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Creativity in the Generation of Machine Rhythms

Scott Barton

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Scott Barton[1]

[1]Worcester Polytechnic Institute
sdbarton@wpi.edu

Abstract. This paper explores musical, psychological and philosophical ideas about how humans and machines interact in creative processes. It argues that creativity is a function of both generator and receiver, and that these roles can be amorphous in the creation and experience of electronic music. It offers an approach to structuring temporal spaces for rhythmic composition, which leads to the idea of *machine rhythms,* which are proposed as a promising area for creative expression.

Keywords. machine creativity, algorithmic composition, rhythm perception, rhythm generation

1. Introduction

Computers have a unique ability to articulate time and thus are a fantastic resource for generating rhythms. As they help composers do so, they become creative tools. As they are programmed to do so themselves, they become creative. This paper will consider the validity of these statements by analyzing the relationship between generators and receivers in rhythmic experience. Such contemplations will lead to *machine rhythms,* which are defined by human-machine symbiosis in the creative process.

2. Machine Creativity

Creativity produces something *new*, *progressive*, *inventive*, *original*, *artistic*, and *transcendent*. It involves *imagination*, *ideas*, *production*, *tradition*, *rules*, *patterns*, and *relationships* [1]–[3]. It involves generation of something that did not previously exist, or was not previously apparent, and distinction from the status quo. At the same time, it is expressed in specific contexts and adheres to the boundaries that such contexts specify. In music, this means a creative EDM producer might implement a never-heard-before effect on a snare drum, but simultaneously avoids numerous tempo and meter changes that would disrupt the motoric continuity that is induced on the dance floor. Creative expression simultaneously reinforces and challenges tradition. It emulates, in order to establish communication and relation, and contrasts with, in order to provide something new and inventive. The degree of creativity depends on where in this space expression is located: too close to the status quo is banal; too far outside contextual boundaries is weird or wrong. The creative artist is less the maverick that breaks all the rules and more a person that knows which rules can be bent and which cannot. The same can be said of a creative machine.

2.1. Creativity and Context

To make creative machines, we must identify the expressive conventions and boundaries that define the interactive context that the machine will function in. The machines themselves could be useful in this process: given their memory size, precision in recall, pattern recognition, and data transfer, machines are able to identify conventions in ways that humans likely cannot. (Advances have already been made in automatic source separation [4], [5] and genre identification and classification [6]–[10].) With that said, even if we are able to exhaustively categorize a particular musical cannon, we will not find all expressions that are both novel and stylistically permissible, thus, identifying contextual boundaries is difficult. How many pitches outside a tonal system are acceptable in a melody? How many meter changes are allowed? How much repetition can be present in a piece? These are questions that have driven composers to push and pull stylistic boundaries throughout musical history.

The amorphous character of contextual boundaries is partly because of the perceiver's role in creative experience. Jean-Jacques Nattiez describes the complexity of the relationships between generator (*poietic*), object (*trace*) and receiver / constructor (*esthesic*) [11]. The poietic process, and thus the generator of the poietic process, inheres in the trace, elementally connecting the two. Poietic and esthesic processes might not correspond, so that what the esthesic process constructs is a function of both qualities of the trace and the context of a particular listener. The interaction between composers, performers and listeners is not simply a matter of encoding a message, transmitting it and decoding it. Instead, meaning, affect and gesture are expressed and interpreted in the context of cultural conventions and individual experiences.[1]

Contextual boundaries are also amorphous because they can move. Once a communication has been received and interpreted, the value that people, both individually and collectively, find in an expression is fed back into poietic processes, influencing the boundaries of future creativity. If machines are part of this feedback loop, they too can influence contextual boundaries. They can therefore be creative not only through expressions that find the right distance between convention and the boundary of acceptable expression, but also by influencing the esthesic processes and aesthetic preferences of listeners, which will affect the future compositional efforts. As Curtis Roads [13] points out, unique capabilities of technology lead us into "uncharted rhythmic territories" (p. 27).

