Affective Motion for Pleasure-Unpleasure Expression in Behavior of Robots

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***Abstract*—Existing human-robot interaction generates the robot's emotion based on the information acquired from an interaction. In this paper, we propose generating a robot's feelings from external environmental information(temperature and, humidity) which is completely unrelated to the interaction. Additionally, we found a strong correlation between a robot's forward-bending angle and the pleasure-unpleasure feelings communicated by it, for about 60 percent of the subjects from the experimental results of our previous research. Therefore, we investigated whether the impression of "being harmonized" could be given to subjects when expressing the robot's feelings by a comfort index. As a result, the group that shows a strong correlation between a robot's forward-bending angle and pleasure-unpleasure feelings communicated by it could be given to subjects impression of "being harmonized".**

***Index Terms*—Affective motion, human-robot interaction, robot's emotion.**

I. Introduction

The conventional communication robot generates its emotion using information from interacting with humans. For example, a cat-type robot generates emotions using information from the surrounding environment, human behavior, life rhythms and sleeping desire [1]. Additionally, a speech communication robot uses information from estimating the dialogist's emotion from the sound which the dialogist uttered [2]. In this way, generating the robot's emotion is based on the information acquired from interaction with humans, and a robot's general approach is observing the interaction between two humans. On the other hand, we consider that human emotion is also affected by information that is completely unrelated to interaction, especially the external environment, for example, the weather, climate, temperature, and humidity. External environment information is also shared between humans, and feelings are harmonized with each other. Thus, human interaction can be realized with no discomfort. We consider that this promotes an understanding of the other person's feelings. If a robot can also be harmonized to human feelings using external environment information, the interaction can be realized with no discomfort under various environments.

Therefore, in this paper, we consider generating a robot's feelings based on easily acquired external environment information. In particular, we propose robot behavior based on the temperature-humidity index and a method of generating the robot feelings that is or is not harmonized to human feelings. To investigate the robot feelings that is or is not harmonized to human feelings needs the following tasks: (1) generating the robot's feelings, (2) relating the robot's feelings to the robot's behavior, (3) communicating the idea of the robot's feelings to human beings by the robot's behavior. Each must be done appropriately. Regarding these tasks, we confirmed that there was a strong correlation between a robot's forward-bending angle and the pleasure-unpleasure feelings communicated by it for about 60 percent of subjects from the experimental results of the previous research [3]. Therefore we adopted a robot feelings and behavior generation method based on external environment information used by previous research. Moreover, we investigated whether the impression of "being harmonized" could be given to subjects when expressing the robot's feelings by the robot's forward-bending angle.

II. Robot Feeling and Behavior Generation Method

A. Robot Feeling Generation

We consider that a change of a human's feelings by a change of the external environment as "pleasure-unpleasure", which comes from heat or cold. There is a temperature-humidity index that deals quantitatively with comfort in relation to temperature and humidity [4], [5]. The temperature-humidity index is an index that is computed using information such as dry-bulb temperature, wet-bulb temperature, relative humidity, the dew point, and various definitions have been made [5]. For example, the temperature-humidity index (I_{th}) can be defined as follows using dry-bulb (t[deg C]) temperature and relative humidity (h[%]).

$$I_{th} = 0.8t + 0.01h(t - 14.4) + 46.4. \quad (1)$$

The temperature-humidity index computed using the same formula is shown in TABLE I.

It can be seen from the table that the temperature-humidity index has a clear pattern that represents sensible temperatures and is tends to increase with increasing temperature with the

TABLE I
TEMPERATURE-HUMIDITY INDEX MATRIX.

Relative humidity [%] (columns); Temperature [deg C] (rows)

