Aesthetic Considerations in Algorithmic and Generative Composition

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Abstract: Models of chance operations, random equations, stochastic processes, and chaos systems have inspired composers as historical as Wolfgang Amadeus Mozart. As these models advance and new processes are discovered or defined, composers continue to find new inspirations for musical composition. Yet, the relative artistic merits of some of these works are limited. This paper explores the application of extra-musical processes to the sonic arts and proposes aesthetic considerations from the point of view of the artist. The scope of the discussion is limited primarily to music composition based on mathematical models. Musical examples demonstrate possibilities for working successfully with algorithmic and generative processes in sound, from formal decisions to synthesis.

Keywords: Algorithmic and generative composition, aesthetics, random and stochastic processes, chaos systems, sound synthesis

1. Introduction

In many ways, the Western classical music tradition is steeped in numerical methods. Numbers define musical intervals, which then form systems in the earliest examples of Western counterpoint. Numerical systems identify chords and harmonies within the Western tonal (as opposed to contrapuntal) system, as well. Classically trained musicians continue to learn these systems and to express the music theory of Western classical systems in these methods.

Although there are the odd examples of musical numerical games emerging from history (e.g., Mozart’s “Musical Games”), numerical systems came to the fore in the 20th century with the serializing of musical attributes such as pitch, duration, and timbre. The Second Viennese School freed music from the Western system of dissonance, consonance, and tonal center, allowing set
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operations to determine musical content through numeric representations of the twelve equal-tempered pitches in Western music.

Once the numbers of music were freed from the harmonic system, composers could look beyond the simple set operations of the Second Viennese School into other sources of numerical patterns, systems, rules, and models. With the advent of computers and ultimately computer music, it seems hardly surprising that composition with any kind of numerical system would become more commonplace. And, once audio itself was digitized, the numbers representing music - sound itself, in fact - expanded beyond the restrictions of Western music notation of pitch and duration.

Despite this, the application of extra-musical models and systems to the numbers of sound and music is relatively new to music-making. As a result, composers are still exploring the true potential of using scientific or mathematical models to provide numbers to translate to music. The results can be surprising and occasionally dissatisfying. This paper seeks to address some arenas where pieces can fail to achieve the promise suggested by scientific or mathematical inspirations. Thus, this paper is a qualitative study of musical practices with extra-musical numbers.

In order to make useful formalizations of musical practice through qualitative assessment, the domain of practice must be defined and limited to a particular mode of artistic work. Specifically, this paper deals with what many composers call algorithmic music or generative music. Furthermore, the music addressed is intended to be experienced as music is experienced in the Western classical tradition, not as a scientific display or as a functional part of another entity. In most cases, this requires music to be experienced in the concert hall paradigm. Finally, there are many numerical systems, patterns, and models that can create the data needed for translation to musical ideas. This paper deals specifically with music drawing on algorithms or processes borrowed from mathematics and science. So, firstly, this paper defines the music by the historical context, intended reception, audience, and compositional methods.

Secondly, to draw conclusions of the effectiveness of a musical strategy pre-supposes a system of judgment, a basis on which music is to be compared. It is unethical to apply all systems of judgment to all systems of music. Therefore, this paper then defines the means by which a work is judged to be successful and, more importantly, how the musical experience is then critiqued.

Based on the constraints of compositional domain, the categories of human/model/computer interaction, and a critical system of comparisons, this paper then proposes some crucial questions and considerations a composer can make when creating algorithmic or generative music. Ultimately, this paper offers some conclusions regarding successful practice. However, it does not do so to set
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requirements or rules for good music, only to identify similarities between successful examples of algorithmic and generative composition.

2. What is Algorithmic and Generative Composition?

Perhaps the trickiest navigation on which this paper is based is the definition of the domain it is examining. Musicians are not scientists, and the vocabulary they use shifts and crosses meanings and often implies methods of practice that may seem entirely independent of the name given. Therefore, it is not enough to simply say this paper addresses algorithmic and generative composition.

