

## **Development of Wearable Haptic Device Using Soft Materials to Deliver Kinesthetic Feedback in Virtual Environments**

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Fluidic actuation has been using in soft robotics to make grippers and actuators. Only a few of the studies have used fluidic actuation to produce kinesthetic feedback in virtual environments. A haptic device was designed to be used in the field of virtual reality to render kinesthetic sensations such as grip force, weight, and impact forces to the user. It was fabricated using silicone rubber (Ecoflex 00-30) and consists of several soft actuators. All actuators are capable of delivering forces to render the aforementioned kinesthetic sensations through pressurized air. Soft actuators were fabricated using a 3D printed mold which was made by acrylonitrile butadiene styrene. Each actuator can be actuated separately and simultaneously using a compressed air supply to achieve a complete device actuation. Atmel328 microcontroller was used to control the soft actuators with solenoid valves. Miniaturized DC air pump (12 V /-90×103 N m<sup>-2</sup> pressure) was used to supply the compressed air. The overall actuation of the device can be controlled by the microcontroller based on the virtual environment feedbacks. The result showed that the haptic device is capable of delivering forces by changing the shapes of soft silicone structures according to applied pressure. The relationship between the delivered force and the applied pressure was linear ( $r= 0.9975$ ,  $p\text{-value}= 0.4233$  and  $R^2= 0.9951$ ). In addition to that proposed haptic device has higher degrees of freedom and low weight compared to heavy mechanical developments. Therefore, soft material-based developments are effective to deliver kinesthetic feedback in virtual environments as per the findings of the study. Furthermore, higher user compatibility and wearability are additional advantages of the device.

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