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Embodiment of an Agent using Anthropomorphization of an Object

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1. Introduction

Recently, many home appliances have acquired multiple functions due to the development of ubiquitous technology. For example, refrigerators are able to provide users the expiration dates of foods to a user from the RFID tags attached to the food package (Chen et al., 2007). The development of such intelligent environments increases the quantity of information passed from appliances to users. For users, it has become more difficult to understand all the appliances' functions and information. Thus, it is important for users to know what functions they should be using and what information they should focus on.

An anthropomorphic agent including virtual agent and real world agent like communication robot is one way of relating this enormous amount of information to users. It can enhance this information by speaking, pointing, and using gestures on screen or in the real world.

There have been many studies on the communication methods and gestures of anthropomorphic agents. For example, Scheutz studied the influence of spoken words of robots on the cooperation task between human and robot (Scheutz et al., 2008). Breazeal studied how users accept emotions expressed via a robot's facial movements using the facial robot Kismet (Breazeal, 1997). Imai et al. succeeded in joint attention between a user and the robot Robovie and attracting the user attention toward a poster using the robot's face and arm direction (Imai et al., 2003). Shinozawa et al. noted in their experiment (Shinozawa et al., 2005) that using a communication robot is a better way for providing real world information than a virtual agent. This study also suggested that a communication robot is useful for describing the information and functional capabilities of home and office equipment.

However, the agent's ability to direct the users' attention towards an artifact sometimes fails because the agent gains more of the user's attention than the target. Presentations given by robots at exhibitions sometimes fail because the people are attracted to the robots more than what the robot is explaining. Murakawa et al. noted that a sales-robot in a shop does not ensure that the amount of goods sold will increased even though it does attract the attention of customers and that they did look at the goods (Murakawa and Totoki et al., 2006). These failures occurred because of an underestimation of peoples' curiosity in robots. Fukayama et al. noted in their experiment using a virtual agent that the agent sometimes draws attention and disturbs the user's attention on the task before them (Fukayama et al., 2003). They

compared two situations in their explanation. The experimental setup consisted of a virtual agent placed in the center of a PC screen and the control condition consisted of a voice without an agent. In the experimental setup, the participants had a harder time remembering the agent's explanation.
We propose a direct anthropomorphization method to solve an information disturbance by an agent. In this method, we attached human-like devices to an artefact so that it can provide information about itself. These devices are attached to the target object, making it into an anthropomorphic agent, and providing the target's functions or information to users intuitively. Our method use gestures, pointing, emotion, and expression to initiate interaction between a human and the object. Compared to text or vocal instructions, our method anthropomorphic appearance allows users to focus more on their interaction. This method does not disturb the users' intentions more than a method that uses separate anthropomorphic agents, because its explaining style is in the form of a self introduction. There are no other agents in the interaction field. Figure 1 illustrates our method.

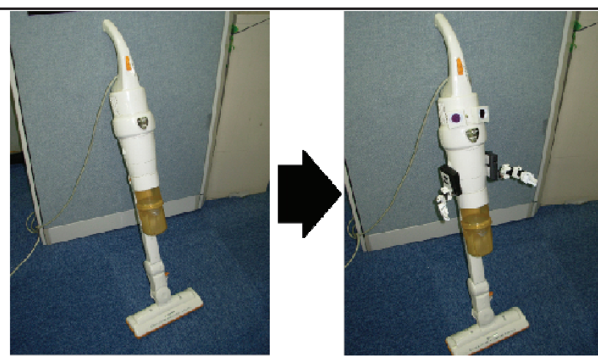

Fig. 1. Anthropomorphized cleaner

To achieve our method, we designed and implemented anthropomorphic robotic devices that resemble eyes and arms. We also conducted an experiment to evaluate the direct anthropomorphization method. This experiment compares the attention and understanding of a user of the functions of an artifact. We had two conditions in this experiment. The first one had a direct anthropomorphized printer explain its own functions and the second one had a humanoid robot "Robovie" (Kanda et al. 2002) explain the printer's functions. The results from participants' questionnaires and gazes during the experiment indicated that they noticed the target artifact and memorized the functions more quickly and easily from using the direct anthropomorphization method than from the "Robovie".
The reminder of this chapter is organized as follows. Section 2 describes the background behind the direct anthropomorphization method and presents a formulation model of this method. It shows basic biological and psychological attitude of humans, especially about The Media Equation, and describes human robot interaction studies and human agent interaction studies that uses these human features to improve interaction. These features are also useful with our method. Section 3 explains our design and the implementation of humanoid parts (eye-like parts and arm-like parts). Section 4 describes the experiment to compare our proposed interaction to that with Robovie. Section 5 presents and discusses the results from the experiment. Section 6 concludes the paper with a summary of our results and provides an overview of future work according to the results.

2. Background

We defined our direct anthropomorphization method by adding human-like devices, such as eyes and arms, to a target object. That way a user can perceive the object as an agent and then they can expect the target object to explain something to them. The user can pay much more attention to the target and more clearly understand it using the direct anthropomorphization method.

Figure 2 shows three method on human and machine interaction. Conventional human-computer interaction improves interface directly like the top image of Fig. 2. Common human-agent interaction uses independent agents like that shown at the middle of Fig. 2. Users are forced to pay attention to not only the target object but also the agent itself under this interaction. On the other hand, if the target object is directly anthropomorphized and becomes the agent using our method as in the bottom image of Fig. 2, users can focus their attention on the body of the agent and the target object because they are one in the same.

