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ABSTRACT This article provides an overview of a real-time, hybrid computational system for the violin, Windowless. The system uses a custom sensor glove, the alto.glove, to track the violinist's movements and drive a panoply of unique digital sound processing effects. The author describes the operations of the system in terms of a broad notion of synthesis, consistency, microintervallic motions and molecular operations. A threefold approach combining dense sonic physics, "loose" computational procedures and high system responsiveness creates a rich and thick performative medium with a vapor-like, particulate level of textural and bitwise computational detail.

As an improvising-computing violinist, I interpose myself in a "machinic" ensemble, a synthesis of heterogeneities constituting a rich biotechnological fabric [1,2]. I often play with abrupt staccato gestures, but the relationship to traditional violin technique is not lost. The computer hyperbolizes these abbreviated gestures, transmuting sonic input into granular clouds of varying density and driving processes of synthesis. In pursuing this middle way between the dynamics of traditional violin playing and a style that embraces the more radical possibilities of digital augmentation, my approach acknowledges the mediating dimension of what Theodor W. Adorno called a "musical material" harboring certain tendencies and historical cues for composers [3]. The computational system I composed for extending my playing, Windowless, provides auditory feedback that is fertile for improvisation. The input elements are live audio and interaction with a physical glove interface I designed, the alto.glove [4].

I approach the question of musical material through a speculative process drawing on the historical genesis of the violin. This could be construed as an attempt to excavate and rekindle textural substrata underlying the accretion of well-honed modern techniques, a kind of "dissolution" that would disinhibit phylogenetically older circuits. With my sharp gestures and sputtering technique, I steer a computational system that selectively scatters this sonic material, making everything tend toward dissolution: interrupted phrases, détaché vectors, volatile bowing, amplification of minutiae, multiplication of grain. When I play, I imagine these interstitial scuffs, scrapes and rattling to reflect the natality of budding technique in the violin's mystifying formative period, its early genesis being led by the experiments of individually radical improvisers—an enchanting thought that harbors an illusion. For the violin has never been and cannot be in a "raw" state. Music is always already inflected by a history, a background, implicitly gathered together as musical material.

Perhaps the better term for what I am up to, then, is bricolage, a collision of disparate materials I have inherited—

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Fig. 1. Performing with Windowless, New York City Electroacoustic Music Festival (NYCEMF) 2018. (© Hubert Howe. Photo © Mengjie Qi.)

historical, biological, technical, digital—and transmute in singular, evolving constellations. According to this conception, novelty is not in the materials themselves but rather in their re/arrangement. Better still is the suggestive word *synthesis*, a term I borrow from Gilles Deleuze and Felix Guattari as they deploy it in *A Thousand Plateaus*. The relationship of this word to the sound synthesizer or "sound machine" is essential to its use there, as what makes the sound machine emblematic of the materialist aesthetic they espouse is its ability to unite "disparate elements" via an assembly of generative and transformative modules rearranging sound in a continuous "operation of consistency" [5]. What Deleuze and Guattari set forth with this creative depiction of the synthesizer is an aesthetic that would render sonorous something unthinkable and completely new. Critical to that outcome, they claim, is the consistency of the operation, the microintervallic and "molecular" operations immanently tying the event together. Without this consistency, the result is merely a "jumble" or "scramble" rather than a genuine event and eruption of novel forces [6].

Synthesis, consistency, microintervallic motion and molecular operations: These are the terms by which I articulate the computational and performative dynamics of Windowless. To synthesize is to unite disparate materials; to synthesize consistently—and successfully, according to Deleuze and Guattari—is to perform continuous, incremental operations on atomic bits of matter. In this sense, even the lapel microphone I place on my violin performs a distinctive kind of synthesis by virtue of its respatializing function. The violin emanates sound in specific spatial patterns with unique spectral signatures, patterns that are recalibrated by electronic spatial diffusion as a new violin-space (Fig. 1) [7]. Likewise, with its potential to amplify the microscopic, a microphone permits subtle exploration of the textural and granular dynamics of the violin. Given that the modern violin is marked by much greater string tension than its Baroque ancestor, it is ironic that the amplification potential of the microphone permits the modern violin to bend toward an ancient predilection for diaphanous whisper, yielding and supple.

Out of such disparateness—a feedback loop of violin respatialized and amplified; an ironic recapitulation of its more ancient mode; an improvising and hybrid human body outfitted with electronic hardware; and digital software that, nontrivially, reduces all of this to a binary code—how can the operations of the system produce the consistency of a singular event? What I aim for with Windowless is digitally augmented violin performance interwoven at a vapor-like, particulate level of textural and bitwise computational detail. My strategy is threefold: dense sonic physics, "loose" computational procedures and maximum system responsiveness.

