EVEN MORE TACTILE FEEDBACK FOR MOBILE DEVICES

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ABSTRACT

In this paper, we present a number of designs and implementations for off-the-shelf mobile computing devices (MCDs) that can significantly improve aspects of force-feedback, expressivity, and "feel." The design philosophies employed in creating our devices include the avoidance of physical alteration to the MCD, utilizing materials that virtually anyone can acquire, simplicity in implementation, and extremely low development costs. We present and detail the application of a number of basic "building block" hardware used in creating the MCD add-ons.

1. INTRODUCTION

Having access to physical resistance is very imnportant in any type of musical instrument interaction scenario. This resistance can be in the form of tactile interaction between strings and fingers when plucking a string, resistance when blowing into a wind instrument, or resistance and force-feedback felt when playing the bass drum with a kick pedal. The clavichord and harpsichord taking the backseat to the piano is probably a good example showing the importance and need for tactile feedback when interacting with instruments and sound [1]. Although modern smartphones and tablets have found popularity as a musical controller and instrument [12], a clear gap still exists when comparing such devices with acoustic and electric counterparts like pianos, electric guitars, and percussion instruments. In the context of dynamicity, expressivity, tactile feedback, and control, smartphones and tablets have much to improve on, no matter how much economic return some apps may have generated.

Interestingly enough, the beginnings of our exploration of tactile feedback for MCDs began when Nieto [7] designed an instrument that actually did not have *any* tactile feedback at all. Nieto's instrument entailed playing the iPad by solely moving the hands and fingers in the air as shown in Figure 1. The instrument, which is called *AirSynth*, was designed and created by making use of a small selection of iPad hardware and software features. This included using the built-in camera and the ever increasing computational power for real-time computer vision and generating sound from hand/finger movements. The final design was a completely touch-free and software-driven instrument.

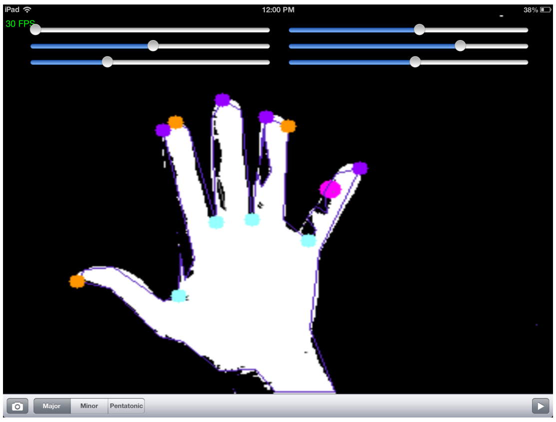


Figure 1: AirSynth screenshot

While observing the theremin-like interface of the *AirSynth* and noticing a general absence of tactile feedback for MCDs, Park began developing concepts and designs that led to *fortissimo* [9] – a simple yet highly expressive interface for mobile computing devices. Fortissimo itself is an add-on that literally anyone can develop and build with minimal development costs (authors spent zero dollars in total for hardware – if we do not consider the MCD itself as an expense). The results were surprisingly positive, leading to significant tactile feedback for MCDs. For the various new designs and implementations introduced in this paper, we embraced the following key philosophies: (1) avoidance of physical alteration to the device itself, (2) easiness in adding tactile-feedback to an MCD, (3) flexibility in modifying expressivity via hardware and/or software, and (4) exploitation of poly-sensory features of MCDs.

1.1. Do not look much further

Musical instruments come in many shapes and sizes but the design philosophies have seemingly remained surprisingly static. One design practice that has gained popularity over the past 10 years or so – especially in academic circles – has been in the area of building instruments and controllers from the ground up. That is, building musical controllers utilizing microcontrollers (e.g. Basic Stamp, Arduino, or Raspberry Pi) to connect various sensors; utilize ADCs and other circuitry for signal conditioning, filtering, and sampling; create custom enclosures; and finally add sound amplification directly to the instrument/ controller itself or adding a data transmission module to send data to a computer for sound mapping and sound synthesis. Another popular instrument-building model involves accomplishing many of the things described above, either by permanently or semi-permanently attaching custom circuitry to an existing acoustic or electronic instrument (e.g. [10, 5, 2]). A final example of controller design is utilizing existing hardware like the wii controller. A great example is the invisible violin[1] where the physical parts of the violin are substituted by a virtual bow (wii controller) and virtual neck (glove). The main issue with these types of designs is the absence of tactile feedback and limited on-board computational resources and other peripherals such as WiFi and cameras.

