Development of robot design evaluating system using Augmented Reality for affinity robots

Shyang Shao
Tokai Univ.
Applied Computer Engineering
Hiratsuka Kanagawa Japan
shaoshyang0523@gmail.com

Satoshi Muramatsu
Tokai Univ.
Applied Computer Engineering
Hiratsuka Kanagawa Japan
muramatsu@tokai.ac.jp

Katsuhiko Inagaki
Tokai Univ.
Applied Computer Engineering
Hiratsuka Kanagawa Japan
ingk@ingk-lab.org

Daisuke Chugo
Kwansei Gakuin Univ.
Sanda Hyogo Japan
chugo@kwansei.ac.jp

Syo Yokota
Toyo Univ.
Kawagoe Saitama Japan
s-yokota@toyo.jp

Hiroshi Hashimoto
AIIT
Shinagawa Tokyo Japan
hashimoto@aiit.ac.jp

***Abstract*—In this research, in order to clarify robot design elements with high affinity with people, we developed an evaluation system that enables users to evaluate impressions from a highly flexible perspective from augmented reality. Human investigated impression evaluation on robot and identified 5 factors which are the evaluation index**

Keywords—augmented reality, robot design, factor analysis, kansei eng

I. INTRODUCTION

In recent years, robots have advanced into the fields such as nursing care, welfare, transportation, etc. It is predicted that people and robots will be together in the activity space more often. However, many current robots are developed with emphasis on only functional performance, and it seems to be difficult to establish smooth relationships with each other. For solving this problem, it is important to pay attention to design which is the appearance of the robot, and to consider the design which is sensitive to humans [1]. And in order to realize the design with improved affinity, a high-quality evaluation system is necessary.

However, at present there is no such evaluation system. In addition, since the direct impression evaluation method using a robot actually manufactured, which is a conventional method, and is often used in the research of robotics [2][3]. For evaluating the real thing in front of the eyes, the obtained affinity evaluation is high credible. However, it is difficult to evaluate the impression for many robots because it requires a reasonable budget and time to produce those actual machines.

In this research, we aim to develop a design evaluation system for evaluating affinity of robots that can obtain high reality at low cost by using Augmented Reality.

II. EVALUATION SYSTEM USING AUGMENTED REALITY

The highly realistic evaluation system described in Chapter 1 means that real landscape is projected using augmented reality as shown in Fig.1 and the CG (Computer Graphics) model of the robot to be evaluated is displayed as a virtual object markerlessly.

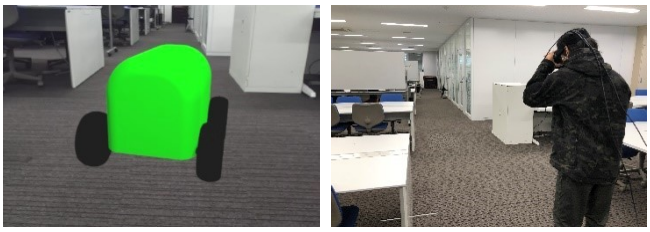


Fig. 1. CG model projected on reality background

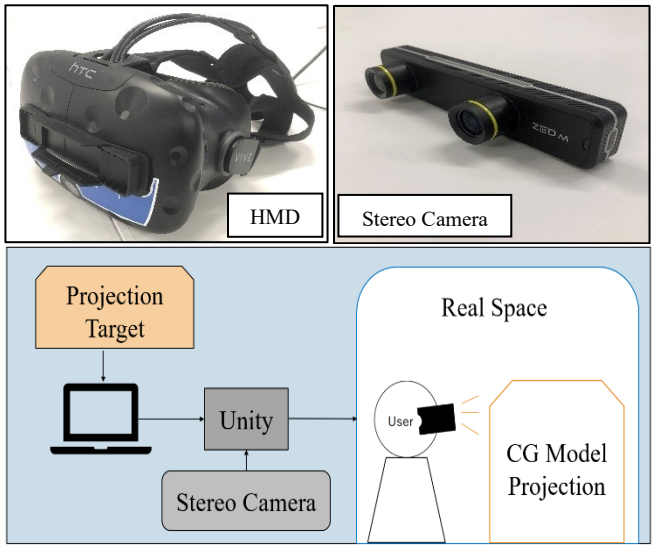


Fig.2 System overview

This system can perform design evaluation from a high viewpoint of degree of freedom.

