-loaded to the cloud environment (distributing the load). Doing so expands the possibilities for realizing various use cases, such as, for example, when searching for a specific person in order to go outside to greet that person, which involves linking to external systems to acquire information on the location of the specific person.

6.1. Roles of the Honda RaaS Platform

One of the main roles of the Honda RaaS Platform is to grasp the state of connected robots and to issue instructions by appropriately distributing tasks among them. For example, in the case of the tea delivery service, the platform takes on the role of task management and instruction control for each robot during the process of executing the overall scenario. As each robot receives task instructions from the Honda RaaS Platform's task management and instruction control, the robots perform the tasks involved, such as loading the tea, transporting the tea, and so on. All of the tasks are managed by the Honda RaaS Platform, and the status of task execution can be checked by developers and operators through the Honda RaaS Platform's Web GUI screen (Fig. 7).

The Web GUI screen of the Honda RaaS Platform consists of a map showing the current locations of the

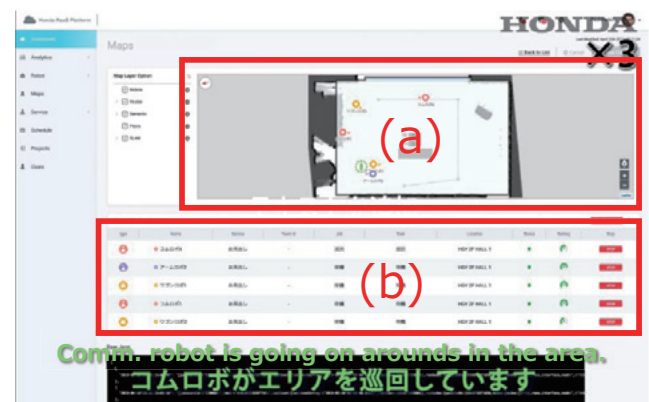


Fig. 7 Web GUI configuration

robots [Fig. 7(a)] and a robot list showing the current status of the robots [Fig. 7(b)].

The robot list provides for control of the status of robot tasks and so on. When there is an update to a task, the line for the robot concerned flashes blue and blinks at the same time that the task update takes place. After the communication robot receives an order for tea, for example, the figure here shows how the wagon robot's task is updated by the Honda RaaS Platform from stand-by to delivery (Fig. 8).

6.2. Image of Overall Function

The image here summarizes the overall function of the Honda RaaS Platform used for the delivery service (Fig. 9).

- (1) Secure communication with authentication by SIM and TLS protection
- (2) Transfer robot data to the User's Cloud environment
- (3) Enable visualization of robot task status and location information
- (4) Create service scenario applications using API

6.3. Architecture and Interface

The diagram of the architecture shown here should help give an overall understanding of the Honda RaaS Platform (Fig. 10). The Honda RaaS Platform is made

up of three layers, which are the infrastructure service layer, the application service layer, and the interface layer. The functions implemented on the infrastructure service layer mainly involve networks and authentication. The application service layer has implementations of various applications related to functions needed by the Web API and Web GUI.

The explanation here will be related primarily to the interface layer. In the interface layer, robots are provided SIM and cirobot-sdk as interfaces that enable the robots to use the Honda RaaS Platform. Robot developers can connect the robots they are developing with the Honda RaaS Platform by inserting a SIM and installing cirobot-sdk, which is an SDK implemented in the programming language python. cirobot-sdk mainly provides functionality relating to communication, and it is software that conceals the authentication and communication protocols (HTTP, MQTT, and so on) between Honda RaaS Platform and the robot. It also provides RosNode, which is geared to use with the robot communication middleware ROS⁽⁹⁾. Equipped in this way, robot developers who use ROS can engage in ROS Topic communication and programming for the purpose of linking and coordination with other robots that are connected to the cloud without having to be any more aware of the cloud than necessary.

The User's Cloud is provided with Web API and ciraas-sdk (a python client application). Service integrators can use Web API and ciraas-sdk to build robotic services. The data that the Honda RaaS Platform receives from robots is transferred to stream services on the User's Cloud. On the User's Cloud, users can freely utilize the Honda RaaS Platform Web API to build applications. The Web API is designed as the REST API, which is an HTTP interface with web systems. ciraas-sdk provides functionality for dialogic programming on the User's Cloud.

Client systems for operation on the PCs, tablets, or other such operator equipment are provided with Web GUI as an interface. Operators who want to use an operational environment can access Web GUI from a device of their own choosing, allowing them to monitor operation while tracking robot registration and location or other such information.



