Comparison of Human Psychology for Real and Virtual Mobile Manipulators*

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***Abstract* - When robots coexisting with humans are designed, it is important to evaluate psychological influence of shape, size and motion of the robots on the humans. For this purpose, an evaluation system of human psychology for coexisting robots using virtual reality is discussed. Virtual (CG) robots are visually presented to a human subject using CAVE system. The subject answers questionnaire about his impression on the robots and their motions, and his psychological state is evaluated. In the present paper, whether humans have similar impressions and feelings for real and virtual robots is investigated. Real and virtual mobile manipulators reach for subjects and pass nearby them. In both situations, the same motion patterns by these robots are presented to the subjects and psychologically evaluated by questionnaire. As the comparison results of this experiment, the subjects had similar feelings for the real and virtual robots.**

Index Terms* –*Coexisting robot, Psychological evaluation, Virtual reality, Mobile manipulator

I. INTRODUCTION

In the near future, robots will be introduced into our living space and help us in daily life. When we design such robots and plan their motions, we must consider interaction between the robots and humans: physical safety and mental safety. Physical safety means that robots do not injure humans. As mental safety, robots should not scare, surprise or displease humans; robots should not make humans uneasy. Physical safety can be evaluated quantitatively and has been introduced to robot design and motion planning. On the other hand, mental safety is not yet fully discussed. This is because which parameters of robots (shape, size, motion, etc.) affect human mentality is not clarified and methods of measuring and evaluating human emotions against robots are not established. For these problems, it is necessary to investigate and compare human emotions for different types of robots and their different motion patterns in various situations. That is, however, quite difficult by using real robots in real environments, because making and controlling real robots require much cost and time and are sometimes dangerous. There are some researches on evaluation of human emotions against coexisting robots, interaction between robots and humans and motion generation of coexisting robots[1-10]. But these studied psychological evaluation or motion planning of a specific robot, or compared different appearances of a limited class of robots, e.g. humanoid robots. Accordingly, some methods or systems for evaluating shape, size and motion of robots comprehensively and comparing different types of robots are required.

In our previous studies[11,12], we have proposed an evaluation system of human psychology for coexisting robots using virtual reality. Virtual (CG) robots are visually presented to a human subject using a head mounted display or CAVE system; the subject and the robots coexist in the virtual world. The subject answers questionnaire about his impression on the robots and their motions, and his psychological state is evaluated. Because of using virtual reality, shape, size and motion of robots can be easily changed and tested, and it is also possible to experiment in various situations. Using this system we evaluated humanoid robots in two situations: a robot holds out an object for a human[11], and a robot passes nearby a human[12].

In order for this system to be useful, it is an important issue whether humans have similar impressions and feelings for real and virtual robots. In this paper, real and virtual robots are compared. We evaluate a mobile manipulator consisting of a wheeled mobile base and a manipulator mounted on the base, because it would be a candidate for coexisting robots used in offices or houses. Real and virtual mobile manipulators reach for subjects and pass nearby them. In both situations, the same motion patterns by these robots are presented to the subjects and psychologically evaluated by questionnaire. Then the evaluations of the real and virtual robots are compared.

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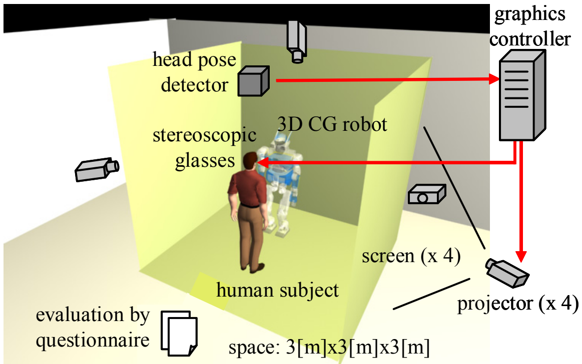


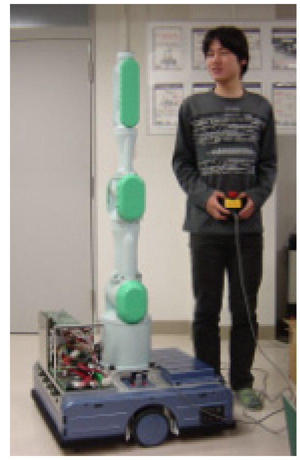
Fig. 1 Psychological evaluation of coexisting robots using CAVE system

