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An Interface for Precise Musical Control

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Abstract
This paper is a design report on a prototype musical controller based on fiberoptic sensing pads from Tactex Controls [8]. It will discuss elements of form factor, technical design, and tuning/sound generation systems tested while building the device I have dubbed 'the Ski'. The goal is the creation of a fine musical instrument with which a skilled performer can play music from standard repertoire as well as break sonic ground in modern forms.

Keywords
musical controller, Tactex, tactile interface, tuning systems

INTRODUCTION
The persistence of traditional interfaces in the control of mainstream electronic instruments highlights both the quality of these generations-old interfaces and the difficulty of creating a new electronic interface with any potential for universality and widespread acceptance. Many alternative interfaces are aimed at creating novel experiences or sounds and/or the control of meta-parameters instead of focusing design on the generation of specific notes, melody, harmony, or other sound under precision control. With the advent of generically sensitive devices like the Tactex pad we are able to approach the arbitrary nature of electronic sound generation with a similarly arbitrary interface, one that imparts a minimum of its own character and allows for a wide range of gestures to be mapped in any number of ways. Of course, even a virtuoso performer cannot be expected to master an instrument that is constantly mutating, so it seems worthwhile to explore a smaller set of gesture mappings that can be used in a variety of styles and situations. The Ski and its tuning system is an effort to develop an instrument that can be custom-scaled to each performer, creating musically useful relationships based on that person's hands. Important goals are the capacity to perform music from as many styles and periods as possible, and also to be able to collaborate in any kind of ensemble: traditional, modern, or a hybrid of both. In its original mandate, Tactex technology was designed to emulate skin for robotic applications. Its fine resolution makes it well suited to tracking subtle gestures. Since nearly all precise musical manipulation is executed with the hands, the Ski takes the form of a specifically shaped surface, played primarily with fingers and hands (see Figure 1).

Figure 1. Ski in standing position

FORM FACTOR
The heart of the device is built on components of the Tactex Multi-Touch-Controller (MTC). The MTC is a foam pad measuring 5.75 x 3.75in. containing a grid of

72 fiberoptic sensors (taxels) connected to a supporting circuit board. The Ski consists of three MTC pads combined on a curved aluminum frame, two in front on a convex curve, and one on the back, the curve set concave. The pad sandwich itself can only bend a small amount in one axis only. Some curvature helps in positioning the hands according to the angle relative to the rest of the instrument. This is an improvement over a flat surface which relies mostly on visual cues for positioning events. The back surface accommodates the opposing thumb allowing it to play and grasp the instrument at the same time. We are seeing increased use of the thumb as a primary manipulator in handheld devices (cellphones, game controllers, etc.) so it seems appropriate to include it fully in a new instrument design. The front and back surfaces of the Ski are set at an angle, so that the varying thickness (top to bottom) can be used as a tactile position cue for the player, similar to the tapered neck of a stringed instrument such as a cello. The front two MTC units are mounted one above the other in 'landscape' orientation, and the one on the back in 'portrait' orientation (see Figure 2). This setup was chosen based on the performance position of the hands as well as on hardware availability and mounting limitations. The entire frame is mounted in a long wooden body, placing the pads in comfortable positions whether played standing or sitting. Like a bass or cello, the Ski rests on the ground and shoulder, an arrangement also used on the Interval Stick [4]. The body gives the instrument enough mass for a substantial feel. The tapered 'ski' shape was chosen with the idea that ultimately we will be able to wrap sensitive surfaces over the entire device, and in keeping with the concept that a tapered design with compound curves will aid in developing a precise technique and allow musicians of different hand size to play it in the same way. The shape also has a novel visual impact, and was natural to create using common woodworking tools.

