Interaction in Algorithmic Composition
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Fundamental concepts of algorithmic composition have been based on and reflect the state of contemporary computer technology at the time. As computer technology advances, algorithmic composition has the opportunity, if not the prerogative, to respond to these developments. Three such developments are discussed here: real time issues, rapid feedback/evaluation systems, and chaos generation.

The development of real time computer music systems has led to application primarily in the realm of live concert performance systems. Less emphasis has been placed on the implications of real time systems for the compositional process. Real time technology can offer the composer an interactive environment for machine mediated music composition. Its immediate nature is able to bring the domains of both performance and improvisation closer to the compositional process. Real time by itself does not introduce new compositional algorithms - in fact it runs the danger of facilitating the spread of trivial algorithms for quick and easy music generation. Conceptual rigor should not be compromised for fast easy results. One should not mistake enabling technology that allows an improved environment for composition with the temptation of instant productivity. The application of real time technology does, however, afford the composer an interactive environment algorithmic composition.

The use of general interactive systems raises needs specific for the task at hand, in this case composition. Important for composition is the need for rapid feedback and evaluation systems. Algorithmic composition techniques traditionally include some level of composer intervention in selection of viable music from a larger superset of machine generated results. Recent advancements in interactive interface techniques include the development of rapid user selection systems. Such selection systems are used in computer graphics systems that generate complex graphics on the basis of genetics and evolution algorithms. Part of the conceptual basis of the genetic metaphor is the Darwinian selective process. In these graphics systems the user is presented with a dozen or more computer generated results from a given generation. A generation is presented simultaneously on multiple screens. The user selects which results please him (are viable). This selects which members of a given generation survive and form the basis of the next generation of output. Such rapid feedback and evaluation systems can be
applied to the compositional process. It affords the opportunity for interactive composer intervention throughout a developmental music generation system. Whether the compositional algorithm is genetics based or not, an efficient selection process can enhance the speed and quality of composer interaction in algorithmic composition.

Interactive selection systems deal with algorithmic composition at a high level - at the level of composer choice. To examine the lower level aspects - the compositional algorithms themselves - leads us to consider families of computational techniques like those that make use of chaos. Chaos algorithms are themselves not a recent development. What is new, however, are recently described techniques concerning the effective control of chaos generation. This is pertinent to music, and to algorithmic composition in particular. For we must remember that the second word in the term is in fact composition - the creation of structure, in this case via machine mediated methodology. The machine does not replace the composer. The composer must maintain an active artistic interest to coax and mold the machine output into a piece. This is relevant in the use of chaos for music. Chaos algorithms produce rich musical output from minimal human input. New approaches in the control of chaos put the human back in the picture. This gives the composer the opportunity to exercise his aesthetic to help drive the development of an algorithmically composed piece. The control of chaos at the structural level is a challenge analogous to the challenge at the timbral level in using and musically controlling noise. By itself, noise is not musical - to be musically effective, it must be sculpted and brought under control by the composer. It can be argued that despite the interesting possibilities that chaos affords, musicality enters the picture upon the application of the composer's aesthetic to drive the course of chaotic music generation.

The composer can intervene at this low level to directly affect the algorithms that generate the music. His manifestation of this control can take place in an interactive way, such as with the use of the feedback-evaluation method described above. Given that this kind of work can take place in a real time environment, we have created a scenario where the productivity of algorithmic composition has been enhanced.

Modeling Music with Computers: Random Thoughts
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Responding to David Cope's invitation to participate in the second ICMC panel on algorithmic composition and to his request for this position statement, I thought of my passionate, fist-raised plea before presenting a
paper on computer modeling processes at the 1987 ICMC: "Random is beautiful", I declared. But, while I still have a deep appreciation of random's power as a beautiful mathematical function, I don't ask the computer to make its beautifully random numbers much anymore in my own pieces: I found out—by using computational modeling processes to emulate my own compositional intuition—that it was again a lot more fun freely to invent musical material—like a real (sic) composer would—than to work to get the computer to do it.

