# DESIGNING INTERACTIVE SYSTEMS FOR NON-LINEAR DRUMSET IMPROVISATION

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## ABSTRACT

This paper describes a process of designing an interactive, computer-mediated system for a non-linear drum set performance, titled *Ephemeral Particulate*. In this improvisation, the performance is first augmented into an electroacoustic solo. Motion tracking and audio analysis are used as input sources to control the real-time processing, where both the original and manipulated signals are recorded into separate buffers. The drummer is then enabled to further access and incorporate these previously played ideas. Through leveraging processed signals into sensor-controlled generative and sequenced material, a repurposing occurs, where one solo improvisation is transformed into musical accompaniment for the same soloist. This concept establishes a programmatic framework for computer-mediated improvisation premised on the concept of Non-Linear Gestural Augmentation. It is a performance-driven system that initially uses transforma tive response methods to broaden the sonic possibilities of the acoustic drum set, while slowly morphing into a system that loosely emulates a Free Jazz Performance Model. Through Non-Linear Gestural Augmentation, the drummer can disembody the timbral and temporal qualities of the instrument's purely acoustic sound from their physical requisites and material dimensions. A number of the conceptual and aesthetics considerations derived from this framework are explained by detailing its functional and musical efficacy in *Ephemeral Particulate, amongst other improvisations.* [1]

## 1. INTRODUCTION

The impetus for this endeavor was primarily motivated by an interest in programming software that could challenge the drummer to re-conceptualize their own vocabulary and the gestures used to enact the motions necessary to execute these musical ideas. The drum set repertoire and performance practice can become inundated with a preoccupation with having an endless reservoir of rhythmic patterns to draw upon, in knowing a multiplicity of stylistic concerns, and with achieving a high degree of physical coordination and technical facility. However, as a result of trying to acquire this vast array of technical skill (the inherent challenges of which compound when playing in an ensemble), drum motion seems to have been thought of as functionary utility rather than as another dimension by which a performer could alter the sonic morphology of the instrument itself. Incorporating motion tracking as another dimension of a drummer's vocabulary facilitates the possibility to dynamically alter the spectral and temporal transients of a real-time performance on a micro timescale. Furthermore, building an interactive system that leverages machine listening and motion tracking technologies enables the concept of Non Linear Gestural Augmentation, where the performer can access previously performed material and further process its sonic properties by using expressive motion that exists independent from any functionary movement associated with playing the drums. This design concept can disembody the drummer's performance motions from the instrument's acoustic timbre, which then enables the performer to think less about rhythmic patterns and focus on generating alternative, novel techniques for producing sustain on an instrument that traditionally has had to manufacture such sounds in the form of drum rolls and cymbal crashes.

## 2. AESTHETIC CONSIDERATIONS

### 2.1. Linear and Non-Linear Approaches

Linear approaches to human-computer composition are analogous to a traditionally noted musical score, where the piece's micro note-to-note temporal and pitch information are sequentially linked to its macro structure

[1]. Each of the score's subsections are played consecutively, summarily executed in the same order upon every successive iteration of the piece. In the context of computer music, this signifies that the substantive structural changes programmed into score following components of the system would be scheduled to execute at the same time upon each performance [2]. With these scores, all relevant information regarding the order of temporal events and sub-structural transitions have been decided upon and saved before the performance commences. Conversely, one of the primary features of a non-linear music score is its foundational indeterminacy, wherein the rate at which the larger sections of a piece change are contingent on the decisions being made during performance in real-time. User-input is instrumental in determining the timing of these structural alterations, and can be used non-linearly itself. This contrasting approach is an implicit agreement to relinquish substantive compositional details over to the performer. Where there is rigidity in the linear approaches, there exist variable timing events and a multiplicity of outcomes within its non linear counterparts.

