19th IEEE International Symposium on Robot and
Human Interactive Communication
Principe di Piemonte - Viareggio, Italy, Sept. 12-15, 2010

Experimental Investigation on a Robot-like Remote Control with Strokes

Kazuki Kobayashi, Seiji Yamada, Shinobu Nakagawa, and Yasunori Saito

Abstract— **This paper describes user studies on a novel remote control manipulatable with stroking its surface. There are lots of remote controls in our houses such as remote controls for TV, air conditioner, and so on. However, when we use a remote control, we need to look at both our fingers and an appliance that we would like to control. It may be not significantly problematic for young people, but elderly people have a difficulty in manipulating remote controls with many buttons. We consider it will be comfortable for various people to use a remote control without looking at their fingers and pushing buttons. We also consider a remote control should have robot-like appearance to become a more familiar artifact to users. In this study, we have proposed a robot-like remote control, Rebo, manipulatable only with stroking its surface and apply to an advanced TV system. The developed remote control has three advantages; familiarity, function awareness, and stroke manipulation, in contrast with conventional remote controls with many buttons. These advantages enable users to feel much familiarity by using it, to easily notice its implemented functions, and to use it without looking at the fingers and buttons. In this paper, we focus on experimental investigation for advantages of Rebo. We conducted experiments with participants and the experimental results supported such advantages.**

I. Introduction

There are various remote controls in our houses. We have remote controls for TV, air conditioner, room light, and so on. Home electronic remote controls are commonplace devices and have been widely spread. However, there are significant problems on remote controls. For example, many remote controls confuse us when we use appliances. A universal remote [1] that aggregates functions of various remote controls is one of technical solutions for this problem. Users can control various appliances by manipulating a universal remote control, not using specific remote controls for each appliance. On the other hand, users for traditional button-based remote control need to search a target button and to correctly move the fingers to push it. It may be not significantly problematic for young people, but elderly people have a difficulty in such manipulation. We consider it will be comfortable and easily manipulatable even for elder people to use a remote control without looking at the fingers. Such a remote control is also comfortable to young people who are familiar to home electronic appliances. We also consider a remote control for an appliance should have robot-like appearance to become a more familiar artifact to users. By such an appearance, users who are not so familiar to appliances get to use a remote control without hesitation.

We have proposed a robot-like remote control testbed, Rebo, manipulatable only with stroking its surface and apply to an advanced TV system. Users only stroke its surface with the fingers to control various home electronic appliances far from them. Rebo has three advantages which conventional remote controls have never had; familiarity, function awareness, and stroke manipulation. Its robot-like appearance and facial expressions make it familiar with users. As for function awareness, we adopt *action sloping* [2], [3] that enables them to notice its functions. Stroke manipulation enable users not to seek a button that they want and use it easily.

In this paper, we foucs on experimental investigation for advantages of Rebo. As a realistic example of the proposed remote control, we develop an advanced TV system in which action sloping is implemented. We also conduct experiments with an eye-tracking system, and evaluate the three advantages by investigating eye movement of users and questionnaires.

The rest of this paper is structured as follows. The concept and the basic architecture are explained in Section II. A remote control for an advanced TV system as an application of Rebo is described in Section III. In Section IV, we explain experiments which we conduct to evaluate Rebo's advantages and show experimental results including questionnaires. We present discussions in Section V and conclude our work in Section VI.

II. Robot-like Remote Control

Figure 1 shows the developed robot-like remote control, Rebo. Rebo is a universal remote control of home electronic appliances. It has a user-friendly appearance; a smooth surface for stroking and a back side fit for users' thighs. We carefully designed the shape of Rebo with cooperation of an industrial designer, one of the authors, and determined a robot-like appearance shown in Fig. 1. We consider this simple and robot-like appearance significantly makes users feel much more familiarity than conventional button-based remote controls. This appearance makes users interested in it and guides them to use it without hesitation. Rebo is 249 mm long, 146 mm wide, and 96 mm high.

