Generating Virtual Tactile Exciter for HD Haptics

a Tectonic Actuators' Case Study

Patrick Coe, Ahmed Farooq, Grigori Evreinov and Roope Raisamo
The Faculty of Information Technology and Communication Sciences, Tampere University, Finland
{name.family}@tuni.fi

Abstract— **Propagating of haptic signals to the finger(s) location from actuators embedded within a mobile device depends on the acoustic impedance of the conductive environment. Parameters of constructive interference such as time-shift and magnitude also play a crucial role in creating effective haptic feedback at the point of contact. However, Propagation of standing waves along deformable surfaces, such as Gorilla glass, quickly attenuates vibration signals, drastically reducing the efficiency of perceivable haptic signals. In order to facilitate signal propagating parameters and create HD haptics, it is necessary to use materials that effectively transfer vibration signals within a mobile device. To minimize attenuation, a display overlay pouch sealed with liquid can be used. In this paper we demonstrate the ability to generate a virtual tactile exciter as the result of the interference maximum of two Tectonic actuators affixed to the display of a Microsoft Surface Go tablet as well as to the display overlay pouch sealed with liquid. For both the liquid mediator and glass surfaces we revealed high similarity in the trend of peak-to-peak values of interference maximum indicated by Excel's LINEST function (0.9805). We also found that the interference maximum in the pouch sealed with liquid to be 19.06dBV greater than that of the tablet. The results can be used for creating HD haptics and applications.**

Keywords—high definition haptics; virtual tactile exciter; interference maximum; liquid haptic mediator

I. INTRODUCTION

High Definition (HD) haptics requires strictly localized tactile feedback be created alongside HD images on the display of a mobile device such as a smartphone. This functionality is not yet provided by any off-the-shelf tactile display. Current actuation techniques cannot accurately generate localized sensations to the specific region of finger(s) contact, without additionally having to accurately and remotely track finger(s) location. Existing displays based on matrices of (piezoelectric) actuators dedicated to the creation of local interference maximums of vibration at a small region of skin contact have been tested and demonstrated to show a promising measure of success. Unfortunately, using opaque matrices of actuators for local stimulation over displays are not suitable for integration with mobile devices [1].

Propagation of standing waves along Gorilla glass quickly attenuate a vibration within a range of perceivable haptic signals (50-300Hz). This loss due to attenuation does not allow for an interference maximum between actuators to be greater than the signal applied to each of the actuation components. Therefore, the user tends to locate the virtual source of haptic signal (phantom vibration) close to the location of a physical actuator. That is, available technology of linear resonant haptic actuators and the multi-component layered configuration of mobile devices limits the possible solutions for HD haptics suitable for human skin stimulation. An effect also known as the funneling effect.

To avoid attenuation of generated haptic signals, authors of the paper were granted a number of patents which use mediation technology [2-5] that allows minimized degradation of transducer signals to the point of finger contact. Calibration of time shift between two actuators working at resonance frequency can stabilize the conditions for achieving an interference maximum greater than each of the components of the resulting signal in a specific environment (mediator). Based on the matrix of time-shift calibration it would be possible to get a predicted virtual haptic source at the point(s) of finger(s) contact with higher accuracy and efficiency than on human skin.

In this paper we have demonstrated the results of the comparative study of generating a virtual tactile exciter with the use of two Tectonic actuators affixed to the display of MS Surface Go tablet (Gorilla glass) on a distance of 16 cm and to the display overlay pouch sealed with liquid which is intended to facilitate transfer vibration signals with a minimum attenuation, according to the patent application US20160011666 [5].

II. EXPERIMENTAL DESIGN

In our experimental design we wanted to create a set-up that would use a user familiar interface. We setup two interface patterns for comparison. One using the Gorilla glass surface of a tablet while the other incorporated a 100-um polyester sheet of plastic surface placed in direct contact over liquid (distilled water) bordered with a frame of plexiglas. This was done in order to compare the differences of applying actuated vibration signals in off-the-shelf product vs that of what might be an ideal medium.

To apply force to the display we used the Tectonics TEAX1402-8 actuator. It is relatively compact in size, specifically designed to excite a rigid panel. The actuators can be powered by a motor controller or driver, such as the Cytron MDD10A full-bridge dual channel DC motor driver. In our set-up we are using an Arduino DUE to control the driver. The

---

This work was supported by project Multimodal In-Vehicle Interaction and Intelligent Information Presentation (MIVI), funded by Business Finland (grant 8004/31/2018).

