New Physical and Digital Interfaces for Music Creation and Expression

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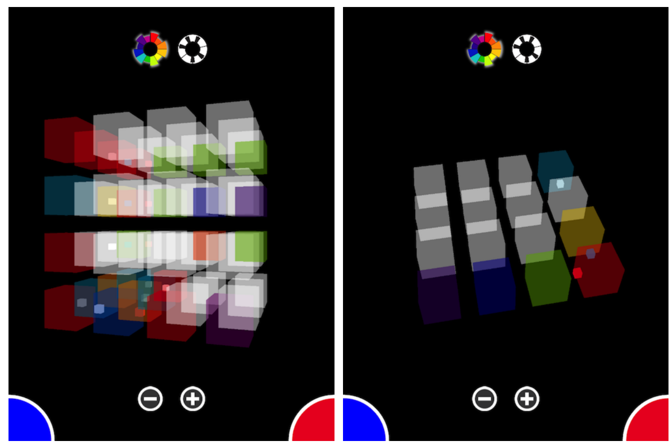
***Abstract*—Technology has vastly altered the ways we create, consume and distribute musical content. The proliferation of personal computing devices affords even the most inexperienced individual the opportunity to be a musician or to dynamically access and control the music that they consume. Conversely, advancements in computing have facilitated the creation of highly complex, specialized devices designed for expert use. We present two classes of musical interfaces in this paper. The first provides beginners with a means to create simple content without the need for extensive training and practice necessary to learn an instrument. The second is an augmentation to a traditional instrument that has a rich history of development in repertoire, pedagogy and performance.**

I. Introduction

The horizon of possibilities in music creation and consumption continues to expand as technology advances at a rapid pace. New styles and genres are created from the adoption of software and devices into the vocabulary of practicing musicians. The demand to push the artistic limits of composition and sound drives innovation and imagination in the development of new technologies for musical expression. The digital age has unleashed a flurry of gadgets and programs of varying complexity to give musicians and non-musicians alike the chance to generate and interact with music in new and exciting ways. In this paper we present a range of devices and applications designed for novice and expert musicians to create and consume music. Considerations of complexity, scale and implementation of devices for musical creation and interaction are outlined in [1], [2].

In our work we use mobile touchscreen devices extensively since the platform is intuitive to interact with. Many of the interfaces are simple to use and require no instructions, allowing someone to instantly create music or modify the content they are hearing. We also work with physical devices, namely the magnetic resonator piano (MRP) which augments the expressive capability of an instrument that has undergone a rich history of study and revision and requires years of practice to become proficient at. Given the large learning curve for piano performance, we reveal several means of interacting with the MRP, each with varying degrees of complexity and control. We begin first by discussing the touchscreen applications in Section II and the magnetic resonator piano and the applications and devices created to interface with it in Section III.



(a) (b)

Fig. 1. The music cube interface on the iPad (a). Each horizontal layer (b) represents a different instrument and the color of a block indicates a different pitch.

II. Touchscreen Interfaces

Touchscreen devices provide a natural means to interface with computers and are particularly suited for musical applications. We have deployed several applications that provide someone without much musical knowledge a means to create and modify content. Music Cube is a graphical interface for real-time musical composition. An expressive drum gesture application analyzes the accelerometer signal of a user's drum stroke and modifies the output audio accordingly [3]. We leverage structured audio representations of musical audio to create interfaces that provide different mood remixes of a single song and predict gain values for individual tracks based on a model that is trained offline [4].

A. Music Cube

In Figure 1a each layer in the cube is mapped to a different instrument and each block in the instrument represents a beat. When a note is loaded into a block, it changes color to represent the pitch class of the MIDI note that is associated

Fig. 2. The virtual percussion system aims to provide a experience that closely replicates an actual instrument. It was inspired by analyzing actual drum strokes and mapping features of the accelerometer signal to sonic qualities.

with the selected block. Each layer has a ball that traverses a pattern in the instrument layer and when the ball enters a block, any sample that is loaded in the block will be played. The combination of the ball paths and the samples loaded into each individual block creates a composition that repeats as the balls traverse their paths.

There are also controls to alter the path of the balls in real time in accordance with preset paths defined by the user. By touching the blue or red semi-circles in the bottom corners, the ball will change trajectory if the option has been added at a particular junction. In Figure 1b the bottom right block shows such a junction. Depressing the blue area will cause the ball to traverse vertically while holding the red area will change the ball's direction to a horizontal oscillation. The simple controls and intuitive interface allow complex sequences to be programmed into Music Cube without any knowledge of MIDI or programming.

B. Expressive Drum Gestures

The expressive drum gesture application seeks to go beyond simple triggering of samples by mapping features extracted from an accelerometer to parameters of the sound playback. To better understand the acceleration characteristics of a percussion stroke, we first recorded the movements of a percussionist striking a drum while holding an iPod Touch (Figure 2). We identified several key features that affect the quality of the sound of a drum hit and designed a system to extract these features in real time on a mobile device.

