Interacting with Reactive Virtual Human using human-scale Force Feedback

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Abstract

Adding haptic information to virtual environment (VE) is effective to make more interactive and enhance presence. However human interface and interaction system involving force and touch feedback, have been scarcely suggested any research. The existing haptic interface has scalable constraints or even a difficulty for integrating force feedback devices with immersive VE due to its size and mechanism.

In the paper, we propose a new kind of interaction system, which combines an immersive VE with human-scale haptic interface. This renders seamless images in real time, and generates high-quality stereovision. A string-based haptic device with a flexible configuration and high visualization, will integrate into the VE. In special, we focus on force-feedback activities in interaction with real human and show a demonstration for the potentials and capabilities of our system.

Key words: Virtual Reality, Force Feedback, Human-scale Interaction, Human Interface and Virtual Human

1. Introduction

Recently, as great progress of CG technologies, realistic looking virtual humans have been simulated in any virtual scene or game. Moreover, the virtual human's behavior acts intelligently, for instance understanding a natural language and speaking with an adequate facial expression and gesture[2][3]. Although these are effective communication channels in most interaction, they are not enough to make us fully engaged in an interaction. When users interact with VE, not only visual quality, but also natural modes of interaction and control, and perception of self-movement affect presence or immersions[1]. These elements can be invoked and accomplished by physical contacts and touch feedback unobtainable with only hearing and seeing.

In an actual world, we experience touch and force feedback in our daily life such as a handshake, sports, dance, and play so on. This interaction is generated and understood by nonlogical information such as intuitive sensibility and reflex movements that aren't controlled by only words or image information. From this point of view, this feedback goes a basic and important communication between people. Therefore, in the computer-human interface, it is natural that force interaction should be involved[6].

Most direct and natural approach that increases user involvement, is adding force feedback with his body to an immersive VE. Many studies[7][9] have also been demonstrated that haptic feedback improves task performance and increases presence in VE. This means that the users to a higher degree felt as if they were present in the virtual environment when they received haptic information.

In this paper, we aim to realize the interaction system can do force effect with user. We implement this interaction in human-scale virtual environment with haptic interface and create the virtual human who can perform a life-like expression and reactive behavior.

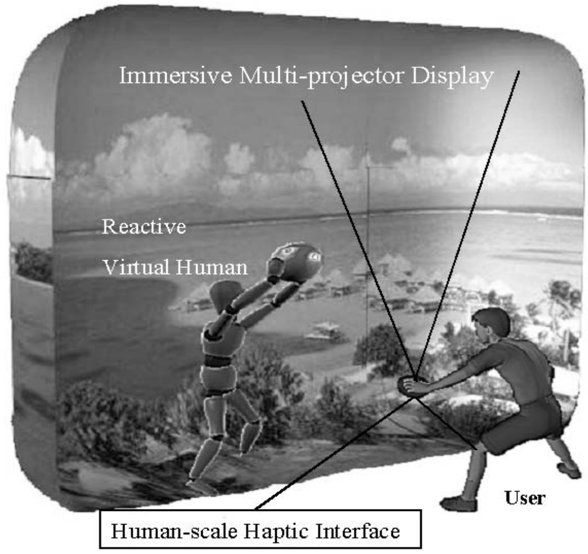

Figure 1 A basic concept for interacting with reactive virtual human using human-scale haptic interface. User can walk around an immersive VE, and interact with virtual human or objects with force reaction.

For creating the force feedback interaction with real human, the system should first of all, give feedback to the user's body in an immediate fashion. It should also represent the virtual human's reactions in a human-scale environment. Secondly, an immersive sensation or presence is an important element when user steps into the virtual world. The sense of presence makes the user feel that they are actually visiting and being part of the virtual environment. The system should allow the user to move freely and easily and to feel and manipulate virtual objects with his body so as to create more interactive VE. At last, virtual human should be life-size. His movements require real and natural styles according to user's action. All of three components are essential elements for the desirable interaction system. These should also integrate well. Figure 1 shows the basic concept of our system.

When these criteria are satisfied, it enables us to increase the sense of togetherness through touch by allowing physical contact. It will invoke the feelings of physical and social presence unobtainable with only hearing and seeing. We ensure that the developments of the system have brought new possibilities to other associated application, human metaphors as well as virtual reality technologies.