Fig. 8 Honda RaaS Platform sends task

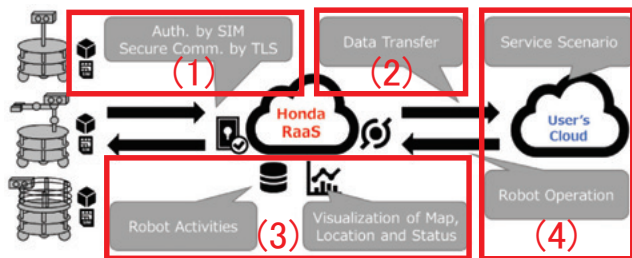


Fig. 9 Overall function

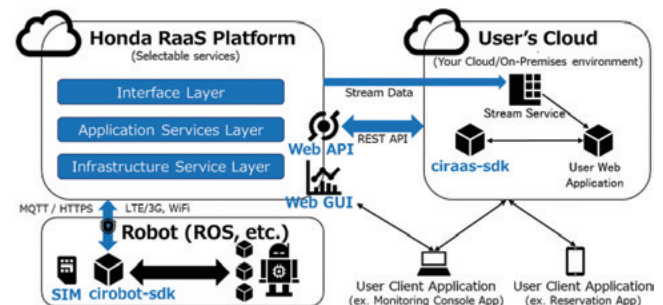


Fig. 10 System architecture diagram

6.4. Methods for Creating Robotics Services

Engineers wishing to create robotic services who are users of the Honda RaaS Platform need to prepare a User's Cloud and mount applications on it. As an example, a case of robotic services created using the cloud environment of Amazon Web Services (AWS)⁽¹⁰⁾ as the User's Cloud is shown below (Fig. 11).

The AWS data transfer service called Amazon Kinesis Data Streams⁽¹¹⁾ is used in order for the User's Cloud side to receive the data stream uploaded from the robot. For a scenario like the tea delivery service here, programming is done using a service called AWS Lambda⁽¹²⁾ that enables simple creation of applications to run in AWS.

Using these resources, AWS engineers can readily implement scenarios for robotic services. Beyond tea delivery, reception services, guide and information services, and other such robotic services can be built.

6.5. Scalable Architecture

The Honda RaaS Platform is built in the AWS environment (Fig. 12). The components of Honda RaaS Platform that perform particularly crucial core functions are Robot Manager, Authentication Manager, and Object Manager.

The Robot Manager performs management of robot registration information. The Authentication Manager manages authentication of robots, and the Object Manager performs management of data. Through these components, robot managers are able to access the Honda RaaS Platform's Web Console (the GUI for managers) and carry out management tasks such as adding and deleting robots. In addition, the robot operators can carry out operation of

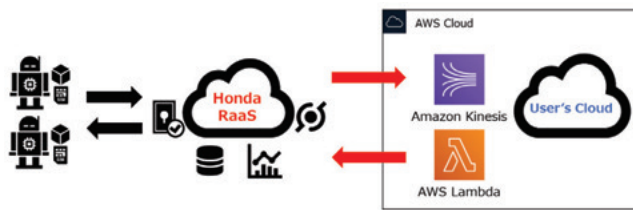


Fig. 11 How to build robotics service on AWS

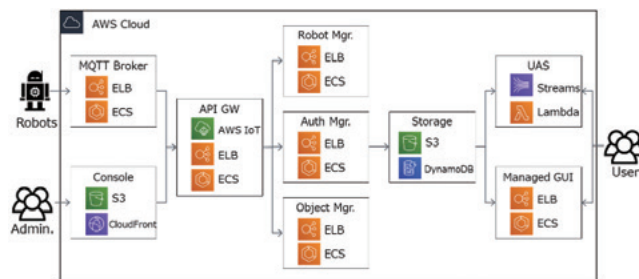


Fig. 12 Cloud architecture diagram

robotic services by accessing the Managed GUI (Web GUI).

The Honda RaaS Platform is envisioned as providing access for various robots in various locations simultaneously and in parallel. For components that are likely to experience concentrated access, provision is made for autoscaling by means of Elastic Load Balancing (ELB)⁽¹³⁾, which automatically distribute the traffic load, and by means of the Docker environment, which is a container management tool configured on the virtualization service known as the Amazon Elastic Container Service (ECS)⁽¹⁴⁾.

6.6. API and Use Cases

As examples of API provided by Honda RaaS Platform, the State API and Object Storage API are shown below together with use cases of the utilization of these respective APIs.

