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Kansei Behavior of Robots Following Instruction of Human

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***Abstract*— When coexisting with humans and support them, robots need to be instructed to move by humans without burden, and the motion should not to instigate anxiety but to be accepted to human psychology. To realize Kansei behavior of robots following instruction of human, the concept of "Kansei transfer function", which can add softness and smoothness to robots, is explained, and the effectiveness of its applications to human-robot interfaces is confirmed from psychological aspects.**

***Index Terms*—Kansei behavior, Kansei transfer function, Instruction of human.**

I. INTRODUCTION)

Nowadays, as interfaces to transmit information from humans to intelligent machines, touch panel, keyboard, controller, etc., are mainly used. These machines need to be directly touched by humans, and humans are requested to operate them with a limited posture.

If human can transmit operational information to robot directly through intuitive interface using movement of human whole body or parts of body, human intention can be transmitted correctly and simply. This intuitive interface is effective for robots coexisting with humans in the same life space for the purpose of supporting the disabled or the aged person.

When coexisting with humans and support them, robots need to be instructed to move by humans without burden, and the motion should not to instigate anxiety but to be accepted to human psychology[1]-[3]. Therefore, with regard to human-robot interface, instruction methods should be simple and be able to transmit intention of users to robots correctly. In addition, generated motion of robots should not be incompatible to users or others and should have smooth profiles.

The authors clarified that motion of robots to which softness and smoothness are added becomes acceptable to human psychology when robots follow human instruction movement. In this report, the concept of "Kansei transfer function", which can add softness and smoothness to the robot, is explained, and the related research instances are introduced[4] [5].

II. KANSEI TRANSFER FUNCTION

In the robot system cooperating with instructive movement of human, by adding dynamic characteristic expressed by the second order lag element to the following movement of robot with human motion, it is possible to realize psychologically acceptable smoothness with the motion of the robot.

We call this adjustable function "Kansei" controller and insert it between instructive point $\vec{u}_s(t)$ of human measured by a sensor and the desired position command to the robot $\vec{w}(t)$ as shown in Figure 1.

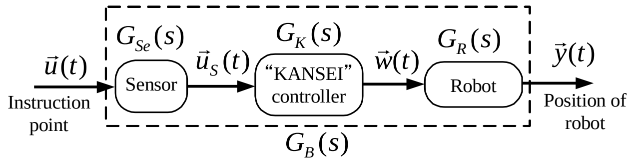

Figure1. Concept of Kansei transfer function.

Desirable characteristics of the broad transfer function $G_B(s)$ between instructive point $\vec{u}(t)$ and actual position of a robot $\vec{y}(t)$ is given to add softness and smoothness to the motion of the robot, and Kansei controller is designed to satisfy the characteristic.

The second order lag element with a lag time is considered as the broad Kansei transfer function to add appropriate delay and smoothness to the motion of robot as the next equation

$$G_B(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} e^{-Ls} \tag{1}$$

Here, ζ is damping coefficient, ω_n is characteristic frequency. Broad Kansei transfer function is given by the product of transfer function of sensor $G_{Se}(s)$, Kansei controller $G_K(s)$ and transfer function of robot $G_R(s)$ as

$$G_B(s) = G_{Se}(s) \cdot G_K(s) \cdot G_R(s) \tag{2}$$

The transfer function of sensors including image processing can be expressed by

$$G_{Se}(s) = K_{Se} e^{-L_I s} \tag{3}$$

If the transfer function of a robot is approximated as

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$$G_R(s) = \frac{K_R}{1+T_R s} \tag{4}$$

the Kansei controller is given by

$$G_K(s) = \frac{G_B(s)}{G_{Se}(s)\cdot G_R(s)}$$

$$= \frac{K_B \omega_n^{\ 2}}{s^2 + 2\zeta\omega_n s + \omega_n^{\ 2}} \frac{1+T_R s}{K_R} e^{-(L-L_I)s}$$

$$= \frac{K_B \omega_n^{\ 2}}{K_R} \left\{ \frac{1-T_R\omega_n}{(s+\omega_n)^2} + \frac{T_R}{s+\omega_n} \right\} e^{-(L-L_I)s} \tag{5}$$

The discrete time model of equation (5) preceded by a zero-order hold and followed by a sampler with the condition of sampling time T and the time delay $L = L_I$ becomes as

$$\begin{aligned} w(k) = &\frac{K_B}{K_S}\left\{\left(1-e^{-\omega_n T}\right)+\left(T_R-\frac{1}{\omega_n}\right)Te^{-\omega_n T}\omega_n^2\right\}u\left(k-1\right) \\ &-\frac{K_B}{K_S}\left\{\left(1-e^{-\omega_n T}\right)+\left(T_R-\frac{1}{\omega_n}\right)T\right\}e^{-\omega_n T}u\left(k-2\right) \\ &+2e^{-\omega_n T}y\left(k-1\right)-e^{-2\omega_n T}y\left(k-2\right) \end{aligned} \tag{6}$$

In the following chapters, examples of robot system in which Kansei transfer function is introduced are shown.

