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力覚を介した等身大インタラクションための リアクティブバーチャルヒューマンの設計

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あらまし 等身大インタラクション空間では，実世界と同様の仮想世界に人間が没入し，様々な作業を行うことが可能である．しかし，その反面，その中で表現される物体やキャラクターは，より現実感が高い人間のような表情や振る舞いが要求される．また，ユーザの環境と等身大の空間に調和できる直感的なインタフェースが，そのインタラクションを活動させる自然な入口である．従って，ユーザが，計算機によって作られたバーチャルヒューマンを実在する人間と同じように存在感を感じ，自然なインタラクションを行うためには，力覚および触覚提示が重要な要素になる．本論文では，ユーザと力覚を介してインタクションできるリアクティブバーチャルヒューマンを提案し，その実例と可能性について述べる．

Reactive Virtual Human Animation Design for Force Interaction

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Abstract Human-scale interaction system involving force and touch feedback, have been scarcely suggested any research although these feedback are most basic elements in real interaction. Therefore, we focus on touch and force-feedback activities in interaction with real human. We have been developed the R*eactive Virtual Human system,* which combines an immersive virtual environment with human-scale haptic interface. It enables a user to get visual and force feedback as implement human-scale virtual environment like real world. In the paper, we describe the case studies such as virtual catch ball and virtual boxing that can be utilized in creating a more natural and intuitive interaction.

1. Introduction

Recently, as great progress of CG technologies, realistic looking virtual humans have been simulated in many virtual scenes or games. Moreover, the virtual human's behavior acts intelligently, for instance understanding a natural language and speaking with an adequate facial expression and gesture [1]. These visual and auditory senses are effective and basic interaction channels in computer games or entertainments, which is mainly generated in web spaces and desktop environments. When it propagates in life-size spaces like an actual world, they are not enough to make us fully engaged in the interaction space. Because they don't provide and reflect feedback to the user's body, the user cannot feel the virtual human's presence to any larger extent and in turn loses interest in the interaction fairly quickly.

However, human-scale interactions involving force feedback, have been scarcely suggested any research. In the computer-human interaction, it can be used to increase the sense of togetherness allowing physical contact. In this paper, we aim to realize the interaction system that can give force effect to the 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. It enables us to realize more intuitive

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and direct interaction with virtual human.

2. Related Works

Adding haptic information to interactive environments is especially effective for interacting and enhancing virtual object' presence in those environments. The recent mainstream of haptic interfaces for the virtual reality adopts a mechanical link structure or wire-driven system. In a interaction space, however, the invasive mechanical links prevent users from seeing surrounding images seamlessly, only work within a limited space, even if that structure is stable for highly accurate and scalable operation. Although several type of improved haptic devices have been developed, they were still not suitable for the use in human-scale environments because of their size and mechanism [2-3]. The problems can be solved by an alternative interface to provide force feedback for direct manipulation within a sufficiently large space. The solution is to use less invasive and more flexible string-based haptic devices.

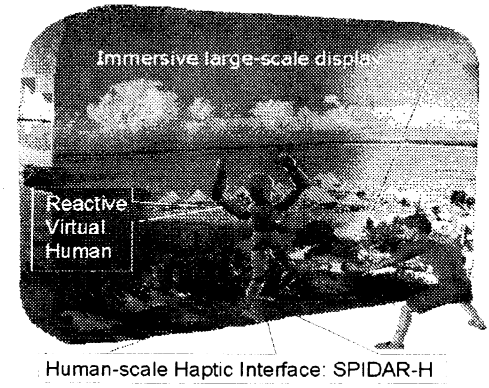
In virtual human's animation, there are two basic ways to gain the interactivity. These are to use motion capture including additional techniques to modify motion, and procedural approach that control motions over computational model's movement parameters such as kinematics and dynamics techniques [5-7]. Kinematics is generally better for goal-directed activities, and slower controlled action. Dynamics is more natural for movements directed by application of forces, impacts and high-speed behaviors. But, at present they are a limited use and still have many difficulties in describing a complicated motion or a subtle nuance in real-time implementation as required. On the other hand, motion-capture based techniques are the easiest way to produce animations in general. In a first case study of our approach, we propose to create a database for the required motion. The virtual human's reactive motion is animated correspondence to user's actions from a pre-stored motion database.

