Generation of Character Motion by Reactive Motion Capture System

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Abstract

Generating character motion from motion capture systems is difficult because they require a variety of task environments. To overcome this drawback, we constructed a reactive motion capture system that combines a conventional motion capture system with force feedback device and visual information in the human-scale virtual environment. Our purpose is to make character animations with character motion data generated from the interaction with force feedback and the virtual environment, using the fact that a person's motion in the real world can be represented by the reactions of the person to real objects. In this research, we made animations via several scenarios for animating character motion generation with the reactive motion capture system. The results demonstrated that character motion generated by the developed system was useful for producing the animation, which includes the scene of reactive motion.

Keywords: Force Feedback, Motion Capture, Human-scale Virtual Environments, Virtual Human

1 Introduction

To generate the human motions in virtual environments made by a computer that are similar to the real world, Virtual Reality (VR) technology is an especially valid means for the sake of simulation and evaluation in several fields. In recent years, the research on virtual humans that are able to interact naturally with users, has also been progressing.

Research for motion generation of virtual humans has used methods such as kinematics and key frame interpolation [1, 2, 3, 4, 5]. The method of kinematics simulates the motion of a virtual human based on the numerical formula model of inverse kinematics. Using this method, 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 a computer by using the key frame, which is made to produce in-between frames for important posture of a series of human motions. In the method of kinematics and key frame interpolation, character motion can be synthesized simply by using the above methods combined, however, in the case of creating a more complicated motion, it is indispensable to find a more skilful technique to make the key frames.

Recently, methods that make use of a motion capture system to obtain a character's motion data have been widely reported [6, 7, 8, 9]. Motion capture can make the animation process much easier, especially when trying to recreate realistic character animation, such as the interaction of multiple 3D characters, or characters

Figure 1: Reactive motion capture system.

engaged in sporting activities. Although the motion capture system can easily acquire the character motion, this method requires preparing a real working environment for performing on a stage and it is also influenced by the proficiency of the user.

To overcome this drawback, we developed a reactive motion capture system that combines a conventional motion capture system with force feedback and the human-scale virtual environment[10]. We verified the accuracy of the reactive motion capture system and performed the evaluation experiments using two different conditions: one is tracing the rim of a real cube using a conventional motion capture system, and the other is tracing the rim of a virtual cube using the reactive motion capture system. The reactive motion capture system is able to actualize the acquisition of various motion data by representing the force feedback with visual information in the virtual environment. Our system improves the weak point of the conventional motion capture method, which requires real objects and the performance of a skilful actor. In this paper, our aim is to make animation with character motion data generated by the interaction between force feedback and the virtual environment, using the fact that a person's motion in the real world can be represented by the reactions of the person to real objects. In order to verify the efficiency of character motion generated by the reactive motion capture system, we will carry out experiments where the user generates the character motion corresponding to force feedback and visual information, and produce character animations using character motion data captured by the reactive motion capture system.

We will describe the reactive motion capture system in section 2 and carry out an experiment with force feedback in section 3. In section 4, we will experiment with force feedback and visual information. Finally, we will conclude this paper by describing future work in section 5.

2 Environment for character motion generation

The reactive motion capture system can acquire the character motion of a user who receives visual information and force feedback. The developed system 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 human-scale haptic device presents force feedback to the user whenever the user interacts with a virtual object. We use a human-scale haptic device SPIDAR-H[11] derived from the original SPIDAR device. The conventional motion capture system captures the motion of the user inside the developed system. In the developed system, due to using a wireless motion capture system, the motion of the user is not restricted.

Figure 1 shows an aspect of the reactive motion capture system mentioned above. The reactive motion capture system is presenting a user with visual information and force feedback in the human-scale virtual environment. The force feedback in the reactive motion capture system reveals interacting user to virtual object for presenting the force. In reactive motion capture, the user's hand positions are represented as virtual points.

During the time the user has contact with a virtual object, gravity, friction and inertia are transmitted to the user by using the SPIDAR-H The force feedback received by the user's hands is the resultant force of tension from strings attached to grips.