Accounting for the span of cultural conventions, individual experiences, their potential interactions and movements over time is an unfathomably complex task. This should not discourage those that seek to make machines interact with people, rather, it is a reminder to be sensitive to context. As we recognize contextual factors in machine design, we will make *artistically fluent* machines that are better able to shape the boundaries that define creative expression. Importantly, a particular context need not be comprehensively

[1] This idea of the independence of and interaction between generator, communication (object, trace, cue) and receiver has also been articulated in psychological theories of emotional expression and interpretation [12].

defined before a machine can interact in it. The most foundational elements can be addressed after which the machine can be equipped to learn ambiguities and nuances through experience. Such an approach is sensitive to the way that humans interact, which is typically a perpetually shifting mélange of clarity, confusion, conflict and agreement.

As machines become more contextually sensitive we should avoid understanding them as truly autonomous, for humans build machines (or build machines that build machines…), establish parameters and how they can be manipulated, construct esthesic experiences and communicate experiential information to machine poietic processes. Instead of the view that as machines become more independent they metaphorically move *away* from us, we see increasing symbiosis between humans and machines in the generation of new ideas: machine creativity is an extension of human creativity.

2.2. The *Whys* and *Whats* of Machine Creativity

Poietic processes involve making choices. Chris Dobrian's timeless article "Music and Artificial Intelligence" [14] explores *why* we make compositional choices. Ultimately, he sees these choices as inspired by *taste* (aesthetics), *intuition* (which can be shaped by experience and knowledge, and thus can involve knowledge-based systems) or *randomness*. We are encouraged to address *why* we make computer music generators as much as (or more than) the *how* we make them. That is, the meter interpretation algorithm or generative rule-based knowledge system that we choose to employ is a means to a particular musical end: we must be careful confuse such things with ends in themselves. Are we creating such machines to learn something about how human musicians perceive and generate ideas? To make an audience re-think a familiar context? By articulating the answers to questions of *why*, we can better clarify *what* a system does or could do.

I am interested in how humans and machines interact in the process of creating rhythms. Machines can generate sound with fine temporal precision and thus are proficient in complex rhythmic configurations. While such *machine rhythms* are generally not producible by humans, and thus are absent in the vast majority of the music that humans have produced, they are perceivable by them. This is an area of the "uncharted territory" that Roads [13] refers to. At the same time, machines can produce rhythms that are familiar to human composers, performers and listeners. Thus, by using machines to generate rhythms, we have an ability to codify new conventions and define the spaces for permissible statements: two of the ingredients required for creative expression.

3. Generating Rhythms

3.1. Defining a Rhythmic Space

To define conventions and exogenous possibilities, we need to establish a larger rhythmic space that can encompass both. A rhythm consists of *n* inter-onset intervals (*rhythmic intervals* going forward) that can be described relative to a *beat*, which is a durationless timepoint that repeats at interval *t,* forming an isochronous series.[2] A rhythmic space can then be defined by 1) *t*, 2) the ways *t* can be evenly divided, and 3) the possible rhythmic configurations that can be constructed from those divisions. Each beat division has two possible states, *on* or *off* (*sound* or *rest*), so the problem becomes one of binary enumerative combinatorics where the possible rhythmic configurations at each beat division level equal 2^{a_i}, where a_i is the divisor for beat *i* (see Table 1).[3] Individual rhythms can be represented in Binary notation (e.g. 1101).

Table 1. Possible rhythmic configurations for each beat divisor.

Beat divisor (a_i)	Number of possible rhythmic configurations per beat
1	2
2	4
3	8
4	16
5	32
6	64
7	128

Rhythms can be created by concatenating beats and their possible subdivisions. The possible rhythmic configurations for a rhythm containing *b* beats would equal 2^y, where y =

$$\sum_{i=1}^{b} a_i \ . (1)$$

This would mean that for a four beat rhythm with each beat divided into four, there are 65,536 possible rhythmic configurations. A five beat rhythm with each beat divided into seven would yield over 34 billion possible rhythmic configurations. Rhythms in popular and common practice period (CPP) European Art music typically utilize configurations represented in beat divisors 1-4.[4] This allows for a manageable number of core rhythmic units that composers and performers can choose between (a measure-long rhythm in 4/4 that uses eighth notes as the smallest rhythmic subdivision would have 256 possible rhythmic configurations). Configurations represented in beat divisors 5 and beyond and uneven divisions of the beat expand the possible rhythmic combinations exponentially.

