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Construction of Task Instruction System for Object Retrieval Service Based on User Satisfaction

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Abstract— **This paper addresses the use of a service robot system working for humans in a daily life environment. The robot system described here always interacts with humans, and is therefore required to consider the satisfaction of users to provide suitable services. Our goal is to develop a robot system offering a hand-over service according to the preference of users. Here, we construct a task instruction system for the hand-over task utilizing the idea of Service Engineering as the first step in our research. The system can be used to instruct a robot to bring the indicated objects only by selecting task information, such as grasping position and posture, which can be utilized to estimate the user's preference.**

I. INTRODUCTION

IT is expected that service robots will eventually assist humans in their daily lives. In the future, it will become more difficult to help elderly people in Japan because there are fewer children. Accordingly, service robots need to provide a method of assisting such individuals. Herein, we evaluate a robot system designed to retrieve and hand over objects selected by a user. Although this task is seemingly simple, it is a fundamental and very important task needed in various situations for service robots. For example, it is required especially by elderly or disabled people to bring and hand-over objects being at a high place or out of their reach.

Various studies have been conducted in the field of object recognition and motion planning to enable the retrieval of objects [1–3] and robots become to be able to detect, grasp, and bring various objects in a daily life environment. However, for developing service robots that are designed to interact with humans, there is still much work to be done. Although the behavior of robots working in industrial plants requires feasibility, stability, and accuracy, the behavior of service robots should be evaluated in terms of not only feasibility, stability, and accuracy, but also user's comfort. For example, how do you feel if a robot hands over a pair of scissors turning its tip toward you? Even if the robot grasps the scissors stably and brings it quickly, we could not receive it as a proper service. It is unreasonable to evaluate the tasks executed by service robots based on only possible outcomes, stability, and accuracy, and therefore a service robot must act while considering the user's feeling.

Many studies of human-robot interaction on object retrieval have been conducted to date [4-6]. For example, Yokoi evaluated a gentle motion, which gives natural feelings to humans, about the motion speed and the trajectory of a robot manipulator based on the experiments when the robot hands an object to a human. Kokabe et al. introduced a Kansei transfer function between human hand movement and robot motion trajectory. This function was designed to allow a controller to generate a handing motion that is acceptable to human psychology. Matsunaga et al. constructed an evaluation system of human satisfaction based on electroencephalogram measurement. In addition, they developed a communication robot that determines adaptive behavior to a human by using the evaluation system. However, in these studies, estimative parameters of user satisfaction, which are also related to the robot behavior, were determined based on the designer's subjectivity. There is no systematic methodology to evaluate a whole robot system in the perspective of the user satisfaction. It is difficult to properly represent user's feelings because they cannot be measured directly. Therefore, we adopt an analytical approach.

Our study aims to develop a service robot that can retrieve and hand over the indicated objects while considering user satisfaction. To accomplish, we first need to understand how users feel about tasks performed by service robots. Therefore, we evaluate the relationship between user satisfaction and tasks performed by robots. Although it is difficult to represent this relationship accurately, we regard the robot task as a service and model the service based on a modeling method from Service Engineering. This method enables to show the integrative relationship between the attribute parameters consisting of an entire robot system and the user's satisfaction to be measured. We then develop a task instruction system to collect concrete data how users feel about various tasks performed by a robot system in an actual working environment.

This paper is laid out as follows: Section II explains the method to indicate the relationship between the user's satisfaction and robot services. Section III provides an overview of the task instruction system we constructed in this paper. The system can be used to instruct a robot to bring the indicated objects only by selecting task information which can be utilized to estimate the user's preference. Section IV shows the results of an experiment conducted using the system. Finally, Section V describes the conclusions.

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II. MODELING OF OBJECT RETRIEVAL SERVICE BASED ON SERVICE ENGINEERING

This section describes the modeling of the service and clarifies the relationship between the user's satisfaction and robot services.