Here the phrase “algorithmic and generative composition” includes many labels practitioners use to be more specific about their musical approach. For the most part, this music requires the use of computers for its generation; though, technically, there are early examples of these compositions that were calculated by hand or on very primitive machines. This phrase is also used to include the sub-domains of computer synthesis and computer-assisted composition. However, one may prefer to reserve the word algorithmic for certain types of compositional process, where the word algorithm is more precisely defined by the field of computer science. For this reason, generative composition is also included in order to accommodate a means of creating music with processes that may not fall within the more carefully circumscribed definition of algorithm.

2.1. Auditory Display vs. Musical Work

There is currently a multi-disciplinary practice arising from the field of data visualization, where sonic specialists and scientists work together to enhance graphical data visualization with the multi-modality and sensory advantages of hearing. The International Community for Auditory Display, or ICAD, is focused on bringing the advantages of a listening environment to the visual representations of large or complex data sets.

Though some of the auditory displays result in surprising or even somewhat pleasant sounds, the primary purpose of these examples is functional and even scientific. There is little room (in fact, it would be detrimental) for the specialists to alter outcomes for aesthetic purposes. Furthermore, the issues and concerns of these examples address scientific or mathematical problems, not the dilemmas faced by the contemporary musical artist working from the Western history of art- and music-making.

2.2. Sound Art vs. Composition

Finally, there are arenas of music-making that extend from other domains of artistic expression, including the visual arts and theatre. Although algorithmic and generative techniques have been applied in these circumstances, it is important to
specify that this paper deals with the most normative and traditional definition of composition.

Unlike works where the artistic aims are beyond the sound alone (e.g., visual support, theatrical/narrative goals, political art, socio-historical commentary), composers of these works intend them to be experienced and attended to in the concert hall paradigm. That is not to say that conclusions or discussions offered here cannot apply to these domains. Simply: to come to some conclusions, it is necessary to exclude the exceptions, however interesting, at the start.

The concert hall paradigm assumes the context of the Western classical tradition musical performance, and any experimentation within that paradigm relates to the presuppositions of the tradition. The paradigm expects a degree of scrutiny and attendance to sonic detail. It assumes that a work has a consistent identity, even if unique performances of that work may differ. A work within the concert hall paradigm will have a fixed duration, and the audience is expected to attend to the piece in its entirety without distraction.

Works that occur in gallery spaces, for example, that are continuous and ongoing and expect the audience to wander through at unexpected and uncontrollable intervals do not fall into this category of composition. Other works that function as background material, either to visual media, theatre performance, a narrative, or even a commercial environment, do not exist within the concert hall paradigm.

To summarize: this paper addresses algorithmic and generative music, which includes any systems from the strictly algorithmic to more open-ended generative processes. More importantly, it presupposes an artistic or aesthetic endeavor and not simply the act of demonstrating data for informational purposes. Finally, it is meant to be experienced within the concert hall paradigm, which relies on a general type of audience within certain traditional conventions including concerts and/or sound recordings associated with Western classical music performance.

Some of the composers who have works falling into these categories include Lejaren Hiller, Iannis Xenakis, Brian Ferneyhough, David Cope, Eduardo Reck Miranda, Julio d’Escrivan, and Hans Tutschku.

2.3. Exception to a common (mis)understanding
There is an unspoken understanding among some composers that “algorithmic composition” results in a specific style of music within the field of computer music. Perhaps this exists because some composers engaging in “automatic composition” have used the phrase “algorithmic composition” synonymously. The result of some pieces, though called music, approaches scientific auditory display and often does not withstand musical scrutiny. Many composers who may
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rely on mathematical or numerical systems will deny their inclusion in the field of algorithmic and generative music on this basis alone. The use of the phrase in this paper supposes, perhaps naïvely, that this connotative definition can be overlooked for the greater issue at hand. Even the author puts aside her usual reservations and is including her own work as algorithmic composition in this case.

