Navigating Outcomes of Rhythmic Anticipation

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Abstract

An approach to computer-aided improvisation that leverages aspects of low-level rhythmic coherence is demonstrated. Nested anticipations at distinct metrical levels determine rhythmic patterns formed by the anticipations' collective outcomes. A connection to number theory provides a self-similar map of rhythmic building blocks, affording control over relative degrees of syncopation and elaboration. The result is real-time navigation and manipulation of rhythmic patterns by means of operations that reflect subjective musical goals.

Introduction

The urge to reshape familiar music sometimes outweighs the urge to hear an entirely new piece. Variation of individual parts of a composition is one avenue to engage material within an existing musical context.

Real-time variation of note patterns is to some degree the exclusive domain of musicians practiced in improvisation. Most people can make syntactical sense of musical patterns, but most non-musicians cannot readily generate a musical surface that reflects spontaneous subjective urges.

A system for rhythmic hybridization was introduced at MUME 2016 (Hardesty 2016b). This demonstration focuses on a more recent approach that manipulates individual rhythms, where variations are generated by a real-time interface that maps schematic expectations to specific note sequences. This approach aims to mitigate a hurdle to real-time music creation, by narrowing the gap between "making sense" of music and improvising music.

Domain and Goals

Many aspects of musical expectation have been investigated during the six decades since the publication of Leonard Meyer's book *Emotion and Meaning in Music* (Meyer 1956). David Huron and Elizabeth Hellmuth Margulis note that by "focusing narrowly on expectation" Meyer showed that musical affect can be investigated in relation to objective musical structure, citing the following passage (Huron and Margulis 2010):

> […] once the norms of a style have been ascertained, the study and analysis of the affective content of a particular work in that style can be made without continual and explicit reference to the responses of the listener or critic. That is, subjective content can be discussed objectively (Meyer 1956).

This demonstration aims to harness musical subjectivity in order to vary note patterns. The subjective element is rhythmic anticipation, and the objective means is a mathematical map of nested occurrences and outcomes of such anticipations (Hardesty 2016a). Affinity between rhythms is defined as the number of shared anticipation configurations at distinct metrical levels. Incremental differences in such affinity can reflect considerable differences on the surface which nevertheless sound intuitively related, an aspect of time organization that might underpin improvisation.

Short looping, quantized rhythms in binary meter within groove-based electronic music are the focus of this demonstration. Computer-assisted variation at that level can be used to generate compositional elements, augment musical performance, and create adaptive music.

Background

This section briefly summarizes the connection between music theory and number theory that underpins this approach, as detailed in (Hardesty 2016a).

Expectation and Rhythmic Coherence

Consider a looping musical pattern within a clearly defined meter. Arrival on relatively stronger beats is repeatedly anticipated, producing a succession of expectations, their outcomes, and subsequent expectations shaped by those outcomes. Subconsciously perceived hierarchical structure that emerges from those nested expectations and outcomes is one aspect of what it means to "make sense" of music. According to Margulis:

> Within a piece, especially in an unfamiliar style, repetition defines what will count as a unit: what musical events will fuse together and function as a thing — a discrete, coherent entity — in the unfolding theater of the piece. Beats create the temporal grid that makes this structuring possible; they lay out predictive spans, the temporal skeletons on which music can hang (Margulis 2014).

David Huron makes a more specific observation regarding rhythmic expectation:

> Both the anticipation and the syncopation depend on the fact that, while events may happen in weak metric positions, they are (nearly always) followed by events that occur on the next strongest metric position (Huron, 2006).

Circularity between repetition of anticipation and anticipation of repetition is encapsulated by rhythmic building blocks defined in (Hardesty 2016a). A tiny set of generative operations that recursively apply strictly defined syncopation and elaboration produces these building blocks, each of which differs from the others by some combination of nested anticipation occurrences and outcomes.

A correspondence between those operations and patterns formed by binomial coefficients accounts for a self-similar mapping detailed in (Hardesty 2016a). That self-similarity forms the basis for the user interaction in this demonstration.