A. SERVICE ENGINEERING

As our economy matures, manufacturers are being required to supply more services in addition to material products. Arai et al. proposed Service Engineering as a new design methodology to increase customer satisfaction rather than achieve product functions themselves [7]. Fig. 1 shows the overview of Service Engineering. Specifically, they suggested a modeling method that represents customer value and its relationship with service contents using a tree structure [8]. To accomplish this, they defined services as an activity between a service provider and a service receiver that is intended to change the state of the receiver (shown in the left side of Fig. 1). Based on this definition, they present the degree of customer satisfaction as the change in the state of the receiver in order to design services. To express the changes in the state of the receiver, their states are categorized as follow: A receiver has a set of Receiver State Parameters (RSPs) that represent the value of a receiver. All RSPs are assumed to be observable and controllable. RSPs are specified based on persona [9], which is the concept of targeting the typical user in management engineering. An RSP only changes according to the contents of the service received. In this study, the contents are represented using Function Parameters under the assumption that service contents are composed of various functions. Finally, Function Parameters are linked with Attribute Parameters because service contents consist of actual entities such as physical products, facilities, employees, information systems and so forth. Herein, the right side of Fig. 1 shows the modeling of the relationship between customer satisfaction and service entities. As a result, we can discuss customer satisfaction based on Attribute Parameters that represent the properties of actual service entities.

B. MODELING FOR OBJECT RETRIEVAL SERVICE

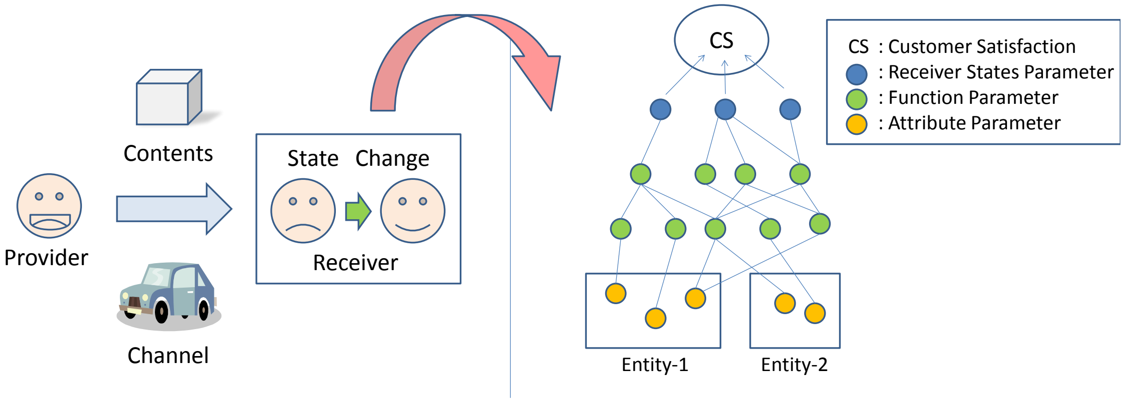
Our goal is to develop a service robot that can retrieve indicated objects. As indicated in Section I, we evaluate user satisfaction by modeling a robot service using the SE modeling method. Fig. 2 shows a model of the robot retrieval service that we constructed. To specify the RSP, it is necessary to determine the user's persona. We defined the possible personalities of the users as "easily scared", "punctual", and "polite." By regarding these personalities as user's needs, they generate the functions of the robot service, which are shown in the upper part of Fig. 2. Specifically, the personality "easily scared" generates the function "don't scare the user," the personality "punctual" generates the function "be on time," and the personality "polite" generates the function "uphold manners." Each of these basic functions is further deployed as several sub-functions. For example, the function "uphold manners" can be divided into "hand-over object suitably" and "bring objects while maintaining their functionality". Finally, each function is associated with actual service entities such as a robot or user interface. The bottom part of Fig. 2 shows attributes of actual service entities such as the motion trajectory of a robot, grasping position, waiting time of GUI and so on. Since the user value (represented through the RSP) is related to the entities in this model, we can perform an evaluation of the user's satisfaction based on these entities and their attributes.

Based on the above modeling, the relationships between the user's satisfaction and service elements can be presented as follows:

$$RSP = f(DP, EP),$$

RSP: Receiver State Parameter,
DP : Design Parameter,
EP : Environment Parameter.