Also, the user can appreciate the virtual environment including the position and velocity of

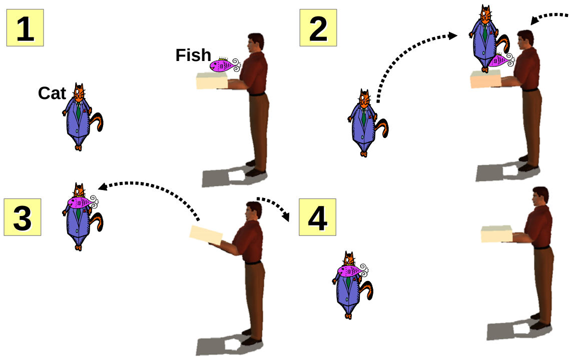


Figure 2: Scenario 1 of character motion with force feedback

virtual objects via the visual information provided by the reactive motion capture system.

We will present two scenarios: one for making animations based on force feedback alone, and another for making animations based on both visual information and force feedback. In order to verify the efficiency of character motion generation with this reactive motion capture system, we made a character animation with motion data, and generated the motion data using the two scenarios in the reactive motion capture system. In section 3, we performed the scenario experiments with force feedback. Then in section 4, we demonstrate character animation under each scenario using both force feedback and visual information.

3 Character motion generation with force feedback

In order to generate character motion with force feedback using a reactive motion capture system, we performed an experiment that changes weight put user.

Character motion was generated under a number of weight change conditions, such as a sudden lift of a heavy weight from a subject's hands. By capturing the subject's motion at that time, we produced character motion animation by applying the captured motion data to a virtual human. Figure 2 shows character motion under Scenario 1, which was generated by the reactive motion capture system with force feedback before product of a character animation.

Scenario 1 is as follows. A man holds a box with a fish, and a cat finds the fish (Scene 1). In order to take the fish, the cat jumps onto the box (Scene 2). The cat then takes the fish into its mouth and jumps down from the box (Scene 3). The cat then runs away (Scene 4). In Scene 2, the moment the cat jumps onto the box, the weight of the box becomes heavier. The hands and head of the man are correspondingly lowered due to the change of weight. In Scene 3, the moment the cat jumps down from the box, the weight of the box becomes lighter. The hands and head of the man are correspondingly raised due to the change of weight.

Therefore, the animation of Scene 2 and Scene 3 needs the character motion of the virtual human due to the change in the box's weight.

Table 1: Experimental conditions

Experimental conditions	Change of weight
Conventional motion capture	Real object
Human's acting	Human's acting
Reactive motion capture	Virtual object

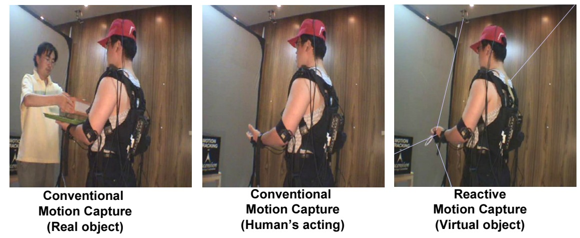


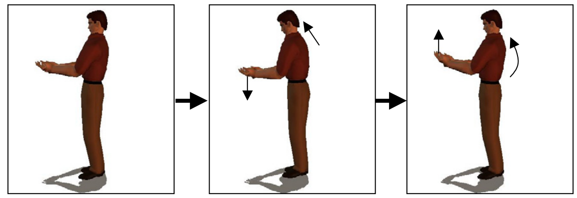
Figure 3: Appearance of character motion generation (Scenario 1).

3.1 Process of character motion generation

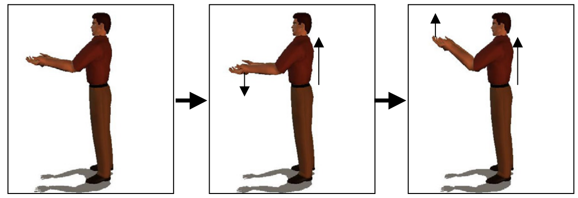
As shown in Table 1, an experiment was carried out under the following conditions, which are a real object and a human acting in a conventional motion capture environment, and the reactive motion capture system with a virtual object. In the case of conventional motion capture, each block of 1kg, 2kg and 3kg weight was prepared and used as a real object. In the case of the human's acting, the subject acts the weight feeling without real object as each weight block. And in the case of the reactive motion capture system, we change the weight of the virtual object by using force feedback that corresponds to the weight of each block.

