Personal VR system for rehabilitation to hand movement

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Abstract

In this paper, the virtual reality system based on a personal computer is proposed. The system is suitable for personal use, and can display visual, auditory and haptic information at the same time. To display haptic information, we use SPIDAR(SPace Interface Device for Artificial Reality). The system is applied to training machine for rehabilitation. System evaluation by actual patients is also reported.

Keywords: Virtual Reality, Human Interface, Force feedback, Rehabilitation

1. Introduction

Due to the advance of the medical technology, human can cure the fatal disease which were once, we thought that can not be cured. Even though many people save their lives, they may suffer from disease which can not be cured completely. Moreover, there are many people who were wounded at incidents such as traffic accidents or sports game, and so on. The purpose of rehabilitation is to help those people to be adjusted in a social life. The rehabilitation system which is practiced in the hospital should not cause an accident. That is, the most important factor in rehabilitation's menu is safety, so it is difficult to carry out a training program which is somewhat dangerous. But those dangerous tasks are so closely related to our life that those are very fundamental works such as dividing food with a knife, and making using the fire. By simulating such a dangerous but necessary work in our life in a virtual environment, the patient can do a rehabilitation without risk of being hurt. In the current training, it is hard for the experienced to gauge the achievement of the rehabilitation. But if we use Virtual Reality, we can more easily observe the achievement through the Virtual rehabilitation than the real rehabilitation. Manipulating the various parameters in virtual rehabilitation, we can set various work levels freely. That is, the patient can attain the result of rehabilitation during the process of the Virtual rehabilitation, and depend on the that result, it is possible to make suitable level to do rehabilitation. More and more, we can add amusement characteristic to rehabilitation and display the achievement of rehabilitation, if we use virtual rehabilitation. So the patient can do rehabilitation continuously without feeling uninterested, even though the term of rehabilitation would be long. And in the future, facing the silver society, there may be assistants of the handicapped shortage. So by connecting the home computer with hospital computer, the handicapped are able a principals depend by interacting with the hospital. That is, one adviser can advise to many handicapped people who live in a remote area but simultaneously. The purpose of this experiment is to construct the virtual rehabilitation system using the multi-modal factors-visual, auditory and haptic information at cheaper price. So, we will display vision, hearing and tactile, using only one personal computer in this experiment. To display vision information, we used Computer Graphic, and about display tactile, we used SPIDAR which was invented by Sato Laboratory.

2. Virtual Reality based on Personal Computer

2.1 Space Interface Device for Artificial Reality as a haptic interface.

In this experiment, user input position information of fingering in real space, as displaying the haptic information, we used SPIDAR which was invented by Sato Laboratory. In figure 1, we display the frame of SPIDAR. This system consists of cubic frame, motor, pulley, and encoder is attached in every corner of each vertex. From this each pulley, string comes out, and intersection is made to bind 4 strings of which were came out from each vertex. Each string is suspended by the tension which is generated by motor, and keep suspended status. The worker manipulates this point freely within 3Dimension space. We achieve each length of string from the encoder rotation data, from the length of 4 strings and we calculate the finger position of the patient. This system is operated by calculating the suitable force depending on the position data of fingering, display the tension from the motor, and reflect the force to the worker. The characteristic of this SPIDAR is to achieve the position information using the length of string, and depend on the that data, it is possible to display haptic feedback. The mess of string is very low. So the patient can manipulate the fingering freely without feeling the gravity, when the fingering never collide with virtual object. And this system has high immersed character and low psychological difficulty, due to the shape is simple.