Introducing the thrust of that 1987 ICMC paper, I wrote then, however, what still seems relevant today: "Unlike the other arts, music is self-modeled, for—except by analog—its sounds cannot be seen or touched, nor can they be consistently understood as symbols representing anything other than music. Yet, we perceive music as tangible, its models clear, existing in our mind's ear, real and valued. Music's models are its own vast array of musical compositions. The form of a composition is, in fact, fashioned in its own image—it is self-similar—both when the composer works to model an original form and when it is an extrapolation, variation, or emulation of pre-existent forms, the composer's own or other composers'. What composers do to invent material for a new piece, then, is to create that piece's modeling process, the working strategy of its creation and design. Essentially, the composer asks, 'How will my piece be like itself?' " In that paper, computer-aided processes were explored and illustrated with musical examples from finished as well as in-progress works, concentrating on those which modeled the composer's intuitive skills in creating, elaborating, and transforming musical material.

In 1969, when I invoked my first random functions for musical reasons, I found the results to be great, surprising fun! Like the process and results of good, high-flying, free improvisation—so important to my own and other's music in the '50s and the '60s—good, high-flying algorithms were great fun through the '70s and into the '80s. Paradoxically, those same intuitively composed musics I explored for algorithmic modeling became once more fascinating, themselves, to me to invent as a composer. Further, algorithmic compositional processes were more and more understood and appreciated by me not in their consummation as whole pieces but as techniques to invent and test materials, subsumed along with all the other elements of invention in the forming of a piece. Composing intuitively had again become more fun that the results of modeling that process in continuing heuristic attempts to produce believable, "fun" compositional results.

It's more, though, than a hedonistic search for fun that has drawn me away from algorithmic composing and now toward a refreshed appreciation of my own intuitive powers as a composer in inventing and modeling musical forms. Whether white, pink, brown, self-similar, self-avoiding, distributed...random is beautiful, random is fun, because random is so
distinctly un-human, artificially intelligent (stupid?), artificially creative, really primitive...real-ly understandable. I would even venture to say that algorithmic composition now has its own common practice musical language, one that appeals to many composers, I believe, because it is so utterly understandable and primitive and fun. With it, a composer can create yards and yards of just about any sort of surface musical material needed. The question for me in such artificial invention is, "Is the surface material of a piece the essence of its form?" I say that even the most attractively sounding surface material of a piece is only as meaningful as the compelling coherence of its deep structure, brought about most readily--so far--through the genius of intuitive invention (notwithstanding the significant work of Ames, Barbaud, Berg, Bolognesi, Chadabe, Cope, Hiller, Koenig, Laske, Loy, Polansky, Rosenboom, Truax, Xenakis, Zicarelli et al)--excluding those works, like Cage/Hiller's HPSCDH, where moment-to-moment experience is everything.

Finally, I find intuitively composed music real-ly fun these days. It's this growing realization, since 1987, that it's musically healthy not to understand how it is we compose intuitively. In fact, if I sense I understand something, I move on to something I don't. As Gertrude Stein said, "If it's been done, it's not worth doing." Or as John Cage put it, "It's beautiful, I don't understand it!"

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Algorithmic Composition [re]Defined
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The term algorithm is associated with the Greek arithmos [number]. It is also an alteration of the Arabic term algorism [standard arithmetical notation of 1, 2, 3...]. It has been defined in the following ways (among others):


"...a sequence of instructions that tell how to solve a particular problem..." in "...a finite number of steps." (Downing, Douglas and Michael Covington. Dictionary of Computer Terms. NY: Barone's Educational Series, Inc., 1989, pp. 6-8)


The words compose and composition may be defined as:
"To make or form by combining things, parts, or elements." (Random House Webster's College Dictionary, NY: Random House, 1991, p. 278)

"...composition means "putting together" and not "taking apart": and while these elements may be studied separately, as various branches of theory, they should be studied as a whole when the subject is composition." (Apel, Willi. Harvard Dictionary of Music, Cambridge, Mass.: Harvard University Press, 1962, p. 168)

As a conglomeration, then, algorithmic composition could be described as:

"A sequence (set) of rules (instructions, operations) for solving (accomplishing) a [particular] problem [task] in a finite number of steps of combining musical parts (things, elements) into a whole [composition]."