The implementation of an expressive virtual percussion instrument requires several integrated components that must operate quickly enough to provide an experience that mimics playing a real instrument. The system must be simple to reduce computation time, but it must also provide enough expressive control to make playing the instrument interesting and engaging.

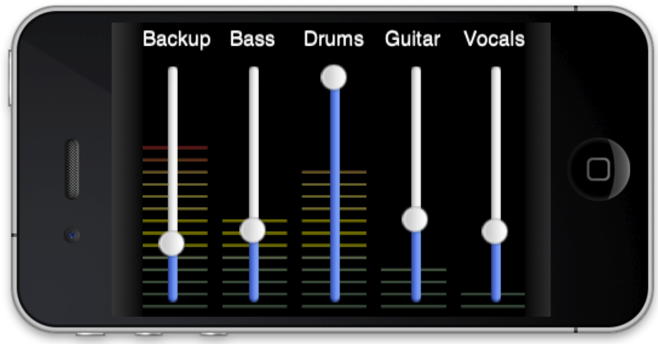


Fig. 3. A screenshot of the automix application on the Apple iPhone.

The proposed system has three subsystems: hit prediction, feature extraction and feature mapping. Each time the device receives a new accelerometer sample, it checks to see if a hit is imminent. If so, the device examines the past motion information to determine what type of hit will occur and extract other related gestural features. The device then maps these features to an output sound.

C. Automated Instrument Mixer

Within the context of a standard rock/pop instrumentation (i.e. guitar, vocals, bass, and drums) the proportion of each track present in the mix is one of the most important factors determining the overall sound of a song. We create a system to predict time varying mixing coefficients for a set of multi-track stems that produces a perceptually coherent mix [5]. Stem files are audio files that contain either a single instrument or a sub-mix of several instances of the same instrument or related instruments.

We train a model offline in the framework of a standard supervised machine learning task, using the fader values for each instrument and spectral features computed on the individual audio tracks as training data. This data is used to train a linear dynamical system (LDS) that models the dynamics of the fader values. We compute the same features for a set of unknown tracks and use the predictions from the LDS as mixing coefficients for each track.

The application running on iOS devices requires the individual audio stems, the features computed on the audio tracks as well as the estimated model parameters. The prediction happens in real time on the mobile device. The user can switch back and forth between the automatic mixing enabled mode and the manual mixing mode. They can compare the mix produced by the model to their own mix or use the predictions as a starting point if they are unfamiliar with studio production techniques. Figure 3 shows the automixing application deployed on the iPhone [6].

D. Musical Mood Remixer

The graphic shown in Figure 4 shows an interface for dynamically altering the mood of a song during playback. The application requires a multi-track representation of the

Fig. 4. A depiction of the mood remix interface with the user currently listening to the 'sad' quadrant.

song. The different moods are obtained by having different takes of the same instrument specifically played to convey different moods. As a user slides their finger from one quadrant to another, the instruments present change as well as any processing on the instruments that further alter the sonic quality to represent the target mood. The moods in the different quadrants are derived from the arousal-valence (A-V) two dimensional representation of emotional affect [7]. Unlike the automatic mixing app, this interface requires that the content be specifically developed to convey the moods in each quadrant.

III. Magnetic Resonator Piano

The magnetic resonator piano (MRP) shown in Figure 5a is an electronically augmented acoustic grand piano that provides increased expressive control over the temporal and timbral

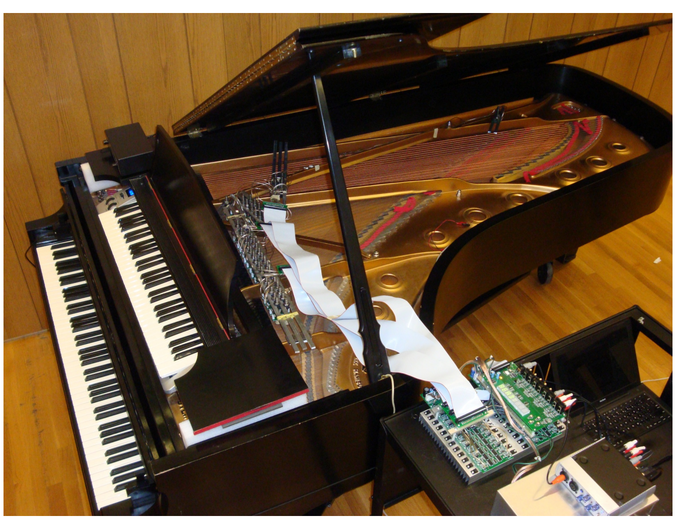


Fig. 5. The magnetic resonator piano modification installed on a grand piano.

