RUI for Home Appliances

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ABSTRACT
A Robotic User Interface (RUI) is a concept wherein robots are used as interfaces for human behavior. We have developed a RUI system for communications and given it the appearance of a teddy bear. This system allows interpersonal communications using robots as physical avatars. In this paper, we propose a new use of the RUI as a physical agent for control of home appliances. This use of a RUI enables people to control home appliance as if playing with a teddy bear.

Keywords
Robotic User Interface, haptic feedback, entertainment, Virtual Reality

1. INTRODUCTION
The concept of a Graphical User Interface (GUI) originated from the NLS (On-Line System) of Douglas C. Engelbart [1] and Alto of Alan Key [2]. It changed the way computers were used. GUIs simplified the use of a computer and played an important role in their spread for public use. However, because GUIs are based on a combination of WIMP (Window, Icon, Menu, Pointing Device), the interaction method used by GUIs has recently been recognized as being limited when interacting with real world situations.

NaviCam [3], Tangible Bits [4] and ActiveCube [5] are attempts to overcome such GUI limitations by using a physical object that exists in the real world as the interface. Many of these attempts use a see-through head mounted display (HMD) or a projector to output information to the user. Therefore, considering that direct interaction with outputted information is still limited, we believe that an output method that makes use of a real object remains to be established.

The intelligent room project [6] proposed the concept of drawing out the computer into the real world of people, and forcing it to be operational there. The intention was to make interactions between human and computer natural by use of human gesture and voice recognition. However, the feedback from input is limited because the information is outputted by projectors or computer voice. Therefore, we think it is difficult for the user to grasp the appropriate amount of manipulation of appliances that have an analog value. We believe that an input method that has direct feedback to the input from a user remains to be realized.

Personal robots such as pet robots [7] and interactive robots [8] are good examples of utilizing real objects. As opposed to a computer Graphics (CG) character on a computer display, these robots have a physical body, the existence of which attracts people. A robot can be regarded as a computer with a physical body that enables it to interact with the real world. Hence, considering the characteristics of their physical embodiment, robots can also be recognized as interfaces for human beings. The concept of using a robot as an interface between the real and information worlds can be referred to as a Robotic User Interface (RUI). We believe that a RUI will be an efficient interface having both input and output for real world situations.

A RUI has three important features.

- Portable humanoid interface

To apply a humanoid robot to a user interface, we have developed a portable humanoid robot. Operations to the robot such as modification of posture or changing shape and motion, are input. The shape or movements of the robot are output. Hence, the humanoid robot used for a RUI system needs a back-drive-torque that enables it to be easily manipulated with single hand.

-Intuitive interaction design

There are two kinds of input methods for people to interact with the information world. One is indirect interaction, such as the operation of a CG character using a joystick or a joy pad in fighting or role-playing games. The other is direct interaction, such as EyeToy™ [9], which uses a person's body actions. Visual and auditory information though are what are chiefly used for output. Force feedback uses haptic information from vibrations and the resistance of a joystick in the entertainment field, but this is a long way from being equated with the haptic information that we obtain in daily life.

Using the RUI system, the user can intuitively operate a humanoid robot using their own body image and schema, and can obtain haptic, shape and visual information through the shape and motion of RUI. As well, it doesn't take a long time to understand how to use a RUI when the user applies his/her own internal models to manipulate a RUI.

-Humanoid robot for haptic display

Various haptic displays have been developed [10, 11, 12]. Most are attached to part of the user's body, so it is difficult for them to display haptic information to the whole body. An RUI is another approach for whole body haptic display. When the user interacts with a RUI system, the humanoid robot and the virtual avatar act as his/her avatar. This humanoid robot enables a metaphorical display of whole body haptic information through the avatar; that is to say, Exo-centric Haptics.

However, by using their body image without looking at the RUI, a user can only get the robot's shape information as the hand senses it through the RUI. By looking at the humanoid robot, the user gets shape and motion information of the avatar. Therefore, an RUI is a haptic, shape, and motion display.

In this paper, we present a new type of interface for controlling home appliances using RUI as a selector and controller with haptic and visual feedback.

2. ROBOTIC USER INTERFACE

We developed the RobotPHONE [13] as a RUI system for interpersonal exchanges using robots as agents for physical communication. The RobotPHONE system employs robots as devices that are called shape-sharing. The shape and motion of remote shape-sharing devices are always synchronized using the bilateral control method. Operations to the robot, such as modification of posture, or the input of motion, are reflected to the remote end in real-time. Therefore, RobotPHONE users can communicate and interact with each other by exchanging shapes and motions of the robot. When users communicate each other by this system, the RobotPHONEs act as their physical avatars. That is, users can make contact with each other indirectly through RobotPHONE.

