Development of Smart Device Interlocked Robot Partners for Information Support and Smart Recommendation

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***Abstract*— Recently, various types of communication robots have been developed all over the world to make up for a lack of human labor. The purpose of communication robots is to provide services such as information support including facility guide and recommendation at airports and shopping centers, nursing homes for elderly people. In general, the effective integration of various modules is important to aim for rapid practical application in an aging society. However, it takes much cost to introduce communication robots because of software customization and contents design for information service in addition to the maintenance cost of software and hardware. Furthermore, we have to pay attention to safe physical interaction and considerable communication of communication robots with people. In this paper, we develop a robot partner for information support and propose a new method to recommend various information flexibly according to human intention.**

Keywords*— *robot partners, communication robot, information support, recommendation

I. Introduction

In recent years, many service robots that can provide people with guidance, customer service, security, etc., instead of human workers, have been developed in addition to industrial robots used in manufacturing sites. With the labor shortage due to the declining birthrate and aging population, the demand for service robots that provide services such as guidance and customer service is expected to increase furthermore. In fact, various types of communication robots [1,2] have been introduced at airports and hotels, etc. For example, "Jibo" robot was developed to make a variety of emotional interaction and communication with users [3]. As another example, "Pepper" was the humanoid robot which can perceive humans emotional states [4]. The purpose of communication robots is to provide services such as information support including facility guide and recommendation. However, it takes much cost to introduce communication robots because of software customization and contents design for information service in addition to the maintenance cost of software and hardware. Furthermore, we have to pay attention to safe physical interaction and considerable communication of communication robots with people.

This paper proposes an interactive information support system using smart device interlocked robot partners with a new hardware platform in order to improve the quality of safe physical interaction and considerable communication. We assume that a developed smart device interlocked robot partner is used to advertise amenities and opportunities in a specific area. In fact, local business including shops and restaurants around a hotel can be promoted by the robot partner. The main aim of the proposed interactive information support system is to provide guidance to the facilities of a hotel and to recommend restaurants and sightseeing spots near the hotel like a smart concierge flexibly according to the requests and preferences of the visitors. Basically, an interactive support system is composed of informationally structured space servers and robot partners as a basic platform [5]. The robot partners perform communication and interaction through voice recognition and gesture recognition in addition to the touch interface. The informationally structured space server selects and recommends the shops, restaurants, and sightseeing spots.

This paper is organized as follows. Section 2 describes the smart device interlocked robot partners: iPhonoid. Section 3 proposes an interactive information support system including an utterance system. Section 4 proposes a smart recommendation system. Section 5 discusses the future direction of this research.

II. Robot Partner : iPhonoid

Based on various needs for robots in recent years, it is important for robot development to consider various services such as service design for robot development and customization for users. Therefore, we should conduct needs analysis, components development, platform design for systems integration, and communication contents design for the experience to develop a service robot as a holistic system.

We have been developing on-table small size robot partners called iPhonoid (Fig. 1) [6-8]. Since an iPhone is equipped with various sensors such as gyro, accelerometer, ambient light sensor, touch interface, compass, cameras, and microphone, it is enough to interact with the user. The robot is equipped with Arduino, and the motor is controlled by sending a signal from the smart device via the Arduino. The robot body is manufactured using a 3D printer, and it is possible to design the robot flexibly according to the service scenes. The advantages of using a smart device for a robot are in the easy customization and update of different components that can be selected according to the purpose. Furthermore, the content for information service can be easily rewritten by updating the data file, and the cost of the robot can be reduced by incorporating a sensor.

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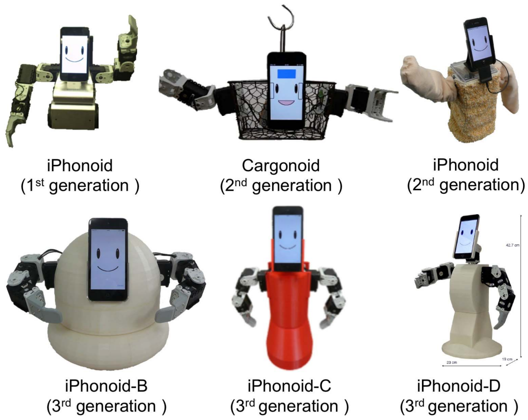