6.6.1. State API

Using the State API allows one to configure and acquire the robot's state. Use cases include acquiring robot battery information and setting tasks for the robot.

State API can be used with robots, as shown below in Fig. 13, to transmit the robot's battery information by means of the Honda RaaS Platform to the User's Cloud. Here, the value of "20" (meaning 20%) is being transmitted under the "battery" key. The data is transferred using cirobot-sdk and transmitted by MQTT, which is a lightweight communication protocol [Fig. 13(1)]. The value transmitted by the robot {"battery":20} is stored in the database on Honda RaaS Platform [Fig. 13(2)]. Next, the information is transferred by means of the Honda RaaS Platform to the Amazon Kinesis Data Streams in the User's Cloud [Fig. 13 (3)].

The flow for setting a robot task from the User's Cloud is shown in Fig. 14. Here, the remaining battery charge is considered to have diminished to 20% according to the battery information in Fig. 13, so that the robot is being issued the task to move to a charging station. The data transfer is carried out by the HTTPS protocol [Fig. 14(1)]. The value {"battery":20,"task": "GoToStation"} is transmitted from AWS Lambda, which has been programmed in the User's Cloud, and this value is stored in the database on the Honda RaaS Platform [Fig. 14(2)]. The value for the task instruction is then transferred to the robot

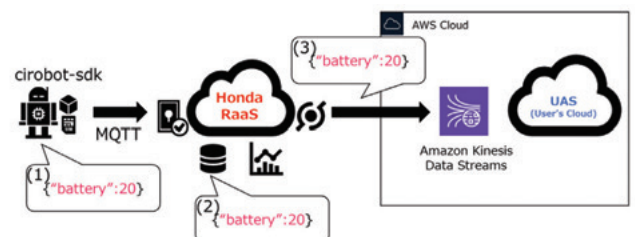


Fig. 13 Battery notification from robot with State API

by means of the Honda RaaS Platform using the MQTT protocol [Fig. 14(3)].

By using the State API in Figs. 13 and 14, the robot's state can be set and acquired. The state of the robot is constantly being managed on the Honda RaaS Platform. This is realized by implementing a mechanism called robot shadow, which synchronizes the robot state with the cloud. In this way, the robot and cloud are kept appropriately synchronized with regard to the robot state and management is possible (Fig. 15).

6.6.2. Object Storage API

The use of Object Storage API enables high-volume bidirectional data transfers between the robot and the Honda RaaS Platform. The use case shown here is the distribution of map data from the User's Cloud to the robot (Fig. 16).

In order to have mobility in an actual space, the robot requires robot-usable map data. However, as map data is ordinarily large in size, it is handled using batch management. Here, the map data is considered to have been uploaded to the User's Cloud environment in advance so

that it is available to be distributed to the robot as common data [Fig. 16(1)].

Map data is transferred to the Honda RaaS Platform from AWS Lambda in the User's Cloud environment by HTTPS protocol using the Object Storage API [Fig. 16(2)]. The Honda RaaS Platform stores the transferred map files in a database [Fig. 16(3)].

At this point the Honda RaaS Platform issues a download URL for the map data to the specified robot by MQTT protocol [Fig. 16(4)].

The robot can download the map data by means of the HTTPS protocol by whatever timing is safe for the robot. For example, it may do this when it has returned to a charging station [Fig. 16(5)].

The robot is constantly engaged in various kinds of processing, such as moving while avoiding obstacles. If the Honda RaaS Platform were to simply break in and distribute a large amount of map data, therefore, it could affect an already ongoing process. Using the Object Storage API in the way illustrated here, however, enables distribution of large amounts of data to the robot in safety.

7. Demonstration Cases

The following shows cases of demonstrations using the Honda RaaS Platform.

7.1. Disassembling and Rebuilding Services

The purpose here is to demonstrate the concept of "collaboration of diverse talents all over the world" by means of the Honda RaaS Platform linking and coordinating a multiplicity of different robotic devices. The example implemented here is a tea delivery service that serves as a case of services built to be provided in a seamless sequence.

The first step was to take the tea delivery service implemented in the past by ASIMO and to disassemble it into three standalone services (Fig. 17), which are:

- (1) Service that receives the order (the communication robot is in charge of this);
- (2) Service that loads the tea (the arm robot is in charge of this); and
- (3) Service that delivers the tea (the wagon robot is in charge of this).