2. Related Works

Adding haptic information to immersive VE is especially effective to make more interactive and enhance presence in those environments. There are good attractive aspects that the additional information from haptic feedback, such as force, weight, or other physical properties brings the reality to the user. Through the immersive environment user can operate virtual objects without losing presence in a natural mode.

The recent mainstream of haptic interfaces for the virtual reality adopts a mechanical link structure[8][10]. That structure is stable for highly accurate operation and scalable. Although improved several type haptic devices have been developed, they were still not suitable for the use in immersive virtual environments because of its size and mechanism. In the immersive VE, the invasive mechanical links prevent users from seeing surrounding images seamlessly, and only work within a limited space. It has been made a constraint or even a difficulty for integrating force feedback devices with immersive VE, too. The problems can be solved by an alternative interface to provide force feedback for direct manipulation within a sufficiently large space[9]. The solution is less invasive and more flexible string-based haptic devices. Buoguila et al.[12] realized force feedback using a string-based haptic interface in a human-scale VE.

However, these proposals have been focused on only interaction with objects and are apt to make weaker link between user and interaction objects. Otherwise, we create a new interaction metaphor through force feedback with life-like virtual human unlike other haptic interaction.

3. System overview

3.1 Immersive Virtual Environment

In many ancient CAVE-like immersive displays, a cubic screen has been almost dominant solution[4]. The cubic screen which used 6 flat screens to completely surround users into that inside, said to an ultimate structure. Other immersive displays with a spherical or arched screen[5] have also been developed. The displays, however, involve crucial problems due to massive space and the high cost of hardware configuration. It requires more complicated structure for flexible extension, and makes more difficult to integrate other mechanical and large-scale interfaces.

Therefore, we adopted to use a large-scale immersive system named “D-vision”[15] that enables to the use of multiple senses flexibly and efficiently. The display part of our system adopts a multi-projector technology, which uses multiple PCs and projectors to provide high resolution and wide view-angle images. The images are projected on a hybrid screen, which consists of a flat central screen and a curved peripheral screen. This design concept reduces installation space. And we generate more streamlined images in the hybrid screen through our rendering method.

The size of the hybrid screen amounts to 6.3m (width) × 4.0m (height) × 1.5m (depth). These curved surfaces are connected smoothly so as not to distort projected images on the jointed part of the screens. Despite the hybrid screen covers only the front half of users, it have no lack of efficiency of immersion at all. Because interfaces for controlling and keeping the users view direction can more flexibly integrate into the D-vision than others.

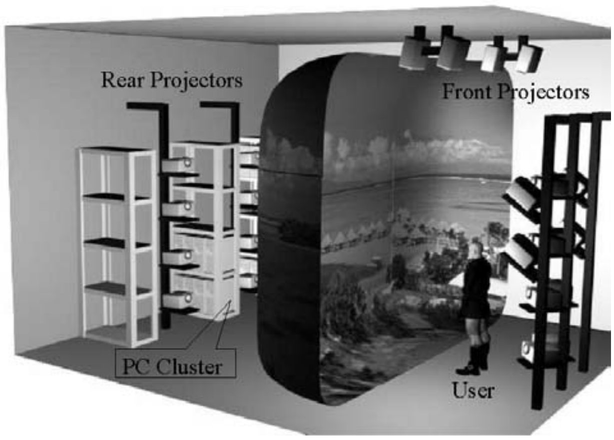

Figure 2 An overview of the multi-projector display. Projectors and a PC cluster for graphics rendering are placed around a hybrid screen.

As shown in Figure 2, the central flat part of the screen is for rear projection with 8 projectors with SXGA, 1280x1024 pixels resolution. The remaining part of the screen is for front projection with 16 projectors with XGA, 1024x768 pixels resolution.

The D-vision has a parallel rendering strategy to generate distributed and high-resolution images in real-time. The rendering processes of the D-vision are distributed to each rendering PC of the PC cluster, and work according to the role of each PC based on target areas on the whole screen.

