Synthesis and Control on Large Scale Multi-Touch Sensing Displays

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ABSTRACT

In this paper, we describe our experience in musical interface design for a large scale, high-resolution, multi-touch display surface. We provide an overview of historical and present-day context in multi-touch audio interaction, and describe our approach to analysis of tracked multi-finger, multi-hand data for controlling live audio synthesis.

Keywords

multi-touch, touch, tactile, bi-manual, multi-user, synthesis, dynamic patching

1 INTRODUCTION

The musician's need to manipulate many simultaneous degrees of freedom in audio synthesis has long driven the development of novel interface devices. Touch sensors integrated with graphical display functionality can provide intuitively direct interactivity with richly dynamic context; however they are typically only able to respond to a single point of contact a time, making them quite limiting for musical input. *Multi-touch* sensors on the other hand permit the user fully bi-manual operation as well as chording gestures, offering the potential for great input expression. Such devices also inherently accommodate *multiple* users, which makes them especially useful for larger interaction scenarios such as interactive tables.

These devices have historically been difficult to construct, but we have taken advantage of a new rear-projectable multi-touch sensing technology with unique advantages in scalability and resolution, to create novel musical interfaces for synthesis and control in a large format dynamic workspace.

2 PREVIOUS WORK

2.1 Multi-Touch Interfaces

Boards composed of a plurality of individual controls such as sliders, knobs, buttons, keys, and touchpads, can in a sense be considered multi-touch interfaces. Advanced devices of this class include large arrays of position-sensitive touch sensors such as Buchla's *Thunder* [2], Eaton and Moog's *Multiple-Touch Keyboard* [7] and the *Continuum Fingerboard* [8]. However, we are more interested in homogeneous interaction surfaces that allow for dynamic contextualization.

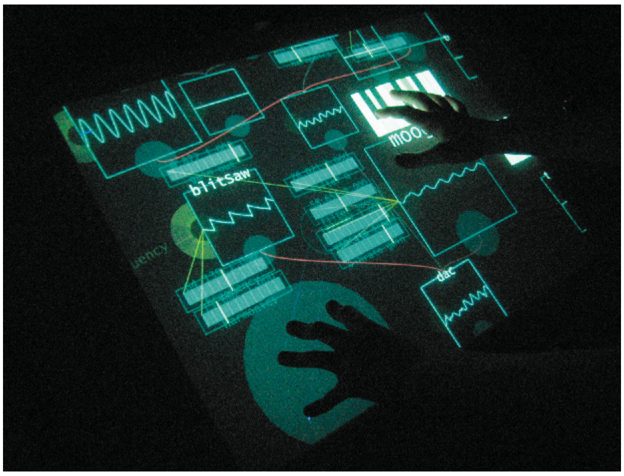

Figure 1: Rear-projected, multi-touch interaction session

Buxton experimented with continuous touch-sensing [22] as well as multi-touch sensing devices for music with the *Fast Multiple-Touch-Sensitive Input Device* [3][14]. This device was an active matrix of capacitive touch sensors, 64×32 in resolution. Instead of integrating it with a display, Buxton utilized cardboard template overlays to partition the interaction surface to provide context, in addition to kinesthetic feedback.

Tactex more recently experimented in the marketplace with a product directly aimed at musicians called the *MTC Express* [23]. This device optically measured the compression of a translucent compressible foam, and though it only had a spatial resolution of 8×9, it has an impressive temporal sampling rate (200Hz) and dynamic range in pressure, making it mostly useful for percussive control.

The recent *Lemur* from JazzMutant [11] is a multi-touch sensor that is tightly integrated with an LCD display. The device is sized for , and functions as a software-configurable controller board. However, the device is low resolution (128×100) and provides no pressure information, limiting the sophistication of the interface widgets that are provided. Furthermore, the system is not open enough to allow access to either the raw sensor data stream or to the raw display itself, limiting its usefulness for the exploration and development of novel interfaces.

All of the systems above have a complexity on the order of the number of tactels, which limits both resolution (though interpolation and other signal processing techniques can mitigate

Figure 2: AudioPad, reacTable*, and Lemur

this for a sparse set of contacts) and physical scale, reducing their role in musical performance to a component within a larger system. Other more scalable multi-touch sensing technologies are starting to become available [6][21][26], but these are still difficult/expensive to obtain, and we have not yet seen any reports of their usage in a musical context.

