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PSYCHOLOGICAL EVALUATION ON SHAPE AND MOTIONS OF REAL HUMANOID ROBOT

Kotaro Sakata [1], Tomohito Takubo [1], Kenji Inoue [1],
Seri Nonaka [1], Yasushi Mae [2] and Tatsuo Arai [1]

1 Department of Systems Innovation,
Graduate School of Engineering Science, Osaka University,
1-3 Machikaneyama, Toyonaka, Osaka 560-8531, JAPAN

2 Department of Human and Artificial Intelligence Systems,
Faculty of Engineering, University of Fukui,
9-1 Bunkyo 3-Chome, Fukui, Fukui 910-8507, JAPAN

E-mail sakata@arai-lab.sys.es.osaka-u.ac.jp

Abstract

For realizing humanoid robots coexist with humans, it is important to evaluate on shape and motions of a real humanoid robot. This paper compares impressions given by the humanoid robot HRP-2 and the mobile manipulator based on psychological methods. We also evaluated the influence of pick and place motion of the humanoid robot to human sense of security. As a result of analysing the questionnaire, it is found that turning the body coordinating with the arm gives good impression on humans. It will be an effect of human-like motion of humanoid robots.

1 Introduction

In the future, it is expected that robots will be introduced in our living space and help us in our daily life. Especially, humanoid robots are expected to work instead of humans in the same environment, since the kinematical structure of humanoid robots is similar to that of humans. In recent years, as the technologies of humanoid robots have progressed, some applications of humanoid robots are being investigated. As the outstanding attempt, Ministry of Economy, Trade and Industry of Japan has promoted the Humanoid Robotics Project (HRP)[1] since 1998 Japanese fiscal year (JFY) for five years. In this project, some applications of humanoid robots – operating industrial vehicles[2], maintenance tasks of industrial plants[3], building and home management services[4], cooperative works by a human and a humanoid robot[5], and so on – have been developed.

By the way, we see a lot of problems where "safety" and "security" are threatened in modern society. It is the highest priority issue to create safe, secure and reliable (SSR) society. For the purpose of creating SSR society, we have proposed an integrated system of monitoring and support system(Fig. 1)[6-7]. The monitoring system finds the sign of trouble/danger quickly in the environment by watching wide area in detail using many fixed or moving cameras. The support system prevents the danger from occurring or copes with the occurring danger rapidly, thus reducing damage to the minimum; in the present project,

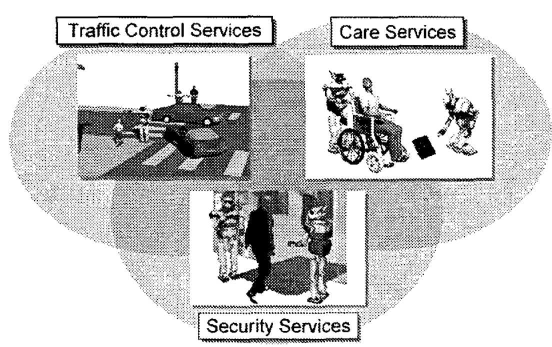


Figure 1: Monitoring and support system using humanoid robots.

we suppose to use humanoid robots as supporting devices. This is because humanoid robots can move in our environment and use some tools and machines as humans do.

For realizing humanoid robots coexist with humans as described above, it is necessary to design the shape and motions of the humanoid robots, considering the interaction between the robots and humans: "physical safety" and "mental safety". Physical safety means that robots do not injure humans. Mental safety will be said that humans do not feel fear of or surprised at robots. In addition, it is important that humans do not feel discomfort or anxiety. There are several ways to realize physical safety: robots avoid humans by measuring the distance between them with some kinds of sensors (for instance, [8]), or robots are covered with some kind of soft material so as not to injure humans (for instance, [9]). It is possible to evaluate physical safety quantitatively, and evaluation could be used in designing robots and planning their motions. Ikuta et al. proposed the general evaluation method of various kinds of safety strategies for welfare and human-care robots[10]. On the other hand, mental safety is not yet fully discussed. This is because which parameters of the robots may affect human mentality is not clarified, and the method of measuring the emotion which humans feel about robots is not established. For these problems, it is important to investigate and compare human emotions for coexisting robots.

This paper compares impressions given by the humanoid robot HRP-2 and the mobile manipulator based on psychological methods. We also evaluate the influence of pick and place motion of the humanoid robot to human sense of security. The rest of this paper is organized as follows: Section 2 describes the related works of this study. Section 3 describes the psychological evaluation on shape and motions of a real humanoid robot HRP-2. Finally, we conclude with the summary in section 4.