Figure 3 details the weight change experiment. Under conventional motion capture (with real objects), the helper controls the weight of a real object using the blocks. The character motion data of Scene 2 is generated by the helper putting the blocks on the hands of the subject. The character motion data of Scene 3 is generated by the helper lifting the blocks from the hands of the subject. In the case of the human's acting, the subject generates character motion under Scenario 1 through acting as a result of weight changes. On the other hand, in the reactive motion capture system, character motion under Scenario 1 is generated by force through force feedback using the SPIDAR-H system.

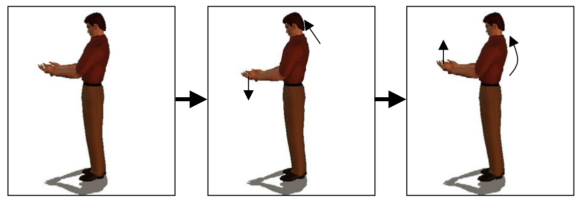
In this experiment, three persons (three males) participated as subjects. We captured motion data at a rate of 30 frames/sec using 15 motion sensors attached to the subjects' bodies, and information on the experimental tasks was not given to the subjects beforehand.



(a) Conventional motion capture (real object)



(b) Conventional motion capture (human's acting)



(c) Reactive motion capture (virtual object)

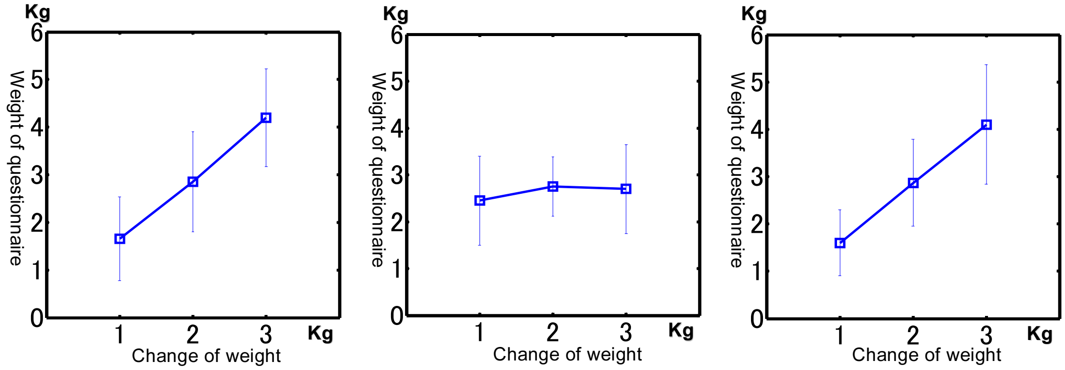
Figure 4: Character motion of virtual human corresponding to change of weight.

3.2 Result of character animation

Figure 4 is an animation produced by the virtual human that reflects the character motion data corresponding to the 3kg weight using the real object, the human's acting, and the virtual object. In the case of the real object, the instant the weight of the real object is added to the user's hands, the hands and head of the virtual human are correspondingly lowered due to the real object's weight, and when the weight of the real object is removed from the real user's hands, the hands and head of the virtual human react accordingly, i.e., they are naturally raised as shown in Figure 4 (a). In the case of the human's acting, the character motion is generated only via the virtual human's hands. The virtual human's head does not naturally generate character motion, as shown in Figure 4 (b). On the other hand, as for the virtual object, adding weight to the hands of the subject with a virtual object using SPIDAR-H, the hands and head of the virtual human are naturally lowered due to the virtual object's weight. The moment the weight of the virtual object is removed from the user's hands using SPIDAR-H, the hands and head of the virtual human are naturally raised as shown in Figure 4 (c).

