Chapter Three

THE INFINITE VIRTUAL VIOLIN

The Deconstructed Violin Reconstructed

She was quiet awhile and then said, Many a night when I was little, alone in that cabin, I wished I could take that fiddle of his up to the jump-off and pitch it and let the wind fly it away. In my mind I'd just watch it go till it was just a speck , and then I'd think about the sweet sound it would make breaking to pieces on the river rocks way down below.

from *Cold Mountain*, by Charles Frazier.[1]

from

Reinventing the Violin

by Daniel Trueman

[1]Frazier, 423.

The grit of rosined horse-hair forcing a string to oscillate is one of the most treasured features of all the violins discussed so far. Schubert's subtle articulations and weighty quadruple stops, Corelli's *cantabile* lines and string crossings, Mark Wood's heavy-metal distortion, and my own "e-fiddle" tunes are all ultimately dependent on this frictional relationship. What would it mean to play the violin without this dependence? What would it mean to draw the bow across the string and hear sounds that are not acoustically motivated by the induced oscillations? What kind of music would we make with such a violin and what aesthetic tendencies would this violin have? What possible forms could this violin assume?

The number of questions I could pose in this vein is seemingly infinite. Pondering any one of them ultimately leaves me feeling overwhelmed by the possibilities and the lack of precedents. And yet, these violins—virtual violins—exist and are becoming more widespread. To begin with, a definition:

> The *virtual violin* is a collection of data derived from the physical process of playing the violin.

As such, the virtual violin is a subclass of the violin superclass—the physical "pose" from Chapter 2—which, rather than (or in addition to) radiating sound directly, generates a set of data that can be mapped to essentially anything; it is therefore without acoustical constraints and could just as easily produce lighting effects as it could sound.

The first examples of such an instrument are pre-digital. A simple case is the envelope tracker; here the envelope of the signal from an electric violin is used to modulate another signal (perhaps the volume of another instrument, the depth of a chorusing effect, the brightness of a light, or anything else that engineering allows). In this case, the sound of the violin is perhaps never heard, and its signal is used to affect something entirely separate. There is nothing about the envelope tracker in particular that is tied to the violin—it has an audio input that can be fed by anything that generates audio—but when used in conjunction with the violin it has the effect of making the connection between the physical activity of performing and the resulting output arbitrary.

Another colorful example is given by Laurie Anderson. In the late 1970s, she developed a violin fitted with audio tape recorder heads and a bow with magnetic tape instead of horse hair. She played the violin by drawing the tape through the tape heads which then transmitted the prerecorded material on the tape to an amplifier. In this case the audio signal reflects the physical motions of the bowing, slowing down and speeding up with bow changes, but the resulting sound is not in any way acoustically derived from the violin. Again, a significant portion of the output is arbitrary—the prerecorded tape material and the mechanism for mapping this to sound—but the physical process of playing the violin is essential. For Anderson, the visual imagery of playing the violin is also of central importance; by connecting a familiar gesture—a gesture associated with the tradition-laden violin, no less—with a familiar sound—music on tape—in an unfamiliar way, she creates a kind of cognitive-sensory dissonance. This tantalizing link contributes to the sense of performance spectacle that characterizes most of her work.

Pitch Detection

Most efforts to draw performance data from the violin have focused on pitch detection. This approach, like the envelope tracker, quantifies the violin entirely from its audio signal and is not specifically tied to the physical process of playing the violin—all that is required is an audio signal, regardless of source. Certain kinds of pitch detection are, however, optimized for the violin. Miller Puckett has developed a pitch detection technique (an object called *fiddle* in the pD and MAX/MSP environments) that is particularly effective for sustained pitches, and can even detect multiple pitches simultaneously.[2] The Axon pitch-to-MIDI convertor from Blue Chip uses a neural-network technique where the device can be "trained" on particular instruments; they have released a version trained on the violin that is dependent (to some extent) on the attack transients of the violin bow-stroke and can theoretically distinguish between *tasto* and *ponticello*.[3] Finally, the Zeta electric violin, with its bridge that isolates the strings from one another, is a reasonably effective instrument optimized for pitch detection.

With pitch detection and envelope following, the virtual violin consists of one to four data pairs: 1–4 pitches (assuming a 4-string violin) with corresponding amplitudes. In most cases, we are limited to a single pair, especially if we are working with a complex acoustic violin signal. There are two primary ways this instrument is played. First, the sound of the violin is replaced by (or doubled by) some other instrument. This is particularly prevalent in New Age and Ambient music, where the violin may be doubled or harmonized by samples of an Irish flute or a Tuvan singer. Second, the violin becomes a kind of conductor. In this case, the virtual violin data may be used to follow a score, with various kinds of musical events triggered, based on the performer's location within the score. Alternatively, precomposed musical motifs can trigger specific events; this is a more useful relationship in improvisatory contexts. With the violin as conductor, the virtual violin is not an instrument, but rather a mechanism for coordinating a conventional violin performance with a precomposed "piece"

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[2]Miller Puckette, Theodore Apel, and David Zicarelli, "Realtime Audio Analysis Tools for Pd and MSP," in *Proceedings of the International Computer Music Conference in Ann Arbor*, by the International Computer Music Association (San Francisco: ICMA, 1998), 109. *Fiddle* is also an effective envelope follower.

[3]Lilit Yoo, and Ichiro Fujinaga, "Zeta Violin Techiques: Limitations and Applications," in *Proceedings of the SEAMUS Conference at Dartmouth College*, by the Society of Electroacoustic Music United States (Hanover: SEAMUS, 1998).

or algorithm; we don't *play* the virtual violin, we play the conventional violin with the awareness that we are being heard by a virtual conductor.