	20	25	30	35	40	45	50	55	60	65	70	75	80
-5	38.5	37.6	36.6	35.6	34.6	33.7	32.7	31.7	30.8	29.8	28.8	27.9	26.9
-4	39.5	38.6	37.7	36.8	35.8	34.9	34.0	33.1	32.2	31.2	30.3	29.4	28.5
-3	40.5	39.7	38.8	37.9	37.0	36.2	35.3	34.4	33.6	32.7	31.8	31.0	30.1
-2	41.5	40.7	39.9	39.1	38.2	37.4	36.6	35.8	35.0	34.1	33.3	32.5	31.7
-1	42.5	41.8	41.0	40.2	39.4	38.7	37.9	37.1	36.4	35.6	34.8	34.1	33.3
0	43.5	42.8	42.1	41.4	40.6	39.9	39.2	38.5	37.8	37.0	36.3	35.6	34.9
1	44.5	43.9	43.2	42.5	41.8	41.2	40.5	39.8	39.2	38.5	37.8	37.2	36.5
2	45.5	44.9	44.3	43.7	43.0	42.4	41.8	41.2	40.6	39.9	39.3	38.7	38.1
3	46.5	46.0	45.4	44.8	44.2	43.7	43.1	42.5	42.0	41.4	40.8	40.3	39.7
4	47.5	47.0	46.5	46.0	45.4	44.9	44.4	43.9	43.4	42.8	42.3	41.8	41.3
5	48.5	48.1	47.6	47.1	46.6	46.2	45.7	45.2	44.8	44.3	43.8	43.4	42.9
6	49.5	49.1	48.7	48.3	47.8	47.4	47.0	46.6	46.2	45.7	45.3	44.9	44.5
7	50.5	50.2	49.8	49.4	49.0	48.7	48.3	47.9	47.6	47.2	46.8	46.5	46.1
8	51.5	51.2	50.9	50.6	50.2	49.9	49.6	49.3	49.0	48.6	48.3	48.0	47.7
9	52.5	52.3	52.0	51.7	51.4	51.2	50.9	50.6	50.4	50.1	49.8	49.6	49.3
10	53.5	53.3	53.1	52.9	52.6	52.4	52.2	52.0	51.8	51.5	51.3	51.1	50.9
11	54.5	54.4	54.2	54.0	53.8	53.7	53.5	53.3	53.2	53.0	52.8	52.7	52.5
12	55.5	55.4	55.3	55.2	55.0	54.9	54.8	54.7	54.6	54.4	54.3	54.2	54.1
13	56.5	56.5	56.4	56.3	56.2	56.2	56.1	56.0	56.0	55.9	55.8	55.8	55.7
14	57.5	57.5	57.5	57.5	57.4	57.4	57.4	57.4	57.4	57.3	57.3	57.3	57.3
15	58.5	58.6	58.6	58.6	58.6	58.7	58.7	58.7	58.8	58.8	58.8	58.9	58.9
16	59.5	59.6	59.7	59.8	59.8	59.9	60.0	60.1	60.2	60.2	60.3	60.4	60.5
17	60.5	60.7	60.8	60.9	61.0	61.2	61.3	61.4	61.6	61.7	61.8	62.0	62.1
18	61.5	61.7	61.9	62.1	62.2	62.4	62.6	62.8	63.0	63.1	63.3	63.5	63.7
19	62.5	62.8	63.0	63.2	63.4	63.7	63.9	64.1	64.4	64.6	64.8	65.1	65.3
20	63.5	63.8	64.1	64.4	64.6	64.9	65.2	65.5	65.8	66.0	66.3	66.6	66.9
21	64.5	64.9	65.2	65.5	65.8	66.2	66.5	66.8	67.2	67.5	67.8	68.2	68.5
22	65.5	65.9	66.3	66.7	67.0	67.4	67.8	68.2	68.6	68.9	69.3	69.7	70.1
23	66.5	67.0	67.4	67.8	68.2	68.7	69.1	69.5	70.0	70.4	70.8	71.3	71.7
24	67.5	68.0	68.5	69.0	69.4	69.9	70.4	70.9	71.4	71.8	72.3	72.8	73.3
25	68.5	69.1	69.6	70.1	70.6	71.2	71.7	72.2	72.8	73.3	73.8	74.4	74.9
26	69.5	70.1	70.7	71.3	71.8	72.4	73.0	73.6	74.2	74.7	75.3	75.9	76.5
27	70.5	71.2	71.8	72.4	73.0	73.7	74.3	74.9	75.6	76.2	76.8	77.5	78.1
28	71.5	72.2	72.9	73.6	74.2	74.9	75.6	76.3	77.0	77.6	78.3	79.0	79.7
29	72.5	73.3	74.0	74.7	75.4	76.2	76.9	77.6	78.4	79.1	79.8	80.6	81.3
30	73.5	74.3	75.1	75.9	76.6	77.4	78.2	79.0	79.8	80.5	81.3	82.1	82.9
31	74.5	75.4	76.2	77.0	77.8	78.7	79.5	80.3	81.2	82.0	82.8	83.7	84.5
32	75.5	76.4	77.3	78.2	79.0	79.9	80.8	81.7	82.6	83.4	84.3	85.2	86.1
33	76.5	77.5	78.4	79.3	80.2	81.2	82.1	83.0	84.0	84.9	85.8	86.8	87.7
34	77.5	78.5	79.5	80.5	81.4	82.4	83.4	84.4	85.4	86.3	87.3	88.3	89.3
35	78.5	79.6	80.6	81.6	82.6	83.7	84.7	85.7	86.8	87.8	88.8	89.9	90.9
36	79.5	80.6	81.7	82.8	83.8	84.9	86.0	87.1	88.2	89.2	90.3	91.4	92.5
37	80.5	81.7	82.8	83.9	85.0	86.2	87.3	88.4	89.6	90.7	91.8	93.0	94.1
38	81.5	82.7	83.9	85.1	86.2	87.4	88.6	89.8	91.0	92.1	93.3	94.5	95.7
39	82.5	83.8	85.0	86.2	87.4	88.7	89.9	91.1	92.4	93.6	94.8	96.1	97.3
40	83.5	84.8	86.1	87.4	88.6	89.9	91.2	92.5	93.8	95.0	96.3	97.6	98.9
41	84.5	85.9	87.2	88.5	89.8	91.2	92.5	93.8	95.2	96.5	97.8	99.2	100.5
42	85.5	86.9	88.3	89.7	91.0	92.4	93.8	95.2	96.6	97.9	99.3	100.7	102.1