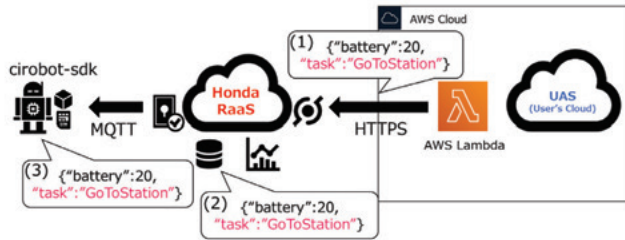


Fig. 14 Set task with State API from User's Cloud

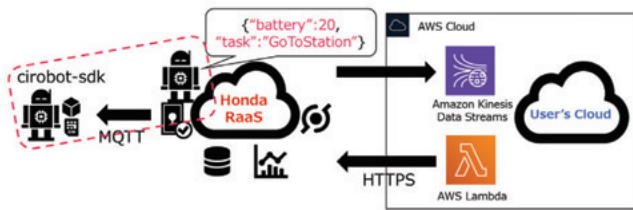


Fig. 15 State synchronization with robot shadows

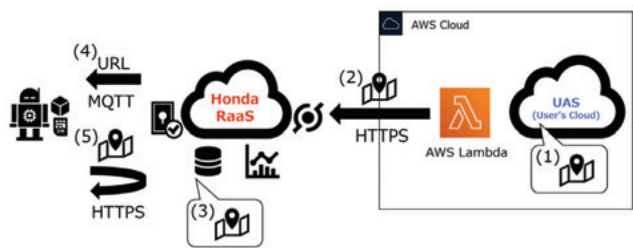


Fig. 16 Map distribution using Object Storage API

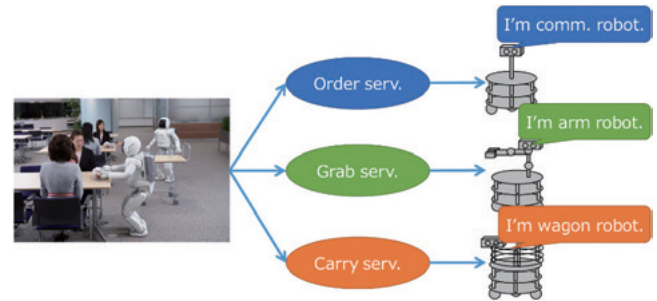


Fig. 17 Assigning role for each service to robot

In past verification tests, everything was done by a single ASIMO unit. With the services disassembled into three, however, the tea delivery service was rebuilt as a sequence of services that link and coordinate three robot units that have different roles. The next step was to install a SIM and SDK in each of these three robots and connect them with the Honda RaaS Platform. In addition, developers and operators were enabled to access the Honda RaaS Platform by means of the web from any terminal.

An environment was, therefore, built that enabled both robots and people to access the Honda RaaS Platform. In this way, a fusion of the cloud and robotic devices was achieved that has the capability to realize services in an integrated manner by enabling management of all the robots on the Honda RaaS Platform and by enacting implementation and control on the cloud of scenarios for realizing robotic services (Fig. 18).

7.2. Distribution of Operations for Each Service

Verification tests were conducted of the tea delivery service that coordinates a multiplicity of different robots using the Honda RaaS Platform.

The figures below illustrate the implementation of services divided into three, namely the service that receives orders (Figs. 19-20), the service that loads the tea (Figs. 21-22), and the service that delivers the tea (Figs. 23-25).

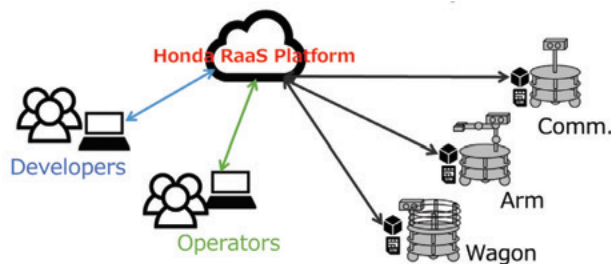


Fig. 18 Fusion of cloud and robotics device



Fig. 20 Acceptance of service request



Fig. 21 Start the task of grabbing tea



Fig. 22 Grab tea up and give to wagon robot



Fig. 19 Request tea delivery service



Fig. 23 Deliver tea to staff seat



Fig. 24 Tea delivery notification by communication robot



Fig. 25 Staff member receives tea

8. Issues for Future Investigation

The realization of a networked robot system by which multiple robots linked together in the same environment provide services requires adjustment of the tasks of each robot, their routes of movement, and their coordinated scenario⁽¹⁵⁾.