3. What is “successful”?

Given that the domain represented in this discussion is algorithmic and generative composition within the concert hall paradigm, then the metric for the relative success or failure of a work can be determined by the genre itself. There are works throughout history whose success is measured by endurance, impact, innovation, or similar features. These works are accepted as part of a canon in a tradition, perhaps what Goehr [4] would call a musical museum, despite any individual’s personal preference for these works.

This paper will review some of these canonic works and some newer examples that, nonetheless, offer examples of musical success to some degree. The newer works were chosen by positive answers to:

- Does the work stand on its own without recourse to scientific or extra-musical explanation?
- Does the work withstand intense and attentive musical scrutiny?

Additionally, this paper will comment on the published methodologies of composers self-identified as algorithmic composers.

In the following examples, there appears to be three main aspects that determine the relative success of an algorithmic composition. Firstly, there is a correlation between successful works and the degree to which the composer intervenes, influences, adds to, or shapes the composition. Alternately, successful works can also be the result of human performer intervention, e.g., algorithmic compositions performed on acoustic instruments by experienced performers.

Secondly, works that tend to stand without the aid of explanation or background have complex mapping paradigms of the data to musical parameters. Again, there is a correspondence between the success of a work and the obfuscation of the underlying process.

The third characteristic of a successful work is whether or not care has been taken in orchestration or design of timbre. At the same time, timbral considerations are intricately linked to decisions made by the composer in instrumentation and mapping. For this reason, timbre may not be considered as a
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third aspect. However, its immediate effect on the reception of the work makes it necessary to address it separately.

3.1. Human Intervention
Perhaps the most telling evidence of the need for human intervention comes from the evident bias against the term algorithmic composition since it can mean automatic composition (without human intervention), as mentioned earlier. Many composers who may rely on mathematical or numerical systems will deny their inclusion in the field of algorithmic and generative music on this basis alone.

History tends to support this bias in musical examples. A very compelling example comes from a work that is often regarded to be musically weak but is nonetheless historically important. Namely, *Analogique A + B* (1959) by Iannis Xenakis demonstrates very clearly that composer intervention and further human performance and interpretation result in more successful outcomes. In two parts, *Analogique A* and *Analogique B*, Xenakis implements the same Markov process in different media. One utilizes short, electronic sine tones arranged and recorded on tape. The other is translated into quantized notes according to Western music notation and scored for strings. Although the process is the same, the electronic version allows Xenakis greater freedom in both pitch and duration, since sounds could be arbitrarily generated. However, it is the string version that was more successful as a musical work.

In many cases, limiting material to a musical scale can reduce the complexity and interest of a governing algorithm. Yet, paradoxically, the acoustic version (*Analogique A*) is a stronger work. The first impression may be that the more familiar and acoustic timbre of the strings makes the version more successful. Yet, taken on its own, *Analogique B* does provide a rich timbral experience, as Xenakis’ method of composition is a precursor to the common practice of granular synthesis today. Rather, the effect that human performance, hence human intervention, of the given musical material is far more salient than the sound source.

In a musicological investigation, a fully automated version of *Analogique B* was created using current software that was unavailable to Xenakis. The experiment attempted to show that newer technologies facilitate the philosophies and aesthetics of Xenakis [6]. The result of the program was surprising; rather than demonstrating the benefit of technology, it revealed that Xenakis made subjective decisions while piecing together the electronic sounds. So, as *Analogique A* was stronger than *Analogique B* as a result of the human interpretation in performance, the original *Analogique B* was stronger than the computer-generated version because all vestiges of human intervention were removed in the latter.
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There is strong precedent for composer intervention (or interference, depending on the point of view) within algorithmic composition. Composers such as Di Scipio [3], Ariza [1], Gogins [5], and Xenakis [8] refer to integrating their feedback into systems, trial and error methods of fine-tuning systems, or “bending” by the composer in the process of writing algorithmic music. Essentially, the composer can make crucial decisions at various stages of the composition. For some interactive systems, composers make subjective judgment calls and guide algorithms. In other cases, composers will tweak systems several times before getting the musical material they need. And, whether the composer is “fudging” the output of a system or perturbing a steady state, composers will interfere and introduce error into the output of an algorithmic system. The resulting complexity of these composers’ works, especially the musicality of them, makes the case for composer intervention.