II. Psychological Evaluation of Coexisting Robots Using Virtual Reality

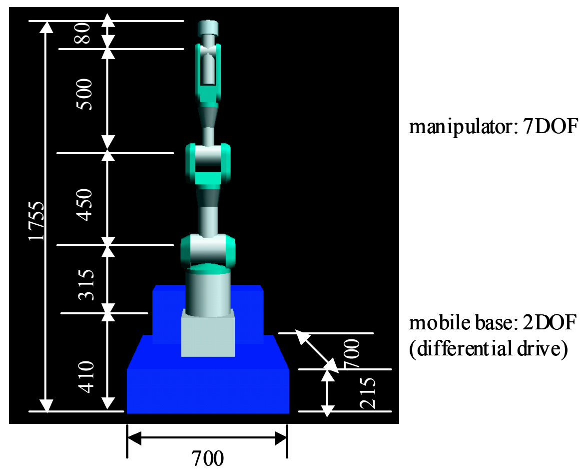
For designing robots with mental safety, it is necessary to investigate and compare human emotions for different types of robots and their different motion patterns in various situations. Appearance and motion cannot be decoupled. Different motions of the same robot may give different impressions on humans, and different types of robots doing the same task may give different influences on human emotions. Human emotions for robots may also depend on situations. It is difficult to evaluate many types of robots and their various motions using real robots, because making and controlling real robots require much cost and time. Preparing real environments for the tests is also difficult, and some situations (e.g. on-street) are dangerous.

For these reasons, we have proposed to evaluate human psychology for coexisting robots using virtual reality. As shown in **Fig.1**, virtual (CG) robots are visually presented to a human subject using CAVE system. CAVE is one of immersive visualization systems. It consists of four screens and a projector for each. The screens are placed on the front, left, right and floor. The subject wears stereoscopic glasses and stands inside the CAVE; it allows a stereoscopic view. As a result, the subject feels like existing inside the virtual world with the robots. CAVE can give higher realistic sensation to humans than head mounted displays. The subject answers questionnaire about his impression on the robots and their motions, and his psychological state is evaluated.

Because we do not have to make real robots, this method allows us to test and compare various types of robots and their different motions easily. It is possible to experiment in various situations and environments, including the cases which are difficult in the real world. We do not have to measure locations of robots using some sensors. Because virtual robots do not physically conflict with subjects, they can experiment in safe. On the other hand, this system cannot deal with the situations where subjects have physical contact with robots. The movable area of the subjects is limited inside the CAVE.



(a) Real mobile manipulator



(b) Virtual mobile manipulator

Fig. 2 Mobile manipulator

III. Comparison of Psychological Evaluation for Real and Virtual Mobile Manipulators

In order for this evaluation system to be useful, it is an important issue whether humans have similar impressions and feelings for real and virtual robots. Here we compare real and virtual robots.

A. Mobile Manipulator

A mobile manipulator consists of a wheeled mobile base and a manipulator mounted on the base. It can move around on a floor and do some tasks using the manipulator. Hence mobile manipulators would be

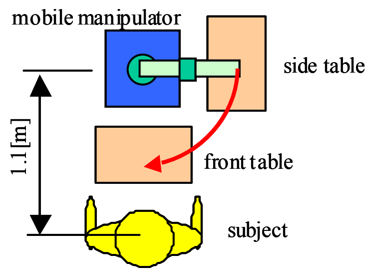
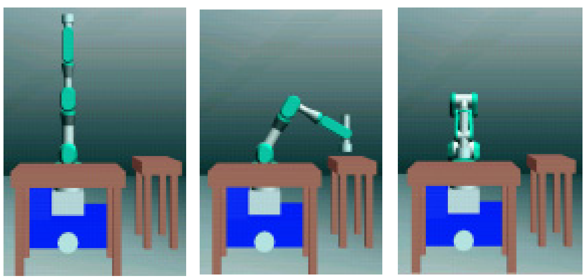


Fig. 3 Setup of reaching motion experiment



(1) (2) (3)

Fig. 4 Reaching motion

a candidate for coexisting robots used in offices or houses. We adopt mobile manipulator as a sample robot for this comparison.

Fig. 2 shows the mobile manipulator used in the experiment. In this section we simply call mobile manipulator as robot.

B. Reaching Motion

We consider two situations which may happen when robots coexist with humans.