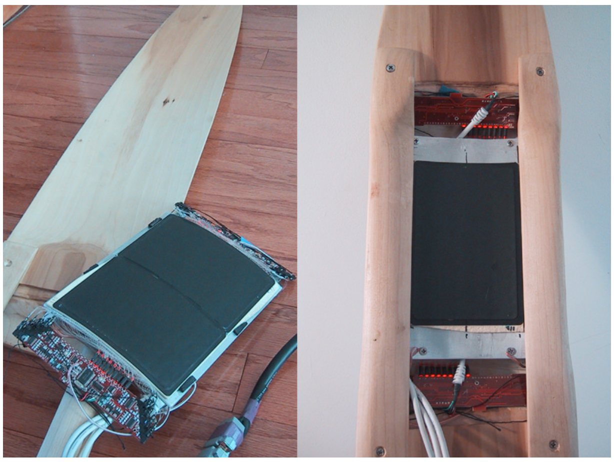

Figure 2. Components, front and back

TECHNICAL DETAILS

Each of the three MTC units is connected to the host computer via a serial interface that sends pressure information for every taxel (72 per pad) at a maximum rate of 200Hz. For a detailed discussion of the inner workings of Tactex hardware, please consult their website. The host computer is a Macintosh running Max/MSP [5]. Max objects resolve individual points of contact, or centroids, interpolating position to less than 1mm. The software is capable of resolving up to 10 discrete centroids per pad. Sound is generated either in MSP, Reason (a commercial software synth) [7], or external midi devices.

SOUND GENERATION AND TUNING

Playing Samples

The very first sound generating patch I created for the original flat Tactex MTC was for sample playback and includes various ways to control the speed of a sample or produce 'scratching' effects. Three basic modes are entailed in the playback design. These modes are: Linear, Polar and Angular.

Linear Mode

In the linear mode one half of the pad is a fader-like speed control ranging from zero to several times real time, backwards and forward, with zero at the center. The computer keyboard is used to trigger and stop playback of looping sounds. On the other half of the pad the sample is simply mapped linearly to the x-axis with a fingertip acting like the playback head itself.

Polar Mode

Here Cartesian coordinates are converted to polar coordinates with the length of the sample scaled to 2 pi radians. The sound plays as the musician draws a circle around the center of the pad.

Angular Mode

Angular mode controls the speed of playback as circles are continuously drawn on the pad, backward or forward. Playback speed is linked to the angular velocity of a centroid instead of directly mapped to positions on the circle.

For the back pad, the linear mode works best due to some difficulty in moving the thumb in a smooth circle. On the front pads I prefer the angular mode as it is more intuitive and there is a clear visual connection to what the audience hears. A fourth mode is in the works: linear velocity. Here one can effectively scribble on the pad with playback speed linked to centroid velocity in any direction. This removes discrete position from the velocity calculation, allowing the location of a moving centroid to be independently used for other parameters. In all modes, careful buffering of the input data is required to smooth playback and prevent warbled or pixellated sound, while still allowing for interesting acceleration and deceleration of the playback speed. Many fascinating effects can be created by varying the buffering coefficients and other parameters.

The pads are also useful for simple realtime playback of sound effect samples mapped to different areas on the pad and crossfaded as centroids move along the surface. There is great potential for use in sound-design and surround control.

Percussion

Another patch uses percussion modeling objects from the PeRColate library [6] to simulate a shaker on the pad. Figure 3 shows one possible configuration. A range of textures can be created with various gestures on the pad, from simply tapping in rhythm to stroking across the pad. It is easy to create sounds beyond the palette of the modeled acoustic instrument. While the patch shows promise in terms of sonic interest, much faster pad sampling rates would be needed, and perhaps a faster host computer, to make a musically viable percussion instrument.

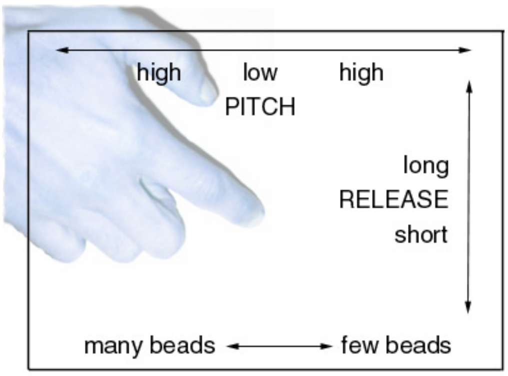

Figure 3. Shaker mapping

Tuning

As stated at the beginning of the paper, most of the work has focused on experimenting with tunings that will allow accurate musical control over pitches played on the Ski. For pitch-based playing, sound can be generated within Max/MSP, or by using iac-bus midi to play other software synthesizers. I have programmed patches for midi output, however each centroid generates multiple controller data on its own channel, thus creating a cumbersome volume of midi data.

