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EVALUATION OF HEAD SIZE OF AN INTERACTIVE ROBOT USING AN AUGMENTED REALITY

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ABSTRACT—
In this paper, we propose a design methodology of robots based on augmented reality (AR). While robot design based on subjective evaluation is useful, the problem of subject-based design is that the developer should prepare all variation of robots to be evaluated. Using AR, a developer can prepare robots using computer graphics. In addition, the AR technology makes it possible to evaluate a robot in an environment in which the robot is supposed to work. We conducted experiments to evaluate a robot's head size using both AR and real robots, and compared the evaluation results. As a result, similar evaluation results were obtained from both evaluation experiments, which showed a possibility of AR-based robot evaluation.
Key Words: ROBOT DESIGN, AUGUMENTED REALITY, HUMAN-ROBOT INTARACTION

1. INTRODUCTION

A robot working around humans should be carefully designed from user-familiarity point of view. Many conventional researches on robotics have focused on development of technology that improves parts of a robot, such as robot vision, robot auditory and manipulator. For the main purpose of such researches is to improve performance of a part of a robot, total design of a robot is out of scope of such researches. Recently, several works have been conducted that develop robots that achieve complicated tasks by combining the elemental technologies. Our work is one of such researches that develop an entire robot system. Development of such robot systems, especially robots that work around humans, requires not only pursuit of high functionality but also careful design work so that the robots do not look like threatening or scary [1].

Robots designed to work around humans, such as HERMES [2] and Care-O-bot 3 [3], are designed by designers or developers according to their sense; therefore the appearance of the robots are not guaranteed to be also supported by the users. As a robot working around humans inevitably interacts with humans, design of a robot's function or appearance concerning human interaction should be determined taking users' opinion into account. As an example of such design method, Hiroi and Ito [4] conducted a subjective evaluation experiment that measured appropriate distances between subjects and a moving robot that had variable height. Their work can be viewed as a method of designing height of a robot working around humans. As other examples, Mutlu et al. [5] and Walters et al. [6] used real robots such as ASIMO and PeopleBot for investigating influence of subjects' age and gender on the human-robot interaction design. However, evaluation of users' impression using real robots requires making many robots with various factors such as height, which is time-consuming and costly. On the other hand, if a ready-made robot such as ASIMO is used for evaluation, one cannot compare users' impression on different robot design.

In this paper, we proposed an evaluation framework of robot design using the augmented reality (AR) technology. The organization of this paper is as follows. In section 2, we proposed an evaluation scheme of robot design using the AR technology. An experiment for evaluating the proposed framework is described in section 3, and discussion on the experimental result is given in section 4. Then we conclude the paper in section 5.

2. EVALUATION OF ROBOT SHAPE USING AN AUGMENTED REALITY

In this paper, we propose a framework of subject-based evaluation of robot design, especially shape of a part of a robot, using an augmented reality (AR). AR is a technology that displays texts or virtual objects overlaying on the real world [7]. Using AR, the virtual objects can be displayed as if they really existed in the real world by updating the virtual objects in real-time considering an observer's viewpoint.

We first discuss on the choice of robot for subjective evaluation among a real robot, virtual reality and augmented reality. First, on evaluating a shape of a robot using several robots with different shape, we can consider two choices — using real robots and using robots realized by computer graphics (CG). Using real robots, we can guarantee that the evaluation result is appropriate for applying the result to the design of a real robot. However, if we want to conduct evaluation for different-sized robots [4], we must actually make the entire robots with individual size. In addition to the cost of making robots, we must also pay costs for keeping robots. Using CG, although we must still pay cost of creating CG objects, the absolute cost and time will be drastically reduced compared with really creating robots.

