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Demo

An Examination of 2-axis Distribution Method for Pseudo 6-axis Motion Rendering with a Rolling Two-Axis Motion Base

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Figure 1: *Pseudo 6-axis Motion Rendering results. From left: neutral, posture (pitch and roll), and inertia (surge and sway).*

Abstract

We propose a method that distributes the swing angle of a rolling 2-axis motion base in order to replace 6-axis motion with 2-axis rolling motion. In this study, we verified the validity of the proposed method by reproducing 6-axis motion in VR space with rolling 2-axis motion and comparing the posture and acceleration of the moving object on Unity with the VR tracker attached to the motion base. As a result, we found that the rolling 2-axis motion base can correctly follow 6-axis motion on Unity.

CCS Concepts

• ***Human-centered computing*** → *Virtual reality;* • ***Hardware*** → *Emerging interface;*

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1. Introduction

Recently, VR technology has advanced, and immersive VR experiences using motion bases, like shaking VR content and driving simulators, have become common. Typically, high-DOF motion platforms with multiple actuators are used to increase immersion by allowing motion in many directions. However, using many actuators complicates control and makes rapid movement challenging and costly due to the load on actuators. Therefore, we proposed a low-cost approach with a spherical body to reduce the actuator load significantly [WTH18]. This design uses two actuators to roll a spherical body, creating a rocking motion similar to a roly-poly. This simpler structure requires fewer actuators, making it more affordable.

However, when a rolling 2-axis motion base is controlled with 2-DOF inputs (pitch and roll), translational motion occurs and is considered as 6-DOF. Since vision affects perceived direction [KHK15], the use of visual compensation may make this extra motion less noticeable in VR. Currently, only 2-DOF angular input is available, which causes discrepancies when simulating pseudo-6-axis motion. Therefore, it is thought that the discrepancy can be reduced if 6-axis motion can be reduced to 2-axis motion. In this study, we first propose a method to replace 6-axis motion with 2-axis rolling motion. Reproducing 6-axis motion in VR and validat-

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ing its effectiveness by comparing the posture and acceleration of virtual objects in Unity with a tracker attached on a motion base.

2. System Overview

In this study, we develop a system that uses Unity to control a virtual moving object and render acceleration and posture to the occupants with a rolling 2-axis motion base. The user controls the moving object in Unity with a joystick and rocks a rolling 2-axis motion base based on the moving object's acceleration and posture information. Here, convert the 6-axis motion data of the moving object in Unity to 2 axes (pitch, roll) and reflect it in the motion base. Table 1 shows the details.

Table 1: *Distribution from 6-axis motion input to rolling 2-axis motion.*

6-axis Motion Input	Distribution to Rolling 2-Axis Motion
Pitch(X)	Pitch(X)
Roll(Z)	Roll(Z)
Yaw(Y)	Roll(Z)
Sway(X)	Roll(Z)
Surge(Z)	Pitch(X)
Heave(Y)	Pitch(X)

Specifically, information in the Pitch and Roll directions is used as is, with the acceleration and Sway directions replaced by Roll and the Surge direction replaced by Pitch; for the Yaw and Heave axes, of the semicircular canals that detect rotational motion in humans, the outer semicircular canals are tilted approximately 30 degrees upward in front from the horizontal plane. Therefore, it is thought that the yaw direction component is affected when motion is made in the Roll direction, which affects perception in the Yaw direction. For this reason, the motion direction axis is set to the roll direction during the presentation of rotational motion in the yaw direction. In addition, since the lateral semicircular canals (horizontal semicircular canals) are tilted forward from the horizontal plane, it is thought that the inertial force in the Y-axis direction due to the partial force of gravity can be presented by tilting in the pitch direction for the Heave axis as well.

Since there is a limit to the oscillation angle, the target oscillation angle to be transmitted by the motion base is determined by distributing -26°to 26°of oscillation in the Pitch direction and -26°to 26°of oscillation in the Roll direction for the 6-axis input and adding them together as the respective transmitted values. Table 2 shows the distribution of the target angle of a rolling 2-axis motion from the 6-axis input employed in this system.

As shown in Table 1, the 6-axis direction input values are distributed to the pitch and roll axes and sent to the motion base. For the Surge, Sway, and Heave directions, acceleration is calculated for each direction of the object's movement in Unity, and inertial force is presented by the motion base; the target sway angle is calculated using the formula $A = G \sin\theta$, where A is the inertia force and G is the gravitational acceleration due to the gravitational force. In this study, for rotational motion rendering to the Pitch, Roll, and yaw directions, the input of the rotation of the object in Unity is limited to the maximum value of the distributed oscillation angle of the rolling 2-axis motion.

Table 2: *Target angle of rolling 2-axis motion.*

6-axis Motion Input	Pitch[deg]	Roll[deg]
Pitch(X)	-11∼11	0
Roll(Z)	0	-11∼11
Yaw(Y)	0	-4∼4
Sway(X)	-11∼11	0
Surge(Z)	0	-11∼11
Heave(Y)	-4∼4	0
Total	-26∼26	-26∼26

3. Implementation and Vision

Figure 1 shows how the motion base simulates the acceleration or change of attitude of a moving object in Unity when it is operated with a joystick. When a moving object is accelerated, the motion base tilts to the angle necessary to represent the force of inertia equivalent to the magnitude of the acceleration in terms of the force of gravity. This allows the user to feel the inertial force by the force of gravity. When the posture of the moving object changes, the motion base tilts to follow the change in posture. In addition to these oscillations, the user is presented with pseudo-6-axis motion with a projector and or HMD to present the viewpoint of a passenger on a moving object in a VR space.

Currently, the state of the motion base is not fed back in real time, so the problem remains that the actuator is not optimally controlled, and the target swing angle and actuator expansion/contraction acceleration do not change appropriately depending on the situation. Additionally, if the actuator parameters constantly fluctuate, unnatural vibrations may occur, so it is necessary to consider a method to stably control the motion base.

4. User Experience

At ICAT-EGVE 2024 Demos, we will demonstrate our latest Pseudo-6-axis motion presentation with our motion platform that enables ±26°rotate.

References

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