From this result, we notice that our system is able to generate character motion that corresponds to weight changes using a virtual object in the reactive motion capture system that is similar to using a real object.

For character motion data acquired by the reactive motion capture system using a virtual object, Figure 5 shows the results of Animation 1 under Scenario 1. It is possible to confirm the situations as shown in Figure 5 (from Image 1 to Image 4). In Image 2, character motion of the virtual human changes as follows: when the cat jumps onto the box, the box becomes simultaneously heavier, and the head and hands of the virtual human are naturally lowered. Furthermore, in Image 3, when the cat jumps down from the box, the box becomes simultaneously lighter, and the head and hands of the virtual human are naturally raised. Moreover, from Animation 1, we can verify that the character motion of the virtual human is generated in accordance with the weight changes caused by the cat



(a) Conventional motion capture (real object)

(b) Conventional motion capture (human's acting)

(c) Reactive motion capture (virtual object)

Figure 6: Results of questionnaire(1Kg, 2Kg and 3Kg).

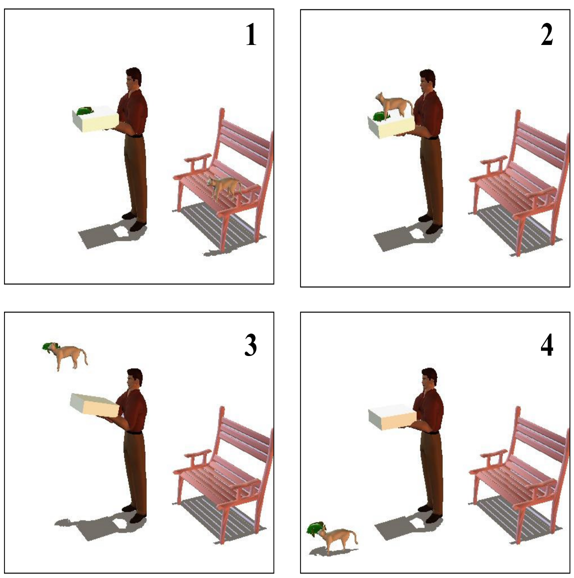


Figure 5: Character Animation 1 by Scenario 1.

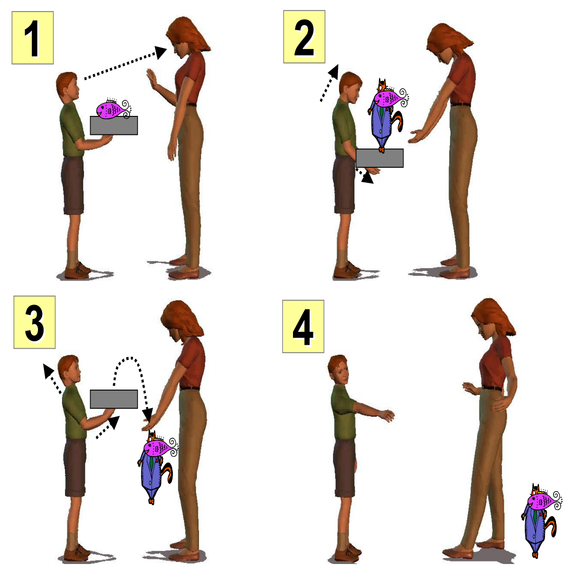


Figure 7: Scenario 2 of character motion with force feedback and visual information.

jumping onto and down from the box.

