What if your instrument is invisible?

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Motivation

As an electronic musician and vocalist, I am largely occupied with the capture and manipulation of sound in real time--the sounds of my voice and of instruments being played by other musicians. Often, both of these instruments are "invisible" to the audience. Over 20 years I have used terms like "real-time live sound-processing", "audio machinations", or "{kaleid-o-phone}" to describe what I do. I grappled with explaining to other musicians, my audience and audio engineers what it is, exactly, that I am doing on stage. I found the technical explanation to be difficult enough, but explaining myself aesthetically and musically has been as interesting and challenging a task. With each new project or collaboration, new issues of musical and acoustic aesthetics arose, which I studied, played with, and sometimes held onto, as part of my growing library and palette for performance and communication. In this text, I will explain why my audio setup feels so consistently to be an *instrument* rather than a pile of audio effects.

Guidelines

In the mid-1990s, I wanted to experiment and find ways to play sound manipulations in musically reactive ways, as an "instrument", and especially in improvised contexts.
I first started, by dragging a Macintosh Plus computer with MIDI-controllable effect units to clubs and venues– and gigging meant carrying a whole lot of equipment. I did not know what to call what I was doing with all the sound processing, but I knew I wanted to do it, and was compelled by what I was discovering in this unchartered territory.

I was lucky to start with a group of very open-minded instrumentalists: with drums, bass, saxophone, a multi-instrumentalist (brass, reeds), a live video artist, and me, singing (in a group sometimes called "Collison" or "Free Jazz Video Collision"). I put microphones on everyone. I routed the sound I brought in through a mixer into an effects unit controlled by a Max[i] patch I wrote. In this way, I created tiny and constantly changing loops, wild mood swings with comb filters, pitch-shifting madness, accompanied by a bit of my singing in between.
Back then, although there were a few instrumentalists in New York bringing computer-based electronics into small club environments, the aural transformations I was experimenting with were more likely heard on the concert stage of a university, in academic computer music.

The musicians I played with both appreciated and supported what I was doing, and reacted very musically to my electronics, experimenting along with me. After our shows, however, people would often say "… fabulous, but you really should do more!"; they thought I was only *doing something* when I was singing. My sound manipulations were not attributed to me because the audience could neither visually identify these sounds as coming from me, nor identify them aurally as my contribution. I realized that I created a complex combination of sounds, that were either being ascribed to the other musicians (who were my source material), or that was so strange as to be unidentifiable, and certainly not created by the singer.

Through this experience, and supported by fellow musicians, I came to discover that I wanted and needed to create a separate sonic identity with my live processing, one that would be distinct from the other players' sounds. I would have to synthesize these ideas myself from my own musical influences and technical background.
Over time, I came up with two guidelines to help me find a sonic identity and tackle my invisibility problem. They are primarily about respecting the sound and independence of the other musicians and help me to make good music:

1. Never interfere with a musician's own musical sound, rhythm or timbre.
2. Be musically identifiable to both co-players and the audience.

The challenge in finding ways to be musically identifiable to an audience, however was somewhat more complex. I found that to *show* what I was doing in a non-ostentatious, and genuinely musical way was only possible if I followed my guidelines. But in addition, the organization of my performance setup, my *instrument*, needed to follow a third guideline:

3. The performance setup must incorporate my body and allow for physical interaction between the technology and myself.

The setup would have to be flexible and physically responsive, just like the acoustic instruments of the musicians.[ii]

My practice

My audio system is meant for performance. In this sense it is reliable and consistent enough for me to think of it as an *instrument*. It can however also be wildly unpredictable, even chaotic, in extremely fun and musical ways: at times I work very close to feedback and find resonances with filters, pitch-shifters and delays. I create complex musical textures with these effects, creating responses and statements that are intrinsically related to, and simultaneously derived from, the music around me. My work, as such, is extremely subject to the acoustics of the performance space. Therefore, the sonic character of my contribution is subject to the physical realities of temperature, humidity, and acoustics of the performance space[iii]. My source sounds are unpredictable, since they are being created by other people. My processed versions of these sounds, which I try to harness/control into being something I can "play", are always subject to environmental conditions. Due to these ephemeral qualities, my live performances require long set up times and long sound checks.