2 Related works

There are some researches on the evaluation of human emotions against robots. Mizoguchi et al. adopted a long-reach robot arm as a coexisting robot and investigated the interspaces and approach trajectories which make humans feel secure[11]. Mitsui et al. investigated psychological effects on humans by physical interaction with mental commit robot. They concluded that the texture of artificial fur and its softness have affirmative effects to mood of subjects[12]. Kanda et al. evaluated impressions given by the robot based on psychological methods and stated that impressions of the robot principally consisted of 4 factors: familiality, enjoyment, activity, and performance evaluation[13]. These researches did not evaluate the shape and their motions comprehensively. In addition, we do not see the research that evaluates the human emotions for humanoid robots.

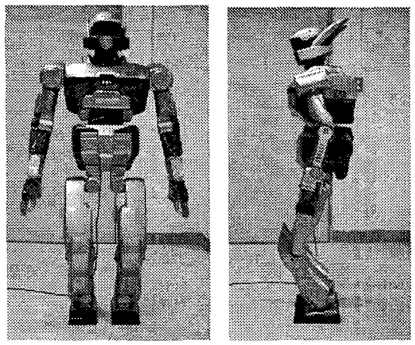
Whether humans can predict the motion of objects including machines seems important in order for the humans not to feel fear of or surprised at the objects. Ikeura et al. studied a method for robot manipulators of preannouncement which gives less fear to humans; they attached LED markers for preannouncement to a manipulator[14]. In this method, humans must memorize the meanings of the preannouncement signs of the robots beforehand in order to predict their motions. By the way, humans can predict other person's motion quite naturally. In the same way, humanoid robots will be able to let humans predict their motions naturally, if they behave like humans. Furthermore, human-like behaviors of humanoid robots will make humans feel comfortable. This is one of the merits of humanoid robots which have human-like shape and can behave like humans.

3 Psychological evaluation on shape and motions of real humanoid robot HRP-2

As the evaluation experiment, this section discusses pick and place motion of humanoid robots: a robot picks up an object and places it on the table in front of human subjects. This motion will happen quite often in the interactions between robots and humans in daily life.

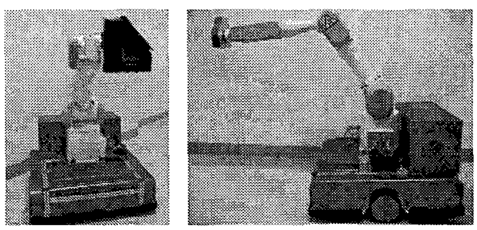
3.1 Robots

Recently, several humanoid robots have developed. Their height and weight are about 300[mm] to 1800[mm] and about 1.5[kg] to 200[kg] respectively as shown in Table 1. Since it is supposed, in this study, that humanoid robots support humans, humanoid robots' size are required more or less the same as humans. In this experiment, we used HRP-2[15] as a model of humanoid robots. This is because, we think, this robot's size is suitable for human support robots. This robot is the final version of humanoid robotics platform of the Humanoid Robotics Project (HRP), and it is 1539[mm] height, 621[mm] width, 58.0[kg] weight, 30 degrees of freedom (D.O.F.) includes 2 D.O.F. for waist, contains computers and butteries in its body. The snapshots of this humanoid robot HRP-2 are shown in Fig. 2. For comparing of a real humanoid robot, we use a mobile manipulator we developed[16]. We adopt a general purpose robot arm PA-10, a product of Mitsubishi Heavy Industries, Ltd., as a manipulator. We adopt a mobile platform customized by PATNA corporation. The mobile platform is 215[mm] height, 700[mm] width, 700[mm] depth, and 90.0[kg] weight. The snapshots of the mobile manipulator are shown in Fig. 3.



(a) front view (b) side view

Figure 2: Humanoid robot : HRP-2.



(a) front view (b) side view

Figure 3: Mobile manipulator.

3.2 Subjects

9 people (4 female) from 21-30 years of age (average 24 years) participated in this experiment. All subjects had normal or corrected to normal vision with no color blindness. They do not include the graduate students and researchers majored in robotics.

3.3 Procedure

Step 1:

A participant read instructions describing the experimental set-up and task. The experimenter then reviewed these instructions with the subjects. When the experimenter was satisfied that the subject understood the task and could perform it correctly, the subject watched the humanoid robot and answered the questionnaire about his impression of the robot. The questionnaire is based on semantic differential (SD) method in 7 levels: from 1("never") to 7("very much"). The following 24 adjective pairs are used: "masculine-feminine", "strong-weak", "beautiful-ugly", "cute-hateful", "fancy-sober", "sociable-unsociable", "merry-sad", "cheerful-gloomy", "friendly-unfriendly", "agreeable-unagreeable", "favorite-unfavorite", "interesting-uninteresting", "kind-unkind", "mild-grim", "careful-careless", "reliable-unreliable",

Table 1: Size / weight of representative humanoid robots.