[2] We can also create and describe rhythms in non-beat-based contexts, but given the idea of the beat provides temporal structure and is used in a variety of musical styles, I will focus on it here.
[3] Configurations that equal zero are counted as possibilities because in a series of notes, a zero space functions to elongate the IOI marked by the beginning of the previous sound.
[4] Multiples of four are not unusual, but are typically broken down into smaller groupings of four.

These possibilities present difficulty to humans because of their timing requirements and numerosity, but the latter are of little consequence to machines. Thus, this is also an area of creative potential in the aforementioned unexplored rhythmic territory.[5]

Limiting these combinatorial possibilities is a challenge that can be addressed in a number of ways. First, rhythms can be grouped based on our ability to perceptually distinguish between them. If human listeners cannot distinguish between the rhythms 1001101001 and 1010101001 at a particular tempo, then we can conflate them into a single category. Research has shown that listeners categorize temporal sequences according to a relatively small number of rhythmic patterns that are typically represented by small integer ratios [15]. Instead of selecting particular rhythms in a generative process, we can choose between these perceptual rhythmic categories. Determining the boundaries of these categories could be the focus of further perceptual experiments. Second, a rhythmic configuration can be chosen for each beat iteratively, and these configurations can be concatenated into larger rhythmic organizations. This reduces the number of possibilities at each choice point significantly (though there will be more choice points): to make a 4 beat rhythm with each beat divided into 4, there are 16 possibilities at each beat rather than the 65,536 possibilities present in the 4 beat rhythm as a whole. For both approaches, the number of beat-units can be restricted, depending on the tempo, so that the rhythm fits comfortably within the boundaries of human short-term memory so that it can be perceived.

3.2. Machine Rhythms

Another possibility is that we combine or divide beat-units into bigger or smaller groups, and then divide each of those groups as previous explained. For example, three beat-units could be combined into one, creating a *meta-beat (3:1)*, and then divided into seven equal partitions that could be articulated by the configuration 1101101. A beat-unit could be divided into three, creating a *sub-beat* (1:3), and then divided into four equal partitions that could be articulated by the configuration 1101. Non-integer proportions of beat-units could be combined or divided. For example, a *meta-beat* such as 1.7:1, could be divided into four equal units that are articulated by the configuration 1111. These non-integer proportions could be divided unequally. These complexities are *machine rhythms*.

The identity, the *quale*, of a *machine rhythm* is often unique, and is not typically apparent after listening to one or even two iterations. It emerges as the rhythm is looped, resulting in a palpable groove that is often lopsided and without the associations with even, symmetrical human motoric activity. The identities of *machine rhythms* are distinct from the notational ideals, expressive timing, and physical movements (both generative and reactive) associated with the low-integer ratio configurations that are the norm of

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[5] This discussion does not address pitch, dynamics or accent, which typically play an important role in the perception of rhythmic groups in real music. This omission is for the sake of tractability given the scope of this paper. The focus here, unaccented temporal organization, provides a foundation for future work.

human expression. These unique musical identities make *machine rhythms* attractive to composers that seek novelty.

As *machine rhythms* are perceptually meaningful expressions enabled by electro-mechanical timing and actuation, they exhibit a way in which humans and machines interact in creative processes. We cannot talk about the creativity of the poietic process without reference to the trace (here, a rhythmic configuration). A generative idea, the means to produce it and its realization are intrinsically connected. Creativity then is not only about poietic choices but also about how they are realized. Further, those choices are often formed by the possibilities of production (developing compositional technique is understanding these possibilities) making the relationship between a creative idea and its realization more circular than unidirectional. As machines make *machine rhythms* a possibility, they become an integral part of the poietic process and creativity.

The timing nuances contained in machine rhythms illuminate human perceptual capabilities. Such temporal variances are usually interpreted as expressive timing in the context of categorical ideals, which are typically represented by low-integer ratios. In the case of machine rhythms, the temporal variances from notational ideals are consistent rather than distributed. This consistency allows us to understand these rhythms as unique configurations, and not as variations of a simpler category. In experiencing *machine rhythms*, we exhibit a degree of perceptual temporal sensitivity that is absent in the world of human production.

