Texture Simulation with One Degree of Freedom Normal to the Surface using a Loudspeaker

Oliver Snyder[1], George Stetten[1], and Roberta Klatzky[2]

Introduction: Many modern commercial technologies have, as one of their primary goals, to provide an immersive and engaging experience for the user, via smart phones, video games, computers, etc. Towards this end, monitors and loudspeakers have seen significant improvements in quality and/or price. However, haptic (the sense of touch) technology has lagged far behind audio and video. To advance haptic research and technology and enhance consumer immersion, the authors are developing an affordable Texture Simulation Device (TSD) to simulate 2D texture of a surface, by actuating with a single degree of freedom (DOF) normal to the surface, in response to motion tangential to that surface. The TSD will potentially have uses in virtual reality applications such as textiles marketing, as well as in basic psychophysics research. The goal of this project is to explore two primary questions: (1) Can a textured surface be simulated with only 1 DOF? (2) Will 1 DOF provide the right kind of sensation to fool the human brain? The TSD has evolved from a previous speaker-based haptic device that simulates tissue forces for surgery [Khera 2016].

Materials and Methods: With the goal of creating an affordable and reasonably high-quality simulation of surface textures, a 5" loudspeaker forms the primary 1-DOF actuator and a Raspberry Pi 3 (RPi) is used as the controller (Fig. 1). Three sensors provide input to the simulation. To sense position, a choice between a computer trackpad and a linear soft potentiometer (LSP) is provided. The trackpad returns 2D position and the LSP returns 1D position and force applied by the user. The third sensor is an optical distance sensor to provide the vertical displacement of the speaker cone. A 3D printed scaffold was created in SolidWorks and glued to the cone of the speaker to provide a sturdy platform for the trackpad and LSP.

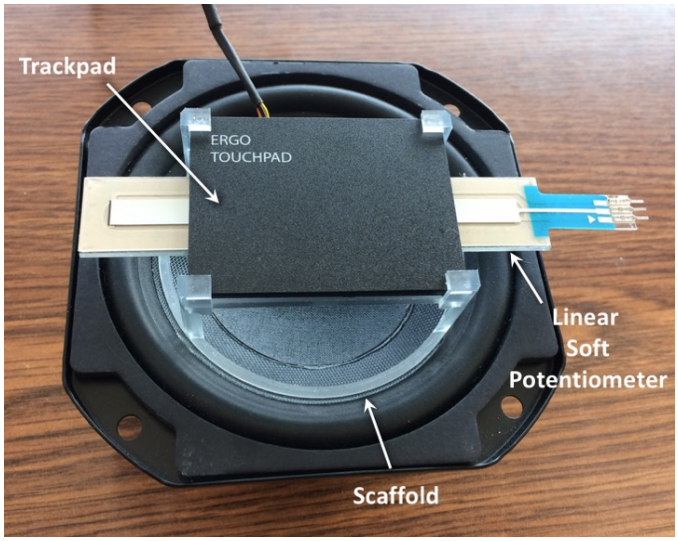

Fig. 1. Texture Simulation Device prototype.

Results and Discussion: Initial, informal testing revealed a multitude of unforeseen challenges in the device. The first is that the user must be isolated from confounding sensations such as native textures, surface friction, and audible noise. The noise problem has been solved with noise cancelling headphones, and the friction and native texture problem with a small strip of electrical tape wrapped over the skin in contact with the TSD. Another challenge is that which arises from trying to use an active surface to simulate what is normally passive. When the user actively explores the device's surface, a "riding" sensation rather than a texture is felt. To convince the brain that it is sensing a textured surface, the device must indistinguishably mimic a passive surface. Despite the difficulties encountered, there have been indications that the device may be successful. When sufficiently isolated, users have reported sensations produced by the speaker as "gritty" and "wavy".

Conclusions: We have made significant progress in developing a new, inexpensive device for rendering textures. A number of basic challenges have been identified and addressed. Further empirical research and development is needed to validate and understand the device.

Acknowledgements: Funded by the Swanson School of Engineering REU program and NSF grant IIS-1518630.

References: [Khera 2016] Khera, A. *Machines* **2016**, *4*, 9.

[1]University of Pittsburgh, Pittsburgh, PA, [2]Carnegie Mellon University, Pittsburgh, PA