2.2 Tangible Interfaces

Larger scale musical interfaces have also developed around the concept of the manipulation of trackable tangible assets, such as blocks or pucks. These tangible interfaces [10] can accommodate more than one hand and/or more than one user, and take advantage of the user's sense of kinesthesia and skills in three-dimensional spatialization.

The *AudioPad* [19], is a tabletop instrument which utilizes modified Wacom tablet systems to track the position and orientation of a limited number of pucks. This tabletop environment enabled the dynamic control of loops of other synthesis through marking menus, and also allowed the pucks to act as dials and other controllers to vary parameters. Pucks could also be equipped with a pushbutton, which could be regarded as 1-bit pressure sensitivity.

d-touch [5] and the *reacTable** [12] are more recent tabletop instruments based on vision-based tracking of optical fiducials. They track many more pucks without compromising the sensing update rate, and have developed several tangible musical interface paradigms.

We find that these, and other tangible instruments [1][16][17][18] provide an intuitive and approachable environment for musical control, but face challenges as the complexity of the environment increases.

3 SYSTEM OVERVIEW

Through the usage of a scalable high-resolution multi-touch sensing technique, we build a system that encompasses the functionality of both the virtualized controllers possible on multi-touch devices such as *Lemur*, and the space and scale of multi-user patching systems such as *AudioPad* and *reacTable**[13].

The technique is based on *frustrated total internal reflection* [9], implemented in the form factor of a 36"x27" drafting table, at a sensing resolution of ~2mm at 50Hz. It provides full touch image information without any projective ambiguity issues whatsoever. The touch information is true- it accurately discriminates touch from a very slight hover, while also providing pressure information. The sensor image sequence is analyzed and parsed into discrete stroke events and paths with a processing latency of about 3.5ms on a 3GHz Pentium 4. Measurements including position, velocity, pressure, and image moments are sent to client applications using the lightweight OSC protocol [27] over UDP. The system is notably graphically integrated via *rear*-projection, preventing undesirable occlusion issues.

For our experiments with audio control, we built a simple set of synthesis modules using STK [4], controlled by a modular patching interface.

4. DISCUSSION

4.1 Graphical Context

As Buxton first demonstrated, context is a critical issue for touch interfaces. While we are a few steps beyond cardboard overlays, context for interaction on continuous control surfaces is a challenging problem. Although the pucks used in *AudioPad* and *reactTable** are visually passive, information is projected on and around the puck to provide additional feedback to the user. As such, they are a convenient metaphor for control in contextualizing the surface.

4.2 Basic Gestures

Pucks emphasize our ability to precisely manipulate objects between our fingers. True multi-touch surfaces should provide a similar capacity for manipulation, in contrast to a discrete set of continuous controls. We begin by extending the dextrous manipulation concept to the touch surface by creating regions of the surface that act as virtual puck-like widgets. Touch information captured by each widget is processed together as a single complex gesture. As with pucks, we use the space in and around these controllers for rich visual feedback.

4.3 Interpretation Model

Free from the limitation of the physical world, we can start to extend the metaphor of the basic puck- for instance, the control region associated with a widget can be dynamically resized or reshaped in the course of a performance.

We can also flexibly divide inputs into separate control groups, and selectively constrain degrees of freedom while maintaining a robust handling of under- or overconstrained input cases. As an example, constraining the transformation to rotation and translation is equivalent to the degrees of freedom in a physical puck, while constraint to single-axis translation acts as a slider.

We implemented the more traditional interface widgets such as sliders, knobs, and keys, which the performer can manipulate any set of simultaneously. Additionally, the availability of pressure information allows for more sophisticated revisions of these basic controls. We also use a 'deadband' model [15] to differentiate between tracking and control, permitting the precise acquisition of control elements by the user. Pressure data is also heavily used for more novel controls such as Zliders [20], as well as control pads which interpret relative pressure values as tilt measurements.

4.3 Complex Gestures

With the input captured from two or more hands, we can start to simulate physical manipulations such as strain, twist, or bending motions. Through this we can consider virtual instruments controlled by simplified physical systems - for example, we could monitor volume of a deformable object to determine the flow rate for a wind controller, or use strain measurements to modify string tension or resonance modes. We are currently exploring