Comfortable ($I_{th} < 73$), mild stress ($73 \leq I_{th} < 78$), severe stress ($78 \leq I_{th} < 83$), potential death ($83 \leq I_{th}$).

same humidity. Therefore, the existing temperature-humidity index cannot necessarily express the degree of "pleasure-unpleasure" at low temperatures appropriately. Therefore, in this research, we define the comfort index (CI_{th}) as an applicable index at low temperature.

$$CI_{th} = \begin{cases} 0.022I_{th} - 0.95 & (I_{th} \leq 72) \\ -0.022I_{th} + 2.22 & (I_{th} > 72). \end{cases} \tag{2}$$

The comfort index represents pleasure if it is 0.5 or more, and represents unpleasure if it is less than 0.5 (TABLE II). In addition, the comfort index that we defined was created by weighting the comfort evaluation that each subject assessed based on the results of the investigation [4].

B. Robot Behavior Generation

Human beings take various postures. Of them, the forward-bending angle has a strong relationship with feelings. For example, humans an take upright posture when feeling good. On the other hand, humans take a rounded back posture when feeling bad [6]. We consider that the robot's feelings can be communicated with such a forward-bending angle. Therefore, in our research, we assign the behavior of the swaying body trunk forward and backward to the robot.

The generation method of a posture is shown in Fig 1. This figure is a side view, and the robot faced direction of G. θ is the angle made by the horizontal axis and the body trunk. We generate swaying behavior at amplitude α [deg] and set cycle β [ms] as the center (oscillating center) of the shaking in accordance with θ. In this experiment, shake behavior was generated by using θ_{CI} defined as follows.

$$\theta_{CI} = \theta_B + \frac{(\theta_{\max} - \theta_{\min})r_{CI}}{2}, \tag{3}$$

$$r_{CI} = \begin{cases} \frac{CI - CI_{\mathrm{mid}}}{CI_{\max} - CI_{\mathrm{mid}}} & (CI \geq 0.5) \\ \frac{CI - CI_{\mathrm{mid}}}{CI_{\mathrm{mid}} - CI_{\min}} & (CI < 0.5), \end{cases} \tag{4}$$

where θ_B is the angle which was defined to express the middle of pleasure-unpleasure. The values of $\theta_{\max}$ and $\theta_{\min}$ are determined by range of motion, so differ depending on robots. The value of $CI_{\max} = 0.63$ and $CI_{\min} = 0.0$ are

TABLE II
COMFORT INDEX MATRIX

Relative humidity [%] (columns); Temperature [deg C] (rows)

