Reactive Motion Generation with Haptic Display in Human-scale Virtual Environments

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Abstract

Creating reactive motions with conventional motion-capture systems is difficult because they require a variety of task environments. To overcome this drawback, we developed the reactive motion capture system that combines the conventional motion capture system with haptic feedback and a human-scale virtual environment. Our objective is to acquire reactive motion data generated from the interaction between haptic feedback and the virtual environment, using the fact that a person's motions in real world can be represented by the reactions of the person to real objects. We make an animation by a scenario for verifying reactive motion generation generated by the developed system. The results demonstrated that reactive motion generated by the developed system is useful for producing an animation, which includes reactive motion scene.

Key words: Motion Capture, Haptic Feedback, Human-scale Virtual Environments, Virtual Human

1. Introduction

Virtual Reality (VR) technology to be able to create the motion of human similar to the real world in virtual environments made by computer is a very valid means for the sake of simulation and evaluation in several fields. In recent years, the research on virtual human which is able to interact naturally with the users in human-scale virtual environments also has been experienced.

The above researches for the motion generation of virtual human have used methods such as kinematics and key frame interpolation [1-5]. The method of the kinematics simulates the motion of virtual human based on the numerical formula model of inverse kinematics. We can generate the motion for a virtual human model and can also give the variation of motion. In the key frame interpolation method, we can interpolate the frames in computer by using the key frame, which is made to produce in-between frames for important posture of a series of human's motion. In the method of the kinematics and the key frame interpolation, a natural motion can be synthesized simply by using the above methods, however the case of creating a complicated motion, a skilful technique to make the key frame is necessary.

Recently, the methods, which make use of motion, capture system to obtain a natural motion data is widely used [6-8]. Although motion capture can easily acquire the reactive motion, this method requires preparing a real working environment for performing on a stage and it is also influenced by the proficiency of a user.

To overcome this drawback, we developed the reactive motion capture system that combines the conventional motion capture system with the haptic feedback and the human-scale virtual environment [9-12]. In order to verify the accuracy of the developed system, we performed the evaluation experiments with two different tasks; one tracing the rim of real cube using the conventional

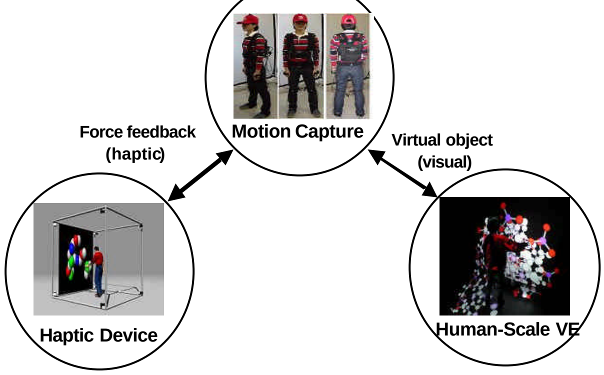


Fig. 1 Structure of reactive motion capture.

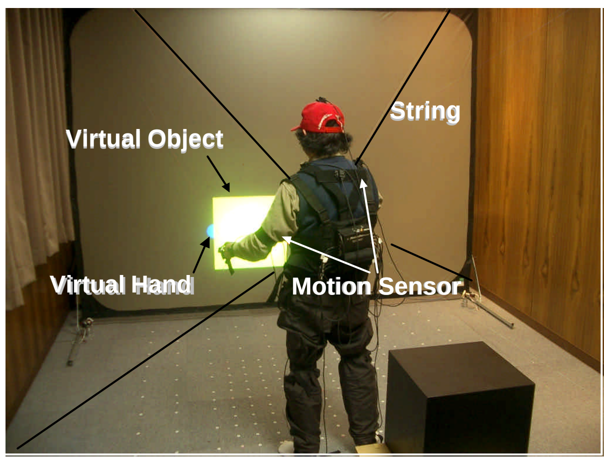


Fig. 2 Reactive motion capture system.

motion capture system, the other tracing the rim of virtual cube using the developed system. We measured the fingertip trajectories and compared the errors about two tasks.