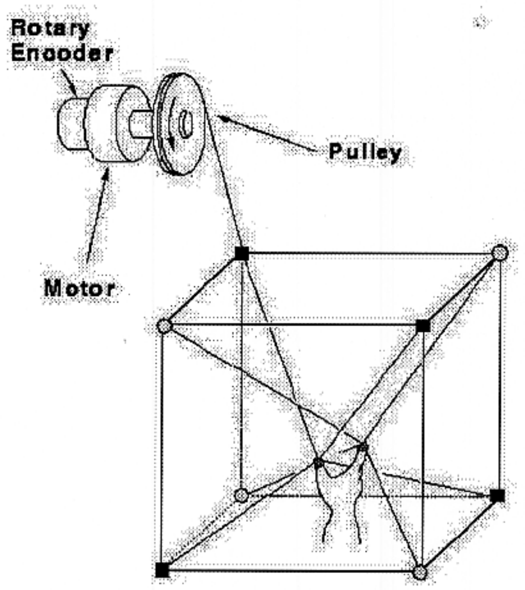

Figure 1 Overview of SPIDAR

2.2 Total construct of this system

In this figure 2, we display this system. In this system we used Pentium 166MHz personal computer as a calculator. From this computer, we present the vision information and haptic information. The vision information is constructed as a 3 Dimension by a personal computer, and displayed to the 21 inch monitor. Calculating the position information and displaying the calculated haptic information is operated by SPIDAR. The position information is calculated by PC, depend on the output signal of encoder which is attached to the motor in each corner of vertex. The haptic information is transformed to 12 bit D/A converter board, and this signal is transformed to the step of 0.1V, after this, it is used as an input signal in regular current circuit to control the motor. In this case, we can not update the haptic data in 300Hz, which is necessary to feedback force, naturally, by updating the vision information and haptic information, if we use interaction operation. And if we set several computers to control its roll, it is not suitable for the individual use. So in this system, we applied the way of controlling the position in display part, and we choose the way to interrupt in haptic part.

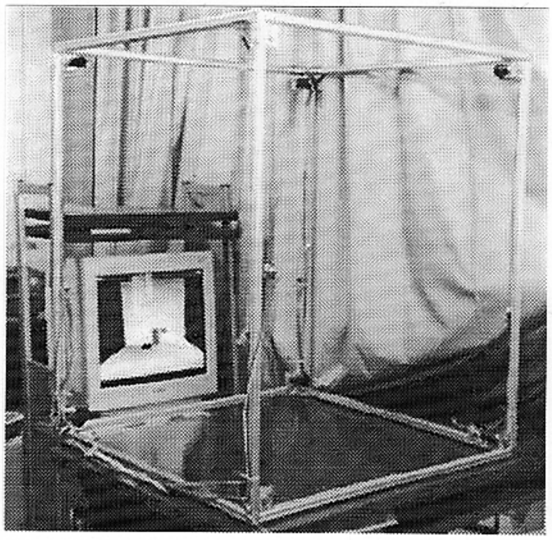

Figure 2 PC-SPIDAR

2.3 Structure of hardware.

In figure 3, we display the view of this hardware system. In this system, we use only an IBM computer with 166MHz as a calculator. We used two 24 bit up-down count boards and 12 bit D/A converter board made by CONTEC corporation.

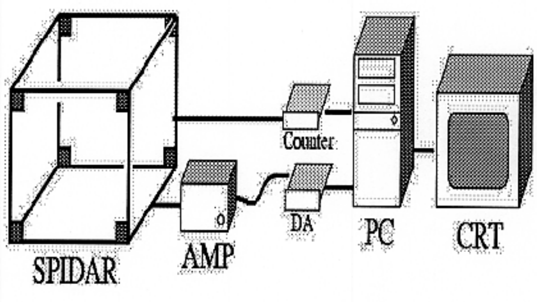

Figure 3 View of Hardware System

2.3.1 Hardware to attain the position information

The position information is acquired from the encoder which is attached to the corner of frame, then the output signal is transformed into length of string. From the 8 rotary encoder, signal outputs are gathered into the amplifier. From this amplifier, the power is provided to operate the encoder. The output signal is divided by 2 part, Motor 0-3, and motor 4-7, and sent to two counter boards. The needed power in this part also is provided by amplifier. For the rotary encoder, we use HP HEDS 5010, which is made by HP. The specification of this encoder is displayed in table 1. This counter board is able to do up-down count in 4 channels by one. We use only 2 channels and 4 times fast sampling mode.

Table 1 Specification of rotary encoder

Resolution	500 $[count]$
Supply Voltage	5 $[V]$
Signal rise time	500 $[ns]$
Signal fall time	200 $[ns]$
Inertia	$0.4[gcm^2]$

2.3.2 Hardware to display feedback force

D/A board can translate input signal data which is 12 bit data to voltage output. The output range is from 0 to 10 V. The output signal reaches to stable value in $10us$, after starting transformation. After commanding the output value in total channels, we command to start the output voltage. Motor is RE025-055038, made by Maxon company, and it's specification is displayed in table 2.

Table 2 Specification of motor

Rated Power	
Rated Voltage	
Starting Torque	
Rotor Inertia	

The motor is fixed to the corner of vertex in the frame by the mounting. The motor is connected with pulley, pulley is bound with string. To fix the motor to the frame, we made mounting made in aluminum, and this mounting prohibits to bind the string in workspace. The diameter of pulley is 16mm and made of light aluminum. We choose the string which is not much stretch, if the force is applied to. The length of frame is 90cm and made up with light aluminum pipe.