Hence, by the words of some respectable defining sources, algorithmic composition embraces all music composed by rules which combine the elements of music into a whole. [Note that the term "computer" is not requisite to a definition of algorithmic composition here nor are there requirements concerning the all-inclusiveness of the algorithmic process. Computers, however, offer the most attractive and beneficial vehicle for the practical realization of algorithmic processes.]

Now, with such a definition, can procedures such as dodecaphony, aleatory, fugue, part-writing, and so on, be described as algorithmic composition? Certainly the "rules" for combining musical parts of each of these processes have been clearly articulated. As well, each of these procedures has been used to produce "whole" compositions.

The use of the term "algorithmic composition," then, should not distinguish composers that create musical automata (independent composing programs) from those composers that don't create musical automata. But it should distinguish composers that use rules to create whole compositions from those that don't use rules. To distinguish otherwise creates a false dichotomy. Shouldn't, then, every composer be interested in the exploration of algorithmic composition? Shouldn't every composer be interested in the advantages computers provide for algorithmic composition as well as for timbral exploration?

At the least, most composers can describe methods which, when followed in a step by step manner, would produce music in their style or, if style is not the issue, music which fits their aesthetic. In fact describing such activity can only enhance awareness of the compositional processes, even if one fails in the achieving of an acceptable outcome. When employed computationally, algorithmic procedures can also be used to determine the effectiveness of certain compositional directions which by other than algorithmic means
would be incredibly time consuming, even psychologically damaging (particularly if they fail). After all, such algorithmic programs can relieve composers of onerous note by note composition in favor of broader strokes of musical achievement. "There has never been so powerful an instructor or decision-making tool for helping you determine which methods have promise and which do not." (Jaxtron. Cybernetic Music. Blue Ridge Summit, Penn.: TAB Books Inc., 1985)

Algorithmic composition, then, is a subject for all composers, not just those involved with automata. We need not look just to Guido, Schillinger, Xenakis, Hiller, and so on, for examples of approaches to algorithmic composition, but as well to Bach, Mozart, and Schoenberg. Especially, however, for those who have the will to admit it, algorithmic composition can lead to powerful and dynamic new models of composition which might be discarded for the lifetime of devotion it would otherwise take to experience their realization.

Why then, is there a need for this special panel? Why do the numbers of papers devoted to computer timbre exploration at these conferences continually and significantly outnumber those devoted to algorithmic composition? Why is computer music so often defined solely in terms of its use as an instrument, however broad this instrument's timbral palette may be? Possibly a [re]definition of algorithmic composition can unmake this imbalance and cast a brighter light in the direction of computational composition. It is certainly time...

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Position Paper

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I am interested by a statement attributed to Coomaraswamy that John Cage often cited during his life: that a function of the artist is to imitate nature in its manner of operation (italics mine). Cage embraced indeterminacy out of regard for the manner in which he understood nature to operate. In recent years, much territory has been explored on the subject of dynamical chaos and the modeling of natural behavior where indeterminate elements mix with deterministic ones. More to the point, iterated functions systems, discrete time maps, chaotic nonlinear systems have been discussed recently by a number of composers (David Wessel and Gary Lee Nelson, among others - see references to my paper in this volume), demonstrating the continuing fascination that these models hold in a variety of musical areas. I believe that these dynamical mathematical models hold such fascination and potential for
composers because they express profound truth about the manner in which the natural world operates around us and within us.

In my work, dynamical algorithms are employed as a means of generating musical material in a MIDI-based electronic music studio. The algorithms are written in MIDIPascal and MAX. With MAX, recursive functions and higher dimensional dynamical models can be implemented and interacted with on the fly. I have realized one, two and three dimensional models on the Macintosh where the output is mapped onto pitch, timbre, and dynamics on synthesizers and samplers. The systems which are of particular interest to me are dissipative in nature, having internal friction and by necessity an 'attractor'. Attractors can take any number of geometrical forms, among them 'strange attractors' which result from the trajectories of iterated functions stretching, diverging and folding between limits without ever visiting the same point twice, giving them a fractal dimension since they exhibit self-similarity on an ever reduced scale. Principally thus far, though not exclusively, I have used the algorithms for the composition of pieces written for traditional instruments. These include works for solo piano, solo violin, piano duo, chamber ensemble, and orchestra. So the computer is used not merely as a tool, but more like a musical instrument on which I play with the models on the fly as MIDI data streams are output and recorded in MAX.