Does this fusing of anticipation and parallelism provide a psychologically realistic boot-strapping of rhythmic coherence? It might seem so if one accepts assumptions about rhythmic expectation adapted in (Hardesty 2016a) from Huron's *Sweet Anticipation: Music and the Psychology of Expectation* and from Lerdahl and Jackendoff's *A Generative Theory of Tonal Music.* No empirical evidence for those assumptions is presented here. Rather, this demonstration represents a speculative effort to explore surface-versus-structure navigation intuitively familiar to improvisers, where that exploration is a creative activity in itself.

Encoding Nested Anticipations

Each building block is encoded by a ternary integer, where a 0, 1, or 2 is assigned to the *m*th place according to which one of the following mutually exclusive generative operations is applied at metrical level *m* to a looping rhythm that is initially a single attack on the strongest downbeat (as, for example, in Figure 1):

0 Do nothing.

1 *Elaborate* by shifting the rhythm one beat earlier at level *m*, and combine the result with the original pattern.

2 *Syncopate* by shifting the rhythm one beat earlier at metrical level *m.*

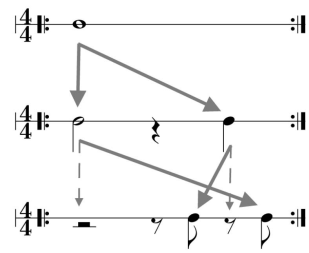

Figure 1. Syncopation applied to elaboration

Accordingly, there are 3^n building blocks within n binary metrical levels. The n-digit ternary encoding of each building block is called an *address* because it also indicates a location on a Sierpinski gasket, where each triangle is subdivided into three smaller triangles with the lower-right mapped to 0, the top mapped to 1, and the lower-left mapped to 2, at the corresponding ternary place as seen in Figure 2.

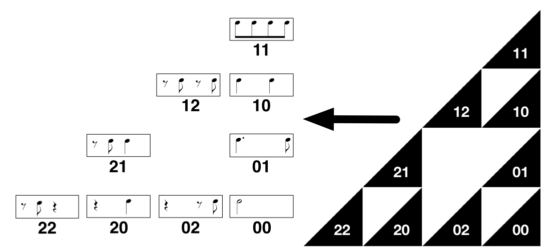

Figure 2. Sierpinski gasket mapped to rhythmic building blocks

Visualization

This geometric mapping of building blocks provides a visual sense of their derivational relationships. As shown in Figure 3, syncopation increases leftward along the *x*-axis, elaboration increases upward along the *y*-axis, and metrical level corresponds to relative triangle size (Hardesty 2016b).

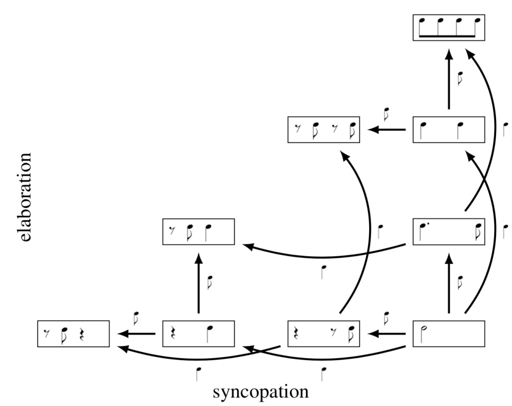

Figure 3. Axes of elaboration and syncopation

Distance Between Building Blocks

Recursive application of generative operations suggests a straightforward distance measure. Since there are three mutually exclusive operations at each metrical level, the Hamming distance between the base-3 representations of two addresses indicates the number of metrical levels at which two building blocks have the same anticipation outcome or, alternatively, absence of anticipation (Hardesty 2016b).

Address Activations

Given a particular rhythm, this distance measure ascribes activations to all potential building blocks, based on the evolutionary affinity of each to those in the minimal set *B* of building blocks required to reconstruct that rhythm. Each of the 3^n possible building blocks for *n* metrical levels is assigned an activation equal to 2^{-m}, where *m* is the minimum Hamming distance between the ternary representations of the address of that building block and the address of any building block in *B*. In short, each potential block has an activation determined by its proximity to the nearest actual building block (Hardesty 2016b).

