Towards a prehistory of evolutionary and adaptive computation in music

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Abstract. A number of systems have been created which apply genetic algorithms, cellular automata, artificial life, agents, and other evolutionary and adaptive computation ideas in the creation of music. The aim of this paper is to examine the context in which such systems arose by looking for features of experimental music which prefigure the ideas used in such systems. A number of ideas are explored: the use of randomness in music, the view of compositions as parameterized systems, the idea of emergent structure in music and the idea of musicians performing the role of reactive agents.

1 Introduction

In recent years the use of evolutionary algorithms (genetic algorithms, genetic programming, et cetera) and related ideas of "adaptive systems" (artificial life, cellular automata, agents) have been used in many ways in creating music. These ideas are surveyed in [6, 10, 2, 3], and have been the topic of a number of recent workshops[1]. Typically such systems are concerned with the generation of electronic music; however in some situations these techniques are used to generate scores for acoustic realization (e.g. [14, 17]).

The aim of this paper is to investigate how some of the ideas involved in the creation of pieces of music via evolutionary algorithms (e.g. the use of randomness as a source of musical material, the use of ideas of reactive agency as a structural principle in music) can be found in mid-to-late twentieth century experimental music.

The main motivation for this is to understand one of the contexts in which these experiments in automated composition and structuring of musical materials arose. It is interesting to speculate as to whether the various experiments with the components of evolutionary and adaptive algorithms "paved the way" for the application of these algorithms in composition. Would musicians have

[1] See e.g. http://www.generativeart.com/, http://www.csse.monash.edu.au/~iterate, http://galileo.cincom.unical.it/esg/Music/ALMMAII/almmaII.htm and http://www.tic.udc.es/~jj/gavam/

been led to consider these ideas without the "scene setting" which these musical experiments provided? Furthermore are there areas of computing which could lead to the development of interesting musical developments, yet which haven't been explored because the right kind of musical groundwork needed to provide the links between the computational and musical structures has not been layed?

Defining exactly what is meant by "experimental" (or an alternative term such as "avant-garde") music is potentially complex (see e.g. the discussion in [13]). Basically I mean the sort of music discussed e.g. by Griffiths in [9]. I shall use the term "experimental music" as a shorthand for these musics for the remainder of the paper.

2 Randomness

One of the key features of evolutionary computation is *randomness*, which acts as the main generator of novel combinations of material, the creator of new material and the engine driving the route through search-space.

Small-scale randomness and variability is a feature of all musical performance. Nonetheless the use of randomness as a deliberate organizing (or disorganizing) feature of music became an important feature of experimental music from the 1960s onwards. However this move towards randomness does not come from a single motivation.

One motivation is to help performers to move away from cliché and provide new sources of material which would not otherwise be considered. In particular John Cage has emphasized that it is difficult for a performer just to do something radically innovative just by trying to do it; they end up falling into cliché and habit:

> Tom Darter: *[...]* some of the players said, "Given that this is going to appear random to the audience, can't we do anything?" What would be your response to that?
>
> John Cage: Well, if they just do anything, then they do what they remember or what they like, and it becomes evident that this the case, and the performance and the piece is not the discovery that it could have been had they made a disciplined use of chance operations. [12]

There may be some prefiguring here of the way in which randomness is used in computational search and exploration algorithms. Instead of attempting to encode a set of suggested rules for dealing with certain kinds of situations (*a la* expert systems), which reaches a limiting point, the randomness of search enables new ideas and combinations of ideas to be formed.

A second motivation, which we may also associate with Cage, is to do with separating intention and action.

> Another idea in *Cartridge Music* [7] is not just transforming sound, but that of performers getting in each other's way in order to bring about nonintention in a group of people, so, if one person is playing a cartridge

> with an object inserted in it, another one is turning the volume down independently. I never liked the idea of one person being in control. - John Cage [12].

This use of randomness promotes a different relationship between composer and audience than is traditional in music. Instead of the action being focused on creating a particular outcome, the focus is on carrying out the action itself, regardless of consequence. Indeed the 'absence of intention' [12] is a key component of the performance/composition aesthetic in Cage's music.

An related important aspect of Cage's aesthetic is the idea of the score as an indication of the actions to be performed, rather than the desired outcome. Such an idea seems radical in music, yet is natural in computing; computers are typically programmed by giving them instructions for action (which in the case of a stochastic algorithm may give rise to an unpredictable result) rather than by specifying the desired end-result of a procedure. Indeed it is interesting to note that much effort is being expended in computing research in trying to go the other way, and find ways of programming computers in terms of specifications of desired output rather than giving an explicit description of action.

A third aim of randomness is radically different. This is the idea of creating music based on the use of stochastic processes to generate the fine-level details of a piece of music (e.g. the particular pitches used and the placement of sounds in time). Instead of a compositional process being concerned with the placement of those individual sound-events, the composition becomes a matter of manipulating the statistical distributions in the sound-space. This approach to composition was pioneered as pioneered by Iannis Xenakis in the 1950s and 60s, giving rise to pieces such as *ST/4* [24], and detailed in the book *Formalized Music* [25]. Some related ideas are discussed by Stockhausen (e.g. the essay *Composing Statistically* in [22]).

This approach to composition arises from a line of thought about complexity in music. Around the time that these pieces were created increasingly complex musical superstructures were being created using 'mathematical' schemes for the organization of musical materials. Given the complexity of material produced as an end result of these schemes, the replacement of the direct methods which a stochastic generation of the same 'density' of complexity seems a natural progression. Perhaps there is a similarity here to statistical mechanics; even though we believe that the large scale behaviour of a fluid is governed by a vast number of small deterministic actions of molecules, it is easier to produce a similar effect (in this context for studying the phenomena in question) by making a statistical approximation to the deterministic phenomenon.