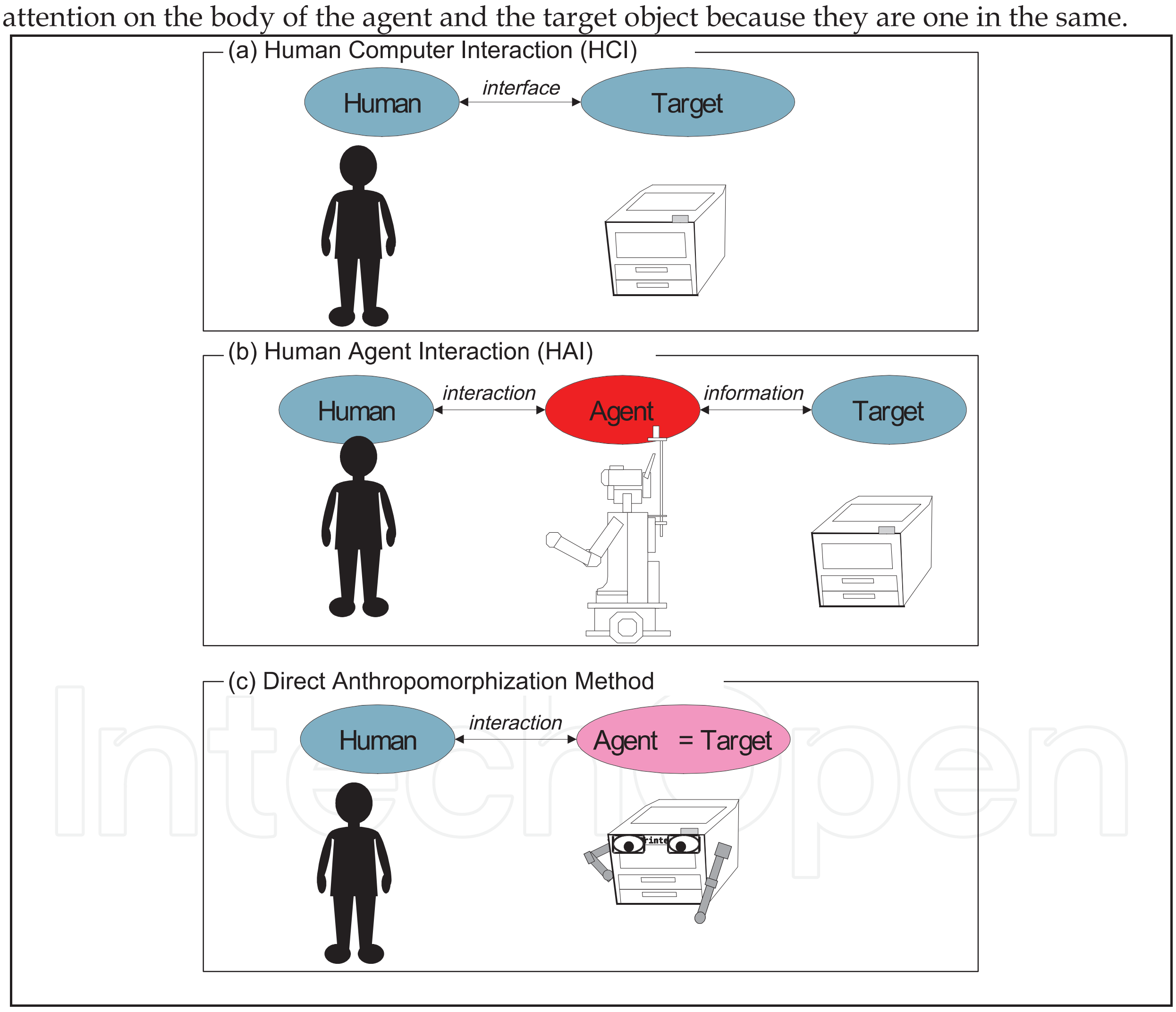

Fig. 2. Three design methods

We examine the basics of our method according to The Media Equation (Reeves & Nass, 1996). People do not expect an object to be an interactive agent. The Media Equation notes people's tendency to communicatively behave even if the target is just a mere object. The

Media Equation states that a human treats informative media like a communicative human. They found through experimentation that users perceive intimacy (as if they are in same group), and respect for a mere computer (attached display and keyboard). This response was found not only in children, but in all age groups.
Our method extends this response and uses it to give information to users. In our method, we attach anthropomorphic human parts, eyes and arms, to an artifact. We believe that these devices create a body image for the artifact.

3. Design and Implementation

In this section, we make human-like devices that attached to an artefact. Many parts of a communication robot can be used for human-like representation. However the design policy of each part is different because our devices attached on an artefact and run with it. We considered the eyes and arms of the robot to be the most important and designed them as follows based on previous study (Sugiyama et al., 2006).

3.1 Eye-like Parts

The eye-like parts imitated human eyes.
The human eye (1) enables vision and (2) indicates what a person is looking at (Kobayashi & Kohshima, 2001). We focused on objects being looked at and hence used a positioning algorithm design.
The eye-like module that simulates the human eye (Fig. 3) uses an "iris" that represents the human iris and pupil together. The open elliptical region on the right in Fig. 3 represents the sclera and the closed circle, the iris and pupil. Here, the eye-like parts looking at a cup consist of a pair of displays to simulate the eyes. The locations of the irises are calculated with respect to the location of the object, which is acquired by a position sensor.

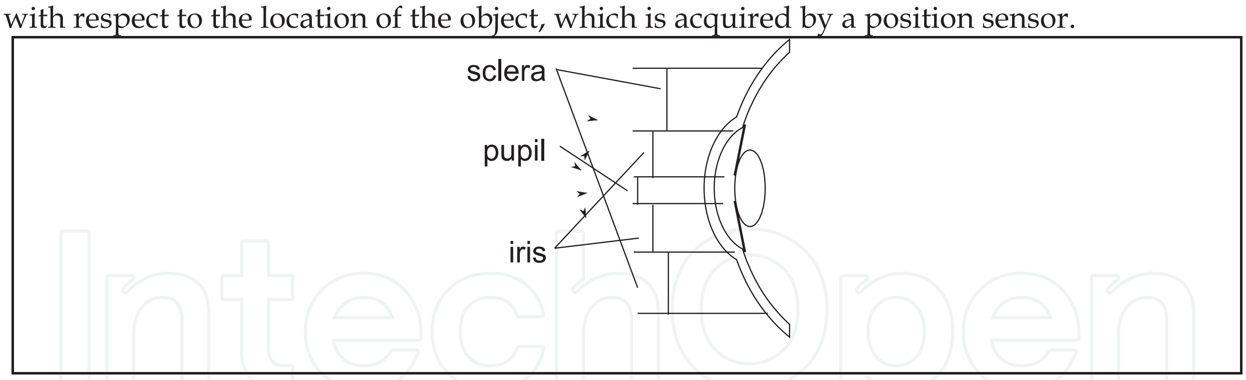

Fig. 3. Human Eye

First, it calculates each iris position as shown below. Each board has an "imaginary eyeball" and it calculates the point of intersection, $\boldsymbol{p}$, of a vector from the object, $\boldsymbol{i}$, to the center of the eyeball, $\boldsymbol{c}$, and board plane $\mathbf{A}$. Based on this point of intersection, the eye-like parts convert the global coordinates of $\boldsymbol{p}$ into display coordinates, $\boldsymbol{i}$; these processes are performed in both eye-like panels (Fig. 4).
Second, it calculates the orientation of the front of anthropomorphized target by the directions of two eye boards as shown below.

