SEMBLANCE OF FERN: INSTRUMENT DESIGN AND INTERACTIVE PERFORMANCE WITH NONLINEAR DYNAMICAL SYSTEMS

SARAH BELLE REID, RYAN GASTON

Abstract (IT): Questo articolo descrive *Semblance of Fern*, un'opera multiformato che comprende uno strumento elettronico personalizzato, un'installazione sonora site-specific a quattro canali e una performance dal vivo. Sviluppato per la "Fern Room" del Lincoln Park Conservatory di Chicago, il progetto utilizza l'algoritmo frattale di Michael Barnsley per la generazione di felci come base per un generatore di tensione di controllo all'interno di un sistema di sintetizzatore modulare progettato appositamente. *Semblance of Fern* esplora le relazioni tra strumento, composizione, performance, installazione e ambiente, trattandoli come manifestazioni interconnesse di uno stesso sistema sottostante. Attraverso la giustapposizione di strutture simili a felci generate algoritmicamente con la collezione vivente del Conservatory, l'opera esamina le relazioni tra sistemi computazionali e sistemi biologici, invitando il pubblico a riflettere su come i modelli di crescita, emergenza e trasformazione possano essere messi in relazione e, al contempo, differire tra questi domini apparentemente distinti. L'articolo discute il quadro concettuale del progetto, la progettazione e la realizzazione dello strumento hardware e il suo impiego come strumento compositivo e di improvvisazione.
Parole chiave: liuteria digitale; composizione algoritmica; installazione; improvvisazione; feedback.

Abstract (EN): This paper describes *Semblance of Fern*, a multi-format work comprising a custom electronic instrument, a four-channel site-specific sound installation, and a live performance. Developed for the 'Fern Room' at Chicago's Lincoln Park Conservatory, the project employs Michael Barnsley's fern-generating fractal algorithm as the basis for a control voltage generator in a custom-designed modular synthesizer system. *Semblance of Fern* explores the relationships between instruments, composition, performance, installation, and environment by treating them as interconnected manifestations of the same underlying system. By juxtaposing algorithmically generated fern-like structures with the Conservatory's living collection, the work examines relationships between computational and biological systems, inviting audiences to consider how patterns of growth, emergence, and transformation might relate and differ between these seemingly distinct domains. This paper discusses the project's conceptual framework, the design and implementation of the hardware instrument, and its use as a compositional and improvisational tool.
Keywords: digital lutherie; algorithmic composition; installation; improvisation; feedback.

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1. Introduction

Semblance of Fern is a multi-format work comprising a four-channel site-specific sound installation, a custom electronic instrument, and a live performance. The work explores the relationships between nonlinear and unpredictable systems, fractal algorithms, the ecological diversity of ferns and the unusual precariousness of greenhouse environments, and, by extension, the relationships between both naturally-occurring and human-made dynamical systems[1].

While these components can be described individually, *SofF* is fundamentally concerned with the relationships *between* them. Instrument, composition, performance, and environment emerge as interconnected manifestations of the same underlying system, raising questions about where one ends and another begins. At what point does an environment become part of a performance? Can an instrument itself constitute a composition or a compositional process? What role does an underlying system play in defining the resulting artwork?

[1] For audio and video documentation of *Semblance of Fern*, visit https://www.sarahbellereid.com/semblance-of-fern.

SofF was commissioned by the Chicago-based non-profit Experimental Sound Studio, and was presented from October to November 2025 as part of their ongoing *Florasonic* series, in partnership with the Lincoln Park Conservatory. Both the live performance and installation component of this project were presented in the "Fern Room" at the Conservatory — a large greenhouse space filled with dozens of ancient fern species.

Conceived specifically for this environment, the project's artistic, technical, and conceptual framework developed in dialogue with the architecture, ecology, and acoustics of the site, as well as external environments in which ferns naturally flourish. In addition to the hundreds of visitors the Conservatory welcomes each day, the Fern Room contains numerous ponds and waterfalls whose continuous sounds form part of its acoustic environment. The diversity of fern species, each with distinct textures, forms, scales, and patterns, suggested analogous possibilities for sonic layering, density, and transformation. Rather than serving simply as a venue, the greenhouse became an active component of the work: a generative environment whose characteristics informed the design of the instrument, the compositional process, and the resulting installation and performance.

2. Ferns, Fractals & Dynamical Systems

At the center of *SofF* is a custom electronic instrument that employs fractal algorithms as stochastic formal structuring elements in live improvisation and composition. The principal algorithm explored in this project is the Barnsley Fern, which was first described by mathematician Michael Barnsley in 1988[2]. This algorithm is a recursive

[2] Michael F. BARNSLEY, *Fractals Everywhere,* Academic Press Professional, Boston, 1993.

process that produces two outputs, intended to be utilized as *x* and *y* coordinates on a visual plot. With each iteration, the most recent *x* and *y* values are passed as variables into one of four tightly specified transformations. The specific transformation used for each iteration is selected at random, with each transformation assigned a specific probabilistic weight. When the two computational products are plotted over hundreds or thousands of iterations, the result is a strikingly detailed image of a fern composed of many smaller self-similar fronds (Figure 1).