Raw musical material as well as certain transformational procedures and larger aspects of the musical design are generated with the aid of the Macintosh and MAX. I have been fascinated for some time by the richness, surprise and dynamism that iterative algorithms yield visually. I, like many other composers, am exploring ways to map these same features into the musical domain. What is consistently surprising is that the emergence of "chaotic" behavior in these models is not random behavior. There is a uniquely beautiful hidden order in chaos. The emergence of complex, mandala-like patterns can be readily seen in the trajectories traced by orbital fractal algorithms. My hope, in employing these algorithms in any composition, is to express what for me is a deeply resonating beauty and dynamism in chaos in musical terms.

Typically, the pieces I make can be thought of as describing paths through an algorithmically created landscape. The analogy of a musical landscape is useful, I believe, because the pieces do not follow a traditional formal procedure subscribing to more linear notions of exposition, developmental encounter, return; rather, their formal paradigm is a nonlinear, process oriented one where the music is in a state of continuous transformation. Like clouds and turbulent flows, the musical forms one encounters along the way are just as likely as not to ever return in their original state. Musical time does not proceed, therefore, according to linear cause and effect, rather, the musical flows come about as a result of orbital trajectories diverging and converging between limits. The performers can be thought of as inhabiting
the musical equivalent of a phase space in which there are continually evolving curves and orbits which tend to stabilize around periodic cycles or fly off into unstable patterns: a direct result of working with the algorithms. In my pieces, I am still very much concerned with connection and causality in the music, but I am searching for other ways to achieve it. I owe a great deal both in inspiration and to the working out of certain practical compositional issues to composers such as Xenakis, Ligeti, Corlou Nancarrow, and Gerard Grisey.

The parallel interaction between computer and composer is one that interests me very much. The successful use of the dynamical models depends in large part upon the composer’s ear. Though the specific output of the dynamical models changes quite sensitively according to initial variables, the models exhibit consistent meta-behavior, including absence of large scale closure, emphasis on process, and a highly charged periodic rhythmic surface with deeper levels of slower harmonic rhythmic. While these characteristics are fascinating, they also highlight those areas where the composer best incorporates artistic judgment based upon more linear thinking. The willingness to circumvent algorithm as the ear suggests is all important in the rendering of them in my view. My approach is decidedly non-purist since the algorithms are treated as procedures which suggest potential paths, not prescribed paths. A great deal of pitch material and some matters of compositional design in the music are generated by the computer while other musical decisions such as color, register, and temporal proportion are made using my ear as my guide.

The use of the computer in the realization of these mappings raises many important issues, among them, to what extent does that which is created with the computer call into question traditional notions of invention, musical identity, and inspiration? For example, I have had the sense when working with dynamical models such as the logistic map or the Lorenz model, that what I was hearing was an object “out there”, occupying a preexistent Platonic realm which is impossible to quantify or locate but which resonates “in here”, at the composer’s center, yet quite apart from that which is merely personal and subjective. There is more a sense of discovery than of creation in the traditional sense of that word. What I hear is not the result of my projecting my own musical personality into the musical landscape, it is rather more like taking the first steps of a journey into a musical landscape that I could not have imagined before that fascinates and invites me. That landscape seems to me to exist both in time and out of time: the composer is a visitor to a terrain that unfolds itself in time, yet its forms seem to have been there all along and will be there again in the future gives their deterministic nature. Also contributing to this sense of otherness about which I am speaking is that dynamical systems often produce musical output whose richness of design far exceeds what is put into it at the outset. Very simple iterative functions can yield trajectories characterized by increasingly complex, self-referential
patterns in the logistic map, for example, the subharmonic cascades created by bifurcation, the universal principle behind transition phases towards more turbulent states via period doubling, are musically viable as source material. Strange attractors yield musical flows that fire the imagination and are applicable across scales in the elements of musical design.