First the robot reaches for a human; we call this "reaching motion". This situation happens when robots hold out something for humans. As shown in **Fig. 3**, a human subject sits on a chair. A front table is placed in front of the subject, and the robot is on the other side of this table. A side table is placed on the right of the robot. The distance between the subject and robot is 1.1[m]. The mobile base does not move. **Fig. 4** shows reaching motion:

(1) Initially the manipulator is straight up.
(2) The manipulator tip is swung down above the side table.
(3) The tip is moved above the front table and in front of the subject.

We apply different patterns to the motion from step (2) to step (3):

A: The manipulator tip is rotated around the base in horizontal plane to the subject's front.
B: The tip is lifted up and swung down to the subject's front.

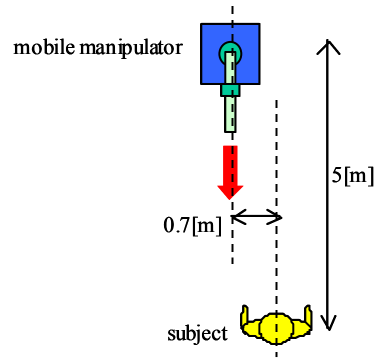


Fig. 5 Setup of passing motion experiment

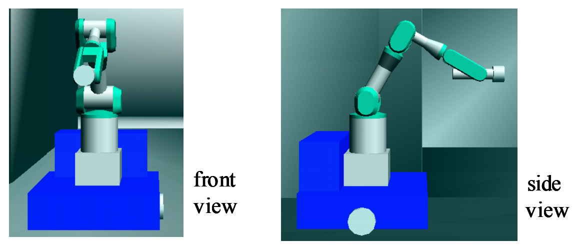


Fig. 6 Pattern D of passing motion

C: The tip is pulled back to the base and reached for the subject's front in the horizontal plane.

These patterns are designed so that the subject may see the tip approaching from side, above and front. It takes 6-12[s] from step (1) to step (3).

C. Passing Motion

Second the robot passes nearby a human; we call this "passing motion". As shown in **Fig. 5**, a human subject stands facing the robot and sees the robot coming from the front in a straight line. The initial distance between the robot and the subject is 5[m]. The distance between the robot's path and the subject is 0.7[m]. It is determined so that the robot can narrowly pass nearby the subject. Because of hardware limitation, moving speed is 0.23[m/s] for the virtual robot and 0.11[m/s] for the real robot. The manipulator makes different poses:

D: The tip is stretched forward (**Fig. 6**).
E: The tip is straight up.
F: The tip is lowered.

D. Experimental Method

Subjects are 13 men in age 22-25. The same six motion patterns A-F by the real and virtual robots (thus total 12 patterns) are presented to each subject. After seeing each pattern, the subject answers questionnaire on the presented pattern for psychological evaluation. Half of the subjects evaluate in the order of the real robot and the virtual robot, and other half do in reverse order.

(1) How does the robot look in your eyes?

No.		strongly agree		no opinion		strongly agree	
1	smooth	1	2	3	4	5	awkward
2	heavy	1	2	3	4	5	light
3	sharp	1	2	3	4	5	dull
		never agree		no opinion		strongly agree	
4	gentle	1	2	3	4	5	

(2) How do you feel abount the robot motion?

No.		strongly agree		no opinion		strongly agree	
5	secure	1	2	3	4	5	anxious
6	restless	1	2	3	4	5	calm
7	comfortable	1	2	3	4	5	unpleasant
8	unapproachable	1	2	3	4	5	accessible
9	favorable	1	2	3	4	5	unfavorable
10	tense	1	2	3	4	5	relaxed
11	unfriendly	1	2	3	4	5	frinendly
12	interesting	1	2	3	4	5	tedious
13	unreliable	1	2	3	4	5	reliable
		never agree		no opinion		strongly agree	
14	intimidated	1	2	3	4	5	
15	surprised	1	2	3	4	5	

Fig. 7 Questionnaire for psychological evaluation of robot motion

E. *Psychological Evaluation*

Fig. 7 shows the questionnaire. (1) The first question asks subject's visual impressions on the robot motion. (2) The second question asks subject's psychological state when he sees the robot motion. The original questionnaire is written in Japanese. Final goal of our research is to evaluate mental safety of robots for designing robots coexisting with humans. Mental safety means that robots do not scare, surprise or displease humans and that robots do not make humans uneasy; these are important for coexisting robots. The method of evaluating mental safety is not yet clearly defined. Hence we built this questionnaire. We assign score 5 to "good" preferences on some questionnaire items and to "poor" preferences on the other items. This is because subjects become bored with monotonous questionnaire.