Fig. 6. Capacitive multi-touch sensors applied to a standard MIDI contoller.

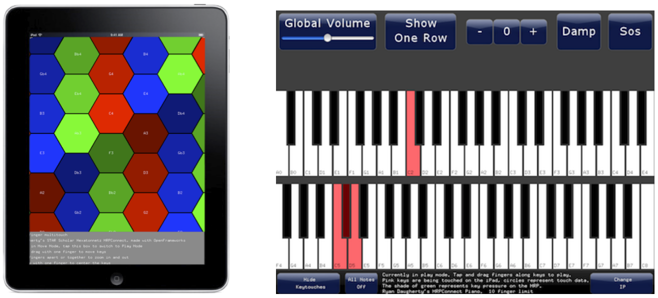
characteristics of the piano [8]. Although the traditional acoustic piano provides a great range of expression on its own there are certain characteristics of other instrument classes that it lacks due to the mechanics of the instrument. Since the sound is produced by a hammer striking a string, the tones a piano generates are limited to a strong attack followed by a decay. Bowed string instruments and wind instruments can be continuously sustained as well as crescendo from silence. These attributes and more are integrated into the acoustic piano though electromagnetic actuation of the strings as well as a feedback-based control system that utilizes a piezoelectric pickup on the soundboard.

A. *Design and Construction*

The MRP places electromagnets inside the piano (one for each note), with the magnets suspended a short distance above the strings. Running a time-varying current through the magnet causes the string to be induced to vibration without ever having been struck by the hammer. By varying the amplitude, frequency and spectrum of the signal to each magnet, a wide variety of effects are possible. New sounds include infinite sustain, crescendos from silence, pitch bends, harmonics, and new timbres, all produced *acoustically* by the piano strings without external speakers. By manipulating the acoustic properties of the piano itself, the MRP acquires much of the same richness and resonance of the piano in which it is installed, particularly the sympathetic vibrations between strings [9]. The controllable parameters available on the MRP consist of the amplitude and amplitude envelope of a note, the frequency, phase and harmonic content.

B. *Controlling the MRP*

Several methods exist to interact the the MRP ranging from simple intuitive interfaces that a non-musician would become adapt at using within a few minutes to a highly paramterized



(a) (b)

Fig. 7. The hexatonal interface for remotely controlling the MRP (a) and the more traditional keyboard interface for playing remotely.

system affording expert control to a performer. To control the MRP directly from the piano keys themselves, a Moog Piano Bar was modified to output continuous key position as opposed to the discrete MIDI information available by default on the device. The customized hardware streams real-time position information for the keys to the computer enabling an extended gesture palette of partial key presses, variable aftertouch and vibrato [9].

In addition to expanded keyboard control via continuous sensing, we explored integrating multiple touch sensitivity directly into each key [10]. A capacitive sensor system records the spatial location and contact area of up to three touches per key. The sensors can be installed on any acoustic or electronic keyboard and while the multi-touch keyboard can be used as a general controller for audio synthesis, it is particularly suited to take advantage of the additional expressive capabilities of the magnetic resonator piano. A picture of the multi-touch enabled keyboard controller is shown in Figure 6.

We developed multitouch applications on iOS devices to control the piano, enabling novices to easily play the instrument or to play remotely. The application displayed in Figure 7a enables real time interaction with the keyboard over a wireless network. The familiar keyboard interface displays the notes that the iOS user is activating as well as what someone at the piano keyboard is playing. The user can switch patches which determine the parameters used to generate the signals sent to the strings and in turn the timbre of the sound produces. The effects of dampening and sostenuto (sustain of current keys activated) can also be engaged remotely.

The hexagonal interface depicted in Figure 7b provides a simple means to actuate the electromagnets mounted above the strings. Each hexagon is mapped to a MIDI note and communicates with the software that controls the magnetic resonator piano using Osculator (OSC) [11]. Users can easily play the MRP just by touching groups of hex shapes without being skilled at playing the piano. While the MRP provides highly trained pianists with an expanded sonic range, the hex controller is an intuitive interface that a user can figure out how create music on instantly.

IV. Discussion

Our work developing touchscreen musical applications is representative of the incredible potential that multi-touch devices have for creating and interacting with music. Mobile devices have proven their use in both complex interfaces with enough options to satisfy experts as well as simple applications that allow a novice to instantly begin creating content. The magnetic resonator piano provides an extended range of expression to an instrument whose breadth of sonic capabilities is already expansive. Several pieces of music have been written for the MRP, and it has been featured in concerts and demonstrations in recital halls across the country. Through this process, ideas are generated through feedback from the musicians chosen to perform the pieces for MRP. Ideally, this organic process of development and feedback from practicing musicians who are not as intimate with the life cycle of these interfaces will drive the innovation and improvement of the work presented here.

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