III. Robot System Cooperating with Instruction by Fingertip Movement

A robot system cooperating with human instruction using fingertip movement is considered. A robot moves following the motion of human fingertip, which is the instruction to move the robot as intended.

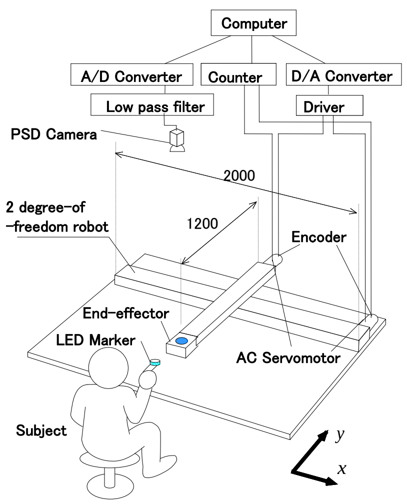


Figure 2. Robot system following instruction with movement of fingertip

Figure 2 shows overview of the system. The robot is orthogonal two-axis type, and the position of the end-effector is given by counting the pulse from rotary encoder through counter board at a computer. A PSD sensor system is used to detect the position of fingertip. In concrete, infrared radiation LED marker attached at fingertip is detected by a PSD camera set at right above, and an analogue signal which is proportional to the position of the LED marker is output. The analogue signal is taken to the computer through A/D converter and is transformed accurately to positional data. Following movement of the end effector with movement of the fingertip is realized accurately based on the data. The movement of fingertip and following movement of the end effector are shown in Figure 3 under the condition that parameters of Kansei transfer function ζ =1.0 and ω_n =2.0. As shown in the figure, appropriate delay and softness are added to the following movement of the robot.

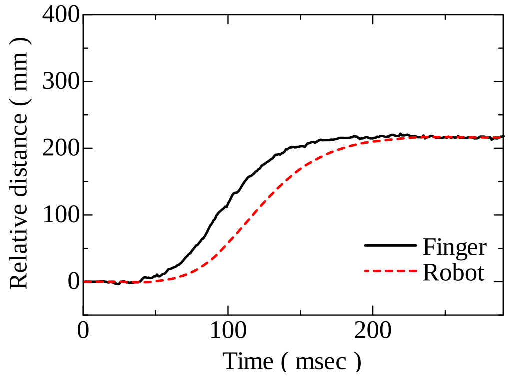


Figure 3. Instruction movement of fingertip and following movement of end effector.

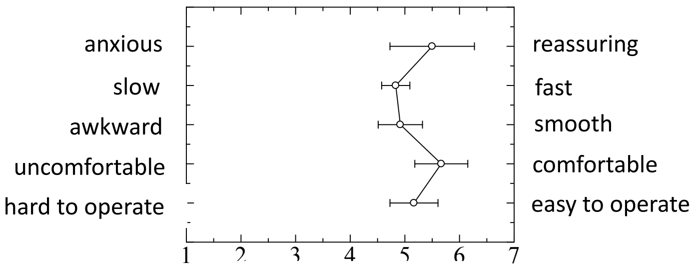


Figure 4. Psychological evaluation for Instruction by fingertip movement

Psychological evaluations are conducted to examine if the following movement of the robot in the proposed method is acceptable to human psychology. The rating scale method, which is a questionnaire type method to evaluate step scales of adjective pairs located at both poles, is used for the evaluation. Selection of adjective pairs is important in the rating scale method, and reassuring – anxious from sense of ease, smooth – awkward from smoothness, comfortable – uncomfortable from comfortableness, easy to operate – difficult to operate from sense of operation are selected. The results of evaluations are shown in Figure 4.

As shown in the figure, good evaluations are obtained on the sense of ease, smoothness, comfortableness, and sense of operation, which shows the effectiveness of Kansei transfer function.