No matter how well rehearsed, each and every performance, even those with the same instrumentation, music, and performance space, will be inescapably different. As a performer, I feel as if I were trying to build a small fire on stage, fanning it all along, building it and keeping it going. But unlike an actual fire, mine is also an interactive system that I can control rhythmically and quickly. This has been the key in creating my instrument.

Invisibility, performance practice and gender trouble[iv]

At first I was very occupied with trying to figure out what to do technically: to avoid sounding like a simple "effect", and to fit into an ensemble sonically using my new ideas. There was no time to worry if anyone else could actually understand what I was doing.

As an example --imagine seeing a saxophonist perform a rhythmic figure that is looped and filtered, but one that is controlled by someone standing on the other side of the stage (who is also singing). By seeing and hearing, it is easy to identify what the saxophone player does, but there is no visual cue or connection with the sound processor/singer. Due to this visual incongruity, the sounds I created were often attributed to the sax player, to other musicians holding instruments, or even to the sound engineer in the back of the room-- but were not attributed to me.

I did not worry about this lack of audience understanding (yet), because I was too busy explaining myself to the sound engineers at the clubs where I played. Without going into great detail here about the invisibility that still existed for a woman working with technology at that time, let me simply state that the combination of an unusual technical setup and my gender led to the absolute necessity for me to allocate an extra 15-20 minutes to *every* setup and load-in, for every gig. It was necessary to plan for enough time for a long "chat" with the sound engineer; to explain what I was doing in detail, even to justify my methods. I had to convince the engineer, usually male, that I did actually know what I was doing even if it was unorthodox, and that I did know how to handle the equipment, in spite of my gender. I knew from experience that without this chat, as soon as the engineer heard feedback (even if intentional and part of my sound), he would turn it down. He would likely mix my electronic sounds so as to be quieter than all the other instruments, assuming my contribution to be merely sound effects (and singing).

What a relief, that nowadays I rarely need to have these conversations. It is often not even necessary to explain my live sound-processing in detail at all, as it is more commonplace. Nor is it necessary to prove myself as competent, as there are many more women working with music technology, both as performers and engineers. These days, a musician performing with a laptop is rather ordinary, and many musicians and engineers are familiar with the idea and practice of live sound-processing for a variety of musical styles, even pop music, and in all kind of venues. These days, when I explain my practice to an audio engineer, I hear a lot more "Oh yes, someone was in here last night doing that".

With more experience, I saw the need, and crafted a careful approach for sound processing, one that is clearer to my fellow musicians. Once I had refined the way I use my sounds, I developed a "body-oriented" live electroacoustics practice. My hope is that this approach enables even a more general, uninitiated audience, to understand that in my performances, the "singer" is also an electronic musician, shaping her instrument out of sound.

Making the Invisible more understood: using my body

My initial musical training was as a jazz guitarist and, later I also studied classical voice. My teachers were very strict about wanting me to keep perfectly still while playing or singing, so as to focus my energy entirely into my instrument. In recent years, I have had to undo this training, to some degree, for the simple reason that electronic instruments do not generally involve acoustic vibration.

These missing vibrations are what would normally allow me to feel physically connected to my (acoustic) instrument or voice, even when I am standing perfectly still. With electronic instruments, the physical gestures I make take the role of the vibrations in creating this connection. Using gesture controllers helps me to connect with my audio, in the moment, and not just passively as a listener, post facto, through my ears._Moving and connecting my body to sound/music/rhythm is of paramount importance. This is how I have turned what I do into a performable instrument.