Fig. 1 Robot Partners : iPhonoid

Table 1 Basic Specification

Size	H200mm W220mm D180mm
Mass	1.1kg
Degree of freedom	neck : 1 arms 1 × 2
Micro computer	Arduino Uno
Basic function	speech recognition, speech synthesis, image processing
Input	DC24V

III. INFORMATION SUPPORT OF ROBOT PARTNERS

A. *Development of iPhonoid-DD*

First, we have to consider a hardware design for the communication robots that require interaction with users, such as information support and nursing care support. Especially, a problem on motor driving noise during gestures can be an adverse effect of interaction with users. The current robots that we were developing also have loud motor sounds during gestures, and we received some reports that some users felt uncomfortable in the interaction and communication with them. Therefore, we develop a new hardware platform for a robot partner using a direct drive motor (DD motor) developed by Microtech Laboratory Inc. [9] for the drive units of the neck and both arms with 3 degrees of freedom. Compared with conventional DC motors, DD motors can be driven while maintaining high torque more silently, than can drive at the sound level of approximately 28 dB.

Table 1 and Fig. 2 show the general view of the developed robot and the basic specification of the robot. The shape of the robot was manufactured with a 3D printer, and the cooperative control of the motor is performed using Arduino Uno. Smart devices can be mounted vertically or horizontally. Communication between the smart device and Arduino Uno is performed by Bluetooth. Fig. 3 shows the communication system for motor control.

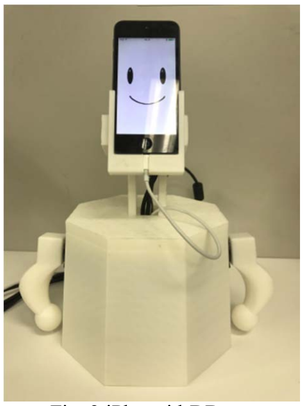


Fig. 2 iPhonoid-DD

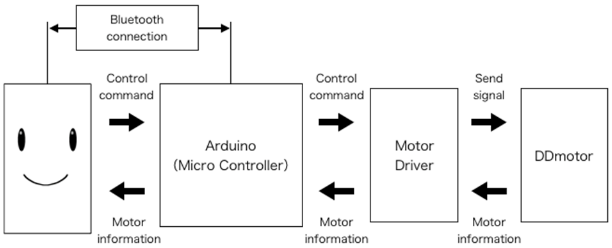


Fig. 3 Communication System for Motor Control

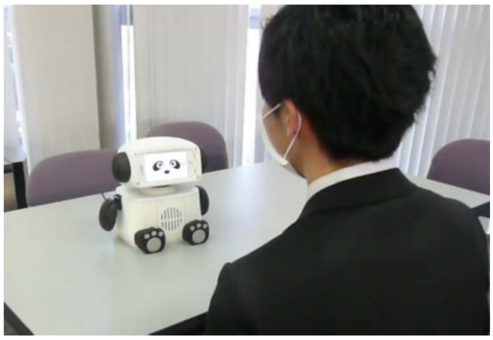


Fig. 4 Example of Providing Information Support

B. *Conversation System*

Service engineering and service science have been discussed to realize sophisticated services [10]. The importance of a service is not just in realizing high-performance functions, but in satisfying the expectation of guests and users. The value of service that providers expect is maximal money that the guests can pay, while the value of service that guests expect is the maximal quality and surprise that the providers can give. The essence of a service is not what is to be provided, but how to provide it.

Robot partners can be used for information support in different types of events and facilities (Fig. 4). In this study, we apply robot partners as a communication and recommendation system for visitors and guests in a hotel like a concierge. A hotel concierge can provide visitors with various types of information support to visitors and guests, e.g., by recommending restaurants, shops, and sightseeing spots according to their needs and preferences.

Fig. 5 and Table 2 show the overall architecture of the developed system. The robot partner is composed of hardware components such as the actuator unit, microcontroller unit, and power supply unit in addition to a smart device. We prepared the perception unit, gesture control unit, utterance unit, and database unit as the software components.

We use MySQL [11] to manage the database. We prepared two tables for utterances (U-DB) and logs (L-DB) (Fig. 6). U-DB includes sentences for utterance, the button titles to be displayed on the screen of the smart devices, and motion data to be used as gesture, while L-DB includes sentence data used by the robot partners, the language type selected by the users, and voice recognition results.

Fig. 7, Fig. 8 show the basic conversation flow and its corresponding scene transition. The scene transition can be performed using either voice recognition or touch interface, but the basic information support is done by the robot utterance, and the information on sightseeing, shops, and restaurants is provided through QR code.

