맥동 피드백: 소프트 공압 액추에이터를 통해 인간 손목의 맥동 렌더링

Pulsating Feedback: Render Human wrist Pulse via soft pneumatic actuator

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Abstract

The present study suggests a haptic interface that operates on pneumatics for medical simulations in virtual and augmented reality. The interface provides haptic feedback to simulate the human pulse during interactions. To render touch and pulsating feedback on human skin, a soft actuator with a dual-layer silicon air chamber is utilized. The outer layer of the actuator provides skin touch feedback, while the inner layer generates pulsating feedback, making it well-suited for simulating pulsations on a human wrist artery. Furthermore, the study includes a numerical analysis to assess the perceptual outcomes of the proposed system.

1. Introduction

In medical simulation, pneumatic haptic feedback has become a useful tool that provides a realistic and interesting learning environment. This technology can mimic the touch and feel of actual bodily tissues, organs, and structures by using air pressure to provide tactile sensations. Healthcare workers will be able to better prepare for what they may experience during actual surgical procedures or other medical treatments as a result [1].

Most existing pneumatic actuators for training purposes are operated based on kinesthetic feedback [2, 3] and usually bulky in size. Participants engage with a virtual patient or anatomical model in a medical simulator that uses pneumatic haptic feedback by using special gloves, instruments, or other interfaces that have air-filled chambers attached to a pressure source. Trainees experience force feedback that mimics the feeling of handling genuine tissues as they perform virtual procedures. This helps them become familiar with the texture, resistance, and physical properties of diverse tissues and organs. For instance, a trainee may feel the resistance of the skin and the underlying tissues when the needle penetrated them while practicing suturing on a simulated wound.

Several studies have focused on simulate pulse beats using commercially available haptic devices. A software-based method to imitate human pulse feedback was proposed by Ullrich et al. [4]. To test their suggested system, they a haptic device that was readily available and a VR setup. In a different study, the author proposed a method that could synchronize the heartbeat with the tactile sense of the distant organ [5]. They have suggested an acceleration-based motion canceling bilateral control approach to provide the haptic feedback. A medical teaching and training system based on pulse simulation was created by Kandee et al. [6]. To provide force feedback in a virtual pulse simulation, they combined augmented reality technology, the Phantom Omni, and a physical medical training instrument.

Motivated by these aforementioned works, this paper proposes a dual-layered wearable soft pneumatic actuator that would allow for the semi-independent control of two distinct types of tactile feedback. Additionally, to demonstrate the potential uses of our suggested pneumatic actuator, we developed a human pulse rendering on the wrist artery along with a human skin touch feedback framework in a virtual reality environment. This kind of VR environment assists medical students and clinicians remotely checking a patient's pulse beat.

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The remaining paper is organized as follows. In Sections 2, we describe the proposed system. The experimental evaluation is explained in Section 3. Lastly, conclusions are drawn in Section 4.

2. Proposed System

Using our suggested actuator, the haptic pulse rendering is carried out in the VR environment. The entire suggested structure for the pulse rendering on the human wrist using the actuator is shown in Figure 1. The actuator consists of two distinct air chambers between the walls of the actuator to render two different kinds of feedback. To maintain the actuator's original shape, the exterior wall is made of a material that cannot be stretched using fiber-based tissue, while the inner wall can be stretched to deliver haptic feedback.

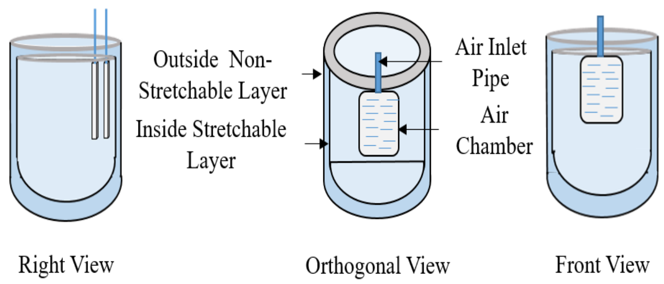

Figure 1: Design and operation of the proposed pneumatic actuator.