In the context of one of this project's resulting compositions, *Ephemeral Particulate,* a hybrid system was designed between these aforementioned approaches. Built in Max/Msp, there are three sections of the piece, all which are being linearly controlled by the software, and instructed to do so before runtime. The piece is initiated by a steadiness measurement in the MUGIC® sensor, which then runs on a [counter] object in Max/Msp~. This counter not only mediates the transitions to subsequent sections of the performance, but when the recording of each section will take place, as well as at what specific timepoints in the piece each processing effect is implanted into the signal chain. While these events occur linearly, previously performed material is recorded during specified points within each of the sections in the score and repurposed as the source material for further spatialization and processing in the following two sections. This is the end result of a compositional approach heavily reliant on three separate iterations of performing, recording and processing. During the performance, this iterative process would transpire over the course of the piece's three primary sections:

1. *Part 1: Drum Granulator* (0:00-1:36): The solo's sonic morphology changes on a micro- time and pitch scale, subsequently being mixed back with the original drum sound. Through elongating the typical gestures associ
ated with the drums, the performance can widen the timbre range and spectrum of transient events. This entire solo is recorded into a buffer.

2. *Part 2: Grain Sequencer* (1:36-3:00): Using the recording of the Drum Granulator as the source material for the performing and recording of a motion controlled, probability-based drum sequencer. The drummer's previous (and henceforth processed) performance informs their improvisation during this section. The drummer changes the sequencer parameters through the use of the motion tracking. Eight short recordings are randomly taken of the performance, and used as the input to the third section of the piece.

3. *Part 3: Generative Drum Machine/Drone* (3:00-5:48):Using the drum sequencer as input for the creation and recording of a generative soundscape. Motion tracking now controls signal processing and gesturally triggers the recordings taken during the first section of the piece.

In Parts Two and Three, the drum set performer does not even have to play if they so choose. The source material has already been recorded, and acoustically augmented through the motion tracking during the Drum Granulator section, and is further altered with body gestures serving as their control source throughout the duration of the performance. This hybrid system took on characteristics of various player-performance models, each used to describe the dynamic existing between the human and computer within interactive systems.

### 2.2. A Layered Approach to Classifying Models of Human Computer Music Expression

From the comprehensive user influence found in the Conductor Model, to the complete freedom displayed in the Free Jazz Model, the amount of control the designer of each paradigm exerts over the overall sonic output diminishes with each model, respectively. The Conductor Model enables the user to be the harbinger of all musical processes, including all the musically relevant information that one would find in a traditionally notated orchestral score, while the Free Jazz Performance Model is a complete repudiation of this method. The other models - the Chamber and Jazz Combo - are similar in the sense that both models showcase multiple musicians ``reciprocally influencing each other" [1] through informed performance, or improvisation.

However, adhering to four standard classifications become far more difficult to achieve as systems have increased in complexity. The realities of working with these paradigms can reveal nuances in categorization, where observable behaviors within one system run contrary to its overall classification. Similarly to the innumerable music genres that resemble a fusion of multiple and varied cultural and performative traditions, it is evident that interactive systems can in fact show an amalgam of the attributes associated with multiple paradigms in order to successfully achieve the desired musical output [2].

Because of the behavioral diversity in these interactive models, expanding the four aforementioned archetypes can be done not only by observing how this communication is organized, but by the way and degree to which the systems respond to a wide variety of user-inputs: to what degree of structural and micro-con trol is the composer willing to relinquish to the computer? The degree to which the computer's decisions affect the actions of the human performer can be broadly determined by whether the objective is to create a virtual musical instrument which acoustically augments a real-time performance by analyzing human gesture, or if the imperative is to construct a cybernated improviser, insising of their own performative behaviors nearly independent from the user input [2]. These considerations are at the crux of studying these primary classifications, their hybrid adaptations and in turn, aid in contextualizing new systems by historically cross-referencing modern interactive behavioral functionality and response methods to those paradigms established by their predecessors.