We produced the animation of the virtual human with real objects, and the human's acting with a virtual object, via an experiment using 1kg, 2kg and 3kg weight changes, in order to verify the fact that the character motion of the virtual human displays the changes due to each weight. We investigated the weight, which is felt through the virtual human from each animation by conducting a questionnaire survey of ten persons who did not know our research. As shown in Figure 6, the bottom of each graph indicates when the weight is actually changed. The lines in this graph show the average and standard deviation of the weight, which is felt by the ten persons through the virtual human for each animation. The unit in the graph is kg. The result of the questionnaire in Figure 6 (a, c) shows that the weight felt through the animation increases in accordance with the increase in weight of the object. The average weights sensed by the ten persons in the case of using real objects (1kg, 2kg and 3kg) are 1.65kg, 2.85kg and 4.2kg, respectively. In the case of using a virtual object (1kg, 2kg and 3kg), the average weight estimates are 1.6kg, 2.87kg and 4.1kg. Therefore

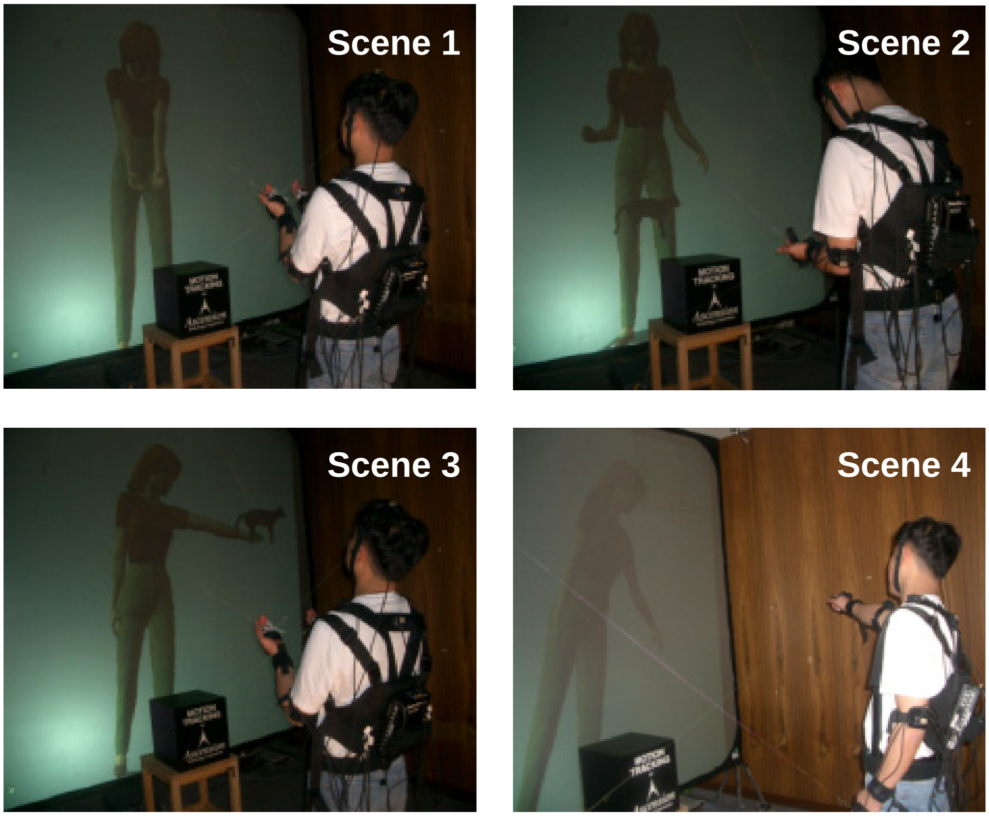


Figure 8: Appearance of character motion generation (Scenario 2).

we perceive that force feedback enables the generation of character motions in the reactive motion capture system as well.

From the results shown in Figure 6 (b), we notice that the weight felt through animation does not increase in exact accordance with the increase in the rate of the weight in the human's acting. This is because the rate of increase in the human's acting does not make a big difference.

4 Character motion generation with force feedback and visual information

In order to verify the efficiency of character animation using force feedback and visual information, we produced character animation using character motion generated by the reactive motion capture system.

Scenario 2, which includes both force feedback and visual information, is as follows. As shown in Figure 7, the moment the child tries to give the fish to his mother, a cat finds the fish. The child gazes at the mother and she comes out of her hands (in Scene 1). In order to take the fish, the cat jumps onto the box (in Scene 2). The cat takes the fish in its mouth and jumps down from the box (in Scene 3). The cat runs away, and the child and his mother chase the cat to catch it (in Scene 4).