For visualization purposes, this activation determines the color of each address in the GUI. Each of the sub-triangles representing a building block in *B* is red, whereas the sub-triangles representing other building blocks are gray with relative darkness indicating higher activation.

Variation

One simple manipulation is to toggle individual addresses on the Sierpinski gasket, thereby splicing in or out specific building blocks and their respective attacks. Pitches can also be collectively incremented or decremented for a selected building block.

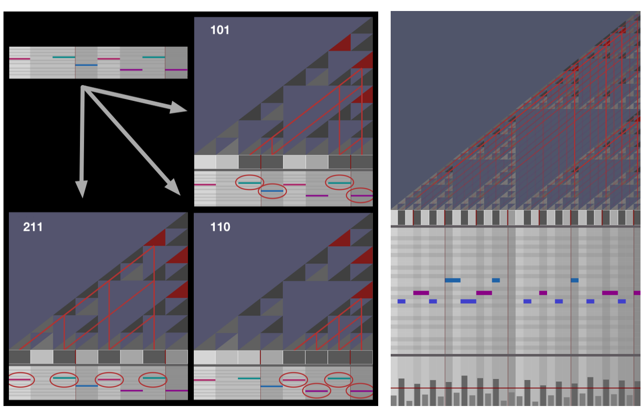

Figure 4. Interface to display and manipulate building blocks

Figure 4 shows examples of rhythmic patterns corresponding to combinations of building blocks displayed in red. The time slots below the gasket represent a looping time-span that proceeds from left to right with the strongest downbeat in the rightmost time slot.

Attack potentials from Address Activations

The rhythmic distance measure described above can be used to characterize a rhythmic pattern as a sequence of attack potentials rather than as strictly binary values. Each potential is treated as an actual attack only if it exceeds a particular threshold. The attack potential for time step *t* is defined as the maximum activation of any building block that contains *t*. The threshold is initially set so that it is exceeded only by the potentials of those attacks in the original rhythm (Hardesty 2016b).

Mutating Rhythms by Address Activation

Interactively raising or lowering the activation of a particular address on the Sierpinski gasket adjusts the potential of each attack composing that building block, assuming that the attack does not already receive greater potential from another building block containing that attack (Hardesty 2016c).

Adjustment of the activation of the selected address is optionally propagated to other addresses, as shown on the right in Figure 4. The relative strength of adjustment for each address is determined by the proximity of that address to the selected address.

Mutating Rhythms Along Geometric Axes

Once a rhythm has been parsed into building blocks, its relative degrees of elaboration and syncopation can be manipulated by tracing a line in a chosen direction in the blank portion of some triangle in the Sierpinski gasket.

The geometric scale of that triangle indicates the metrical level at which the rhythm will by mutated. Each actual building block is replaced with three potential building blocks, one for each possible generative operation at that metrical level. The slope and length of the line along the elaboration and syncopation axes determine the relative activations of the new building blocks. The result is a new set of attack potentials.

Genetic Algorithm to Reduce Congruence

Some compelling rhythmic patterns, such as the *clave* or *bossa nova*, are not particularly congruent with nested anticipations (Hardesty 2016a). A genetic algorithm is optionally used to similarly reduce any rhythm's parsimony in terms of building blocks while retaining aspects of that rhythm's character. A fitness function rewards the following:

- A greater number of building blocks required to parse the new rhythm
- A smaller Euclidean distance between the vector of all building block activations in the new rhythm and the vector of all building block activations in the original rhythm

Examples

Video examples of the above interactions are online at http://coord.fm/mume-2018.

Conclusion

This approach enables the user to steer rhythmic variations in terms of hierarchical structures that pertain to low-level rhythmic coherence, based on incremental branching of schematic expectation outcomes. The crystallization of those branching possibilities onto a self-similar map affords tractable algorithmic co-processing of intuitive improvisational actions, enabling real-time navigation of a mapping between subjective musical content and concrete musical note patterns.

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