Mixed Reality Robotic User Interface: Virtual kinematics to enhance robot motion

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ABSTRACT
A Robotic User Interface (RUI) is part of a concept in which a robot is used as an interface for human behavior. By combining the RUI with Mixed Reality (MR) technology, we propose a MR RUI system that enables the presentation of enhanced visual information of a robot existing in the real world. In this paper, we propose the virtual kinematics to enhance robot motion. A MR RUI system with virtual kinematics can present a selection of visual information by controlling the robot through physical simulation and by changing the parameter dynamically.

Categories and Subject Descriptors
H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Artificial, augmented, and virtual realities*

General Terms
Design, Experimentation, Human Factors

Keywords
Robotic User Interface, Virtual Kinematics, Visual Display, Physical Avatar, Mixed Reality, Entertainment

1. INTRODUCTION
Robots, especially industrial ones, are chiefly considered as machines that perform work in place of human beings. Personal robots, however, such as pet [1] and interactive [2] robots are good examples of utilizing real objects. Many types of robot are now used in the entertainment field. There are robots that play soccer [3], and others that engage in combative sports [4]. A robot can be regarded as a computer with a physical body that enables it to interact with the real world. Hence, if one considers the characteristics of a robot's physical embodiment, it can also be recognized as an interface for human beings.

A robot used as an interface between the real and information worlds is referred to as a Robotic User Interface (RUI) [5]. We believe that the concept of a RUI provides an efficient interface that has both input and output methods in real world situations. We propose a system that uses a humanoid robot as the RUI. The system uses it as an input-output device to the communications device, the information world, and the object in the real world [6,7]. The RUI enables intuitive input and the presentation of visual and haptic information by using the body of the robot. For the presentation of visual information, the bodily movements, shape, and externals of the robot are used. These depend on information physically possessed by the robot.

We propose a MR RUI that combines mixed reality (MR) [8] technologies and seamlessly fuses the information world expressed by computer graphics (CG) and the real world with the RUI. The MR technology is assumed applicable to various fields such as medicine, welfare, construction, city design, the arts, and entertainments [9,10]. NaviCam [11] is a kind of palmtop computer that has a small video camera to detect real-world environments. This system allows a user to look at a real object and have access to related information generated by the computer. A Tangible Augmented Reality Interface [12] enables interactions with the MR environment by using a cup and paddle type tool. Augmented Coliseum [13] is a system that combines robots with MR technology. This system enhances the power of expression of the real object by superimposing a CG image to a vehicle type robot. Moreover, the sense of the existence of the CG image is presented using the movement of the robot. Kobito [14] is a

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system that presents the sense of the existence of a character in the information world by operating the object. Research that superimposes the operating person's visual information to a tele-existing robot to enhance the information that the humanoid robot presents has been reported [15]. U-Tsu-Shi-O-Mi [16], which presents the user the CG character superimposed on the robot, is a system that can change the visual information on the robot by changing the superimposed CG character. It is also possible to obtain haptic and touch sense information by touching the robot.

Visual information that the RUI presents can be enhanced with the MR RUI. In this paper we focus one information presentation that uses the bodily movement of the RUI, and propose "Virtual kinematics" as a technique for enhancing the reaction in the entertainment field. The bodily movements involved with mime become possible through collisions with the CG model etc. by controlling the robot in the real world to accord to a physical simulation. In this case, the bodily movement of the RUI in the real world can be easily changed by dynamically and appropriately adjusting the physical parameters of mass and elasticity, etc. This changes the operation of the CG avatar in the information world.

2. MR ROBOTIC USER INTERFACE

MR Robotic User Interface (MR RUI) is a new type of RUI system that incorporates Mixed Reality (MR) technology.

The system utilizes a RUI that uses a humanoid robot to display visual information. The visual information can be presented as movement, shape, and through the externals of the robot. There are two kinds of movement information. One is a programmed movement. The other is a movement under the influence the CG avatar receives in the information world when shape synchronizes between RUI and CG avatar. The visual information conveyed by shape and externals of the RUI is difficult to alter as it is fixed to the physical nature of the robot in the real world.

Information is presented through the physical existence of the robot. However, visual information like shape and the externals of the robot is physically fixed. To change information, the mechanism is physically changed or it is necessary to prepare another exterior.

On the other hand, when a CG is used, visual information is presented to the person through the display and a projector. The visual information, shape and externals on the CG model can be modified just by altering the CG model with different colors and shapes, etc. in the computer, and then changing these characteristics for further changes.