Experience on several traditional instruments has influenced the development of the ski tunings. Certainly the manual, percussive nature of keyboard technique is present, albeit without individual keys and with continuous control of position and pressure after contact is made. The scaling of the surface has similarities to a stringed instrument in that one pitch component is mapped vertically, with lower pitches toward the top of the pad. Unlike a string, pitches are spaced evenly instead of logarithmically. Spending many hours with kalimbas [3], mbiras, and some exposure to the harp family convinced me to experiment with a symmetrical arrangement for the left and right hands, so that the same notes (and unisons) could be played by both hands, in complimentary positions. For this reason the pads are divided in the center making left and right halves mirror images, with lower pitches in the center of the pad, and higher toward the edges. If a line is drawn on the pad representing a unison, it looks basically like a 'v' shape (figure 4). The 'v' unison evolved by combining the string-like vertical pitch component, horizontal symmetry, and a desire to have accidentals reachable by extending or retracting the fingers horizontally. To customize the scaling to individual players the angle of the unison can be adjusted, and some curvature applied.

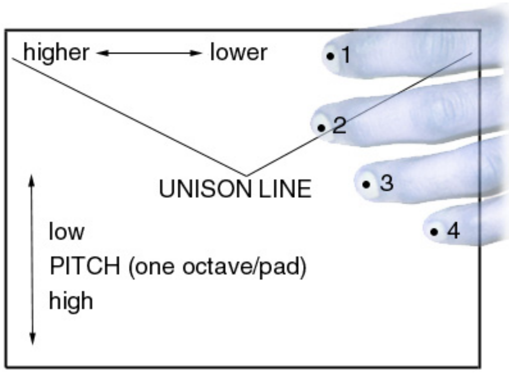

Figure 4. Basic tuning

Using such a scaling with a comfortable hand position will result in the following pitch relationships at the 'home position' (first finger and fourth finger at the top and side of the bezel, respectively; thumb at top corner of back pad; see Figs. 1 and 4):

thumb	-	root
first finger	-	fifth
second finger	-	sixth
third finger	-	octave
fourth finger	-	tenth

Accidentals are reached by simply extending the finger toward the center, edges, or up and down by a small amount; roughly one fingertip-width per half step. The back pad is mapped similarly to the front so that intervals will be consistent as one moves up and down the instrument.

Even using such simple pentatonic relationships between fingers, it is still difficult to 'play' the instrument in a precise and repeatable way, especially when moving around to different parts of the pad. However, I do find that I can quickly reference back to the home position and, like any musical instrument, things get better with plenty of practice. Pitch can be quantized or not. I have set up a time response where a note is initially quantized, then becomes unquantized over a specified period of time. A crossover time between 100 and 1000ms allows for bending of notes that begin ‘in tune’.

There are many possibilities for continuous control of events. A simple one that I have implemented is the use of pressure for volume and/or filter cutoff (in an analog synth model). The first two pressure values for a centroid are used to calculate velocity, then subsequent values are used for continuous control. Another idea tested uses distance traveled along the unison line as a controller. This way a note can be phrased by moving one way or the other on the unison to change volume or timbre. The effect is generated only when the event stays on or near the unison line.