2.4 Structure of software

Table 3 shows the program and it's roll. The structure of software is displayed in figure 4.

Table 3 Program and it's roll

Program file name	It's roll
PCCounter.cpp	Initialize counter board
PCDisp.cpp	Initialize display
PCgeometry.cpp	Calculate position
PCMotor.cpp	Control each motor
PCMain.cpp	Main, Interrupt
PCTimer.cpp	Calculate Time
PCcalc.cpp	Dynamic Memory
PCSpidar.cpp	Library for SPIDAR

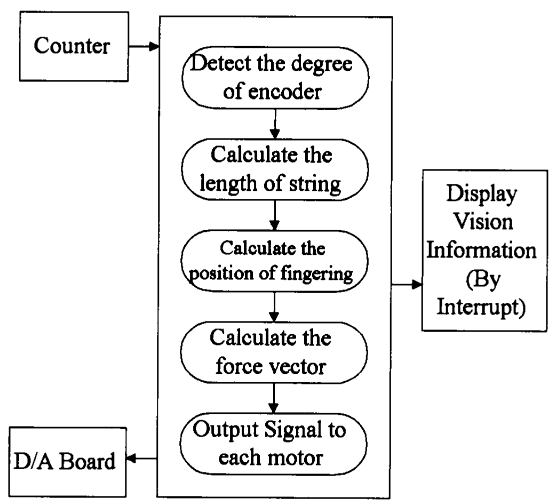

Figure 4 Structure of software

3. Construction of rehabilitation

3.1 Artificial Reality for rehabilitation training

Using the Artificial Reality system which is able to force feedback, we construct the system to train for rehabilitation. Considering the characteristic of this system, we select volunteers in these categories.

- The person who has injury at the tip of hand, and try to restore it.
- The person who has been training toward comeback to society and at the last level of rehabilitation.

From now on, we argue training system which we invented.

Striking a match

This training is a cooperative work which is frequently done in every day life using two hands. If the user does good cooperative work using two hand, he can strike a match. But the user does not perform cooperative work well, he can not strike a match. That is, the cooperation of two hand is displayed the easier way to understand as light in the match. As adjusting the parameter, we can change the difficulty level of work. We display the step order below sentence.

1) Insert both left and right finger into fingering of SPIDAR (Left hand corresponds to virtual box in the monitor, right hand does tip of virtual match in the monitor. figure 5)
2) Try to strike a match using cooperative work between left hand and right hand.
3) If the worker does cooperative works were done properly, the user can strike a match. (figure 6)
4) After firing, the left hand changed into candle.
5) One more time, cooperative work is needed with both left hand and right hand, if the user do properly, the candle turns on.
6) The user can try to turn on the candle which is located on the floor up to 3 times.

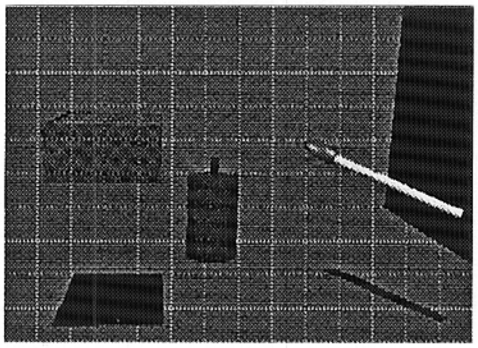

Figure 5 Candle and match in initialize state

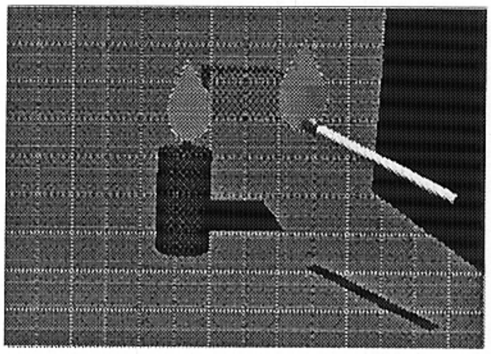

Figure 6 State of candle and match turn on

Conveying objects

The purpose of this training is to train to grasp the object with proper force. The patient grasps the object and moves that to the determined place. Figure 7 display the shape. The patient inserts the finger into fingering of SPIDAR. In virtual environment, there are virtual finger and box are capable to move by manipulating the SPIDAR. The patient has to grip the virtual box using virtual hand watching that. If the virtual hand touches on the virtual box, the force is displayed to the patient from SPIDAR, and also can confirm that he or she touches the virtual object using the vision and tactile. If the patient clutches the virtual box, he or she can move the virtual box, and then he or she moves that virtual box to determined place holding it. If the virtual box places in a proper place, new virtual box is happened in virtual environment with notifying to the adviser that work is finished completely, and the patient can continue to train. The patient moves that virtual box into determined place with holds it and moves.

