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Demo

Avatar Walking Control with Sole Load

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Figure 1: *Comparison of user and avatar postures using a sole load device. From the left: the postures are neutral, forward walking, backward walking, rightward walking, leftward walking, right turning, and left turning.*

Abstract

We propose a low-cost avatar walking control method that can restrain the feet and estimate the avatar's walking and turning movements in all directions from the sole load. Walking devices are required to control avatars under spatial constraints, but there is still no optimal solution for walking devices. Therefore, in this study, we restrain the user's feet and estimate the avatar's walking and turning movements in all directions from eight loads on the front, back, left, and right sides of the soles of the feet.

CCS Concepts

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

1. Introduction

In recent years, the spread of VR technology has led to an increase in VR users. It is widely known that using only controllers to navigate smoothly in VR space while wearing an HMD easily induces VR sickness. On the other hand, methods that involve physically walking in VR carry risks of collision with obstacles and require large spaces, which limit the usability environment. To address this issue, there is a need for methods that enable efficient avatar control within confined spaces. Conventional VR-based walking devices include sliding surface [IF96] and treadmill types [Iwa99], which can provide users with a walking sensation close to reality. However, there are problems such as an uncomfortable feeling of feet slipping and difficulty in controlling the floor according to the user's movements. Therefore, we have proposed a walking device that supports the thigh [WTH18] to solve these problems, but in order to achieve omnidirectional walking, the device would be large-scale and the cost would increase. In this study, we propose a novel device that utilizes eight load sensors positioned on the front, back, left, and right of the soles of the feet. By using this device, it is possible to estimate the avatar's omnidirectional movement and turning motions, enabling omnidirectional walking at a lower cost.

2. Avatar Walking Control System

This system utilizes a foot device that users wear like slippers to enable avatar manipulation in a VR environment. This device is equipped with eight load sensors arranged on the front, back, left, and right of the soles of the feet to measure the user's weight fluctuations, with data sent to a PC via Arduino. The PC receives this sensor data through a COM port and retrieves it in real time within Unity using a serial receiver. The walking control system in Unity processes this load data to determine the stepping judgment, calculate the direction vector, and control the avatar. During this process, the avatar's movements are animated appropriately in response to the user's actions and output to the display.

2.1. Stepping Judgment

Before performing avatar control, a stepping judgment is implemented. This judgment determines whether the user intends to

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move, allowing the avatar to move only when the judgment is True. The judgment method first assesses whether the user's foot is a supporting foot (in contact with the ground) or a swinging foot (lifted off the ground). This determination is made by considering a foot as a supporting foot when the load sensor value exceeds a predefined threshold. Next, if the other foot becomes a supporting foot within 0.7 seconds, the stepping judgment is classified as True; otherwise, it is classified as False. Here, the 0.7-second threshold was established based on an analysis of five subjects' walking cycles, which ranged from approximately 0.3 to 0.7 seconds.

2.2. Movement Direction and Turning Angle

The walking direction of the avatar is determined based on the direction vector of the user's weight fluctuations. The direction vectors for left/right (x) and forward/backward (z) are calculated based on the difference in the average of their respective weight values. This can be expressed in equations (1) and (2).

$$x = \left(\frac{L_0 + L_1}{2} - \frac{L_6 + L_7}{2}\right) \tag{1}$$

$$z = \left(\frac{L_0 + L_3 + L_4 + L_7}{4} - \frac{L_1 + L_2 + L_5 + L_6}{4}\right) \tag{2}$$

Here, L_0 to L_3 for the right foot (right front, right back, left back, left front) and L_4 to L_7 for the left foot, similarly to the right foot.

Additionally, the turning angle is calculated simultaneously. This is done by assessing the twist of each foot using equation (3) and (4), with the larger absolute value being used as the avatar's turning angle.

$$yaw_R = \left(\frac{L_0 + L_2}{2} - \frac{L_1 + L_3}{2}\right) \tag{3}$$

$$yaw_L = \left(\frac{L_4 + L_6}{2} - \frac{L_5 + L_7}{2}\right) \tag{4}$$

Furthermore, these values are cubed and normalized to reduce noise. The maximum value used for normalization is set in advance by the user.

3. Implementation Results

Figure 1 shows the avatar's behavior while the user is walking forward, backward, left, right, and rotating, and it can be seen that the avatar behaves as intended.

To measure how accurately the avatar performs as intended, a quantitative evaluation experiment was conducted with five subjects. The experiment began by having the subjects perform various movements on the foot sole device while adjusting parameters to become accustomed to the actions. Subsequently, the subjects were instructed to take ten steps forward while shifting their center of gravity forward, and the lateral deviation during this process was calculated using the mean squared error. This operation was performed in all four directions (forward, backward, left, and right), and for lateral walking, the deviation in the forward and backward direction was calculated. Additionally, for turning, the subjects performed a 90-degree turn to the right or left, and the deviation from the true value of 1 (90 degrees) was calculated. Figure 2 shows a boxplot of data from five subjects.

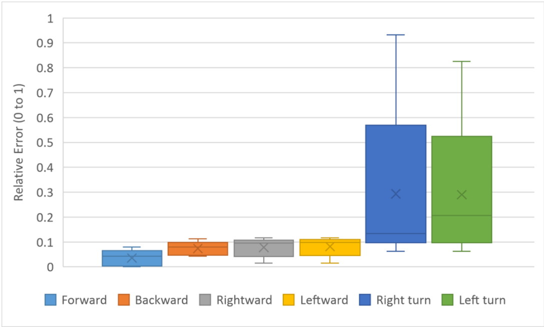

Figure 2: *Relative error in omnidirectional walking and turning movements.*

From this result, the mean squared error for omnidirectional walking falls within the range of 0 to 0.1, indicating that the implementation is functioning as intend-ed from a quantitative perspective. However, the error for the turning motion was significantly larger. Among the five participants, four had errors ranging from 0.06 to 0.22, while the remaining participants had results of 0.93 and 0.82. This discrepancy is believed to be because this participant's foot size was approximately 3 cm smaller than those of the others, resulting in the slippers not fitting properly and an inability to accurately capture the foot twisting motion. This suggests that it is necessary to develop a device that can accommodate various foot sizes.

4. Conclusions

In this study, we proposed a low-cost method for enabling omnidirectional walking by constraining the user's feet. Specifically, we estimated the avatar's omnidirectional walking and turning movements using data from eight load sensors placed on the front, back, left, and right sides of the sole. As a result, we achieved the intended outcomes for omnidirectional walking; however, it was confirmed that the results for turning movements varied depending on the size of the feet. In the future, we plan to make improvements to accommodate various foot sizes.

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