The MR RUI enables shape and external information on the robot to be changed easily. A CG model is prepared in the information world, and synchronized with the shape of the RUI in the real world. For the image that the RUI takes, the CG model is superimposed onto the RUI. The change in the physical exterior becomes unnecessary because the exterior (the MR exterior) is determined by a CG fixed to the robot in the MR RUI. Visual information of robot can be easily changed by preparing two or more CG models with different shapes and colors, and by changing the superimposed CG model. The expression and size of the RUI can be instantaneously changed by using the MR exterior, something that is impossible to do to a physical exterior.

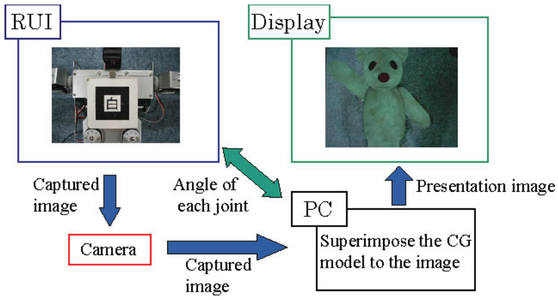

Figure 1. MR exterior

3. VIRTUAL KINEMATICS

3.1 Mime by Robot

The virtual kinematics that we propose in this paper involves a system that enhances the bodily movement expression of a RUI by using MR technology. The RUI system as a visual presentation device uses the operation of CG model in the information world where a physical simulation is applied. Then it uses a RUI in the real world as the display where bodily movement is presented.

Physical simulation is usually used to achieve more realistic operations and the reactions to a CG model in the information world. Therefore, it is necessary to appropriately set parameters like mass, gravity, and friction and elasticity, etc. to the CG model. Contrarily, the operation and the reactions of a CG model in the information world can be changed to be exaggerated or just small by changing the parameter set within an appropriate range. In our RUI system, the RUI in the real world is synchronized with the CG model in the information world. Thus, expressions of the body movement of the RUI, just like a mime artist, can be produced using a physical simulation.

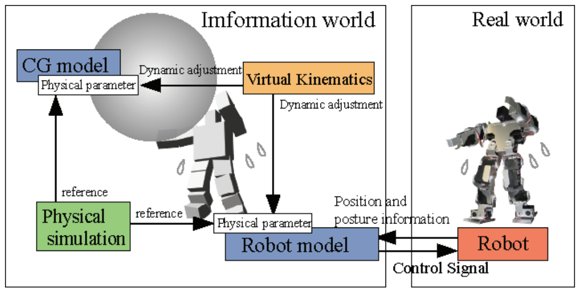

Figure 2. Virtual Kinematics

In this research, a robot is prepared in the real world, a CG model is prepared in the information world, and these are then synchronized. The robot is controlled according to the result of a physical simulation where it goes to the CG model. As a result, a scene acted out by the robot is achieved. We aim to improve the power of the expression that uses the body movements of the RUI in the real world. When a scene is set where obstacles collide with the robot in the real world, the CG model of the RUI operates by making it collide in the CG model of the RUI and the CG model with the obstacle in the information world. As a result, the robot in the real world that has been synchronized with the shape of the CG model operates. Thus a collision with n obstacle that doesn't exist in the real world can be expressed through the body movement of the robot. Figure 2 shows another example. The robot in the real world moves like it is shouldering an invisible sphere and soy makes the CG model of the robot shoulder a real sphere.

Table 1. Visual information obtained from the robot (Shape and Externals)

	Robot	CG model	Robot + Mixed Reality
Presentation method	Actual existence	Display and projector, etc.	CG model is superimposed on the robot.
Visual information	Fixed physically	Possible to change dynamically	Possible to change dynamically
Easiness of visual information to change	Hard	Very easy	Easy
Change method	Physically change the exterior and the mechanism	Prepared CG model with different shapes and colors etc. and then change	Prepare other superimposed CG models and change

3.2 System Configuration

In this paper, we propose "Virtual kinematics" that apply sense of fast and slow to the movement of the robot by having parameters that suit the real world in a physical simulation that is not set but is dynamically adjusted. Expressions of "Comical overreaction" and "Action not caught in a specific physical law like the law of conservation of momentum etc." are enabled using virtual kinematics. Though the physical character of the robot is fixed, the virtual kinematics can give extensions to expressions that use body movement because the robot can move according to various situations.

The MR RUI system configuration of is as follows.

For the RUI in the real world, we use a KHR-1 (Kondo Kagaku Co., Ltd) to present the body movements using the whole body. KHR-1 has 1 degree of freedom (DOF) at the neck, 3 DOF at each arm, 5 DOF at each leg, and 17 DOF in all. To generate in the information world where a physical model is applied and to generate the "virtual kinematics", we used "Springhead" [17], an open source software toolkit for virtual environment development.