In this system, whole images of the scenes are divided into 16 areas for the distributed rendering in each PC that is connected to each projector. The 8 areas of the central, up and down side view are rendered by 16 PCs for the stereoscopic viewing using polarized glasses. As a result, the total of 24 PCs are used for image generation of the D-vision.

3.2 Human-scale Haptic Interface

To realize a flexible configuration and high visualization, we integrate a string-based human-scale haptic interface named “SPIDAR-H”[12] into immersive VE. The SPIDAR-H consists of only some motors and flexible string not electromagnetic force sensor. Because of its simple prototype, it enables us to flexibly implement into the D-vision. It also allows full body activity to user and a practicable large-scale manipulation space.

Like the previous SPIDAR system [11], the SPIDAR-H allows force feedback on one distinct point, like middle finger, with 3 translations. As four motors are necessary for each point, 8 motors are installed for both hands. The motors have a rotary encoder, which counts the length of the string from user’s ring to the motor (See bottom of Figure 3). They are positioned on non-adjacent vertices of a cubic frame in the origin structure. This is simplest configuration for both hands force feedback and displaying haptic in every direction.

The haptic rendering is implemented by the spring and damper model. Force feedback occurs when collisions or impacts happen. The simulation frame rate is variable from 1kHz to 10kHz. The haptic and visualization rendering will be synchronized stably by high speed I/O and high definition haptic controller[13].

A configuration of the haptic device may be a little laborious work for satisfying all criteria both human-scale force feedback and highly immersive display. The string-based haptic devices have flexible properties, but on the other hand they are apt to have a little sensitive precision at scaleable size. The larger the SPIDAR space is, the less accurate the manipulations will be. However, the solution of used interface depends on whether interaction work is task performance- and human physical and natural mode-oriented. If the manipulation space is $1.1m^3$, the absolute errors are ±1.5cm. Despite larger space like double size, it will be within 2~3cm range.

We implemented the SPIDAR-H without fixed cubic frame into D-Vision, which offer a flexible hardware configuration and high visualization. Each hand manipulation space size is extended approximately $3m^3$ to fill as fully as possible visualization space of D-vision. In this system, total 8 motors for both hands are placed as surrounding the users. Circles in top of Figure 3 illustrate the position of the motors on the D-vision. Four motors placed in the front side of the users are fixed behind screens, and the strings are tensed through a small hole on the curved peripheral screen.

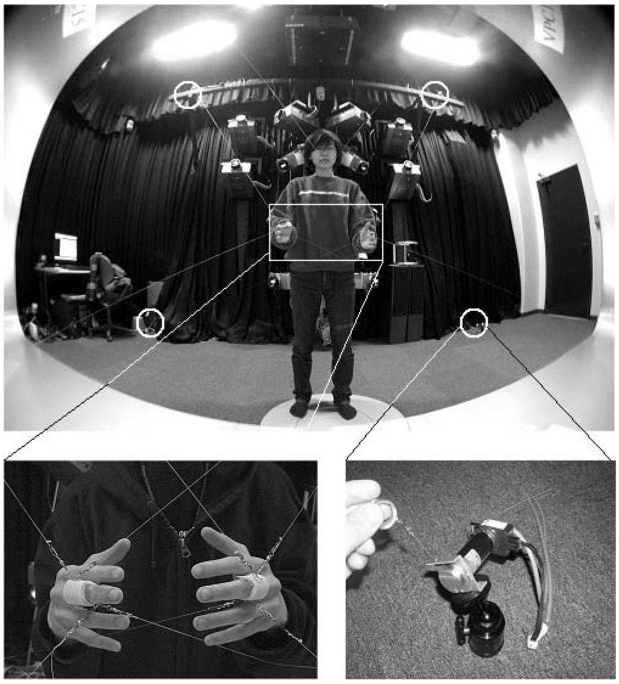

Figure 3 A snapshot of whole system that integrated the SPIDA-H interface into D-vision. User's each hand is connected to 4 strings and motors for force feedback. String-based structure is quite safe, and is less restrictive at user's full body movements.

The other motors are placed behind the users by using a frame for projectors. By using the length of the four strings, the position of the ring is calculated, and the force displayed to the users is controlled as they interact with the virtual object by their own hand directly.