I must move, and I must touch something while I'm playing. I shape the music using actions that require physical effort corresponding to the sound. The best controllers (ones that I can either hit hard enough or that are sensitive enough to allow for subtle control), help me to use my entire body, and lessen the "invisible instrument" problem.

Over the years, I've performed and experimented with many different "controllers-of-the-moment" and interfaces as part of my instrument. At first, I did wonder whether the use of controllers —Wii Remote, MIDI fader boxes, iOS devices, LEAP motion— was intended more to facilitate my playing or rather to promote audience engagement. If these controllers were for my audience's benefit, then was this to "show them" that I am performing? That felt awkward to me. If the controllers were meant for me to make my performing easier, then my challenge would be to find ways to make each physical gesture analogous to the musical gestures, avoiding overuse of simple correlations (such as moving hands up and down to control volume or pitch.)

In recent years I started getting positive feedback about this from fellow musicians-- that I do move while performing and actively engage my body. One collaborator[v] wrote I bring "the energy and physicality of free jazz to experimental electronic music" which I took as a high compliment. It has turned out that all the dance classes I took growing up, and Dalcroze Eurhythmics taken as an undergraduate, have all informed my electronic music practice.

Looking back to the mid-90's—to when experimental video artist Kristin Lucas joined many of our performances in "Collision", it is clear that her practice at that time served both as a contrast and counterpart to my own performance identity in the group. Lucas performed using a toy guitar as a video controller, standing on stage amongst the musicians; cameras attached to her and to the other musical performers. With both a projector and a camera mounted on her bicycle helmet, Lukas projected her intriguing images, created in the moment, onto the the musicians/instruments and the entire room, in the same sort of appropriation of the immediate environment that I was experimenting with. (She collected and processed images, I collected and processed sounds). Yet, Lucas' wonderfully prescient "video instrument", one normally not visible to the audience, was intended to be seen, and perceived as connected to the music, while my "musical/audio" instrument remained "invisible", unless I sang and processed my own voice.
It would be simple to solve the invisibility problem, if all that was needed was to use the right gestural controller, or perform in a more outwardly visible or extroverted way as Lucas did. However, it turned out that much more than a visual identification was necessary-- my instrument had to be *aurally* identifiable too. Hence my approach is more complex and involves an aesthetic approach to listening and acoustics, as well as active engagement in my body.

Sound decisions

This aural identification, can be broken down into several simple parameters of electroacoustic music, and specific approaches I have taken using these parameters specific to playing with live sound-processing.

Envelope / Dynamics

Being able to shape the volume and subtleties of my sound is an important part of my musical expression and my instrument, as it is for all other instruments. Shaping the envelope and dynamics of my live-processed sounds is central to my performing, and it is the first thing I teach my students. *If I cannot control volume, I cannot do anything else described in this article. I use volume pedals and other interfaces, as well as compressor/limiters for constant and close control over volume and dynamics.*

Rhythm

I cannot express strongly enough how important control over rhythm is to my entire concept. It is what makes my system feel like an instrument. My main modes of expression are expressed via timbre and rhythm. Melody and direct expression of pitch using electronics are slightly less important to me, though the presence of pitches is never to be ignored. I choose rhythm as my common ground with other musicians. It is my best method to interact with them.

Nearly every part of my system allows me to create and change rhythms by interactively altering delay times, or by tapping in the desired pulse. Tapping in pulses has helped me put my body into my performance, and therefore helped me with my invisible instrument problem. We need our bodies involved!