In this paper, our purpose is to acquire reactive motion data generated from the interaction between haptic feedback and the virtual environment, using the fact that a person's motions in real world can be represented by the reactions of the person to real objects. In order to verify the efficiency of reactive motion generated by the developed system, we carry out the expriment that human generate the reactive motion corresponding to a change of object's weight. We make a virtual human's animation by a scenario using reactive motion data.

2. Environment of reactive motion generation

As shown in Figure 1, the environment of reactive motion generation consists of three parts: a human-scale virtual environment, a human-scale haptic device and a conventional motion capture system. The human-scale virtual environment represents visual information as if a real environment exists. The haptic device presents haptic feedback to the user, when the user interacts with virtual environment. The conventional motion capture system captures the user's motion inside the developed system. In the developed system, due to using the wireless motion capture system; the motion of the user is not restricted [13].

Figure 2 shows an aspect of the reactive motion capture system mentioned above.We use a human-scale haptic device "SPIDAR-H" derived from the original SPIDAR device [14] [15]. The SPIDAR-H delimited a cube frame that encloses a cave-like space, where the user can move around. The developed system visualized in real-time the motion of virtual object and constructed the human-scale virtual environment. We set up the 120-inch rear screen in front of the user; that the presentation of the CG is possible.

In this reactive motion capture system, we can capture a motion data generated by human's performance, human's motion interacted with real object and virtual object in human-scale virtual environment

3. Evaluation experiment of reactive motion generation using the Reactive Motion Capture System

In order to verify the efficiency of reactive motion generation with the developed system, we make a virtual human's animation with the scenario, and we generate the reactive motion using the developed system. We capture the data of the human motion for the scenario. Then, we compare the virtual human's motion of conventional motion capture and reactive motion capture.

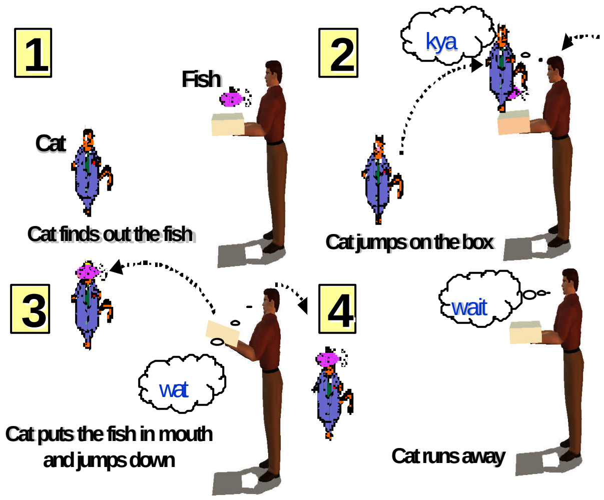


Fig. 3 Scenario : Cat & Fish.

3. 1 Scenario: Cat & Fish

The scenario named "Cat & Fish" is as the following. As shown in Figure 3, human has a fish on a box, and a cat finds out the fish. In order to take the fish, the cat jumps on top of the box. And the cat puts the fish into it's mouth and jumps down on the box. The cat runs away. In the scene 2, the moment the cat jumps on the box, the weight of the box suddenly becomes heavy. Hand and head of human corresponding the change of weight are suddenly lowered. In the scene 3, the moment the cat jumps down the box, the weight of the box suddenly becomes light. Hand and head of human corresponding the change of weight are suddenly raised. Therefore, animation of the scene 2 and the scene 3 need the reactive motion of the human corresponding to the change of box's weight.

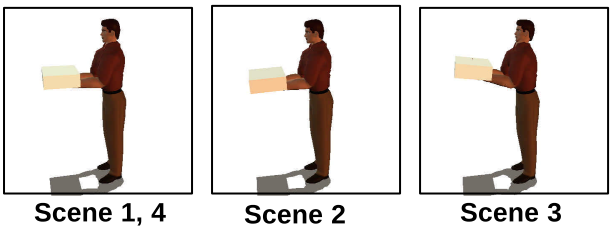
3. 2 Experimental Method

Fig. 4 Appearance of experiment.