3.2. Complexity of mapping
The second, obvious attribute contributing to the success or failure of a work is the complexity of the mapping of the system or data output to the musical parameters. To accurately measure complexity is to pursue a study beyond the scope of this paper. Additionally, most composers do not publish their processes to the degree to which it would be necessary to quantify the complexity of their individual mapping. However, by looking at common student practices compared to those of established composers, the extreme ends of the spectrum can be identified.

Students learning the practice of algorithmic composition must learn a variety of skills relevant to the multi-disciplinary field. For example, they may need to learn the mathematics behind a particular equation or iterated function. They may then need to learn computer science skills that enable them to realize the mathematics in an environment that can lead to music or sound production. Finally, they must learn the art of composing and music-making, which is inherently a critical and subjective domain learned and advanced only by continual practice. To some degree, it is this last aspect that students cannot learn quickly, though some may have better natural instincts than others. Therefore, it is this final objective that students fail to realize in their short careers as students. As a result, student works in the algorithmic domain may show advanced understanding of scientific or mathematical systems and may exhibit sophisticated implementation of the systems in programming environments. Yet, students tend to fail dramatically in making music from these skills.

The fundamental difference between the student work and the established composer is the way the algorithms are translated into music. A student does not have the experience or depth of musical understanding to do much more than the most straightforward mapping of data to sound. For example, a two-dimensional
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system may be very simply translated into pitch and duration values, or pitch and instrument assignment.

Unfortunately, the use of MIDI led many early algorithmic composers to realize their ideas in this simple way. The resulting works have a primitive quality and quickly lose any interest or novelty. In some cases, the mapping of output to musical parameter was so simple and the music was so automatic, that the results would be more accurately described as auditory display.

The fundamental problem with this note-based approach to algorithmic composition is that it is inherently simple. Despite the complexity of the stochastic or chaotic system, the output is directly mapped to obvious musical qualities, making the reception unchallenging and less engaging. Though the systems exhibit compelling qualities, the results fall flat when translated to the temporal domain in the form of sound.

More seasoned composers searched for a way to complicate the relationship of the systems to output. For example, Bidlack [2] utilized a note-based approach to algorithmic composition realized in MIDI. In order to complicate the mapping while working within the same constraints, Bidlack implemented multi-dimensional systems (Lorenz and Hénon-Heiles) so that the third and fourth dimensions could be utilized for duration and loudness in addition to pitch. Additionally, it appears that Bidlack chose timbres without recourse to a deterministic system, an example of composer intervention.

However, even more successful works exhibited a complexity of mapping to the degree that any sign of the original algorithm is hidden beneath the immediacy of musical material. The listener hears music, not an algorithm. Complex patterns may emerge or dissipate, but they seemingly follow an internal musicality, not deterministic rules.

One example, *Olivine Trees* (1994) by Eduardo Miranda, demonstrates that complexity of the application of the algorithm can be manufactured not simply by the number of dimensions or parameters the algorithm controls, but by the time scale on which it is controlled. Miranda uses cellular automata to control grains of sound (reminiscent of the Xenakis example above). In his own description, Miranda likens the blending of these small grains to that of impressionistic painting [7]. The composer is inspired by the artistic potential of the system and reflects it in a sophisticated approach to implementation. In addition to CA, Miranda uses other processes and composers’ tools to further influence the sound of the piece. In this sense, Miranda not only obfuscates his mapping, but he introduces a free reign of composerly intervention.

