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Description	

Spider Hero: A VR application using pulling force feedback system

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Figure 1: *Appearance of experience on Spider Hero.*

Abstract

The super hero has overwhelming speed and power. Especially, the greatest characteristic is his special ability. In our VR application, the user can jump from one building to another by using a web and being stuck to it like Spiderman™, the famous super hero. In fact, the aim of this application is to give the user the enjoyment of using superpower.

In this application, the user wears the web-shooter, which is the device to shoot a web, and takes aim at a target building with this device. Then, when the user swings his arm ahead, the web is launched and is stuck to the target building on the screen. After the web is stuck to the building, the user's arm is pulled in the direction of the target building by the pulling force feedback system, which can give the feeling of pulling to the user directly and smoothly, as if he were attached to an elastic string. Finally, the user moves to the target building.

In exhibition, we surveyed from guests by the questionnaire. And we got evaluation from this questionnaire. As results, we were able to confirm that a lot of users had enjoyed "Spider Hero".

Keywords: virtual reality, force feedback, entertainment, interaction

1 Introduction

The super hero is always admired by everyone. Especially, the greatest characteristic is his special ability. In our VR application, the user is given superpower like the super hero. It is a great ability, to jump from one building to another by using a web and being stuck to it like Spiderman™.

In this VR application, the big problem is to give a feeling of pulling force feedback from the web to the user. Hence we introduce to this VR application a novel pulling force feedback system. In addition to this, the system is made more realistic by using an air module which blows wind toward the user, a sound system to output wind sound effects, and motion blur to increase the feeling of speed. These give the user a strong illusion of movement and the user feels exhilaration. In the interface, we made the web-shooter launch the web, and the chair pressure sensors measure the posture of the user sitting in the chair. By integrating these interfaces, the user can control the system easily and intuitively. We apply bump mapping and reflection on the elaborate model in a virtual city as features in this VR application. This VR application gives users' the same experience as a super hero, you will be able to experience a new way to fly freely through a virtual city.

2 Related Works

As representative examples of existing haptic devices, there are SPIDAR [Burdea 1996] and PHANTOM [Massie and Salisbury 1994]. The SPIDAR method is to reel off four strings which stretch from four vertices on the cubic frame. In particular, these four strings connect to the user's fingers with ring caps. By controlling the strength of pulling force using motors, the user is given haptic feedback.

On the other hand, PHANTOM use a pen-shaped device. The user has a pen-shaped device attached to a robotic arm, he/she can use it freely. However, when this device encounters an object in the virtual space, the user feels the object through the robotic arm. Among applied systems, Virtual Canoe[Kato et al. 2005] and RoboGamer [Shirai et al. 2005] use SPIDAR. In addition, a VR application for representing object deformations has been proposed, called "Nuku" [Kimura et al. 2005]. This device uses air pressure, it can give the users strong powers.

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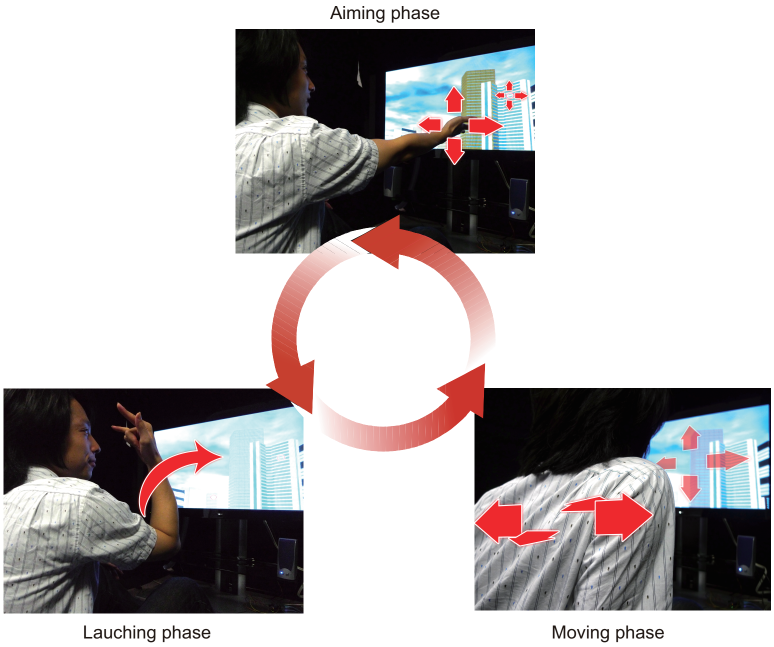