Hardware and Computation

I designed the alto.glove to track salient features of violin playing (Fig. 2). A flex sensor on the fourth finger provides information about the continuous horizontal pivoting of the bow in the hand and circumstances in which the bow is gripped, as in pizzicato technique. A flex sensor on the wrist provides a qualitative measure of the distance of the hand from the violin. Placement of a motion sensor at the wrist provides an accurate representation of bowing motions, with the gyroscopic z-axis responsive to lateral bow movement and the x-axis reflective of string crossings produced by radial movement of the forearm. Two pressure sensors on the inside of the thumb and index finger can be actuated during performance with only partial release of the bow grip.

The Windowless software consists of three individually compiled applications coded in Max MSP. One of these applications receives wireless data from the alto.glove, performs feature extraction, then sends the parameters via the OSC network protocol to the applications that perform sound processing. Additional feature extraction occurs in some of the individual sound processing modules, many of which produce choreographic, composite effects that are idiosyncratic and highly specific. For instance, tremolo playing triggers a spectral freeze that initially rises at the center of the sound field, pans either left or right and is released at the culmination of the trajectory. Each choreographed vector corresponds to a particular modulation of the spectral freeze. For instance, amplitude tremolo during the panning phase is particularly conspicuous and also demonstrates a metaphorical relationship to the input trigger.

When I grip the bow during pizzicato playing, a mix of dry and pitch-shifted violin input is passed through a reverberator with a long decay. If a bow stroke is sustained for a certain period of time, a quiet spectral freeze takes place, to which minor harmonization, reverberation and tape warble are added. A subtle "stutter" effect continuously samples violin input and probabilistically plays these samples back several octaves higher with delay added to differentiate left and right channels.

Generative elements in Windowless include a 50-voice polyphonic pulsar synthesis engine I coded that produces a wide range of scintillating, gurgling or electricity-like textures and ambiences. Passing the output of this module through a resonant bandpass filter with a randomly varying cutoff frequency yields chaotic pulses. These pulses are generated according to a combined metric of microphone amplitude and bow acceleration. String crossings initially activate and perturb a form of rapidly modulated, glisson-like synthesis, with subsequent actuations toggling between these glissandi and live granular synthesis modulated with pink noise.

One of the most predominant sound modules in Windowless is a quasi-granular effect that records input from the violin into 16 individual buffers, then loops each buffer during playback according to a global envelope setting and algorithmically determined playback speeds. Continuous panning and slow, periodic amplitude modulation produce an undulating sonic undertow. Sequential recording into each buffer is controlled by a noise gate with a "hold time" parameter set to a short value in order to generate a chaotic response.

In the performance captured in the online supplement to this article, Windowless does not pass through a series of presets. My intention was to preserve the operational consistency of the system by making all its potential available at once. The onus of consistency is thus ultimately on the improvising performer, who requires a rich and responsive computational system with great depth to be explored in performance. Every musical gesture and sonic outcome must be interwoven—synthesized—without reliance on an escape hatch that would exchange the synthetic operators with a set of new ones. I have as yet allowed myself only one discrete control over the system, provided by the sensor located at the side of the index finger. By actuating this control, all actively looping buffers pass into a reverberator just prior to their erasure, thereby making use of what Curtis Roads calls "reverberant space as a cadence," a convincing means of phrasing in electroacoustic music [8].

The impact of Windowless is a result of the sheer density of its sonic layering and granulizing tendencies, described here for the most part, albeit in necessarily broad strokes. I embrace the ethos of synthesis described by Deleuze and Guattari by combining both live violin input and generative computer sound. Moreover, close scrutiny of the performance

Fig. 2. The alto.glove interface used in Windowless. (© Seth Thorn)

seen in the supplemental video will reveal irregularities in the activation of features as I have described them, a result of my decision to compute bowing metrics with slack procedures and iffy calculations. For instance, I set a variety of thresholds and time conditions for recognizing a string-crossing "mode," but when I find this mode activated unexpectedly, I refrain from adding layers of windowing that would improve its accuracy, especially at the cost of system responsiveness. As with the Baroque violin, a quick and sensitive response is paramount. I therefore object to machine learning classification here for the simple reason that it reifies technique and obliterates textural nuance. By contrast, loose system dynamics create conditions for unanticipated responses and unforeseen input magnitudes, thereby producing a rich and thick medium for improvised performance.

References and Notes

1 Gilles Deleuze and Felix Guattari, *A Thousand Plateaus* (Minneapolis: University of Minnesota Press, 1987) p. 330.

2 Andy Clark, *Natural-Born Cyborgs* (Oxford: Oxford Univ. Press, 2010) p. 58.

3 Theodor W. Adorno, *Philosophy of New Music* (Minneapolis: University of Minnesota Press, 2006) pp. 31–34.

4 Seth D. Thorn, "Alto.glove: New Techniques for Augmented Violin," *Proceedings of the International Conference on New Interfaces for Musical Expression* (Blacksburg, VA, 3–6 June 2018).

5 Deleuze and Guattari [1] p. 343.

6 Deleuze and Guattari [1] pp. 343–344.

7 Perry Cook and Dan Trueman, "Spherical Radiation from Stringed Instruments: Measured, Modeled, and Reproduced," *Journal of the Catgut Acoustical Society* **3**, No. 8 (1999).

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