Considering the above scenarios, an interesting observation can be made: with the advent of MCDs such as smartphones, tablets, and phablets most of the mentioned components and features already come built-in. MCD's typically include powerful processors, loudspeakers, audio I/O, as well as an assortment of on-board sensors including microphones, accelerometers, gyroscopes, proximity sensors, and GPSs. The Android OS, for example, supports additional hardware and software capabilities including sensors for ambient temperature, ambient light, gravity, magnetic field, orientation, ambient air pressure, proximity, humidity, rotation vector, and temperature[2]. Accelerometer and microphone examples used in musical applications are aplenty and can be found in examples such as [3], [6], and [11]. Additionally, MCDs are robust, mass-produced, include small and efficient batteries, and have on-board WiFi. In short, we can strategically exploit many of these "standard" features in off-the-shelf and ubiquitous MCDs to explore possibilities for augmenting expressivity and tactile feedback for musical purposes.

2. BASIC BUILDING BLOCKS

In this section, we introduce a number of highly expressive tactile feedback control configurations that have resulted from design approaches based on rudimentary *building blocks*. These buildings blocks are "hardwares" that you might find in a common office supply store, basement, wash-closet, or recycling bin. The three main building blocks we used in our designs were padding foam, rubber bands, and a ball.

2.1. Padding Foam

The *padding foam* building block was used in *fortissimo* [9] to provide force-feedback during touchscreen interaction with MCDs. Two simple performance modes resulted: (1) the table-top mode and (2) the handheld performance mode. For both modes, we designed a setup for force-feedback by using accelerometer measurements, the MCD touchscreen, and foam pad. This resulted in channel aftertouch-like expressivity and control. Figure 2 and 3 show the table-top mode.

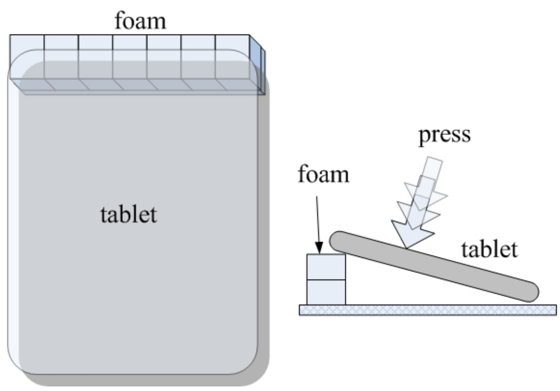


Figure 2: Diagram of Fortissimo

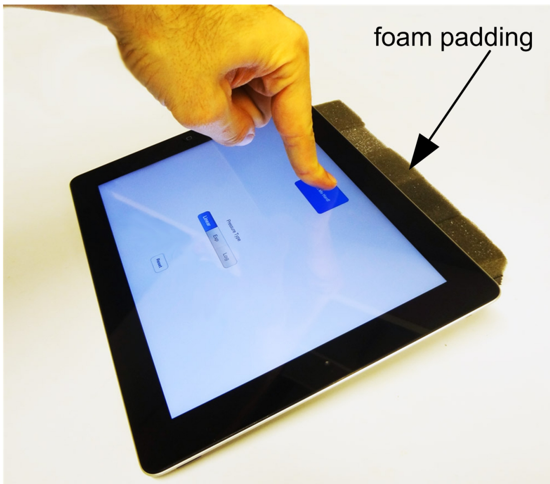


Figure 3: Fortissimo in action

The handheld *fortissimo* configuration was equally simple to set up and used standard rubber bands to secure an MCD (e.g. iPhone) to a "sponge."' This setup rendered a flexible interaction configuration with the MCD while additionally providing the benefits of mobility. As the control messages are sent over WiFi, there is no need for cables or any other type of wired connection to the computer. Furthermore, as the battery life and power management of MCDs are highly efficient, there are practically no concerns for power issues.