### 2.3 Performance Model Hybridity

The system constructed for this project is a combination of the Conductor, Jazz Combo, and Free Jazz Performance Models. While the "Score Conductor" of the piece is controlled by a process that cannot be modified by the performing musician once it has been initiated, it is through real-time data analysis that the system produces sonic variances similar in the way that two humans would influence each others' improvisations. There is enough indeterminacy in the system where each gesture performed by the drummer will not produce an exacting, correlated output, as it is affected by a layered set of signal processing instructions, each being applied differently based on the incoming data analysis of those real-time physical decisions (actions). In effect, this creates a dynamic between the human and computer where the system acoustically augments the performance by means of data analysis, yet the electronics act as a semi-cybernated "virtual player," whose acoustic augmentation greatly affects future decisions made by the human performer. The drummer then has the option to play "with" their past musical performance, thereby establishing an environment where the drummer initially acts as a primary soloist, while transitioning to a role that is perceived to be more collaborative and conversant with the computer accompaniment in ensuing sections.

Labeling this system under the classification of the Free-Jazz Performance model may seem abstract, considering that there is only one performer in the system. The reasoning for this classification is due to the drummer non-linearly accessing previously recorded material to inform real-time decisions, and exactly how the experience of interacting with this feedback mechanism provides the sensation of playing with, and reacting to, another performer. The system transitions from being purely reactive during the Drum Granulator - to providing the interactive source material to the drummer, in forming them on all subsequent decisions regarding processing, and even whether or not to continue playing the drums. After this first section, the virtual drummer is playing a processed version of a past performance, while the human performer is provided the opportunity to experiment with more sustained, elongated motion, further transforming the original source material. Somewhat transparently, a role reversal takes place. This role reversal is made especially apparent if the drum set player interprets the output of the system as a response to their original idea, and subsequently allows this outcome to influence future decisions. Furthermore, the programmed score does not provide any notation nor instruction regarding the way in which the drummer should perform and interact with the system during any section, making this a free improvisation. It is a system that utilizes the Free Jazz Performance Model as much as it relies on the Conductor Model to automatically manage its sectional transitions, recordings, playback, and signal routing.

### 2.4 Examples of the Free Jazz Performance Model

An ideal example of a system using a virtual performer within a Free Jazz Performance Model is George Lewis's *Voyager* program, where the music system was attempting to "embody the African-American cultural practice" [3] of collective improvisation so that the human and virtual player would have undeniably distinct improvisatory sensibilities, but would still produce performances where there was a undeniable mutuality in their influence over the other participatory entity. *Voyager* experimented with the degree to which the independency of the both human and virtual performers was a necessary component of these systems, as it incentivized the human performer to have to listen and dynamically respond to the virtual performer in a way that mirrored the communication and listening practices commonly observed with in the solely human-driven free jazz experiments of the 1960's [1].

Mari Kimura's *Izquierda e Derecha* is an interactive system focused on the player-paradigm dynamic, predicated on the virtual player dynamically altering the chromatic passages and sonic ambience of the violin's output as it coincides with a user-specified range of pitches [4]. Another composition featuring Kimura's playing is Rowe's *Maritime* [4]. Utilizing his *Cypher* system, Rowe's program can "listen to the violinist, and makes up responses up responses according to how it thinks she is playing…kinds of response are determined in advance, and in some sections the program asserts it own personality, and decides itself how it will play" [2].

## 3. TECHNICAL CONSIDERATIONS

### 3.1 MUGIC® Controller

The project's primary technical consideration was focused on how to design a system that could transparently transduce the physical gestures needed for traditional (or otherwise) drum set technique into a control signal for further audio processing. The transparency and sonic output of this processing would greatly inform the next performance gesture, thus affecting the overall experience of interacting with the system. Presented with this issue, an inherent challenge in constructing the interactive system for the drum set is in designing it to be as transparent as possible during live performance. The program had to function so as to not impede on the motions upon which a drum set player utilizes to execute a musical thought, nor on the sensory experience of playing the acoustic instrument. This is a delicate balance, as the main impetus for constructing the system was to challenge and subsequently expand the gestural possibilities of the drum set, yet the system had to be flexible enough not to insist on such a radical departure from any and all functional movement inherent to drum set technique. Maximizing the performance possibilities of the system was contingent on the way the drummer would react to the indeterminate outcome of the system, and on the precision of the parameter mapping. This is especially apparent in this environment, where the drummer is not only executing their own musical thoughts during the *Drum Granulator*, but these same decisions are then influencing any improvisational choices made in the future.