Name	Height [mm]	Weight [kg]	D.O.F.
Kaz (Univ. of Tokyo)	340	1.6	18
morph3 (ERATO)	380	2.4	30
Mk.6 (Aoyama Gakuin Univ.)	390	2.0	26
Alviss (Univ. of Tokyo)	430	2.1	20
HOAP-2 (Fujitsu)	500	7.0	25
SDR-4X (Sony)	580	6.5	38
PINO (ERATO)	700	4.5	26
ASIMO (Honda)	1200	52.0	26
Saika-3 (Tohoku Univ.)	1270	53.0	30
H7 (Univ. of Tokyo)	1370	55.0	36
isamu (Univ. of Tokyo)	1470	55.0	30
T θ (Univ. of Tokyo)	1500	50.0	23
HRP-2 (Kawada)	1539	58.0	30
P3 (Honda)	1600	130.0	30
WABIAN-RV (Waseda Univ.)	1890	127.9	43

"good-bad", "complex-simple", "stable-unstable", "fast-slow", "safe-unsafe", "new-old", "big-small", and "soft-hard". In a similar way, the subject answered the impression of the mobile manipulator.

Step 2:

Then the subject watched the 6 motion patterns of the humanoid robot, and answered the questionnaire about his impression of the robot. This questionnaire is in 7 levels: from 1("never") to 7("very much"). The following 4 emotional words are used: "fear", "surprise", "discomfort", and "anxiety". In addition, the subject marked the score on a 100-point scale for 6 motion patterns.

Step 3:

Then the subject answered the questionnaire about his impression of the humanoid robot that consists 24 adjective pairs again. Finally, he gave his general impression of this experiment and any comments.

3.4 Motion patterns

First, two combination of moving parts are considered for comparing human-like motion and robot-like motion.

A-1) Moving only the arm.(robot-like)
A-2) Moving the arm and turning the head to the subject. (human-like)

Second, three levels of hand speed are applied.

B-1) Hand speed: 0.2[m/sec]. (slow)
B-2) Hand speed: 0.4[m/sec]. (normal)
B-3) Hand speed: 0.6[m/sec]. (fast)

Finally, two hand pathes that are shown in Fig.4 are also applied.

C-1) Hand path A.
C-2) Hand path B.

Combining the above-mentioned moving parts combination (A-1), A-2)), hand speed (B-1), B-2), B-3)) and hand path (C-1), C-2)), we prepared 6 motion patterns of the humanoid robot. Fig.5 and Fig.6 show the snapshots of [MP1] and [MP6] respectively.

[MP1] A-1), B-2), C-2)
[MP2] A-1), B-1), C-2)
[MP3] A-1), B-2), C-1)
[MP4] A-1), B-1), C-1)
[MP5] A-1), B-3), C-1)
[MP6] A-2), B-2), C-1)

3.5 Results and discussions

3.5.1 Comparison of impression of humanoid robot and mobile manipulator

We compared of impression of the humanoid robot HRP-2 and mobile manipulator using a t test[17-18]. Table 2 shows the average values of scores and P-values of t test. There is significant difference at the 5% significance level in 5 adjective pairs: "masculine-feminine", "sociable-unsociable", "interesting-uninteresting", "kind-unkind", and "complex-simple". On the other hand, there is not significant difference in the following adjective pairs that are related to the machine performance: "strong-weak", "stable-unstable", "fast-slow", and "safe-unsafe". Significant difference in "masculine" and "complex" is caused by the appearance

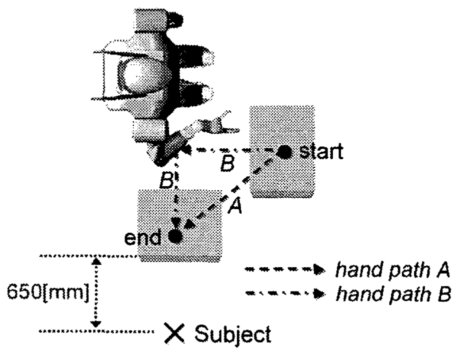


Figure 4: Experimental conditions (upper view).

design of the humanoid robot. Significant difference in "sociable" and "kind" shows that humanoid robot's appearance have human friendliness. Significant difference in "interesting" shows that the subjects care about the humanoid robot. Taking these results into account, we can see that humanoid robots are suitable for human support robots.