This evaluation system is thought not to be evaluated by conventional indications such as a monitor or an indirect presentation such as paper but directly impressions can be evaluated in front of the eyes so that high quality design can be considered possible.

978-1-7281-2927-3/19/$31.00 ©2019 IEEE

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.

A schematic diagram of this system is shown in Fig. 2. In order to realize this system, in this research, we use two devices, HMD (Head Mounted Display) capable of visualizing virtual objects, and a stereo camera capable of tracking real background with high precision, and Visual SLAM. This system use Unity to display CG and Blender to create CG model to project.

The object is tracked from the acquired background image, mapping is performed, the position and orientation of the HMD are specified by the attached base station, and then the plane detection and the CG model display position are determined using Visual SLAM. Thereafter, these images are sent via the HMD that the user wears. Also, to make it easier for users to make impression evaluations, we implemented a function that allows you to move and rotate CG models using HMDs and controllers.

III. ROBOT DESIGN ELEMENT EXTRACTION

In this research, in order to establish a harmonious relationship in the coexistence of a person and a robot, it is necessary to investigate the design elements of the robot taking into account the affinity with people. In this issue, we focused on mobile type service robots that provide guidance to people at public attractions and facilities where there are many eyebrows.

A. Selection of Evaluation Items Using KJ Method and SD Method

In order to clarify the design elements of the robot, it is necessary to conduct some preliminary experiments and final impression evaluation experiments. Further, the evaluation item to be handled in the experiment is selected. Therefore, we first investigate people's impression on robot by SD (Semantic Differential) method [4] used as a sensitivity measurement method. In the field of robot engineering, the SD method is often used for impression evaluation on robot therapy and humanoid service robots [5][6][7]. Since the SD method can quantify invisible parameters such as sensitivity of human beings, it is used to investigate what kinds of evaluations are received by people's requirements specifications and finished products in the market.

Since the SD method measures human sensibility using multiple adjective pairs, it is necessary to select an adjective pair for use in sensitivity evaluation. As a method of selecting adjective pairs, a method of selecting from 76 kinds of adjective pairs of Osgood and a method of collecting by using a questionnaire etc. beforehand is general [4], and this time, for the general public to do the impression evaluation along the impression with the robot, the latter method was adopted. Specifically, as a preliminary step of the impression evaluation, as a preliminary experiment, we conducted a questionnaire with a free description method on robots and collected keywords.

We conducted a questionnaire to 58 people, carefully selected from 512 words obtained by multiple people and extracted 53 keywords. Among them, the words obtained as adjectives and adjective verbs, such as "new - old" and "heavy - light", the words used in previous studies on impression evaluation of service robots are used as it is . Furthermore, we decided to consolidate and use words similar in meaning such as

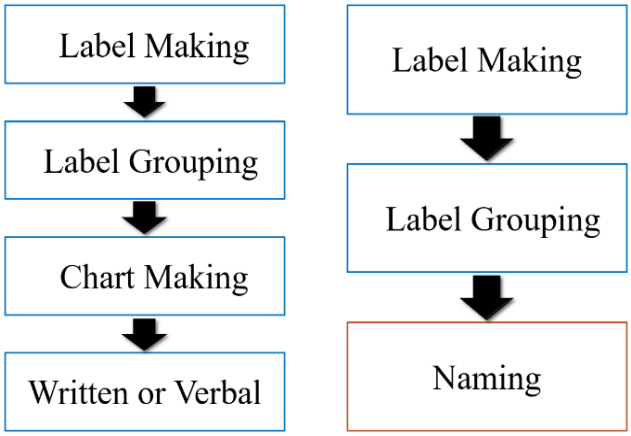


Fig.3 Original process(left) and proposed process(right)