Next, when using CG for evaluation of robot shape, we have to choices — use of virtual reality (VR) and use of AR. Goetz et al. evaluated head shape of a robot through experiment using CG [8]. In their evaluation, the CG-generated image is presented to evaluators as a two-dimensional image without background image, which means that they did not consider the difference between the CG-generated environment and the real environment in which the robot is used. If we use VR technology, we can conduct evaluation experiments in more realistic situation including the environment around the robot. For example, Onishi et al. [9] used VR technology using immersion type environment for simulation of whole body manipulation. Although their simulation environment was effective, the immersion display environment is expensive, and it is difficult to realize more "realistic" environment in which a robot really works, including rooms, desks, objects in the room, etc. Because of the latter problem, it is difficult to conduct similar evaluation of a robot using VR to the robot in the real environment.

To realize CG-based simulation under real environment for evaluation of robot shape, we propose a framework that uses AR for evaluation. There are two merits for using AR as a method of robot design evaluation. First, time and cost for building robots are drastically reduced compared with building real robots. Second, the AR technology makes it possible to evaluate a virtual robot in a real environment. Fig. 1 shows an example of realization of a computer-generated robot in a real environment. By mixing real background and computer-generated robot, we can evaluate the robot under the real environment where the robot is supposed to be used.

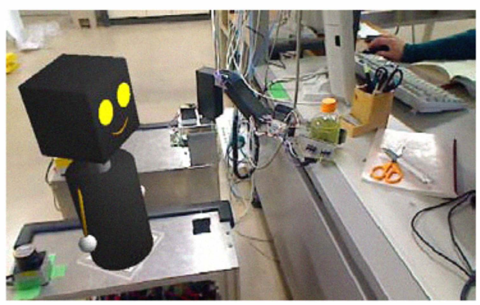


Fig 1. An example of a robot rendered by AR in a real environment

Evaluation of products using AR is useful for quantitative design such as variations of color and shape. For example, Lee et al. [10] applied AR for product design simulation. However, AR-based design has not been applied to designing robots. Quantitative design of a robot is mainly a design of proportion of body parts, such as length of arms or size of a body. In this paper, we applied this framework for designing head size of a robot avatar. Robot avatar [11] is a robotic interface proposed by Hiroi et al. A robot avatar is used with a service robot such as a patient care robot. A service robot that interacts with humans should have many functions such as dialogue, face recognition and environment recognition in addition to the function to achieve the target task. However, it is difficult to implement all of required functions in one robot. A basic idea of robotic interface using a robot avatar is to divide functions of a service robot into human interface and task achievement, and a small robot (avatar) attached to the service robot is in charge of human interface. By using a properly designed robot avatar, user familiarity of the whole service robot system can be improved [11].

3. EVALUATION EXPERIMENT

3.1 OVERVIEW

Even if AR technology is used, it is difficult to completely reproduce a real robot in a virtual space including the robot's feel of material or lighting. Therefore, the difference between the real and virtual robots could be affect the result of subjective evaluation. To investigate if this difference is a matter or not, we conducted an experiment of comparing the subjective evaluation results by real and virtual robot. The task of evaluation is determining head size of a robot avatar.

We carried out the following two experiments. In the experiment 1, the subjects evaluated design of robots whose heads were realized using CG. In the experiment 2, the whole parts of the robots including their heads were actually built.

3.2 REALIZATION OF A ROBOT USING AUGMENTED REALITY

We used ARtoolkit developed by Kato [12]. Using this toolkit, we can easily develop the environment of evaluation without complicated know-how of AR.

Figure 2 shows the real part of the robot to be evaluated. The robot's head is generated using CG and overlaid by AR toolkit. A USB camera recognizes a marker behind the robot body, and the marker position determines the position of the head. Recognition of the marker and determination of head position are functions provided by the ARtoolkit. What we have to do is to prepare a marker and a model of robot's head using CG. The overlaid scene is shown in Fig. 3. As the head is realized by CG, it is quite easy to change size of the head.

We can realize the body of the robot using CG as well. The reason why we modeled only the head part of the robot is that we are planning evaluation of a robot that contacts with an evaluator in the future. If all of the body is realized by CG, the evaluator cannot touch the robot, which means that the evaluation using a full-CG robot is limited to an interaction without contact. Conversely, if the body of the robot is real, we can evaluate the robot that has interaction with body contact, e.g., handshaking.