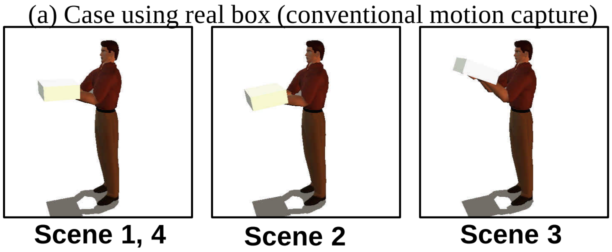
In order to capture the human's reactive motion data of the scene 2 and the scene 3, we carry out the experiment that the weight of box suddenly changes.

As shown in Figure 4, in the conventional motion capture, helper controls the weight of a real box using the block of 3kg. The reactive motion data of the scene 2 is generated by helper putting the block of 3kg on the real box. The reactive motion data of the scene 3 is generated by helper lifting the block of 3kg on the real box. In the reactive motion capture, the reactive motion data of the scene 2 and scene 3 is generated by the weight of a virtual box that is changed using SPIDAR-H. In the case of performance, subject performances human's motion of scene 2 and scene 3 in the conventional motion capture.

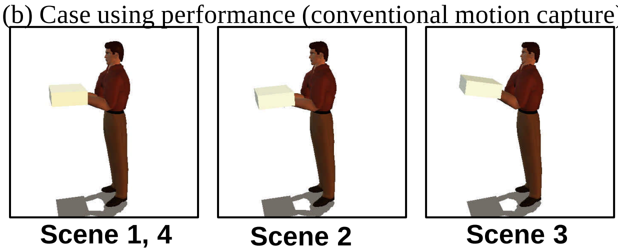
The subject was not given the information of experimental task. We captured the motion data of 30 frame/sec using the motion sensor attached on the subject's body.



(a) Case using real box (conventional motion capture)



(b) Case using performance (conventional motion capture)



(c) Case using virtual box (reactive motion capture)

Fig. 5 Results of motion generation.

3. 3 Experimental Results

As shown in Figure 5, we made the virtual human's motion using real box, performance and virtual box. In case of real box, reactive motion is generated. Hand and head of virtual human corresponding to the change of real box's weight are suddenly lowered and are suddenly raised as in Figure 5 (a). In case of performance, the motion is generated only on virtual human's hand. Virtual human's head is not generated reactive motion as in Figure 5 (b). The case of virtual box is also generated reactive motion corresponding to the change of virtual box's weight on the hand and head of virtual human as in Figure 5(c).

By means of the reactive motion data acquired by virtual box, we show the virtual human's animation as in Figure 6. It is able to confirm the situations as shown in Figure 6 through the image1 to the image8.

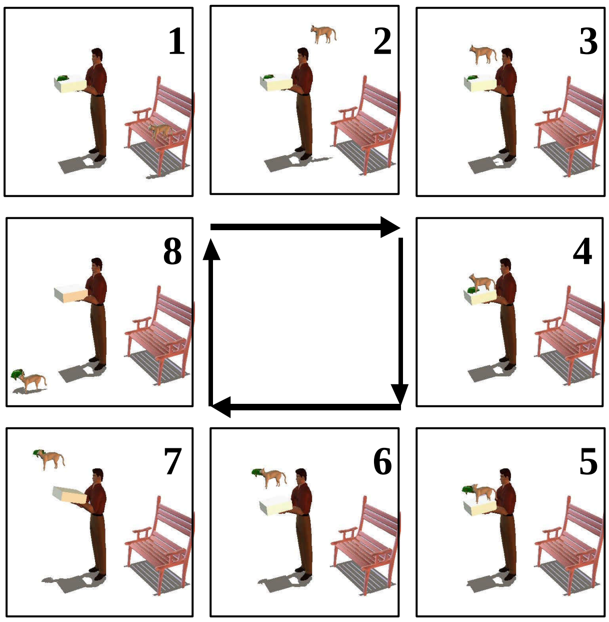


Fig. 6 Animation: Cat & Fish.

We can see the reactive motion of virtual human corresponding to the change of weight in Figure 6. In the image 3 and 4, the moment the cat jumps on the box, the weight of the box suddenly becomes heavy. Hand and head of virtual human corresponding the change of weight are suddenly lowered. In the image 5, 6 and 7, the moment the cat jumps down the box, the weight of the box suddenly becomes light. Hand and head of virtual human corresponding the change of weight are suddenly raised.