3.5.2 Comparison of impression of 6 motion patterns of humanoid robot

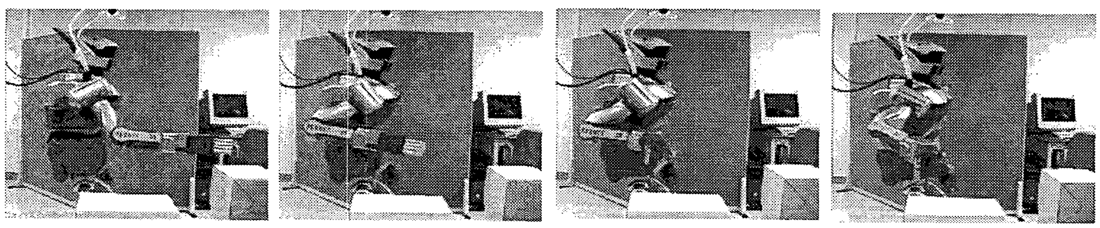


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Figure 5: Motion pattern [MP1]: Moving only the arm, Hand path B.

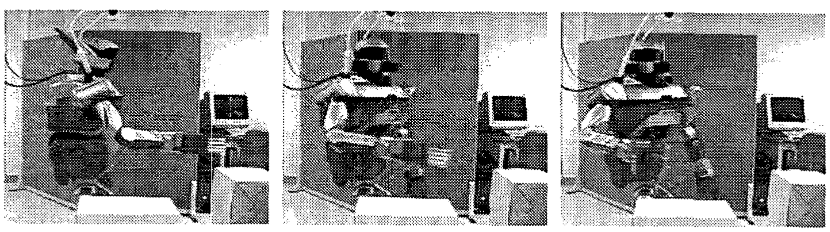

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Figure 6: Motion pattern [MP6]: Moving the arm and turning the head to the subject, Hand path A.

Table 2: Comparison of impression of humanoid robot and mobile manipulator.

Adjective pairs	H.R.[1]	M.M.[2]	P-value[#]
masculine−feminine	5.2	4.0	**0.047* / 0.024***
strong−weak	4.6	4.6	— / —
beautiful−ugly	4.7	4.2	**0.56 / 0.28**
cute−hateful	4.6	4.3	**0.72 / 0.36**
fancy−sober	4.6	3.2	**0.096 / 0.048**
sociable−unsociable	4.6	3.2	**0.035* / 0.018***
merry−sad	4.6	3.9	**0.17 / 0.085**
cheerful−gloomy	4.9	4.8	**0.81 / 0.40**
friendly−unfriendly	4.6	3.7	**0.34 / 0.17**
agreeable−unagreeable	4.7	4.0	**0.17 / 0.085**
favorite−unfavorite	4.8	4.1	**0.30 / 0.15**
interesting−uninteresting	5.7	3.8	**0.0013* / 0.0006***
kind−unkind	4.6	3.6	**0.028* / 0.014***
mild−grim	4.6	3.9	**0.26 / 0.13**
careful−careless	4.4	5.0	**0.18 / 0.089**
reliable−unreliable	4.6	4.7	**0.82 / 0.41**
good−bad	4.8	4.4	**0.40 / 0.20**
complex−simple	4.7	2.9	**0.060 / 0.030***
stable−unstable	4.9	5.1	**0.79 / 0.40**
fast−slow	3.7	3.8	**0.84 / 0.42**
safe−unsafe	4.8	4.8	— / —
new−old	5.3	4.3	**0.18 / 0.092**
big−small	4.8	4.7	**0.80 / 0.40**
soft−hard	2.6	2.9	**0.67 / 0.33**

[1] H.R. : Humanoid Robot, [2] M.M. : Mobile Manipulator
[#] P-value : Double P-value / Single P-value
[*] The significance level is 5%.

Table 3 shows the rating score in 7 levels and point score on a 100-point scale for 6 motion patterns. From these tables, we find that body turning gives better impression to humans even on the manipulation task. We also find that slower motion give better impression on humans. There is no significant difference between hand path A and B in this experiment. On the other hand, Mizoguchi et al. showed significant difference of human impressions between hand paths of a long-reach robot arm[11]. We think that, in case that people watch humanoid robot motions, they do not focus on their arm, even when a humanoid robot performs their manipulation tasks. In other words, people watch their whole body in such cases.