DP consists of parameters for robot motion such as position, posture, motion trajectory of the robotic arm, timing to hand-over an object to a user as well as waiting time and the operability of the interface shown in the bottom layer of



Definition of Services

One of the modeling methods in Service Engineering

Fig. 1. Overview of Service Engineering

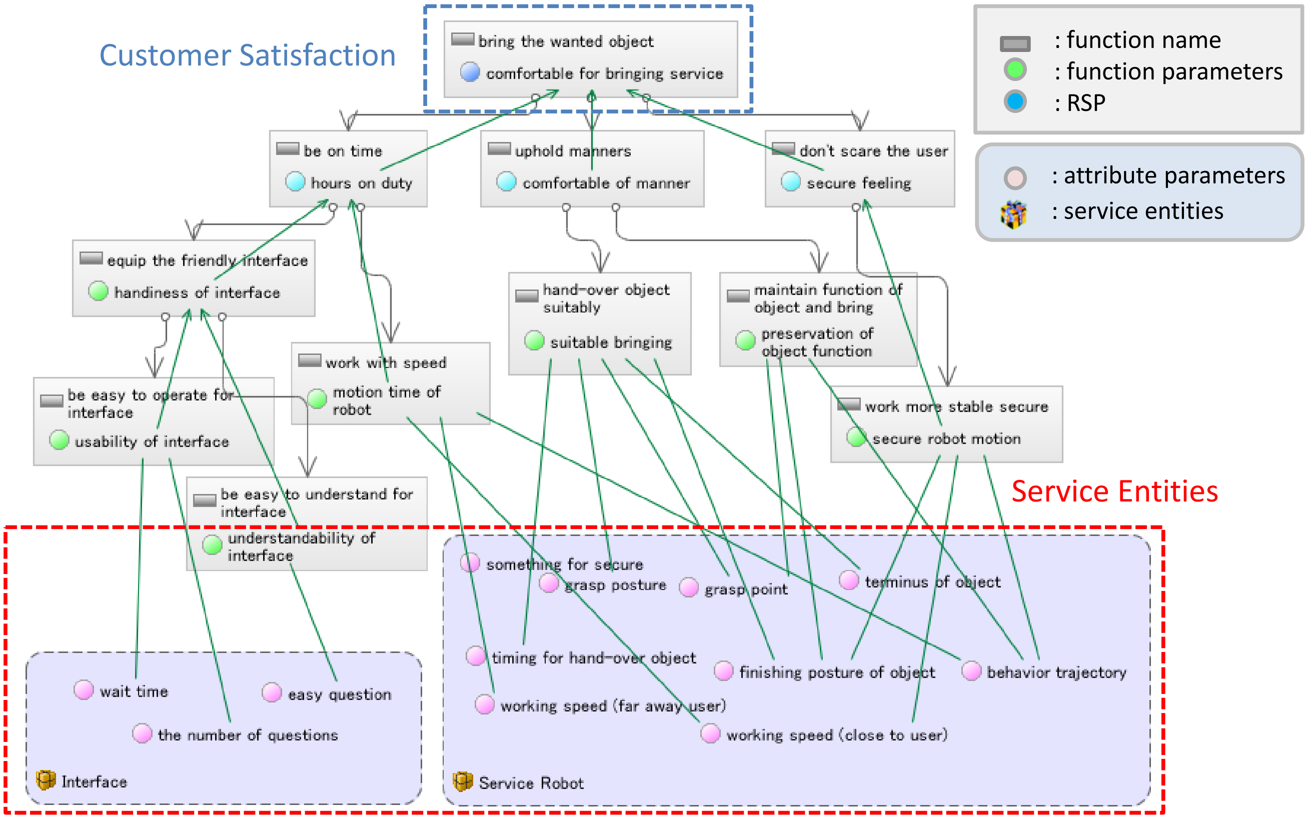


Fig. 2. Modeling of the retrieval service –evaluation structure to receive a robot service comfortably–

Fig. 2. Conversely, *EP* indicates the parameters of an experimental environment including temperature, lighting conditions, and types of object or object shapes.

Our research remains the challenge to set up a function of above equation. For example, to set up this function for a passenger transportation service in airplanes, Yoshimitu et al. used the tree structure which was constructed by using the above modeling method [10]. Then, they suggested satisfaction functions against each attribute parameters and presented user satisfaction as a weighted linear combination of each satisfaction value on the attribute parameters based on the tree structure model whose nodes were weighted by using questionnaire data of the target service. Although they fixed *EPs* and each weight, user satisfaction may have uncertainty associated with them. Namely, user satisfaction fluctuates continually as a result of factors such as changing environment or user's experiences of target services. Therefore, it is necessary to present the satisfaction dynamically. In addition, for object retrieval services, it is difficult to provide appropriate satisfaction functions based on questionnaire data. Accordingly, we constructed a system of task instruction to discuss user satisfaction through time. This system employed user data obtained during the use of an actual system to understand the relationship of user satisfaction and attribute parameters.

