A Kickball Game for Ankle Rehabilitation by JAVA, JNI and VRML

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ABSTRACT

This paper presents development of a virtual environment that can be applied to the ankle rehabilitation procedure. We developed a virtual football stadium to intrigue a patient, where two degree of freedom (DOF) plate-shaped object is oriented to kick a ball falling from the sky in accordance with the data from the ankle's dorsiflexion/plantarflexion and inversion/eversion motion on the moving platform of the K-Platform*. This Kickball Game is implemented by Virtual Reality Modeling Language (VRML). To control virtual objects, data from the K-Platform are transmitted through the communication module implemented in C++. Java, Java Native Interface (JNI) and VRML plug-in are combined together so as to interface the communication module with the virtual environment by VRML. This game may be applied to the Active Range of Motion (AROM) exercise procedure that is one of the ankle rehabilitation procedures.

Keywords: ankle rehabilitation, virtual environment, VRML, JNI, K-Platform

1. INTRODUCTION

Ankle is one of the most important joints in our body for walking. When it is hurt during daily activities including sports, however, the recovery takes long time and requires a lot of efforts. Moreover, deficiency in flexibility in ankle motion and weakness of muscle strength can cause re-injury easily. Therefore, patients should follow the rehabilitation instruction of doctors or therapists [1].

There have been conventional procedures for ankle rehabilitation such as flexibility remedy, muscle strengthening, proprioception enhancement and so on. Some passive devices such as Dura Disk, Foam Rollers (Perform Better) and Multi-Joint System (Cybex) have been used in the ankle rehabilitation training [2 ~ 4]. The present ankle rehabilitation process, however, is so repetitious that patients get bored very easily. To get over these shortcomings, Giron et al. developed the Rutgers Ankle, a six DOF ankle haptic device with an embedded PC. This device was used to control the virtual environment, which was developed with WorldToolKit™ [5].

This paper presents development of a Kickball Game that can be applied to the Active Range of Motion (AROM) exercise, a procedure of ankle rehabilitation exercises. AROM is the range, which a joint can move (typically angular, in one-DOF) without assistance or resistance [6]. The AROM exercise can make patients alleviate the ankle's flexibility deficiency and enhance the proprioception. In the Kickball Game, a virtual plate motion is matched with the plantarflexion/dosiflexion and inversion/evasion of the patient's ankle to help the patient be immersed into the rehabilitation procedure. Since commercial VE programs such WorldToolKit™ are very expensive for individual use and for telerehabilititation, we used VRML and Java programming languages to develop the Kickball Game.

The virtual exercise system for the ankle rehabilitation is composed of four elements shown in Figure 1 [7].

* K-Platform is a haptic device based on the regular Stewart Platform with six pneumatic actuators.

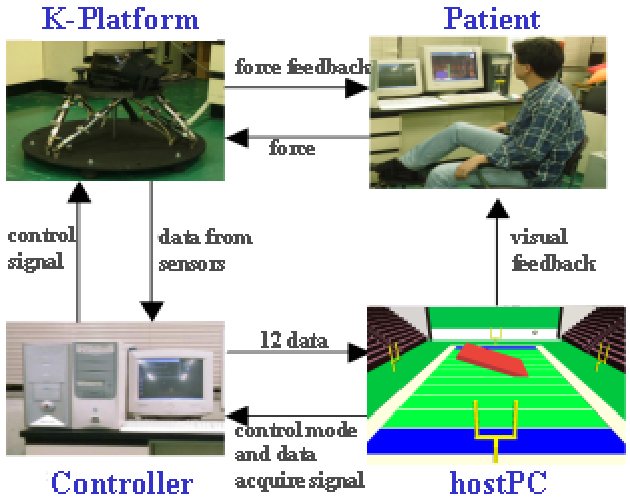

Figure 1. System Configuration

The K-Platform is a six-DOF haptic device that is driven by pneumatic actuators. This haptic device can resist the patient's ankle motion, thus providing muscle strength exercise. A DOS-based interrupt-driven controller and communication program are implemented in a PC called the controller. The hostPC loads the virtual environment in VRML browser and is connected to the controller through an RS232C serial cable. To interface the communication program in C/C++ with the virtual environment in VRML, JNI (Java Native Interface), Java and VRML plug-in are utilized, which are installed in the hostPC [8].

The virtual environment for the Kickball Game is a football stadium with four goals in each direction and a rectangular plate in the center as shown in Figure 2. The plate rotates in two DOF, corresponding to two rotations of the ankle, to kick a ball falling from the sky. The patient follows the doctor's instructions through GUI and moves his/her ankle to kick a ball.

