Wireless Vibrotactile Tokens for Audio-Haptic Interaction with Touchscreen Interfaces

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ABSTRACT

New interfaces for vibrotactile interaction with touchscreens are realized. An electromagnetic design for wireless actuation of 3D-printed conductive tokens is analyzed. Example music interactions are implemented using physical modeling paradigms, each investigated within the context of a particular token that suggests a different interaction metaphor.

Author Keywords

haptic, token, vibrotactile, touchscreen, physical modeling

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, H.5.2 [Information Interfaces and Presentation] User Interfaces—Haptic I/O.

1. INTRODUCTION

Low quality equipment has the potential to interfere with expressive music performance and music production. For this reason, musicians often seek to use the highest quality equipment available. However, much of the touchscreen-based haptic technology available on the commercial market is aimed at inexpensively providing simple notifications, rather than for supporting live music performance using continuous gestures.

For example, previously the fidelity of touchscreen actuation technology for has been limited by the following characteristics:

- actuator designs have caused slow startup and stop times of haptic excitations [6],
- actuator designs have limited the frequency range of excitations to a narrow bandwidth [5, 7],
- the rigidity of touchscreen and device enclosures have limited clearly perceptible vibrations to higher frequency ranges [2], and/or
- more recent approaches to surface haptics have modulated the friction of the user's finger moving along a touchscreen; however, these approaches have been limited to frictional forces–for example, they have not been able to exert forces on a stationary finger [2].

The present work aims to improve the fidelity of vibrotactile haptics for touchscreen interfaces, take advantange of pressure-sensing capabilities available in new touchscreen devices, realize a wireless token-based actuator design emphasizing metaphor and craft, and explore these from the perspective of enabling users to play virtual musical instruments via an enhanced haptic interface.

2. ELECTROMAGNETIC DESIGN

The present design operates as follows. A touchscreen is laid flat on a table, a coil is placed around the perimeter of the touchscreen, and a current is made to run counterclockwise around the screen perimeter (into the page on the right and out of the page on the left in Figure 1). If a permanent magnet in is placed on top of the touchscreen in the field (see the "N S" (purple) rectangle in Figure 1), a torque and force can be exerted on it [3]. For example, a dipole magnetic moment vector u can be drawn progressing from the south pole S of the magnet through the north pole N of the magnet. The exerted torque (see the dash-dotted red arrow in Figure 1) will primarily serve to rotate the magnet so that its vector u aligns locally with the magnetic field induced by the solenoid (see the simulated field lines with many black arrows in Figure 1). When the permanent magnet is inserted inside a 3D printed token as shown below, then the whole token will tend to rotate.

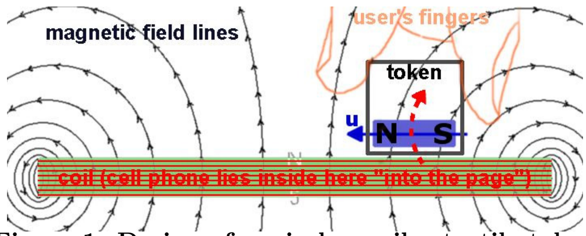


Figure 1: Design of a wireless, vibrotactile token.

Because the token is printed using a conductive material, touch gestures are conducted through the token into the touchscreen surface, leveraging touchscreen gestures typically used by touchscreen apps.

3. EXAMPLE MUSIC INTERACTIONS

Using the left audio headphone output for listening and the right output to control the coil, vibrotactile feedback can be provided for a wide array of musical instrument apps available in the App Store. The authors designed additional apps using the physical modeling paradigm to enable testing of wireless, vibrotactile token affordances.

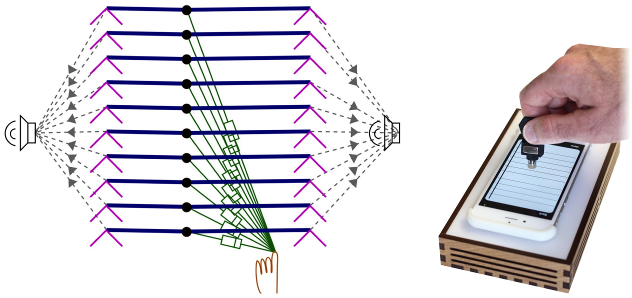
3.1 Linearly Plucking a Virtual Harp

The iPhone 6S/6S+, which first became available in Fall 2015, was the first iPhone series that could not only sense multiple touches simultaneously, but could also estimate the downward pressure applied with each of these touches. To test this functionality, it was decided to simulate a bed of

NIME'16, July 11-15, 2016, Griffith University, Brisbane, Australia.

strings, for which **the virtual plectrum stiffness, both for computing the haptic feedback and the audio signal, was set to be proportional to the downward pressure applied**. The plucking point along the strings was adjusted according to the x-position of the token, realizing an additional intuitive timbreal control.