I am strongly attracted to polyrhythms, which is not surprising, my family is Greek, so there was lots of dancing in odd time signatures growing up. Because it is so prevalent in my music, I implemented a mechanism that allows me to tap delay times and rhythms that are complexly related to what is happening in the ensemble at that moment.
Pianist Borah Bergman once explained a system he though I could use for training myself to perform complex rhythms, and I created a Max patch to facilitate this. Later I implemented this polyrhythmic metronome, to control the movement between any two presets quickly, creating polyrhythmic electroacoustics. Other rhythmic control sources I have used included Morse Code as rhythm, algorithmic processes, and a recreation of features influenced by North Indian Classical Tala. vi

Delays and Filtering

As stated in my first guideline, I avoid interfering with another musician's own musical sound, rhythm or timbre. If I were to play in a purely "transformative" manner, or merely mirror what they do, I worry that I might interrupt their own thought process about rhythm and timbre. Instead of "piggy backing" my sound on theirs, I'd rather aurally transform and reflect on their sound-making, creating a statement of my own, based on their sound.
To achieve this, my primary tools are delays and filters. Filters change timbre. Yet when my filtered version of a performer's sound is mixed with their own direct live sound, my contribution might not be heard as an entirely separate gesture. The filtering that I do might be heard merely as an effect. To avoid this, I take extra care when changing certain parameters. It all comes down to filters, delays and time. They are all interrelated.

By modulating delay time, it is possible control everything from timbre to rhythm to musical form. In Karlheinz Stockhausen's lectures "Four Criterion of Electronic Music" (1972)[vii], he described a continuum of timbre-rhythm-form -- inherent perceptual qualities determined by the rate of notes: from very fast pulses to very, very slow rhythms. Perceptually, rhythmic pulses faster than 16-20Hz become pitches of various timbres. Rhythmic pulses slower than this range might be heard simply as relating to traditional rhythms and tempo. If pulses/rhythms are played at slowest end of this continuum, they are perceived as pertaining to musical form.[viii]

By modulating the amount of feedback in a delay line, I am also able to control sustain, and overlap of sound. In many cases, this also allows me to alter timbre, in that the overlap of many copies of a signal, effectively cancels out or emphasizes timbre-rhythm-form frequencies, creating something akin to a comb filter. The delay times and overlap relate directly to the timbre-rhythm-form continuum described by Stockhausen.

With interpolating delay lines, I am able to adjust the length of the delays in real-time without clicks or distortion. A welcome side effect is a Doppler effect, resulting in inadvertent pitch changes when increasing or decreasing the delay time. This is something fun and useful in forging a new sound out of what is being played by another musician.

Delay Time / Length / Interaction

The length of a delay in relation to an incoming sound is the key feature to be considered in order predict what will happen in a "musicianly" way.
I use long delays (i.e., longer than the captured phrase) to create rhythmic structures. This use of delay/repetition is a time-honored musical gesture, employed successfully for centuries in many kinds of music and heard today rather ubiquitously in loop-based electronic music.
To create a separate voice for myself, I must undermine the expectations set up by this structure. I could change the delays slowly over time as a long-form musical gesture, but I prefer to change my delays in a clearer musical gesture, in response to what I hear from the ensemble. Working with Doppler, with feedback levels, with various delay times and other effects are all effective to this end. But it also works to simply change delay parameters to create overlapping sounds or "not-overlapping" sounds.
If a delay is shorter than the length of its input phrase, it results in overlapping copies of the sound. This overlap causes filtering and resonance, especially when the delay effect has a high feedback level. The feedback creates even more overlap. By shortening a delay time to be shorter than the sound I'm delaying, I create instant resonance, or with slightly longer delay times, resonant textural density.

With delays of less than 30ms (approximately), any incoming sound with sharp transients will turn into pitches that I can use as sound gestures. The frequency of the sounding pitch is inversely proportional to the length of my delay[ix]. Conversely, sustained sounds and long tones resonate at the same frequencies, but they sound rather like they are being comb filtered rather than delayed because of the overlap. When I use this procedure on someone else's sound, I contradict my first guideline, and so, to maintain independence, I am careful how I use resonance on long tones.

These phenomena all relate, of course, to physical modeling and periodicity pitch. But all technical thoughts aside, I know that playing with delay length and feedback (overlap vs. non-overlap) gives me the ability to rapidly transform a sound into something seemingly unrelated to the sound I started out with and that I am processing.