While calculating the normal vector ***a*** in certain cases, for example, if the eye-like parts are based on one panel, some additional sensors need to be used, e.g., gyros, to calculate the orientation of panel **A**.

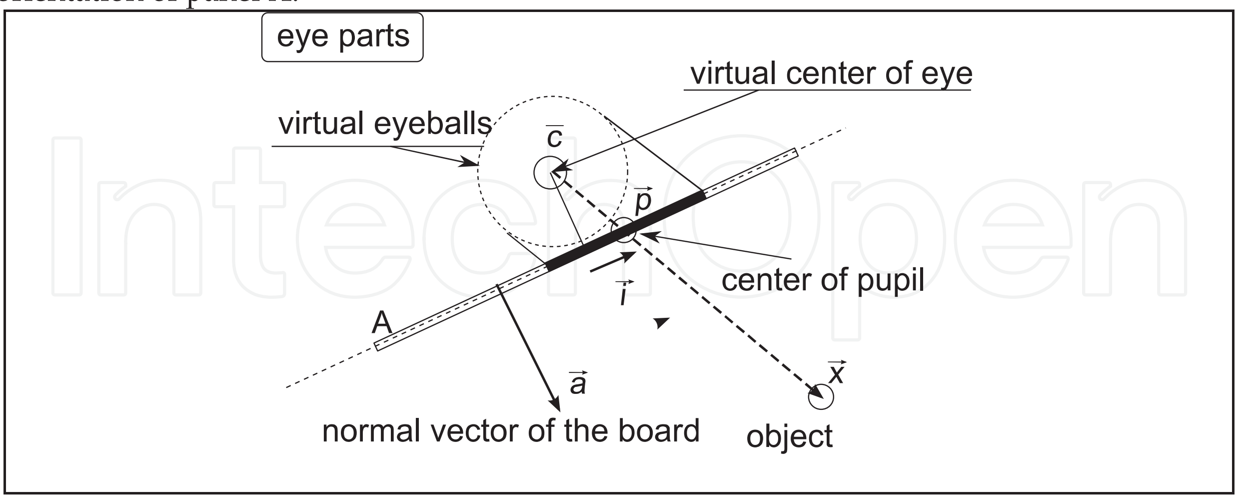

Fig. 4. Positioning of iris on each board

Since the eye-like parts use two panels, ***a*** is calculated from the vector ***r*** between the position sensors in the right and left panels. Restrictions exist when the two panels are symmetrically oriented with plane in the middle of the two boards, when the panels are placed vertically (i.e., their pitch angles are 90 degree), and when the tilt angle is known. Under these restrictions, the eye-like parts calculate the iris positions even if one of the two panels moves.

3.2 Arm-like Parts

The arm-like parts of the robot imitated a human arm in all respects except in terms of manipulating objects.

When the arm-like parts pointed at the outside of an attached common object, we used the vector from the root of the limb to the tip of the hand as the pointing vector, as shown on the left side of Fig. 5 according to Sugiyama's study on pointing gestures of a communication robot (Sugiyama et al., 2006). However, when the arm-like parts pointed at the inside of an attached common object, we used the vector from the root of the hand to the tip of the hand as the pointing vector, as shown on the right side of Fig. 5.

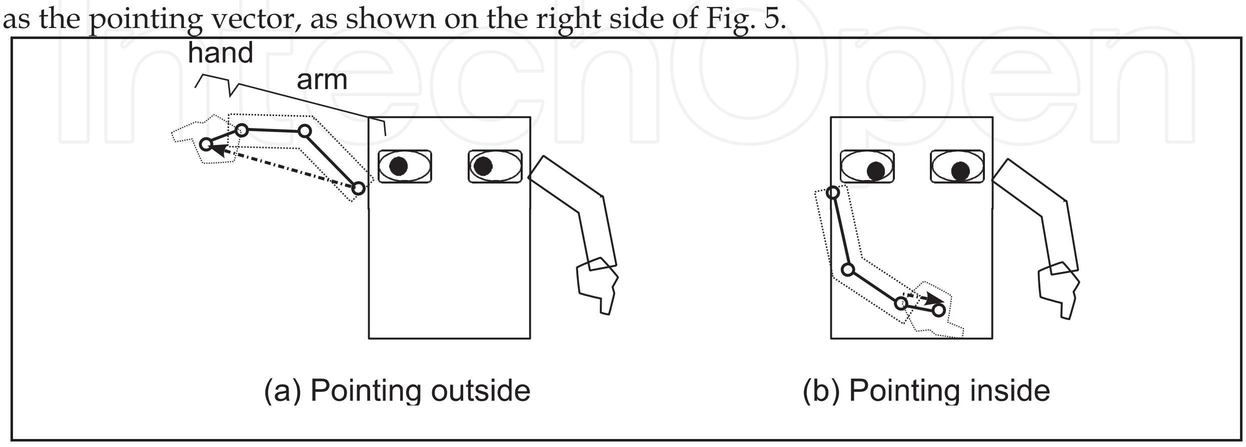

Fig. 5. Pointing vector

3.3 Implementation

Our anthropomorphized object did not need to manipulate other objects using its attached hands. Because the target already has its own task, and our devices are used for just expressionism. Instead of manipulation, these devices must be simple and light so they can be easily attached. We developed human-like robotic devices and attached them to our target by using hook and loop fasteners.

The eye-like parts are consisted of a TFT LC Panel. They were used to determine the positions of the pupils and irises using the 3-D coordinate of the places they were attached to and their direction vectors. The eye-like parts were 2-cm wide. They were thin and could be attached anywhere. They can be used to gaze in any directions as if the implemented eye of the object were watching.