[**Fig. 1** - Barnsley Fern, plotted using P5.js]

The Barnsley Fern was selected not only because it produces the recognizable image of a fern, but because of a conceptual linkage to the context in which the work would be presented. The algorithm generates an idealized fern through the repeated application of a simple set of mathematical rules, while the Conservatory houses a living collection of ferns sustained through careful cultivation and ongoing human intervention. This juxtaposition prompted a simple question: could the Barnsley Fern

as a *process* become the basis of a musical instrument? We therefore set out to develop a custom hardware instrument that used the algorithm as its basis.

Composers have explored the use of "algorithmic" or automated processes, including fractal patterns, for hundreds of years[3]. Of particular relevance to this work—and of particular influence to the authors—are stochastically-oriented instrument designs such as Donald Buchla's Model 266 Source of Uncertainty[4], algorithmically-fueled compositions such as David Rosenboom's *Zones of Influence*[5], and Ami Radunskaya's visionary writings on fractal sound synthesis—which suggest that such algorithms may hold unique musical promise, even if their outcomes challenge conventional standards for what constitutes musically useful or aesthetically "beautiful" material[6]. These all suggest, explicitly or otherwise, that art can emerge from the examination of generative, dynamical phenomena, and indeed, that a piece's focus can *be about* the examination of such phenomena and the ways that such processes manifest in the natural and human-made structures that we direct and that direct *us*. This perspective also aligns with broader developments in experimental music and digital lutherie that have increasingly questioned conventional distinctions between instrument, score, composition, and performance. Rather than treating instruments as simply tools for realizing predetermined musical ideas, many artists have approached the critical examination and recontextualization of existing instruments and the design

[3] John MCDONOUGH and Andrzej HERCZŃSKI, *Fractal patterns in music*, in «Chaos, Solitons & Fractals», vol. 170, 2023.

[4] Ryan GASTON, *Tiptop's Reimagined Buchla 266 Source of Uncertainty*, 2022, available at https://www.perfectcircuit.com/signal/tiptop-buchla-266t-review.

[5] David ROSENBOOM, *Zones of Influence*, available at https://www.davidrosenboom.com/zones-of-influence.

[6] Ami RADUNSKAYA, *An Algorithm for the Construction of Fractal Waveforms*, Unpublished Bachelor's Thesis, Pomona College, 1991.

of *new* instruments as a creative and compositional practice. In David Tudor's later electronic works, for example, hand-built and repurposed circuits functioned simultaneously as instruments, scores, and performative systems, with their behavior discovered through interaction rather than prescribed in advance[7].

Gordon Mumma's *Cybersonic Cantilevers* similarly positions instrument design as a compositional act. Built around custom electronic circuitry that transformed incoming sounds, the work invited participants to interact directly with the system, influencing its behavior while continuously generating new material. Rather than composing a fixed sequence of musical events, Mumma composed a dynamic process whose apparent form emerged through the interactions between human participants and the electronic system[8].

A similar perspective can be found in composer-performer-designer Salvatore Martirano's SalMar Construction — a hybrid, digital-analog "interactive composing machine" built in the early 1970s[9]. As Rosenboom describes: «Martirano regarded the SalMar Construction itself as a composition or compositional world. He considered all the emanations of this instrument, from its first sonic outpouring to when it went out of use, as representing the unified composition»[10].

Like the SalMar Construction, the Barnsley Fern instrument is not intended to produce a single fixed work but a potentially unlimited collection of related musical outcomes.

[7] You NAKAI, *Reminded by the Instruments: David Tudor's Music*, Oxford University Press, New York, 2021.

[8] Gordon MUMMA, *Cybersonic Cantilevers*, in *New American Music, Vol. 4: New York Section: Composers of the 1970's*, Folkways Records, New York, 1975.

[9] Dorothy MARTIRANO, *The SalMar Construction*, available at http://sal.martirano.net/salmar.html.