Filter strategies

Julius O. Smith, a longtime researcher at the Center for Computer Research in Music and Acoustics (CCRMA), wrote: "Any medium through which a signal passes can be considered a filter"[x]. This implies that all parts of my system — my delays, the room I am playing in, the speakers — all have an effect on my sound.

But how can *I* be identified, when I'm filtering another performer's sound? My solution is essentially that when I use effects to alter a source sound, I almost always make an active choice to do something *different* than what my "source musicians" are doing. To *be different*, I *listen first*. *Only then, do I react*-- in one of the following ways.

Temporal Shift
I could play my filtered "response" later (in time) by feeding my filtered sound through one or more long delays. The delay applied to the filtered sound makes it evident that sound processing is happening and separate from my source. The temporal shift makes it clear that my processed output is not merely part of the original sound, but rather that it is something *I* am doing and contributing. Of course, I select my delay times keeping aware of any other rhythms and tempi played at that moment.

Sweep
I could modulate parameters such as Q factor, center frequency, bandwidth, and/or feedback. I like to perform these modulations rhythmically and in a way that differs from whatever my source musician does pitch-wise or rhythmically. This approach works best on sonically rich sounds.

If I observe my source musicians are playing quickly while using using a wide pitch range, I will choose to sweep center frequencies, or modulate other parameters, more slowly and create a contrast. If the other musicians are moving slowly, I may choose to move more quickly. If they create fast or complex rhythms, I do not compete, and stay fixed in a position. If they play drones or with a limited note range, I have the option to either articulate pitches by selecting a high Q factor and resonance for my filters or to perform fast rhythmic gestures, e.g., by quickly moving the center frequency around. In other words, the key to maintaining a separate identity when using filters is *contrast and/or temporal displacement*.

Pitch-Shifting and other manipulations
Another way to distinguish my sound is to use pitch-shifting. As a composer and singer/instrumentalist, I am keenly aware of the implications of all pitches that are being played by all the musicians, and do not pitch-shift sounds without considering the sonic and harmonic mess I might create if by disregarding stylistic and harmonic rules. I can choose to break these rules, of course, but I am always aware of what new pitches I've added to the overall sound, just as if I were playing these pitches/notes on a traditional instrument.

These considerations aside, I otherwise follow the same guidelines I use for filtering (regarding contrast and temporal displacement). If I pitch-shift a sound without delay or modulation, as with filtering, my contribution will likely be heard simply as an effect.

Reversed sounds/speed changes
When reversing real-time sampled sounds, it is difficult, to make useful generalizations regarding the outcome, because the resultant sounds are so tied to the individual envelope of the sound. For the most part though I cannot predict an outcome unless I know in advance what the envelope of the sound will be, or unless I first sample and repeat the sound myself. There is some predictability and usefulness in resonant percussion sounds played backwards with their lovely sudden cutoffs, and how we all know how enticingly beautiful backwards piano sounds, but most instruments have significant variation in the types of envelopes they can produce, especially with skilled players . There are also a great many sounds that do not benefit from being reversed and others that are even humorous because of spectral distortions, and so the outcome is as varied as the input. This lack of ability to truly generalize on this subject was first noticed by with Pierre Schaeffer in the 1940's.[xi]
Reversing a sound, however, does have its usefulness help however me create the distinction and otherness between my sound source and my own sound gestures, especially when combined with pitch-shifting or other processing.

Similarly, the speed of playback is not that interesting for me to generalize about beyond to say that some sounds are quite interesting when slowed down to reveal their internal rhythmic structures and hidden resonance. They can be interesting when sped up to create new rhythms. But how they actually sound is also very dependent on the algorithm that is used for the speeding up and slowing down, and whether or not it is accompanied by pitch changes (since this can now be decoupled). However, looping the rhythmic structures, or speeding up and slowing down, especially in

conjunction with pitch-shift, are all useful and simple musical statements that I can make and use often. They are useful, because they nearly always will sound different than my source audio.