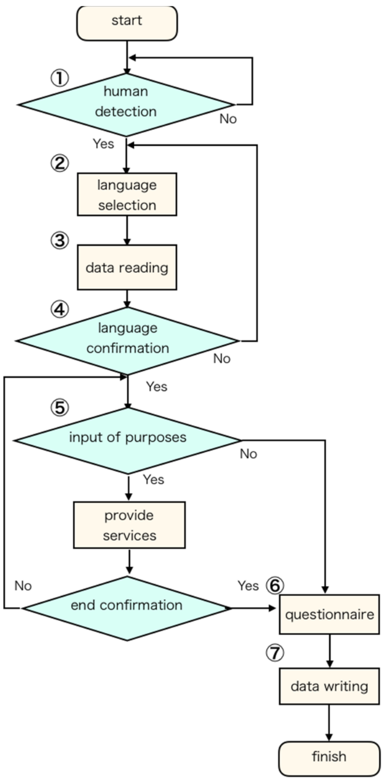
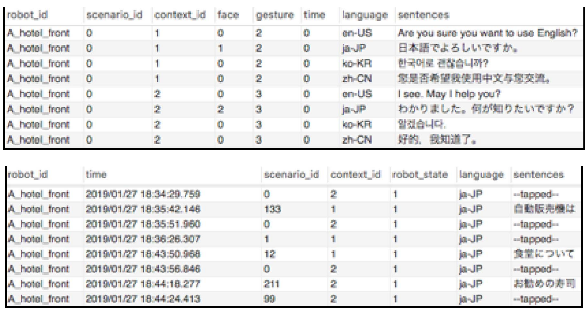


Fig. 5 Basic Conversation Flow



robot_id	scenario_id	context_id	face	gesture	time	language	sentences
A_hotel_front	0	1	0	2	0	en-US	Are you sure you want to use English?
A_hotel_front	0	1	1	2	0	ja-JP	日本語でよろしいですか。
A_hotel_front	0	1	0	2	0	ko-KR	한국어로 괜찮습니까?
A_hotel_front	0	1	0	2	0	zh-CN	您是否希望我使用中文与您交流。
A_hotel_front	0	2	0	3	0	en-US	I see. May I help you?
A_hotel_front	0	2	2	3	0	ja-JP	わかりました。何が知りたいですか？
A_hotel_front	0	2	0	3	0	ko-KR	알겠습니다.
A_hotel_front	0	2	0	3	0	zh-CN	好的，我知道了。

robot_id	time	scenario_id	context_id	robot_state	language	sentences
A_hotel_front	2019/01/27 18:34:29.759	0	2	1	ja-JP	--tapped--
A_hotel_front	2019/01/27 18:35:42.146	133	1	1	ja-JP	自動販売機は
A_hotel_front	2019/01/27 18:35:51.960	0	2	1	ja-JP	--tapped--
A_hotel_front	2019/01/27 18:36:26.307	1	1	1	ja-JP	--tapped--
A_hotel_front	2019/01/27 18:43:50.968	12	1	1	ja-JP	食堂について
A_hotel_front	2019/01/27 18:43:56.846	0	2	1	ja-JP	--tapped--
A_hotel_front	2019/01/27 18:44:18.277	211	2	1	ja-JP	お勧めの寿司
A_hotel_front	2019/01/27 18:44:24.413	99	2	1	ja-JP	--tapped--

Fig. 6 Utterances-DB (upper) and Logs-DB (lower)

Table 2 Configuration of the Robot Partners

	Event	Process
(1)	Human detection	We use CoreImage in CIDetector class of Image Processing Flamework provided by iOS SDK. If a person is detected, the robot partner exchanges greeting with the detected person
(2)	Language Selection	A communication language is selected by the result of voice recognition through the greeting, or touch interface on the screen.
(3)	Data Reading	Selection of suitable utterance sentences from U-DB
(4)	Language Confirmation	Choice of user language
(5)	Inputs of Purposes	Selection by buttons of 4 items.
(6)	Questionnaire	Selection by the buttons on user’s satisfaction for evaluation of the system.
(7)	Data writing	Update of L-DB using the above logs.