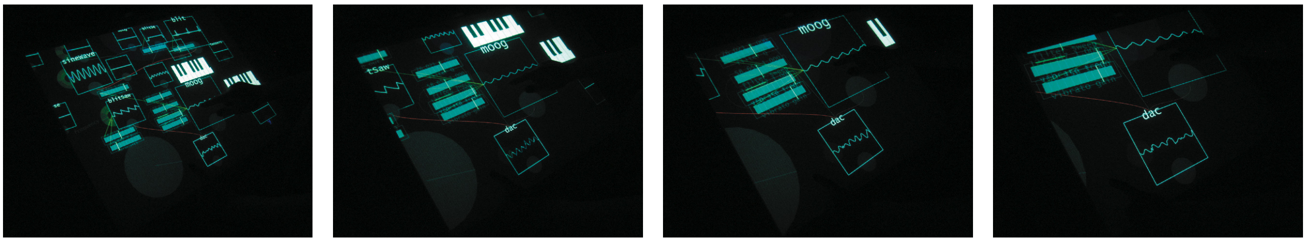

Figure 3: Dynamic workspace- users easily pan/zoom/rotate with a bimanual gesture

the possibilities using a fretboard and plucked string model to produce an autoharp, or koto-like instrument.

4.3 Structural Flexibility

We find that contextualizing manipulation through widgets allows similar precision in parametric control as a physical puck model, and that multi-touch gestures are a natural extension of the control space. Capturing the wide gestural range possible with the hand [24] requires that the sensor accurately track points in close proximity, and control gestures must recognize the limitations of hand geometry as described in [25], to prevent painful or impractical gestures. One advantage to virtualization is that each arrangement can conform to the size and shape of the user's hands, preventing undue stress. As with any continuous control surface, widgets may be adjusted, expanded or repositioned without the synchronizing the location of their physical counterparts. In Figure 3, we show the use of a two-dimensional view manipulator, actuated with a simple two-fingered gesture, allowing the user to pan, zoom, and rotate the workspace and inspect a modular element in detail with no loss of context, giving the performer the ability to manage large workspaces much more effectively.

5 FUTURE DIRECTIONS

There are some limitations in the core implementation that we would like to address that would further increase its usefuless for musical applications. For instance, our current sample rate of 50Hz is good but not great, particularly for percussive input, although this is mitigated by the fact that a large amount of simultaneous information can be updated for each frame. We will be immediately upgrading the system to achieve 120Hz or more.

Also, our current setup provides context only through visual means, but we are definitely looking to be able to provide some degree of haptic feedback as well.

We will continue to explore new and design of new widgets in this new domain. While the table has its advantages over traditional control surfaces, we are primarily interested in controls that take full advantage of the multi-touch data. A uniform control surface also raises the possibility of flexible interfaces - for example, a piano keyboard interface that adjusts spacing based on a user playing a set of prompted chords. In provided a customized scaling of the interface we can adapt to different players to better fit their stature, or to reduce RSI related conditions.

The versatility of the sensor allows for much more interesting form-factors than the console table we have shown here. In particular, for multi-user collaborative setups, we can envision a wider setup where two musicians perform on the same surface, while passing or linking sonic elements in a shared workspace.

Multi-touch sensing is currently an active field in HCI research, so we stand to harness the fruits of much other work in advancing the intuitiveness, efficiency, and usability of this unique family of interfaces.

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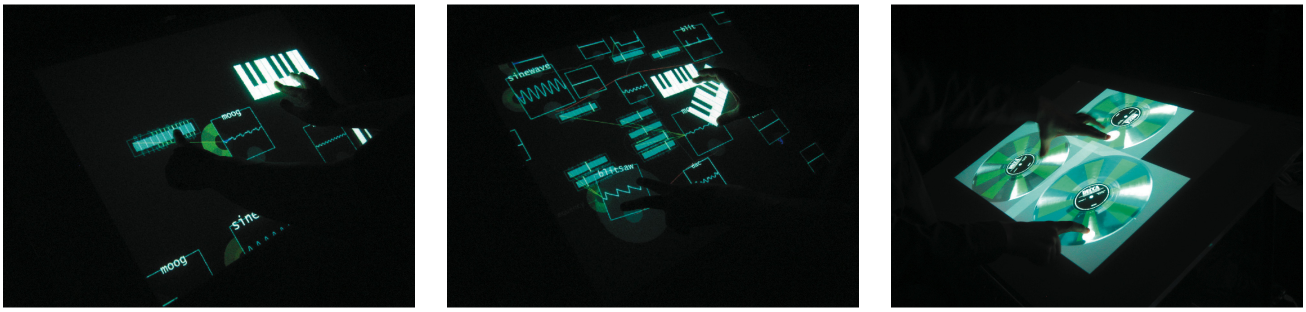

Figure 4: Experiments in multi-touch interfaces

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