IV. COOPERATIVE HANDING MOTION OF FROM AN ARM ROBOT TO A HUMAN

In order for robots to be human-friendly and to support humans in daily life, handing motion from a robot to a human is very elementally and should be done naturally like human to human handing motion. We focus on a cooperative handing motion from an arm robot to a human and a system adopting a control law based on mimic and the Kansei transfer function is shown. Figure 5 shows the system and Figure 6 shows structure of an arm robot.

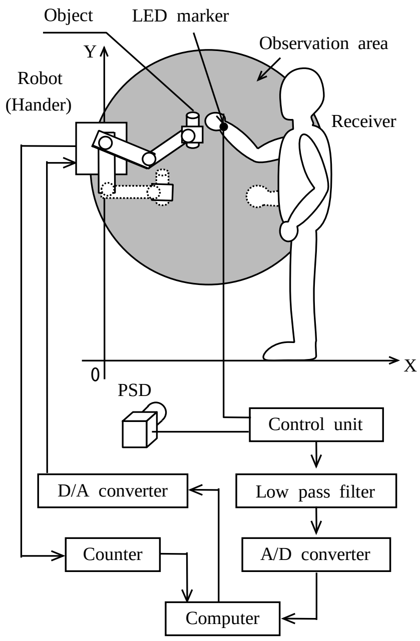


Figure 5. System configuration of handing

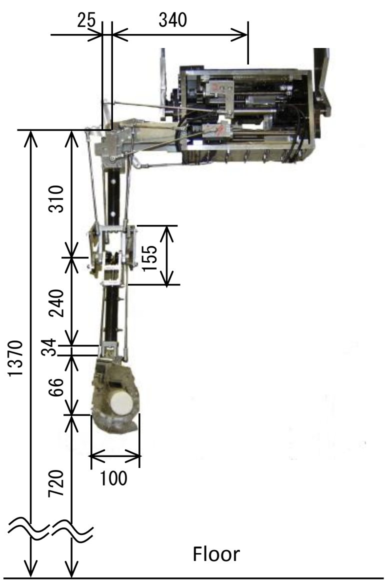


Figure 6. Structure of arm robot

To realize cooperative handing motion from the arm robot to a human, a model to produce motion trajectory of arm robot is considered based on characteristic of human to human handing motion.

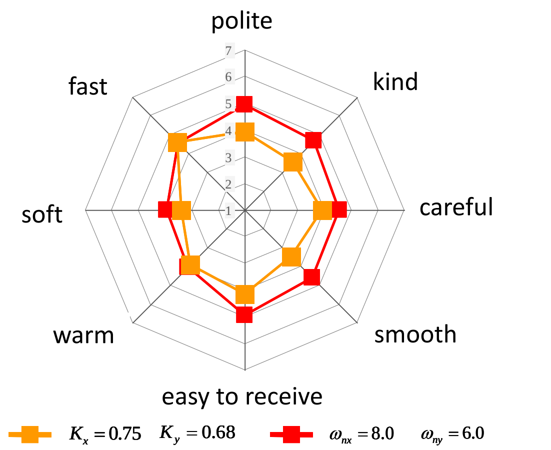
The model to generate motion of end effector to hand an object over to a human is proposed from the following viewpoints

- Basically end effector mimics the motion of the receiver
- Kansei transfer function when regarding the position of the receiver input and the position of the end effector output is adopted.
- By adjusting the gain of Kansei transfer function, difference between the movement distance of the end effector and that of receiver is expressed so that the position where handing and receiving an object will be conducted becomes desirable.
- By giving appropriate values to the parameters of Kansei transfer function, acceptable characteristics for human psychology are added to the movement of the end effector.

Next, psychological evaluations are conducted to examine the motion of the robot arm under various parameter values of Kansei transfer function. The values of parameters of Kansei transfer function are changed in the direction of x axis and y axis respectively as shown in Table 1.