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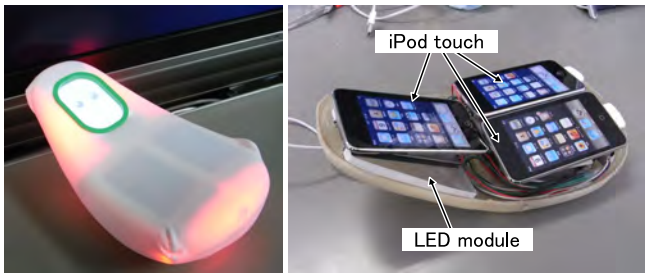

Fig. 1. Robot-like Remote Control: Rebo

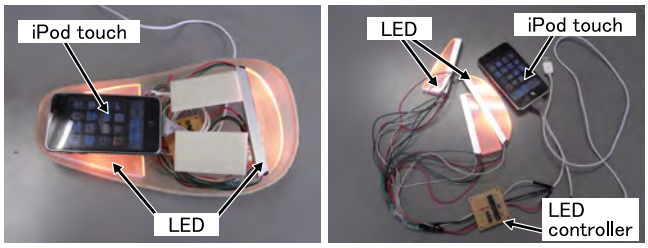

Fig. 2. Inner Structure of Rebo

A. System Architecture

Figure 2 shows the inner structure of Rebo.A display for facial expressions, full-color LED bars, a LED controller, and three touch devices (iPod touches) are embedded in the body. Two iPods are used as touch sensors and the remaining one is used for displaying facial expressions. The iPod touches used as touch sensors are covered with a soft, thin and smooth cloth.

Touch positions are sent to a host PC through WiFi from iPod's web browser, Safari. We adopted Open Sound Control (OSC) [4] as a communication protocol. When a user touches the browser on an iPod touch, a JavaScript program is executed and then a PHP function sends OSC packets to a connected PC. One of the embedded iPods is used for the facial expression display. An OSC server on the PC deals with OSC packets and rewrites a local XML file. A JavaScript program on the iPod for facial expression periodically accesses the XML file using Ajax. According to the XML file description, the program on the iPod changes gif animations. The concrete facial expressions are described in Section III-B.

Three full-color LED bars embedded in Rebo provide a user with some light-based feedback when he or she manipulates it. The user can grasp the result of their manipulation from their peripheral vision. The LED bars are controlled by an iPod touch. When the iPod touch receives a command to change LED color, it sends color value to the LED controller through serial connection. We use a programming language, Processing, to send and receive OSC packets from a PC to an iPod touch, and to manage LED color.

B. Advantages of Rebo

Rebo has three advantages which conventional remote controls have never had; familiarity, function awareness, and stroke manipulation. Its robot-like appearance and facial expressions make it familiar with users. As for function awareness, we adopt *action sloping* [2], [3] that enables them to notice its functions. By stroke manipulation, users do not have to seek a button that they want and use it easily. Details are described in our previous work [5], [6]. Those are described briefly bellow.

1) Familiarity: Rebo has a robot-like and life-like appearance (Fig. 1) and facial expressions to acquire familiarity with a user. We adopt the concept of "intermediate entity between artifacts and animate beings". Rebo is not only a tool but also a partner to users. The body of Rebo is covered with soft and bouncy cloth and it is pleasant to the touch. When the user strokes Rebo, it changes its facial expressions to inform him or her of various emotional states. We consider this makes the user more comfortable with Rebo. Therefore, interaction with Rebo can be the purpose of the user as well as manipulation of home electronic appliances. We believe that this concept plays an important role for establishing familiarity between users and Rebo.

2) Function Awareness: In this study, we adopt *action sloping* [2], [3] that enables a user to notice its functions. Action sloping makes machines provide feedback that gradually changes in intensity as the user carries out given actions. As for intensity of feedback behavior, it is assumed that the volume, frequency and quality of representation are changed. For example, available patterns of feedback behavior are changing lights displayed, sounds emitted, or timing of movements.