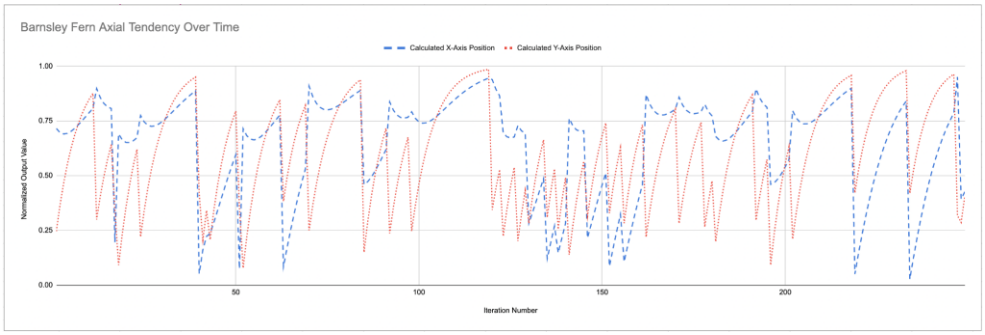
[10] David ROSENBOOM, *Exploring Compositional Choice in the SalMar Construction and Related Early Works by Salvatore Martirano*, in Miller Puckette and Kerry L. Hagan (eds.), *Between the Tracks: Musicians on Selected Electronic Music*, The MIT Press, Cambridge, 2020, p. 119.

Each performance becomes a distinct realization of the same underlying system, shaped by the instrument's architecture and its interaction with the performer. The following sections describe the development of the instrument, its role in the installation and live performance, and the artistic questions that emerged through its use.

3. Designing the Instrument: Early Prototypes

Our initial prototypes explored two fundamentally different approaches to working with the Barnsley Fern algorithm: treating it as an audio source, and treating it as a source of parametric data. Our first tests involved implementing the Barnsley Fern algorithm as a two-channel signal generator in Cycling 74's [gen~] environment in order to use it as a direct sound source. Running the algorithm at audio-frequency calculation rates results in relatively spectrally flat noise-like signals: perhaps useful in some contexts, but sonically similar to typical broadband noise, and upon that basis, of relatively little interest to the authors.

When plotting both the *x* and *y* axis outputs as functions over time, their instantaneous values can be difficult to predict; however, their evolution exhibits perceptible recurrent tendencies (see figure 2). As such, we began to use the algorithm as a source of changing parametric data, producing seemingly "gestural" control when mapped to pertinent aspects of synthesized sound. In initial tests, we mapped the algorithm's two outputs to various aspects of an existing [gen~] implementation of pulsar synthesis, including both "direct" parametric controls as well as multi-parametric "macro" controls—more on this below. These experiments showed promise for both relatively direct pseudo-gestural mappings, as well as longer-term and less direct parametric mappings, serving to shape phrase- and formal-level temporal structures.



[**Fig. 2** - Normalized plot of the Barnsley Fern's *x* and *y* outputs over 250 iterations]

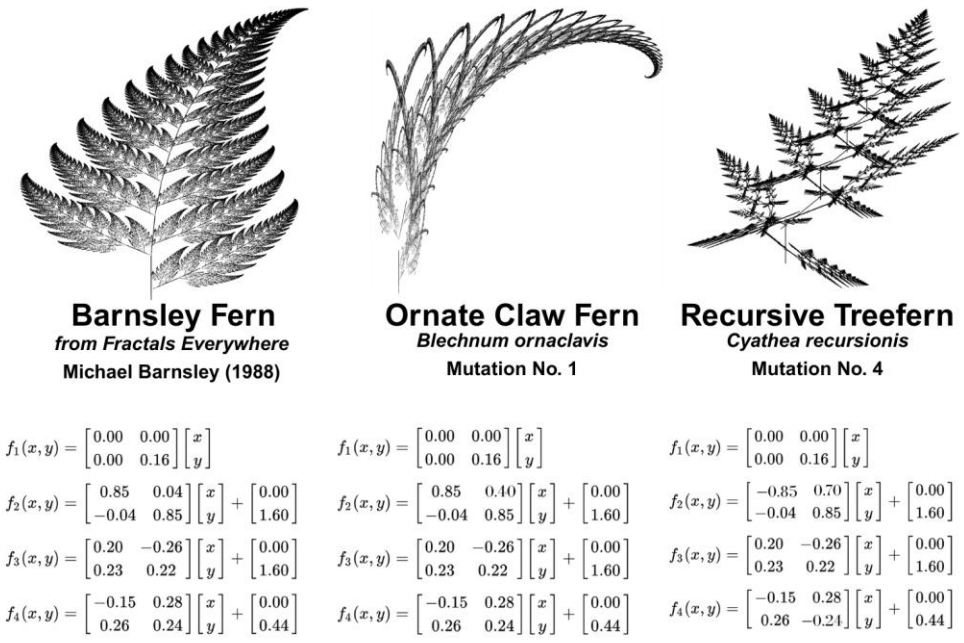
Creating "Mutations"

In addition to the classic Barnsley Fern algorithm, we also designed numerous "mutations" of the algorithm by experimentally adjusting the numerical coefficients that define each of the algorithm's transformations in order to influence the fern's growth trajectories and tendencies (see Figure 3). Subtle changes to these coefficients alter the scaling, rotation, and translation associated with each transformation, often producing dramatically different patterns of growth while retaining recognizable characteristics of the original algorithm. The development of these mutations was largely intuitive and iterative rather than guided by predetermined mathematical goals. Each variation was visualized by plotting its *x* and *y* coordinate outputs in p5.js[11], allowing us to observe how relatively small changes to the algorithm produced dramatically different patterns of growth. Note that in the final set of mutations, the probabilistic weight of the four transformations was left unaltered; only the coefficients internal to each transformation were altered.