Previous work towards drum set acoustic augmentation includes *The Augmented Drum Kit* [5], which used incoming audio analysis as a control source for real time processing of a live acoustic drum performance. This experiment distinguishes itself from that research by incorporating a wearable sensor for the purposes (among many) of monitoring XYZ positional data - a concept recalling Max Matthews' approach to Radio Baton [6]. While expressive control over an instrument with webcams and contact microphones have been extensively used to detect beat onsets and stroke velocity in *The Augmented Snare Drum* [7], to modify a cymbal to respond to user-induced feedback [8] and to control a mul timodal, audio-visual performance [9], the wearable MUGIC® sensor (https://mugicmotion.com) can send MIDI data through USB and wireless control. The MUGIC® sensor is relaying data salient to the motions utilized to perform drumming gestures. These quantifications include the "pitch," "yaw," "roll," "rotation," and "stick position" (whether my hand is pointed more upwards or downwards while playing).

Other MUGIC® measurements include the "steadiness" and "energy," measurements, which can be thought of as the motion-sensor equivalent of frame differencing in videos. These measurements are nearly opposites, as the "steadiness" tracks how much time (in milliseconds) has elapsed without any motion, while the "energy" determines the level of activity occurring when player movement is present in the system.

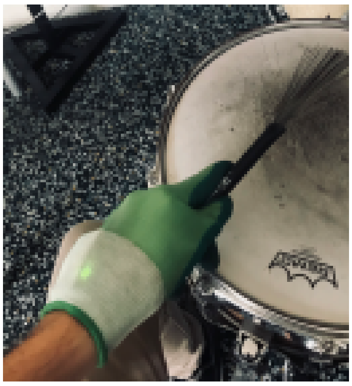

**Figure 1.** The wearable MUGIC® Sensor

### 3.2 Parameter Mapping

Examples of how these measurements affected the sonic output of the system are numerous, but can remain somewhat opaque to perceive when this processing takes place on the granular level. In the particular context of this performance - and particularly in the *Drum Granula tor* (0:00- 1:36) - the data from MUGIC® was mapped to the following parameters in Table 1:

| MUGIC Measurement | Parameter Mappings |
|---|---|
| Pitch | Grain Size<br>Grain Pitch Variation |
| Yaw | Grain Separation<br>Grain Rate Variance |
| Roll | Grain Size Variation Factor Grain Pitch Variation Factor |
| Steadiness | Grain Playback Position (Forward or |

| | |
|---|---|
| | Backward) |
| Energy | Stereo Spread of Grains |
| Up/Down (Stick Posi tion) | Total Number of Voices |
| Rotation | Amount of Grain Pitch Randomization |

Table 1. MUGIC® Mappings for the Drum Granulator

Since these MUGIC® measurements were sent to software in the form of standard MIDI value ranges, this data could be scaled and mapped to their intended routings. The utility of MIDI values made it a relatively simple process of mapping the same incoming data to multiple parameters. This is evident in the way that the MUGIC® data is mapped to a number of different parameters in Table 1. However, each with differing ranges of musically salient values that needed to be discovered through a trial by error process, one where the testing of these mapping strategies occurred in three steps:

1) Improvising while monitoring and recording the original and augmented outputs together.

2) Improvising while only monitoring the original drum performance, but recording the entire performance

3) Improvising while only monitoring the augmented output, but recording the entire performance.

All of these steps were invaluable, but the most revealing was the last in the process. Muting the original signal and listening to the augmented material in real time enabled the user to refine the parameter mappings, while experimenting with the sonic morphology of each individually processed instrument included in the drum set-up. Essentially, the performer is on hearing their gesturally augmented sounds, providing invaluable feedback regarding the system's response to motions that could be considered extraneous to any orthodox drum technique. When physically possible (and musical coherent), the same gestural data would be scaled and mapped to a synthesis parameter that modified both the signal's pitch and temporal characteristics. This practice-based process yielded far more timbral and pitch surprise and continuity than any other approach taken, oft at times rendering the processed and original audio as being perceived as a singular, morphing sound object.