3.3. The Importance of Timbre
From the first works of electroacoustic music composition, timbre was the primary material of music. Pitch, rhythm, loudness, silence – these were the
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brushes, but timbre was the paint. The fascination with electroacoustic means of making music was the palette it provided.

As more composers began working with the new tools, new foci entered the domain of practice. As a result, later music relied less on timbre as its primary material. This was especially true for algorithmic composers whose primary material was the system or algorithm itself.

Yet, this attitude has been a detriment to the field of algorithmic composition. Timbre is an immediate attribute that anyone can perceive, regardless of his or her musical sophistication. It does not take a musical education to be aware of badly synthesized sounds, nor to grow fatigued with poor orchestration. Therefore, the most successful algorithmic compositions are examples of excellent instrumental or sound design choices.

It is difficult to address the timbre problem without addressing the human factor or the complexity question. Therefore, timbre can really be seen as a consequence of those aspects.

For example, if human intervention happens at the performance stage, i.e., live instrumentalists realize a work, then timbre is a consequence of the acoustic instruments. As a result, it has the richness, variety, and familiarity these instruments have in the culture. Likewise, if the mapping of a system is to the microsound level or to sound synthesis, then the complexity and interest of the system used is mapped into timbre, resulting in rich and interesting sounds.

However, since timbre is the immediate attribute first perceived in a work, it warrants separate consideration. Recognizable timbres can improve or ruin a work. In the case of works by Lejaren Hiller, notably the Quartet No. 6 for Strings (1973), the natural instrument timbres performed by live humans create music that stands on its own, regardless of its algorithmic roots. Hiller augments his timbral possibilities with the extended playing techniques developed in the 20th century. In comparison, much more algorithmically complex works that were realized with MIDI and commercial synthesizers now sound dated and awkward.

In the earlier examples, both Xenakis and Miranda synthesize complex timbres through algorithmic processes applied to granular synthesis. However, there are many different ways in which algorithmic processes can enhance timbre. Chaos and stochastic systems have enhanced spectral (frequency domain) synthesis as well as physical modeling synthesis methods. These systems applied to acoustic science in this way are effective tools for sound design.

This aspect is an extension of the notion of complexity; an algorithm applied to the microsound of digital synthesis is rarely perceptible in its original form. Rather, algorithmic systems generate interesting and complex timbres in and of themselves, without immediate recognition.
4. Conclusion

Given a restricted domain of music that is made using algorithms and/or generative processes, it is possible to identify three aesthetic considerations common to the most successful works of the genre.

First, an algorithmic or generative system is rarely sufficient on its own. In the most enduring examples, the composers had significant input to the musical material, reserving some musical parameters for subjective judgment and development. Additionally, many influential composers intervened and modified their systems, either by perturbing them or by bending the outcomes.

Secondly, the systems used must be mapped complexly to musical parameters. Though it is not always the case, this usually means that the algorithms are not easily detected or identified.

Works that fail to reach these first two points, namely employ a lack of human intervention and simplistic mapping systems, create results similar to scientific, auditory display. Though informative in its own right and occasionally interesting sonically, this rarely withstands aesthetic scrutiny.

Thirdly, and intricately dependent on the first two points, the choice of timbre in an algorithmic work plays a significant and immediate role in the relative success of a work. Timbre is dependent on the first two points, because in one possible instantiation, acoustic instruments realize musical material generated by systems. In this case, human performative interpretation fundamentally changes the reception of a work. In some other cases, systems operated on the microsound level, the level of sound synthesis. This complex mapping of system to musical parameter often results in rich, varied, and interesting timbres. However, timbre can be the result of many other compositional decisions. And, its impact in the reception of a work is quite large. Therefore, it requires separate consideration.

Pieces that were used as examples include works by Iannis Xenakis, Lejaren Hiller, and Eduardo Reck Miranda, while the methodologies published by Rick Bidlack, Agostino Di Scipio, Christopher Ariza, and Michael Gogins supported these conclusions.

5. References

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