3.3 Implementation

As shown Figure 4, this system represents a real virtual human's movement in a large-scale display using a motion database while the user performs actions in real time. In addition to the visual representation, the force feedback interface produces intuitive interaction between the real- and virtual world.

When a user interacts with virtual human, the physical information of the user input by haptic interface is analyzed by a motion processing and control PC, and it decides what kind of reactive motion do virtual human. The part retrieves the data that cope with motion database. A required motion is retrieved by quickly and reliably query through an Open Database Connectivity API. The input parameters from the haptic interface are used in the execution of a series of statements that produce a resultant motion. When the specified conditions are met, the matched motion series are returned to the calling server environment. The server share and send motion data to a group of rendering nodes using broadcast messages. Then those animate in accordance with time and physical space on an immersive display, and at the same time, transmit an appropriate force to user.

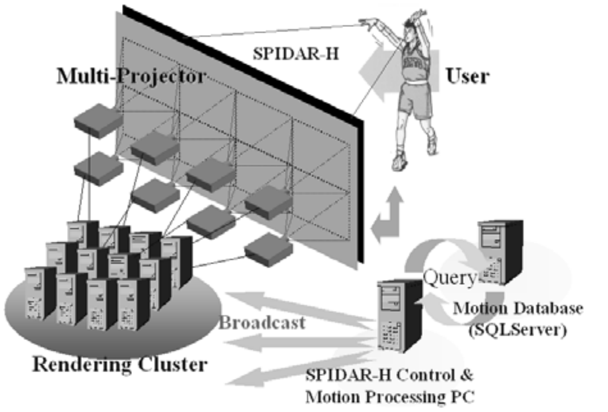

Figure 4 An implemented system overview for human-scale force interaction with user. A motion processing and SPIDAR-H control PC analyzes haptic information originating from the user. It becomes key factors when generating the virtual human's reactions. The decided actions convey to the nodes which rendering virtual world using broadcast messages.

4 Interacting with Reactive Virtual Human

The force interaction system with virtual human is an ongoing research. As a first work of our system, we implemented a Virtual Catch Ball [16]. We use the principal of "catch ball" that the user instinctually judges speed and ball trajectory with referring to his body. Like real world, user can hold and throw the virtual ball using the SPIDAR-H device. As the instant when the ball reaches the hands of the virtual human can be determined, virtual human is able to decide his behavior in response to user's physical information.

In first, we capture two actor's catch and throw motions under the various environment and situation such as throwing point and speed. Then we classify the motions with some category of primitive action by analyzing locus of ball and hands, and record the action unit to our designed motion database through data converting process. The actions consist of catch, hold, throw and "I'm ready"-movements and so forth.

Using reactive motion capture system[14], we can compute the instant of the virtual human's catching contacts and impacts of releasing according to the ball direction and speed. The information is recorded as the parameter table as key-frame. By predicated on the catch time, we determine a most approximate value from ball's falling position and retrieve a catch-able virtual human's motion using the minimum distance between the ball and hand position (See bottom of Figure 5). The matched motion maps to the data structure of the virtual human model. Lastly, reactive motions are generated through a motion synthesis.