Rather than selecting these mutations based on their sonic behavior, they were initially

[11] p5.js, available at https://p5js.org/.

evaluated according to their visual characteristics. As the selected mutations were incorporated into the instrument, it became clear that their visual differences were accompanied by equally distinctive musical behaviors. Each mutation generated control signals with its own characteristic tendencies, ranging from fairly stable and perceptually repetitive gestalt shapes to unpredictable and chaotic outcomes. To reinforce these distinct identities, the mutations were given fictional genus and species names, creating an imagined taxonomy of algorithmic ferns. While the greenhouse contained ferns shaped through biological evolution and careful cultivation, the *SofF* instrument introduced a collection of mathematically generated species whose behaviors could be explored through musical interaction.



[**Fig. 3 -** The Barnsley Fern alongside two novel fictitious ferns, plotted in P5.js. Modifications to transformation processes are noted]

4. Adaptive Scaling and Interpolation

Notably, despite its overall form being relatively predictable, the Barnsley Fern's numerical output range is not explicitly defined in the functions that comprise it. When employed to generate images, it is necessary to know this range in order to determine the size of the canvas; likewise, in our use of the algorithm as a signal generator, it was necessary to know the upper and lower boundaries of each of the axes in order to map the values to a normalized output range. Additionally, each mutation can yield a vastly different range of values relative to one another.

As such, we implemented an adaptive scaling scheme which, as the algorithm iterates, re-scales the output by continually tracking and storing the maximum and minimum output values to define the upper and lower limits of a linear remapping process. By comparing each new x and y output to these stored boundary values, our adapted algorithm remaps its output values to a standardized range of 0–1, ultimately translating to an amplitude range of 0–5 volts on the final hardware device. Because of this approach, the earliest calculations tend to swing between relatively extreme values; however, typically, a reasonable approximation of the "boundary" values is produced within the first tens of iterations, after which the adaptive mapping adjustments become more subtle.

To access greater musical variety, we also applied a simple linear interpolation algorithm to the outputs, continually "crossfading" between the two most recently calculated values to create a smooth, linearly sloped version of the algorithm's direct output values.

5. Hardware Design

Both authors are performing musicians whose process involves improvisational

interaction with physical tools. Though we had tested the algorithm's musical prospects in Max, we believed that novel uses might emerge if the algorithm were manifest as a physical object that could be intuitively adjusted and "played" in real time.

Having recently developed a suite of voltage-controllable synthesizer modules by compiling [gen~] code for use on the Electrosmith Daisy[12] platform, we elected to continue along that course. The final design of the *Semblance of Fern (SofF)* module produces four simultaneous control voltage outputs: two corresponding to output values from the classic Barnsley Fern algorithm, and two relating to our various mutant algorithms (see Figure 4).



[**Fig. 4 -** Two Semblance of Fern modules]

[12] https://daisy.audio/.

A single trigger output briefly goes high each time a new calculation is performed; in conjunction with the "start" and "stop" parameters, the module offers a variety of means of synchronizing the fern process with other devices. The "propagation rate" parameter determines the rate of calculations.

The "contour" parameter acts as a macro control for both voltage level quantization and output interpolation, allowing access to a variety of stepped and/or smooth interpretations of the core algorithm. Note that the quantization does not aim to restrict the output levels to any sort of pitch-based scale. Instead, it is used as a method to, when desired, restrict the output to a pre-defined number of equally-spaced voltage intervals, effectively "rounding" the instantaneous calculated values to a variable number of discrete steps, the number of which is determined by the travel of the "contour" control clockwise or counterclockwise from center (with 1-bit resolution at center and, ultimately, no imposed quantization at the control's extreme positions).

The "mutation" parameter determines which of nine variations of the algorithm are produced at the two dedicated "F_M" outputs. Importantly, each of the module's principal paramters—calculation rate, mutation select, and contour—are voltage-controllable, enabling dynamic control from external sources.