Table 1 Parameter values of Kansei transfer function

Number	K_x	K_y	ω_{nx}	ω_{ny}	ξ_x	ξ_y
1	0.75	0.68	/	/	/	/
2	0.75	0.68	0.8	0.6	1.0	1.0
3	0.75	0.68	2.5	2.0	1.0	1.0
4	0.75	0.68	8.0	6.0	1.0	1.0
5	0.75	0.68	14.0	14.0	1.0	1.0
6	0.75	0.68	20.0	20.0	1.0	1.0



(a) Comparison of the evaluation for $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$ with that for only gains

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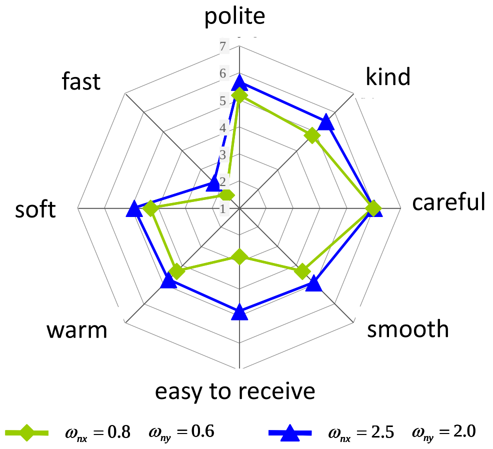
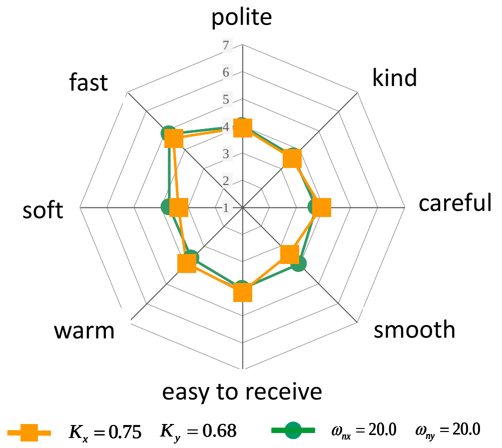


(b) Comparison of the evaluation for $\omega_{nx} = 0.8$ and $\omega_{ny} = 0.6$ with that for $\omega_{nx} = 2.5$ and $\omega_{ny} = 2.0$



(c) Comparison of the evaluation for $\omega_{nx} = 20.0$ and $\omega_{ny} = 20.0$ with that for only gains

Figure 7. Average values of the results of psychological evaluations.

Figure 7 shows the average value of the results of psychological evaluation with radar graph. Figure 7(a) shows comparison of the evaluations for $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$ with evaluations for only gains of $K_x = 0.75$ and $K_y = 0.68$. As shown in the figure, the movement with only gains gives human neutral impressions for all the adjective pairs. On the contrary, the movement with parameters of Kansei transfer function $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$ improves evaluations for all the adjective pairs.

Figure 7(b) shows the results for $\omega_{nx} = 2.5$ and $\omega_{ny} = 2.0$, and $\omega_{nx} = 0.8$ and $\omega_{ny} = 0.6$ as representative results when the values of ω_n are smaller than $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$. As shown in this figure, the evaluations on sense of speed become very low. In the case of $\omega_{nx} = 2.5$ and $\omega_{ny} = 2.0$, evaluations for politeness, kindness, being careful, and being warm become better than those for $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$. On the contrary, in the case of $\omega_{nx} = 0.8$ and $\omega_{ny} = 0.6$, the evaluations for being easy to receive becomes lower significantly (t-test, significant level of 5 %). This is characteristic when the values of ω_n are too small, and this tendency becomes more remarkable if they are smaller than these values.

Figure (c) shows comparison of evaluations for $\omega_{nx} = 20.0$ and $\omega_{ny} = 20.0$ with evaluations for only gains of $K_x = 0.75$ and $K_y = 0.68$. As shown in this figure, when the values of ω_n are larger than $\omega_{nx} = 8.0$ and $\omega_{ny} = 6.0$, the evaluations approach those for only gains.

From these results, it is confirmed that the handing motion with Kansei transfer function of the second order lag element gives human psychologically acceptable impressions, and changing values of parameters can influence human psychology causing Kansei effects.

V. Mobile Robot Operation Interface Using Instruction of Neck Movement

Recently with the rapid progress of aging society, robotic technology is expected to apply for substituting function of the physically disabled and supporting nursing care of the aged person. In addition, the need for robots supporting rehabilitation and daily life activity of the disabled has been heightened.

Against this background, we propose an interface in which the change of face direction by rotating neck is an instruction command to the motion of a mobile robot. Using this interface, even human who has handicap in uttering voice or moving upper limb can instructs the robot. In order for the interface to be intuitively understood by a user, a laser pointer is attached to the user's head and projects laser spot on the floor which is the instruction point to be followed by the robot. Using this laser spot, the user can clearly understand the relation between the face direction of human and the instruction point, and can instruct the intended movement to the robot.