2.2. Rubber Bands

The next building block we explored was the *rubber band*. As was the case with padding foam (and likely even more so), rubber bands are easy to acquire, easy to replace when they break, cost next to nothing, and are furthermore easily attached to an MCD. Removing them from MCDs is also not difficult. Several configurations and uses of rubber bands for the MCD are described below. Some are variations of *fortissimo* (*bandbox* and *wobble-phone*) while others were designed to improve hand (wihout eye) coordination when interacting with the touchscreen (*finger*

[1] http://www.youtube.com/watch?v=TyqATpi_knw
[2] http://developer.android.com/

grid and *MCD sandwich*).

The *bandbox* is a table-top MCD configuration where rubber bands are wrapped around a ridged enclosure with an opening on top, slightly larger than the MCD as shown in Figure 4. The bandbox is configured by affixing tightly wrapped rubber bands, mostly under the MCD, with additional bands over the MCD for stability. This results in a velocity sensitive trigger pad. Acceleration on the z-axis is used to emulate velocity rendered via finger strikes to the touchscreen.

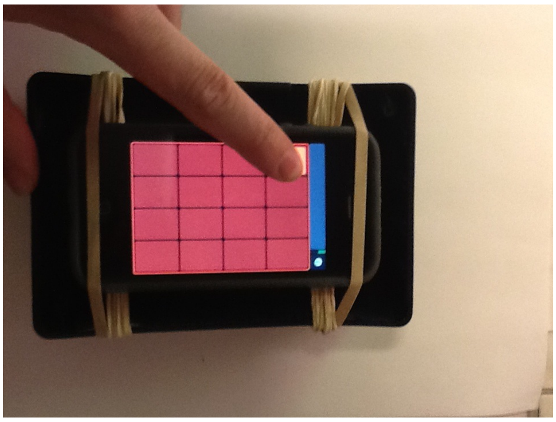


Figure 4: Rubber band box configuration

The *wobble phone* uses long and low-tension rubber band (or chains of bands) configuration to suspend the smartphone between two hands or four fixed poles such as an inverted chair. The low-tension rubber bands create an expressive performance setup where the user interacts with the MCD by pushing, pulling, and moving the phone in 3D space. The four rubber bands keep the MCD suspended and centered between the four poles while providing tactile feedback interaction as shown in Figure 5. Traditional touchscreen interaction can be used when in the suspended setup as well. In the handheld mode, additional controls such as rotation (roll) and inclination (pitch) are also available.

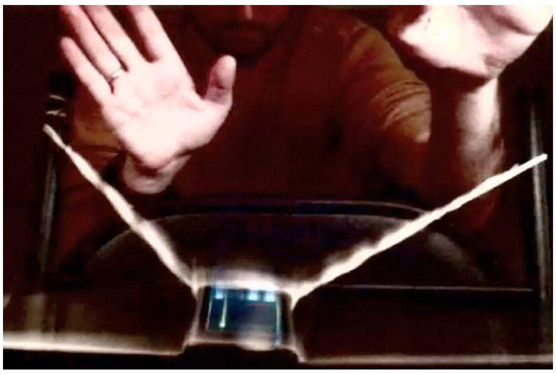


Figure 5: Wobble phone configuration

The *finger grid* mode uses rubber bands to create tactile boundaries which helps the user navigate between GUI buttons on the touchscreen interface as seen in Figure 6. This mode is helpful as visual feedback is no longer necessary when interacting with GUI buttons as the user can now "feel" the location of the buttons via the rubber grids.