2.1. Overall Framework

The Unity game engine is also used in this effort to construct the VR experience. For our effort, we placed a fictitious human hand in the VR framework as shown in Figure 2. Leap Motion Controller [7] is used to track the user's hand while they interact with the simulated human hand in the VR environment.

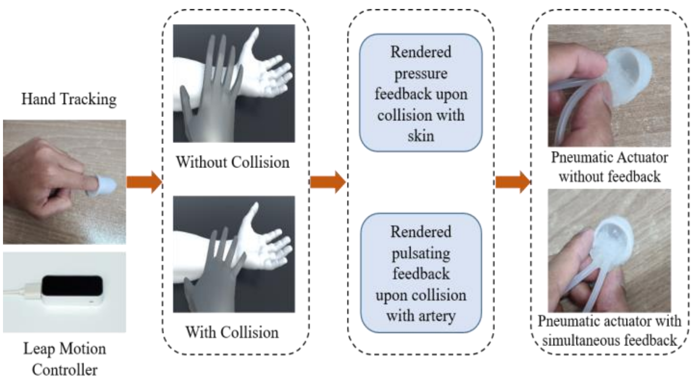

Figure 2: Flowchart of our proposed framework for haptic texture rendering using pneumatic actuator.

Figure 3 depicts the user's tracked hand avatar and a 3D virtual human hand model in a virtual reality setting. The user can real-time operate his hand in the VR environment after tracking. The user can feel pressure while interacting with the skin of the virtual human hand in the VR environment. The user can feel pulsation feedback together with pressure feedback from contacting human flesh when he moves his hand over the top of the wrist artery area.

Figure 3: 3D hand model and user's tracked hand avatar in VR environment.

In our work, the pulsating feedback rendering scene was designed using the unity engine 2019.3.5f1, and the solenoid valves (SC0526GC, 6V, 387mA) that were utilized to drive the pneumatic actuator were controlled using an Arduino Uno. Each solenoid valve is controlled by a mosfet transistor (TIP120), a resistor with a 10K Ohm value, and a diode (1N4007).

3. Evaluation

In this part, we evaluate the performance of the proposed approach with numerical experiments.

Figure 3 depicts the rendered pulsing feedback with pressure feedback for the representation of a human wrist pulse in the time and frequency domain. A three-axis accelerometer module (GY-61 ADXL335; Analog Devices, Inc.) was used to acquire the acceleration data.

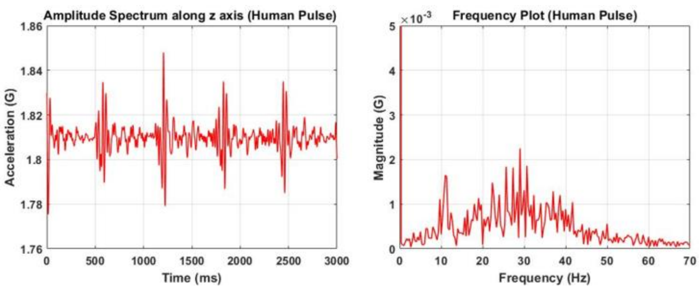

Figure 4: Rendered simultaneous pressure and pulsation feedback for human wrist in time and single-sided frequency domain.

4. Conclusion

In our study, we developed a new pneumatic actuator that gives users the ability to depict haptic pulses in a VR environment. By simultaneously sensing the high-frequency pulsation of the wrist artery and the quasi-static pressure of the human skin, this work aids a user in exploring a real human pulse beat on a human wrist using a finger. Finally, a numerical analysis is done to show how effective the suggested approach is. In the future, we'll combine our work with ECG sensor-based real-time pulse data collecting. In order to compare the performance of the proposed system with the current systems, we also intend to conduct a perceptual user study with their help.

Acknowledgement

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