TABLE I. 22 PAIRS OF ADJECTIVES EXTRACTED

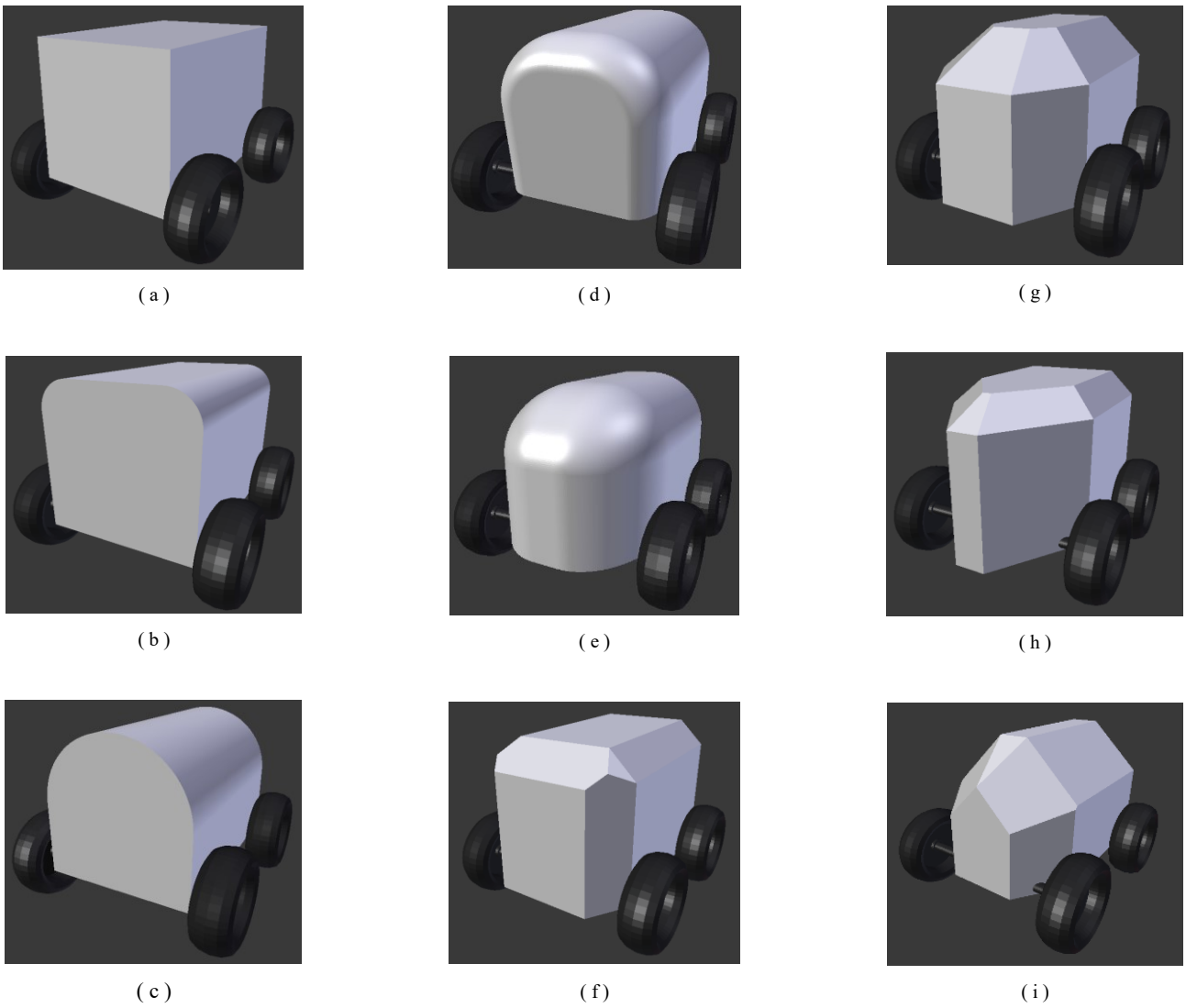
Large	Small
Fast	Slow
Heavy	Lightweight
High	Cheap
Cool	Ugly
Scary	Cute
Hard	Soft
Convenient	Inconvenient
Gentle	Bleak
Helpful	Useless
Precarious	Safe
Dependable	Unreliable
Difficult	Simple
Exotic	Sober
New	Stale
Banausic	Individual
Pesky	Quiet
Strong	Meager
Smart	Senseless
Flimsy	Brassbound
Delightful	Pained
Intricate	Unsophisticated

"advanced" or "futuristic" according to the adjective versus selection rule of SD method [4], and also use "factory" and "elderly" with regard to nouns such as "KJ (Kawakita Jiro) method [8], we decided to use it as an evaluation paper after making an adjective.