Because the physical model was computed using Synth-A-Modeler [1], a relatively low frequency component was perceptible haptically. This component seemed to be enhanced via the vertical height of the plectrum token, which because of the torque shown in dashed (red) in Figure 1, may have been transmitted to the user's fingers not only as a torque but also as a horizontal force, acting through the 3D printed token as a lever. It was informally determined that this haptic feedback made it possible to more precisely play the individual strings, even if the torque polarity was reversed, and the pressure-sensitivity seemed to be useful for naturally controlling the dynamics of the sound.



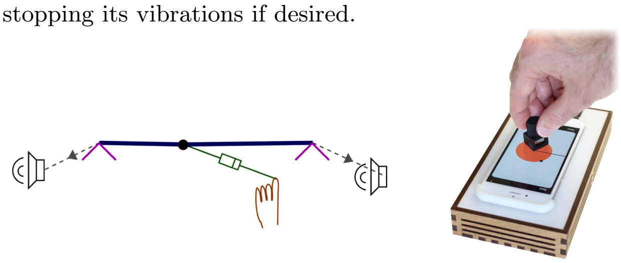
(a) Physical model (b) Plectrum token

Figure 2: Plucking a virtual harp of ten strings.

3.2 Rotationally Plucking a Virtual String

Due to the pervasiveness of rotational dials in audio engineering, a **dial token** with an embedded magnet was created, and it was decided to use this to rotationally pluck a string. This interaction was realized as follows: a horizontally oriented virtual string appeared on the touchscreen wherever the token was placed (see Figure 3b). Then, **whenever the user rotated the dial such that the dial indicator passed over the virtual string, the physical model acted to calculate the sound and the haptic feedback** as represented in Figure 3a. The y-position of the dial was employed to bend the pitch over two whole steps, and the x-position was employed to adjust the brightness of the string sound.

As with the previous model, informally it seemed to the authors that the haptic feedback made it easier for a user to play the model more accurately since the user could feel the string before plucking it, as well as feel the string while stopping its vibrations if desired.

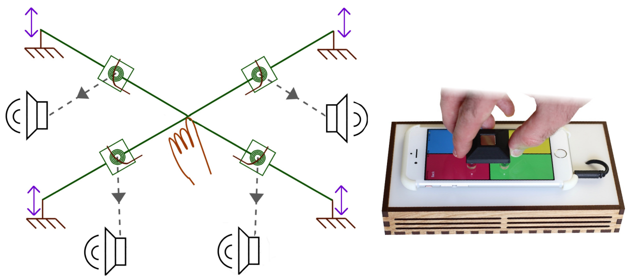


(a) Linear representation of model (b) Dial token

Figure 3: Rotationally plucking a single string.

3.3 Four-Way Crossfading with a Joystick

Tokens with multiple feet were also explored for sensing tilt. For example, **four-way crossfading was realized using a "joystick token" with four conductive feet**, each of which pressed on a differently colored corner of the screen (see Figure 4). By using each corner to control the volume of a rhythm track (via the nonlinear touch links shown in 4a), it was possible to crossfade between synchronized rhythms using only the most minute movements of the joystick token, while the volume could be controlled via the average downward pressure applied to the joystick. This control seemed to be intriguing in the opinion of the authors. In the future, using more advanced detection of (more mobile) joystick corners, the authors believe it could be fruitful to try combining this control with dial-like functionalities.



(a) Physical model (b) "Joystick" token

Figure 4: The pressure applied in each color region effectively modulated the average stiffness of the nonlinear touch links ( ), enabling control over the transmission of the 4 recorded rhythm vibrations, which were used to control the 4 virtual positions (indicated using the vertical arrows) of the ground objects ( ). Each branch is a nonlinear version of the "switch model" in [4].

4. PRELIMINARY CONCLUSIONS

The following interactions will be demonstrated at NIME: `https://www.cct.lsu.edu/~eberdahl/VibrotactileTokens.m4v` Now that the first steps have been taken toward realizing musical interfaces using this technology, the authors will strive to create music performances using the interfaces, aiming to discover new musical and technological developments that may emerge.

5. REFERENCES

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