Scene 1 includes the element via visual information, Scenes 2 and 3 include the element via force feedback, and Scene 4 includes the element via visual information. Displaying visual information and using force feedback simultaneously generates character motion of the child corresponding to the changes in the box's weight and the motion of the mother. We produced character animation by generating character motion of the virtual human using the reactive motion capture system as in Scenario 2.

4.1 Process of character motion generation

In the process of motion generation, the distance between the subject and the virtual mother in the

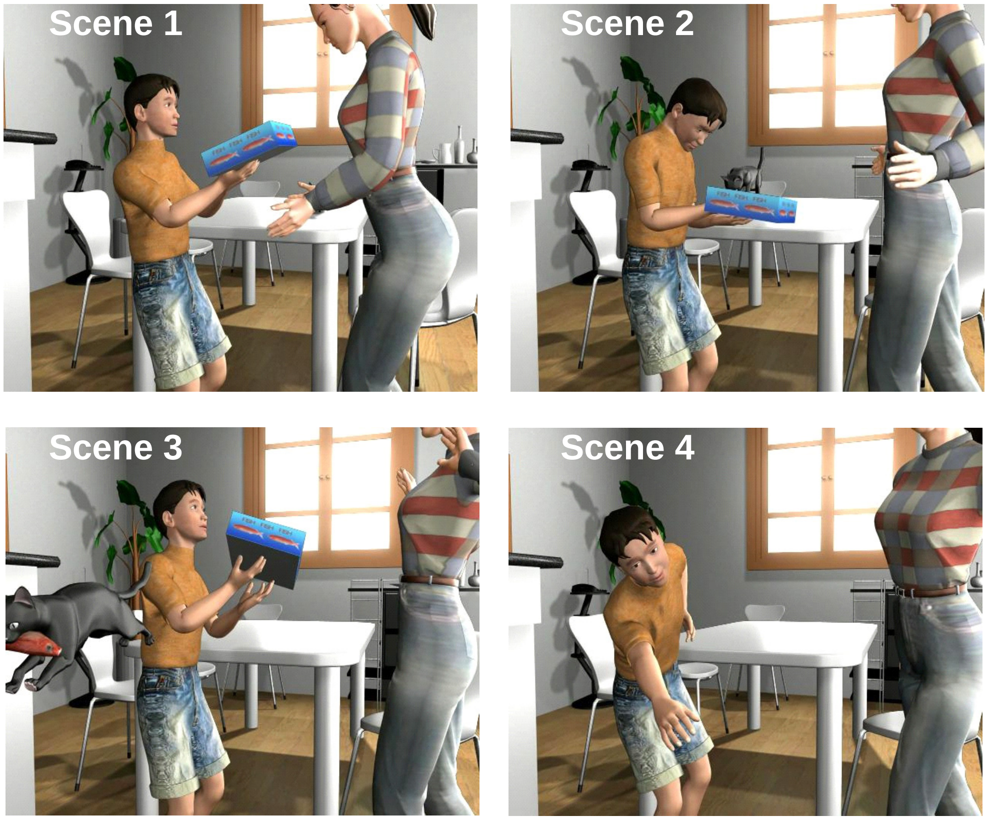


Figure 9: Character Animation 2 by Scenario 2.

human-scale virtual environment was 170cm, the height of the subject was 165cm, and the height of the virtual mother on the screen was 210cm.

As shown in Figure 8, to generate the child's character motion using the elements of visual information and force feedback, the motion of the virtual mother was previously captured by the reactive motion capture system as detailed in Scenario 2. The virtual mother's motion is displayed in the human-scale virtual environment. The subject can generate a natural gaze and motion by interacting with the virtual mother's motion (Scene 1 of Figure 8). In the cases of Scenes 2 and 3 of Figure 8, changes in the virtual cat's weight provided by SPIDAR-H enabled us to generate the subject's motion containing force feedback. Regarding the motion of the child in reaction to the cat running away, the subject can generate gaze and motion naturally by interacting with the virtual cat's motion as shown in Scene 4 of Figure 8.