We have proposed another type of RUI [14] that synchronize the shape and motion between the RUI in real world and a virtual avatar in the information world. This RUI system enables people to directly interact with the information world. Figure 2 shows an AirHockey game in which the user can play with the RUI. We implemented the computer simulation of kinematics. The puck is a thin disk that moves and rotates in a two-dimensional surface. RUI avatars have mallets in both hands. Users move the mallets that the RUI avatar has by manipulation of the RUI's arms in the real world. When the mallet collides with the puck, haptic information is displayed to the user. The reflection force of the mallet and the puck is calculated by the simulation; it applies to a set point of the servomotor. Therefore, a user can feel as if they are directly manipulating the RUI avatar.

Figure 1. RobotPHONE

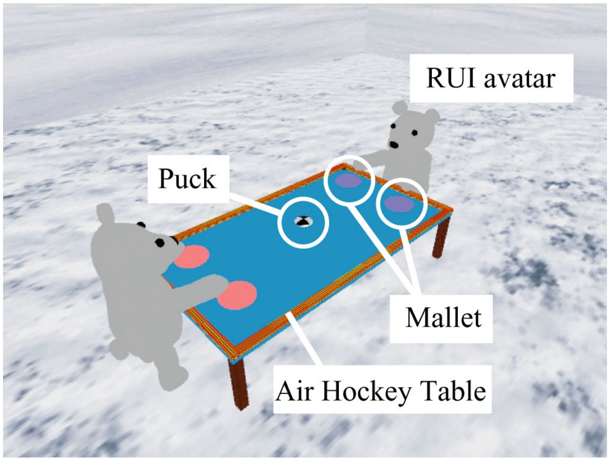


Figure 2. AirHockey application window

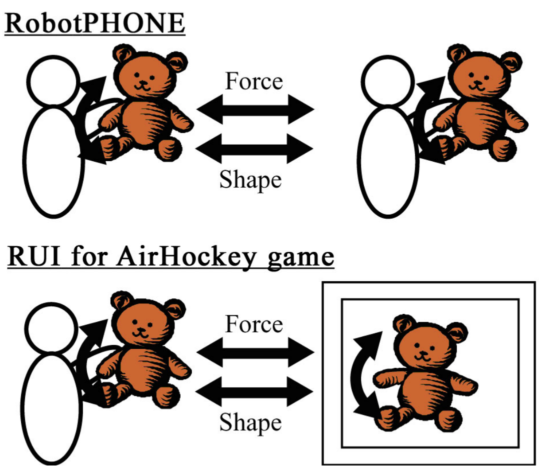


Figure 3. Shape-sharing of RUIs

3. RUI FOR HOME APPLIANCES

3.1 System Overview

Figure 4 shows an overview of the RUI for home appliances. A user can control home appliances using a RUI. As a proto-type, this system is applied to control lights, fans, and TV. The user can not only turn lights and fans on or off, but can also control their brightness or their air flows with analog values. For control of the TV, the user can turn it on or off, change channels, and adjust the volume.

The methods of interaction with this system are as follows. A user of this system can choose the appliance to be controlled by turning the RUI's face to it. When the RUI recognizes the appliance, the RUI starts tracking it and continues to look at it while showing the state of the appliance through its robotic gesturing. After outputting the state of the chosen appliance the user can start to control the appliance as desired.

Compared to ordinary remote controls, this system has three advantages as follows. Firstly, a user can choose the appliance to be controlled by showing it to RUI. Hence, he/she can choose the appliance according to its position in the real world. In contrast, when a user controls an appliance with an ordinary remote, he/she has to find out the remote, which can control the appliance. Secondly, a user of RUI can input with haptic and visual feedback. He/she can easily grasp the present state of control with haptic and visual information. Finally, a user can feel close to this system because RUI has a heartwarming appearance compared to ordinary insipid remote controls.

When a light or a fan is chosen, the RUI raises its arm according to the present brightness of the light or the present air flow of the fan. The relationship between the gesture of the RUI and the control of lights and fans are shown in Table 1. We relate raising the RUI's arm reflecting brightening lights and increasing air flow as an image of increasing value judged by raising an arm to the right level. Because the user can only alter the output of the state of the appliance with the RUI, this system prevents sudden changes of values of the current controlling device as set by previous input values. After outputting the states of appliances, the user controls them by raising and lowering the RUI's arm.