Arduino operates on an 84Mhz clock, allowing microsecond precision for generating haptic signals.

Surface Go incorporates a Gorilla Glass 3 display with a slick oleophobic layer. Normally this is desirable as it keeps the display clear of fingerprints and slightly slippery to the touch. In our case, these properties proved to make physically attaching the actuators to the display, problematic. In order to produce accurate results, the actuators need to be placed firmly in an identical manner. Slight movements or deviations can significantly alter the behavior of the set-up. Adhesives such as '3M Scotch™ double sided bonding pressure sensitive tape' do not adhere to Gorilla Glass 3 properly. Our solution was to apply a layer of epoxy glue under a bonding tape coated, where epoxy glue was retained using a stiff paper until the glue fully polymerized. The actuators would be affixed to the bonding layer. This delivered the most accurate results (Fig. 1).

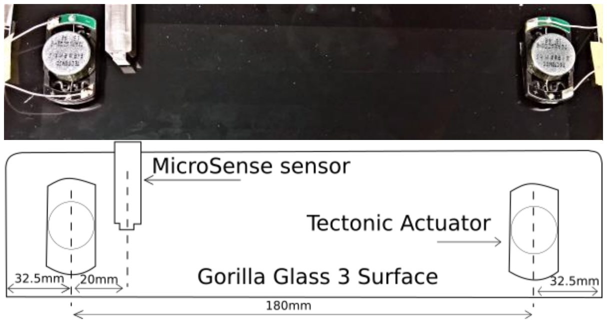

Fig. 1. Tablet set-up.

The forces applied to the glass were affected by the placement and size of the adhesive strip that attached the actuator to the display. We used an adhesive strip size of 16 mm, which fit to the Tectonic actuator frame. Placing the MicroSense capacitive sensor on the display at 20mm from the actuator gave us an average amplitude of 1.81V on the left actuator and 2.39V on the right actuator. The aim is to have these values as close as possible to each other as that meant the force applied to the glass is relatively equal on each side. The time-offset of the interference maximum at a location was not affected by the difference in amplitude between actuators.

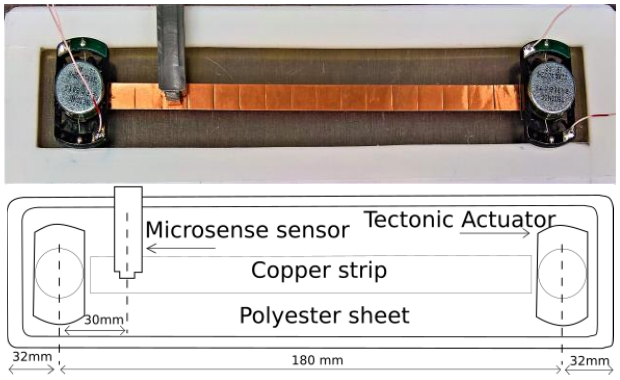

Fig. 2. Display overlay pouch sealed with liquid set-up.

For our second set-up (Fig. 2) we wanted to create an ideal medium for wave propagation with minimal loss due to attenuation. For this reason, we used distilled water sealed under a plastic layer. Water was placed in a polycarbonate frame with a plexiglass backing and a polyester sheet of flexible plastic surface. Air bubbles were then removed with a hypodermic needle placed through the adhesive layer under the plastic surface. The amount of liquid in the container also changed the properties of our surface. As full capacity was reached the surface became stiffer with a visible outward curve. This, in turn, reduced the measurable peak vibration as the surface had less compliance with the load the actuator was able to provide (Bl Force factor 2.4 Tm). Therefore, it was important to leave some flexibility to get the strongest vibration through the surface. We used 33 ml for our setup.

III. MEASUREMENTS AND RESULTS

To determine at what offset or delay constructive wave interference occurred we measured the resulting vibration signal at a given point using the MicroSense sensor (Model 5622-LR Probe, with 0.5 mm x 2.5 mm rectangular sensor). The sensor has an accuracy of 0-±200um at a noise of 3.44 um-rms @5kHz amplified with Gauging Electronics until ±10V and attenuated to a range of 0 to 5V to be compatible with Arduino analogous input.