It is within this model that most of the recent work with the virtual violin has taken place. Mari Kimura, violinist and composer, is well known for having developed a substantial repertoire of outstanding pieces that depend on pitch detection and score/motif following. In *U (The Cormorant)*, the virtual violin enables her to create concerto-like texture, pitting her own virtuosic playing style against a computerized ensemble that she conducts vicariously via a pitch-to-MIDI convertor and software score follower. As evidenced in Sound Example 29, the virtual violin data is not used primarily as a trigger, where discrete performed events have a direct correlation with synthesized events. Rather, the derived performance data is used to mediate between the precomposed "orchestra" part and the solo part. This wonderful sense of invisible (yet attentive) orchestra is supported by the frequent occurence of orchestra-like sounds—brass, percussion, and low strings—but is also undermined by otherworldly, synthetic, non-orchestral sounds.

In *ECO II*, Kimura establishes a different function for the virtual violin. Rather than conductor, the collected data serves to subtly reinvent the violin by changing the acoustic violin's signal processing dynamically. In Sound Example 30, clear harmonics gradually become shrouded in reverberated, delayed, transposed versions of themselves. Just shy of one minute into the example, aggressive short bowstrokes provide opaque obstructions for lugubrious shadows of signal processing. As Kimura's bowing becomes shorter and her pitches higher, the processing changes to resemble a swarm of crickets. The shadows then return and gradually dissipate, leaving the violin alone, in darkness. In some ways, this music is reminiscent of Paul Giger's improvisations within the crypt (Sound Example 13). Here, rather than "playing the room," Kimura changes the room—the virtual violin is a mechanism for modifying signal processing algorithms. This relationship is wonderfully invisible; as far as the listener can tell, Kimura is simply playing her acoustic violin in a dynamic, changing space—we cannot hear "triggers," and are not even aware that there are any.[4]

Clearly, pitch detection is a powerful new tool for extending the violin. However, unlike the physical changes that occurred to the "Classical" violin—lengthening the neck, changing the strings, etc...—or the dramatic effect that amplification has, pitch detection does not change the physical relationship between the violin and violinist. To some, that is the appeal—it is possible to attach various external synthesis, signal processing, and algorithmic techniques to the violin without perturbing it. As pointed out earlier, there is little about this approach that is specifically dependent on the unique physical and acoustical properties of the violin—any audio signal

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[4]This is not the case in *Los Perfumes da la noche profunda*, composed for Kimura by Ivar Frounberg. At times, using a Zeta MIDI violin, violin notes directly trigger percussion (or other) sounds. Compared to Kimura's own invisible relationship in *ECO II*, this seems banal.

will do.[5] It is not without problems, however. Most importantly, it is often not consistently accurate; as Miller Puckette admits: "We'll never have a perfect pitch detector."[6] Violinists who work with pitch detectors are familiar with the frequent octave displacement errors that occur, or even the outright misses, where the detector produces pitches a major 6th away, or 2.5 octaves away. The detector is oblivious to the subtle articulations that violinists prize, and often will send multiple messages during a single sustained note.[7] Finally, there is an inherent delay while the detector figures out what pitch is being played.[8]

Physical Inputs

Taking a different approach, Tod Machover, Neil Gershenfeld, and Joseph Paradiso, of the MIT Media Lab, have constructed what they call "hyperinstruments."[9] In the case of the violin family, they have built a variety of sensors and mounted them on the instrument in an effort to measure performance gestures.[10] The hypercello consists of a sensor-bow that can transmit information regarding finger pressure, wrist and bow position, and a set of sensors that detect left-hand fingerboard position. This data is sent to a network of computers for analysis and control of synthesis, samplers and signal processors:

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[5]As described above, in some cases the pitch detection is optimized for the violin, and in the case of Zeta, the violin itself is optimized for independent string pitch detection.
[6]Puckette.
[7]Yoo.
[8]Pitch detection depends on analyzing repeated waveforms; for low pitches with longer waveforms, it requires more time to accumulate enough repetitions for accurate analysis. A variation on the Heisenberg Uncertainty Principle is often used to illustrate this. The Uncertainty Principle states that the momentum (p) and position (x) of a particle can only be measured simultaneously to a certain degree of precision: $\Delta p * \Delta x > h$, where h is a constant. Similarly, the frequency (f) and time (t) resolutions of an audio signal can be measured simultaneously so accurately: $\Delta f * \Delta t > h$. A variant on this, $\min(f) * \min(t) > h$, indicates that to minimize (min()) the lowest frequency measurable, we must increase the amount of time required for analysis.
[9]Tod Machover and Joe Chung, "Hyperinstruments: Musically Intelligent and Interactive Performance and Creative Systems," in *Proceedings of the International Computer Music Conference in Columbus, Ohio*, by the International Computer Music Association (San Francisco: ICMA, 1989), 186.
[10]For details, see Joe Paradiso and Neil Gershenfeld, "Musical Applications of Electric Field Sensing," *Computer Music Journal* 21 (Spring 1997): 69–89.

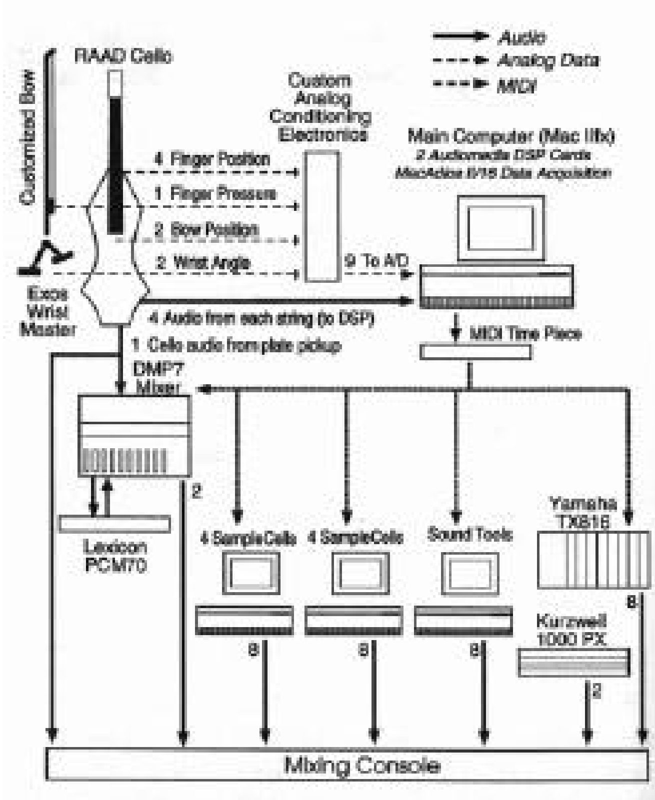

Figure 1. Diagram of Hypercello setup used by Yo Yo Ma[11]