Independence Day — Feedback as solution

After a few years of performing, progressing and learning about my instrument, (around 1998) I saw the need to become less dependent on others for my sound sources without relying on samples and pre-recorded sounds. The end to this dependency on others for sound came spontaneously during a recording session. At some point someone pointed at me to play a solo, and I realized that I could not play solo because all my sounds depended on someone else playing! To get around the dependency problem and play my solo that day, I innovated and improvised. By routing my effects processor back into itself I created *no-input* feedback, and also built audio feedback using the room tone. These impromptu solutions soon became a regular part of my instrument. Since then, I have found feedback to be an immensely rich source of sonic material that does not require anyone else nor even my voice to work.

I like to use quick changes and modulation of feedback in my delay systems to quickly increase or decrease density of my sound, and (as mentioned above) I also find it useful for creating sustained pitched sounds. This is why a critical part of my technical setup is the compressor/limiter on my output. The compressor is set with a fast attack and high compression ratio. This enables me to get dreadfully close to sound system feedback levels without actually hurting anyone's ears or losing control.

Using feedback as a musical source was central to the "Ha!" trope in my trio *What is it Like to be a Bat?*[xii] *(1996, with Kitty Brazelton)*. In one of our pieces, I would yell/sing "Ha!" into the microphone and then trigger a sequence of enormous, feeding-back, swiftly changing delays resulting in Doppler effects. The result sounded *very* big and I used it in a duet with the drummer. Although it was at first challenging to consistently repeat the effect, I eventually found a way and the "Ha" turned into a signature element of the piece.

Location, Location, Location

My earliest experiences performing as an electronic musician were at a time when I questioned all my roles as a performer. Nearly all of the electronic musicians I knew at the time were computer musicians trained in academia. My (mostly male) colleagues would participate in performances of their pieces, often from the middle of the audience, sitting at the sound board or a computer, playing from the vantage point of an audio engineer rather than as a performer from the stage. [xiii]
These considerations led to us questioning the role of our audio engineer in "What is it like to be a Bat?". We considered the engineer to be a performing member of the group, using electronics from the desk. At one point we even had him sing a chorale with us, conducted from the stage. [xiv]

I came to ask myself:
When performing with sound utilizing the acoustics of the entire space as part of the musical gesture, at which position should I perform? Does standing on stage make me a performer? Does standing in the audience makes me a technician? How does the utilization of space (as part of my created instrument) differ from the attention given to the sound of a room by any trained acoustic musician? Do I want to perform on stage as a musician, or run my pieces off-stage, recognized as a high-end technician/composer/audio engineer? I discovered that I was uncomfortable being in the engineer's position. Although the sound was better sitting in the middle of the room, as a performer, I always preferred to be on stage, interacting with the other musicians. For all my projects, I therefore decided to be on stage, even when my role did not involve any singing at all.

Creating the invisible instrument so it could be understood by musicians

Instrument control

To turn my setup into an instrument, the first thing I did was to code up every available parameter I could control. What started to interest me was how the parameters moved in relation to each other. But I quickly realized that I could not effectively control very many parameters at the same time. I simply do not have that many fingers! Also, I needed to be able to control my instrument quickly, because otherwise I could not control rhythm, nor react rhythmically.
So, next I began to do two things: grouping parameters of my delays/pitch-shift/comb filters to control many things at once (which also expanded my palette), and creating algorithmic strategies to rhythmically control these parameter groupings. Grouping parameters into meta-parameters is similar to what is done in instrumental or vocal music, where

many individual actions cause a vibrato on a violin or a glissando on a trombone. Vibrato and glissando are meta-parameters that group those actions.
The algorithmic controls allow me to interact and lock-in both rhythmically and poly-rhythmically with other musicians.