While the *SofF* module was the primary instrument developed for this project, it was not the only generative system used for the creation of the installation and performance. A second programmable module, TEST[13], was incorporated to provide additional modulation sources. Rather than generating conventional low-frequency waveforms, TEST was driven by environmental data collected by Reid in rural Ontario, where she spent much of her childhood. Temperature, humidity, and atmospheric pressure measurements recorded in a forest populated by native fern

[13] Ryan GASTON, TEST, 2024, https://ryangastonmusic.com/hardware#/test-2024/.

species were normalized and mapped to three concurrent control voltage outputs, which were used to modulate various parameters of the *SofF* modules and, by extension, many other aspects of the performance patches.

The decision to use environmental data from rural Ontario was not intended to recreate or sonify a particular landscape. Instead, it reflected an interest in bringing another fern ecosystem into dialogue with the work. Data collected in a forest where Reid spent much of her childhood became part of an instrument performed within the Lincoln Park Conservatory, creating a conceptual connection between the synthetic space of the electronic instrument, the greenhouse in which the work was presented, and a landscape that held personal significance for the composer. In this way, the environmental data became yet another active participant in shaping both the behavior of the instrument and the music that emerged from it.

6. Creating the Sound Material for the Audio Installation

The audio installation component of this project was composed using the *SofF* module as a primary control generation source, alongside a small digital modular synthesizer system built by author Gaston. The audio component was recorded in Reid's home studio and prepared as a fixed quadraphonic audio file.

The synthesizer system was largely conceived and developed before *SofF* was commissioned, designed for rapidly prototyping components of new musical compositions by physically manifesting several of Gaston's preferred processes for generating and manipulating sound and formal structure. Previously, Gaston typically created such pieces using computers alone, but designing the physical system allowed for an embodied approach to creating new works.

The system prioritizes the creation of relatively unpredictable sounds and formal structures, positioning surprise, coincidence, and emergence as critical drivers of the

creative process. The system fosters this approach through three general categories of module/algorithm, each of which leverage nonlinearity in categorically distinct fashions:

a) Sound generators: typically, utilizing uncommon synthesis methods whose internal logic/DSP flow has been "hacked" to introduce variable instability
b) Audio processors: mostly time-based audio processors, used to alter and temporally dislocate/scramble the sounds from the core sound generators
c) Control generators and processors: control voltage generators used to impose form/structure/direction, as well as processors which disrupt the linearity of such form-defining control signals

In realizing the sonic component of the *SofF* installation, Reid employed two specific sound generators: Compact Oscillator Network[14] (a nonlinear waveshaping-based cluster of oscillators) and Compact Impulse Generator[15] (a digitally "hacked" implementation of pulsar synthesis). Additionally, she employed two key audio processors: Retention Mechanism[16] (an audio buffer manipulation device) and Temporal Drag Processor[17] (a nonlinear time-based audio processor and spatializer). These modules embody much of the system's design philosophy. Each embraces extreme ranges for all parametric controls, including ranges that introduce audible

[14] Ryan GASTON, Compact Oscillator Network, 2025, available at https://ryangastonmusic.com/compact-oscillator-network.

[15] Ryan GASTON, Compact Impulse Generator, 2025, available https://ryangastonmusic.com/compact-impulse-generator.

[16] Ryan GASTON, Retention Mechanism, 2025, available at https://ryangastonmusic.com/retention-mechanism.

[17] Ryan GASTON, Temporal Drag Processor, 2025, available at https://ryangastonmusic.com/temporal-drag-processor.

aliasing artifacts—turning controls that at first seem to impact relatively straightforward musical parameters (e.g. pitch, timbre, delay time) into multimodal controls that couple said parameters with additional effects on the sound's spectral structure (that is, the relationship between its rhythmic, harmonic, and inharmonic components). Each of these modules also feature macro controls which serve to alter their internal signal routing, morphing between different states of internal modulation, timbral evolution, and movement across the stereo field with relatively minimal intervention from the user: dramatic effects can be induced, for instance, by moving a single knob or a applying a single control voltage to any of these devices. Additionally, both Compact Oscillator Network and Compact Impulse Generator feature "destabilization" controls which inject the core synthesis structures with feedback at various critical points—disrupting the linearity of internal calculations used to determine the devices' frequency, phase, timbre, spatial spread, etc. These implementations of internal feedback carry important musical implications. For instance, in such feedback-based systems, parametric controls that seem suggestive of a particular purpose tend to assume new functions, leading to apparent parametric couplings or "cross-mappings[18]" in which, for instance, a knob that in *some* situations alters only a sound's timbre suddenly *also*, by nature of the induced feedback, alters the perceived pitch or loudness. Such emergent couplings can be fairly uncanny and nuanced, essentially breaking past a purely parametrically stratified approach to sound design and toward an approach in which, like in acoustic systems, many properties of sound are interrelated.