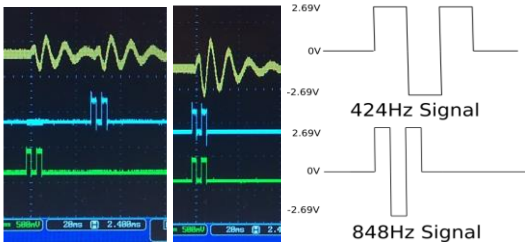

Fig. 3. Monitored view of tablet set-up via oscilloscope (on the left). Unipolar oscillograms of vibration signals have been taken from grounded resistors in a circuit of full-bridge amplifiers. Measurements recorded at 80mm from the left actuator. Example of the Haptic signal received by the Tectonic Actuator (on the right).

In each set-up measurements have been done at 10mm steps from the left hand actuator. For each 10mm step measurement have been recorded at 1ms intervals for an offset ranging from 0 to 30ms before and after triggering the left actuator. The measurements consist of the MicroSense data during the offset as well as 10ms after the second vibration signal was triggered. A peak-to-peak voltage measurement was made for each measurement. The offset with the largest peak-to-peak maximum was where we were able to record the largest range in vibration, and where constructive wave interference occurred.

Making superposition of five measurements at a single point determined that there was a negligible amount of variability between measurements. This meant that in our experience the results were stable and reproducible.

Fig. 4 is an example of five measurements made on the display overlay pouch sealed with liquid from an offset pulse measured at 8cm from the left actuator. Right actuator is triggered 1ms before the left actuator was excited.

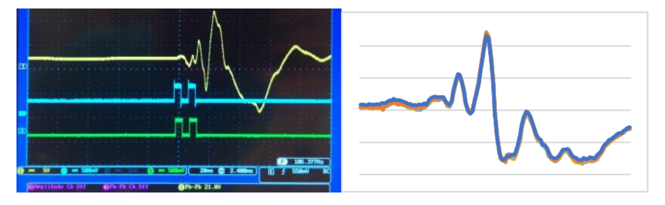

Fig. 4. Example of haptic vibration outside of MicroSense sensor dynamic range (on the left). Superposition of 5 pulses showing that there is a negligible difference between measurements (on the right).

Although previously we had found that a 212hz (4.717ms) pulse to be at or near the resonance frequency, we found that we could not use this pulse for data gathering. In our tablet set-up the strong pulse resulted in a stick-slip effect, which introduced additional unpredictable movement of the whole tablet and/or overlay. In our display overlay pouch sealed with liquid set-up the same strong pulse resulted in vibrations beyond the dynamic range of the MicroSense sensor (±10V output, as shown in fig. 4). Therefore, we would be required to reduce the generated signals length to gather comparable data for both setups. All pulses described operated at ±2.69V.

In order to keep measurements within the dynamic range of the MicroSense sensor, the pulse of the pouch sealed with liquid set-up was reduced to 848Hz. For the tablet set-up a 424Hz pulse was chosen as the 848Hz resulted in a vibration too weak to be properly measured by the MicroSense sensor.

An example of constructive haptic wave forms can be viewed in Fig. 3. In the left image the actuators are excited 30ms apart leading to very little wave interference. In the right image the actuators are excited simultaneously leading to visible constructive interference.

The charts in Fig. 5 show the offset required to reach maximum peak-to-peak interference values. The X-axis represents the time-offset between haptic vibrations starting from the left actuator. A negative value means that the right actuator was excited prior to the left actuator. The Y-axis represents the measurement records points with a 10mm step in centimeters from the left actuator. For both liquid and glass surfaces we revealed high similarity in the trend of peak-to-peak values of interference maximum indicated by Excel's LINEST function (0.9805).

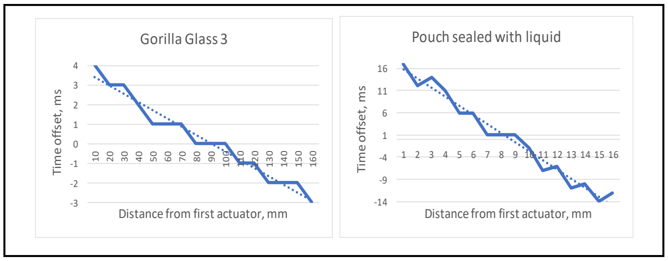

Fig. 5. Charts of maximum peak-to-peak values. (X-axis is the value of the time offset. Y-axis is the measurement step).

As expected, near the center (80-90mm) we found that constructive interference occurs at a delay of at or near 0ms. It takes the same amount of time for a wave to reach the center from either actuator.