Figure 2: *Flow of the user's experience.*

In our VR application, we introduce an air module. Here, we describe "BYU BYU view" [Ida et al. 2007] and "Wind stage" [Kosaka et al. 2007] which are interfaces to give the feeling of wind. The feature of these interfaces is the wind display. The former display uses a special display which has a lot of holes at the micro level, and this display can input the data of the user's breathe and output the wind toward the user. The latter display is a domal display. This device consists of 25 blower fan modules. The user experiences the wind confusing by getting into this domal display. These devices are complex and expensive. Consequently, we use simple and low-cost devices in our application.

3 System Overview

This chapter describes the system overview. The main feature of this VR application is that the user can move freely in a new way by flying using a web through a virtual city. Here, Figure 2 shows the flow of the user's experience.

First, the user wears the web-shooters which is the interface to launch the web, on his/her arm. The user aims' at a target building projected on the screen using the web-shooter.

Aiming Phase: When the user takes aim at a target building and pushes the trigger button of the web-shooter, the target building is set.

Launching phase: Next, the web is launched when the user swings his arm ahead. The distance, which is the limit of web-length, is set by the speed of the user's arm swing. To send the web to a distant building, the user should swing his arm more strongly. However, if a target building is too far away, the user cannot stick web to it.

Moving phase: Finally, the user moves to a target building, feeling drawn by the force feedback system. The user can move while flying by swaying from side to side. And the user should dodge some buildings which obstruct the path. Because, if the user hits a building, the user falls from the sky. Through these three phases, the user can fly from one building to another continuously.

4 System Configuration

This system consists of some modules installed on a framework of iron piping. Figure 3 shows the system overview of our application. And Figure 4 shows system layout.

This system consists of four sub-systems, which are 1) force feedback system, 2) projection system, 3) sound system, and 4) chair pressure sensor. The force feedback system is a pulling force feedback system, which gives the user the feeling of being pulled, and an air-module, which gives the user the feeling of wind. This system allows giving the user force feedback of flying from one building to another. The projection system projects a CGI on the screen from the rear, to keep enough space between the user and the screen. There are two reasons why we adopt rear-projection. One reason is the user's actions; it is just conceivable that the user would swing his/her arm strongly or would moves his/her body from side to side excessively. Another reason is to prevent casting a shadow on the force feedback system. Sound system is used to emit some sound effects. Chair pressure sensor is used to detect the user's posture in the chair.

5 Implements

5.1 Pulling force feedback system

Pulling force feedback system is the most important feature in this VR application. This force feedback system gives the user the feeling of being pulled. Figure 5 shows the configuration of pulling force feedback system.

This system connects the user's arm to an elastic material web (line). And this line gives the user the sense of being pulled. This line is fixed on the rubber plug. This rubber plug is vacuumed by the vacuum device. However, if this goes on, the user will just be pulled by this system indefinitely. Hence, we introduce a openable cap using servomotor (Extended figure in Figure 5) . By this openable cap, we can control the strength of the pulling force. When