We carry out a questionnaire for surveying a virtual human's natural-looking motion of each reactive motion data captured by real box, performance and virtual box. Participants of the questionnaire are 20 persons (men: 15, women 5). Age is from 20 to 40. The participants do not know the contents of our research. We make inquiries about the questionnaire of Cat & Fish.

At first, we made a demo of Cat & Fish based on Figure

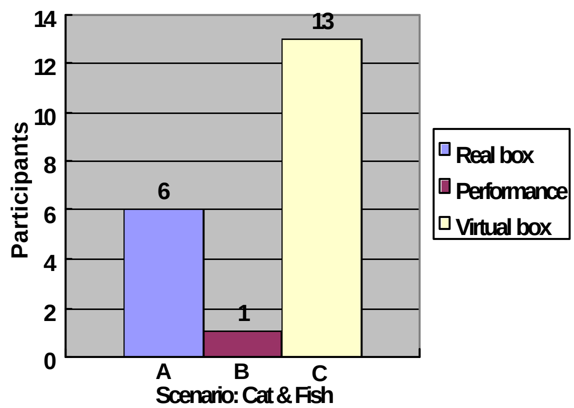


Fig. 7 Results of questionnaire

6. Demo of Cat & Fish is the animation based on scenario of Cat & Fish as shown in Figure 3. We asked participants about the questionnaire of Cat & Fish to: Please arrange the demo of Cat & Fish (A, B, C) in the turn felt natural-looking. A, B and C of demo are the animation based on each reactive motion data captured by real box, performance and virtual box. Participants of the questionnaire do not also know the contents of A, B, C.

Figure 7 shows the results of questionnaire about demo of Cat & Fish. We consider the results of questionnaire with respect to the demo of Cat & Fish. As in Figure 7, the result of questionnaire has many participants who selected in order of C and A. One participant selected B. Therefore, we know that participants feel the natural-looking motion in the animation of C and A with reactive motion.

The participants of questionnaire comment the selected reason. Participants who selected the demo of C and A comment that hand and head of virtual human corresponding to the cat's weight naturally move, virtual human has a reality like a motion of human, the body of virtual human is observed a force corresponding to the cat's weight. In case the demo of B, the participants comment that the demo of B generates a motion only on virtual human's hand corresponding to the cat's weight, a motion of virtual human looks unnaturally.

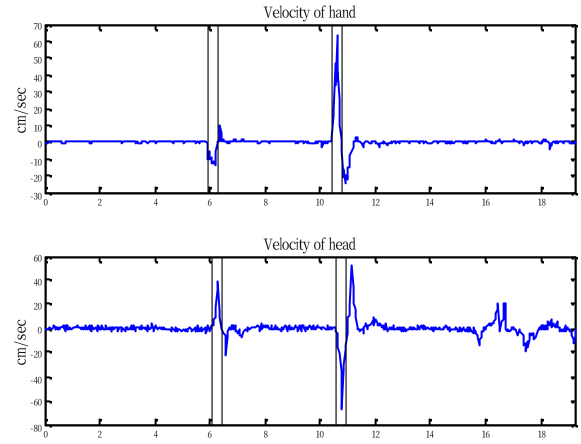
4. Evaluation of reactive motion

As shown in Figure 8, we showed the velocity of human's hand and head. We chose hand and head of virtual human by the comment of questionnaire and the Figure 6 for verifying the reaction. In the comment of questionnaire and the Figure 6, hand and head of virtual human corresponding to the cat's weight are observed the reactive motion.