FUTURE DIRECTIONS

There are still more tuning options to explore, as well as ways to refine the current systems. I am working on a way to quantize pitch to the relative spacing of events instead of physically to the pad itself. In practice I have found it easiest to think of the relationship between notes in a polar way. That is, events are positioned at an angle and distance from a related or nearby event. Also, each time a new event is quantized to this polar ‘grid’ the grid itself should center on the new event, affecting only subsequent events, not ones in progress. It is hoped that this will make it easier to play consistently and in-tune. In another tuning map experiment the ‘home position’ will produce a diatonic rather than pentatonic basic scaling. Also, I would like to explore ways to incorporate just intonation and microtonality into the system. As the fine-instrument tuning evolves, it will be interesting to define graded simplifications of that system as a way to teach the technique. This way the student can use the same physical interface from beginner to virtuoso simply by changing refinement levels in software. Above all, the instrument should challenge the musician and reward diligent practice with increased musicality at every level of expertise [1].

Inherent limitations in the hardware contribute to limiting the musical precision of the instrument. The first such limitation is speed. At 5ms per scan of the pad, data is simply not generated soon enough to play quickly in precise time. In addition, if the device was sampling at rates above 1kHz properties such as velocity and acceleration could be calculated with much higher resolution. The host computer plays a significant part here as well. A recent upgrade from a 466MHz G3 to a 500MHz G4 made a pronounced improvement in performance. There are other areas where speed hinderances are unclear; for instance, the USB to serial interfaces required to connect the MTCs to newer computers. A second limitation is the density of individual sensors on the surface. In its current form, discrete events are difficult to resolve unless they are more than roughly an inch apart, meaning the area covered by comfortably spaced, adjacent fingertips will be interpreted as one centroid. There are ways to address this problem using more advanced software, but I believe a combined solution will ultimately be needed. I have yet to bridge the seam between the two front pads in software, so currently they behave as separate devices sounding an octave apart. It is reasonable to expect some of these problems to be resolved in future generations of the technology. A larger, faster, more precise surface will be developed and may one day include flexible visual and haptic displays. For the time being I am working with visual and tactile markers applied to the pad with adhesive. An interesting idea is employed on the Interval Stick where a scalloped surface along the ribbon aids positioning yet still allows continuous unquantized control.

The body of the instrument has proven to be somewhat larger than needed. Even if the entire surface were sensitive, it probably wouldn’t need to be quite so long. A retractable leg would allow the instrument to be adjusted to the individual whether in standing or sitting position. Perhaps a strapped-to-performer arrangement is worth exploring. On the Chapman Stick [2] a standoff attaches at the waist and a shoulder strap supports the upper end. The instrument is self-supporting (one can let go of it completely) and allows freedom of movement on stage. Another improvement would be to include a touchpad on the instrument body to control the host computer. Furthermore, other kinds of sensors can be added to the body to capture overall motion, position, and contact with feet, legs, or floor.

CONCLUSION

The Ski is generating interest from musicians and non-musicians alike. Sample playback and percussion patches are very intuitive to use so that nearly anyone can begin making interesting sounds as soon as they pick it up. The musical tuning is much more difficult to gain control over, yet the experienced musician will find that practice leads to improvement, rather than frustration with the limits of the instrument.

I am already using the Ski in performance situations and have made ample use of it in the studio for sound-design purposes. It is well suited to bass parts as well as long textures, clusters, and beating tones, due to the ability to bend each note individually.

Sound samples of the Ski can be found at: http://underdog.sytes.net:8080/huottsound/ski

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REFERENCES

[1] Buxton,W.A.S.(2000)Round Table In Wanderley and Battier (eds.)Trends in Gestural Control of Music, Ircam Centre Pompidou,Paris,France.

[2] Chapman Stick, Stick Enterprises www.stick.com

[3] Hugh Tracey Kalimba, African Musical Instruments Ltd., Grahamstown, South Africa

[4] For a description of the Interval Stick: http://www.ideo.com/studies/interval.htm

[5] Max/MSP, Cycling '74 www.cycling74.com

[6] PeRColate Objects, Dan Trueman and R. Luke DuBois, http://music.columbia.edu/PeRColate/

[7] Propellerheads Software, Reason software synth www.propellerheads.se

[8] Tactex Controls, Smart Fabric technology www.tactex.com