Presentation of Stepping Up and Down by Pneumatic Balloon Shoes Device

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Abstract. In recent years, to have a realistic experience in the VR space, various study and contents employed the sense of walking. In this study, we developed a light weight shoe-type VR device for uneven height presentation using pneumatically driven balloons. While previous shoe-type walking simulation device becomes heavy, the balloon enabled light-weight wearable device. The weight of the presenting device was about 430g on one foot and the thickness of the shoe sole when non-operation was about 1.0cm. We report the method of presenting stepping on the stage by the shoes device.

Keywords: Locomotion Device, Pneumatic Balloon, Height Presentation, Shoes Device, VR Device.

1 Introduction

Virtual reality (VR) is most commonly experienced through head mounted displays (HMDs). VR contents using HMD has become common. In order to have a realistic experience in the VR space, various study and contents employed the sense of walking, by using motion platforms, tactile presentation devices or large space [1][2][3][4]. On the other hand, most of these attempts supposed to walk on a flat surface, with addition of texture feeling by vibration [5][6][7] or MR fluid actuator [8].

On the other hand, presentation of topographical information, such as slopes and obstacles (e.g. stairs) is quite limited. Sugihara et al. developed ALF, which presents the uneven shape of the ground by placing hexagonal actuator units on the floor [9]. Noma et al. proposed a walking device that presents slopes and steps by providing segmented stages that operate up and down in the treadmill [10]. However, in the case of such install type walking devices, there is a problem that the cost is higher compared to a simple treadmill. In contrast, Schmidt et al. developed "Level-Ups", which is a wearable device that presents differences in surface height when climbing to a stage using a mechanism that raises and lowers the sole [11]. This type of wearable device is expected to widen the range of usage, but it still has the problem of heavy weight and size of the shoe sole is excessive.

In this research, we propose a shoe-type device consisting of pneumatic balloons actuated by vacuum pumps. The pneumatic balloon enables a significant reduction in weight and sole thickness compared with conventional devices.
This paper, reports the method to present the sensation of stepping on the stage by the proposed shoes device.

2 Height Presentation using Pneumatic Balloon Shoes

2.1 Overview of Height Presentation

Fig. 1 shows the height presenting shoes using pneumatic balloons. The weight of the device was about 430g on one foot and the thickness of the shoe sole when uninflated was about 1.0cm, which is within the range of ordinary shoe sole. Two balloons made of thermoplastic polyurethane are arranged in the front and rear of the shoe. The balloon expands to increase the height of the shoes. On the contrary, by pulling out air with the pump, the balloon contracts and returns to its original height when air is extracted with the pump. When inflated, the shoe was approximately 5.0 cm higher without load compared with non-operation state. When loaded with 60 kg weight person, it is approximately 3.0cm higher than the non-operation state. It took 700msec for Balloon to expand to its maximum, which is slightly slower than normal human footsteps, but endurable for basic experiments.
The position and tilt of the shoe are measured using a tracking device (VIVE Tracker (2018), HTC) attached to the top of the shoe, and they are reflected to the state of foots in the VR space. The balloon is expanded at the timing when the foot comes on the stage in the VR space as shown in Fig. 2. The user perceives the height change by stepping on the inflated balloon. In the case where the foot leaves from the stage, the balloon contracts and returns to its original height.

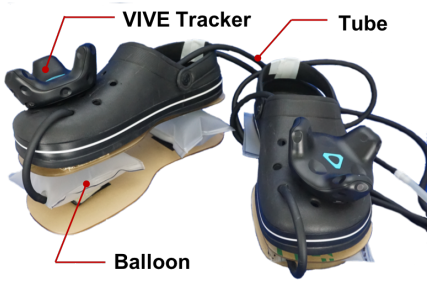

Fig. 1 Height presenting shoes using pneumatic balloons

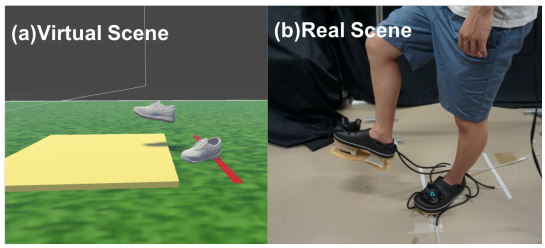

Fig. 2 State of height presentation using pneumatic balloon shoes: (a)Virtual Scene (b)Real Scene

2.2 Device Configuration

Fig. 3 shows the system configuration of this device. In this system, two vacuum pumps (VP 0940, Nitto Kouki) are used for one balloon, one for exhaust and the other for intake, to achieve faster response. By controlling the solenoid valves (VX 313, SMC) connected to the vacuum pump, the state of the balloon can be changed. The inflation of the balloon is controlled by two types of atmospheric pressure sensors for positive pressure and negative pressure and a microcontroller (ESP32-DeviKitC, Espressif Systems).

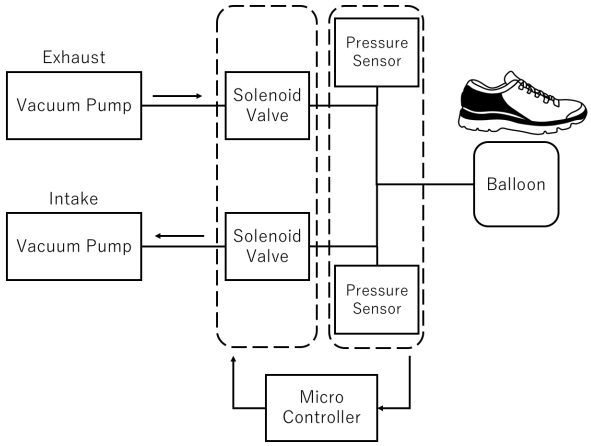

Fig. 3 System configuration of pneumatic balloon shoes

3 Conclusion

In this research, we proposed a shoe device using pneumatic balloons actuated by vacuum pumps as a method to solve the problem of excessive weight and thickness of previous shoe-type devices.

Our proposed device can present height of approximately 3.0 cm when loaded with 60 kg weight, and it is possible to dynamically present a stage in the VR experience. Current main issue is that, it takes 0.7 second to inflate the balloon to its maximum, which

is a little slow for natural walking. Furthermore, we found that the softness of the balloons made the experience not realistic. Our future works include improvements of these issues, and development an application to the VR scene.

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