Thus far, Machover has composed one work for the Hypercello (*Begin Again Again...*, 1991) which has received several performances by Yo Yo Ma and others. Not yet available on record, *Begin Again Again...* is a substantial work (25 minutes) that requires significant technical support to realize in performance; it is "like Stockhausen's *Kontakte*, at once an expression of musical thought and feeling and a report on the current state of the art of the technology of making music."[12] From Machover's own description of the work:

> In fact, *Begin Again Again...* is, among other things, about the idea of creating a hyperinstrument. It starts out with the performer exerting careful control over the electronic extensions, each bow change, each accent chosen to elicit a specific response. Gradually, however, the computer part starts to develop on its own—as if a Pandora's Box had been opened—becoming denser and more complex than a single human could control. After an explosion at the work's climax, the piece "starts again," tentatively at first, but soon establishing a gentle, balanced dialogue between performer and computer. At the end of *Begin Again Again...*, a hyperstring instrument

[11]Reproduced from Paradiso.
[12]Levenson, 306.

> has emerged, ready to continue the musical journey of the trilogy, drawing less and less attention to itself.[13]

An interesting duality emerges from this instrument which is similar to some of Kimura's work. Rather than a single instrument, the hypercello seems to be (at least) two instruments: "the computer part starts to develop on its own—as if a Pandora's Box had been opened—becoming denser and more complex than a single human could control" and "the piece starts again,...soon establishing a gentle, balanced dialogue between performer and computer." In a sense, the hypercello is not an instrument at all. Rather, Yo Yo Ma plays the cello (which is the instrument), the sensors detect what he is doing, and this controls a preprogrammed software orchestra; Ma does not *play* the hypercello so much as he plays the cello under close watch. While the mechanism for creating this relationship is different than Kimura's (and specifically dependent on the physical process of playing the cello), the relationship is essentially the same.

It is clear that the developers of the hyperstrings are intent on leaving the physical relationship between player and instrument unperturbed. They are primarily interested in measurement, not in transforming the instrument:

> The research focus of all this work is on designing computer systems (sensors, signal processing, and software) that measure and interpret human expression and feeling.
>
> We sought to develop techniques that would allow the performer's normal playing technique and interpretive skills to shape and control computer extensions to the instrument.
>
> Special techniques (wrist measurements, bow pressure and position sensors, left hand fingering position indicators, direct sound analysis and processing, etc.) enable the computer to measure, evaluate, and respond to as many aspects of the performance as possible.[14]

and:

> This system [the hyperviolin bow], while usable, does modify the playing characteristics of the bow, mainly due to the added mass of the battery. To reduce this impact, we are currently researching designs using extremely light, remotely powered, passive-position sensors.[15]

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[13]From http://www.media.mit.edu/Projects/machover.html.
[14]*Ibid*.
[15]Paradiso, 174.

This is in contrast to the work of Jon Rose, Chris Chafe, and myself; we have all built sensor-bows of varying designs that in some way invite the performer to play the instrument differently.

In the late 1980s, Jon Rose collaborated with researchers at STEIM (in the Netherlands) on the construction of a sensor-bow. Consisting of a pressure sensor under the index finger (this is the same technique used at MIT for detecting finger pressure) and a sonar sensor to detect bow position, the bow is considerably simpler than the MIT bow. It does not provide as much data as the MIT bow, but for Rose, this is desirable:

> I've tried to keep a one to one connection between violin and digital instrument by using only one midi channel in performance. Sort of basic monophonic solidarity! For me, an important aspect of expression comes out of pushing the natural physical limitations of an instrument to the edge of its possibilities, this includes digital ones as well.[16]

Because of this simplicity, he does not require a team of technicians to setup his instrument; as a result, he has used it in performances all over the world, hundreds of times and on several recordings.

Figure 2. Jon Rose and his sensor-bow, made at STEIM[17]

In *Warm-up Exercises* (Sound Example 31), it is impossible to hear a clear relationship between the bowed violin and the bowed samples, in spite of the simple arpeggios.[18] However, there is a sense of a kind of machine comprising the violin and samples that is tied together in some way:

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[16]From the Jon Rose website: http://www.euronet.nl/users/jrviolin/chaotic.html.

[17]Image from http://www.euronet.nl/users/jrviolin/chaotic.html.

[18]*Warm-up Exercises*, from the compact disc *Pulled Muscles: music satire on sport, politics, and the violin* (Immigrant 019) combines the "sanctified sounds of sport" (in this case, presumably the huffing and puffing sounds of heavy breathing) with the violin.

> Specific areas of interaction can be set up which focus on some found sonic or physical relationship between the two systems (finger pressure and bow position). Add to this the voice coming from the violin and there are three pools of information which, through the action of horizontal bow movement or vertical bow pressure combine to form musical structures that appear to be pulled together by some kind of attractor (to use Chaos Theory jargon).
>
> Sometimes the attractor is clearly the violinist who can at any time achieve a demonstrative role (*i.e.*, he can shield information from the sensors, he can stop playing, scratch his head, or turn the whole thing off in disgust, etc.). But at other times it seems there is a control centre working away independently of all constituent parts, as happens often in the best of improvised music.[19]

Rose is clearly not interested in measurement. Rather, he is "looking for a physical connection, not trying to avoid one;" he is *playing* the bow, not being monitored by it, and he conceives of the whole as a *single* instrument—an attractor—that he is more or less in control of.