A user interacts with Rebo by stroking it. This kind of interaction manner bears a continuous action and easily achieves action sloping. For example, when a user strokes Rebo for a short time to turn off the TV, Rebo decrease the image dimensions of the TV for a short time. If the user strokes Rebo for a long time, it decreases the image dimensions and turns off the TV power.

3) Stroke Manipulation: Rebo has no button and a user strokes its surface to control an appliance. In this kind of manipulation, he or she does not need to move the fingers correctly and not seek the button that he or she wants to push. It is more comfortable for the user to gaze at a machine that he or she wants to control than to gaze at the remote control because the feedback from the machine is more important than that from the remote control. Thus, we consider Rebo's manipulation by stroking has advantage over conventional button-based remote controls.

III. Rebo as a TV Remote Control

We applied Rebo to a TV remote control and designed feedback behavior of a TV and constructed an advanced TV system. The advanced TV system is a simulated TV in which a movie player plays recorded TV programs on a PC monitor in multiple channels like a commercial TV. Details are described in our previous work [5], [6]. In this section, the advanced TV system is described briefly bellow.

A. Stroke Manipulation

Functions we implemented in the advanced TV system are channel select, sound volume change, and power on/off.

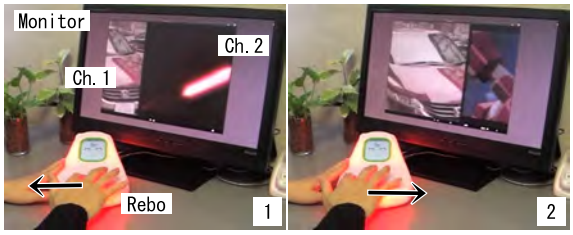

Fig. 3. Channel Selecting

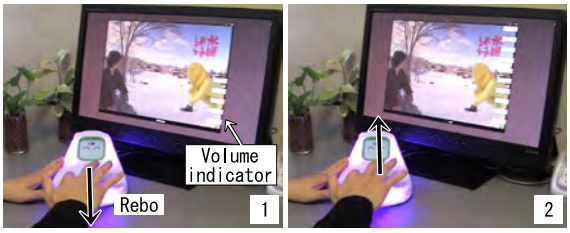

Fig. 4. Sound Volume Changing

In this section, manipulation methods of Rebo and feedback behavior of the TV are described.

1) Channel Select: When a user widely strokes the surface of Rebo with the fingers right and left, a video picture goes the outside of the TV frame and another video picture comes into the frame like Fig. 3. When a user strokes Rebo for a short time, a part of another video picture comes into the frame and then goes out of the frame automatically.

2) Sound Volume Change: When a user strokes Rebo up and down, the volume indicator (a vertical bar) is shown on the video picture like Fig. 4. The length of the indicator is changed as the movement distance of the fingers is changed.

3) Power On and Off: When a user touches Rebo for more than one second, the image dimensions of the video picture are reduced and finally disappeared like the left picture of Fig. 5. When the TV has been turned off, the picture is gradually enlarged while the user touches Rebo like the right picture of Fig. 5. If the user stops touching Rebo before the function is completely executed, the size of a video picture automatically goes to a previous size.

B. Facial Expressions and LED lighting

Figure 6 shows implemented facial expressions of Rebo. It goes a sleep mode when its surface is not touched for 10 seconds. Facial expressions are changed based on a user's stroke manipulation related to each function.

C. Function Awareness

Users easily manipulate it without looking at the fingers and searching buttons. They can concentrate on the feedback from the TV monitor, but Rebo. Animations of the video picture such as sliding and zooming are implemented based on function awareness. They can understand the meaning of the animation based feedback from the TV before the function is completely executed.