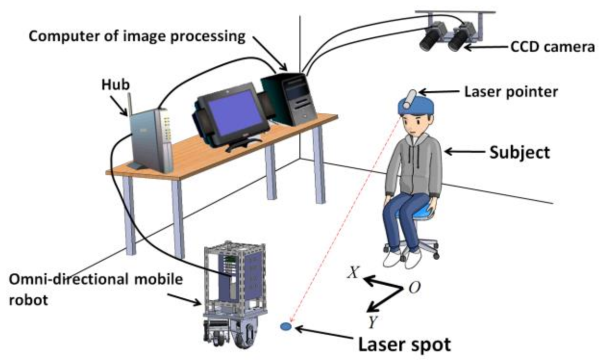


Figure 8. System configuration of mobile robot following instruction by neck

Figure 8 shows the system configuration. The user projects laser spot to the floor by rotating his or her neck. The laser spot, which is the instruction point to the mobile robot, corresponds

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to user's face direction. The position of the laser spot is measured by two CCD cameras attached at the high positon in the circumstance. Omni directional mobile robot generates following motion to the change of the position. To examine generated movement characteristic of the robot through Kansei controller, we conducted practical experiments in which human subjects operate the robot. Figure 9 shows the experimental condition. Subjects wear a cap with which a laser pointer is attached and is seated at a chair located at the origin of x-y coordinate.

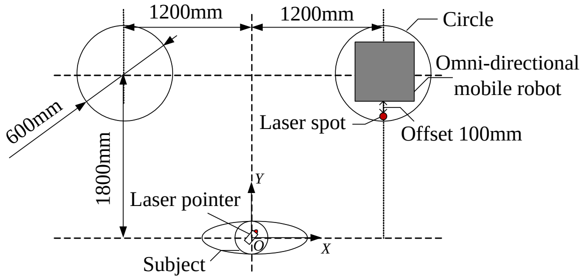

Figure 9. Experimental condition for a human to move the mobile robot using neck movement.

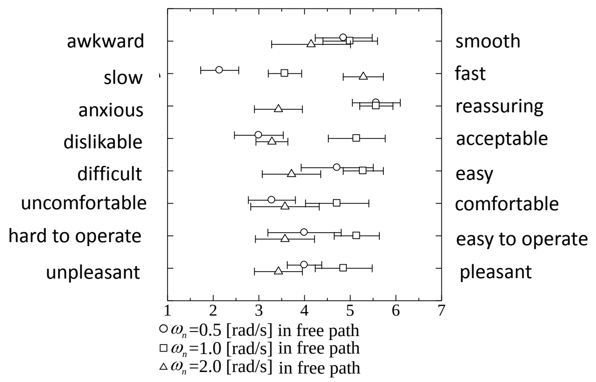

Figure 10. Results of the rating scale method when human operates the robot.

After that, the subject moves the robot from right circle to left circle by rotating his or her neck. When the subject judged that he or she succeeded to move the robot in the left circle, the subject stops his or her operation. The line between the center of light circle and that of left circle is proportional to the line between two shoulders of the subject. The trajectory, speed, and movement time are arbitrary by the subject. The value of ζ is fixed as 1.0 not to occur vibration phenomenon and the values of ω_n are 0.5 rad/sec, 1.0 rad/sec, and 2.0 rad/sec in the experiments.

Figure 9 shows the results of the rating scale method. In the figure, average and variance when giving one to seven point to each stepwise between adjective pairs are shown. For the results of awkward – smooth, average values locate at the center or the right position, which shows good evaluations. This is because the following movement becomes smooth, which is the effect of Kansei controller. For $\omega_n = 1.0$ all the average values except sense of speed locate at the right position, which means good evaluations. For $\omega_n = 2.0$ the evaluations of sense of security and feeling of operation deteriorate because the response to instruction is too quick. On the other hand, in the case of $\omega_n = 5.0$ the evaluations decline because of too moderate response speed to the instruction.

VI. CONCLUSIONS

In this report, dynamic characteristic expressed by Kansei transfer function is added to following movement of a robot with instruction movement of a human so that the movement shows Kansei behavior. Systems adopting Kansei transfer function such as an operational interface using fingertip movement, arm robot's handing an object over to a human, and an operational interface using neck movement are introduced. Through these systems, it is confirmed that appropriate delay and smoothness are added to robots, which are acceptable to human psychology, and that desirable values of parameters of Kansei transfer function change with the sort of human-robot system.

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