	20	25	30	35	40	45	50	55	60	65	70	75	80
-5	-0.10	-0.12	-0.15	-0.17	-0.19	-0.21	-0.23	-0.25	-0.27	-0.29	-0.32	-0.34	-0.36
-4	-0.08	-0.10	-0.12	-0.14	-0.16	-0.18	-0.20	-0.22	-0.24	-0.26	-0.28	-0.30	-0.32
-3	-0.06	-0.08	-0.10	-0.12	-0.14	-0.15	-0.17	-0.19	-0.21	-0.23	-0.25	-0.27	-0.29
-2	-0.04	-0.05	-0.07	-0.09	-0.11	-0.13	-0.14	-0.16	-0.18	-0.20	-0.22	-0.24	-0.25
-1	-0.01	-0.03	-0.05	-0.07	-0.08	-0.10	-0.12	-0.13	-0.15	-0.17	-0.18	-0.20	-0.22
0	0.01	-0.01	-0.02	-0.04	-0.06	-0.07	-0.09	-0.10	-0.12	-0.14	-0.15	-0.17	-0.18
1	0.03	0.01	0.00	-0.01	-0.03	-0.04	-0.06	-0.07	-0.09	-0.10	-0.12	-0.13	-0.15
2	0.05	0.04	0.02	0.01	0.00	-0.02	-0.03	-0.04	-0.06	-0.07	-0.08	-0.10	-0.11
3	0.07	0.06	0.05	0.04	0.02	0.01	0.00	-0.01	-0.03	-0.04	-0.05	-0.06	-0.08
4	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.00	-0.01	-0.02	-0.03	-0.04
5	0.12	0.11	0.10	0.09	0.08	0.07	0.06	0.05	0.03	0.02	0.01	0.00	-0.01
6	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07	0.07	0.06	0.05	0.04	0.03
7	0.16	0.15	0.15	0.14	0.13	0.12	0.11	0.10	0.10	0.09	0.08	0.07	0.06
8	0.18	0.18	0.17	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10
9	0.21	0.20	0.19	0.19	0.18	0.18	0.17	0.16	0.16	0.15	0.15	0.14	0.13
10	0.23	0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.19	0.18	0.18	0.17	0.17
11	0.25	0.25	0.24	0.24	0.23	0.23	0.23	0.22	0.22	0.22	0.21	0.21	0.20
12	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.24	0.24
13	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.27
14	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
15	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35
16	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38
17	0.38	0.38	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.42
18	0.40	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.44	0.44	0.44	0.45	0.45
19	0.43	0.43	0.44	0.44	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.49
20	0.45	0.45	0.46	0.47	0.47	0.48	0.48	0.49	0.50	0.50	0.51	0.52	0.52
21	0.47	0.48	0.48	0.49	0.50	0.51	0.51	0.52	0.53	0.53	0.54	0.55	0.56
22	0.49	0.50	0.51	0.52	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.58	0.59
23	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63
24	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.63	0.62	0.61
25	0.56	0.57	0.58	0.59	0.60	0.62	0.63	0.63	0.62	0.61	0.60	0.58	0.57
26	0.58	0.59	0.60	0.62	0.63	0.63	0.61	0.60	0.59	0.58	0.56	0.55	0.54
27	0.60	0.62	0.63	0.63	0.61	0.60	0.59	0.57	0.56	0.54	0.53	0.52	0.50
28	0.62	0.63	0.62	0.60	0.59	0.57	0.56	0.54	0.53	0.51	0.50	0.48	0.47
29	0.62	0.61	0.59	0.58	0.56	0.54	0.53	0.51	0.50	0.48	0.46	0.45	0.43
30	0.60	0.59	0.57	0.55	0.53	0.52	0.50	0.48	0.47	0.45	0.43	0.41	0.40
31	0.58	0.56	0.54	0.53	0.51	0.49	0.47	0.45	0.43	0.42	0.40	0.38	0.36
32	0.56	0.54	0.52	0.50	0.48	0.46	0.44	0.42	0.40	0.38	0.36	0.35	0.33
33	0.54	0.52	0.50	0.48	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.31	0.29
34	0.51	0.49	0.47	0.45	0.43	0.41	0.39	0.36	0.34	0.32	0.30	0.28	0.26
35	0.49	0.47	0.45	0.42	0.40	0.38	0.36	0.33	0.31	0.29	0.27	0.24	0.22
36	0.47	0.45	0.42	0.40	0.38	0.35	0.33	0.30	0.28	0.26	0.23	0.21	0.19
37	0.45	0.42	0.40	0.37	0.35	0.32	0.30	0.27	0.25	0.22	0.20	0.18	0.15
38	0.43	0.40	0.37	0.35	0.32	0.30	0.27	0.24	0.22	0.19	0.17	0.14	0.12
39	0.40	0.38	0.35	0.32	0.30	0.27	0.24	0.22	0.19	0.16	0.13	0.11	0.08
40	0.38	0.35	0.33	0.30	0.27	0.24	0.21	0.19	0.16	0.13	0.10	0.07	0.04
41	0.36	0.33	0.30	0.27	0.24	0.21	0.19	0.16	0.13	0.10	0.07	0.04	0.01
42	0.34	0.31	0.28	0.25	0.22	0.19	0.16	0.13	0.10	0.07	0.03	0.00	-0.03