3.5.3 Impression of humanoid robot before and after experiment

We compared of impression of the humanoid robot using a t test, before and after the subjects' watching 6 motion patterns. Table 4 shows the average values of scores and P-values of t test. There is significant difference at the 5% significance level in 3 adjective pairs: "fancy-sober", "careful-careless", and "stable-unstable". Significant difference in "sober" is caused that 6 motion patterns in this experiment are partial motions. Significant difference in "unstable" is caused by the robot's vibration on pick and place motions.

4 Conclusion

In this paper, the shape and motions of a real humanoid robot HRP-2 are evaluated. As an example of robot's motion, subjects watched the pick and place motion. This motion will happen quite often in the interactions between robots and humans in daily life. As a result of analysing the questionnaire, it is found that turning the body coordinating with the arm gives good impression on humans. It will be an effect of human-like motion of humanoid robots. In other word, this is an effective usage of the redundant degrees of freedom which are not used for performing objective tasks. We also found that slower motion give better impression on humans.

We also proposed an evaluation system of human sense of security for coexisting robots using virtual reality[19]. It is significant that human emotions for virtual robots indicate a similar tendency to those for real robots. In the future works, we will investigate the relationship

Table 3: Rating score and point score of 6 motion patterns.

	Rating score [7 levels from 1("never") to 7("very much")]				Point score [100-point scale]	
Motion Pattern	"fear" ①	"surprise" ②	"discomfort" ③	"anxiety" ④	Average (Order[##])	S.D.
[MP1]	4.8 /7 **(4)**	5.2 /7 **(4)**	4.9 /7 **(6)**	4.8 /7 **(4)**	35.6 /100 **(6)**	20.1
[MP2]	2.8 /7 **(2)**	2.7 /7 **(2)**	3.0 /7 **(2)**	3.1 /7 **(1)**	60.0 /100 **(2)**	25.9
[MP3]	4.9 /7 **(4)**	5.3 /7 **(5)**	4.8 /7 **(5)**	5.1 /7 **(5)**	39.0 /100 **(4)**	19.8
[MP4]	3.3 /7 **(5)**	3.7 /7 **(3)**	3.2 /7 **(3)**	3.7 /7 **(3)**	58.4 /100 **(3)**	27.1
[MP5]	4.9 /7 **(5)**	5.3 /7 **(5)**	4.6 /7 **(4)**	5.1 /7 **(5)**	38.7 /100 **(5)**	25.9
[MP6]	2.3 /7 **(1)**	2.2 /7 **(1)**	2.2 /7 **(1)**	3.4 /7 **(2)**	69.4 /100 **(1)**	20.8

[#] ascending order. [##] descending order.

Table 4: Impression of humanoid robot before and after experiment (step 2).

Adjective pairs	Befor	After	P-value#
masculine—feminine	5.2	4.8	**0.22 / 0.11**
strong—weak	4.6	4.8	**0.65 / 0.32**
beautiful—ugly	4.7	4.3	**0.28 / 0.14**
cute—hateful	4.6	4.3	**0.45 / 0.22**
fancy—sober	4.6	4.1	**0.035*/0.018***
sociable—unsociable	4.6	4.2	**0.20 / 0.098**
merry—sad	4.6	4.0	**0.096 / 0.048***
cheerful—gloomy	4.9	4.6	**0.20 / 0.10**
friendly—unfriendly	4.6	4.2	**0.50 / 0.25**
agreeable—unagreeable	4.7	4.4	**0.45 / 0.22**
favorite—unfavorite	4.8	4.4	**0.20 / 0.10**
interesting—uninteresting	5.7	5.2	**0.31 / 0.16**
kind—unkind	4.6	4.1	**0.31 / 0.16**
mild—grim	4.6	4.6	— / —
careful—careless	4.4	4.1	**0.081 / 0.040***
reliable—unreliable	4.6	4.0	**0.21 / 0.11**
good—bad	4.8	4.4	**0.59 / 0.30**
complex—simple	4.7	4.8	**0.88 / 0.44**
stable—unstable	4.9	3.7	**0.047*/0.024***
fast—slow	3.7	4.8	**0.11 / 0.053**
safe—unsafe	4.8	4.3	**0.45 / 0.22**
new—old	5.3	5.2	**0.76 / 0.38**
big—small	4.8	5.0	**0.56 / 0.28**
soft—hard	2.6	3.1	**0.37 / 0.18**

P-value : Double P-value / Single P-value

* The significance level is 5%.

between human emotions for virtual robots and those for real robots in detail.

We will consider some physiological indices and methods of analyzing them and investigate the human impressions of humanoid robot's motions quantitatively. That will give a hint to design the human support motions of humanoid robots. This study aims at considering user's psychological aspect in robot motion planning.

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