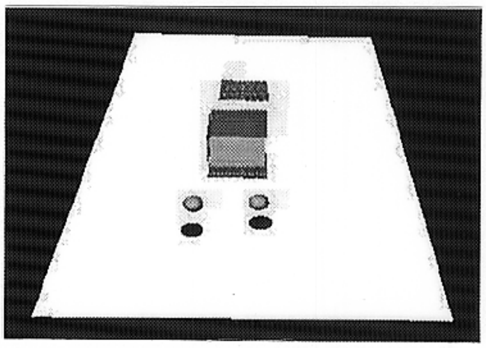

Figure 7 View of conveying objects

Pegging in the ring

The purpose of this training is to train the hand movement based on the vision information. In the virtual space, the virtual ring and ball is set, and the patient can move those things using SPIDAR with 3 Degrees Of Freedom. The patient moves the ring with the left hand, and ball with the right hand. The patient moves has to insert virtual ball into virtual ring which are located separately. (figure 8, 9) If the ball is collided with ring without penetrating the ring turn back the force and inform to the patient using vision information and haptic information, the ball is bumped in improper place. If the ball is penetrated into the ring completely, notify with alarming.

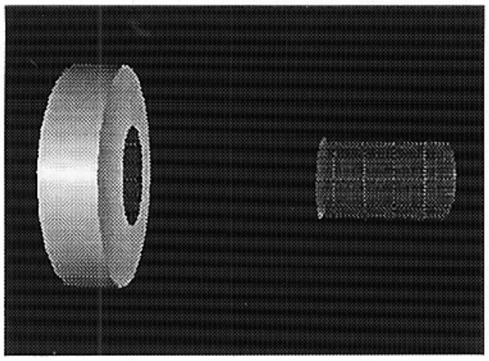

Figure 8 Initialize state of ring

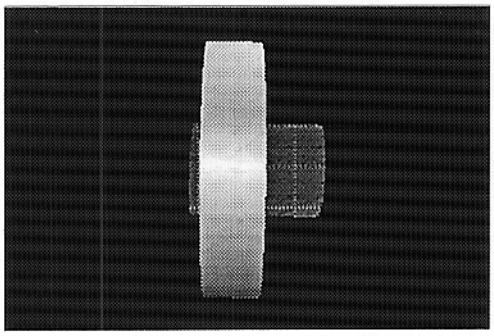

Figure 9 View of pegging in the ring

Writing virtual character.

The purpose of this training is to write character on the virtual paper which is placed in virtual space using the virtual pen. figure (10.1), (10.2) shows the picture. At first, make flat floor in virtual space. Set the fingering of SPIDAR to be a tip of virtual pen. If the patient touches the virtual paper (flat floor), the feedback force is turned back to the patient and character is drawn. From the left side of the front of view, virtual switch is located, if the patient pushes the virtual button, all characters which the patient wrote until now are removed, and the patient is able to restart.

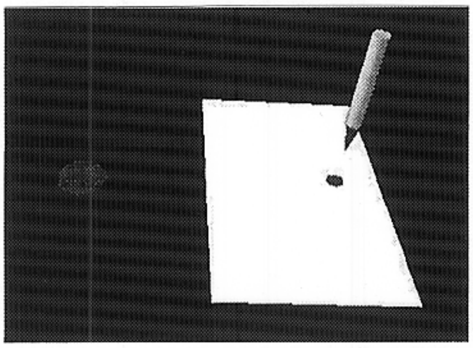

Figure 10.1 View of writing virtual character

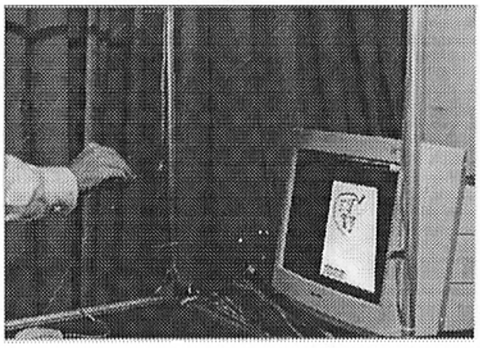

Figure 10.2 View of writing a virtual character

3.2 Trial of training hand movement system

We have done a trial using this system, with the cooperation of the IBARAKI PREFECTURAL UNIVERSITY OF HEALTH SCIENCES.