Presets / Starting Points

Arranging parameters I want to control into *presets* has been of tremendous value, because it helps me gain speed in my reactions. These presets are both starting points and safe zones that assure me of a known position or sound to which I can return, allowing me to experiment more freely and without reservation.
Augmenting this control, I set it up so that I can control my presets and transitions by manually sequenced them or triggering them algorithmically, or in short poly-rhythmic patterns. This rhythmic control over my "presets" (parameter groupings and their transitions) are another important and evolving part of what constitutes my instrument. I can create new presets on the fly and reuse them during performance.

Giving up control over time == automated processes
Sometimes it is useful for some of my sound processes to work on their own. This way, I can create a richer sound world, especially when I'm playing solo. It also injects bits of unpredictability, surprises and aleatoric possibilities to my performances. Examples of these autonomous processes are: (1) random variations around the current value of parameters, and slowly drifting towards new values which can be set manually at any time; (2) totally randomizing parameters with the only control being the range of random numbers, offset and the speed of newly created values; (3) "Mutate" which randomizes given parameters around loop points of my live-recorded samples.

[insert Figure <Screen Shot Programming> here]

Voice Activated Controls

More recently, I added a set of "Voice-Activated" controls to my instrument: using my incoming audio signals as my only control source. These programming routines are meant to unfold in the background, autonomously. They were created originally for my voice in solo performances, but I have since used them with other instruments, projects and compositions.

In one routine, I connect pitch-tracking with a moving, sweeping subtractive synth. What feels like a "comet tail" becomes attached to the incoming sound, loosely following its pitch slightly weighted and behind schedule. Another control routine recognizes attack transients to decrease or increase the speed of a looping audio sample.

Though musically useful, these controls, are invisible too. As much as I like them, they do not particularly help my audience with understanding what I'm doing on stage. Nevertheless, I like the outcome, and so I continue experimenting with it.

[insert Figure <solobanner-1024x488.jpg > here]

Outro

Building an electronic instrument that makes use of sounds that are not generated by the electronic musician-performer represents several challenges. The sounds, collected from elsewhere, and so one challenge is visually connecting those sounds to the electronic musician's body and person. If the sound source is another musician on stage, and also audible to the audience, there are further challenges in creating aural distinctions between the source and the electronic instrument's output. These challenges make creating such a live sound-processing instrument a difficult task. It is inherently *invisible* to the audience, although it might be present and recognizable to the musicians on stage.
These challenges can be addressed by carefully combining an awareness of acoustics, some basic psychoacoustics and good listening. The combination of these elements establish an aesthetic and predictive approach to live sound processing informed by an awareness of musical styles and rhythm. The electronic musician's own performance must furthermore be connected in some way to her body, through creative use of gestural controllers and other input devices, mapped to salient groupings of musical parameters in physically meaningful ways. This approach creates the musical distinction between the output by the electronic musician and her sources. Gestural controllers properly connected to these distinguished sounds create "control intimacy" noticed by both fellow performers and by the audience. With training and practice, this instrument will eventually become less "invisible" and better understood by all.

Learning from the masters

For some further reading and research—here are some books and articles I recommend.

- Stockhausen's London lectures – particularly Lecture V: "Four Criteria of Electronic Music" available *as DVD or on UbuWeb*. Stockhausen discusses a continuum from pulses to rhythm to form (a sped up a rhythm can become a spectral quality, slowed way down it can be conceived of as form.) and many other such insights.)

- Pierre Schaeffer "Solfège d'Objet Sonore" (book/3 CDs)
- Pierre Schaeffer *In Search of a Concrete Music*. U of California, 2012
- Sonic Experience: *A Guide to Everyday Sound.* Edited by Jean-Francois Augoyard, Henri Torgue, McGill-Queens University Press 2005

Links.

Video: "Live Sound Processing Strategies" -- performances at my 2012 workshop, were with Robert Dick (flute) and Satoshi Takeishi (percussion). https://youtu.be/x9hWMSzMdTI

Video: "Clip Mouth Unit" duo -- trombonist Jen Baker / Dafna Naphtali. Electroacoustic Improvisation Summit. New York. January 2016. https://youtu.be/-816MfgftTo

Video: duo -- percussionist Luis Tabuenca / Dafna Naphtali. Festival Audio Tangente. Burgos, Spain. 2013. https://vimeo.com/81507978.