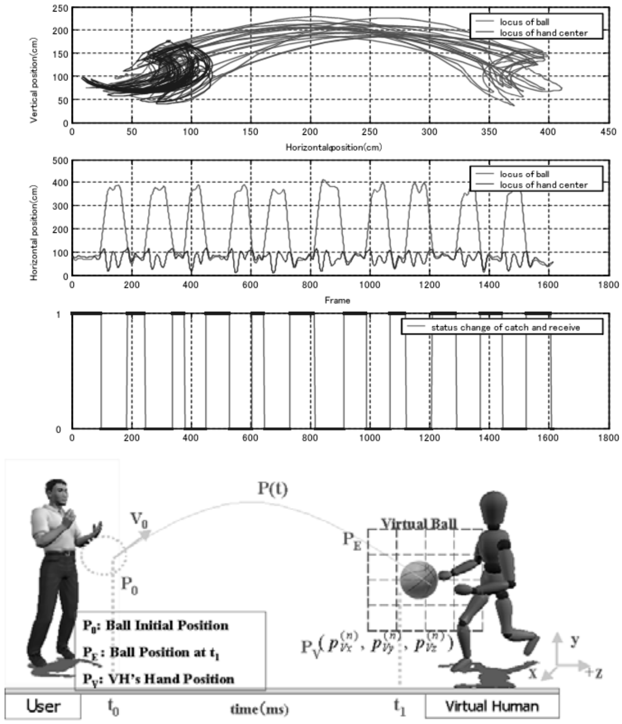

Figure 5 A graph about actor's hand and ball locus during ball play. Catch or throw movements are classified by this analysis (Top). The bottom depicts retrieve condition for a best-fit catch point and time.

If the user detaches his two hands from the ball at once and the ball exceeds a defined acceleration limit, we suppose that the user wants to throw the ball. After release, the ball moves in the virtual space in accordance with the basic laws of physics. The virtual human catches the ball using physical parameters estimated from information supplied by SPIDAR-H.

As shown in left of Figure 6, the user grabs and handles the virtual ball using his hands. In this system, the user can rotate and move the ball like in the real one because the virtual ball's physical movement and forces are generated according to the direction and force exerted by the user.

When the virtual human sees the approaching ball, it goes through *catch or not* transition. If the ball is estimated to come close enough to the virtual human's hand, in other words it has found a matching key-frame data in the motion database, it is decided the state of *catch* or *catch miss* according to the collision point. If the ball collides with some other part of the virtual human's body before it reaches his hands, the ball will fall onto the ground and it goes through *Catch Miss Phase*. If not, it enters into *catch phase* and the virtual human decides the throw direction so as to reach the user's hands. After *the throw phase or catch miss phase*, the virtual human enters the following state and a new cycle begins (See middle of Figure 5). The *Catch Ball play* between virtual human and user are depicted in Figure 7.

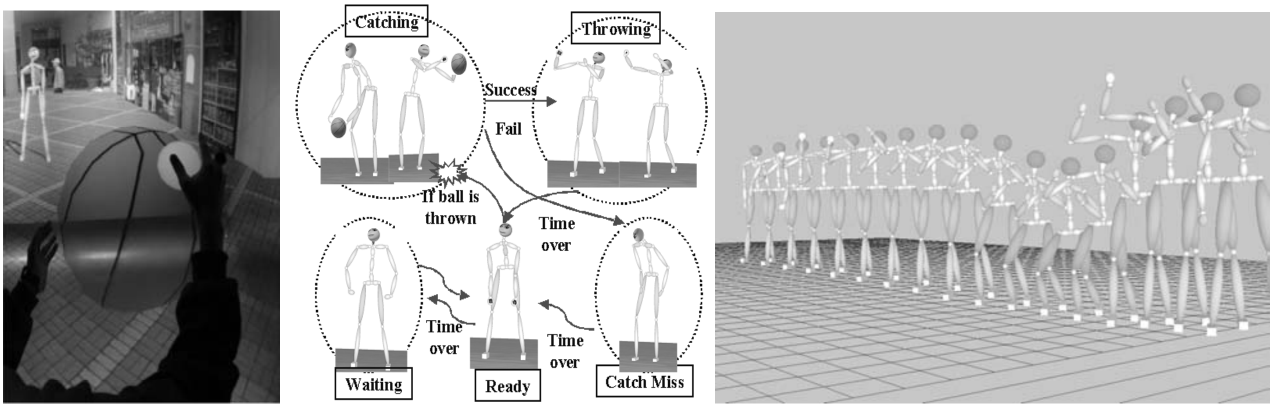

Figure 6 A user is handling a virtual ball using SPIDAR-H device (left). The middle is the virtual human's motion control flow diagram. A Snapshot of virtual human's catching and throwing motion (right).