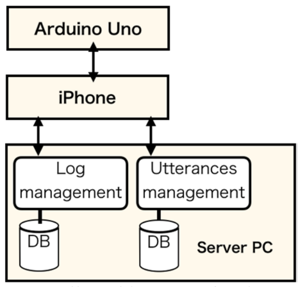


Fig. 7 Overall Architecture of Robot Partner

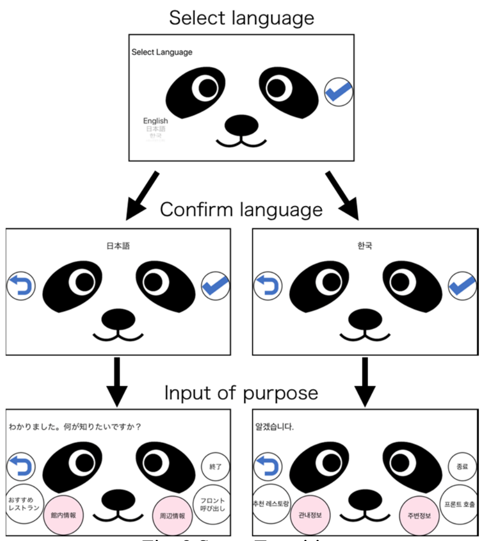


Fig. 8 Scene Transition

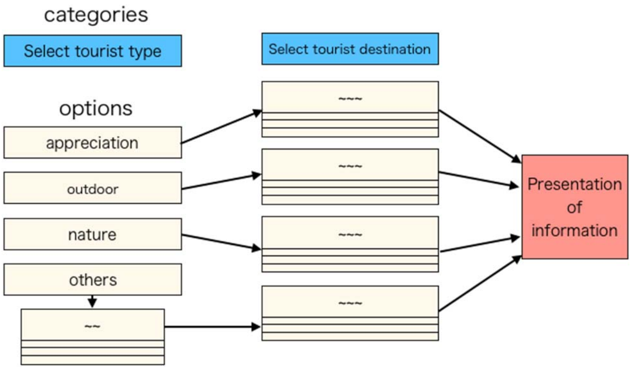


Fig. 9 Example of Conversation Flow

IV. Smart Recommendation Systems

A. Recommendation of Robot Partners

The main requirements for information support in this study are devided into (1) regular tasks in a predetermined format, and (2) tasks dependent on uncertain or unclear requests of individual users. A robot partner can easily deal with (1) regular tasks in a predetermined format. On the other hand, it is relatively difficult for a robot partner to deal with (2) dependent on uncertain or unclear requests of individual users. Today, as information and communication technologies have been developed, the value of services that provide users with "clear answers" like information guidance based on Q&A, has become lower than before, because intelligent devices such as smart speakers are available everywhere. On the other hand, the value of service to deal with "ambiguous questions" have become more important. An excellent concierge is very good at responding to "ambiguous questions" based on information about the uncertain and unclear requests from the users. Nowadays, such a recommendation system is required for robot partners.

B. Dynamic Conversation Flow

In the developed information support robot, the conversation flow from the start to the end of the guidance is programmed in advance, and the conversation proceeds as the user selects each option. However, this system is difficult to meet the needs of all users, and some users feel like a predefined regular work. If a system that guides the user while dynamically changing the conversation flow according to the needs of the user and the environment can be created, a better response like an excellent concierge can be realized. In this section, we consider a method to realize such a smart recommendation system with the developed robot.

In the current system, based on the conversation DB that is set in advance, the static conversation flow transitions and branches sequentially according to the user's selection (Fig. 9). This system is easy to use for users whose destinations have been decided in advance, but difficult for users who do not decide beforehand. Therefore, we develop the following structure. Further, when the user wants to know multiple destinations in consideration of the relationship with the destination such as the neighborhood relationship, the system is also difficult for users to use.

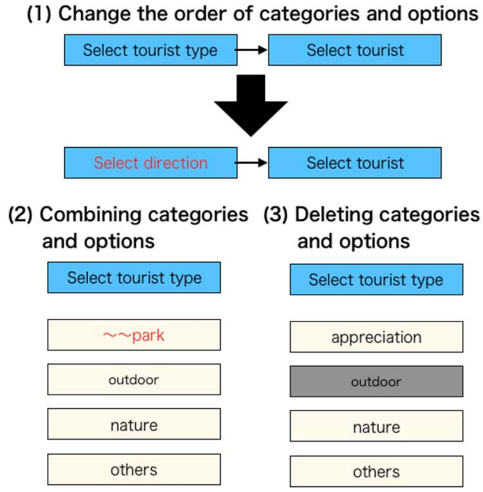


Fig. 10 Construction of Conversation Flow

The following processing can be realized by storing information such as the category, the time required for sightseeing, and the distance from the current location in each option in the conversation flow (Fig. 10).