F. *Results and Discussions*

We analyze the correlation between subject's psychology for the real robot and that for the virtual robot when he sees the same motion of these robots.

We represent score of the real robot by $S_R(i,j,k)$ and score of the virtual robot by $S_V(i,j,k)$, where *i*: questionnaire item (1-15), *j*: motion pattern (A-F), and *k*: subject (1-13). Average scores of all subjects for each item *i* and each pattern *j* are calculated by

$$\overline{S}_R(i,j) = \sum_{k=1}^{13} S_R(i,j,k)/13 \quad (1)$$

$$\overline{S}_V(i,j) = \sum_{k=1}^{13} S_V(i,j,k)/13 \quad (2)$$

Fig. 8 shows the relationship between $\overline{S}_V(i,j)$ and $\overline{S}_R(i,j)$: the graph (i) plots $\left(\overline{S}_V(i,j), \overline{S}_R(i,j)\right)$ of six motion patterns $(j = 1, \cdots 6)$ for questionnaire item *i*. **Table 1** summarizes the correlation coefficients between $\overline{S}_V(i,j)$ and $\overline{S}_R(i,j)$.

The following items have correlation coefficient greater than 0.7: "gentle", "secure/anxious", "restless/calm", "comfortable/unpleasant", "unapproachable/accessible", "favorable/unfavorable", "tense/relaxed", "unfriendly/friendly", "unreliable/reliable", "intimidated".

As the discussions of this result:

(1) On the subject's visual impressions, the correlation coefficients of the questionnaire items expect "gentle" are low. This seems due to a little difference between the real robot's motion and the virtual robot's motion. For example, the virtual robot moves on a completely flat floor in the passing motion, thus moving smoothly. But the real robot slightly trembles because of the roughness of the floor.

(2) On the subject's psychological state, the correlation coefficients are positively high except "interesting" and "surprised". It strongly depends on the subject's individual taste whether the reaching and passing motions of the