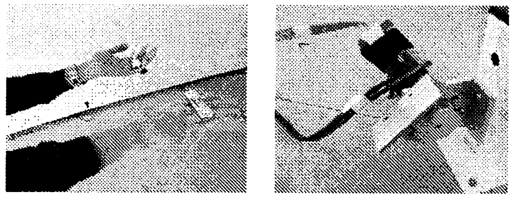
However, there are a number of issues that make difficult work with motion capture data; re-use, creating infeasible motions, imperfections of reality, response of physical change. In order to retain the advantage of each technique, much of the recent research [6-8] has been directed towards applying to motion created with dynamics and physical model. The existing studies have only control of virtual human in a fragmentary system, while our desired system is a full interaction not just control between user and virtual human. Therefore, we should seek a more effective way to keep a balance between physical motion and life-like animation in a human-scale interaction. The other case study shows a possibility to satisfy the criteria.

3. System Overview

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, 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 an intuitive interface. 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.

To satisfy these criteria, we adopted to use a large-scale display system with multiple senses; the wire driven force feedback interface and a multi-projector display.





(a) Hand clips (b) motor and encoder unit

Figure1. This is a basic concept for interacting with reactive virtual human using human-scale haptic interface. In the right, it shows a snapshot of implemented the SPIDA-H interface.

This system represents a real virtual human's movement in a large-scale display 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.

The haptic interface, SPIDAR-H [4][10] driven by 8 motors for both hands are placed on around of the user. One end of wire is wrapped around a pulley driven by a DC motor and the other is connected to the user's finger. By controlling the tension and length of each wire, the SPIDAR-H generates an appropriate force using four wires and calculates position of the user's hands. Because it is a wire-based system, it has a transparent property so that the user can easily see the virtual world. It also provides a space where the user can freely move around. When a user manipulates virtual objects and avatar through this interface, haptic- and physical information is conveyed from the real world to the virtual one. The information originating from the user becomes key factors when generating the virtual human's reactions.

4. Case Study1: "Virtual Catch Ball"

As a first work of our system, we implemented a Virtual Catch Ball [9]. This uses the principal of "catch ball" that the user instinctually judges speed and ball trajectory with referring to his body. Because the instant when the ball reaches the hands of the virtual human can also be determined, the 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 in term of throwing point and speed. Then, we classify the motions with some category of primitive action and record the action data to our designed motion database.
To look up a key-frame motion in motion database, we compute the virtual human's catching time using physical information such as the ball direction and speed. By predicated on the catch time, we determine a most approximate value from ball's falling position and retrieve a catchable virtual human's motion using the minimum distance between the ball and the hands' position. The matched motion maps to the data structure of the virtual human model. Lastly, reactive motions are generated through a motion synthesis process consisting of choosing catch, hold, throw and "I'm ready"-movements.

The Virtual Catch Ball play between virtual human and user are depicted in Figure 2.
When user takes hold of and throws a virtual ball using his hands interacting with haptic interface, the virtual human catches and throws the ball.

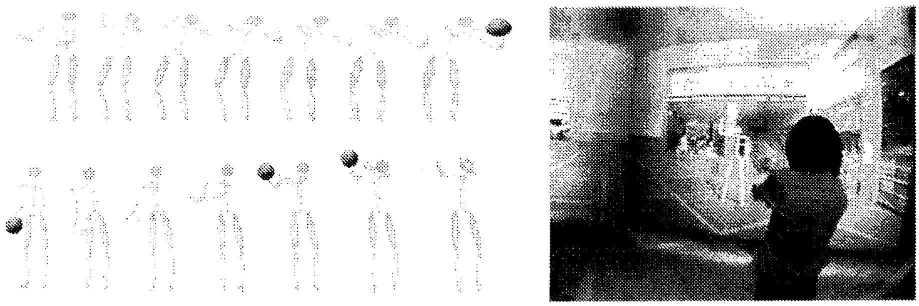
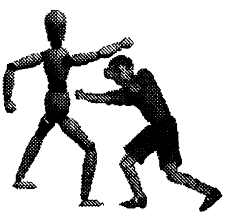


Figure2. A Snapshot of virtual human's catching and throwing motion (left). The right shows "Virtual Catch Ball" system that a user is handling a virtual ball.