The KJ method is a method of information processing devised by Mr. Kawakita Jiro, a method to arrange, classify and integrate vast amounts of information obtained by questionnaire and brainstorming based on intuition. Originally the KJ method carries out the processing of "illustration" and "documentation" after "keyword collection" and "grouping", but this time it is used only for noun adjectiveization, so after each "grouping" processing, we propose a method of "tagging" tasks to give appropriate adjective names to groups. Fig.3 shows the original process of the KJ method and the flow of the process proposed this time. Also,

Here are two reasons for suggesting such a method. First, the burden on experiment participants is reduced by simplifying work. It takes time of several hours when working up to

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.



(a) (d) (g)

(b) (e) (h)

(c) (f) (i)

Fig.4 9 types of robot models

"documentation" according to the original KJ method's procedure, but in the case of the proposed method of performing "tagging" work after "grouping" we were able to complete the work in about 30 minutes in total for the topic. Furthermore, as an advantage of the second point, the purpose of this time is to make adjectives of nouns, and there is no need to perform "Illustration" and "documentation" work. Specifically, taking the "factory" as an example, the phrases

"explosion" and "danger" that can be associated with the noun "factory" are written one after another on paper and grouped together with things having similarities. And tagged each group - tagged the group containing 'explosion' or 'danger' as 'dangerous'. In this way, the noun adjectiveization was performed using the KJ method.

22 pairs of adjectives extracted from these methods are shown in Table1, and evaluation papers of 6 scale were prepared using this pair of adjectives.

B. Factor Analysis

Using this method, adults always keep calm like "adult likeness", like pets like "animal likeness", feel like they are " disturbance ", light and easy to carry, "ease of handling", “robustness" The five factors of robustness were extracted. These 5 factors become robot design indexes, and are treated as the contents of evaluation items for impression evaluation experiments.

C. Creating CG Model for Evaluation

In the CG model prepared for the impression evaluation experiment, impression evaluation experiments are conducted by impressions evaluation from persons as to the 5 factors "adult likeness" "disturbance" "animal likeness" "ease of handling" "robustness" , It is a model to clarify how the various shapes and colors of robots give people a more impressive impression.

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.

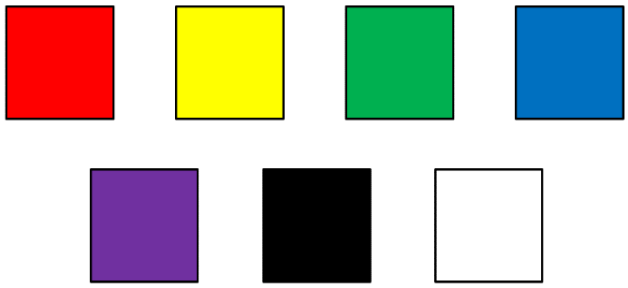


Fig.5 total of 7 colors

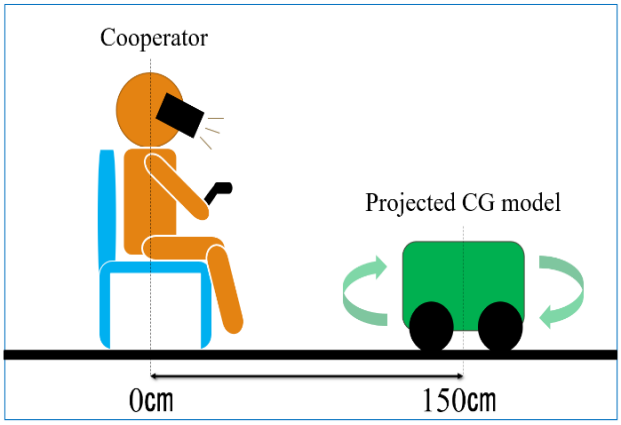


Fig.6 The outline of the experiment

Fig.7 Experimental scene

At the moment, it is unclear how the impression changes due to the change of shape in order to properly fill these five factors. Therefore, in order to clarify the influence of shape and color factors on the five factors, 9 types of robot models with different shapes were prepared by chamfering or filleting the basic shape from square to square. Their models are shown in Fig.4 (a) to (i). In addition, each model has a total of 7 colors, which are achromatic 2 black and white colors shown in Fig.5 and 5 colors of red, blue, green, yellow, and purple, which are the basic colors of the Munsell color system. Total 63 types of CG models are made.