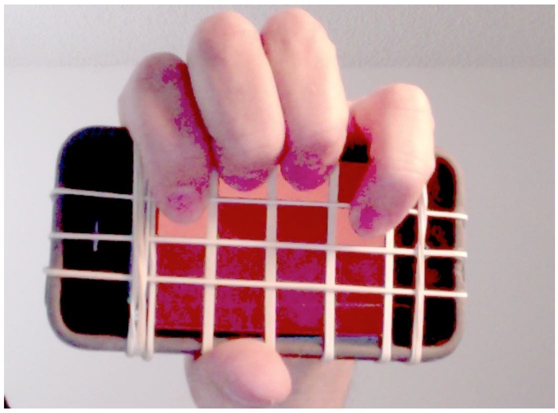
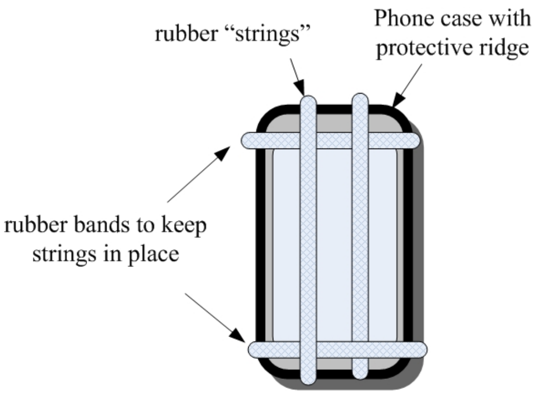


Figure 6: Finger grid configuration

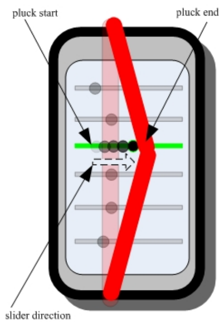
The *MCD sandwich* uses two MCDs, rubber bands, a paperclip, and reclaimed corrugated cardboard. The two MCDs are "sandwiched" such that the touchscreens are both exposed: thumb on one side and the rest of the fingers on the other side as shown in Figure 7. The MCD Sandwich provides a setup for "no-look" operation. Our current configuration and setup is very similar to the MIDI-Airguitar [4] where fingers are mapped to pitch class, thumb to octave, and acceleration mapped to trigger sound events or control parameters such as filter settings.

Figure 7: Sandwich configuration

The most recent configuration and application of rubber bands for the MCD is the plucked string design as shown in Figure 8a. As in our previous designs, we simply attach rubber bands to the MCD where the vertical bands are used to emulate physical string interaction. Additionally, horizontal rubber bands are used to secure the *rubber strings* to the MCD. The rubber string acts as a force-feedback mechanism and does not produce any sound on its own: triggering and "velocity" of pluck is simply rendered by measuring slider displacement values as shown in Figure 8b. In other words, a string pluck necessarily requires making contact with the touchscreen. Z-axis acceleration was also found to be quite useful in the rubber string mode, providing ways for dampening the synthesized string sound or modulating the amplitude envelope.



(a) Rubber string configuration



(b) force-feedback and velocity via slider interaction

Figure 8: Rubber Strings

The *rubber string* can also be configured with multiple “strings”, depending on size of the MCD. The number of “frets” can be controlled by the strategic positioning of GUI sliders. The resulting force-feedback is similar to plucking an actual (loose) string. The MCD’s protective case conveniently acts like bridges found in stringed instruments, keeping the rubber strings suspended above the touchscreen. Additional controller expressivity can be added by using the accelerometer or gyroscope for vibrato and tremolo-like effects during and after a pluck. Although we are currently using existing software for most of the designs presented in this paper (e.g. TouchOSC and c74) , we are planning to develop custom controller software to further augment expressivity and control.

2.3. The Ball

The final building block discussed in this paper is the *ball* building block. For this design, we place the MCD inside the ball which allows access to the microphone, GPS, gyroscope, and accelerometer to measure various types of MCD movements including rotational interaction, tapping, scratching, and kicking events. Although we tested this building block using a foam ball as shown in Figure 9, we plan to insert the MCD securely into larger inflatable (and transparent) beach-balls. This setup has particularly interesting performance implications not just for on-stage performers but also when considered in the context of audience participation. As a side note, it is worth mentioning the importance of keeping the device safe inside the ball with enough foam padding or other protective material.