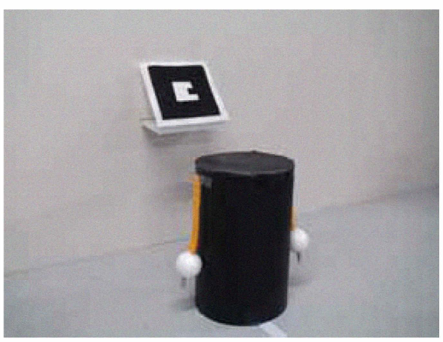


Fig2. The robot's body

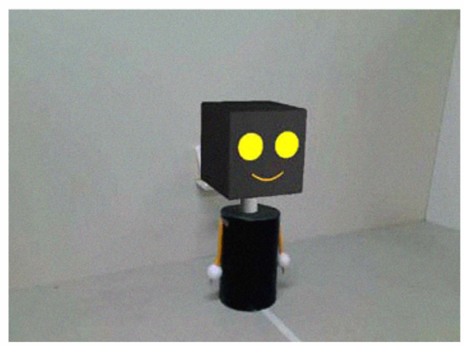


Fig 3. The robot with head generated by AR

Fig4. HMD with camera

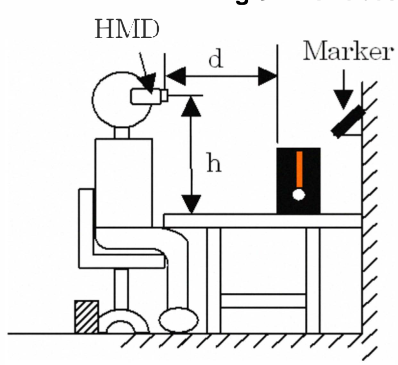


Fig 5. Experimental setup

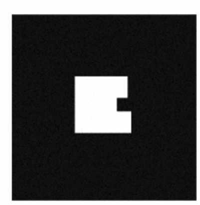


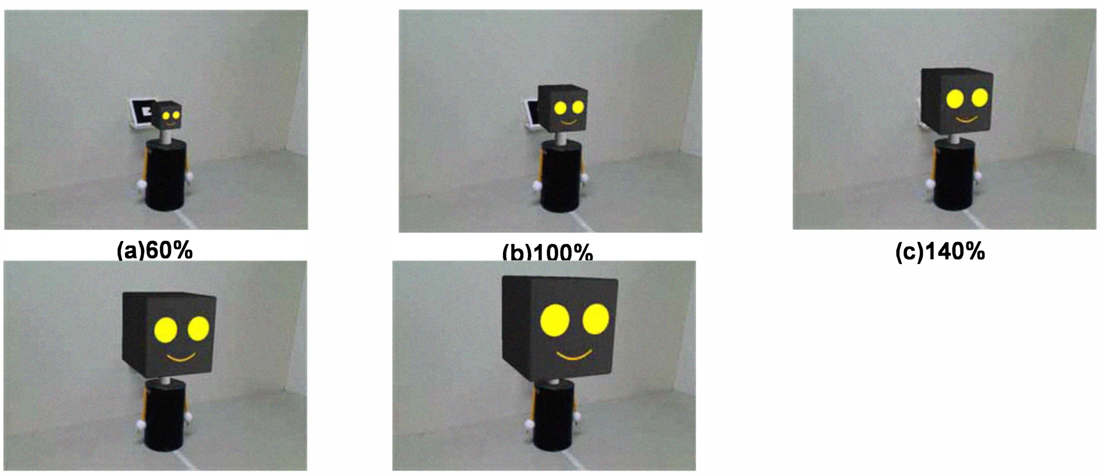
Fig6. Marker

3.2 EXPERIMENTAL SETUP (EXPERIMENT.1)

The devices for experiment were composed of a laptop PC for running ARtoolkit, A head-mounted display (HMD) for presenting a subject the AR-generated image, a camera for capturing the marker and the background image, and the body of the robot. The specification of the laptop PC was Intel (R) core2 DUO, 2GB memory with Windows XP OS, which conforms to the recommended environment of ARtoolkit. We used VUZIX iWear VR920 as an HMD, which had 640×480 resolution. The camera was Logicool Qcam Pro for Notebooks, which had 2 million pixels and 75 degree view angle. The camera was mounted on the HMD as shown in Fig. 4. The body of the robot was cylindrical shape as shown in Fig. 2, with 130mm diameter and 190mm height. Figure 5 shows the experimental settings. We used a marker shown in Fig. 6, which was mounted on the wall behind the robot in 45 degree for avoiding misrecognition by the toolkit. Distance between the camera and the robot, indicated as *d* in Fig. 5, was set to 600mm that is determined considering the robot's working environment, under which speech recognition is used. The distance in this experiment is a maximum distance for keeping speech recognition performance high [13]. The height of the camera, indicated as *h* in Fig. 5, was adjusted subject by subject. The average height was 429mm and the standard deviation was 19mm.

We prepared five heads with different size using CG, as shown in Fig. 7. The size of the head is indicated as the proportion to the diameter of the body, where 100% means that the width of the head is identical to the diameter of the body. The sizes of the prepared heads were 60%, 100%, 140%, 180% and 220%.