When the TV is chosen, the RUI raises both its arms to a horizontal level to show that the user can start to control the TV. In this prototype, the system doesn't know the state of the TV. The system can only send commands through an IR signal by a universal remote. Therefore, the system doesn't output the current state of the TV by the RUI, but shows the user that they can start to control the TV by robotic motion. After the system is ready to input, the user can control channels by the right arm, volume by the left, and the power by nodding the RUI as shown in Table 2.

We think of a RUI as an agent of the system that controls home appliances. This interactive design is as if people teach something to their child or even a pet step by step.

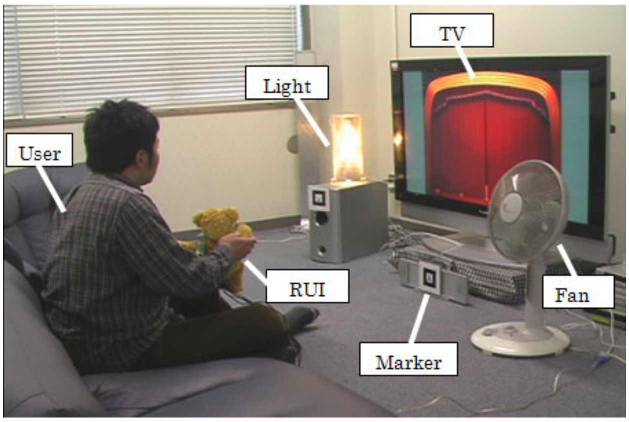


Figure 4. System overview

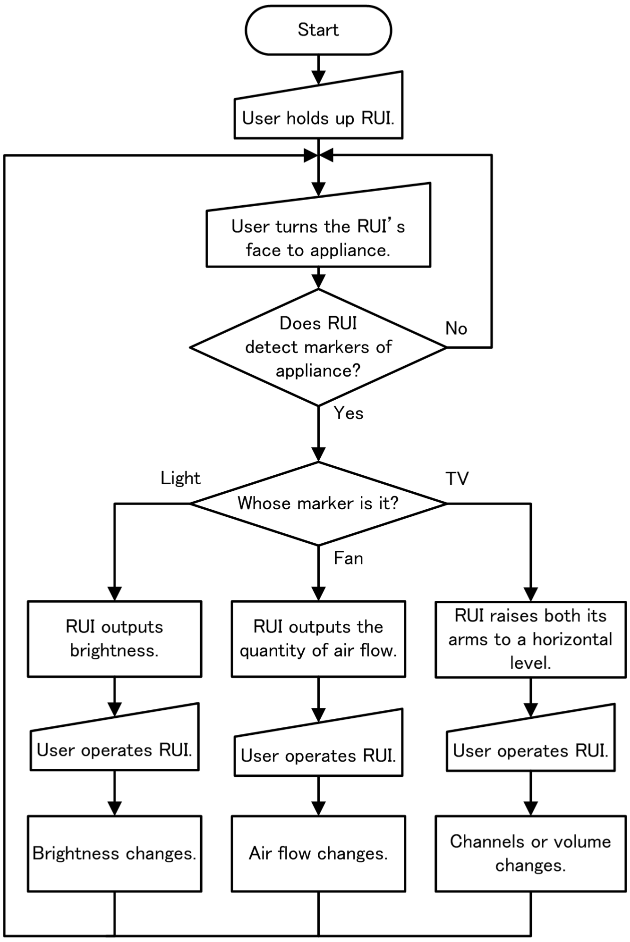


Figure 5. Flow chart of controlling home appliance

Table 1. Relationship between a RUI'S gestures and control of lights and fans

Right arm	Lights	Fans
Raise up	Brighten	Increase the air flow
Put down	Darken	Decrease the air flow

Table 2. Relationship between a RUI's gestures and control of a TV

Left arm	Volume
Raise up	＋
Put down	－

Right arm	Ch
Raise up	＋
Put down	－

Neck	Power
Nod	ON/OFF

3.2 Structure of the RUI

We use a RobotPHONE customized for this system as the RUI. This humanoid type robot has 2 degrees of freedom at each arm, 2 degrees of freedom for the head; therefore, 6 degrees of freedom in total (Figure 6, Figure 7). Each joint is composed of a servomotor consisting of a potentiometer for measuring the joint angle and a DC motor for rotating the joint. All DC motors of the RobotPHONE are controlled by microcontrollers inside the device. RobotPHONE software running on a PC controls the RobotPHONE through a USB connection. The software can acquire each axis angle and set target axis angles to be moved by the servo motor. Therefore, the RobotPHONE user can communicate and interact with the information world by exchanging shapes and motions of robots. The user operates the RUI holding it with both hands and interacting with the information world.