III. ROBOT SYSTEM FOR OBJECT RETRIEVAL SERVICE

This section describes our developed task instruction system for object retrieval service (Fig. 3). Using the system, a user instructs a robot to bring the needed object through a control interface. The robot then detects and retrieves the object based on the user's instructions. The system saves the instruction data and is gradually improved based on the obtained data.

A. REQUIREMENT

To develop a robot that possesses adaptive behavior for the retrieval service that varies in response to the user's feelings, the system should satisfy the following requirements:

- The robot can work in a daily life environment.

  To retrieve common items, the robot has to recognize their information of posture, position, and shape.
- The system can anticipate the users state of mind.

  As already mentioned, the robot has to perform a task according to the preference of the user. To evaluate user satisfaction, the system has to be able to get the information of actual service entities, which are related to user satisfaction, as shown in the bottom layer of Fig. 2.
- The system can grasp the task condition.

  User satisfaction changes by the effect of not only *DP*

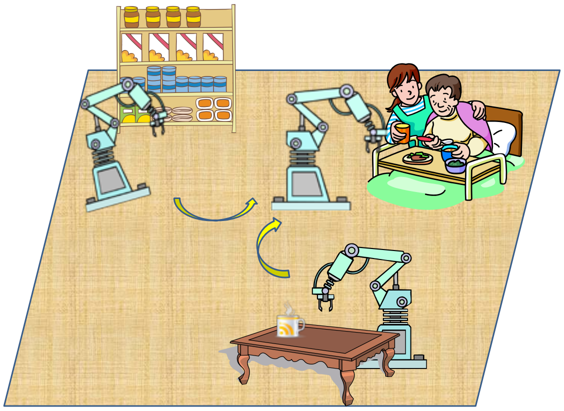


Fig. 3. Robot working in a daily life environment and the system construction

but also *EP*. Therefore, the system has to measure the information regarding the task environment.

- Users can easily provide the instructions to the robot

  In order to obtain detailed and precise data of the user instructions, the control interface of the system should be simple and enable flexible instructions.
- The system can be improved based on the user instruction data.

Regarding these needs, the system should collect data for an actual case and learn the adaptive task to the user based on that data. We then propose a system that could garner the user's instructions to complete the task. To garner the information of actual service entities from user instructions, the system is required to have the remote control function of the robot. For example, Nagata et al. proposed a task instruction scheme in the concept of shared autonomy by which the robot can share a task with a human [11]. Their scheme conducted a robot to execute a task with user's simple task instruction. Our system is constructed based on their task instruction scheme. Because user satisfaction can be assumed to be similar to the function of the designed system, it is only necessary that the system record the parameters that directly influence the user instructions.

In this paper, we developed the task instruction system focusing on the grasping part of the retrieval task. The elements of each parameter of our system are presented in Table I.

The elements of DP are picked up as shown in the bottom layer of Fig. 2. Conversely, the elements of EP are collected for the following reasons.

- ➢ The images of cameras

  They have the information of the experimental environment.
- ➢ The name of objects

  Appropriate grasping form would vary according to the functions of the target object. Therefore, the name of objects needed to be saved since it is deeply related to its functions.

Table I
Parameters obtained by the task instruction system.

The elements of *DP*	**The elements of *EP***
Grasping position	Images of cameras
Grasping form	Name of objects
Motion speed	Shape of objects
	Page timing of GUI

- ➢ The shape of objects

  Since appropriate grasping form would also vary according to the shape of the target object, the shape of objects should be saved.
- ➢ Page timing of GUI

  Page timing is an important factor to evaluate the usability of the interface. Namely, it is closely associated to user satisfaction as shown in the left side of Fig. 2.

B. *TASK INSTRUCTION SYSTEM*

This subsection describes the procedure of the developed system. The system adopts a GUI system as a control interface. A camera image of the task environment is shown on the display. A user can provide some instructions to a robot by clicking somewhere on the camera image or a button, filling in a form, and moving a slider. Fig. 4 shows the flow of the system, which is composed of the following seven steps.

