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Omnidirectional Motion Input: The Basis of Natural Interaction in Room-Scale Virtual Reality

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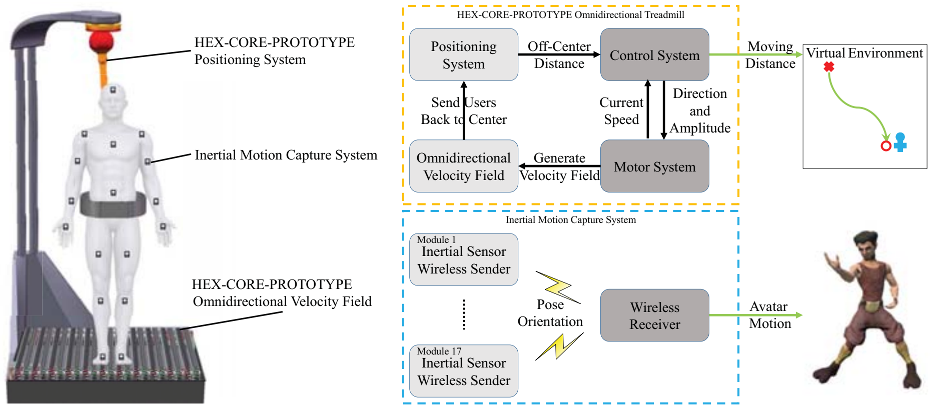

Figure 1: The flow chart of our omnidirectional motion input (OMI) system. It could provides two different type of motion inputs include the locomotion input and body motion input. The HEX-CORE-PROTOTYPE omnidirectional treadmill generates an omnidirectional speed field to send the user back to the center based on the positioning system. The control system calculates the moving distance of the user which could be used as the movement signal of virtual environments. The inertial motion capture system measures the pose orientations of 17 parts of the human body, as the right figure shows, includes the head, arms, feet, etc. All the pose orientations are sent to the wireless receiver to control the avatar motions.

Abstract

The basis of natural interaction in VR is the exact input of human motions, which includes the locomotion, body motion, facial expressions, etc. We define the input of all such human motions as the Omnidirectional Motion Input(OMI). Traditional motion input systems are designed for a specific motion. In this work, we propose an OMI system that could provide the room-scale locomotion input and the body motion input simultaneously. Our system only needs $2m^2$ area and the time delay less than $20ms$. The experiments demonstrate the effectiveness of our OMI system.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Computing methodologies—Computer graphics—Graphics systems and interfaces—Virtual reality

1 Introduction

With the development of virtual reality (VR) technology, as depicted in the movie "Ready Player One", the scene where VR enters millions of households is within reach. For a natural interaction in room-scale VR, that is, walking in the virtual world on your own legs, touching the virtual world on your own hands, and only need no more than 2 square meters in the real world, the most important basis is the exact omnidirectional motion input (OMI). An ideal OMI system could capture all of these motions exactly. In this paper, we propose a basic OMI system that could provide locomotion input and body motion input. We demonstrate the application demos of different motion inputs to show the effectiveness of our OMI system.

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2 System Overview

Figure 1 shows our OMI system, which could provide the locomotion input by the HEX-CORE-PROTOTYPE (HCP) omnidirectional treadmill and body motion input by the inertial capture system respectively. From a functional perspective, the two parts are separate and will not affect each other.

3 HEX-CORE-PROTOTYPE Omnidirectional Treadmill

For the locomotion problem [5], the HCP system is based on the principle of the Mecanum wheel [1] and could provide a real walking in place experience as the belt-based omnidirectional treadmill, such as the F-ODT [4], Infinadeck [3]. But it is much smaller in volume, which can be reflected in the height that our system only has $16cm$ height which is 40% of the Infinadeck.

3.1 Omnidirectional Velocity Field Scheme

As Figure 2 shows, when we want to have a synthesis velocity v_* with amplitude $|v^*|$ and direction θ_{v^*} on the omnidirectional velocity field, the velocities v_{c1}, v_{c2} of two chains could be computed by

$$|v_{c1}| = |v^*|\,|\cos\theta_{v^*} - \sin\theta_{v^*}|\,, \theta_{v_{c1}} = \begin{cases} 0 \;\; for \;\; \cos\theta_{v^*} - \sin\theta_{v^*} \geq 0 \\ \pi \;\; for \;\; \cos\theta_{v^*} - \sin\theta_{v^*} < 0 \end{cases},$$
$$|v_{c2}| = |v^*|\,|\cos\theta_{v^*} + \sin\theta_{v^*}|\,, \theta_{v_{c2}} = \begin{cases} 0 \;\; for \;\; \cos\theta_{v^*} + \sin\theta_{v^*} \geq 0 \\ \pi \;\; for \;\; \cos\theta_{v^*} + \sin\theta_{v^*} < 0 \end{cases}. \tag{1}$$

Based on the Equation 1, we could control the servo motors to construct a fast-responding omnidirectional velocity field.