Chris Chafe, of Stanford University, uses a cello bow with a bend sensor in the middle of the bow (on the stick) and an accelerometer in the frog. The bend sensor can correspond to bow pressure, or to any other action that causes the bow to bend (such as waving it vigorously in the air). The accelerometer is a microscopic weight on a spring that can function as a position sensor (where gravity serves as the force to pull the weight) or a motion sensor (where changes in velocity cause the weight to accelerate). Chafe often plays just the bow in performance, leaving the cello silent, and has developed a set of gestures that are motivated by the design of the sensor-bow—the bow is an instrument, not a measurement device.

[19] *Ibid.*

BoSSA (the Bowed-Sensor-Speaker-Array)

My own R-Bow (designed and built with Perry Cook) is similar to Chafe's bow, but rather than a bend sensor, we mounted two *force-sensing-resistors* (*FSRs*) between the stick and hair on light foam:

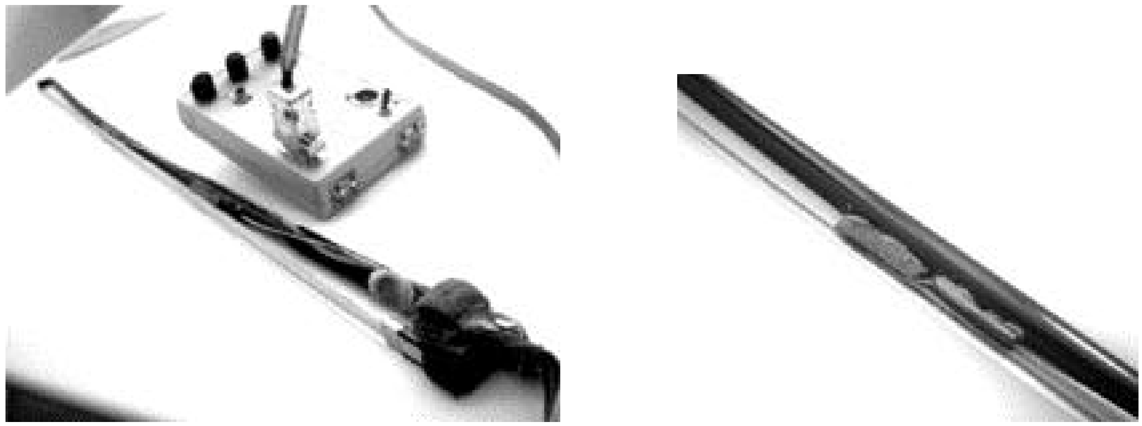

Figure 3. (a) R-Bow, and (b) FSR on R-Bow.

FSRs feature a non-linear response, with it's most sensitive region at low pressure:

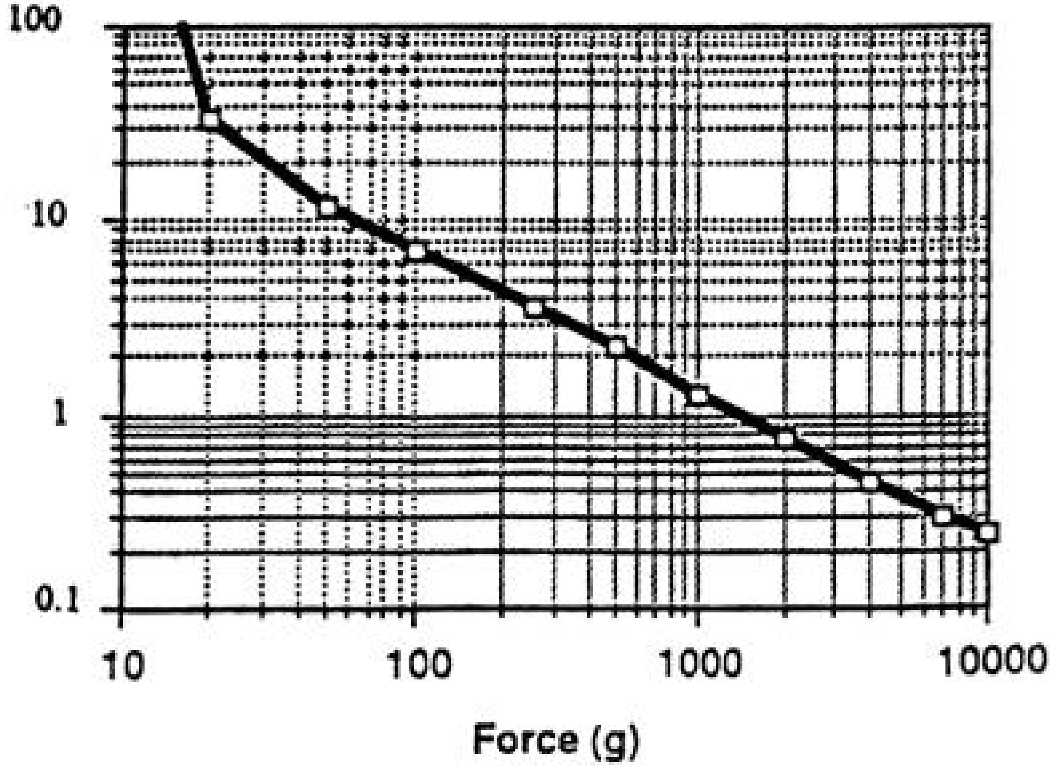

Figure 4. FSR response. The vertical axis represents resistance.[20]

[20]Reproduced from http://www-ccrma.stanford.edu/CCRMA/Courses/252/sensors/node8.html.