It is also the case that robotic services realized by means of the Honda RaaS Platform will utilize SIMs and a cloud environment. Consequently, modification of the design of system architecture and adjustment of resource allocation is expected to be necessary in order to realize services across a broad range of varying environments both indoors and outdoors.

For example, when searching for a person outdoors, the system will have to acquire imagery from many robots and IoT cameras, recognize and identify the person on the cloud, and calculate the optimal route to that person's location from various environment data, map data, and other such information. This involves high-load processing. However, the robot with the role of finding the person only needs to perform the low-load process of receiving that location information and moving there according to the given route. It is conceivable that processing loads will be adjusted in such ways.

The computational resources available for use in the cloud environment are abundant by comparison with the limited hardware resources internal to the robot. Since communication occurs between the robot and the cloud, however, real-time immediacy is lost. On the other hand, even though engaging in processing with the robot's internal hardware resources provides a high degree of real-time immediacy and responsiveness, there is a trade-off due to the constraints on the computational resources.

It is necessary, therefore, to design the system architecture with attention to how the computational resources are to be assigned in a balanced manner according to the use cases.

As a general guideline, when complex computation is required, as, for instance, in the case of computation of scenario control extending across multiple robots, or in that of computation of the destinations to which robots are moving in a large-scale perspective, then the abundant computational resources on the cloud will be utilized. When more immediate, real-time processing is necessary, as, for instance, in the case of detecting and avoiding obstacles, or in that of interactions with people, it will be considered desirable to perform processing on the robot side (Fig. 26).

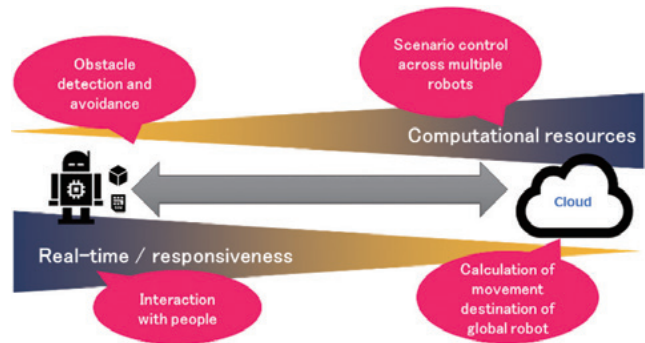


Fig. 26 Role sharing between robot and cloud

9. Summary

Honda RaaS Platform is a platform for the purpose of developing and operating robotic services.

In addition to describing the architecture and interfaces of the Honda RaaS Platform, this paper has presented a demonstration case of the concept of “collaboration of diverse talents all over the world” realized by linking and coordinating a multiplicity of different robotic devices to perform a sequence of delivery services.

This paper demonstrates that adoption of the Honda RaaS Platform can enhance the development and operation of robotic services (Table 1) by means of SIM to enable expansion of the operating area and provide a secure

Table 1 Comparison of enhancements

No.	Issues	Previous (ASIMO)	Present (Honda RaaS Platform)	Effect
1	Network security	Per-network authentication	Device authentication by SIM	Secure communication to cloud
2	Experimental environment	Complex individual construction	Build on cloud environment	Provide scalable environment
3	Development environment	Physical update	Update via remote	Enable agile development
4	Operation environment	Human operation at each site	Remote central operation	More efficient remote monitoring
5	Service scalability	Individual implementation	Utilizing common API	More efficient development

communication environment, a scalable infrastructure environment that uses the cloud, a development and debugging environment that is network accessible, an operational environment capable of remote monitoring, and, by means of API provision, an environment for the establishment and expansion of service.

Going forward, it will be necessary to further enhance the functions and tools required for the development and operation of robotic services by verification tests for a variety of different use cases. In order to enable handling use cases in a variety of indoor and outdoor areas, it will also be necessary to continue modifying the design of the system architecture to make it capable of using 5G networks and flexibly distributing resources between the robot and the cloud.

10. Conclusion

In a first for Honda, the company has globally disseminated content that constitutes a “software platform.”

In order to realize the 2030 Vision and the Robotics Vision declared by Honda, it will be important to build an ecosystem not just by the efforts of this company alone, but together with a variety of partners. For that purpose, the Honda RaaS Platform needs to be made known to a variety of engineers and professionals not just in the field of robotics, but also in the cloud and IoT. With the benefit of their fellow feeling and cooperation, growth toward the goal will be possible together.

It is to be hoped that this paper will help to bring about concrete progress with the Honda RaaS Platform as a “collaboration of diverse talents all over the world.”

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