While a subject was observing the robots through the HMD, the robot's head was moving so that the robot looked nodding. This motion was designed based on the fact that an observer felt more familiarity to the robot when the robot was nodding appropriately while talking with a user [11]. In this experiment, the robot was just nodding (without any utterance) in 30 nods/minute.



(a)60% **(b)100%** **(c)140%**

(d)180% **(e)220%**

Fig.7 Model of EXP1

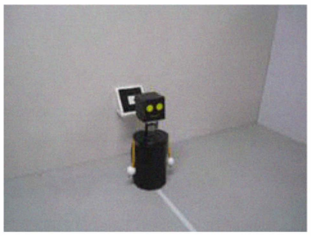
The subjects were 17 male students who are from 20 to 23 years old. All of the subjects were not explained anything on the experiment, and were never seen the robot. The procedure of one session of the experiment was as follows.

1. Instructions of the experiment were given to a subject.
2. A subject sat on the chair with his back stretched, and wore the HMD.
3. Height and position of the viewpoint was adjusted by changing height of the chair.
4. Five kinds of robots with heads of different sizes were presented randomly to the subject. Then the robots were presented again in the same order as the previous presentation.
5. The subject evaluated "familiarity" (or "friendliness") of each robot in ten grades, 10 to be the most familiar.

3.3 EXPERIMENTAL SETUP (EXPERIMENT.2)

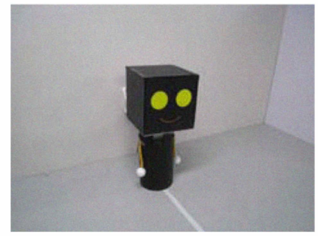
The experiment 2 was conducted in the same procedure as the experiment 1. The different point was that real heads were used in experiment 2. The neck had one DoF using which the same movement as the AR-based robot could be performed. KONDO KHR-786 was employed as an actuator of the neck, controlled with RCB-1 controller. The speed of nodding was the same as that in experiment 1 (30 nods/minute). We made the heads so that their proportions to the body were same as that in the experiment 1, i.e., 60%, 100%, 140%, 180% and 220%. Figure 7 shows the pictures of the robots with real heads.

The same subjects as experiment 1 were employed in this experiment. This experiment was conducted at least one week after experiment 1. To make the condition of this experiment as identical as that of experiment 1, the subject wore HMD for looking at the robots. When changing the robot between the stimuli, white background with a message “please wait for a moment” with black letters was presented to the HMD.