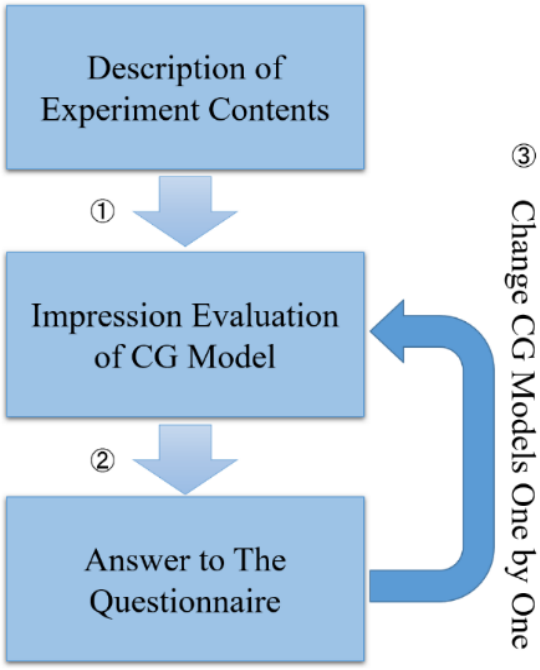


Fig.8 Experimental procedure

IV. Impression Evaluation Experiment

In this experiment, it is possible to realize a design of a sensitive robot which is not giving a bad impression such as discomfort, so the investigation of the design element as the indicator and the utility of the evaluation system are aimed at.

In this time, we focused on two factors, "disturbance" and "adult likeness" from five factors which are evaluation items. The impression evaluation in the experiment indicated that the former is low and the latter is high by listing.CG model. It is possible to extract design elements

A. Experimental Method

In this experiment, we conduct experiments for a total of 10 students, including 7 men and 3 female university students, and have them answer the evaluation sheet.

In the experiment procedure, the CG models of the 63 robots produced are projected one by one to the experiment collaborators as virtual objects in front of the eyes. Have each CG model perform an impression evaluation from a free angle by using HMD's controller for about 1 minute.

Fig.6 shows the outline of the experiment and Fig.7 the experimental scene. Measurement is carried out by the experiment collaborator in a seated posture. This is because the height of the CG model is lower than that of person's knee and in an upright posture the experiment collaborator becomes lower in waist and looks down to the robot, so it is considered to be inappropriate as a measurement environment. Also, since it has a slightly heavier HMD on the head, the burden of both legs and neck around the experimental collaborators in a long time evaluation experiment shall be prevent. After completing measurement

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.

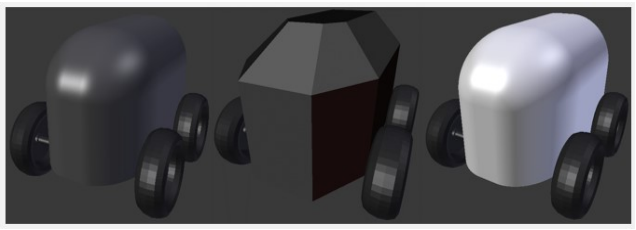


Fig.9 CG model superior on "Adult likeness" factor

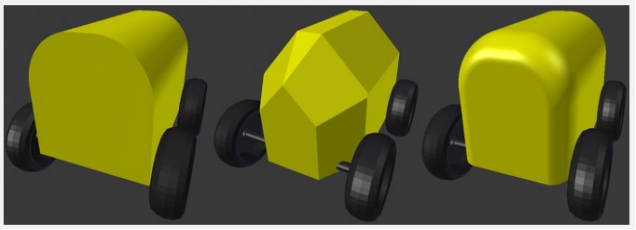


Fig.10 CG model inferior to "Adult likeness" factor

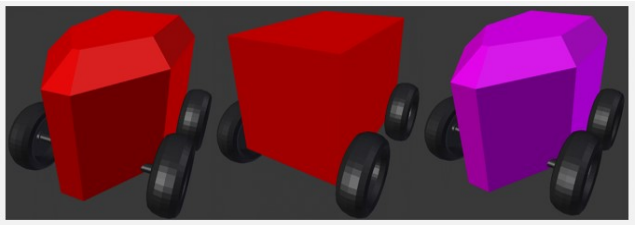


Fig.11 CG model superior on “Hindrance" factor

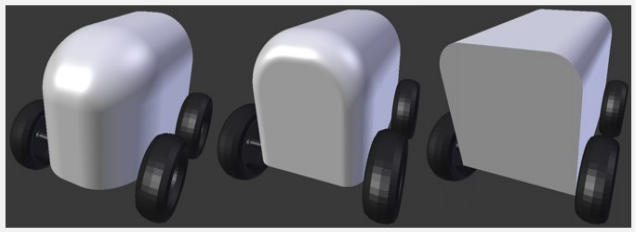


Fig.12 CG model inferior on “Hindrance" factor

B. *Experimental Procedure*

Fig.8 shows the flow of the experimental procedure.