3.2.1 Condition of experimental use

We set the PC-SPIDAR in that hospital, and our trial is assured by experiment. figure 11 presents this shape. We put the SPIDAR as a haptic interface on the office desk, and in front of SPIDAR, we put the 21 inch monitor. The patient trains with seeing the screen. Patients who attended this experiment were 4, one was woman, and others are men. Each person is 64(A : Stroke, hemiplagia), 54(B : Cerivical spinal cord injury), 49(C : Spinal cord injury, Axillary nerve palsy) and 19(D : Hemilplagia, Mental retardation) years old. The person chosen to join this train manipulate this system because he or she has been taking a rehabilitation training, even though he or she has injury on the tip of finger.

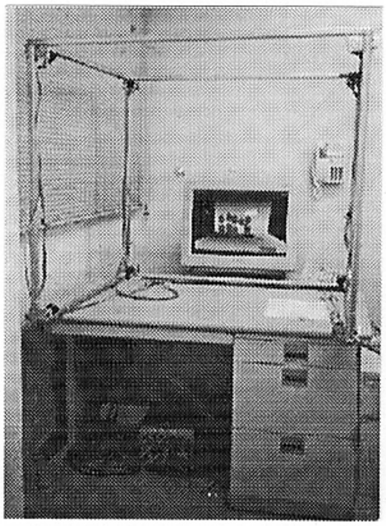

Figure 11 View of PC-SPIDAR set in hospital

3.2.2 Impression of patients and doctors

Below the sentence, we write impression of patients and doctors who participated in this experiment.

Impression of Patients

- "It was difficult to train because this was the first time."
- "It seemed like playing game."
- "The train that striking a match was simple, but it was difficult for me because grasping the object with two hands and moving that to determined place."
- "I feel somewhat tired."
- "I think that this system is helpful to concentrate."
- "The place which system is located is high and the work space is also high"
- "It was very interesting, because this train was the first time, but I'm not sure that if I get used to this system, this task would be interesting or not."
- "I never feel tired."
- "Striking a match was most interesting."

Impression of doctors

- "I hope to attain and replay position information from the position data."
- "I wish to see the time value that were taken in this train using this system."
- "The patient may need more data to feel achievement of train taken by the patient."
- "More sense of the immersion is needed."
- "It is difficult to distinguish the depth."

3.2.3 Consideration

We got the impression that all volunteers train many experiments with enjoyment. Rehabilitation training has to be fun. This system satisfies in that point. Still more, if the patient accomplishes the task, the step to display easier form to inform the achievement to the patient is needed. The patient may get confused when grasping the object and moving object than striking a match which task is needed to accord with between movement of arm and movement of virtual object. That is the reason why the patient does not get used to the direction of depth in the 3 dimension which is displayed in monitor. Moreover there was an opinion that "it was difficult to manipulate this system, because it was the first time." We think that if the patient never had experienced to move objects with seeing the screen, they may need experience. For the question that if they got tired after the training volunteer A said "I feel somewhat tired.", but volunteer B said "I don't feel at all tired." That experiment which volunteer A and B did was almost same. That is to say, even though same training sense of tiredness is different up to the individual. There was opinion that "The place work space is high". We think that height of workspace is suitable where user does not need raise his or her hand to train. That is to say, if the patient trains in the standing position suitable height to train is where elbow can be fold in 90 degree. If the patient works in stand, the height of elbow differs by an individual. So it is best way to use a chair which can control the height, when the patient works in the standing position. There was an opinion that immersion is necessary. To raise the sense of immersion, a bigger and wider monitor or screen is needed, and we found that the direction of screen also affects the sense of immersion. The level of this system is only suitable for the lightly injured people or already well trained people. Still more, if we make a simple level of training, heavily injured person also can train using this system. For our future work, using the characteristic of Virtual Reality, we will set various special situations which are not happened in real life, we will validate the reaction about that environment.

4 Conclusion

In this experiment, we made multi-modal haptic interface using technology of Virtual Reality for the purpose of using for the individual based on PC, and we also confirmed the application as a rehabilitation. This system which we invented based on PC, has several problems about demonstrating vision information speed than system using the GWS. But, if we consider the speed rate of development of ability of handling information of PC, to commercialize this VR system based on PC can be possible sooner or later. Our remained thing to do is to evaluate the result from this experiment, and have to think the effect for a long time, even though we can confirm the possibility of this system.

Acknowledgments

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