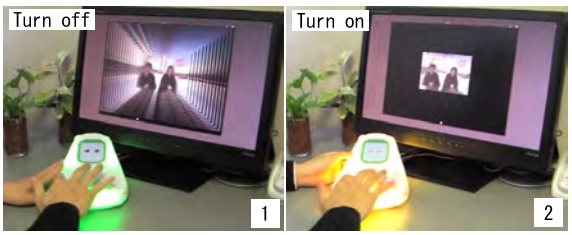

Fig. 5. Power On and Off

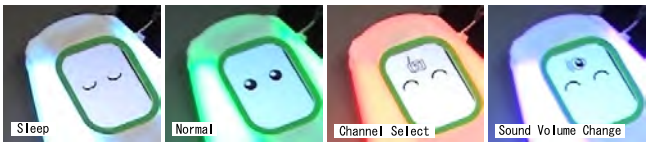

Fig. 6. Facial Expressions

IV. Experiments

We conducted experiments to evaluate the advantages of Rebo. Impression on the appearance, usability, ease of finding functions, and eye movements were compared between Rebo and a typical TV Infrared remote (IR remote). Eye movements were used to investigate the manipulation without looking at Rebo. Through these experiments, we evaluate Rebo's advantages: Familiarity, Function awareness, and Stroke manipulation.

A. Participants and Experimental Environment

Twelve male participants took part in the experiments (mean age: 23.7, S.D. = 1.9). They were undergraduate students and graduate students of Faculty of Engineering, Shinshu University.

We used an eye tracker Tobii T60's LCD monitor to display videos that were recorded from terrestrial broadcast. The size of the monitor was 17 inch and we set the resolution at 800 $\times$ 600 pixel. Three videos were used and its categories were news, animation, and comedy. We call this system including the eye tracker an *advanced TV system* on which various types of function awareness were implemented. Fig. 7 shows the experimental environment. The experimenter accompanied with a participant and instructed him.

Figure 8 shows the TV remote which we used in the experiments. A power button, a channel select button, and a sound volume button were used. The channel select button and the sound volume button had seesaw structures; the upper part and the lower part of the buttons can be pushed separately. For example, when a user pushes the upper part of the channel select button, the channel is changed in the forward direction, and when he or she pushes its lower part, the channel is changed in the backward direction.

B. Procedure of the Experiments

We used a within-subject design as experimental design. Participants used Rebo and the IR remote. The order of providing the devices to each participant was different among participants and was counter balanced. The experiments

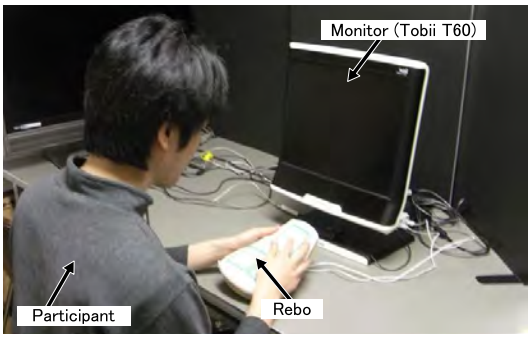

Fig. 7. Experimental Environment

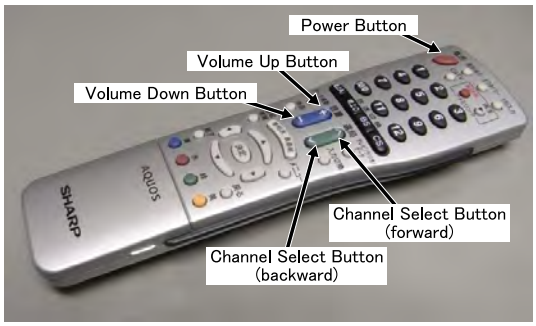

Fig. 8. IR remote

TABLE I

INSTRUCTION OF TV MANIPULATION

No.	Instruction
1	Turn on the TV.
2	Change the channel twice.
3	Change the channel 4 times in reverse order.
4	Maximize the sound volume.
5	Minimize the sound volume.
6	Change the channel 4 times.
7	Raise the sound volume in the medium degree.
8	Change the channel twice.
9	Turn off the TV.
10	Turn on the TV.
11	Maximize the sound volume.
12	Change the channel once.
13	Turn off the TV.