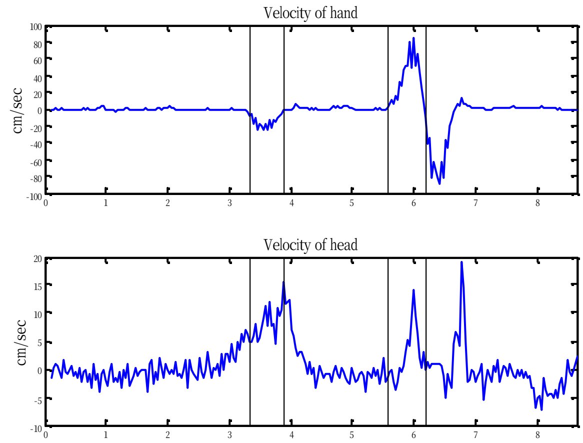
The (a), (b) and (c) of Figure 8 are the velocity of human's hand and head captured by real box, performance and virtual box. In the graph of Figure 8, X-axis of graph is time and Y-axis is velocity. The unit of time is Sec. and the unit of velocity is cm/sec. In the Figure 8, two vertical lines of front are an interval of reactive time for the moment the weight of the box suddenly becomes heavy in the scene 2 as shown in Figure 3. Two vertical lines of back are an interval of reactive time for the moment the weight of the box suddenly becomes light in the scene 3.

In (a), (c) of Figure 8, hand and head of human are suddenly generated the reaction the moment the weight of the box is suddenly changed.

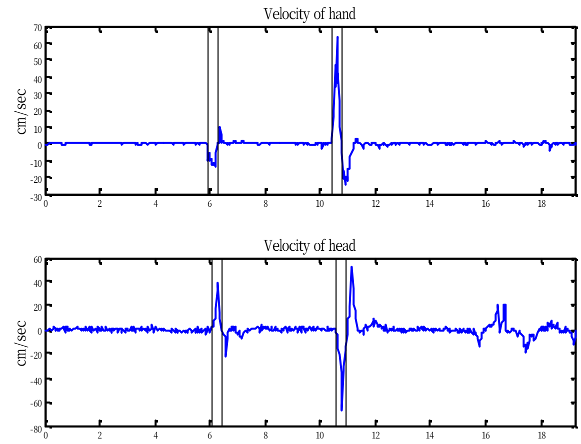
In case of performance, motion is generated only on hand of human like the comment of questionnaire. Human's head don't generate the reaction as in Figure 8 (b). We know that the performance is difficult to generate reactive motion of human corresponding to the change of object's weight.



(a) Case using real box (conventional motion capture)



(b) Case using performance (conventional motion capture)



(c) Case using virtual box (reactive motion capture)

Fig. 8 Velocity of hand and head

Figure 9 shows the calculated results about the average of reaction time, which presents the interval of reaction when three subjects generate the reactive motion using real box, performance, virtual box. In the Figure 9, X-axis of graph is each condition of scene 2, scene 3 and Y-axis

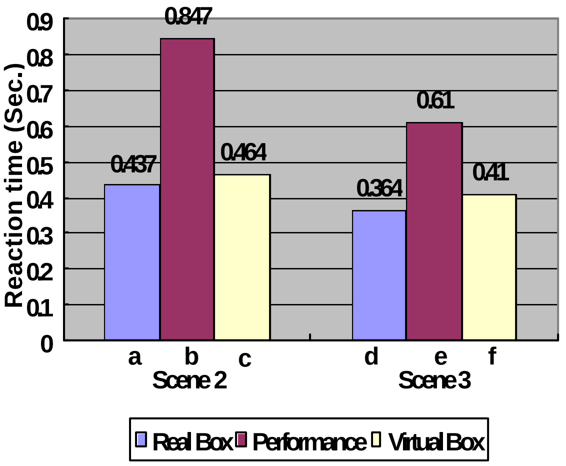


Fig. 9 Reaction time

is the average of reaction time under each condition. The unit of time is Sec.

We consider the reaction time with respect to the influence of haptic feedback corresponding to the change of weight. As shown in the Scene 2 of Figure 9, under the condition (c) of having haptic feedback, in the experiment that the subject interacted with virtual box, the reactive time is 0.464Sec. This reactin time value isnear the reactin time value of the case of the experiment under the condition (a) that interacted with a real box.

The condition (b) without haptic feedback in the performance, there was a reaction time, which is approximately 0.847Sec. Since the haptic feedback wasn't presented when the subject performances, it is thought that the reaction time became longer. These differences are obvious in the (a), (b) and (c) of Figure 9.