The destabilization controls in these devices also often lead to sounds that tend to

[18] Tom MUDD, *Playing with Feedback: Unpredictability, Immediacy, and Entangled Agency in the No-input Mixing Desk*, in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, ACM*, New York, 2023.

evolve on their own, without the need for continued interaction or external intervention. These sounds may range, for instance, from rhythmic sputters and crackling textures to continuous tones that undulate between stable harmonic and deeply inharmonic states. To the right user-listener, the level of textural animation is musically suggestive, and can inspire further performative alterations in response to its unpredictable outcomes[19].

Additionally, the interaction of these properties—that is, the tendencies of such systems to produce emergent perceptual parametric couplings *and* their tendencies to continuously evolve in unpredictable fashions—can lead to a particularly dynamic form of improvisational performance. Through continued use, the user develops a sensitivity *to* the system's tendencies, beginning to understand both physically and sonically where critical threshold between stable and unstable behaviors lie. Through this evolving sensitivity, the performer can more fluidly engage in so-called "edge-like interaction": developing a playing style in which they embrace the system's ability to produce both stable and unstable outcomes, hinging pieces and improvisations on a willingness to navigate this spectrum of known and unknowable behaviors[20]. Designed with an awareness of these potential dispositions, these compartmentalized nonlinear audio structures in a sense embody an aesthetic proposition: that apparent larger musical forms can emerge from microcosmic nonlinear dynamical processes.

[19] Dario SANFILIPPO and Andrea VALLE, *Feedback Systems: An Analytical Framework*, in «Computer Music Journal», vol. 37, no. 2, 2013, pp. 12–27.

[20] Tom MUDD, Nonlinear Dynamics in Musical Interactions, PhD thesis, The Open University, 2017, pp. 259–266.

7. Mapping Strategies

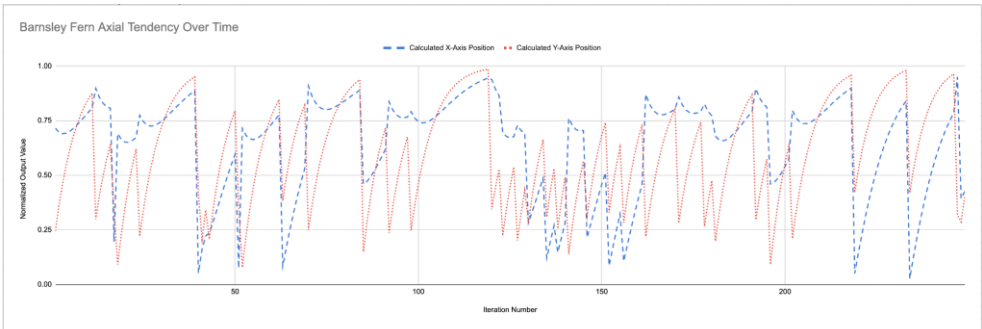
In *SofF*, direct human intention is not the only force behind all such time-based alterations of these nonlinear dynamical sound generation/processing algorithms. In creating the sonic component of the *SofF* installation, much of Reid's compositional decisionmaking was focused on specifying overall signal flow and control mapping within the system.

The audio recording's high-level structure was generated by layering and sequencing recordings from several patches on the system. While Reid did establish initial parametric settings and interconnections between modules for these patches, most low-level form/mesostructure was generated by the chaotic tendencies of the sound generators and the application of largely unmediated influence from two of the *SofF* modules. The outputs from the *SofF* modules acted, in many cases, like a stand-in for the types of human interactions we described above—serving to modulate macro parameters and overall levels of instability, turning fairly simple voltage trajectories into relatively animated stretches of sound.

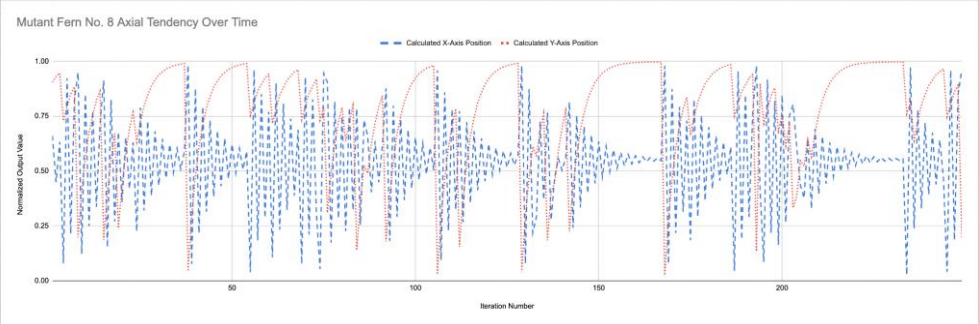
In other instances, the sound-generating and processing modules were left in somewhat more stable states, and the fern algorithms' outputs used to directly modulate more immediately apparent musical parameters (e.g., fundamental frequency and formant frequency of Compact Impulse Generator's pulsar synthesis processes, or the Compact Oscillator Network's frequency modulation index and waveshaping depth). In these states, the fern algorithms' potential as a direct gestural control source are somewhat more apparent, creating their own types of evolving stochastic parametric couplings. In many cases, using one *SofF* module's direct Barnsley Fern outputs and "mutant" outputs simultaneously were used to create especially complex multiparametric modulation structures.