With the bow hair tightened so as to barely touch the *FSRs,* the comfortable range of bow pressure falls in this sensitive region, resulting in an instrument that has relatively high resolution; compared to the pressure sensor mounted under the index finger on the MIT bow and Rose's bow, this technique is highly sensitive.[21]

Mounted on the frog of the R-Bow is a biaxial accelerometer:

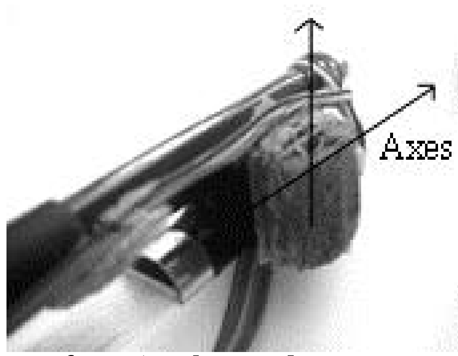

Figure 5. R-Bow frog (with accelerometer axes illustrated)

This sensor provides relative position data on two axes: (1) as I move the bow from low string to high string and (2) as I tilt the bow forward and backward (or lean forward and backward). It can also be thought of as a motion sensor, indicating changes of velocity: (1) in the bowing direction and (2) perpendicular to the surface of the violin (up and down). These sensors are all wired to a belt-mounted microcomputer which produces four MIDI continuous control messages corresponding to the four sensors (2 FSRs, 2 axes of the accelerometer):

Figure 8. R-Bow belt-mounted computer (with ChapStick for scale)

The technical requirements for using the R-Bow are minimal, and I have used it in many performances with few problems.[22]

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[21]Simply laying the index finger lightly on the FSR will push it out of its sensitive low pressure region.
[22]See the Appendix for more technical information regarding the construction of the R-Bow. Also see Dan Trueman and Perry Cook, "BoSSA: The Deconstructed Violin Reconstructed," in *Proceedings of the International Computer Music Conference in Beijing, China*, by the International Computer Music Association (San Francisco: ICMA, 1999).

In Sound Example 32 (from a performance at the Not-Still-Art festival in Cooperstown, NY), the R-Bow is used in conjunction with a pitch detector (Miller Puckette's "fiddle") and my 6-string electric violin to create a virtual violin with 6 data streams: two *FSRs* (pressure), two accelerometer axes (position or acceleration), pitch, and amplitude. These are mapped to a sampler of my own electric violin samples in various ways. With one mapping, the two *FSRs* are summed and used to crossfade three looping sustain samples of different intensities and lengths; the different tonal qualities of these samples and the phasing that results from looping samples of different lengths helps prevent "sample fatigue," where our ears tire of hearing the same sound over and over. Sudden changes in the *FSR* values trigger short samples of various kinds of bow attacks, again in layers to prevent fatigue. If I choose bow position to control pitch (which I don't in this sound example), it is possible to play the bow without the violin; my shoulder makes a convenient surface for bowing. When feeding the pitch detector with my electric violin, I might use sudden changes in bow pressure or position to query the pitch detector for the current pitch; this way, I can sustain one pitch with the bow and play others with the violin, having the bow play new notes only when I ask (not just because I play new notes with the violin)—this allows me to play "duos" with the bow and violin.

With the same virtual violin, I play physical models (or, more correctly, physically-inspired models) of various shakers and scrapers in Sound Example 33 (from a performance at Rensselaer Polytechnic Institute).[23] Here, pitch data controls the resonant frequency of the shakers, but the volume of the violin itself is turned down; I use it only as a pitch source and resistant surface on which to play the R-Bow. One shaker (a maraca) is tied to an accelerometer—by literally shaking the bow, I shake the maraca. A model of a guiro is associated with bow pressure—the harder I press, the slower I scrape along the guiro. The damping of the shaker and the number of beans in the shaker depend on bow position—the further I bend over, the longer the maraca "sustains" and the more beans there are inside the shaker. Thrown into this mix is a software audio-scrubber; the shakers are recorded into a delay line (about 5 seconds long) and the speed in which I move through the delay line (and the direction) when playing back depends on bow position, allowing me to control playback pitch—this can be clearly heard at 28 seconds (descending; I bend over) and at 38 seconds (ascending; I straighten up). Following are three frames from a video of this performance which illustrate some of the positions I assume in order to "play" the R-Bow:

[23]Perry Cook, "Physically Informed Sonic Modeling (PhISM): Synthesis of Percussive Sounds," *Computer Music Journal* 21 (Fall 1997): 38–49.

Figure 9. Three frames from a video of a performance with the R-Bow. To "play" the accelerometers, I move the bow (and my whole body) into unusual positions.

Later on in this improvisation, I change the kinds of virtual shakers hanging from the R-Bow on the fly, sometimes rapidly altering both the sounds and the mappings that determine the physical techniques required to play the bow.

Like Laurie Anderson's magnetic-tape bow, the R-Bow capitalizes on both the physical and visual aspects of traditional violin technique. Learning to play the R-Bow (an ongoing process) also reminded me of the experience I went through learning the Hardanger fiddle (as described in Chapter 1). With the *hardingfele*, my body adjusted to the different weight and bow speed requirements, and to the left hand requirements, of the smaller, lighter fiddle; I feel and look different playing the *hardingfele* than I do playing the electric or "Classical" violins. Similarly, I have learned a variety of gestures that are meaningless without the sensor data. For one, I can simply press down with varying degrees of weight and play a virtual instrument without pulling the bow across a string—the grit of the bowed-string relationship is non-existent. Secondly, I can move the bow, or shake the bow, and depending on the kind of gesture, play a virtual shaker or adjust a signal processing parameter. Again, the bowed-string is irrelevant. In fact, the violin itself is irrelevant. By combining these new gestures with the familiar ones available, I have an entirely new way of playing the violin—it is an instrument with a unique, and only partially explored, expressive potential.