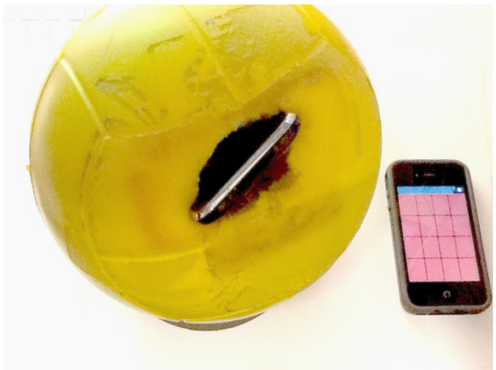


Figure 9: The ball building block

3. PERFORMANCE AND THE EXPANDING GIGBAG

We have significantly explored the usability and expressivity of our designs in various musical situations. This has included modulation of timbral dimensions, triggering samples and sound synthesis engines, employing large and small gestures, continually modifying sound parameters, and combining various interaction modes with positive results. One of the most positive outcomes has been in being able to “feel” a connection with the sound that is produced, a feature that is inherently part of acoustic instruments. This is captured in some of our initial videos are available online[3]. To further explore possibilities concerning flexibility, expressivity, control, and musicality of our designs, we have also created a computer music ensemble as part of the Computer Music Group. The aim is not to carve out a niche area for a “MCD orchestra” per se, but rather, our hope is to contribute to the notion of the musician’s “expanding gig-bag.” That is, offer musicians a wide range of expressive musical controller choices in lieu of traditional acoustic instruments, electronic instruments, custom-made instruments, and MCD-based instruments.

4. SUMMARY AND DISCUSSION

We have described design principles and philosophies that have lead to implementations of add-ons for standard mobile computing devices. The building blocks and controller designs described in this paper may each be used in unique forms of presentations. This may range from large gesture-based performances such as extreme arm swings for robust accelerometer and gyroscope readings, to intimate and subtle MCD interactions via tapping and plucking, to interactive performance as well as music games

[3] http://files.nyu.edu/thp1/public/fortissimo

using MCD embedded balls. We hope that our design approaches and philosophies – which result in instant force-feedback with expressive MCD musical control – can serve as a starting point for musical exploration for anyone having access to a computer, an MCD, and some of the hardware items suggested above.

4.1. Future Work

Our immediate future goals are to develop custom mobile applications to take full advantage of our designs. In the case of the *rubber strings*, the plan is to create custom "velocity sliders" that will follow the amplitude envelope trajectory of the synthesized sound: maximum slider displacement at the attack region followed by lower position in sustain region and a slowly decaying one in the release portion of the signal. This will not only help with visualizing and monitoring the remaining energy in the strings, but also enable mimicking of string muting techniques. Other updates will include creating a custom surface to resemble a fretless guitar neck models where the touchscreen will essentially be comprised of a large number of "sliders". Technically speaking, it will be possible to have as many sliders as we have horizontal pixels.

We also plan to replace the foam ball with a transparent inflatable beach ball in which an MDC or MCDs are safely suspended. We anticipate a number of inherent benefits from this design which includes improving transportability by deflating the ball and protection for the MCD. Additionally, the MCD's touchscreen display could also provide visualizations and possibilities for *light shows* when used under low light conditions.

Additional future work will include using the sandwich configuration to emulate devices like the MIDI Airguitar [4]. Also, combining several building blocks and multiple MCDs into one composite performance setup could further lead to new musical interfaces designs or emulation of existing controllers. For example, one could reproduce controllers such as the *Silent Drum* [8] by mounting multiple MCDs on a web of elastic bands, or the a Force Sensitive Multi-touch Array [13] by attaching a number of MCDs to a large piece of foam and a grid of sponges linked by rubber bands.

5. CONCLUSIONS

We have presented various ways of providing tactile feedback for mobile computing devices (MCD). By using a variety of hardware that are easily accessible (e.g. rubber bands, foam padding, and beach balls), we have presented design philosophies and design implementations that render musical expressivity and force-feedback for MCDs. The designs presented in this paper are easily implementable, do not result in permanent alteration to the MCD, and require virtually zero development costs.

6. ACKNOWLEDGMENTS

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