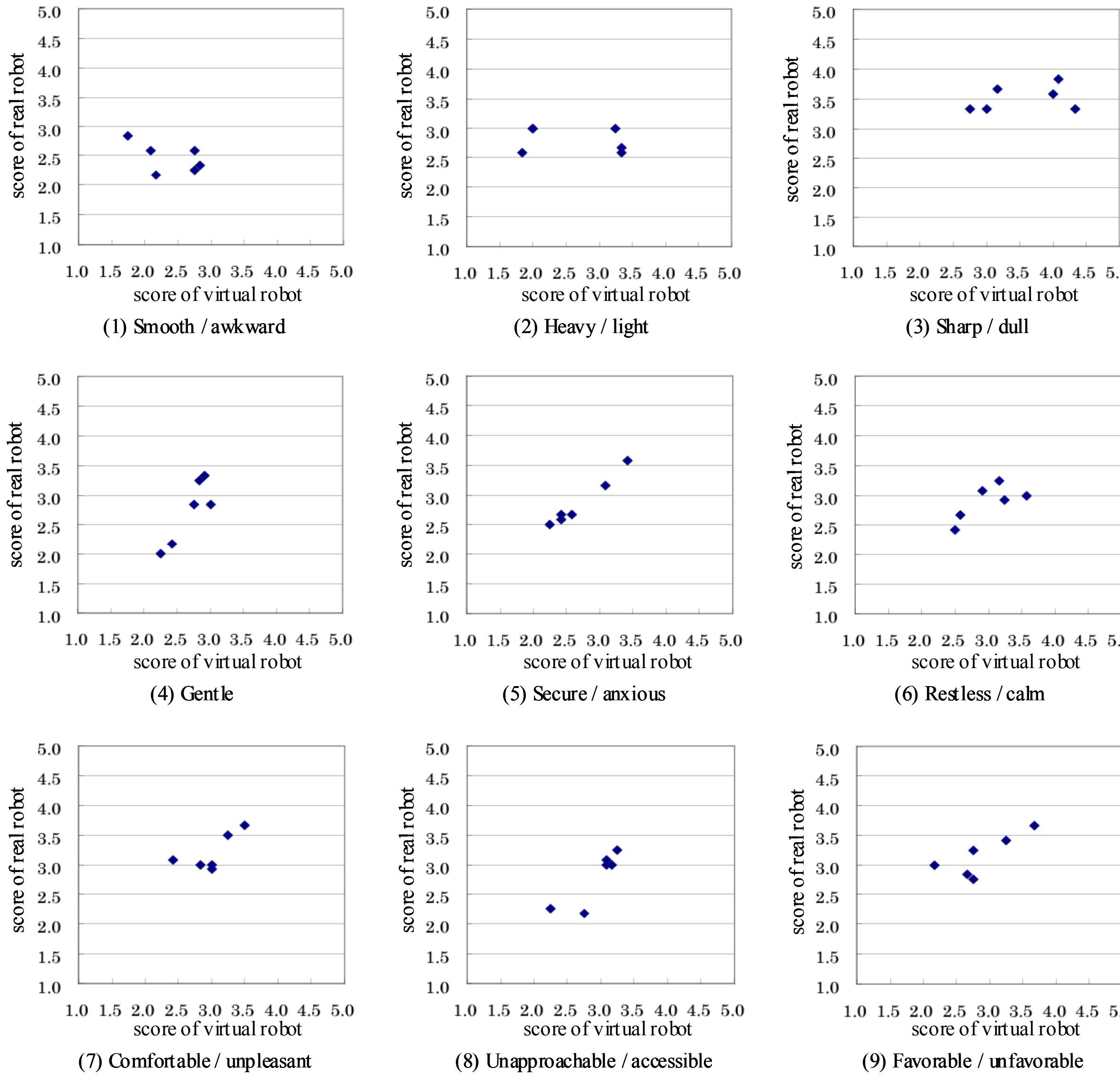


Fig. 8 Relationship between score of virtual robot and that of real robot in psychological evaluation (1/2)

robot are interesting or not. These motions are not so high-speed or unexpected as to surprise the subjects. These seem the reasons why the coefficients of "interesting" and "surprised" are low.

When humans coexist with robots, the psychological states of the humans (whether they feel secure, comfortable and relaxed for the robots) are important rather than the visual impressions of the robots. As this experimental result, the virtual and real robots made the subjects in similar psychological states. Hence our evaluation system of human psychology for coexisting robots using virtual reality will be useful for evaluating mental safety of coexisting robots.

IV. CONCLUSIONS

We examined whether humans have similar impressions and feelings for real and virtual robots. The same motion patterns by real and virtual (CG) mobile manipulators are presented to human subjects and evaluated by questionnaire. The result shows that the psychological states of the subjects for the virtual robot are almost same as those for the real robot. Accordingly our evaluation system of human psychology for coexisting robots using virtual reality is useful.

In future works, we will continue comparison of human psychology for real and virtual robots furthermore: using different types of robots, for more subjects and by a between experiment (different groups