The arm-like parts are consisted of six servo motors. Its hand had three motors and it could express delicate gestures with its fingers. The hands looked like long gloves, were covered with cloth, and concealed the implementation required for intuitive interaction.

The parts' locations are obtained from ultrasonic 3D tags (Nishida et al., 2006) on the parts. They send ultrasonic waves to implemented ultrasonic receivers, which calculate 3D axis of the tags. Humanoid parts search for “anthropomorphize-able” objects according to the locations of the parts.

Specifications of parts for an experiment are presented in Tables 1 and 2, and the parts are depicted in Fig. 6.

Scale	120mm x 160mm x 50mm
Weight	180g
TFT Controller	ITC-2432-035
Wireless module	ZEAL-Z1(19200bps)
Microcontroller	Renesas H8/3694
Connection method	Velcro tape
Cover	Sponge sheet, Plastic board

Table 1. Specification of eye parts

Scale	250mm x 40mm x 40mm
Weight	250g
Motor	Micro-MG x 3, GWS-pico x 3
Wireless module	ZEAL-Z1(9600bps)
Microcontroller	Renesas H8/3694
Connection method	Velcro tape
Cover	Aluminum, sponge, rubber, gloves

Table 2. Specification of arm parts

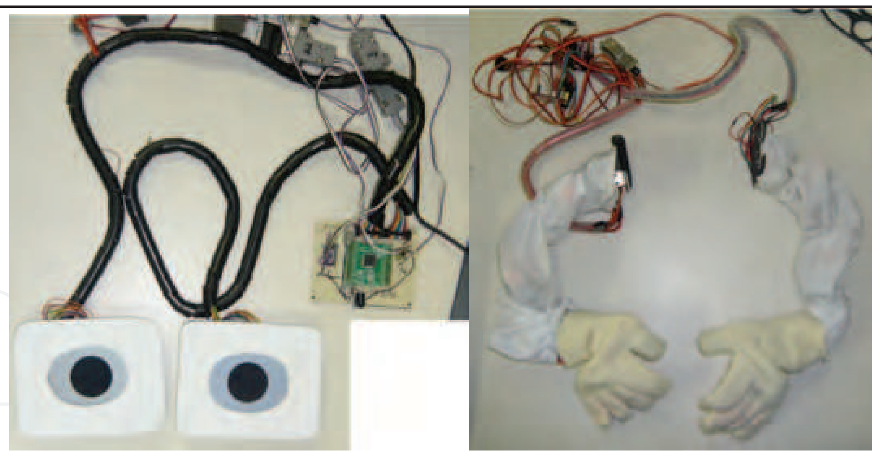

Fig. 6. Humanoid parts

4. Experiment

4.1 Hypothesis

We hypothesize that users pay more attention to a target using anthropomorphization by humanoid parts than when using an independent anthropomorphic agent. This hypothesis is based on the fact that if a target is the agent, the attention of the user is focused on the target object because the target and the agent are one.

4.2 Condition

We used two experimental conditions. In one, we used a printer with human-like devices attached to it and in the other we used a printer and an independent humanoid robot Robovie.

To verify an interaction in a natural situation, we conducted this experiment as a field experiment. For this purpose, we sought ordinary people as subjects at our booth in a university festival.

The detailed conditions of the experiment are as follows. We called the participants who joined our experiment with the direct anthropomorphized printer the experimental group and those who joined the experiment using Robovie, the control group. The up photograph in Fig. 7 shows a scene from the experimental group and the down one is a scene from the control group.

Fig. 7. Experimental (left) and control (right) group

4.3 Environment

We isolated a 3 x 3 m space on the floor and used it for the experiment, and we used an office laser printer LP-9200 (made by EPSON, Inc.). We assumed that the participants were not familiar with using the printer since it is typically not used in homes.

We used the same voice for the experimental and control groups, except a name of “the first person”. The voices were played from the back of the printer in the experimental group and from Robovie's mouth in the control group. We tried to avoid several differences between the two groups to maintain accuracy.

We also used an eyemark record device EMR-8B (made by NAC Image Technology, Inc.) to detect where the participants looked. Radial motion was measured to detect the participants' focus of attention. Although we were unable to directly measure the participants' focus of attention, we assumed that the time duration for which humans stare at something can approximately determine where they are focusing their attention and this duration could be measured.

Each device was arranged as shown in Fig. 8. The left side of this figure shows the experimental condition and the right side, the control condition. Participants were videotaped under consent using a side camera and eyemark recorder.

To detect participant action certainly, this experiment was conducted by the “Wizard of Oz” method. All utterances and gestures of the printer and Robovie were conducted according to the determined scenario. Instructions toward participants are informed by an assistant of the experiment.