Potential death ($CI_{th} < 0.4$), severe stress ($0.4 \leq CI_{th} < 0.45$), mild stress ($0.45 \leq CI_{th} < 0.5$), comfortable ($0.5 \leq CI_{th}$).

maximum and minimum values of CI_{th}, respectively, and $CI_{\text{mid}} = 0.5$ is a changing point from unpleasure to pleasure.

III. EXPERIMENT

We investigated whether the impression of "being harmonized" could be given to the subjects when expressing the robot's feelings by comfort index.

A. Robot

In this experiment, we used $PALRO$, which is a humanoid robot made by Fujisoft Inc. The appearance of $PALRO$ is shown in Fig 4. $PALRO$ has a height of 39.8 [cm], weight of 1.6 [kg], 20 [DOF], microphone, and speaker. It is a small communication robot with various sensors (pressure, ranging, gyroscope, acceleration). Motion parameters were $\theta_{\min} = 80$ [deg], $\theta_{\max} = 105$ [deg], $\theta_B = 92.5$ [deg], $\alpha = 3$ [deg], $\beta = 750$ [ms].

The posture when $\theta = 80$ [deg] is shown in Fig 2, and the posture when $\theta = 105$ [deg] is shown in Fig 3.

B. Presented Behavior

In this experiment, we used three behaviors generated when $\theta = \{\theta_{\min} = 80, \theta_{\max} = 105, \theta_{CI}\}$ [deg]. θ_{CI} is computed using the comfort index, and the specific values used in the experiment are described in the next section.

C. Methodology

The flow of the experiment is shown in Fig 5. In the experiment, first we explained the details of the experiment to the subjects. Next, we presented the robot's behavior to the subjects and did the questionnaire by the pair comparison

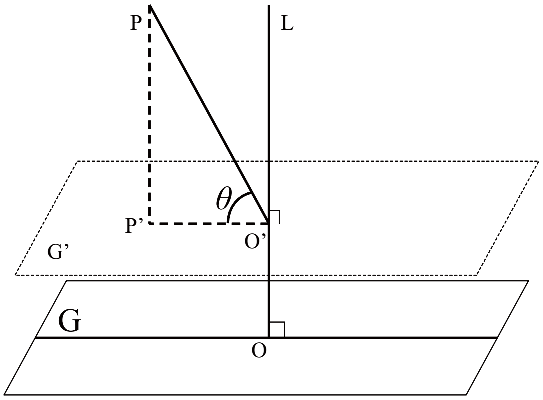

Fig. 1. Posture definition


Fig. 2. Posture($\theta = 80$[deg])


Fig. 3. Posture($\theta = 105$[deg])

method and the SD method. After the experiment, we classified the subjects and verified whether the impression of "being harmonized" could be given to the subjects.