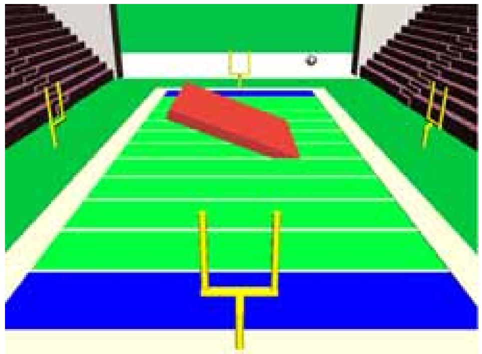

Figure 2. Virtual Environment for Kickball Game

Signals from pressure and Linear Variable Differential Transformer (LVDT) sensors in the K-Platform are converted into six position data and six torque/force data by forward/inverse kinematics in the controller. Those data in turn are transmitted to the virtual environment for visual feedback showing the virtual object's movement and the applied torques to the patient.

2. PROGRAM COMPONENTS FOR KICKBALL GAME

Figure 3 shows the program components and data flow in the controller and the hostPC.

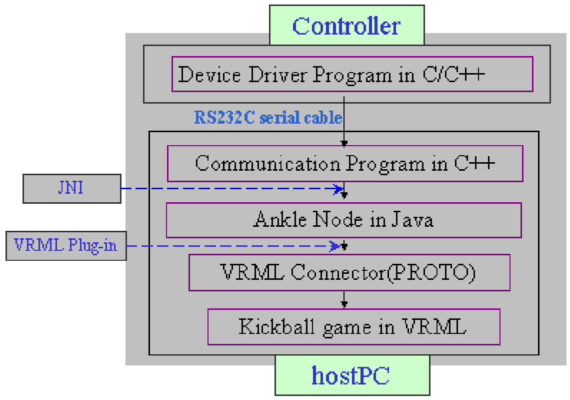

Figure 3. Program Components and Data Flow

The device driver program deals with tasks related to control and communication in the controller. The six position data are transmitted from the device driver in the controller to the virtual environment in the hostPC. JNI is to interface the communication program in C/C++ with ankle node in Java. VRML plug-in has a Java module and a VRML module. The Java module, which is the ankle node, is composed of Java classes to convert data for the coordinate system of the virtual environment and to embody output/input fields for the VRML module. The VRML module, which is VRML PROTO statement, is to connect output/input fields implemented in Java module to the virtual environment

2.1. Interface between the communication module and Java module

When an instance of the ankle node object is called in the hostPC by an input field of VRML plug-in, an instance of the communication class is created at the same time through the JNI. Among member functions in the communication instance, a member function to receive data is called and requests the controller to transmit six position data. Then the controller sends data for calling mode with the acknowledgement to the virtual environment through the JNI and the VRML plug-in..

2.2. Data conversion and ankle node on Java module of VRML plug-in

Figure 4 shows the world coordinate system (x y z) and the coordinate system of the virtual environment (x' y' z'). Data conversion for the coordinate system is needed since the world coordinate system is different from the virtual environment's counterpart.

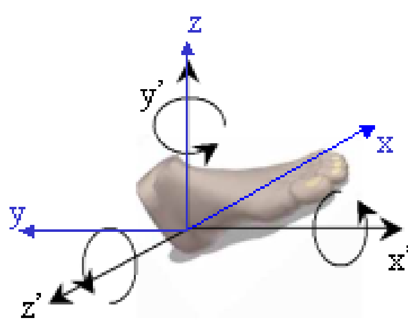

Figure 4. The World and Virtual Environment Coordinate Systems

Among the six position data from the JNI, roll and pitch angles respectively correspond to inversion/eversion and plantarflexion/dorsiflexion motion of the patient's ankle. These two angles are converted into two fields in the ankle node to describe the motion of the ball and the plate in quaternion format [10]. This step is embodied in Java classes, of which instances are called from VRML plug-in (See Figure 5).

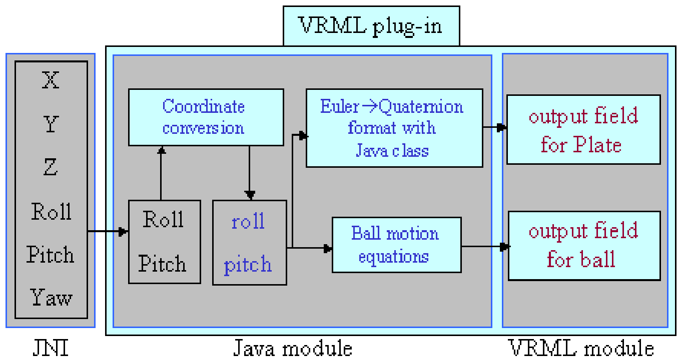

Figure 5. Data Conversion on Java Module of VRML Plug-in

An output field in the ankle node to describe the virtual plate rotation in VRML is in quaternion with four entities. Quaternion consists of a direction vector and an angle about the direction vector. It is, therefore, necessary to convert data into quaternion format.