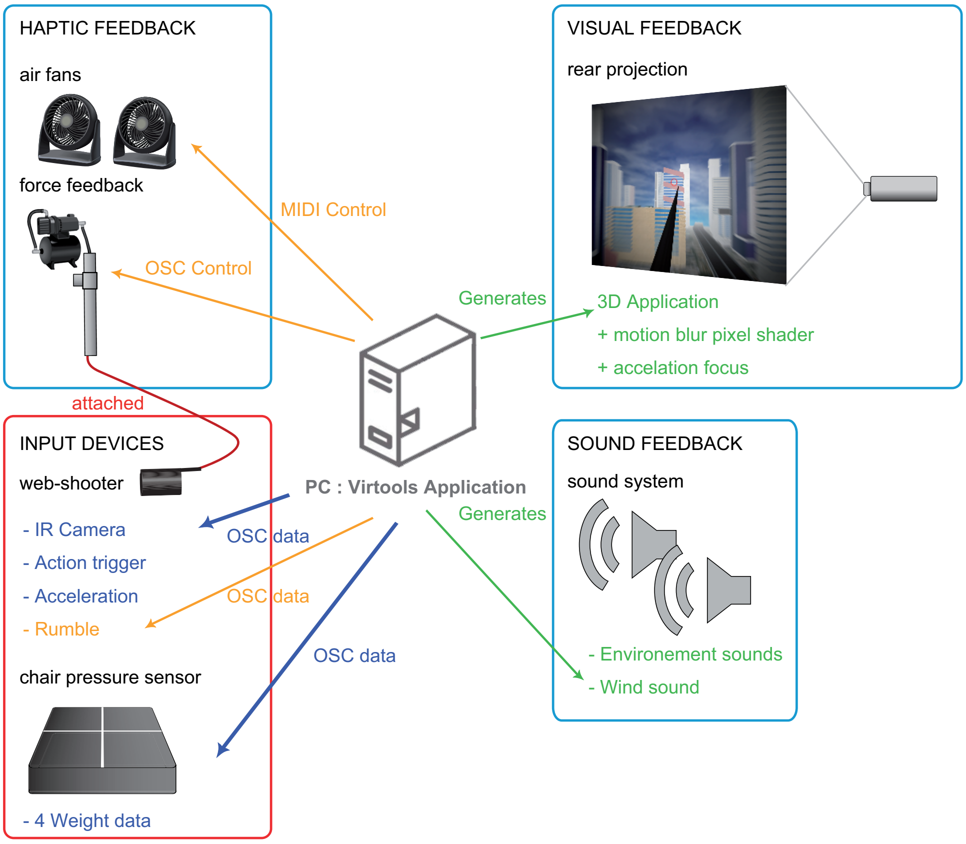

Figure 3: *System overview.*

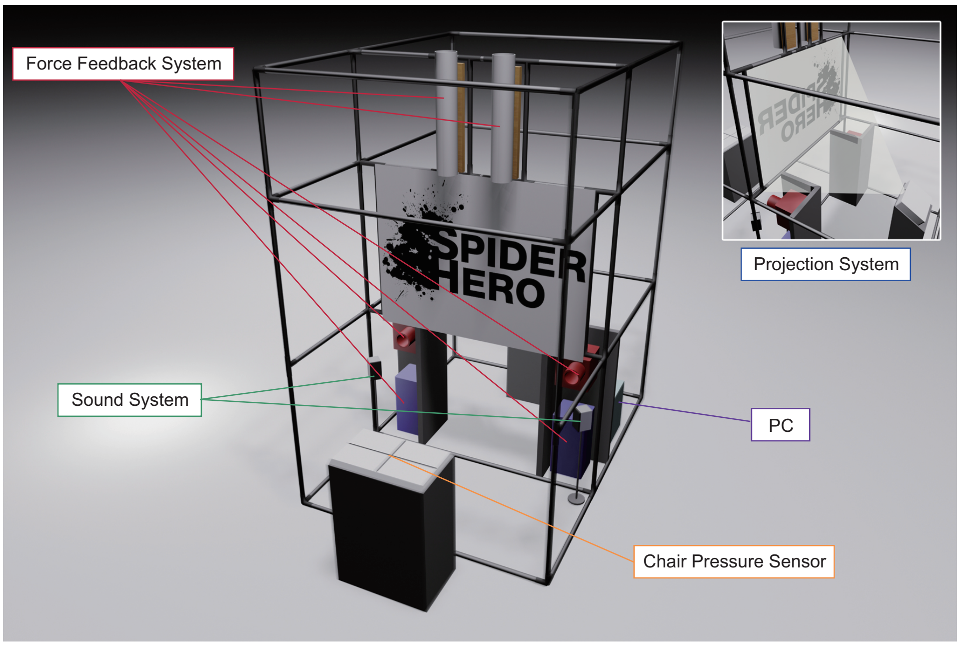

Figure 4: *System layout.*

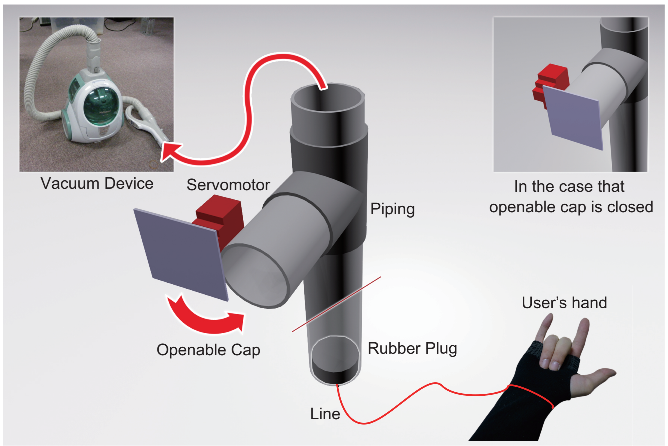

Figure 5: *Pulling force feedback system.*

the openable cap is closed, the pull force is strongest. On the other hand, when the openable cap is open, the pull force is nothing. In other words, the user gets the same feeling as if the web were cut. In previous study, some devices with pulling force feedback were proposed, such as SPIDAR, PHANTOM, and force display [Amamiya et al. 2009] which is used to guide waiters or waitresses toward the right place by the pulling force. However, these methods have some problems. They require high cost and complicated structures, so buying or making these devices is very difficult. For the feeling of being pulled by a web, we think that our pulling force feedback system is superior to the above devices, because our system uses stretch elastic.

5.2 Web-shooter

Web-shooter is an interface with which the user can launch a web. The user wears this interface, takes aim at a target building and swings his/her arm toward a target. Figure 6 shows the Web-Shooter.

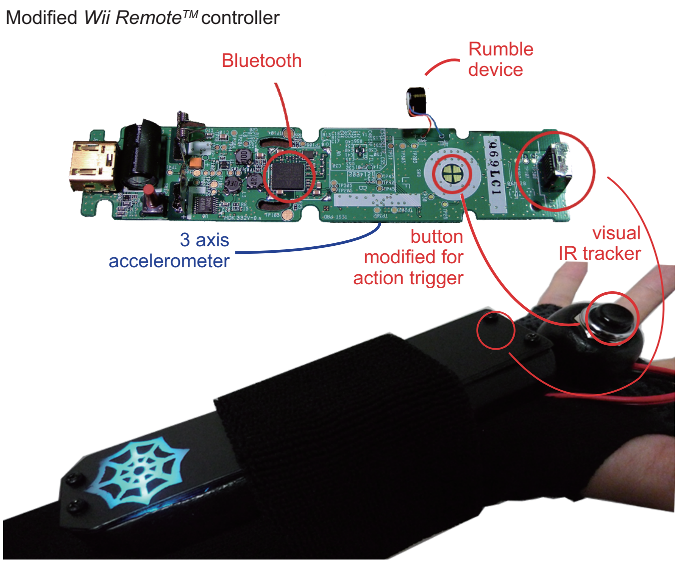

Figure 6: *Web-shooter.*

This interface is based on $Wii\ Remote^{TM}$ controller, and includes an acceleration sensor, infrared camera, rumble device, and action trigger. The acceleration value captured by the acceleration sensor is used to measure the user's swing speed, and to decide the bounds value of web-length. Infrared camera detects infrared LEDs which are mounted on the lower part of the screen, and is used to move a pointer. Rumble device is used as force feedback when web touches at a target building. Action trigger is used to set a pointer. And, we utilize Bluetooth for this data communication.

6 Technical Programming

6.1 Multi-Pointer management

In this application the user has the possibility to launch web lines from both of his hands. Actually even if the user cannot move two strings at the same time, he has the opportunity to launch a second "spider-web" when he wants, in order to change his destination point and consequently his trajectory. Therefore, the application must handle two pointing devices, in order to select and determine the destination point depending on each hand. This application runs on Virtools 4.0, and no multi-pointer system is natively implemented. In this part we will describe how we created a new and simple system of multi-pointer for this application which can also be transposed to other problems requiring multi-pointer devices.