1) Experiment Environment: During the experiment, the indoor temperature was set to 25±1.0 [deg C], and humidity was set to 52±10 [%]. The comfort index at this time was 0.57±0.02. We made the subjects enter the experimental laboratory one at a time and sit down in a position 40 [cm] from a robot. Therefore, the subjects observe two robots


Fig. 4. *PALRO*

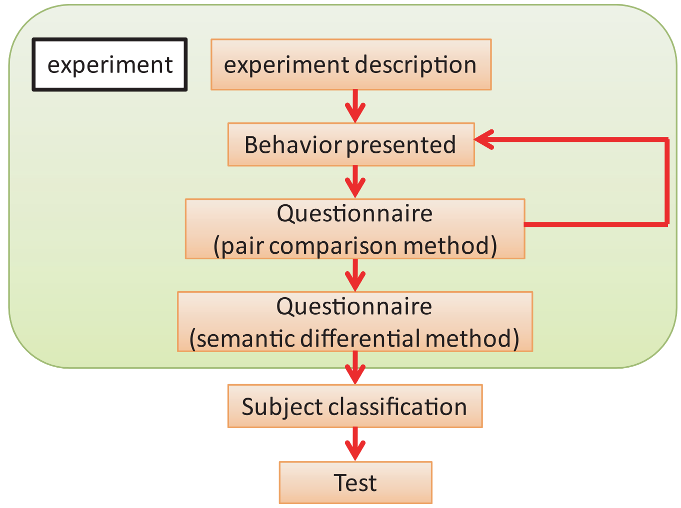

Fig. 5. Flow chart

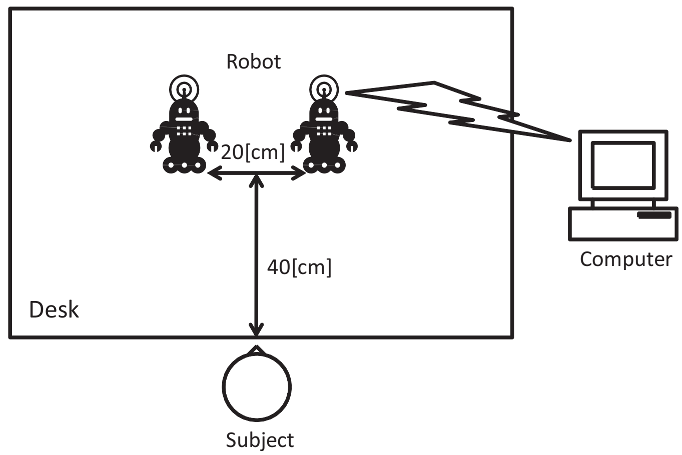

Fig. 6. Experiment environment

from the front. Moreover, the distance between robots is 20 [cm]. Next, the robot's behavior was presented for 30 [sec]. After that, the questionnaire was done by the pair comparison method by the subjects. Two behaviors were presented when $\theta = \{80, 105, \theta_{CI}\}$, and the subjects were made to repeat the questionnaire and compare the behaviors of the two robots.

In the above experiment environment, we selected a conditions that had a sufficiently small change of comfort index and conducted the experiments for five days. The external average temperature of the five days was 19.3±2.0 [deg C] and the external average humidity was 61.8±10 [%]. And since the comfort index was set to 0.48±0.04, this means that pleasure and unpleasure were in the middle.

The subjects were 20 young men in their 20s.

2) Questionnaire: In the pair comparison method, out of three behaviors were shown, and the subject answered the following questions.

- Question 1:"Before the beginning of the experiment, which is closer to your feelings about the behavior of left and right robots?"

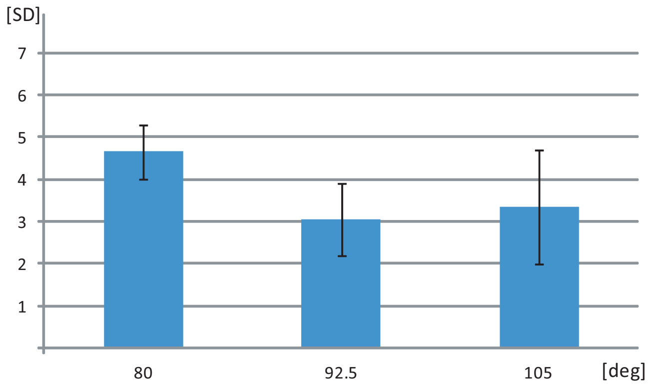

Fig. 7. Results of questionnaire

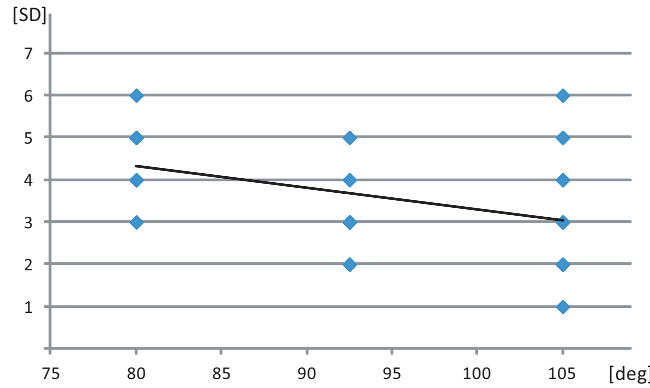

Fig. 8. Scattergram of all results ($R = -0.44$)