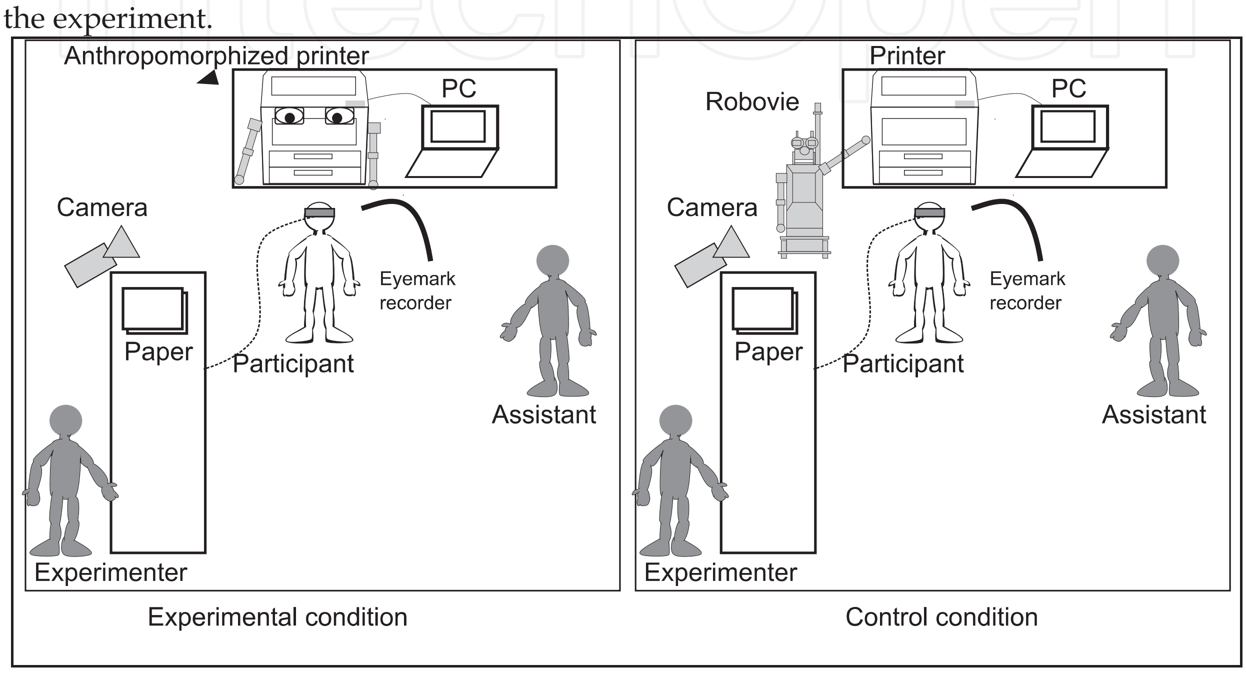

Fig. 8. Experimental system

We conducted this experiment in the lab presentation space at a university festival. The experiment was conducted during 3 days in 2007. We conducted the experiment on the experimental group on October 20 and December 22 and that on the control group on October 21. The participants were unaware that they would be participating in an experiment until after they visited our space. They consented to the experimental conditions. The participants had no prior knowledge of the experiment and had no deep motivation for the success of the experiment, as compared to normal human experiments.

We believed that our experimental condition was better, than the condition in a normal experiment, for our purpose to verify the validity of our method, because this experimental style is the same as HRI in the real world (in vivo) and differs from experiments conducted in a room (in vitro).

4.4 Instruction to Participants

First, we briefly explained our experiment and obtained participant consent. In addition, we attached the eyemark recorder only if a participant allowed its use.

After obtaining consent, we executed each experimental scenario for the participants in the experimental group (EG) and control group (CG).

- Self introduction
  - EG "Hello, my name is printer."
  - CG "Hello, my name is Robovie, and this is a printer."
- Explaining names: formal name (LP-9200) and nickname (ESPER)
  - EG "My formal name is LP-9200. Everyone calls me ESPER."
  - CG "Its formal name is LP-9200. Everyone calls it ESPER."
- Function: printing
  - "(My/Its) purpose is to print papers."
- Function: power button
  - EG "My power button is on my right side."
  - CG "Its power button is on the right side of the printer."
- Leading action: push power button
  - "Let's push it."
- Function: printing speed
  - EG "I can print 20 pages per minute."
  - CG "This printer can print 20 pages per minute."
- Function: resolution
  - "(My/Its) resolution is 1200 dpi."
- Function: The principle of a laser printer
  - EG "I use a laser for printing."
  - CG "This printer uses a laser for printing."
- Function: The principle of a laser printer (cont.)
  - "The cost of printing using my functions is much cheaper than for home printers because (I/it) pastes ink using a laser."
- Leading action: printing
  - "Let's print something! Push a button on the PC beside me."
- Fail of printing
  - "(I/It) can't print anything … hmm … oh, there is no blank paper in a bin."
- Leading action: insert blank papers
  - EG "Insert blank papers into my mouth."
  - CG "Insert blank papers into its mouth."
- Function: repairing miss print
  - EG "If you missed printing something, please lift up my head."
  - CG "If you missed printing something, please open its top."
- Function: printing papers that one surface is not used
  - "(I/It) can use papers that one surface is not used.
  - But, they always jam.
- Function: remove jammed papers
  - "If there is a paper jam, remove the paper from here (with pointing)."
- Function: help button
  - "If you find other errors, push the left button(with pointing)"
- Questionnaire
  - Participants filled out questionnaires after the experiment.
- Fee for the experiment
  - Participants got souvenir photos and a cookie for participating.

In the experimental group, the printer used "I" and "My" for explaining. On the other hand, Robovie used "This printer" and "It" for explaining printer functions to the control group. Other words are the same in both experiments. Because each instruction pair on the above scenario has same duration, we think that there is no difference in instruction complexity between these two groups.
Each participant listened to the description of nine functions during the experiment. The experiment was interactive, explaining that each participant should manipulate the object according to the instructions. We think that this interactivity helped motivate the participants to concentrate on the experiment. The participants had an easier time answering the questionnaire according to the interactive explanation. Each utterance and gesture was repeated when participants did not understand it.
Finally, the participants filled out a questionnaire, which asked them about the functions explained to them (printing speed, resolution, and other functions they remembered).

4.5 Participants

Twenty-one males and eight females participated in our experiment. There were 13 males and 3 females in the experimental group and 8 males and 5 females in the control group. Their ages ranged from 10 to 60 years. The age distribution of the participants is presented in Table 3.

Age	Experimental Group	Control Group
10-19	8	3
20-29	2	4
30-39	2	1
40-49	1	0
50-59	3	5

Table 3. Age of each participant

We conducted an F-test with a $p > 0.10$ basis for gender and age to check that all values in the two groups are dispersed according to the F-distribution. The results in each case were $p = 0.640 > 0.10$, and $p = 0.207 > 0.10$. The results show that there was no deviation in these two groups. We asked participants, through the questionnaire, about their experience with the printer, Robovie, and the humanoid parts. No participant used these devices.

4.6 Prediction

The predictions from our experiment based on the abovementioned plan are as follows.
The participants in the experimental group were able to write more about the functions in their questionnaires, because they remembered the explained functions more clearly than the participants in the control group.