The RUI specifications are as follows. The length between the axis of an arm unit and the tip of an arm unit is 70[mm], the length between outstretched both arms is 249[mm], the weight of internal mechanism is 450[g], and the whole weight of the RobotPHONE including its teddy bear-like exterior is 630[g]. The gear reduction ratio of the servomotor is 69:1. The maximum torque that can be presented is 302 [mN-m]. The torque necessary for moving a joint of the arm unit is 19.6 [mN-m], which is a torque that can be operated easily by adults or children.

Cameras installed in the robots function as sensors of the real world. Movable robots use cameras as sensors to detect obstacles. Cameras also perform functions in working robot to recognize targets and their positions for operational situations.

In these robots, we installed a camera in the nose part of the RobotPHONE (Figure 8) to detect objects that the user wants to control. The camera specifications are as follows. Resolution 640x480, horizontal angle of view 34 degrees, vertical angle of view 26 degree, and the connection to PC is a USB. The camera corresponds to eye sight 0.3 (20/66). Installing a camera in a RUI means that we add sight to the RUI. Hence, this type of RUI is an interface that has both a body and sight. The combination of body and sight extends RUI applications to interactions with objects present in the real world.

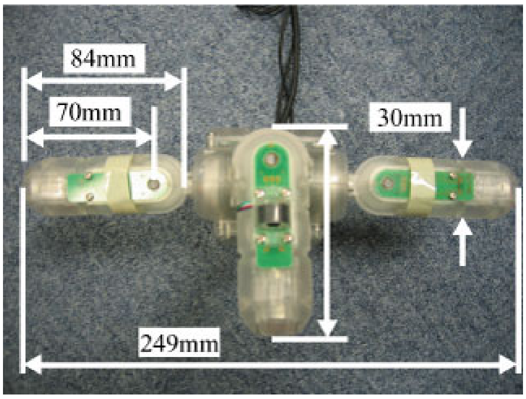


Figure 6. RobotPHONE dimensions (Top View)

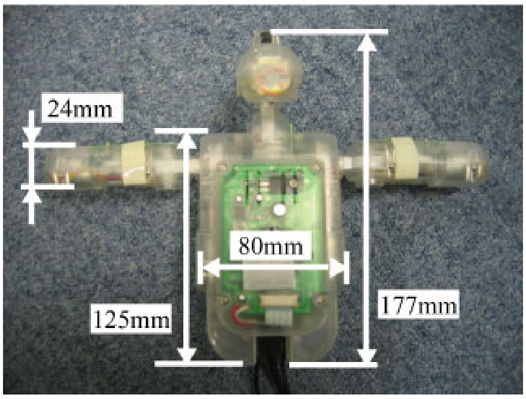


Figure 7. RobotPHONE dimensions (Front View)

Figure 8. RobotPHONE with camera

3.3 Detection of home appliances

Cameras are installed in various kinds of robots and function as sensors with suitable image processing for the robot's various tasks. A humanoid robot walking on two feet, such as ASIMO[15] and HRP-2[16], uses cameras for object recognition and for its depth map of environment. PaPeRo[17], a kind of personal robot to interacts with human beings and assist their life, has a stereoscopic camera for face detection, facial identification, and face tracking.

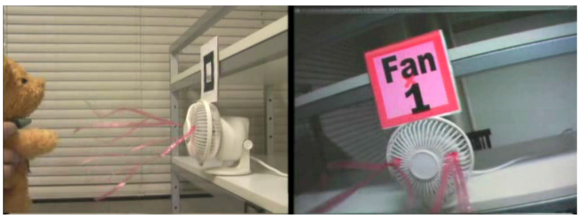
Computer vision is used to build Augmented Reality systems, which are systems for interactions between the real and information worlds. ARToolKit [18] is a significant software library for building Augmented Reality applications. The ARToolKit library supports three-dimensional position detection of each of different square maker patterns utilizing a common low cost camera.