- Question 2:"During the experiment, which is closer to your feelings about the behavior of left and right robots now?"
- Question 3:"Which robot is expressing pleasure, the left or the right robot?"

Regarding Question 1 and 2 of the questionnaire, we ordered the questions so that an evaluation that is different only when feelings change during the experiment might be made. We explained to the subjects to make different evaluations only when feelings change during the experiment for Question 1 and 2 of the questionnaire. Moreover, to extract a group with a strong correlation between the robot's forward-bending angle and the pleasure-unpleasure feelings communicated by it, we conducted the questionnaire survey by the seven-step SD method as in previous research.

3) Subject Classification: The subjects were classified into a group with strong correlation and a group with out strong correlation for the correlation between the robot's forward-bending angle and the pleasure-unpleasure feeling communicated by it.

4) Test: We evaluated the behavior using the pair comparison method (Nakaya's method [7]: 7 stages) of Scheffe for correlation between the robot's forward-bending angle and the pleasure-unpleasure feelings communicated by it.

The results of the questionnaire (before being classified) by the SD method is shown in Fig 7. The horizontal axis shows θ, the vertical axis shows the value of the SD method, and the robot takes the upright posture as the value of θ becomes large. As shown in this figure,it turns out that the robot is recognized as feeling bad when the value of θ is small. Moreover, the standard deviation also becomes large as the value of θ becomes large.

The scatter diagram (before the results are classified) is shown in Fig 8. From Fig 8, it can be seen that although weak correlation ($R = -0.44$) was confirmed, we infer that there are two groups: one group with negative correlation, and the other group that does not have correlation. Then, the subject is classified into either the right correlation group with $R \geq 0$ or the negative correlation group with $R < 0$. The scatter diagram of the right group (7 subjects) is shown in Fig 9, and a negative group (13 subjects) is shown in Fig 10.

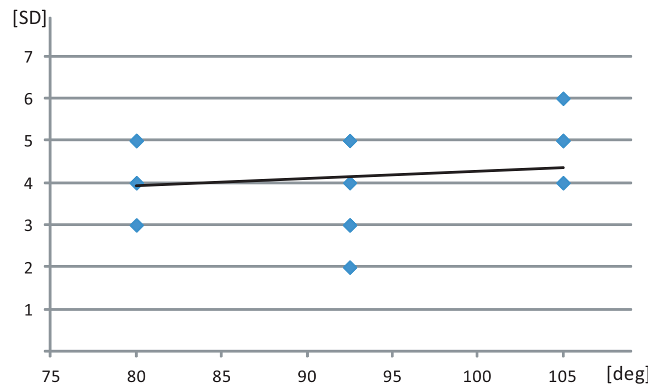

Fig. 9. Scattergram of positive correlation group ($R = 0.16$)

The correlation coefficient of the right correlation group was $R = 0.16$, and that of the negative correlation group was $R = -0.75$. From the above result, it turns out that there is a strong correlation between the robot's forward-bending angle and the pleasure-unpleasure feelings communicated by it for the 13 subjects of the negative correlation group. We verified by a pair comparison method for the negative correlation group.