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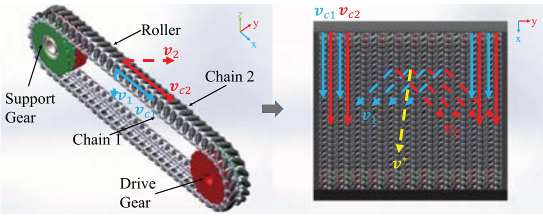

Figure 2: The mechanical design of the omnidirectional velocity field. The left image demonstrates the core components of our scheme, i.e. the two mirror-symmetrical chains. The right figure shows the system surface structure after arranging the two kinds of chains alternately.

3.2 Positioning Scheme

As Figure 3 shows, when the user standing on the center of the velocity field, record the length of the retractable rod by L. Take the Point1 as the coordinate origin. The user's current position coordinates could be denoted by $\mathbf{p}_0 = (0,0,-L)$. When the user walks to $\mathbf{p}_t = \left(x_t^p, y_t^p, -L\right)$, the spatial attitude of the retractable rod could be measured and denoted by the quaternion $\mathbf{q}_t = (w_t^q, x_t^q, y_t^q, z_t^q)$. The unit vector in this spatial attitude is denoted by $\mathbf{n}_t = (x_t^n, y_t^n, z_t^n)$, which could computed by the quaternion operation that $(0, x_t^n, y_t^n, z_t^n) = \mathbf{q}_t^{-1}(0,0,0,-1)\,\mathbf{q}_t$. Since $\mathbf{n}_t$ and $\mathbf{p}_t$ are collinear and in the same direction, the $\mathbf{p}_t$ could be computed by $\mathbf{p}_t = -\frac{L}{z_t^n}\mathbf{n}_t$. Here $\left(x_t^p, y_t^p\right)$ are the position of the user.

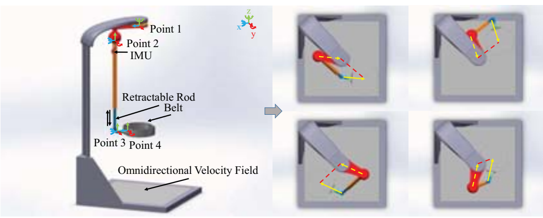

Figure 3: The IMU based positioning system. There are four rotation points. Each rotation point has specific rotation axes. No matter where the user standing on and which direction facing for, the line from the center of the user's body to Point1, i.e. the red dash line, is always parallel to the retractable rod.

4 Inertial Motion Capture System

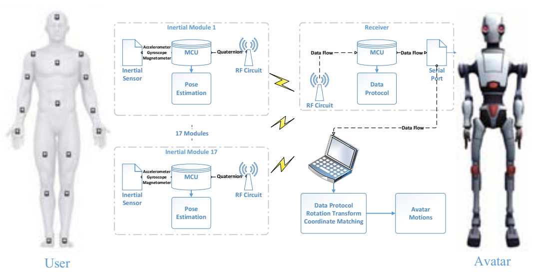

Figure 4: The inertial motion capture system. Each IMU estimates the pose orientation based on the accelerometer, gyroscope and magnetometer. Totally 17 IMUs are set on different part of human bodies to control the motion of the corresponding part of the avatar.

The inertial measurement unit (IMU) based motion capture [2] is a relatively mature technical solution, which has the advantages of strong real-time performance, high accuracy, and will not be blocked. Figure 4 shows our wireless inertial motion capture system. Each IMU only has 42g weight and the time delay is less than 20ms. It is possible to realize the real-time motion control of the avatar.

5 Application

We further develop the virtual environments to demonstrate the effectiveness of the different motion inputs include the locomotion input and body motion input. Figure 5 shows the video screenshots.

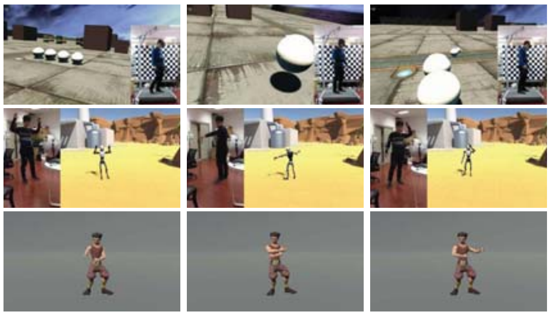

Figure 5: The first row shows the demo of HCP omnidirectional treadmill, which provides a room-scale locomotion input. The user could walk in infinite areas in the virtual world. The second and third rows show our inertial motion capture system using different avatars. It could provide a real-time and wireless body motion input.

6 Conclusion

This paper proposes an room-scale OMI system, which could provide the omnidirectional locomotion input and body motion input simultaneously. That is the basis of natural interaction in VR. However, there are still a lot of room for improvement, such as the camera-based markless motion capture could provides a more convenient experience; the height of the HCP can be further reduced and the control system can introduce some more advanced control strategies to get a more immersive experience.

Acknowledgments

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