Inspired by the R-Bow, I have also constructed interfaces that use the violin fingerboard and bowed strings as metaphors. The Fangerbored is a violin fingerboard with a linear position sensor that can be played with traditional left-hand technique—a single string.[24] It can be held by the right hand, and has four *FSRs* which can be played by the four fingers of the right hand:

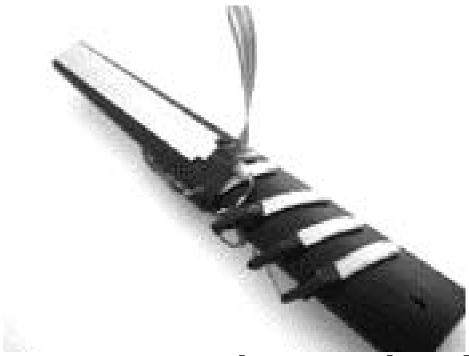

Figure 10. The Fangerbored, alone, and held in playing position

The right hand sensors—clearly not derived from the violin—are perhaps most like the holes on a Baroque flute, which have a range of "coveredness," from open to fully covered, that allow for subtle pitch manipulations. In addition, since the Fangerbored is not connected to a large resonating body, it has a biaxial accelerometer, creating two further expressive dimensions. The resulting virtual violin has seven data points: left-hand position (1), right hand finger pressure (4), and position/motion (2).

The Bonge, motivated by the bowed string, consists of four bowed "sponges." Each "string" consists of a small piece of foam-covered wood resting freely between two fixed FSRs:

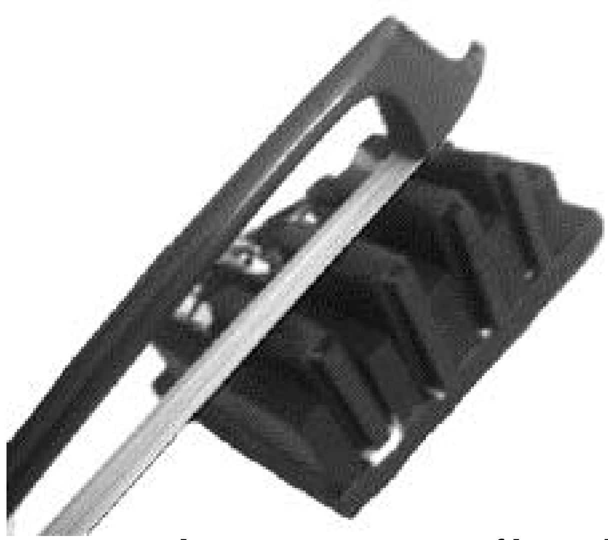

Figure 11. The Bonge; an array of bowed "sponges"

[24]Commercially available position sensors are quite wide, and only one fits on a violin fingerboard. I hope to be able to put four on a single fingerboard (as they do at MIT) in the future.

Each "string" can be bowed, creating a data point that depends on direction, pressure, and bow speed; negative values indicate "up-bow," positive values indicate "down-bow." When bowed with the R-Bow, this virtual violin has eight dimensions: the four R-Bow dimensions and the four "strings" of the Bonge.

With the creation of the Fangerbored and the Bonge, we have essentially deconstructed the acoustic violin into its primary constituent physical interfaces and offered one (of many) potential human-computer interfaces that use the violin as metaphor. When we plugged in the acoustic violin, we freed it from its resonating body (Chapter 2); similarly, when we cover it with new sensor technology, we free it from the constraint of resonating strings. And just as electricity resulted in the *detachment* of sound source from physical interface, sensor technology detaches the physical interfaces from one another.

So far in this discussion of the virtual violin, I have neglected to mention sound source; the resonating body as speaker is one of the primary features of the acoustic violin, and, as discussed in Chapter 2, choice of speaker technology is crucial to configuring the electric violin. Since the virtual violin, as defined here, is simply a collection of data, the sound source (assuming we're even using it to generate sound) can be anything. In all the cases mentioned thus far, traditional monophonic amplifiers are used, including most of my work with the R-Bow. This is one solution, but perhaps not ideal for all situations. Regarding the premier of Machover's *Begin Again Again...*, with Yo Yo Ma on hypercello, loudspeakers were clearly unsatisfactory:

> The (Amsterdam) Concertgebouw is one of music's cathedrals, one of the very best concert halls in the world. It preserves the nuance and detail of a performance better than virtually any other major space in the classical music world, so that the audience hears every note, every gesture that a musician has the skill to make. Machover's piece, though, can only be heard through loudspeakers, whose blocky presence, suspended above the audience, burst like strange growths into a room built for live performance.
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> There was, in other words, an apparent (and partly real) clash of cultures between the technical wizards and the priesthood of classical music. (Martijn Sanders, director of the Concertgebouw, asked at one point in a rehearsal of Machover's piece: "Does it have to be so loud?..." As the saying goes, same planet, different worlds.)[25]

[25]Levenson, 307.

Perhaps it is as simple (or complex) as a cultural clash, but I believe it has more to do with the assumption that electronically generated sound always has to come from mono-directional loudspeakers. The sound source is often the last thing considered, and rarely is it considered in any kind of depth—standard P.A. speakers are assumed.[26]

What kind of sound source should we use, and how should it be related to the elements of the "deconstructed" virtual violin—the R-Bow, Fangerbored, and Bonge? Combining the multichannel spherical speaker technology of Chapter 2 with these new input devices results in the following unusual creation:

Figure 12. BoSSA (Bowed-Sensor-Speaker-Array)

BoSSA, for Bowed-Sensor-Speaker-Array (also known as The Critter), consists of a 12-channel spherical speaker array (constructed with my father, Larry Trueman) with the Bonge mounted on top and the Fangerbored mounted loosely on the side. When played with the R-Bow, BoSSA has fourteen data points: six from the Fangerbored (one of the accelerometer axes is rendered irrelevant by the mounting; the other is playable by rotating the Fangerbored up and down), four from the Bonge, and four from the R-Bow. This is actually more than a single player can play simultaneously. For practical purposes, the right hand "holes" on the Fangerbored are not usually played (assuming the right hand is holding the R-Bow), but can be used as switches by the left hand. Also, given that BoSSA is essentially stationary, it is impossible to bend over and take full advantage of the R-Bow accelerometers when bowing the Bonge. This effectively reduces the number of dimensions to nine, though there are other possible configurations that could reclaim a dimension or two.

