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Seamless-walk: Novel Natural Virtual Reality Locomotion Method with a High-Resolution Tactile Sensor

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ABSTRACT

Natural movement is a challenging problem in virtual reality locomotion. However, existing foot-based locomotion methods lack naturalness due to physical limitations caused by wearing equipment. Therefore, in this study, we propose Seamless-walk, a novel virtual reality (VR) locomotion technique to enable locomotion in the virtual environment by walking on a high-resolution tactile carpet. The proposed Seamless-walk moves the user's virtual character by extracting the users' walking speed and orientation from raw tactile signals using machine learning techniques. We demonstrate that the proposed Seamless-walk is more natural and effective than existing VR locomotion methods by comparing them in VR game-playing tasks.

Index Terms: Human-centered computing—Human computer interaction (HCI) —Interaction paradigms—Virtual reality

1 INTRODUCTION

Virtual reality (VR) allows us to experience new interesting spaces by creating a virtual environment (VE). However, existing space-efficient locomotion methods, such as point & teleport and arm-swing, are different from the actual gait motion. They require users to use their hands to locomote, fostering unnatural conditions. Thus, there is a gap between real-world and VE movements, which can provide an unnatural feeling of movement [1].

To address this issue, several foot-based locomotion techniques have been proposed, such as thread mill [2,3] and shoe-type interface [6]. However, these methods force users to wear equipment; thereby, constraining the human body and causing inconvenience for the users [4]. For example, most thread mill systems use a vest or railing to constrain users. Additionally, users have to wear a foot-equipment to use the shoe-type interfaces.

In this study, we propose Seamless-walk, a novel VR locomotion technique, to enable the real world's gait action as a virtual world's locomotion input using high-resolution tactile carpets [5]. The proposed method enables users to locomote on VE through walking-in-place (WIP). It identifies the user's intentions by extracting the direction and speed of in-place walking from raw foot pressure image. We employed machine learning techniques to process raw sensory signals produced by tactile carpet. Unlike existing WIP-based VR locomotion methods, the proposed method allows users to freely adjust locomotion without constraining their bodies. Furthermore, we evaluated the proposed Seamless-walk method on VR game-playing tasks and compared the result with existing locomotion methods. The result shows that the proposed method performs better than other widely used locomotion techniques in terms of natural locomotion. It is also effective when using hands and feet simultaneously to play VR games.

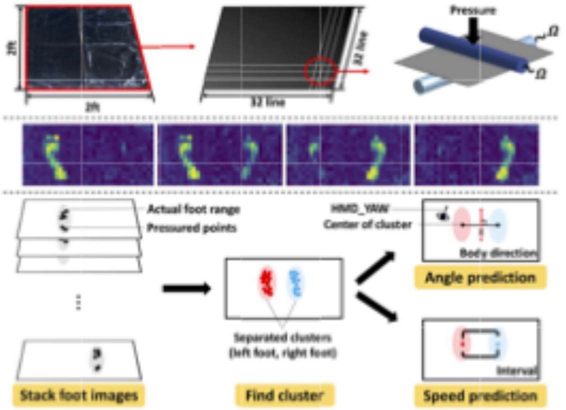

Figure 1: **Top:** Each sensing carpet tile is 2 ft x 2 ft in size with 32 x 32 sensors. Each sensor is locates at the intersection. **Middle:** Sensing responses from sensing carpet when a person is walking. **Bottom:** The clustering technique specifies the left and right feet using sensing response images to extract user movement.

2 METHOD

As illustrated in Figure 1 (top), our tactile sensing carpet is constructed by orthogonally aligning the electrodes on each side of the piezoresistive films. The sensing carpet enables measurement in real-time during the VR game, as shown in Figure 1 (middle). We use the proposed sensor and clustering technique to find the location of the user's feet (Foot1, Foot2) through pressured points in 14 consecutive sensing responses. Then, we find the body direction by taking the arctangent from the perpendicular slope of the straight line connecting the center point of each cluster (foot), as expressed in equation 1.

$$BD = \arctan\left(-\frac{Foot1_x - Foot2_x}{Foot1_y - Foot2_y}\right) \qquad (1)$$

After that, choose the moving direction by referring to the HMD yaw direction, as shown in Figure 1 (bottom). Additionally, we calculate the movement speed using the user's foot switching interval time. If the current interval time (I_c) is longer than the upper bound interval time (I_u), set speed 0. Otherwise, adjust speed in proportion

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