(1) Change the order of categories and options
A different conversation flow is constructed by changing the flow of the set categories and the order of the options.
Example) I want to select a sightseeing spot near here.

(2) Combining categories and options
Combine options with different categories.
Example) I want to find a restaurant near the tourist spot I want to go to.

(3) Deleting categories and options
Delete unnecessary categories and options.
Example) I don't want to go outdoor spots because it's raining.

C. Recommendation Method using LOD

In order to develop a dynamic conversation flow, it is important for the data schema to have a graph structure that clearly shows the relationship of each data, not just a table structure. Therefore, in this section, we propose a recommendation system that uses LOD (Linked Open Data). LOD is a kind of Linked Data described by using a unified graph data model called RDF (Resource Description Framework) and refers to what is published as open data. The most basic form of RDF is to define data described in "subject", "predicate" and "object" formats. This form is called "triple". By publishing the data in such a form, the data structure linked to each other can be obtained and the data described by LOD can be utilized as a huge network (Fig. 11).

The following is a proposal of a system that uses LOD to integrate and recommend sightseeing spots and restaurants. The sightseeing information is obtained by using DBpedia Japanese [12], which has the LOD structure of the information described in Wikipedia. The information described in Wikipedia forms a category tree by classifying data with the same attribute and relevance (Fig. 12). By following this tree, we can easily transition to the target

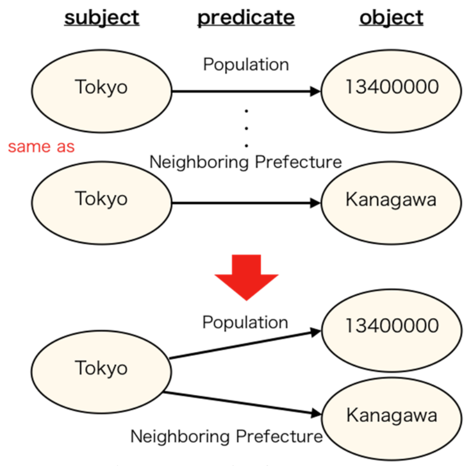


Fig. 11 Example of LOD Data

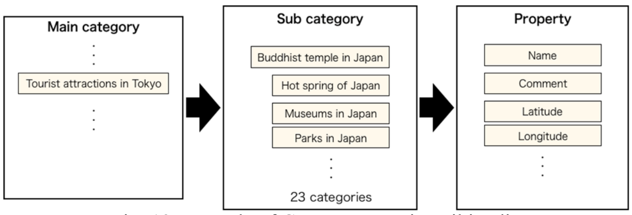


Fig. 12 Example of Category Tree in Wikipedia

information. In addition, the outline and geographical information are stored in the same format in each data of sightseeing spots, and integrated information support becomes possible by utilizing these data.

The Overall Architecture of the proposed system is shown in Fig. 13. The restaurant information is searched using the restaurant search service provided by the Gurunavi API [13]. In the conventional information support mode, when searching between different categories, it was necessary to return to the initial screen and transition the category tree again after acquiring one piece of information. In this recommendation system, by acquiring the category information related to the content selected during the interaction, it is possible to obtain the related information without repeating the category tree.

The recommendation procedure and its example are shown below.

(1) Input user request
The user inputs a main request and a sub request for narrowing down based on the information to be acquired (main: sightseeing, sushi restaurant, sub: near, etc.).

(2) Generate Query
The system generates a search query based on the use's request.

(3) Format and display data
The system acquires and displays the data from the DB. After acquiring the data in JSON format, convert it to a format that can be easily used by the application.