1) Select an object that the user want to take

The system initially requires the user to select a target object. The user finds the object in a camera image, which is captured by the hand-in eye camera system of the robotic arm, and click on it. The system uses the data of click point for recognizing the object. The system recognizes the object based on the click point, which has the 3D position information. The system then stores the image and the click point selected by the user.

2) Select the name of the object

The system requires the user to click the button that is nearly equivalent to the name type of the object. If there is no buttons whose meaning matches the target object, the user can create new button by filling in the bottom form. The system then stores the object name and uses them as the elements of *EP* for the evaluation of user satisfaction.

3) Instruct the shape type of the object

The system requires the user to click the button that is nearly equivalent to the shape type of the object. There are four buttons corresponding to a cylindrical shape, cuboid shape, spherical shape, and to none of aforementioned shapes. The system stores the object-shape selected by the user, and then uses the shape data for step 4.

4) Select the grasping form

The system requires the user to select the grasping form.

The system stores the selected form and uses it for step 5. The relationship between step 4 and 5 is described in detail later.

5) Determine the detailed grasping posture and position

The system requires the user to make the final decision regarding the grasping posture and position of the object via a computer graphics (Fig. 4-(5)). For example, if the shape of the target object is cylinder and the user indicates that the object should be grasped from the top, there are three degrees of freedom to determine the detailed posture and position. Thus, the user set the posture and position by using the sliders corresponding to each degree of freedom. The robot hand moves along the center line of the cylinder, rotates around the center line, and tilts about the center line. The system then determines the posture and position of the robot hand and stores the data.

6) The robot moves to grasp the target object.

The user must then allow the robot to bring the selected object actually.

7) Evaluate the task executed by the robot

Finally, the user has to answer the questionnaire. The user should evaluate the overall performance of the system. Namely, the user must scores based on not only the behavior of the robot task (service) but also that of the system such as the GUI. The score-slider ranges from +5 to -5. This estimation is treated as user satisfaction shown in the top layer of Fig. 2. The system then memorizes the estimation data for subsequent analysis.

Herein, the reason to store the object shape in four categories at step 3 is described. Since there are many kinds of objects with various shapes in a daily life environment, it is impossible to save each shape with available grasping forms. Thus, we categorized the shapes of grasping objects by considering applicable grasping forms of a robot hand [12]. In this paper, we utilized a parallel two-fingered gripper as a general robot hand and adopted four kinds of primitive shapes to estimate user's preference: a cylinder, square pillar, sphere, and shape derived from a cylinder and square pillar. Each primitive shape has unique grasping forms. For example, a cylindrical shape has four basic grasping forms (Fig.4-(4)): grasping the cylinder from the top and the side, grasping it by the edge, and grasping it by the upper and lower surfaces that is applicable to a thin cylinder like dishes. In step 4, the task instruction system presents the choices of grasping forms based on the primitive shape selected in step 3. The detailed grasping posture and position is then determined in step 5.