1. To the experiment collaborators, describe the contents of experiments to be done from now on, how to use the controller to rotate the model, and the evaluation items to be answered. After explanation, practice to make smooth progress of experiment and remember feeling
2. Proceed one by one from the CG model of 63 types of robot and perform measurement. In consideration of the order effect, the measurement order of robot color is replaced for each experiment collaborator.
3. After completing the measurement, ask the experiment collaborator to fill out the evaluation form every time. Repeat steps 2 and 3 for other models as well

C. *Experimental Results*

From the results of the impression evaluation experiments, the top three and the lowe three CG models of the "adult likeliness" and "disturbance" factor scores are shown in Fig.9 to Fig.12, respectively.

D. *Discussion*

Experimental results obtained are discussed as following;

Top CG model to "Adult likeness" factor

The scoring order among these three types is left> medium> right. There were many black and white coloring, and the shape was rounded and angular model were chosen in a well-balanced manner. In addition, the CG models other than the top three are colored with cold and green neutral colors such as white, black, and blue, and the CG models giving a calm impression are thought that overall worked hard on these items. Also, from the comment section on the evaluation sheet, there was a description that "It seems to fit in an interior room" and "Black is luxurious".

Inferior CG model to "Adult likeness" factor

Regarding this item, all models with yellowish coloring were scored low, and these models were particularly low in score. This is thought to be the result of reflecting the impression of "boldness" and "bustling" of the color yellow [9]. Also in the comment section, there was a description that "Noisy", "Restless", "Child-like".

Top CG model to "Hindrance" factor

The top models in this item are chosen which are with red, purple and yellow coloring that are not often seen in everyday life in general, and with angular shapes. Many descriptions such as "That is great presence" and "The color distorts the eyes" were also seen in the comment section.

These colors become very impactful colors when used as a part of the whole as an accent color, but when used in a single color, colors such as "flashy" and "intensity" It is thought that there were many people who feel that they have disturbed their eyes because of having to push out the image with [9].

Inferior CG model to "Hindrance" factor

Most of the models that were chosen as the top are cited as white coloring that is easy to blend into the background, resulting in many rounded shapes overall. This is because the white itself has a clean image, it is thought that there is an impression that gives less discomfort to people. Moreover, because it gives the impression that it became smaller than rounded model, it is thought that the existence of model is reduced. In the comment section, there was a description of "white as chic image" or "no discomfort in the public place".

From these results, the score will be raised by applying calm coloring of white or black, the factor of "disturbance" is based on white which is easy to dissolve in the background and is made into a rounded shape it turns out that the score decreases. From this fact, in order to design a robot with improved affinity for people, it is necessary to avoid the angular shape as much as possible and require coloring based on the white color system that gives a soft impression as the design elements.

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.

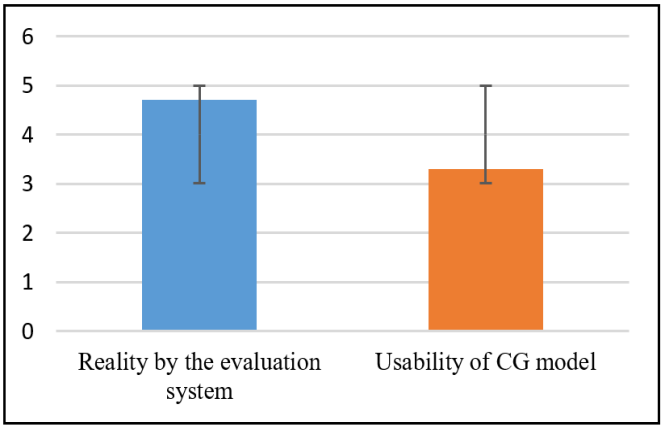


Fig.13 Questionnaire results

V. UTILIT OF EVALUATION SYSTEM

Impression evaluation experiments were carried out on 63 types of robot CG models made with the selected evaluation items, and we were able to find design elements of robots with high affinity for people. For the experiment of this time, it is also a purpose to measure the usefulness of the evaluation system developed in this experiment together with the investigation of design elements.