A CG model with the same shape and size as KHR-1 was prepared in the information world. The robot in the real world and the CG model in the information world are synchronized for shape and operation by mutually sending and receiving the value of the angles of each joint. The CG model in the information world moves according to when the robot in the real world side is moved by a person's hands. In reverse, the robot in the real world moves according to when the CG model receives some actions and shape changes in the information world. The visual and haptic information are presented to the user by the robot's movements.

The parameters that can be changed in Springhead are as follows. A parameter concerning the environment is gravity acceleration. Parameters concerning the object are the mass, size, an inertia tensor, position of the center of gravity, and coefficients such as those of the penalty method used to calculate contact power, and dynamic and static friction. The parameters concerning the object with joints like the robot are a coefficient of the joint that determines the softness of the joint etc. We produced various body movements of the RUI by effectively and dynamically changing those parameters.

4. IMPLEMENTATION

We made the robot carry out bodily movement expressions involved in "Collisions objects (It is shot with a gun)" and "Contact with objects (It is cut with a sword)" as a mime. CG models of two KHR-1s were prepared in the information world. The model of the bullet was made to collide" and "The model of the sword cuts the other CG model's arm". The CG model of the information world moves by the simulation. As a result, the RUI synchronized with the CG model will mime the action in the real world.

Some advantages of the virtual kinematics in the expression of this scene. The parameter of the bullet can be dynamically changed for the expression of being shot with a gun. Therefore, the degree of body movement when shot can be dynamically changed by increasing the mass of the bullet. The CG model and the program need not be changed.

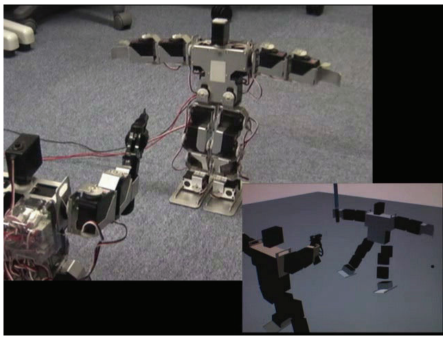

Figure 3. Mime by robot "Collision of object (The robot is shot with a gun.)"

The CG model of the sword in the information world is enlarged to that of the sword in the real world, as shown in Figures 6 and 7. As a result, the expression of the body movement comes into contact only in the information world. The sword doesn't collide with the left arm of robot in the real world and so the robot is not damaged because the objects don't actually come into contact.

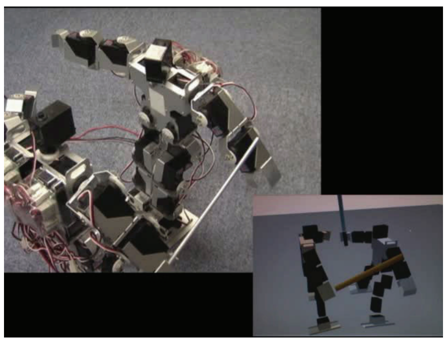

Figure 4. Mime by robot "Contact of object (The robot is cut with a sword.)"

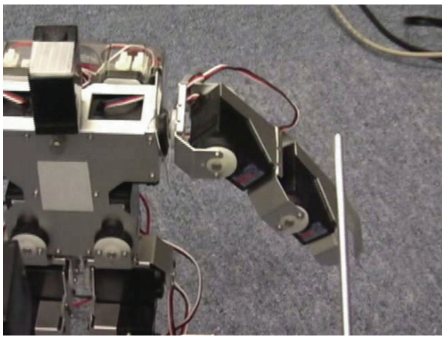

Figure 5. Expression of contact by noncontact in the real world

Table 2. Comparison of methods of generating movement of robot

	Usual method	Physical simulation	Virtual Kinematics
Purpose	Presentation of an apparent operation	Presentation of realistic operation	Presentation of an enhanced realistic operation
Setting of movement	Setting of operation program	Setting of appropriate physical parameter	Setting of appropriate physical parameters
Change of movement	Change in program	No change (Always follows the simulation.)	Dynamic changes in physical parameters
Width of movement	Number of programs	Physical law	Physical law + mime
Contact with another object	Contact	Contact	Non-contact (contact in information world)

5. CONCLUSION

In this paper, we proposed a system that enhanced body movements of a robot in a MR RUI that combined RUI with the MR technology. "Virtual kinematics" enabled a realistic operation that enhanced the presentation using a physical simulation. The width of the movement of the robot was expanded by changing a physical parameter. The expression of contact with another object was enabled by a non-contact action in the real world. The expression of the body movements of the robot can be made more dynamic using our "Virtual kinematics".

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