The system has a lot of common points with human view and gesture, we can figuratively-speaking decompose it into three objects in the following Figure 7: the eyes as the system's camera, a finger in order to point out an object which will be the pointer on the screen (we can have as many pointers on the screen as we want), and an invisible ray as a light ray. This ray is launched from the camera position, passes by the pointer and reaches the target object. It is similar to the accepted-fact that if someone points to something with his finger, another person will not see the same thing.

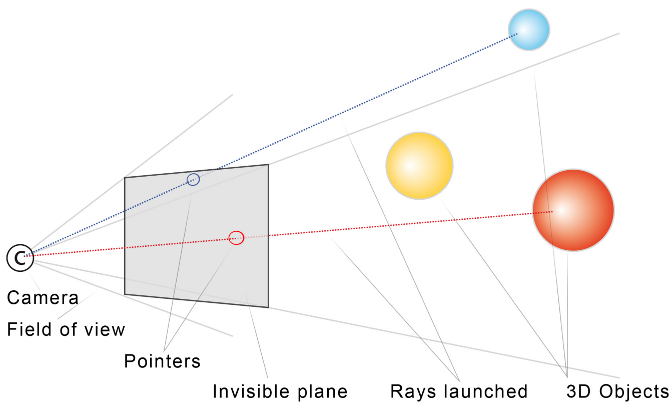

Figure 7: *Multi points.*

To recreate this situation of pointing, we use one main tools integrated in $Virtools^{TM}$, the Building Blocks "Ray Intersection". This Building Block returns the first object, of a specific group, intersected. Our system uses it in order to launch a ray from the center position of the camera, which will pass through a pointer and return the first object intersected. Relatively simple, this system needs 3D entities as pointers, placed in the virtual world, instead of a usual mouse pointer that can be considered as a layer on the screen. In our system we chose to hierarchically attach a transparent plane, very close to the camera in front of it, which will perfectly fit to its field of view. This plane handles the pointers, in order to easily define their positions on the plane proportionally to the screen resolution. In this application the pointers are controlled by 2D values sent through the data sending protocol OSC (Open Sound Control) by the hardware pointing devices, and read into Virtools in order to give the right position to the pointers on the screen. In the end this method allows a potentially unlimited number of pointing devices.

6.2 Collision detection

In a normal context, the collision detection and comportment depending on this collision is not difficult to manage. But in this specific case, especially because we cannot use realistic physics, we had to deal with many constraints, especially the fact that the collision detection, is at the same time used to keep the user avatar stuck on a target and used to detect whether the avatar has collided into an obstacle. The main problem was to know the impact point, in order to react according to direction. For example, if the user bumps into an obstacle in front of him, he will be pushed back, but if he bumps something on his left, the reaction will be to the right. This part is the most important part of the collision detection work. Therefore, we had to use a simple and light way to determine the impact position, because collision detection is already a heavy task.

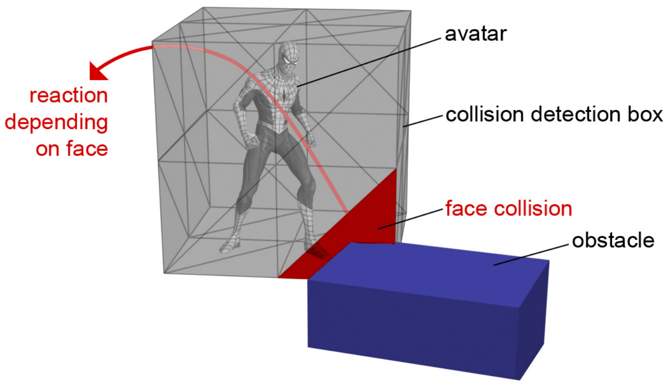

Figure 8: *Collision detection.*

In the application the player is represented by an invisible avatar, behind the camera. To determine the collision, a box is used around the avatar, copying the orientation of the camera. This box is composed of 48 faces (8 per side), each of these faces is referenced into an array in order to know its position relative to the avatar.

In the end the system apply a repulsion force vector related to the speed of the impact and the face touched.

