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Enhancing Vibrotactile Signal Propagation using Sub-Surface 3D-Printed Waveguides

Ahmed Farooq[1], Hong Z. Tan[2], Roope Raisamo[1]

[1]Tampere Unit of Computer-Human Interaction (TAUCHI), University of Tampere, Tampere, Finland

[2]Haptic Interface Research Lab (HIRL), Purdue University, West Lafayette, USA

Ahmed.Farooq@tuni.fi Hongtan@purdue.edu, Roope.Raisamo@tuni.fi

SUMMARY

Vibrotactile feedback is affected by the properties of the material and structure that transmit vibration from an actuator to the entire device surface. Therefore, it is important to understand how the source vibration can be properly mediated or guided throughout the device to achieve globally uniform vibrotactile feedback. This research compares three off-the-shelf waveguide materials and one custom-designed 3D-printed ABS structure for creating feedback signals on a flat interaction surface. Results indicate that, compared to the three off-the-shelf materials, the 3D-printed Embedded Haptic Waveguide design with ABS plastic can mediate the applied signal throughout the entire actuation surface more efficiently.

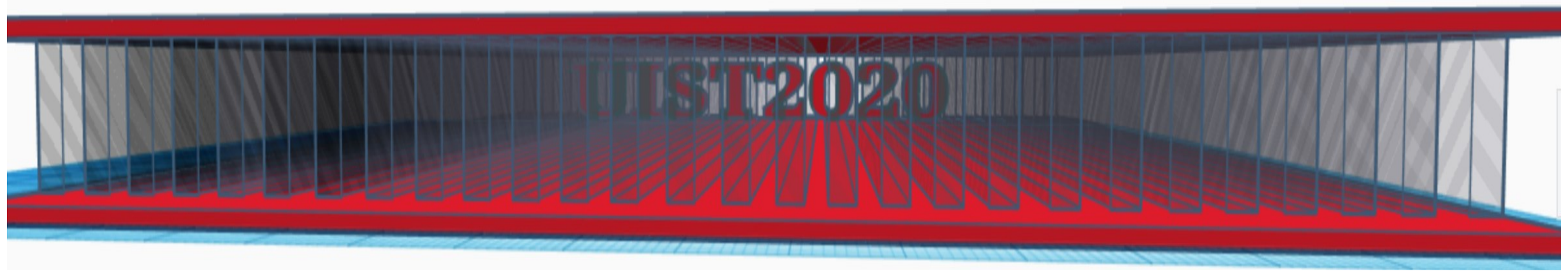

Figure 1. Custom designed 3D-printed Embedded Haptic Waveguides (EHW) with 1:1 ratio of solid waveguide to empty space.

DESIGN AND SETUP

Our novel EHWs design uses multiple waveguides within the 3D-printed object of 1.5mm chambers (Fig. 2) with a ratio of solid waveguide to empty space of 1:1. We also tested solid waveguide to empty space ration of 1:1.5 to calibrate higher frequency signal mediation.

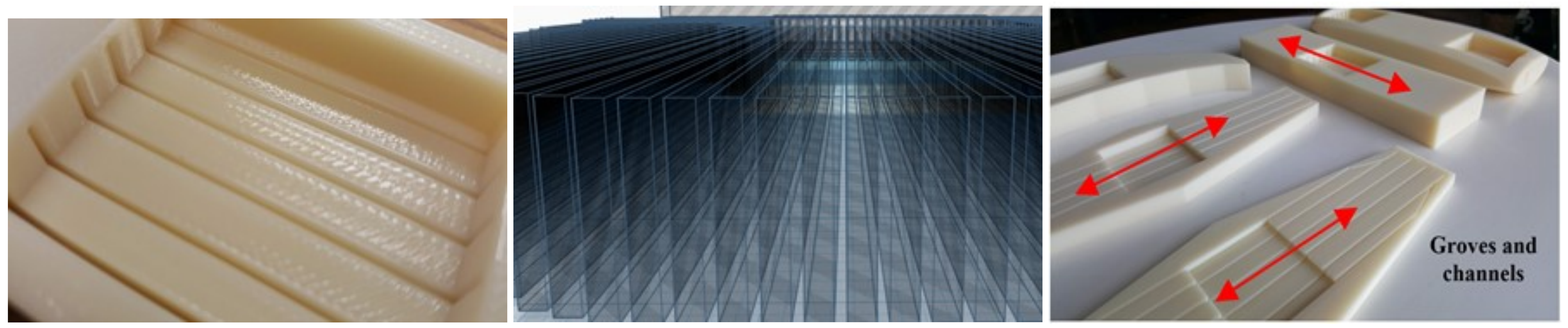

Figure 2. 3D-printed waveguides with embedded shafts (center); various prints with surface/subsurface groves (left & right).