5. Result and Discussion

5.1 Result

We counted the total number of functions recalled by each participant. Figure 9 presents the differences between the experimental and control groups. Figure 10 presents their distributions. The Y-axis in Fig. 9 represents the answered functions. The X and Y axes in

Fig. 9 represent the number of noted functions and participants, respectively. The average number of functions noted was 2.3 for the experimental group and 1.3 for the control group.
We conducted an F-test with a $p > 0.10$ basis to check that all values in two groups are dispersed according to F-distribution. The results showed a p value of 0.876, which is greater than 0.10, and there was no deviation in these two groups. We conducted a Welch's t-test with a $p < 0.05$ basis for each of the recalled functions to verify our prediction. The results showed that there was significant difference, $p = 0.029 < 0.05$, between the two groups.
There were 11 participants in the experimental group and 11 in the control group whose gaze times were detected using the eyemark recorder. Figure11 shows the ratio of attention in each experiment. The X-axis in both the top and bottom graphs in Fig. 11 represents the participant and the Y-axis in the top graph is the ratio of the time of gaze toward the printer to that toward other objects. The Y-axis in the bottom graph of Fig. 11 represents the ratio of the time of gaze toward the printer, that toward Robovie, and that toward other objects.

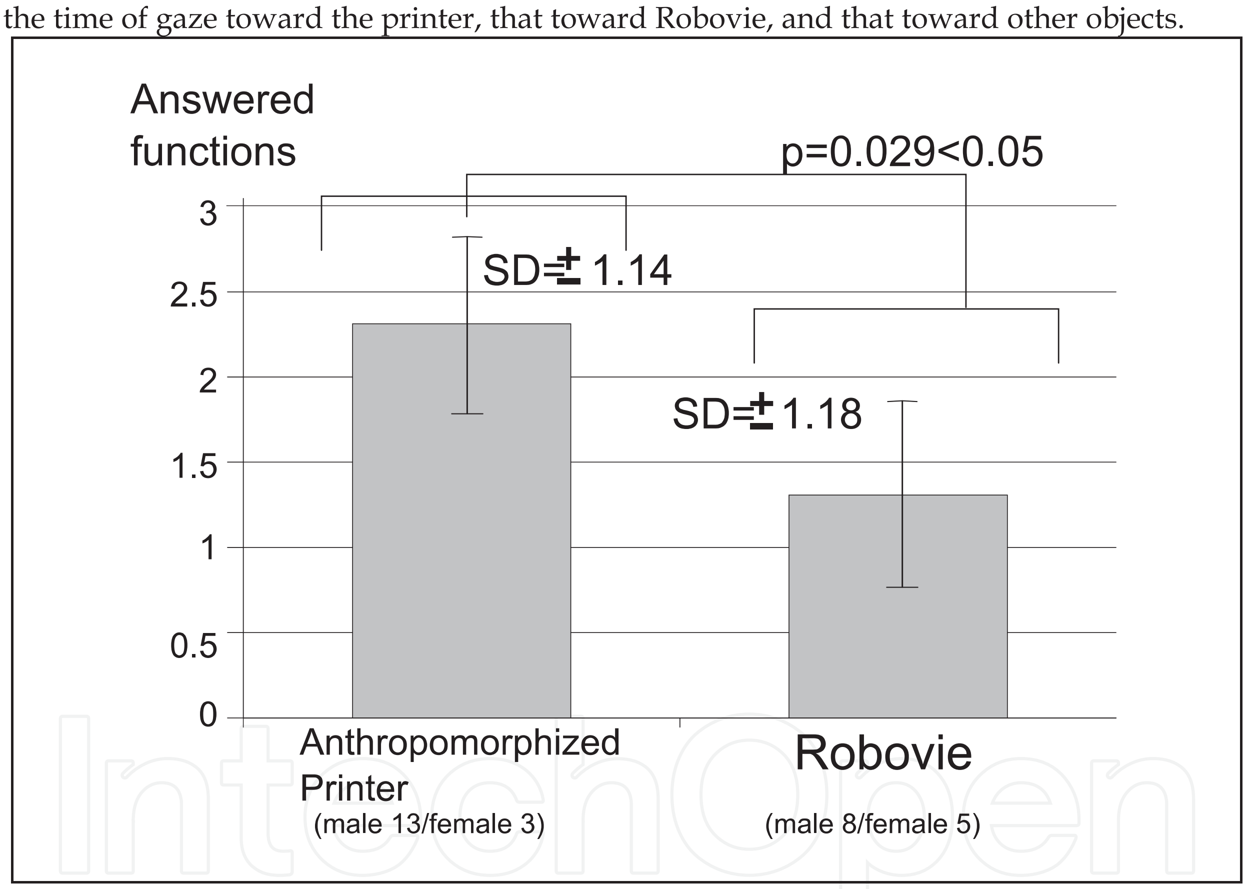

Fig. 9. Difference in noted functions of printer

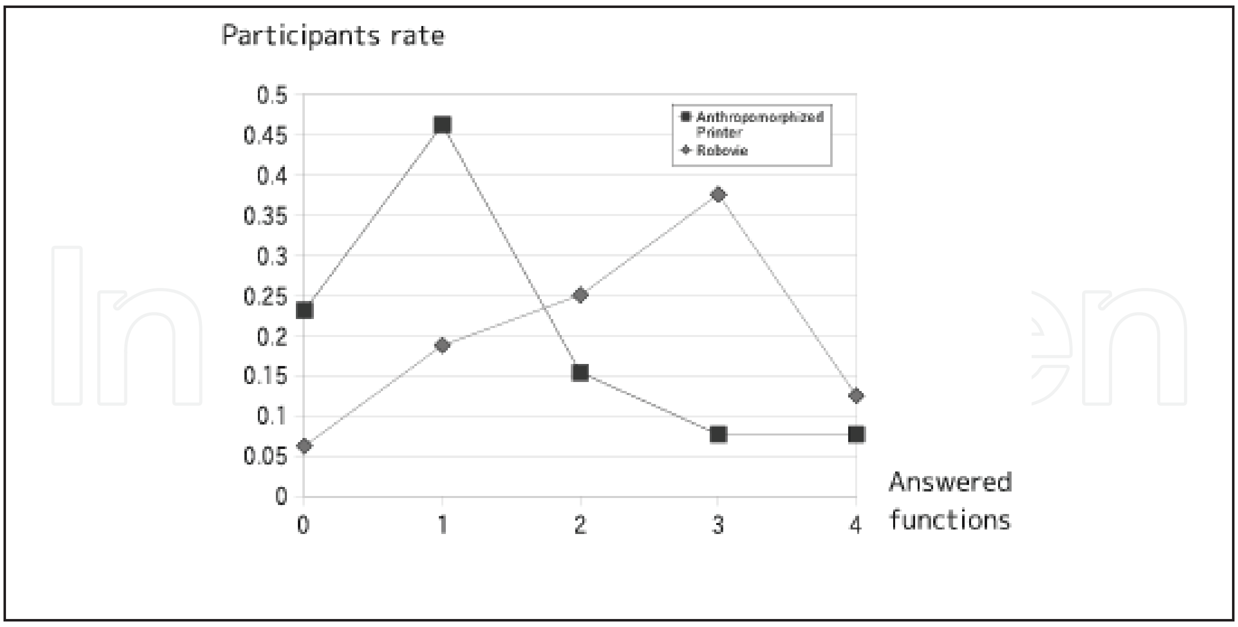

Fig. 10. Distribution of noted functions of printer

5.2 Discussion