6.3 Unrealistic physic comportment

Because the context is very different from a usual application, in order to increase some feelings of speed and movement, we had to work on unrealistic physics and comportment. Through its physics pack, Virtools, based on $Havok^{\mathrm{TM}}$ technology, provides an interesting resource of physical comportment. But realistic effects do not fit the aim of this work. That is why we had to play with more pre-calculated movements on 3D curves placed in the 3D environment in order to control comportment and find the best rendering for the user. The system uses a series of 3D curves where the user's avatar will move, and follows with speed variation depending on the location of the destination point, the user weight and initial condition of the movement. The weight influences particularly the vertical bending of the curve, and the initial speed influence the horizontal trajectory and the speed on the curve.

6.4 Visual and sound effects

In order to make this application as immersive as possible we had to work on the visual and sound effects. This part is particularly important to increase the feeling by the user.

The main purpose of the visual effects is expected to reproduce some optical properties related to motion speed. Therefore we chose to implement a motion blur, and to modify the field of view of the user depending on his moving speed. In reality, during movement the angle of the human field of view becomes narrower depending on the speed, and the environment around the focal point is significantly blurred. We intended to reproduce these effects by working onto pixel-shaders in order to create a blur effect. This effect is proportional to the movement speed in the world. Furthermore, a mask is generated, also depending on the speed, in order to focus onto the center of screen and increase the motion feelings.

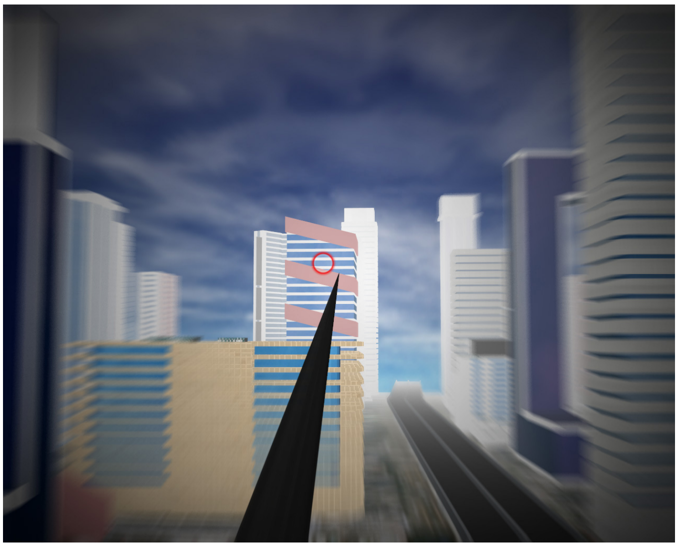

Figure 9: *Motion blur.*

Sound is also an important point to improve the user experience. In addition to simple sound feedback synchronized with user actions, the application generates a wind sound depending on the location of the user, and also particularly on the motion speed. To create this sound, the application uses a pre-created sound loop of wind, and modifies the pitch of this sound depending on the motion speed. The result is a low deep sound of wind when the user is static or moves slowly, and a very high-key, loud and cold sound of wind when the user reaches a high speed. The sound varies between these two extremes and gives strong movement feedback.

7 Experimental Evaluation

We exhibited "Spider Hero" at the International Collegiate Virtual Reality Contest (IVRC), which was held at Miraikan in Tokyo from 22nd to 25th October, 2009.We surveyed from the guests of this exhibition by questionnaire. This questionnaire has 8 evaluation items on a 5-point scale, including satisfaction, operability, immersion, attraction, exhilaration, pulling force, and wind effect. The number of answers was 163, 33 were females, 119 were males and other 11 were unknown gender. Table 1 shows the results.

In table 1, F_{Ave} denotes the average value of female answers, M_{Ave} denotes the average value of male answers and A_{Ave} denotes the average value of all answers. We calculated test statis-

No.	Evaluation item	Questionnair items
1	satisfaction	Did you enjoy “Spider Hero”?
2	operability	Were you able to handle “Spider Hero” easily?
3	immersion	Were you able to get a feel which is like a “Hero”?
4	attraction	Do you want to play Spider Hero again?
5	exhilaration	Did you feel enough exhilaration by flying in the air?
6	pulling force	Did you feel enough pulling force?
7	wind effect	Did you feel enough wind effect?