We attached a Tectonics TEAX14C02-8 actuator on top of each waveguide surface and used a unidirectional piezoelectric sensor (WS-16025YDW) to measure the vertical components of vibration introduced by the actuator at 95mm from the actuator (Fig. 3). 22 university students (8 male, 14 female) felt a 120Hz sinusoidal signal generated by the actuator on each surface at two discrete points, A 28mm and B 190mm away. The participants rated the perceived difference between the signals felt at point A and point B on a scale of 0-10, where 0 represented no difference and 10 represented completely different signals (Fig. 6).

Figure 3. Experimental Setup; Gorilla glass (left), Aluminum (center) and Plexiglas (right) attached to a Microsoft Surface Pro 3 tablet device

RESULTS AND DISCUSSION

Results show that the custom-designed 3D-printed waveguide was able to relay the actuation signals with the least attenuation and distortion compared to the other three surfaces. This is visible at all the measured frequencies (100Hz, 140Hz, 180Hz and 220Hz) in a similar 3D-printed ABS surface (Fig. 4) as well as the 4 sampled surfaces (Fig. 5).

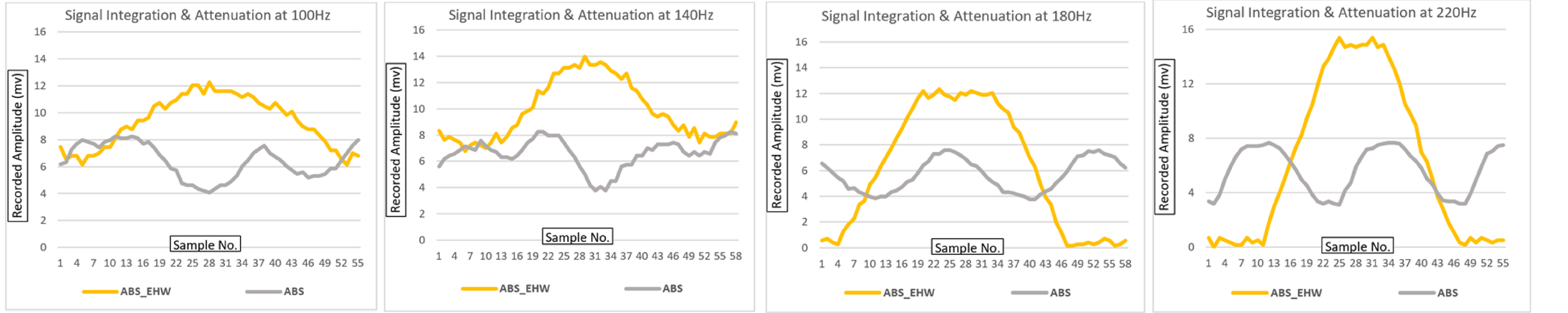

Figure 4. Comparision between common ABS plastic and ABS Embedded Haptic Waveguide surfaces at 100, 140, 180 & 220Hz averaged over 500 samples per frequency range.