### 3.3 Developing Performance Practices

While the system's "Conductor" was an effective control mechanism for changing the signal flow during the performance , there also needed to be a design feature that would enable the drummer to access many of the drum sounds that were recorded into buffers during the performance. Since one of the primary motivations - from a performance perspective - was to eliminate any excessive functional motion that had no correlation to musical input into the system, the "energy" measurement in MUGIC® was used to replace these movements. The most clear example (and only example, in this piece) of this "gestural gating" is during the *Generative Drum Machine* (at 3:52) , when the initial drum solo is triggered by the "energy" measurement exceeding the very high threshold that is hardcoded into the system. As it is such a high value, there would be a nearly impossibility to unintentionally trigger this audio file. Organizing the score's events in this way meant that the drummer rarely had to interface with anything else but the drum itself - there is no touching of buttons or incessant monitoring of screens. This allowed for a heavily processed amalgam of sounds and diverse timbres, while the drummer could focus on the most pressing aspect of the real time performance - the execution of musical ideas. There are numerous other examples of gestural gating being appropriated for other functions, particularly during the *Grain Sequencer* (1:36-3:00). Each parameter of the sequencer - pitch, loop point, starting point, time-stretching, rest probabilities - are controlled by separate "energy" thresholds being met.

**Figure 2.** Gestural Gating with MUGIC® Sensor

Gestural data was conceptualized as a technological solution for musical problems. However, as the result of using this technique, unintended compositional outcomes emerged that ultimately expanded the performance practices and possibilities on the drum set. Gestural gating caused instant alterations in the piece's spatial morphology, rhythmic patterns, and generative qualities that were inaccessible in a purely acoustic setting. This gating technique provided the improvisation with some semblance of a compositional structure; functional and technical movements (decisions) started coalescing to substantiate musical intention between both programmatic and performative elements. Gesturally gating an audio file meant that an inordinate amount of energy had to be used in order for that musical moment to be actuated. However, this disparity in energy would actually cause other parameters that were also linked to "energy" to be drastically changed as well. This also changed the physical sensation of playing the drums. Disparate amounts of energy was needed from the left hand (the hand upon which the MUGIC® sensor was placed) compared to the right. This is a sensation that feels completely foreign to a drum set player familiar with the technique of Drum Set Independence , where each of the performer's limbs plays interconnected yet separate linear patterns in an effort to express a macro musical pattern or phrase. Doing this is predicated on balance, precision, and immense physical control - three qualities that run counter to using a great amount of energy to gesturally process or trigger an audio file with one sweeping motion. Combining these contrasting physical requirements is a partial redefining of what it means to possess Independence on the drum set, one that extends the concept beyond the physical requirements of playing the acoustic drums in a pattern-oriented way and into a conceptual dimension where other gestures are meant to alter timbre, pitch, and an overall sonic morphology. In this performance practice, a drummer now has agency to simultaneously explore pitch and temporal relationships by combining conventional Drum Set Independence with an expansion of more pronounced, elongated gestural possibilities at their disposal.

## 4. FUTURE WORK

Future expansion of the system will feature the capability of recognizing, indexing, and autonomously making music decisions based on an analysis of drum input or physical gesture. Currently, the software is not making any intelligent determinations, nor is it monitoring the drum nor gestural performance over long periods of time. While being non-linear in musical structure, sonic and gestural input causes an immediate output. The future goal is to build into the system the capability to analyze gestures over the course of an entire piece (or longer) then to formulate future musical responses as a result of data classification. The software will even more closely resemble a completely cybernated musician, having undeniably distinct improvisatory sensibilities from its human counterpart. This behavior will be learned, adaptive, and emergent, and will aid in expanding this system to become multimodal in its output response methods. In an attempt to make the system more multimodal, future iterations will implement a framework for visualizing both the audio-driven and gesturally-driven data derived and synthesized from the computer's future decision-making autonomy.

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