The results showed that the participants in the experimental group remembered more functions than those in the control group. We think that this difference arose because the participants in the experimental group could more easily concentrate on the printer since they did not need to focus their attention on other objects. On the other hand, the participants in the control group looked at Robovie most of the time and only sometimes focused their attention on the printer. This proves that the participants in the control group were more distracted than those in the experimental group.

We also calculated the attention rate R_{user} under these conditions using an independent agent and the attention rate R'_{user} with the direct anthropomorphization method using the data from the graph presented in Fig. 11. The average for each set of results was $R_{user} = 0.419$ and $R'_{user} = 0.851$. This result suggests that participants concentrate on the printer more in the experimental condition than in the control condition.

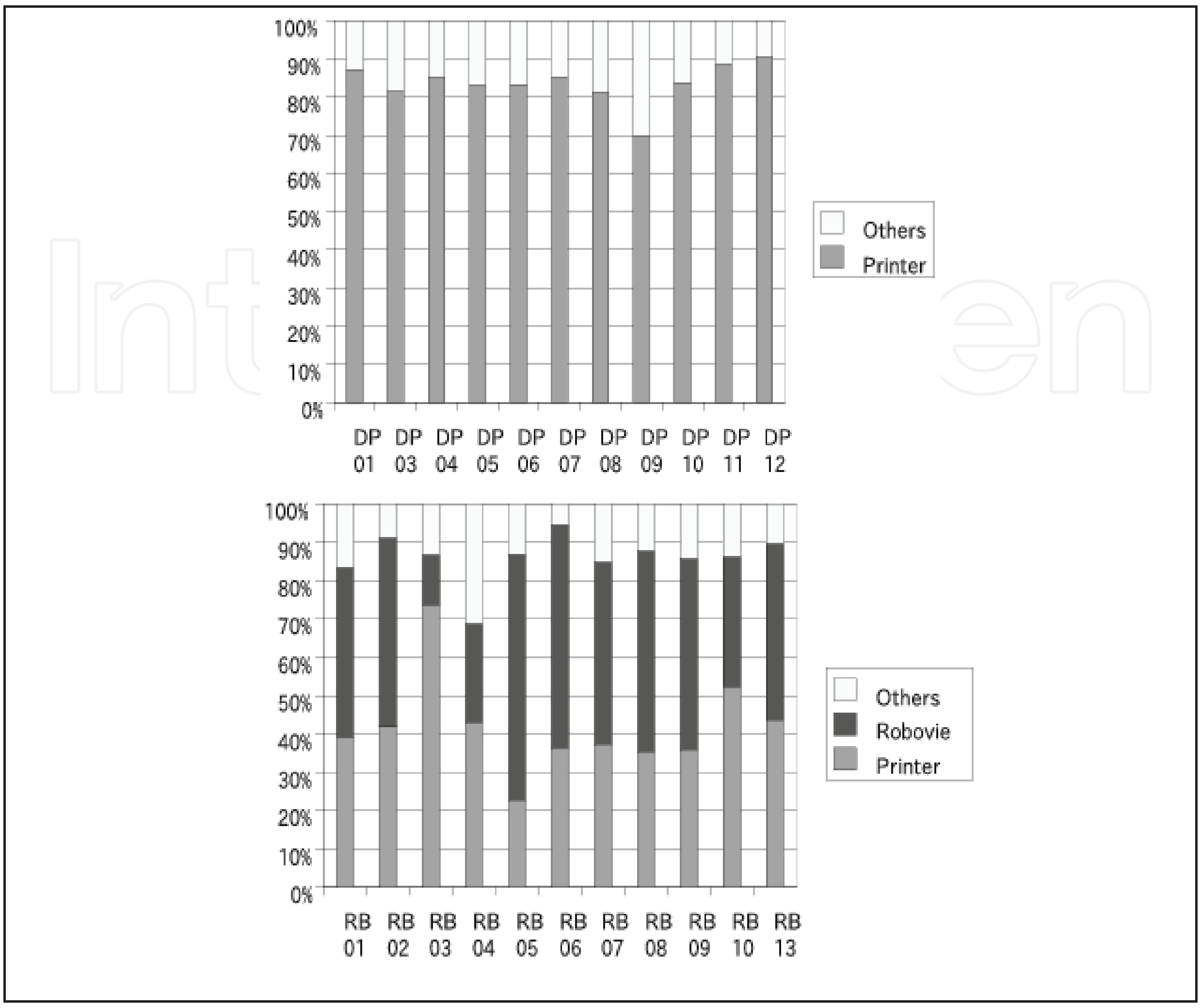

Fig. 11. Gaze time ratio of Experimental (top) and control (bottom) groups

The results graphed in Fig. 11 show that eight participants in the control group gazed more at Robovie than they did at the target printer. These participants almost always focused their attention on Robovie. If Robovie pointed to the printer and explained it, they looked at the printer but focused on Robovie once again. In addition, they sometimes moved their eyes quickly between Robovie and the printer. However, participant RB03 always looked at the printer while listening to Robovie and sometimes even nodded to Robovie. This was a rare case. His score was better than the average score for the noted functions in the control group. This style is similar to that observed in human-human explanation interaction. However, this is not always true when using a humanoid robot. This result suggests there is a contradiction when a humanoid robot develops well and attracts more attention, and thus does not appropriately explain target information. However, there is no contradiction with the direct anthropomorphization method.