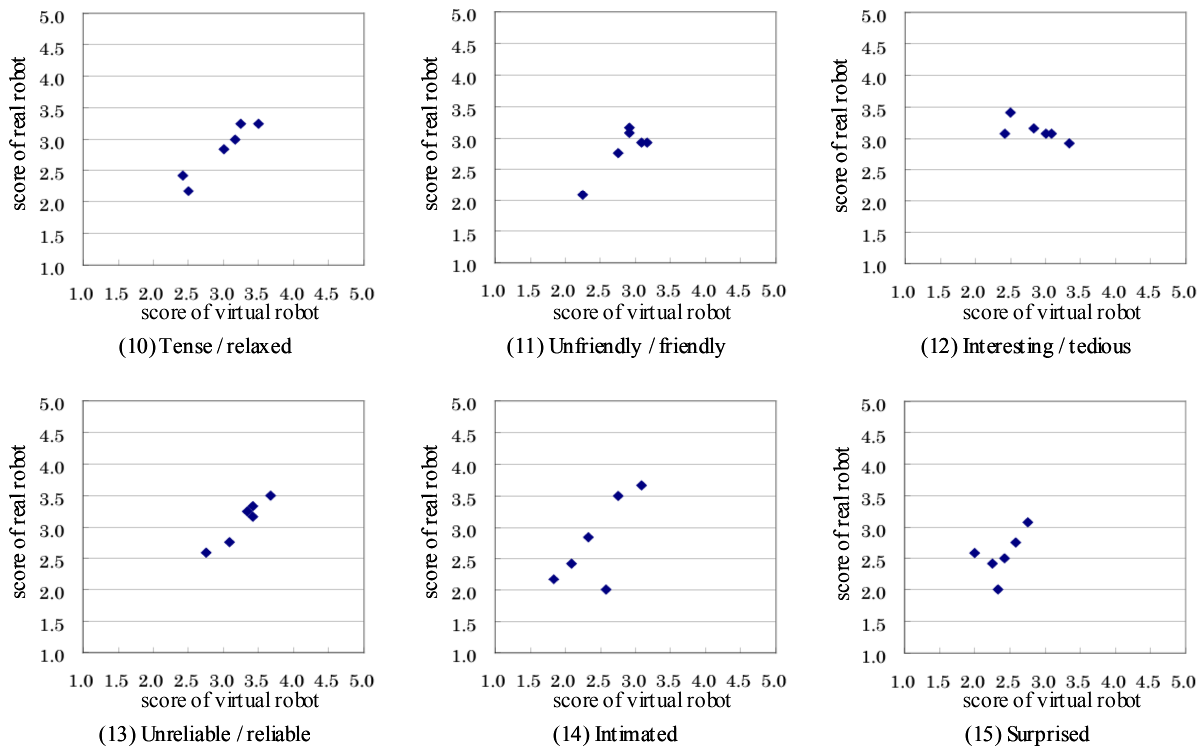


Fig. 8 Relationship between score of virtual robot and that of real robot in psychological evaluation (2/2)

Table 1 Correlation coefficients between scores of virtual and real robots

Item	Coefficient
Smooth / awkward	-0.53
Heavy / light	-0.25
Sharp / dull	0.35
Gentle	0.89
Secure / anxious	0.99
Restless / calm	0.71
Comfortable / unpleasant	0.72
Unapproachable / accessible	0.87
Favorable / unfavorable	0.78
Tense / relaxed	0.95
Unfriendly / friendly	0.85
Interesting / tedious	-0.69
Unreliable / reliable	0.96
Intimidated	0.74
Surprised	0.56

of subjects for each of real and virtual robots). We should also compare realistic and simple CG models of robots; that will clarify the effects and limits of psychological evaluation using virtual reality.

REFERENCES

[1] T. Shibata, et al., "Subjective Evaluation of a Seal Robot at the National Museum of Science and Technology in Stockholm", Proc. ROMAN2003, 2003.

[2] T. Shibata, et al., "Subjective Evaluation of Seal Robot in Brunei", Proc. ROMAN2004, 2004.

[3] B. Robins, et al., "Robots as Assistive Technology –Does Appearance Matter?", Proc. ROMAN2004, 2004.

[4] B. Robins, et al., "Investigating Autistic Children's Attitudes Towards Strangers with the Theatrical Robot –A New Experimental Paradigm in Human-Robot Interaction Studies", Proc. ROMAN2004, 2004.

[5] S. Woods, et al., "The Design Space of Robots: Investigating Children's View", Proc. ROMAN2004, 2004.

[6] J. Goetz, et al., "Matching Robot Appearance and Behavior to Tasks to Improve Human-Robot Cooperation", Proc. ROMAN2003, 2003.

[7] N. Kubota, et al., "Interactive Trajectory Generation using Evolutionary Programming for A Partner Robot", Proc. ROMAN2003, 2003.

[8] D. Sakamoto, et al., "Cooperative Embodied Communication Emerged by Interactive Humanoid Robots", Proc. ROMAN004, 2004.

[9] Y. Akiwa, et al., "Imitation based Human-Robot Interaction –Roles of Joint Attention and Motion Prediction", Proc. ROMAN2004, 2004.

[10]N. Nakazawa, et al., "Psychological Evaluations of Fusion Motions Emulating Exercises of Human's Arm Extension with Shoulder Movements", Proc. ROMAN2004, 2004.

[11]S. Nonaka, et al., "Evaluation of Human Sense of Security for Coexisting Robots using Virtual Reality (1st report: Evaluation of Pick and Place Motion of Humanoid Robots)", Proc. 2004 IEEE ICRA, pp.2770-2775, 2004.

[12]K. Inoue, et al., "Evaluation of Human Sense of Security for Coexisting Robots Using Virtual Reality (2nd Report: Evaluation of Humanoid Robots Passing by Humans in Corridors)", Proc. SSR2005, 2005.