TABLE II

RATED ADJECTIVE PAIRS FOR IMPRESSION ON APPEARANCE

Positive	Negative	Rebo	IR remote	t
		Mean (S.D.)	Mean (S.D.)	
likable	dislikable	4.50 (1.31)	4.50 (0.90)	0.00
$**$exciting	dull	5.42 (1.16)	3.17 (1.53)	3.39
$**$comfortable	uncomfortable	5.58 (0.79)	4.33 (0.89)	3.80
$*$ interesting	boring	4.92 (1.31)	3.33 (1.61)	2.50
$**$warm	cold	5.58 (1.00)	2.75 (1.29)	4.71
$**$casual	grave	5.50 (0.67)	3.67 (1.56)	3.63
$**$friendly	unfriendly	5.67 (0.65)	3.67 (1.15)	4.51
$**$cute	uncute	5.67 (1.67)	3.17 (1.80)	3.19
$**$attractive	unattractive	4.25 (1.42)	2.92 (1.38)	3.75
companionable	uncompanionable	5.83 (0.83)	4.50 (1.68)	2.11

$* p < .05$ $** p < .01$

were composed of two phases; finding functions phase and eye tracking phase. First the finding functions phase was conducted and then the eye tracking phase was conducted.

When a participant entered an experimental room, he was explained about the experiments. If the participant agreed with the informed consent, we begun the experiments. The participant was instructed to have a posture and adjust the chair to be relaxed and easy to watch a monitor.

1) Finding Function Phase: Rebo or the IR remote was provided for a participant. The experimenter explained him that its functions were power on/off, channel selecting, and sound volume changing. The experimenter instructed him to find manipulation methods to execute these functions. A trial was continued until a participants reported he found all the functions or five minutes have passed. Because an initial state of the advanced TV system was power-off, the experimenter turned on the TV system without showing the manipulation to the participant if he could not find the power-on manipulation for one minutes.

After the trial, the experimenter explained correct manipulation of the device to the participant and requested him to try manipulating it freely for five minutes.

Finally, he answered questionnaires about impressions and usability of the device. The participant was instructed to check the number which he feels about the adjective pairs. The same procedure was conducted with the different device.

2) Eye Tracking Phase: The eye tracking phase was conducted after the finding function phase. Rebo or the IR remote was provided for a participant. First, calibration of eye tracking was executed for the participant and then eye movements were recorded. We used a Tobii T60 eye tracking system for this phase. After the TV system software was executed, the participant was instructed to manipulate the device as the experimenter told to him. In addition, the participant was instructed to concentrate the monitor and the device, and not to look at the experimenter. The experimenter stood behind the participant. Table I shows detailed instruction of TV manipulation given to the participant. The experimenter did not instruct the participant not to look at the devices and not to use both hands.

C. Experimental Results

The experimental results of impression on appearance, ease of finding functions, usability, and eye movements are showed as follows, respectively.

1) Impression on Appearances: Table II shows the rated adjective pairs for impression on appearance of Rebo and the IR remote. The adjective pairs in the table are translated from Japanese words that we used in the questionnaire. The ratings are based on a seven-point Likert scale (1: strong agreement with a negative adjective, 4: neutral, 7: strong agreement with a positive adjective). In order to compare Rebo with the IR remote, we performed paired t test. There were significant differences in eight out of ten items, which are marked with asterisks in the table. The t-values of the tests are showed in the right side of the table. All of the ratings for Rebo with identified significant differences have higher ratings than the IR remote. The results suggest that Rebo had higher familiarity than the typical IR remote.

2) Ease of Finding Functions: In the IR remote condition, all of the participants were able to find all of the functions.