In this experiment, two persons (two males) participated as subjects. We captured motion data at 30 frames/sec using the 15 motion sensors attached on the subjects' bodies. Information on the experimental task was not given to the subjects beforehand.

Results of character animation

Figure 9 shows Animation 2, which was made by an animation company using the character motion data generated by the motion of the virtual human as described in Scenario 2 using the reactive motion capture system. In Animation 2, the distance between the virtual child and the virtual mother was 70cm, the height of the virtual child was 135cm, and the height of the virtual mother was 165cm.

In Scene 1 of Figure 9, when the child tries to give the fish to his mother, we can verify that the child's gaze and the position of their hands are generated naturally according to their height. In Scene 2 of Figure 9, the moment the cat jumps onto the box, the weight of the box simultaneously becomes heavier due to the cat, and the hands and head of the virtual child are simultaneously lowered in accordance with the change in weight. In Scene 3 of Figure 9, the moment the cat jumps down from the box with the fish in its mouth, the weight of the box simultaneously becomes lighter. The hands and head of the virtual child are simultaneously raised in accordance with the change of weight. In Scene 4 of Figure 9, when the cat runs away, the child and the mother chase the cat.

5 Conclusions

In this paper, we made an animation for verifying character motion generation in the reactive motion capture system, and successfully generated character motion under Scenario 1 and Scenario 2 using the reactive motion capture system. It becomes clear that by using the reactive motion capture system it is possible to realise the acquisition of character motion data by presenting force feedback and visual information in the human-scale virtual environment. In Animation 1, we showed that the reactive motion capture system was very useful for generating character motion by using force feedback. Through Animation 2, the character motion data was contained in the animation by visual information and force feedback that was generated by the reactive motion capture system, and applied to the virtual human of animation. It was verified that the reactive motion capture system allows the generation of character motion in the animation.

For future research, we plan to develop a multi-modal reactive motion capture system, combining visual, haptic, and auditory information with the reactive motion capture system. Also, we plan to produce animations under scenarios based on 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. 5:2–13, 1998.

[2] D. Tolani, A. Goswami, and N. Badler. Real-time inverse kinematics techniques for anthropomorphic limbs. *Graphical models*, Vol.62, No. 5:353–388, 200.

[3] C. Welman. Inverse kinematics and geometric constraints for articulated figure manipulation. *Simon Fraser University, Vancouver*, Master's Thesis, 1993.

[4] H. Ko and N. Badler. Animating human locomotion with inverse dynamics. *IEEE Computer Graphics and Application*, Vol.16, No. 2:50–59, 1996.

[5] B. Le Callennec and R. Boulic. Interactive motion deformation with prioritized constraints. *Proceedings of ACM SIGGRAPH / Eurographics Symposium on Computer Animation*, Motion editing and compression:163–171, 2004.

[6] T. Molet, Z. Huang, R. Boulic, and D. Thalmann. An animation interface designed for motion capture. *Proc. Computer Animation'97, IEEE CS Press*, 1997.

[7] T. Moeslund and E. Granum. A survey of computer vision-based human motion capture. *Computer Vision and Image Understanding*, Vol.81, No. 3:231–268, 2001.

[8] M. Gleicher. Animation from observation: Motion capture and motion editing. *ACM SIGGRAPH Computer Graphics*, Vol.33, No. 4:51–54, 2000.

[9] P. Glardon, R. Boulic, and D. Thalmann. On-line adapted transition between locomotion and jump. *In Proceeding of Computer Graphics International (CGI)*, 2005.

[10] W. Choi, S. Z. Jeong, N. Hashimoto, S. Hasegawa, Y. Koike, and M. Sato. Reactive motion capture system design using a haptic display. *The Journal of ITE*, Vol. 57, No. 12:1727–1732, 2003.

[11] Y. Cai, M. Ishi, and M. Sato. Position measurement improvement on a force display device using tensed strings. *IEICE TRANS. INF. SYST.*, E79-D:792–798, 1996.