[26]When talking about performance, that is. Composers of "tape" music often take great care in dealing with speaker arrangements, and there is much work currently in progress with multi-channel "immersive" speaker environments. Live "diffusion" of "tape" music is also common.

As a whole, BoSSA is more like a traditional violin than any of the virtual violins described thus far. In terms of input, the MIT violin stays closer to the violin—they actually use a violin—but for output, they rely on detached loudspeakers, essentially splitting the instrument in two. By combining a rich acoustic diffuser—one that can imitate the spatial radiative timbral qualities of the violin (from NBody; Chapter 2)—with input devices inspired by the physical interface of the violin, BoSSA enables the player to conceive of the instrument as a single entity.[27]

What have we gained by building such a creature? Why would we rather play this "reconstructed violin" than a "real" violin? There are several reasons. As with all virtual instruments, we have the ability to arbitrarily map the physical gestures to anything. In the *Lobster Quadrille*, the first piece composed for BoSSA, I chose to set a poem by Lewis Carroll from *Alice in Wonderland* (Sound Example 34). I recorded the text (as read by Monica Mugan), separated the sentences into individual samples, and associated the four "strings" of the Bonge with the first four sentences (initially) of the poem. Down-bows played the sentences forward, up-bows played them backward. My left-hand finger position on the Fangerbored determined the relative pitch level of the samples; I could gliss, trill, and vibrate with familiar violin left-hand technique. The sentences were then sent through a 4-voice bank of comb filters. I controlled the feedback coefficient—and hence the relative presence—of the comb filters with the position of the Fangerbored; rotating the Fangerbored up resulted in rich comb filters, rotating it down left the samples essentially alone.

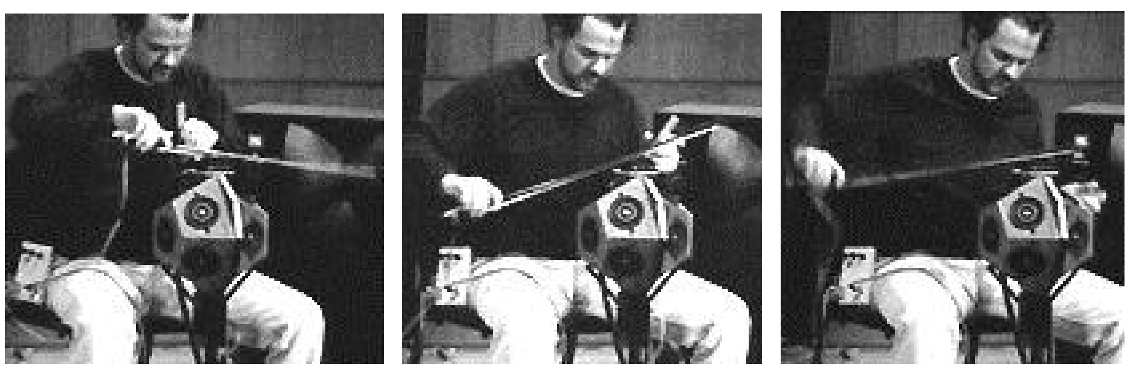

Figure 13. Three frames from a performance of the *Lobster Quadrille*. Note the varying positions of the Fangerbored, which I use to "play" the comb filters.

I composed a "chorale" which controlled the pitches of the comb filters. By pressing one of the right hand "holes" on the Fangerbored, I could page through both the chords of the chorale and the sentences of the poem. At certain points in the piece (*e.g.,* the beginning), the Bonge would also supply

[27]Please note that I am not making a value judgement here; I don't feel that it is *better* to conceive of a virtual violin as a single instrument. But, it is exciting to *be able* to do so.

a noise source to drive the comb filters, allowing me to reinforce the pitch content of the chorale. I attached a model of bamboo wind chimes to the accelerometers of the bow; when not bowing the Bonge, I could shake the chords. I also mapped bow pressure to comb *vibrato*; by leaning into the bow, the chords would gently oscillate. Each of the four comb filters and sentences were assigned to their own channel of drivers on the surface of the speaker, resulting in spatially diverse diffusion.

This is one particular mapping of an infinite number, hence the "infinite virtual violin." Being able to compose such mappings is one of the most exciting aspects of "virtualizing." Being able to change these mappings "on the fly" in performance also poses an interesting challenge; by changing the mapping, we change the physical relationship between player and instrument. This is a bit like being able to transform a Baroque violin into a modern violin instantaneously, without putting the instrument down. Although we don't actually alter the physical interface, we can change the way it responds, forcing the player to adapt. In this way, instrument design, composition, and performance combine into a single activity.