The other output field in the ankle node describes the ball movement. Its motion is divided into two parts: before and after collision with the virtual plate. For the more effective data conversion, the motion data is parsed in array forms into the ankle node.

The physical equations for the ball motion before it collides with the virtual plate are described by

$$\begin{aligned} x &= 0 \\ y &= h - \frac{1}{2} g t^2 \\ z &= 0, \end{aligned} \tag{1}$$

where *x*, *y* and *z* are respective position of a ball in the virtual environment coordinate and *h* is the initial height from which a ball falls, *g* is the gravity acceleration and *t* is time.

After the ball hits the rotating plate, the ball's motion can be described by

$$x = v_i \cos\alpha \; t \tag{2}$$

$$y = v_i \cos\alpha \cos\beta \; t - \frac{1}{2} g \, t^2 \tag{3}$$

$$z = v_i \cos\beta \; t \tag{4}$$

where v_i is the collision velocity when a ball collides with the plate and is given by $v_i = \sqrt{2gh}$.

Angles α and β are counter-clockwise angles that are computed with the $pitch$ around x-axis and $roll$ angles around y-axis from JNI when a ball hit the plate and are given by

$$\alpha = -(\frac{\pi}{2} - 2 \; pitch) \tag{5}$$

$$\beta = \frac{\pi}{2} - 2 \, roll \; , \tag{6}$$

2.3. Data conversion and ankle node on VRML module of VRML plug-in

With two output fields for the ankle node, the Java module of the VRML plug-in is ready for the data transmission. The ankle node, which has two output fields and an input field for the virtual environment to activate the JNI and get data from the K-Platform though the controller, is implemented in Java module of VRML plug-in.

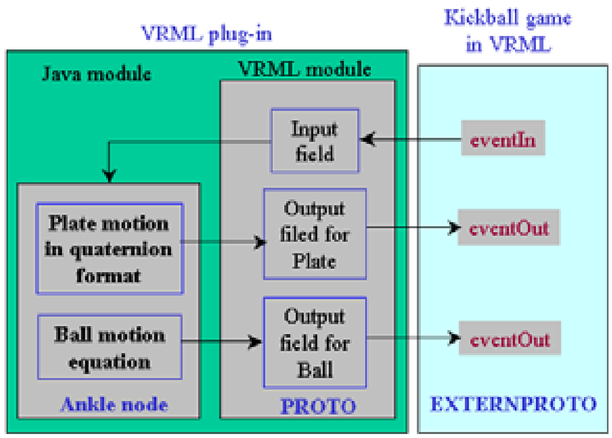

Figure 6. Data Conversion on VRML Module of VRML Plug-in

As depicted in Figure 6, as soon as the virtual environment runs, the input field of VRML module of VRML plug-in activates the Java module of VRML plug-in, which is implemented in the ankle node, and JNI to get data to move the virtual objects such as the plate and the ball. Then two orientation data from K-Platform are converted and transmitted immediately to the virtual environment through JNI and VRML plug-in.

In the virtual environment in VRML, the relations of input and output fields are realized by routing as described in Figure 7.

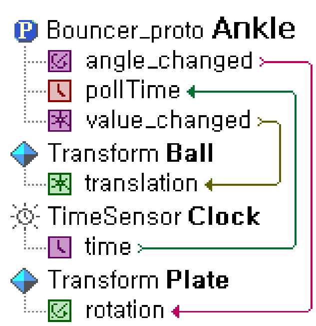

Figure 7. Routing in Virtual Environment

3. CONCLUSIONS AND FUTURE WORKS

This paper presented a methodology to interface the virtual environment for the ankle rehabilitation exercises in VRML with the hardware through JNI and VRML plug-in, which is free unlike other VE development tools. VRML and Java are hardware independent and are effective for the web-based application, while the virtual environment with OpenGL is limited on it. This methodology can be applied to other contents for the ankle rehabilitation procedures.

The proposed Kickball Game contents are expected to attract patients to be actively involved in the otherwise boring rehabilitation process. Some special effects can evoke more zest of the patient. Whenever the patient kicks a goal, some effects such as fireworks show, ovations from the virtual audience and score recording show up. With stereo viewing system such as stereo glasses or view port changing in the virtual environment, the Kickball Game can be developed in 3D for full immersion.

They can also be applied to other rehabilitation procedures such as upper extremity.

4. ACKNOWLEDGMENT

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