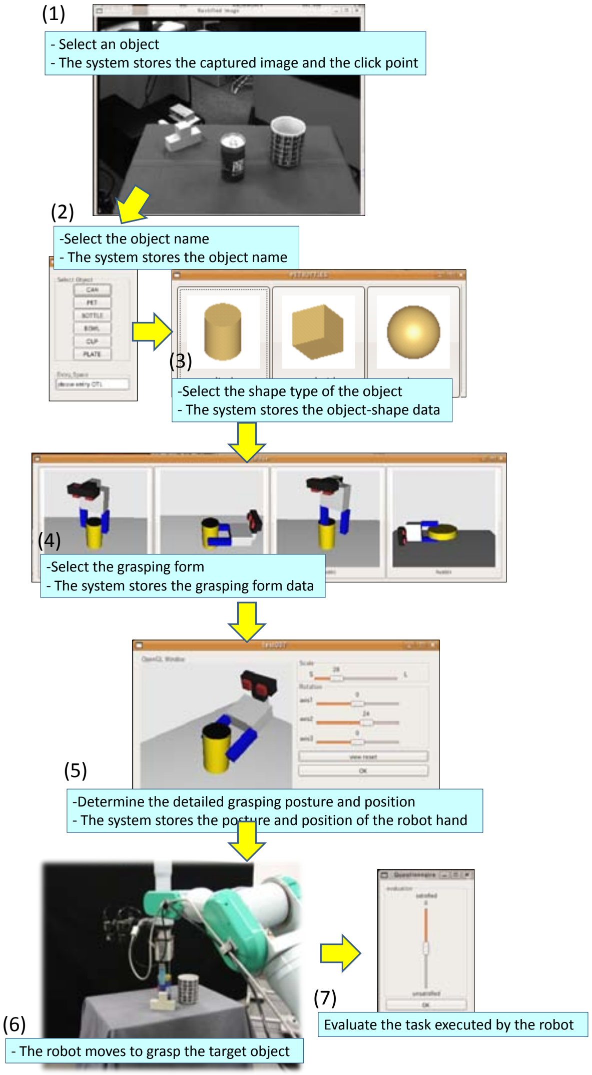


Fig. 4. System flow chart

Based on the obtained instruction data, the system should comprehend the user's preference and improve its behavior. Although the current system requires five instructions to users for achieving a task, it could reduce the effort of task instructions, which are required to users, based on the analysis of the obtained data. For example, if the system organized the instructed grasping forms as being related to the selected primitive shapes or environment data, the system could recommend an appropriate grasping form that suits the user's preference. Consequently, the system will be finally able to determine that scissors should be grasped at the tips for handing over, without user's instructions. The learning process is one of our future works.

IV. EXPERIMENT

This section shows the results of the experiment conducted using the task instruction system described in the above section.

1) ***Experimental setup***: Fig. 5 presents the work environment of the experiments. The robot system was composed of the PA10 manipulator (Mitsubishi Heavy Industries, LTD.), parallel-jaw gripper (Takano Bearing Co., LTD.), and three IEEE 1394 digital cameras equipped at the wrist of the manipulator. The camera image and selection windows were shown on the display, and users instructed the robot through it. For the recognition of objects' position and orientation, the VVV system [13] was adopted.

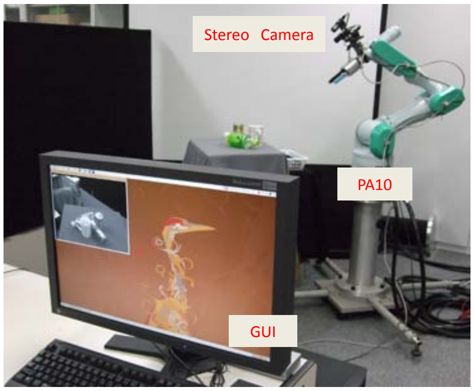


Fig. 5. The experimental environment

In the experiments, the robot did not have mobile function, and thus, some environment parameters (position and posture of experimental equipments except objects) were fixed.

2) ***Picking up objects on the desk***: Fig.6 shows the image of the experiment and the data describing each of the parameters. The images shown in scene 1 and scene 2 depict different situations provided to the user who must then respond by providing instructions to the system. The system collects the data obtained from actual examples such as those provided in these examples.

V. CONCLUSION

In this paper, we constructed a task instruction system in order to develop a service robot that can retrieve and hand over the indicated objects while considering user satisfaction in a daily life environment. First, the relationship between user satisfaction and a retrieval task executed by a robot was described with the modeling method from Service Engineering by regarding the robot task as a service. Based on the analysis of the service, the system in which a user can instruct a robot to bring the indicated objects appropriately, was then constructed in order to comprehend the user's preference. In our future work, the system should be improved based on the user instruction data which is stored by using the system repeatedly.

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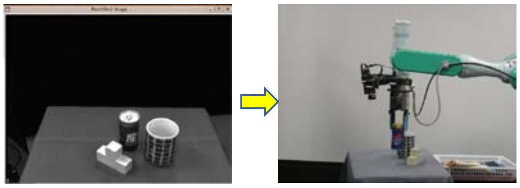
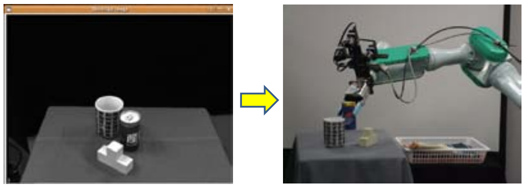


scene1



scene2

User	A	A
Scene	1	2
Object	CAN	CAN
Grasp position	P_1	P_2
Grasp form	R_1	R_2

P_1,P_2（ R^3 ）
：the vector of grasp position
R_1,R_2（ $R^{3\times3}$ ）
：the rotation matrix of grasp form

Fig.6. Results of the experiments