From the perspective of electronic music, there are two particularly exciting features of BoSSA. As discussed above, electronic/computer music is almost always heard through multiple spatialized loudspeakers. This precludes the kind instrumental *presence* that acoustic instruments have (Chapter 2) and makes it difficult to blend acoustic and electronic instruments. BoSSA takes advantage of the radiative properties of spherical speakers to engage the reverberant qualities of the performance space and provide just that sense of presence. Unlike the electric violin, however, where the physical instrument is still detached from the speaker, the speaker *is* the instrument; to my knowledge, BoSSA is the first such instrument. This allows for a kind of *intimacy* unknown in electronic music. It is easy to imagine inviting someone into a living room, asking them to "come closer, listen, watch." We can now conceive of creating a sort of "electronic chamber music," combining electronic and acoustic instruments, interacting as chamber musicians do—breathing together, making eye contact, phrasing, etc...—that has never been possible. We can, as David Wessel suggested, try to "calm the religious wars between 'acoustic' and 'electronic' performers and stimulate the development and performance of an intimate and mixed music that would thrive in small private and public spaces."[28]

Physicality, Expression and Communication

It is easy to imagine an enormous family of instruments like BoSSA, instruments with input interfaces inspired by every known existing instrument, and with speaker arrays of various shapes and sizes (I would

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[28]David Wessel, "Instruments that Learn, Refined Controllers, and Source Model Loudspeakers," *Computer Music Journal* 15 (Winter 1991): 82–86. In this paper, Wessel suggests we create "source model speakers"—spherical speakers for diffusion. He does not go as far as to suggest the combination of input (sensors) and output (speakers) devices (like BoSSA), though he has (at CNMAT) created an 6-channel cubical speaker for demonstration purposes.

love to play an instrument that combines more sophisticated versions of the Fangerbored and Bonge with an elegant configuration of gently curved electrostatic speaker material that could be held under the chin like a traditional violin). In designing these instruments, we have an opportunity to create new vehicles for human expression. It is my belief that the violin "as interface" has resulted in the creation of a rich tradition of physical performance technique that is not simply a compromise between human body and resonating body, but is in fact a natural and powerful expressive technique that can transcend the resonating body and be applied more generally in electroacoustic music; the "pose" (from Chapter 2) is significant in its own right, apart from the instrument. This is another facet of the answer to my opening question of Chapter 1: what is it about the violin that has attracted players, composers, and listeners for more than 400 years? The violin "as interface" has proven to be remarkably robust and flexible. It has encouraged musicians to imagine how it could be *different*, how it could better reflect our personal and changing expressive needs, how it could be *reinvented*.

At the root of this process of imagination is a sense of *physicality*; we look at the violin—any violin—and imagine how we might approach it, take it in our hands, and draw sound from it. We imagine how we might take *ownership* of it, in a musical sense. This is where we learn something about words like expression and communication. Clearly, what we express—or better, how we are expressive—with a violin depends on whether it is a high-strung Schubertian violin, a loosely strung Baroque violin, a resonating Hardanger fiddle, an immersive "stadium electric violin" (the violin that surrounds the violinist with hundreds of speakers in a football stadium, from Chapter 2), or a deconstructed virtual violin. Our physical relationship with the instrument depends on the instrument, and our sense of being "expressive" or being able "to communicate" is born from this relationship.[29]

Performers readily accept the intransitive meaning of the word "expressive;" we do not (usually) need to know *what* we are expressing (the transitive meaning).[30] Simply being expressive—*espressivo*—is a familiar state. When we say that an instrument is especially "expressive," the concern is not *what* we are expressing. Rather, we are commenting on our physical relationship with the instrument. This does not prevent us from having a sense of *communication*, however. The ethnomusicologist Steven Feld, in his essay *Communication, Music, and Speech about Music*, suggests that the oft asked question "What does music communicate?" is perhaps better replaced by questions like:

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[29]In this context, it seems misguided for Machover to expect his hyperinstruments to "lead to a gradual redefinition of musical expression," when his work is focused on leaving the physical relationship between player and instrument untouched (Machover, 186).

[30]Sadie, Stanley, ed. *The New Grove Dictionary of Music and* Musicians (London: Macmillan Publishers Ltd., 1980), s.v. "Expression, II" by Roger Scruton.

> What is the shape of a music communication process? How are music communication processes activated? How do music communication processes implicate interpretation.[31]

He argues persuasively that communication is a *process* that "is not located in the content communicated nor in the information transferred,"[32] rather:

> Communication is neither the idea nor the action but the process of intersection where objects and events are rendered as meaningful or not through the work of social actors.[33]

As "social actors," musicians, whether they are performing or listening, take part in this process and "render as meaningful" the music they hear and play. *What* the meaning is, is not of primary importance—communication takes place.

For performers, our physical relationship with our instrument is the wellspring of energy and "objects" for this process. As the social anthropologist and ethnomusicologist John Blacking said: "music begins... as a stirring of the body."[34] He also extends Edward Cone's notion of "vicarious performance" by suggesting that "to feel with the body is probably as close as anyone can ever get to resonating with another person;"[35] if our vicarious performance is so successful that we actually feel a "stirring" in our bodies, some sort of deep communication has taken place.[36] For Blacking (and for me), this kind of communication is of no small significance:

> I suggest that they [music and dance] have remained key factors in human life, and are, in particular, means for people to bridge gaps of communication and understanding between their lives in societies that prescribe certain ideas, sentiments, and definitions of experience, and their bodily experiences as individual feeling beings."[37]

In this context, the future of the violin—be it Schubert's violin, an electric violin, or BoSSA—is seemingly rich with potential, just as its past has been rich with success. As a tool for engaging the body and mind in the processes of music making, expression, and communication, the violin is unique yet

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[31]Steven Feld, "Communication, Music, and Speech about Music," in *Yearbook for Traditional Music* 16, 1984, 15.
[32]*Ibid*., 2.
[33]*Ibid*., 2.
[34]John Blacking, *How Musical is Man* (Seattle: University of Washington Press, 1973), 111.
[35]The phrase "vicarious performance" is from Edward Cone, *Musical Form and Musical Performance* (New York: Norton, 1968), 21.
[36]Though I have to express reservations concerning Blacking's interest in proclaiming a cross-cultural, universal "biogrammer."
[37]John Blacking, *Music, Culture, and Experience* (Chicago: University of Chicago Press, 1995), 241–2.

multitudinous. If anything has been learned from this exploration, it is that as violinists and composers, we must reinvent this tool to suit our needs. And as we reinvent the violin, we reinvent ourselves as well.