To implement the interaction where the user turns the RUI's face to the home appliance to be controlled, we use ARToolKit and a camera installed in the RUI. The user has to set individual markers on the home appliance to enable their control. The system can then recognize which home appliance is in RUI's direction of gaze and can estimate their position. When more than one home appliance is detected, the system chooses the home appliance nearest the center of the captured image to be controlled by the user. Figure 9 shows a control scene and the ARToolKit application window, which is on a PC display. The user doesn't need to watch the display though. The user has only to see the direction of the RUI's face and the positional relationship between the home appliances and the RUI while selecting an appliance.

To show the user that the system recognizes a marker and chooses one home appliance, the RUI tracks the marker by moving its neck. When the user is turning the RUI's face to near the target home appliance direction, the system recognizes the marker and turns the RUI's face using the DC motors in its neck axes. The target angle of the neck axes are calculated from the position of the marker in the camera coordinates that are estimated by ARToolKit.

With this system, the user turns the RUI's face to the object and shares the gaze direction with the RUI. That is, the system doesn't observe the human gaze direction, but shares the gaze direction. Therefore, the system recognizes the objects that the user directs their attention to and so the RUI can be a interface the user uses intuitively in a real world situation.

(a) Controlling a light (b) Marker recognition window



(c) Controlling a fan (d) Marker recognition window

Figure 9. Scene of control

3.4 Home Appliance Controller

The brightness of the light and the quantity of air flow are controlled by a power supply controller that we developed for this system. This controller communicates with the PC through a RS232C. It can change the electric power supply to home appliances continuously through commands from the PC. For example, to darken a light, the PC sends a command for this power supply controller to decrease the amount of power supplied to the light. The command from the PC to the power supply controller is determined according to the value of the RUI's right arm axis angle.

A TV is controlled by a universal remote that can be controlled by a PC through a USB. This system can also control other home appliances, such as audio players and VTRs, which can be controlled by an IR signal.

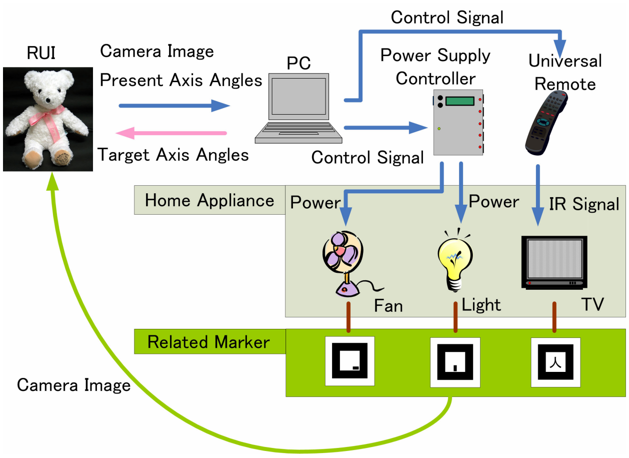


Figure 10. System diagram

4. EVALUATION OF RANGE CAPABILITY

The range capability of the remote control is one of the requirements for usability of this system. Therefore, we evaluated the distance that this system can recognize the square marker from by using the camera installed in the RUI with the ARToolKit software library.

As shown in Figure 11, we undertook the evaluation. We prepared 40[mm] and 80[mm] square markers for the evaluation. Initially, we set the marker 0.5[m] ahead of the camera and then progressively put it father in 0.5[m] steps. If the system couldn't recognize the marker after putting it 0.5m father away, we took the previous distance between the marker and the camera as the correct result. The luminance of the room where we undertook this evaluation was approximately 700[lx].

The result is shown in (Table 3). The system could recognize the 40[mm] square marker at 3.5[m] in front, and the 80[mm] square marker at 5.5[m]. We used a commonly available USB camera; the range capability was sufficient in a 4[m] square room with the 40[mm] square marker. If a wider range is required, we would choose a narrower angle lens or a high resolution camera.

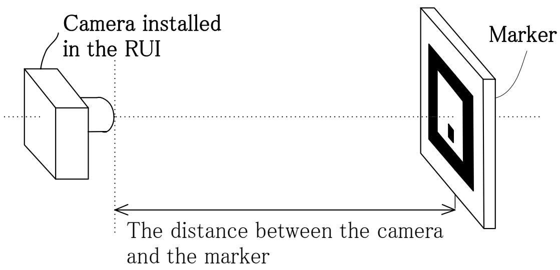


Figure 11. Evaluation setup

Table 3. Range capability results

The size of Marker [mm] square	40	80
The Distance between camera and the marker [m]	3.5	5.5

5. CONCLUSION

We presented our interactive remote control system for home appliances using a teddy-bear based RUI installed with a camera. A user can select the appliance to be controlled based on the positional relationship in the real world by turning the RUI's face to the appliance. This system displays the state of a home appliance and controls it through the robotic gestures of the RUI. The presence of the RUI is based on its body and motion; this system can be an effective display of the state of a home appliance and can provide information about it. A user can control home appliances with haptic and visual feedback from the RUI, and so easily understand the operation situation.