On the other hand, the participants in the experimental group paid complete attention to the printer, as shown in the top graph in Fig. 11. Their attention wavered during some actions such as moving paper or the pushing the PC button. However, these actions were needed for proper interaction. Fast moving eyes were not recorded in the experimental group, another point of difference between the experimental and control groups.

It appears contradictory that if a humanoid robot attracts more attention then it does not appropriately explain target information. Many HRI studies presupposed that users will understand a robot's explanation well if the robot is attractive to them.

We think that this hypothesis is inaccurate. A user's state toward the robot is divisible into the following two states; (1) Humanoid appearance and actions are attractive; (2) Humanoid appearance and actions are reliable and can explain other things.

In our anthropomorphization method, the explainer and target are synthesized. We think that the attractiveness of the target is strongly related to its reliability for itself under this situation. Using an independent robot, however, we must estimate the user's state more carefully. Murakawa et al. and Miyashita et al. suggested in their research of a selling robot in a shopping center that even if users highly evaluate a robot, there is no relation between attractiveness and shop sales (Murakawa and Totoki et al., 2006) (Miyashita et al., 2008). These results show that a deeper evaluation of a user's state for the robot is more important.

In this experiment, it is still not clear that the difference in attention duration depends on the manner of anthropomorphization. To say in other words, what is a key role for anthropomorphic image of users are still ambiguous. To solve this problem, we are planning to analyze manner of anthropomorphization of users using several conditions with decreasing anthropomorphic elements.

However, the result of the experiment shows an advantage of our method compared with independent agent method (like virtual agent or humanoid robot). Users must consider both agent and the target at least in independent agent situation because it is impossible to remove the independent agent in this method. It is able to say at least that we can reduce attention duration of users to synthesize an explainer and a target using our method.

Based on these results, we believe that our hypothesis, users pay more attention to a target when using anthropomorphization by humanoid parts than when using an independent anthropomorphic agent, is verified.

Our proposed interaction also improved user intimacy for a common object. The anthropomorphized printer or Robovie instructed printer had both a formal name and a nickname during this experiment. We asked participants, through a questionnaire, "What is the name of the printer?" Three participants in the experimental group responded with the nickname, no participants responded with the formal name, and 13 participants responded with no name. On the other hand, no participants in the control group responded with the nickname, 5 participants responded with the formal name, and 8 participants responded with no name. We conducted a Fisher's exact test with a $p < 0.05$ basis on this result. The result showed a p value of 0.0087, which was less than 0.05, and showed significant difference. This result suggested that anthropomorphization of a common object increases not only the concentration of participants but also intimacy among them and the object. In the future, we will study what model leads to this result.

5.3 Comparison with Related Studies

A commonly-used method to instruct users uses built-in LCD panels or a computer monitor. There are several advantages to our approach compared with current approaches that use monitors;

- Our approach does not depend on the cultural differences or literacy of users because it is based on the human body image and human-like motions. The user understands its instructions by body metaphors even if they did not have prior knowledge about the target. This representation does not need indirect imagination for the space.

- In the monitor situation, for example, a user must interpret a directed point from the information on the monitor and make an image at first. Next, he/she searches the target in the real world using the image. Using our method, users directly understand what is instructed without above process.

Norman suggested famous design guideline using affordance of the object - the fundamental properties of a device that determines its way of use (Norman, 1998). In this guideline, adding moving arms and eyes not only increases the product's cost and complexity, but they increase the possibility of wear and tear, malfunction, obstruction and maintenance.

However, we think that our approach complements Norman's approach because our method uses “attachable” human-like parts. The first reason is that users can customize the explanation style of the object according to their own knowledge. If a user needs more explanation for a smart design object, he/she can attach these human-like parts for explanation. If a user thinks human-like acts are needless for his/her task, he/she can simply remove these parts.

Second reason is as follows. There are two interactions between a user and an object; (1) Interaction to use an object; (2) Interaction to learn about an object.

We think that anthropomorphization parts are appropriate, especially for second goal. Additionally, we think that this attachable explaining method may simplify an original object's design much more, due to the above reasons.

6. Conclusion

We proposed humanoid parts that can be attached to a common object and anthropomorphize it as if it had an intention and its body was like that of a communication robot.

To verify our approach, we developed eye-like and arm-like parts and attached them to a target object and conducted experiments in order to verify the user's perception of the intention of a target (with an anthropomorphized refrigerator) and the imaginary body image of a target (with an anthropomorphized desk and box). We also used our approach to compare the explanation of the functions of a printer by an anthropomorphized printer and explanation by an independent agent Robovie.

The results obtained by observing the actions of participants and administering questionnaires during the experiment indicated that users can interact with a target while perceiving its intention and its imaginary body image. Users also noticed target artifacts and memorized target functions more easily when the direct anthropomorphization method was used than when an independent humanoid agent was used.

6.1 Future Works: Explanation Using Body Metaphors

Our experimental results proved that a user accepts a target's intention and imaginary body image by our proposed anthropomorphization method. Our proposed method, in comparison to the use of an independent agent, is also better at gaining the attention of users for explaining the functions of artifacts.

We think that this method is easy to use, allows various representations, and will extend the application of HRI studies. We believe that this method has the following possibilities.
It is possible to use metaphors for pointing at the location of an artifact. For example, the printer can say “I have a stomachache” when it is jammed. These metaphors would be impossible to use for normal explanation using an independent agent. If we study these metaphors more closely, we might be able to use more understandable expressions for the artifact using our method.

7. Acknowledgements

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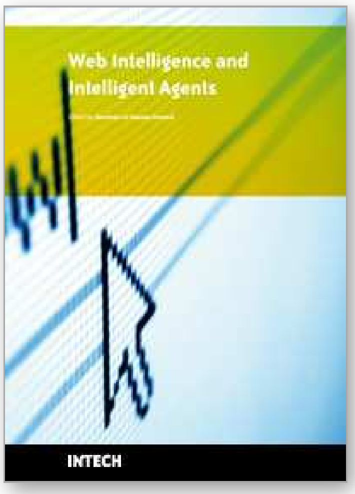

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