(4) Generate additional query
When there are multiple pieces of information requested by the user, a query is generated, and the data is acquired and displayed. At that time, if there is something that can be

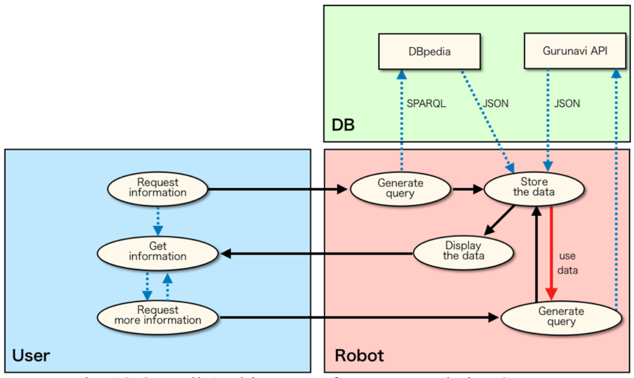


Fig. 13 Overall Architecture of Recommendation System

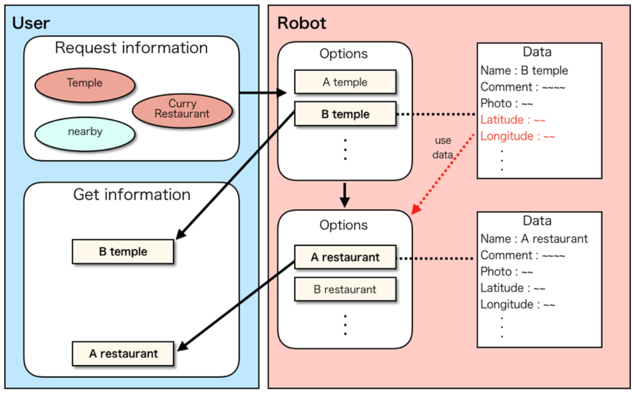


Fig. 14 Example of Recommendation

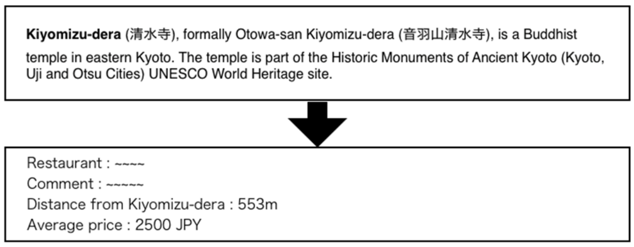


Fig. 15 Example of System Response

utilized in the previous search data, the data to be acquired is narrowed down by using that data as well.

The example in Fig. 14 assumes a user who wants to visit a temple and eat at a curry restaurant. In this situation, the user is requesting a near field search as a sub request. In this example, the search can be shortened by utilizing the geographical information of the temple selected by the user to generate a query for restaurant search. The recommendation result is displayed as shown in Fig. 15.

In this way, by constructing the conversation flow in the interaction with the user, it becomes possible to make a recommendation considering the relevance of each destination. In the current system, the user presents the request to the robot, but in the future, we think that more interactive information support can be realized by utilizing the user's tendency and dialogue history. And although the restaurant data was obtained from the API, we think a system that considers the relationship between the data can be realized by creating Linked Data using this data.

We show a preliminary experimental result of using LOD in Fig. 16.

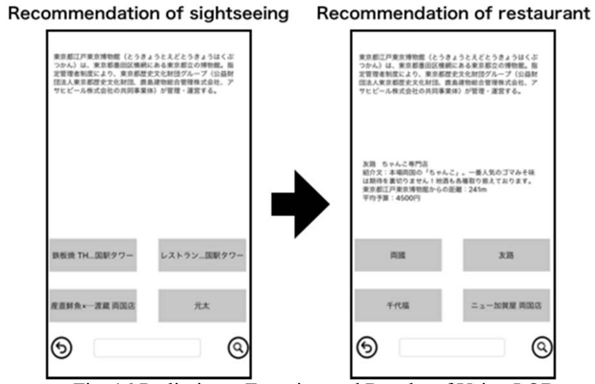


Fig. 16 Preliminary Experimental Results of Using LOD

V. CONCLUSION

In this paper, we developed a new hardware platform for a robot partner using a DD motor and discussed information support methods using a new robot partner. Further, we also proposed an interactive smart recommendation system using LOD. Preliminary experimental results show the effectiveness of using LOD for smart recommendation. We can reduce the work for human manual update of information support database built in informationally structured space.

As future works, we would like to implement a system that changes the conversation flow in real time. Specifically, we plan to develop a method that recommends and learns by integrating the data on LOD with both environment information and user information. In addition, we are developing a system that acquires information such as age that can be estimated from the user's face during interaction using Core ML [14], a machine learning library. By combining these AI libraries, we expect to realize more interactive information support with only smart devices and servers. Moreover, we should consider information support with appropriate inter-dialogue and conduct more social experiments to demonstrate the effectiveness of the proposed method.

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