Audio: duo (interlude) Martin Speicher / Dafna Dafna er. Third Eye Bitches Re-Brewed ensemble (Hans Tammen), Sound Symposium Festival, St. John's, Newfoundland, Canada. July 2004. http://bit.ly/2b76nQQ.

Audio: archival tracks of Free Jazz Video Collision. New York. 1996-2000. https://dafnalula.bandcamp.com/album/fjvc-archive.

Artist website: www.dafna.info.

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[i] I started using Max in 1992 (v2.0 Opcode) at a time when commercial/affordable versions of Max could not yet do live signal processing. Real-time signal processing using MSP was added in 1997. Max/MSP is now developed and maintained by Cycling '74.

[ii] Many of the following ideas were presented as a workshop "Live sound-processing strategies" (at Harvestworks in New York, May 2012), and as a six-day intensive course "Aesthetics of Live Sound Processing" (at UniArts Sound Art Summer Academy in Helsinki, August 2014). The demonstration performances at the 2012 workshop with were with Robert Dick (flute) and Satoshi Takeishi (percussion).

[iii] Invited by pianist Kathleen Supové to process her playing "Phrygian Gates" by John Adams. I used many of the techniques described in this article, including feedback, and discovered radical variations in my sound in each of ten performances we did in the same venue! The patches and processing were nearly identical in each case, were well rehearsed. Only the weather changed, (and the people in the audience) and therefore the way in which my feedback processes worked in that space.

[iv] In writing this article, I struggled with whether I should first be describing my technical solutions or my aesthetic ones. I have opted for the chronological explanation since it was difficult to solve my aesthetic problems without the technical ability to do so. Over time I have come to understand these as distinct problems, yet more intertwined than expected.

[v] The multi-talented pianist/composer Gordon Beeferman, personal communication 19 January, 2016.

[vi] I have learned some patterns related to North Indian Classical Tala through self-study and private study with other musicians/collaborators, some quite accomplished, who were willing to help me find ways to use them in my work. These patterns, which I use in my live sound-processing work are merely reflections of these encounters and collaborations. For example of the patterns, see those listed at https://www.ancient-future.com/theka.html. In my programming, I assigned the various syllables, each to a particular preset in my patches and the result reflects the Tala-inspired patterns in the live sound processing.

[vii] *Lecture 5 - Four Criteria of Electronic Music (KONTAKTE), Part 1.* Karlheinz Stockhausen.

[viii] According to him, this happens with periods longer than 8 seconds between the single attacks.

[ix] In an example of "periodicity pitch" -- a 1ms delay line with high feedback resonates at 1000Hz, 2ms at 500Hz, 3ms at 250Hz. This pattern continues until around the pitch is out of hearing range, (sub audio) and it actually starts to sound like delay.

[x] Smith, Julius O. 1985. Fundamentals of Digital Filter Theory. *Computer Music Journal*.

[xi] Schaeffer, Pierre. 2012. *In Search of a Concrete Music*.

[xii] What is it Like to be a Bat?, originated as a "digital punk" trio (Kitty Brazelton, Danny Tunick) back in 1997. Computer music, live processing, guitar, bass, drums and 2 multi-octave voices. CD on Tzadik label 2003. http://www.tzadik.com/index.php?catalog=7707. More info: http://www.allmusic.com/album/what-is-it-like-to-be-a-bat-mw0000596991

[xiii] Two notable exceptions are George Lewis, and Mari Kimura, whose performances from the stage as composer/performers and improvisers with computers were very inspiring to me at that time.

[xiv] Unfortunately, and as expected, this resulted in some reviewers assuming that the audio engineer did all of the live electronics.