We can also observe that the waves propagate quicker through the Gorilla glass of the tablet rather than through the liquid. For example, data at the 20mm point demonstrated that for wave interference to occur we need to excite the second actuator 2ms after the first actuator on the tablet, while through the liquid this delay increases significantly to 12ms.

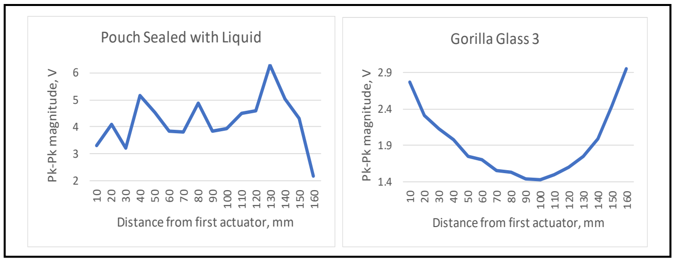

Fig. 6. peak-to-peak Voltage measurements corresponding to the previously found time offset constructive wave maximum.

The pouch filled with liquid demonstrated less loss due to attenuation than the Gorilla Glass 3. In the setup with Gorilla Glass 3, shown by chart in Fig. 6, a consistent minimization of maximum peak-to-peak voltage is shown. The lowest values appearing near the center of the glass interface. This point is the furthest away from the two actuators. The Pouch Sealed with Liquid is more variable likely due to the inconsistent shape of the polyester surface as it interacts with the filled liquid, as seen from Fig.6. Nonetheless, our results did not reveal the same loss curve as in Gorilla Glass.

Using Measurements of the peak-to-peak Voltages on both the tablet and the pouch filled with liquid at 848Hz at 130mm from the left actuator gives us a difference of 19.06dBV. Given identical haptic signals the liquid pouch exhibits far less loss due to attenuation.

IV. CONCLUSION AND FUTURE WORK

It has been demonstrated that for generating haptic signals with a virtual tactile exciter at a 10 mm step constructive wave interference is possible with the use of two haptic exciters. It has also been demonstrated that for a given material as a liquid mediator (distilled water) wave propagation is consistent. Therefore, it may be possible to save the necessary offset signal required for a given point on a display into a calibration matrix. Understanding that a modern display would then be capable of presenting this higher efficiency vibrotactile feedback with precision to a user.

With the current placement of the two haptic exciters we measured a significant loss due to attenuation. In the future this might be remedied by bringing the haptic exciters closer together. For example, at a distance more like that of a mobile phone display rather than a tablet.

The propagation of these vibrotactile signals is affected by the material they propagate through. In the pursuit of High Definition haptics, it might be useful in the future to explore the propagation properties of other mediation materials, such as various thickness of gels.

REFERENCES

[1] Ch. Hudin, J. Lozada and V. Hayward, “Localized Tactile Feedback on a Transparent Surface Through Time-Reversal Wave Focusing,” IEEE Transations on Haptics, 2015, vol. 8, n. 2 pp. 188-198.

[2] G. Evreinov, A. Farooq, R. Raisamo, A. Hippula, D. Takahata, K. Ikehama, T. Arasawa, “Living Body Stimulation Device And Living Body Stimulation Method,” US9485964B2, Nov. 8, 2018.

[3] G. Evreinov, A. Farooq, R. Raisamo, A. Hippula, D. Takahata, “Haptic Device,” USA Patent US9789896B2, Oct. 17, 2017.

[4] G. Evreinov, A. Farooq, R. Raisamo, A. Hippula, D. Takahata, “Tactile Imaging System,” USA Patent US 9672701B2, June 6, 2017.

[5] G. Evreinov, A. Farooq, R. Raisamo, A. Hippula, D. Takahata, “Tactile Type Device,” JP Patent Application JP2014141264A and USA Patent application US20160011666, Jan. 14, 2014.

[6] H. Kato, Y. Hashimoto, and H. Kajimoto, “Basic Properties of Phantom Sensation for Practical Haptic Applications,” A.M.L. Kappers et al. (Eds.): EuroHaptics 2010, Part I, LNCS 6191, Springer-Verlag Berlin Heidelberg, 2010, pp. 271-278.

[7] D. Alles, “Information Transmission by Phantom Sensations,” IEEE Transactions on Man Machine Systems, vol. 11, n. 1 (1970), pp. 85-91.

[8] H. Richter, A. Hang, B. Blaha, “The PhantomStation: Towards funneling remote tactile feedback on interactive surfaces,” In: Augmented Human International Conference (AH'11), March 12-14, 2011, Tokyo, Japan, Article No. 5.