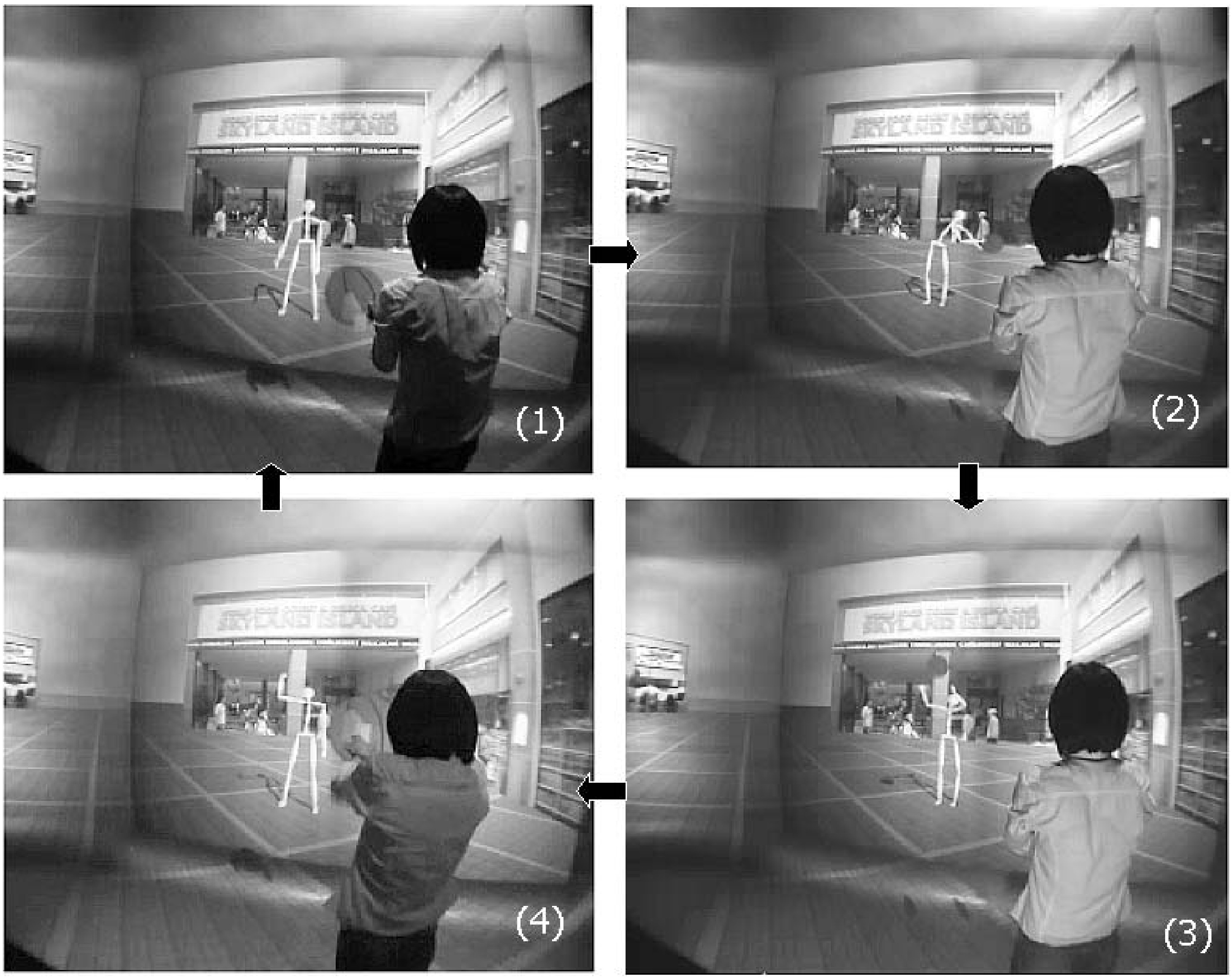

Figure 7 A demonstration of "Virtual Catch Ball"; (1) user throws the ball (2) virtual human catches the ball (3) virtual human returns the ball to user (4) user starts to catch the ball.

5. Conclusion

In this paper, we proposed a novel interaction system that integrates a human-scale haptic interface into an immersive VE. And we realized reactive virtual human that can do visual- and force feedback with user.

With the implemented system, we developed Virtual Catch Ball system with force interaction like real world.

Through this development, we could confirm the potential of this system as a framework of natural and intuitive interaction. In the near future, we will build a more believable multi-modal interaction system that involves other senses such as gaze and tactile sensation and improve haptic interface to increase user's comfort. And we will try to develop combination method of database and kinematics for more flexible motion generation.

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