We compared the results under the condition (b) without haptic feedback with the results under the condition (c) with haptic feedback. We see that the difference is approximately 0.383sec. And we compared the results under the condition (b) with haptic feedback with the results under the condition (a) with haptic feedback. We see that the difference is approximately 0.027sec. This means that, by providing haptic feedback, the reactive motion of human can be generated by the virtual object in virtual environments. The reaction time's result of Scene 3 is similar the Scene 2 of Figure 9. We compare the reaction time in the Scene 3, the condition (d), (f) of having haptic feedback is faster than the condition (e) of not having haptic feedback

According to the results, we can say that it is important to present haptic feedback corresponding to the weight of object for generating the reactive motion. In even virtual environments, through presenting haptic feedback, we know that it is capable to generate the reactive motion similar to real-world motions. Through the comment of questionnaire, we know that participants feel the reactive motion of virtual human corresponding to the change of weight in the demo of Cat & Fish. We can also say that it is important to present the reactive motion corresponding to the weight of object in the animation, which includes reactive motion scene.

5. Conclusions

In this paper, we made an animation by a scenario for verifying a reactive motion generation in the developed system and presented the scenario of Cat & Fish. We actually generated the reactive motion about the scenario of Cat & Fish using the developed system. The developed system was possible to actualize the acquisition of reactive motion data by representing the haptic feedback with visual information in the virtual environment. Through the evaluation experiment, we showed that the developed system is very useful for generating the reactive motion corresponding to change of object's weight and the reactive motion of virtual human is showed in the animation of Cat & Fish.

As a future works, we will develop the multi-modal reactive motion capture that combined vision, haptic, and auditory with the developed system. Also, we will produce the animation by the scenario based on a reactive motion.

References

1. D. C. Brogan, R. A. Metoyer and J. K. Hodgins: "Dynamically simulated characters in virtual environment", IEEE Computer Graphics and Applications Vol.18, No. 5, pp. 2-13 (1998)

2. SIMM: http://www.musculographics.com/

3. Boston Dynamics: http://www.bdi.com/

4. J. Lander: "Oh god I inverted kine: inverse kinematics for real-time games", www.darwin3d.com

5. Animanium: http://sega.jp/animanium/

6. D. Komaki, H. Ishii, N. Ichiguchi, H. Shimoda and H. Yoshikawa: "A Study on Effective Representation Method for Human Walking Motion by VR", Information and Communication Engineers, Technical Report of IECE, MVE99-17 (1999)

7. D. J. Sturman: "A Brief History of Motion Capture for Computer Character Animation", SIGGRAPH94, Course9 (1994)

8.HUMOSIM: http://www.engin.umich.edu/dept/ioe/HUMOSIM/

9. W. Choi, S. Z. Jeong, N. Hasimoto, S. Hasegawa and M. Sato: "An Interactive Motion Capture System with a Large Workspace Haptic Device in Human-Scale Virtual Environments", ICAT2002, pp. 59-64 (2002)

10. W. Choi, S. Z. Jeong, N. Hasimoto, S. Hasegawa, Y. Koike and M. Sato: "A development and evaluation of reactive motion capture system with haptic feedback",

Proceedings. Sixth IEEE International Conference FG2004, pp. 851 – 856(2004)

11. W. Choi, S. Z. Jeong, N. Hasimoto, S. Hasegawa Y. Koike and M. Sato: "Reactive Motion Capture System Design using a Haptic Display", The Journal of ITE Vol. 57, No. 12, pp. 1727-1732 (2003)

12. S. Z. Jeong, W. Choi, N. Hasimoto, S. Hasegawa, Y. Koike and M. Sato: "Virtual Human Animation Design for Force Reactive Motion", Proc. 65th of IPSJ pp. 2T7A-5 (2003)

13. MotionStar Wireless: Http://www.ascension-tech.com/

14. Y. Cai, M.Ishi, M. Sato: "A Human Interface Device for CAVE Size Virtual Workspace", IEEE International Conference on System, Man and Cybernetics, pp. 2084-2089 (1996)

15. L. Buoguila, Y. Cai, M. Sato: "New For Human-Scale Virtual Environment: Scaleable-SPIDAR"， ICAT'97, pp. 93-98 (1997)