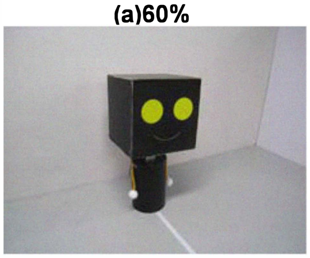


(a)60%

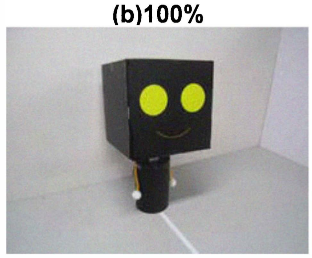
(b)100%



(c)140%



d)180%



(e)220%

Fig.8 Model of EXP2

4. EXPERIMENTAL RESULTS AND DISCUSSION

Result of experiment 1 is shown in Fig. 9. The horizontal axis is the head size (proportion), and the vertical axis is sum of the familiarly scores. We found significant differences among these values using Friedman’s test (p<0.01). Then, we conducted Steel-Dwass' multiple comparisons. As a result, the subjects supported 100% and 140% head size of the robot.

Next, result of experiment 2 is shown in Fig. 10. We found significant differences among these values using Friedman’s test (p<0.01). Then, we conducted Steel-Dwass' multiple comparisons. As a result, the subjects supported 140% head size of the robot.

To investigate similarity between evaluation scores of both experiments, we calculated Pierson’s correlation coefficient for the scores of two experiments. The result was 0.745, which indicated that the scores of the two experiments had significant correlation.

From these results, it is shown that subjective evaluation using AR gives similar result as the evaluation using real robots.

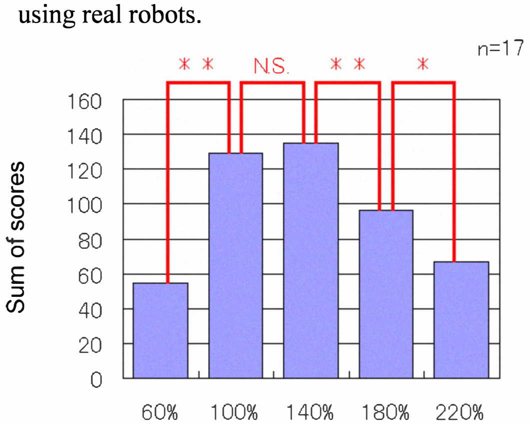


Fig 9 Result of experiment 1
(: p<0.01, *: p<0.05, N.S: not significant)**

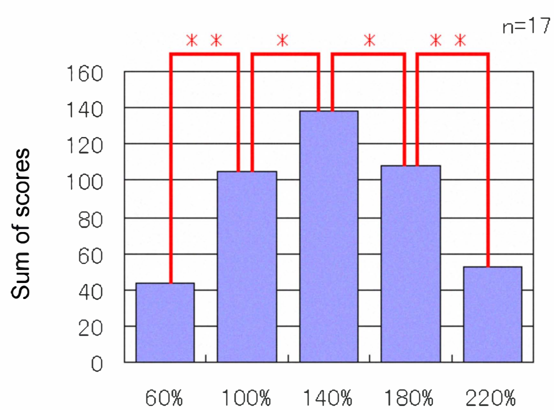


Fig 10 Result of experiment 2
(: p<0.01, *: p<0.05, N.S: not significant)**

5. CONCLUSION

In this paper, we proposed a framework of subjective evaluation using AR. In the experiment, we evaluated head size of a robot among five levels. We conducted two evaluation results conducted using AR and real robots. In the former experiment, the subjects supported heads with 100% and 140% sizes; in the latter experiment, 140% head was supported. The scores of the two experiments had significant correlation. From these results, we think that evaluation of robots using AR was justified.

Using AR for subjective evaluation of robots reduces time and costs for preparing multiple robots. For example, changing colors of the robot can be done by CG very easily. In addition, the AR-based evaluation can be conducted in the real environment in which the robot is supposed to work. Our result will expedite the development of a complicated robot system.

As the future work, the proposed framework should be further evaluated by applying robot evaluation other than head size. Using the AR-based evaluation, influence of personality such as age or gender on preference of robot design will be investigated. In addition, we will investigate the effect of contact-based interaction such as handshaking on the impression of a robot.

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