TABLE III

RATED ADJECTIVE PAIRS FOR USABILITY

Positive	Negative	Rebo	IR remote	t
		Mean (S.D.)	Mean (S.D.)	
enjoyable	annoying	4.50 (1.24)	4.00 (0.74)	1.15
$*$ simple	complicated	5.08 (1.16)	3.42 (1.88)	2.16
$*$ fast	slow	3.67 (1.50)	5.08 (1.83)	-2.38
$*$ convenient	inconvenient	4.42 (1.44)	3.17 (1.70)	2.70
unmistakable	mistakable	4.42 (2.07)	3.83 (1.99)	0.70
$**$easy	uneasy	5.00 (1.48)	2.92 (1.31)	3.42

$* \ p < .05 \quad ** \ p < .01$

In the Rebo condition, all of the participants were able to find the sound volume function and the channel selecting function, and seven participants were able to find the power on/off function. The results suggested that manipulation of Rebo in channel selecting and sound volume changing was as easy as that of the IR remote. However, manipulation of Rebo in the power on/off function was not easy to manipulate and was more difficult to find it than the IR remote.

3) Usability: Table III shows the rated adjective pairs for usability. The adjective pairs in the table are translated from Japanese words that we used in a questionnaire. The ratings are based on a seven-point Likert scale (1: strong agreement with a negative adjective, 4: neutral, 7: strong agreement with a positive adjective) as well as Table II. In order to compare Rebo with the IR remote, we performed paired t test. There were significant differences in four out of six items, which are marked with asterisks in the table. The t-values of the tests were showed in the right side of the table. The ratings of three items for Rebo with identified significant differences were higher than the IR remote. In the adjective pair fast-slow, IR remote was recognized faster than Rebo. The results suggested that Rebo was more simple, convenient and easy than the typical IR remote. We discuss about that Rebo recognized slower than the IR remote in Section V.

4) Eye Movements: Table IV show the number of eye movements to the devices. We excluded two of 12 participants' data due to low accuracy of eye detection. The eye trucker was able to record the eye movements in the screen. Its sampling rate and accuracy of the eye tracking was 60Hz and 0.5 degree, respectively. The number of eye movements to the devices was measured by analyzing the participants' eye movement data. We employed the criteria described as follows to measure the number of eye movements to the devices because the eye movements to the outside of the screen was not recorded.

- Select more than two consecutive screen-outside values to exclude noise.
- Select the values whose previous values indicate the movement to the bottom of the screen.
- Select the values whose previous value is in the bottom part of the screen (y $<$ 540).

Our hypothesis is that participants can manipulate Rebo with less number of looking at it than the IR remote. In order to compare Rebo with the IR remote, we performed Wilcoxon's signed rank test with continuity correction. Although the Rebo's mean was less than that of the IR remote, there was no significant difference ($Z = -1.18, p = 0.24$).We discuss about that there was no significant difference in eye movement to the devices between Rebo and the IR remote in Section V.

TABLE IV

THE NUMBER OF EYE MOVEMENTS TO THE DEVICES (N=10)

	Mean	S.D.
Rebo	2.00	2.91
IR remote	3.20	2.04

TABLE V

COMMENTS FOR REBO'S APPEARANCE

Advantages	N
It is cute or friendly.	7
Its surface is good feeling.	4
Facial icons are comprehensive.	3
It is conspicuous and provides avoidance of loss.	3
Blinking is good.	2
No button design is good	2
Disadvantages	**N**
It is too large.	11
Its face and LED are unnecessary.	7
I am anxious about dirty by fingerprints or skin oil.	2
It needs to improve its posture to be easily viewable.	2

N: the number of participants

D. Participants' comments

In the experiments, participants were interviewed on appearances and manipulation of devices. Table V and VI show summarized participants' comments about appearances. A majority of participants answered "cute or friendly" for Rebo as its advantage. Some participants answered "too large" and "its face and LED blinking are unnecessary." Although Rebo's appearance having its face and LED is considered as its advantage, its face and LED are considered as unnecessary. We discuss about this contradiction in Section V.

Regarding the appearance of the IR remote (Table VI), some participants answered "the layout and touch feeling of buttons are good" as its advantage. Disadvantages are "too many buttons and confusing" and "buttons are small" Although buttons of the IR remote are considered as its advantage, their size and quantity provide confusing impression to participants.