To illustrate the above, consider a rhythm consisting of the IOIs (msec) 243 307 700. If asked to transcribe such a rhythm, one might be come up with the one of the interpretations in Figure 1.

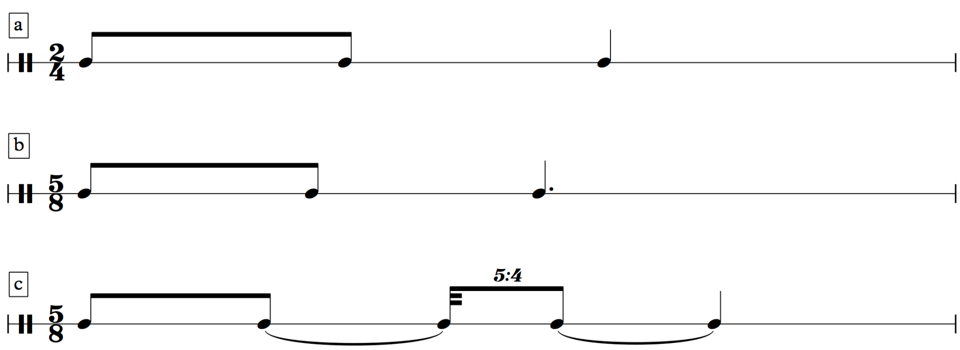

Figure 1. Possible interpretations of the machine rhythm 243 307 700 (msec).

It may be that our tendency to perceive low-integer interval ratios prevails [16]–[19] yielding the simplest interpretation (a) which contains only the ratios (1:1 and 1:2) in a two-beat meter. Interpretation (b) is closer to the phenomenal configuration and thus is more complex: it contains the interval ratio (1:3) and it also reflects that the third note in the pattern does not divide the entire pattern's duration evenly. Interpretation (c) is even closer to the actual *machine rhythm*, though it is unlikely that even an expert would produce a transcription of this complexity. Whatever the results, we must be careful to not confuse transcription with perception: a listener could notate 243 307 700 as interpretation (a) but still be able to distinguish between mechanical renditions of the two. We must therefore be careful not to disregard the possibility of such fine temporal distinction, and thus the creative possibilities of *machine rhythms*, in the context of research that focuses on expressive timing in human performance. The characteristics of such fine temporal distinction capabilities presents possibilities for future experimental research.

In experience, looping the machine rhythm 243 307 700 produces a lopsided-yet-groovy pattern that exudes a quale different from that of its low-integer ratio relatives. It is not that we generalize away temporal nuance in service of pre-established categories, instead, we apprehend the pattern's unique shape as it is repeated. You can listen to the *machine rhythm* and interpretations a) and b) by downloading the sounds from this link.

The bulk of creative exploration and innovation in recent technologically-generated music has occurred in the world of timbre. *Machine rhythms* present similarly exciting possibilities for the world of rhythm. Composers need not be constrained by the temporal grids that define European rhythmic notation and the software based on such practices. There is a world of rhythm between those grid lines that is waiting to be explored, inhabited by patterns and grooves that can move people (both figuratively and literally) in previously unheard ways. Because these rhythms require cycling, they could be equally at home in dance music as in avant-garde experimentation. As these possibilities are articulated, we will learn more about the capabilities and malleability of human perception and production, which may affect how we listen to and perform music in the future. Technologies that provide visual and haptic experience, such as robots and virtual reality, can further shape these developments. These human-machine poetic processes result in new kinds of traces that inspire new kinds of esthesic experiences.

4. Conclusion

Machine rhythms illuminate the distinctions and connections between the poietic and esthesic. We use computers to do what we cannot, but restrict their generational processes in ways that produce expressions that are meaningful to us in musical experience. Creativity occurs as machines inhere in the poetic process to help push beyond the boundaries of convention, but not beyond those that are acceptable as defined by our perceptual capabilities. Machines become creative not because they become autonomous and independent of humans, but because their unique expressions excite something in us. We communicate this excitement, giving a clearer sense of the boundaries between the conventional and the contextually acceptable, further expanding the abilities for humans <-> machines to be creative.

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