After completing the experiment, 10 participants who took part in the questionnaire are asked to answer about the evaluation system. As the contents of the questionnaire, similar to the evaluation system using augmented reality, an answer is asked in the questionnaire paper with evaluation of 4 scale about the "reality" that means the evaluation object projected in front of the eyes really exists there and the "Operability" that means the movement of the CG model projected using the HMD controller such as rotation. Fig.13 shows a graph obtained by averaging the results from the questionnaire results.

From the graph results, the " reality" due to augmented reality in the evaluation system is in high results. Also, in the comment section, an opinion is obtained that "When there is a shade matching the light source of real space, the reality becomes higher." As a result, the developed system is thought to be able to measure affinity more than evaluating the object through paper or display.

However, we understood that there is still improvement in operability using the controller. Experimental collaborators got the knowledge that "the speed of movement and rotation is slightly slow" or "CG model change or questionnaire response can also be done with the controller, the experimental efficiency gets better". We will feed back these opinions and make improvements to become a high quality evaluation system.

VI. CONCLUSION

In this research, in order to clarify robot design elements with high compatibility with people, we developed an evaluation system that enables users to evaluate impressions from a free viewpoint using augmented reality. In addition, we investigated the impression of the robot by questionnaire and selected the evaluation items to be handled in the experiment using KJ method and SD method.

We conducted impression evaluation experiments on 63kinds of robot models using the developed system, measured the usefulness of the system by questionnaire, and investigated the design elements of the robot to improve affinity for people. In order to improve the "adult likeliness" factor and reduce the "disturbance" factor from the results of the experiment, by giving a white coloring to the exterior of the robot and shaping it to be rounded, the two factors condition realized the design of a robot that can be met appropriately.

As a future prospect, in this experiment we used a total of seven primary colors including five chromatic colors and two achromatic colors for coloring the model, so the change in hue, lightness, saturation, the material of the surface of the robot. It is necessary for a person to verify the change in the impression on the robot by the change in the robot. Furthermore, we aim to improve system performance by adding shading to CG model by recognizing light source in real space.

In addition to that, we will reflect the design elements obtained by the experiment on the real machine, carry out the experiment in the public actually and verify whether we can obtain the same impression as the result of the experiment.

REFERENCES

[1] Haring KS, Watanabe K, Mougenot C, “The influence of robot appearance on assessment,” IEEE International Conference on Human-Robot Interaction, pp131-132, 2013.

[2] Takayuki Kanda, Hiroshi Ishiguro and Toru Ishida, “Psychological evaluation on interactions between people and robot,” Journal of the Robotics Society, pp1001-1010, 1999.(in japanese)

[3] Takayuki Kanda, Hiroshi Ishiguro, Tetsuo Ono, Michita Imai and Ryohei Nakatsu, “An evaluation on interaction between humans and an autonomous robot Robovie,” Journal of the Robotics Society, vol. 20, No.3, pp1-9, 2002.(in japanese)

[4] C. E. Osgood, G. J. Sugi and P. H. Tannenbaum, “The measuremen of meaning,” Univesity of Illinois Press, Urbana, 1957.

[5] R. Li, L. Zhao, L. Ge, L. Sun and T. Gao, “The Development of a General Type of Security Robot,” Proc. of the 2007 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp.47-52, 2007.

[6] T. Jacobs and G.S. Virk, “ISO 13482 – The new safety standard for personal care robots,” Proc. of the 2014 IEEE International Symposium on Robotics (ISR), pp.698-703, 2014.

[7] Ryuzo Sonoyama, “Introduction to Robot Design, ” Mainichi Communications Inc., 2007.

[8] R. Scupin, “The KJ Method: A Technique for Analyzing Data Derived from Japanese Ethnology,” Human Organization, vol.56, pp.233-237, 1997.

[9] Kobayashi Shigenobu, “Color Image Scale,” Kodansha, 2001

Authorized licensed use limited to: University of Calgary. Downloaded on August 13,2021 at 00:24:00 UTC from IEEE Xplore. Restrictions apply.