Table VII and VIII show summarized participants' comments about manipulation. Regarding Rebo (Table VII), a majority of participants answered "intuitive and comprehensible." However, many participants answered "the power switch is incomprehensible" and "direct selection of a specific channel is necessary" as its disadvantages. Rebo's manipulation method is almost accepted by them except for the power switch manipulation. Regarding the IR remote (Table VIII), some participants answered "comprehensible" as its advantage and "difficult to manipulate" as its disadvantage. Although both Rebo and the IR remote are considered as "comprehensible", the number of participants who answered it for Rebo is larger than that for the IR remote.

TABLE VI

COMMENTS FOR IR REMOTE'S APPEARANCE

Advantages	N
The layout and touch feeling of buttons are good.	5
Textual information is comprehensive.	3
High functionality is good.	3
The size of the remote is good.	2
Disadvantages	N
There are too many buttons and it is confusing.	5
Buttons are small.	4
It is insipid and ordinary.	2
It is large.	2
The color combination is not likable.	2

N: the number of participants

TABLE VII

COMMENTS FOR REBO'S MANIPULATION

Advantages	N
It is intuitive and comprehensible.	9
The movie sliding animation is good.	4
Its response is quick.	4
I can manipulate it with looking at the TV monitor.	3
Disadvantages	N
The power switch is incomprehensible.	9
Direct selection of a specific channel is necessary.	9
The sliding manipulation is troublesome.	3

N: the number of participants

V. DISCUSSIONS

The difficulty of finding the power on/off function of Rebo would be caused by the long response time from the advanced TV system. The participants obtained no cue to find the function. There was one second to response for the power on/off manipulation of Rebo. This design policy was to avoid the manipulation collision among channel selecting, sound volume changing, and power state changing. It needs further consideration to improve the response time and manipulation method of all functions.

The usability investigation showed that manipulation of Rebo was recognized slower than that of the IR remote. This would be caused by displaying animation such as movie sliding and zooming. A few participants pointed out this problem. They reported that they wanted to turn off the TV immediately if they were busy and did not want to wait the finish of turning off. Therefore, power manipulation of Rebo would provide the slow impression.

We discuss about the eye movements investigation. Although our hypothesis was that participants can manipulate Rebo with less number of looking at it than the IR remote, there was no significant difference in the number of eye movements to the devices between Rebo and the IR remote. This result would be caused by participants who look at the facial and LED expressions of Rebo. Although the expressions were used to improve the familiarity, they would excessively grab participants' attention. If they got used to Rebo, there would be no problem. As another view point, this result would be caused by the low number of TV functions. Participants would be able to manipulate the IR remote without looking at it, because there were a few buttons that were easy to be pushed as shown in Fig. 8.

TABLE VIII

COMMENTS FOR IR REMOTE'S MANIPULATION

Advantages	N
It is comprehensible.	5
It is easy to hold.	4
I am used to manipulating it.	3
Disadvantages	N
It is difficult to manipulate.	5
It needs to enable number buttons.	3
Its response in sound volume manipulation is slow.	3

N: the number of participants

Regarding the result of participants' comments, although Rebo's appearance having its face and LED is considered as its advantage, its face and LED are considered as unnecessary. There is a contradiction between the comments. We consider that the contradiction is caused by a weak association between facial/LED expressions and the manipulation method. Feedback by facial/LED expression is unnecessary when they manipulate a TV because feedback of TV manipulation is provided from the TV monitor itself. They would consider that it is more important to reduce its body size than to perform facial/LED expressions because they answered Rebo is too large. Such a design problem between a body size and functionality is an issue in the future.

VI. CONCLUSION

In this paper, we proposed a robot-like remote control, Rebo, for controlling home electronic appliances and implemented an advanced TV system. Rebo has three advantages; familiarity, function awareness, and stroke manipulation. Robot-like appearance and facial expression makes it familiar with users. We implemented four facial expressions as a life-like behavior and video picture animations as feedback from the TV to enable users to easily notice its functions. We also conducted experiments with participants to evaluate Rebo's advantages and the experimental results supported the advantages. In the next state of our work, we conduct investigation into the effectiveness of function awareness and the possibility of context-sensitive remote control.

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