With MAX, one may experiment live with musical processes set in motion by an algorithm, thereby affecting the evolution of a piece. This kind of flexibility and play is, needless to say, all-important to a composer who wishes to engage his or her ear and heart in the rendering of the algorithms. In my view, it is the journey through the dynamically modeled musical landscape rather than the landscape itself that alters according to one's interaction with it. While I am not a philosopher and cannot sufficiently address the issues that surround any claim to a platonic musical realm (nor is that my intention), I am interested by the fact that this question has arisen so forcefully in my mind as a result of my interaction with dynamical algorithms. I am not suggesting that the music that is fashioned with these algorithms happens without precomposition or thought or without the composer's subjective taste and cultural framework playing an important part, but I am very interested by both the "impersonality", in a sense, of the algorithmic processes and my own visceral and intellectual interaction with them in real time in the shaping of a composition.

What Is Composition Theory?
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1. Definition
On the face of it, 'composition theory' is a theory of the process of composition, not only of music, but of any composition. The notion of composition is crucially transformed by the use of contemporary technology, such as computers, especially digital signal processors. By way of technology, composition becomes a traceable, interactive process whose structure can be documented, researched and understood as a human activity in its own right. Theoretically, this amounts to a revolution in thinking about composition.

2. Function in Cognitive Musicology
In my own theoretical work, interactive computer music composition has been the foundation of a new conception of musicology called cognitive musicology. Since 1970, I have conceived of musicology as a form of systematic musicology whose task it is to understand mental processes called 'musical.' For re-conceiving of musicology in this fashion, computer music composition has served as a paradigm for how to conceptualize musical
processes generally. As a musicologist, I have assumed that music is a set of
tasks that humans (like to) do, not just something humans understand. This
notion has led to the further notion that musicology, rather than being a
hermeneutic science, is an 'action science.' An action science establishes, to
speak with Argyris, a community of inquiry within a community of practice
(Argyris 1985). It targets living practitioners and their collaborations as its
topic of inquiry (Laske 1993).

3. Two Paradigms of Music Research
Whether one sees musicology as a hermeneutic or an action science, it is
important to realize that there are two major paradigms of musicological
research, viz., Composition and Listening. Both of these provide different
lenses through which to look at musical activities. All of present musicology
and music theory (so-called) is based on the Listening paradigm. However,
Listening is a mysterious process that is little understood, since it leaves no
traces and encompasses perception as only one of many ingredients. In my
view, listening is closest to story understanding, and thus massively based on
imagination, that is, massively interpretive.

4. The Musicological Relevance of Composition Theory
It is here that the theoretical relevance of composition theory clearly emerges.
Composition, especially in the form of an interactive computer-based activity,
is a traceable process whose internal structure can be analyzed on the basis of
knowledge elicitation (Laske in Balaban 1992) with relative ease and great
stringency (Laske 1991a/b, 1990, 1979). Also, it can be simulated by computer
programs in the sense of 'artificial intelligence' (Baggi 1992; Balaban et al.
When adopting Composition, in contrast to Listening, as a paradigm of
musicological research, one is on firmer ground as to the structure of the
activity one is researching. This is not to deny the fact that composition as an
activity encompasses listening as an ingredient. Nevertheless, in my view,
one is less prone to speculation when looking at musical activities
empirically through the lens of Composition (capital C), rather than
Listening (capital L).

5. Link to Practice
In my as a composer, composition theory has provided me with a host of
strategies for inventien that without I could not have imagined and
developed. The theory has freed me from the 'the terror of the (acoustic)
material' as well as the 'terror of the (computing) machine,' both in
instrumental/vocal and electroacoustic compositions. Even as a poet I have
benefited from the computer. Beyond my compositional and theoretical work
in music, composition theory has given me a viewpoint regarding 'AI and
the arts' generally. It is a fact that a computer-assisted composer has more in
common with a computer-assisted weaver than a composer and a weaver
otherwise have.
6. The Future of Composition Theory
In my view, the future of composition theory, both in and by itself, and as an ingredient of systematic musicology, looks most promising. There is an interaction with formal language research as well as with building so-called intelligent computer music systems. Our notions of mindware and software gradually approach each other. By this I mean that, although often the hard way, we are gaining the experience necessary to mold software to the idiosyncrasies of the human imagination, not just of human problem solving. And, as I have indicated, by using Composition as a paradigm of music research, we are on firmer ground than we can be when speculating about what listening might be.

References