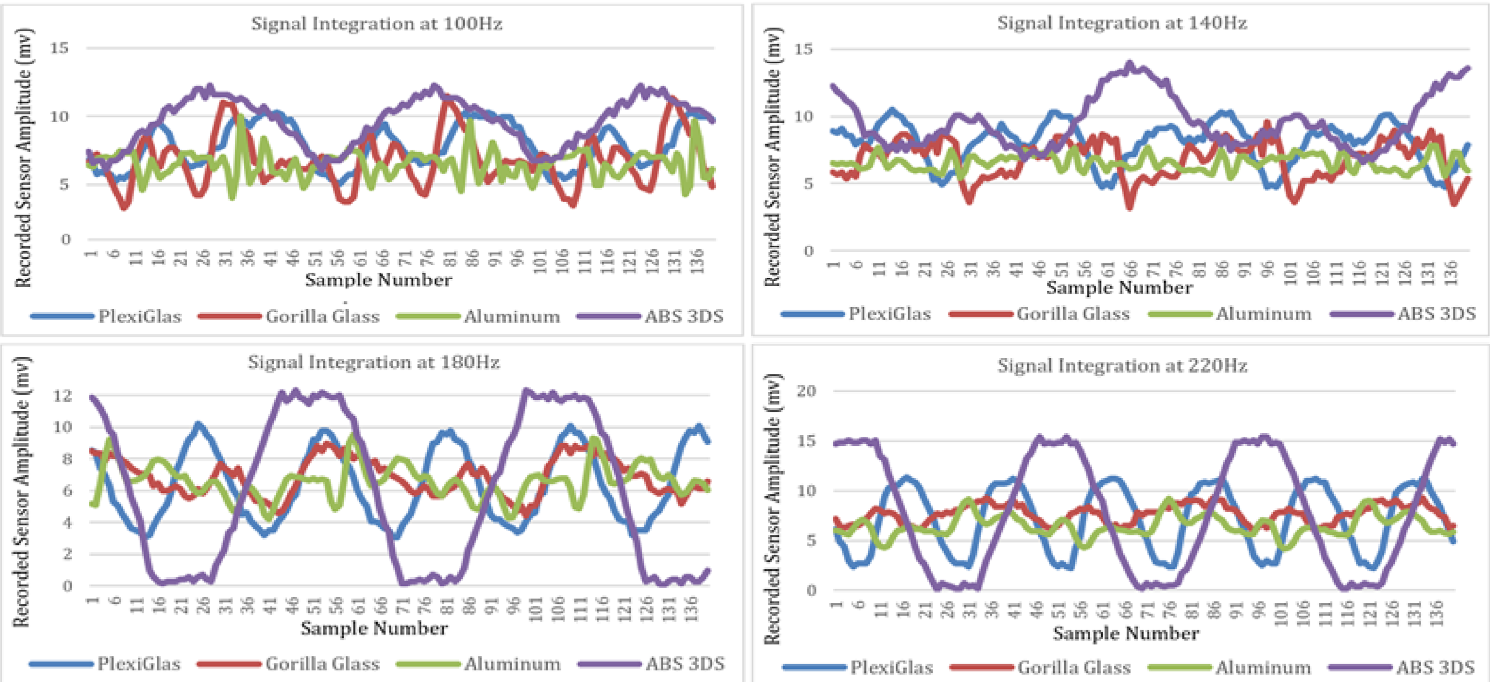

Figure 5. The variations in Applied and recorded signals for all 4 samples (Plexi -Glas, Gorilla glass, Aluminum and ABS EHWs) at 100, 140, 180 and 220Hz.

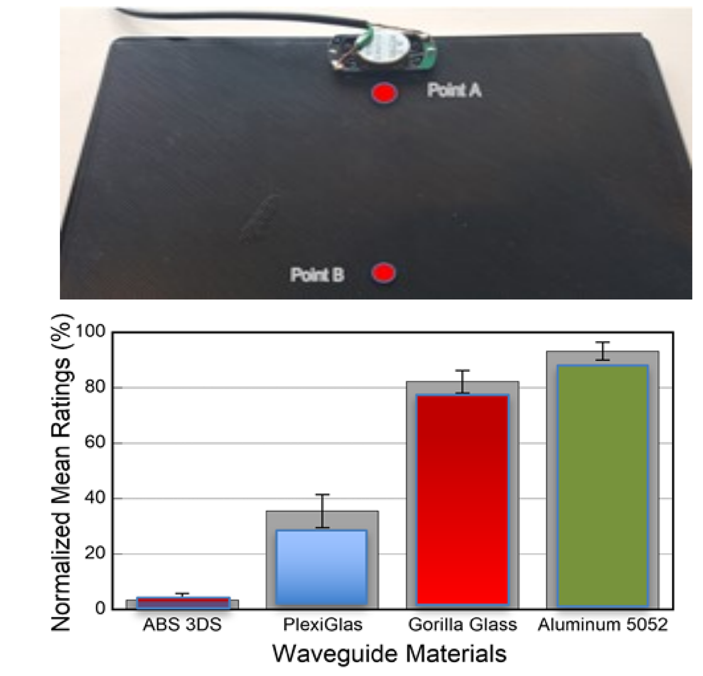

Figure 6. The Comparison in mean ratings of perceived differences between signals at points A and B for all 4 surfaces

Custom designed 3D-printed waveguides are more efficient and can improve vibrotactile feedback in devices where actuation components are embedded within different materials and are located at a distance from the surface or are not in direct contact with the users' skin.

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