8. Musical Observations

A central curiosity throughout this project was whether the Barnsley Fern algorithm would exhibit musically distinctive behavior, or if it would just come across as another "flavor" of randomness. Through the compositional process, we found that the original algorithm and each of its mutations developed recognizable gestural characteristics that made them musically distinguishable from one another (see Figure 5a and 5b).



[**Fig. 5a.** Normalized plot of the original Barnsley Fern's *x* and *y* outputs over 250 iterations.]



[**Fig. 5b.** Normalized plot of Mutation No. 8 over 250 iterations.]

A visual rendering of each mutation can be considered a type of two-dimensional probability distribution plot—indicating not only the likelihood of any given value on each axis, but *also* the likelihood of the temporal coincidence of *x* and *y* values within specific ranges. That is to say that, observing a plotted fern after hundreds or thousands

of iterations, one can predict the probability of coincidence of specific combinations of *x* and *y* values by observing the visual density of the "fern" at any given point on the plot. Areas with high visual density represent relatively likely coincidences of specific *x* and *y* values; areas with lower visual density represent relatively unlikely correspondences between the algorithms' two simultaneous outputs. This can, of course, be useful in predicting the nature of parametric couplings—though in practice, we primarily used a "listen and see what happens" approach when composing. We do believe, however, that the characteristic probability distributions (and "coincidence probabilities" between the two axes) of the various modifications to the core algorithm do give the device and the piece a more distinct and structured form than would have been yielded through more "purely" random processes. In the course of creating the piece, a few recurrent approaches to incorporating the "fern data" did emerge. One such approach involved using the *x* and *y* outputs to determine the upper and lower limits for Koenig-style "tendency masks[21]," specifically used to apply evolving constrained randomization to the fundamental frequency, formant frequency, and other phrasing-level macro parameters of the aforementioned pulsar synthesis oscillator.

The "mutation select" parameter allows mutations to be continually crossfaded between using external control voltages. As such, the module can act as a sort of nonlinear amplitude remapping function. This, too, can be used for techniques similar to tendency mask generation, or as a means of converting relatively linear control information into unpredictably remapped outputs by way of a two-dimensional, evolving nonlinear transfer function. The unpredictable outcomes of such transformations are valued for their ability to engender a sense of risk and surprise

[21] Robert ROWE, *Interactive Music Systems: Machine Listening and Composing*, MIT Press, Cambridge, Mass., 1993.

between the performer and their instrument.

9. The Audio Installation & Live Performance

The installation component of *SofF* consisted of a 40-minute four-channel fixed-media work presented in the Lincoln Park Conservatory from 5 October 2025 to 23 November 2025, and replayed every hour throughout the exhibition. Visitors encountered the work while moving freely through the Fern Room, allowing it to be experienced as an evolving sonic environment rather than within the fixed temporal boundaries of a concert performance.

Throughout the Conservatory, plaques depicting the Barnsley Fern and its various mutations were displayed alongside the botanical labels identifying the living fern species. Each mutation was presented as a fictitious fern species, encouraging visitors to move fluidly between the living collection and its algorithmic counterpart. In doing so, the installation invited audiences to consider the relationships between the natural environment surrounding them, the algorithmically generated soundscape they were hearing, and the broader nonlinear systems that connect them.

In addition to the installation, the authors presented a live semi-improvised duet during the exhibition opening. Each performer used a small specially-designed digital modular synthesizer system with a *SofF* module serving as the primary source of modulation, similar to the system used for the recording. Although the performance included a loose formal structure with several predetermined musical landmarks, the majority of the musical material emerged through improvisation and interaction with the instrument.

As a site-specific installation and live performance, many aspects of *Semblance of Fern* existed only within the Fern Room during its exhibition. Most audiences will therefore only encounter the work through documentation, technical descriptions,

photographs, recordings, or critical reflection rather than through direct experience of the installation itself. Rather than viewing these materials as secondary representations of a completed artwork, this project considers them to be extensions of the work itself. Engaging with the documentation, reflecting on the underlying systems, and considering the questions posed by the relationships between the instrument, the environment, and the resulting music all constitute meaningful ways of experiencing the project—even for those who were never physically present during its presentation.