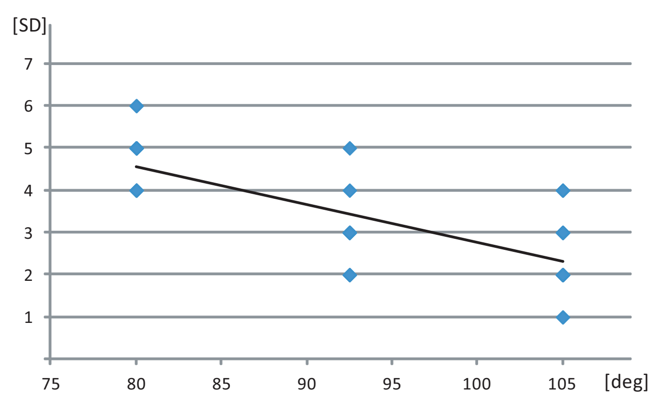

Fig. 10. Scattergram of negative correlation group ($R = -0.75$)

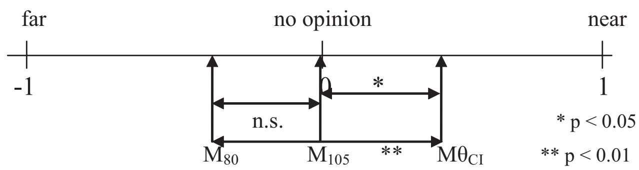

Fig. 11. Results of question1

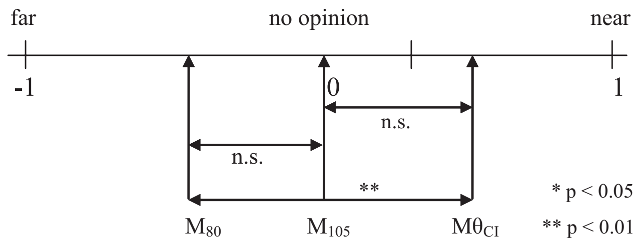

Fig. 12. Results of question2

As a result of conducting analysis of variance for each question, in every question, the main effect of the presentation stimulus is significant for a 1% level. And it turned out that there is a difference among the impressions transmitted by forward-bending angle.

Next, we investigated the significance of the difference during each stimulus with the pair comparison method. Figures 11, 12 and 13 show the result of the pair comparison method of Question 1 (tuning the feelings before beginning the experiment), Question 2 (tuning the feelings in the experiment), and Question 3 (appropriateness of pleasure expression), respectively. In these figures, M_{105} is θ = 105 [deg], $M_{\theta_{CI}}$ is θ = θ_{CI}, and M_{80} is θ = 80 [deg].

In Fig 11 (tuning the feelings before beginning the experiment), p value between $M_{\theta_{CI}}$ and M_{80} was less than 0.01, and p value between $M_{\theta_{CI}}$ and M_{105} was less than 0.05. From this result, we consider that expression of the robot's feelings by the comfort index of the behavior $M_{\theta_{CI}}$ can be the most harmonized to the subject's feelings. On the other hand, in Fig 12 (tuning the feelings in the experiment), only p value between $M_{\theta_{CI}}$ and M_{80} was less than 0.01. We consider that the robot's feelings, which is generated by the external environment rather than the indoor environment, may be more harmonized to the subject's feelings. In Fig 13, appropriateness of pleasure expression, p values between M_{105} and M_{80} and between $M_{\theta_{CI}}$ and M_{80} was less than 0.01. From this, we consider that the rounded back posture

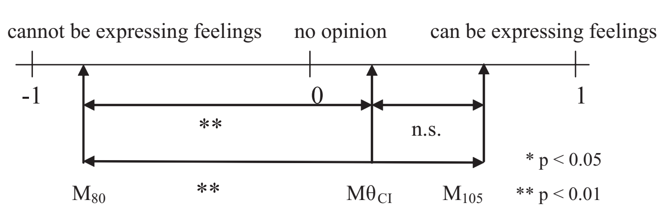

Fig. 13. Results of question3

gives an impression of unpleasure. In contrast, there was no significant difference between M_{105} and $M_{\theta_{CI}}$. Because the subjects observed robots from the front in this experiment, when two behaviors are compared, the subjects could not see a sufficient difference in the height of the head and the position of the trunk, and therefore we inferred that there is a difference of impression between the two behaviors, but there is not a statistically significant difference.

IV. Conclusion

In this paper, we proposed generating a robot's feelings from external environmental information (temperature and humidity) completely unrelated to human interaction. Moreover, we investigated whether the impression of "being harmonized" could be given to subjects when expressing the robot's feelings by comfort index. As a result, the group that has a strong correlation between the robot's forward-bending angle and pleasure-unpleasure feelings communicated by it could be given to subjects impression of "being harmonized".

We will investigate whether the impression of "being harmonized" could be given to subjects when expressing the robot's feelings by comfort index at different times.

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