5. Case Study2: "Virtual Boxing"



This "virtual boxing" application creates reactions of the upper part of the virtual human's body, such as attacking, blocking and dodging motion. These motions are mainly composed of reaching motion model. Our virtual human body model used prosperities based on the dimensions, weights and inertias of the body parts, the limits of joint angles referring standard database of human characteristics. In addition, we apply a default angle and a spring-damper model for each joint to a base posture of the model. The user uses avatar that reflects the user's operation through a haptic interface. The user can add the outside force to virtual human directly by operating avatar, and virtual human recognizes user's movements from the avatar. In here the same kinetic model as virtual human defines the avatar. The body models are fixed to the ground via spring and damper models to keep the position and orientation of the bodies. The posture control of the whole body of the model is used with a kinetic and PD control. That is, the posture is decided by adding force so that it is close to the target value by the PD control.

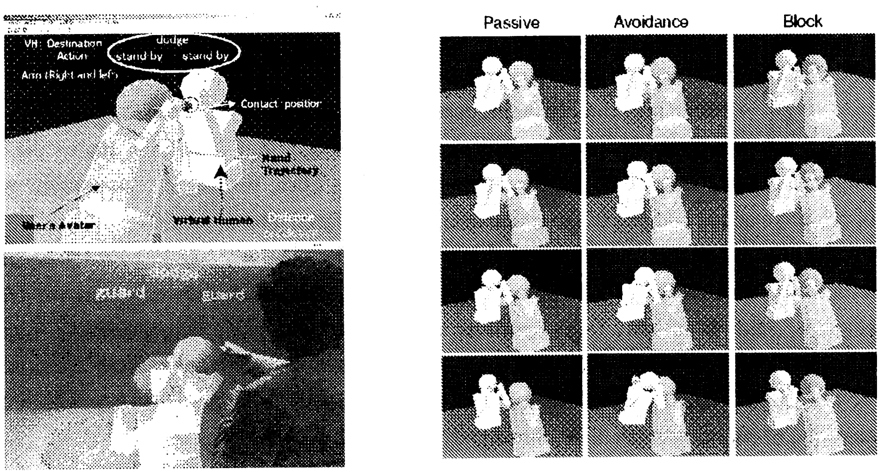


Figure3. In the left side, it is snapshots of doing "virtual boxing" between user and virtual human. The reactive motions clip is described in the right side.

The forecast behaviors are composed by four processing of motion prediction, collision decision between models, action selection, and target achievement movement. The both models' movements are predicated with a physical simulator. And then, it is decided whether to change a virtual human action pattern according to the importance degree of the predefined parameter (contact part, priority). Action decision assumed by the input can transfer each of the state of "standby", "attack" and "defense". As shown in left of Figure3, a user can experience "Boxing" with virtual human using his hand or avatar connected by haptic interface. A right side of Figure3 depicts snapshots of generating action and reaction during boxing.

6. Conclusion and Future works

We implemented a new kind of interaction with force feedback, which involves not only user's usual body-movement, but also reflection of virtual partner's reaction in physical space. Through developments of various applications at present, we could confirm the potential of this system as a framework of natural and intuitive interaction.

The development of believable interaction system requires the improvement of user-interface and the elaborative reaction of virtual human in real-time. For instance how to recognize user's action, to reflect virtual partner's reaction to user's body, and to get a fast responsive time including processing and analysis of multi-modal interfaces.

In detail, above all, used haptic feedback interface arises a little gap between real and virtual world due to point contact approach as a substitute for two hands plane, while our human-scale haptic device is relatively stable and allow user to move freely compared to other devices. We will sustain efforts to do improvements of our system in convenience in handling, adding other rich physical properties. Moreover it should build a believable multi-modal interaction system to involve various senses such as the user's head and eye movements.

In closing, it is worth consideration that we will try to develop combination method of database and physical simulation for more flexible motion generation. On the other hand, it may be also an alternative to utilize captured live motion data to the maximum as described by the reactive motion captures study [10].

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