No.	1	2	3	4	5	6	7
F_{Ave}	**4.6061**	2.7576	**3.4242**	**4.4242**	**4.0000**	**4.5758**	**3.7273**
M_{Ave}	4.3529	**3.0756**	3.2458	4.1949	3.5339	4.3613	3.4202
A_{Ave}	4.3896	2.9294	3.2284	4.2346	3.6235	4.3926	3.5153
z	1.8455	2.8281	1.3357	1.8602	3.3066	1.8332	2.0170
P	0.0650	<u>0.0047</u>	0.1817	0.0629	<u>0.0009</u>	0.0668	<u>0.0437</u>

Table 1: *(Upper) Questionnair items. (Lower) Evaluation results.*

tic z and significance probability P using Wilcoxon rank-sum test. Note that we set level of significance $\alpha = 0.05$. The higher value, which is compared F_{Ave} with M_{Ave}, is indicated in boldface. In case of $P \leq 0.05$, P is indicated by underline. As results, we can confirm that evaluation values of female answers are higher than ones of male answers. Especially in operability, exhilaration and wind effect, there are significantly different between female and male. Some male players commented that it is better to speed up the movement. Thus, we consider that exhilaration is not enough for males and the same holds for wind effect. On the whole, operability is lower, in particular, females feel that “Spider Hero” is difficult than males. Nevertheless, satisfaction and attraction are higher. Furthermore, pulling force is also higher. In fact, we can say that “Spider Hero” achieved our aim which is to give to an enjoyment of using super power, and the force feedback system is also satisfactory.

8 Conclusion

Our new VR application, “Spider Hero”, has a dreamlike aim. It is to give to everyone an enjoyment of using super power. Therefore in this paper, we proposed a VR application using pulling force feedback system. Now in our VR application, the user can feel being pulled, and can feel the wind through a force feedback system. Visual and sound effects immerse the user in this VR experience.

And we thought the web-shooter is wearable device, the chair pressure sensor is intuitive interface, these devices increase the operability of this VR application. However in experimental evaluation, we could confirm the operability is not enough, and so we have to improve these devices. On the software side, in order to give a better experience for male, we have to speed up the movement and turn up wind. Our current pulling force feedback system handles the pulling force only in one direction. We plan to overcome this limitation by adding on a few pipes with openable cap. And in the software module, we will try to brush up the content to increase the sense of immersion. Additionally, in the process of exhibiting our application, we think that we will try to incorporate a lot of user’s comments, we will modify this application for high quality, as a VR application letting users live their dreams.

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References

AMAMIYA, T., MAEDA, T., AND ANDO, H. 2009. Location-free haptic interaction for large-area social applications. *Personal and Ubiquitous Computing 13*, 5 (June), 379–386.

BURDEA, G. C. 1996. *Force and Touch Feedback for Virtual Reality*. A Wiley-Interscience Publication.

IDA, S., AWAJI, T., MORISHITA, K., ARUGA, T., TAKEICHI, R., FUJII, T., KIMURA, H., NAKAMURA, T., FURUKAWA, M., AND SHIMIZU, N. 2007. Byu-byu-view: A wind communication interface. In *Proceedings of SIGGRAPH 2007*.

KATO, M., DOBASHI, Y., AND NISHITA, T. 2005. Virtual canoe: Real-time realistic water simulation for haptic interaction. In *Proceedings of SIGGRAPH 2005*.

KIMURA, H., IYODA, A., KAKIUCHI, Y., TAKEI, S., DU, X., FUJII, S., MASUDA, Y., MASUNO, D., AND MIYATA, D. 2005. A vr application for representing object deformations by means of novel haptic device. In *Proceedings of NICOGRAPH 2005*.

KOSAKA, T., MIYASHITA, H., AND HATTORI, S. 2007. Development and evaluation of immersive 3d wind display. In *Proceedings of INTERACTION 2007*.

MASSIE, T. H., AND SALISBURY, K. J. 1994. Phantom haptic interface: a device for probing virtual objects. In *Proceedings of the 1994 International Mechanical Engineering Congress and Exposion*, 295–299.

SHIRAI, A., DOMINJON, L., AND TAKAHASHI, M. 2005. Robogamer: Development of robotic tv game player using haptic interface and gpu image recognition. In *Proceedings of ACE 2005*.