6. REFERENCES

[1] Engelbart, D. and English, W. A Research Center for Augmenting Human Intellect, Conference Proceed-ings of the 1968 Fall Joint Computer Conference, San Francisco, CA, Vol. 33, pp. 395-410, 1968.

[2] Key, A. Microelectronics and the Personal Computer. Scientific American 237, No.3, pp.230-244, Sep. 1977.

[3] Rekimoto, J. NaviCam: A Magnifying Glass Approach to Augmented Reality Systems, Presence: Teleoperators and Virtual Environments, Vol.6, No.4, pp.399-412, MIT Press, 1997.

[4] Ishii, H. and Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, in Proceedings of CHI '97, pp.234-241, 1997.

[5] Watanabe, R., Itoh, Y., Asai, M., Kitamura, Y., Kishino, F., and Kikuchi, H. The Soul of ActiveCube - Implementing a Flexible, Multimodal, Three-Dimensional Spatial Tangible Interface, Proceedings of ACM SIGCHI International Conference on Advances in Computer Entertainment Technology ACE 2004, pp. 173-180, Jun. 2004.

[6] Brooks, R. The Intelligent Room Project. In Proceedings of the 2nd International Cognitive Technology Conference (CT'97). Aizu, Japan, 1997.

[7] Fujita, M. and Kitano, H. Development of an Autonomous Quadruped Robot for Robot Entertainment, Autonomous Robots vol.5, pp.7-8, Kluwer Academic Publishers, 1998.

[8] Brooks, A., Gray, J., Hoffman, G., Lockerd, A., Lee, H., and Breazeal. C. Robot's Play: Interactive Games with Sociable Machines. Proceedings of ACM SIGCHI International Conference on Advances in Computer Entertainment Technology ACE 2004, Jun. 2004.

[9] Marks, R., Scovill, T., Michaud-Wideman, C. Enhanced Reality: A New Frontier for Computer Entertainment, ACM SIGGRAPH 2001 ConferenceAbstracts and Applications, pp.117, 2001.

[10] Tachi, S., Maeda, T., Hirata R., and Hoshino, H. A Construction Method of Virtual Haptic Space, Proceedings of the 4th International Conference on Artificial Reality and Tele-Existence (ICAT '94), pp.131-138, Jul.1994.

[11] Massie, T. and Salisbury, J. The PHANToM Haptic Interface: A Device for Probing Virtual Objects, Proc. ASME Winter Annual Meeting, 1994.

[12] Ishii, M. and Sato, M. A 3D Spatial Interface Device Using Tensed Strings, PRESENCE, Vol.3, No.1, pp.81-86, 1994.

[13] Sekiguchi, D., Inami, M., and Tachi, S. RobotPHONE:RUI for Interpersonal Communication, CHI2001 Extended Abstracts, pp.277-278, 2001.

[14] Shimizu, N., Koizumi, N., Sugimoto, M., Nii, H., Sekiguchi, D., and Inami, M. A Teddy-Bear-Based Robotic User Interface, Proceedings of ACM Computers in Entertainment, Vol.4, No.3, July 2006.

[15] Sakagami, Y., Watanabe, R., Aoyama, C., Matsunaga, S., Higaki, N., Fujimura, K.. The intelligent ASIMO: system overview and integration. In IEEE/RSJ International Conference on Intelligent Robots and System vol.3, pp.2478 – 2483, 2002.

[16] Matsui, T., Hirukawa, H., Yamasaki, N., Ishikawa, H., Kagami, S., Kanehiro, F., Saito, H., and Inamura, T. Distributed Real-Time Processing for Humanoid Robots. In 11th IEEE International Conference on Embedded and Real-Time Computing Systems and Applications, pp. 205 - 210, Aug. 2005.

[17] Osada, J., Ohnaka, S., and Sato, M. The scenario and design process of childcare robot, PaPeRo. In proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology, Jun. 2006.

[18] Kato, H. and Billinghurst, M., Tracking and HMD Calibration for a Video-based Augmented Reality Conferencing System. In 2nd Int'l Workshop on Augmented Reality, pp 85-94, 1999.