10. Artistic & Compositional Reflections

Perhaps more significant than any individual mapping strategy was the shift in compositional practice encouraged by the instrument. Rather than treating the Barnsley Fern as a source of random variation, the compositional process increasingly became centered on exploring the behavior of the algorithm itself. A single adjustment may influence numerous downstream processes simultaneously, altering not only the resulting sound, but also the evolving state of the instrument itself. Composition and performance therefore unfold as a continual feedback process between performer and system, with each influencing the behavior of the other in real time.

One question that arose repeatedly throughout the development of *SofF* concerns the relationship between the Barnsley Fern algorithm and the resulting sonic experience from a listener's perspective. Depending on the mapping strategies employed, listeners may perceive characteristic differences between the Barnsley Fern and more conventional forms of stochastic control. In other cases, particularly when the algorithm is mapped to more abstract formal parameters, these distinctions may be less apparent. This raises a reasonable question: if the audience cannot reliably identify the Barnsley Fern algorithm through sound alone, does it matter that the work is built upon a fern-generating algorithm?

We believe that it does, for several reasons: first, *Semblance of Fern* grew out of a curiosity about the Barnsley Fern algorithm. Had we not chosen to pursue this direction, the project would likely not have developed in the same way. Although the relationship between the algorithm and the resulting sound may not always be immediately perceptible, understanding and working with the algorithm fundamentally shaped the design of the instrument, the compositional process, and the artistic decisions made throughout the project.

Second, *SofF* is a multimodal work, in which observing one form of dissemination inevitably changes the way the others are understood. A visitor could simply walk through the Fern Room, hearing an evolving sound installation while surrounded by living ferns. That experience changes, however, upon noticing plaques describing fictitious fern species displayed alongside the Conservatory's living collection, or by learning that the sounds are generated through a mathematical algorithm designed to produce the image of a fern (a point described in both signage and programs available at the entrances to the installation space). Likewise, someone who later encounters the work through documentation, video, technical writing, or critical discussion experiences a different work than someone hearing the sounds alone. In this sense, no single medium fully contains the project. Rather, each mode of presentation provides a distinct lens through which the others are understood. Documentation, technical writing, and critical discourse therefore do more than simply record the work; they become additional ways of engaging with the questions the project poses. For many audiences, these forms of dissemination are not secondary representations of the work, but the primary means through which it is encountered and considered.

Finally, the Barnsley Fern algorithm underpins one of the project's most important, albeit non-obvious and intangible concepts, by suggesting that there is something worth pondering about the relationships between naturally occurring dynamical systems and algorithmic systems designed to resemble them. At first glance, the work appears to introduce an artificial, computational semblance of a living fern into an

organic environment, inviting audiences to reflect on their own responses to increasingly life-like algorithmic systems. However, the context of the work immediately complicates this proposition. The performance took place not within an untouched natural landscape, but within the Lincoln Park Conservatory: a carefully maintained oasis where people carve time out of their lives to encounter ancient fern species thriving, despite all odds, in the middle of one of the largest and most industrialized cities in the United States.

SofF does not take the position that algorithmic systems exist in opposition to nature, nor that one is inherently preferable to the other. Instead, it invites audiences to consider the unusual position we occupy between these natural and synthetic systems. By bringing together the Barnsley Fern algorithm, environmental data collected from a rural Ontario forest, the electronic instrument, and the greenhouse itself, the work encourages reflection on the increasingly intertwined relationships between the environments we inherit, the systems we construct, and the ways in which we understand the boundaries between them. At the same time, it serves as a reminder that both ecological and many computational systems are fundamentally nonlinear, capable of gradual evolution as well as sudden and often unpredictable transformation. As our relationships with such systems evolve — due to the changing nature of our environment and the gradual intertwining of algorithmic systems into our daily lives — it is important that we continue to consider just how volatile such dynamical systems can be.

Ultimately, the central question that motivated this project also changed over the course of its development. We began by asking, “What does the Barnsley Fern sound like?” Initially, this seemed to be a question about sonification: could a mathematical algorithm designed to generate the image of a fern produce musically distinctive results? While this question inspired the creation of the instrument, it became less important as the project evolved. Instead, we found ourselves asking a different set of questions: what happens when a fern-generating algorithm becomes the organizing

principle for an instrument rather than simply a source of musical data? How does a compositional process change when it emerges through interactions between computational, ecological, and human systems? How might those relationships be understood differently through sound, visual imagery, documentation, and the physical context of performance?

In this sense, the Barnsley Fern ultimately becomes more than a source of musical data. It becomes a means of organizing relationships between performer, instrument, algorithm, environment, and audience. The question "What does the Barnsley Fern sound like?" therefore remains open, not because it cannot be answered, but because the process of asking it continues to generate new artistic possibilities.

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