A similar kind of thinking seems to underpin the creation of music via methods such as cellular automata (e.g. [15, 16, 19, 20]). In such systems the composition lies in the creation of rules about the relationship between the objects in the system, rather than about the direct placement of individual sounds. Nonetheless there are differences too; in a cellular automaton model the manipulation of the global effect is done in a bottom-up fashion; the music emerges from the effects of the rules. In the Xenakis approach the attitude is much more top-down, concerned with the sculptural manipulation of the space of where the sounds are allowed to be. Perhaps the cellular automata models are closer to a tight version of the total serialist systems, where parameters such as pitch, volume, et cetera, are organized by visiting different values in a fixed order.

3 Music and parameters

Leigh Landy [13] has suggested that a key characteristic of experimental music in the mid-late twentieth century is the conceptualization of music in terms of *parameters*. Firstly he notes that a trend in musical history has been towards the expansion of the scope of a particular musical parameter (though it is unlikely to have been seen as such until recently). For example pitch expands out from early scales with a small number of notes, to more complex scales involving more pitches, to a point at which pitch can be described as a continuum measured in Hertz. He points out that the idea of regarding music as exploration of parameter-space was first formalized by Joseph Schillinger in the 1940's, and traces the development of the idea first as an *analytic* technique, then examines the role of explicit thought about parameters as a compositional tool. We may want to think of this as the analytic technique being turned around to form the basis of a synthetic technique.

There are a number of ways in which the formalization of music in terms of manipulable parameters can be used directly by composers. For example (again the example is from [13]) Stockhausen makes use of the idea of coupled actions through parameterization, e.g. in matching physical action to sound by realizing both of them from a single underlying parameter. Another example comes from the idea that timbral characteristics can be manipulated directly in the same way as other characteristics of music, e.g. in Schönberg's idea of the *Klangfarbenmelodie*—a melody made up of different timbres ('sound colours') rather than pitches.

A related point has been made by Barrett [1], who suggests that composers such as Boulez, Xenakis and Stockhausen work within *"a general field theory of which particular compositions are offshoots"*. Offshoots (suggesting the idea of moving away from a particular starting point) may not be the best choice of word here; perhaps the concept is more of choosing a particular point within a parameter space (or a particular route through that space), or else one of "collapsing" the parameter space to a particular piece.

Such an approach has been considered by Pierre Boulez:

> I prefer to think of mobile form as a *material form*, i.e to regard it as a basis for one or more "fixed" scores chosen from the multiplicity of possibilities. [5].

Many of these ideas have close parallels with the idea of *search space* in computer science (a concept which was being developed at the same time as many of these ideas were being developed in music) and with the older idea of *phase space* in theoretical physics. The conception of music existing in some kind of space which can be explored seems to be key to many of the applications of evolutionary and adaptive systems in music; after all, it is difficult to apply a search algorithm without first describing the space to be searched.

The granularity of this space varies from system to system. Sometimes an entire composition may exist at each point in the phase space (e.g. consider a space where each point consists of a set of rules for a cellular automaton which in turn gives rise to the ordering of sounds as that automaton runs). Alternatively the act of moving through the space may itself create the temporal structure of the piece (examples are given in [15, 18]), with each timestep representing e.g. a time interval, or the triggering of a single action.

A number of interesting perspectives on the shape of sound space (and whether we always want to consider sounds as living in such a space) are given by Wishart [23].

4 Emergence and interaction

Another concept which is important in many evolutionary and adaptive pieces is the idea of structure as an emergent property from small-scale actions in the music (a bottom-up approach to structure) rather than as a top-down concept where an explicit form is created and various musical components placed within that form.

This relates to another concept which is the idea of musicians (or sound-creating devices) acting as *agents*, reacting to other musicians according to some instructions. The newness here is perhaps in the idea of simultaneously following a score and reacting to other players. Clearly micro-reactions (e.g. adjusting tuning to be "in tune" with other players) have long been a part of music, and improvising alongside and in response to other players is a core part of most musical traditions.

These ideas are important in a number of experimental compositions too. Some examples are given in the work of Cornelius Cardew, in particular in *The Great Learning* [8]. An excerpt which shows this clearly is paragraph 7 from the piece, illustrated (in it entirety) in figure 1. A performance of this piece can easily consist of 60–90 minutes of complex, structured music, yet the entire formal structure can be expressed on a single page. The piece consists of a number of lines of text, each of which are sung independently by each member of a large vocal ensemble. However there is interaction between the various members of the ensemble, because at the end of each line the singer chooses a note which they can hear being sung elsewhere in the ensemble. Therefore the piece gradually converges on a single pitch or pair of pitches. The fact that each performer moves through the piece at their own pace adds to the richness of the texture.

This "convergence" clearly reflects aspects of the text. In particular other parts of the text from other "paragraphs" in the piece make the ideas clearer still, emphasizing the Confucian ideal of good government arising first from personal clarity of thought and self-discipline, through families and communities and eventually giving rise to 'equilibrium' throughout the empire. Thus the bottom-up emergence of structure reflects the ideals of the piece.

These aspects have been emphasised more than once in analytical exegeses of this piece. Michael Parsons emphasises the economy of the notation and the way in which it exploits differences and random initial choices (perhaps in contrast to many traditional musics which rely on commonality as the basis for their structure, e.g. keeping to a common time):

> The idea of one and the same activity being done simultaneously by a number of people, so that everyone does it slightly differently, [...] gives one a very economical form of notation—it is only necessary to specify one procedure and the variety comes from the way everyone does it differently. This is an example of making use of "hidden resources" in the sense of natural individual differences (rather than talents or abilities) which is completely neglected in classical concert music. (Michael Parsons, in [21]).

Some related themes are discussed by Dusman:

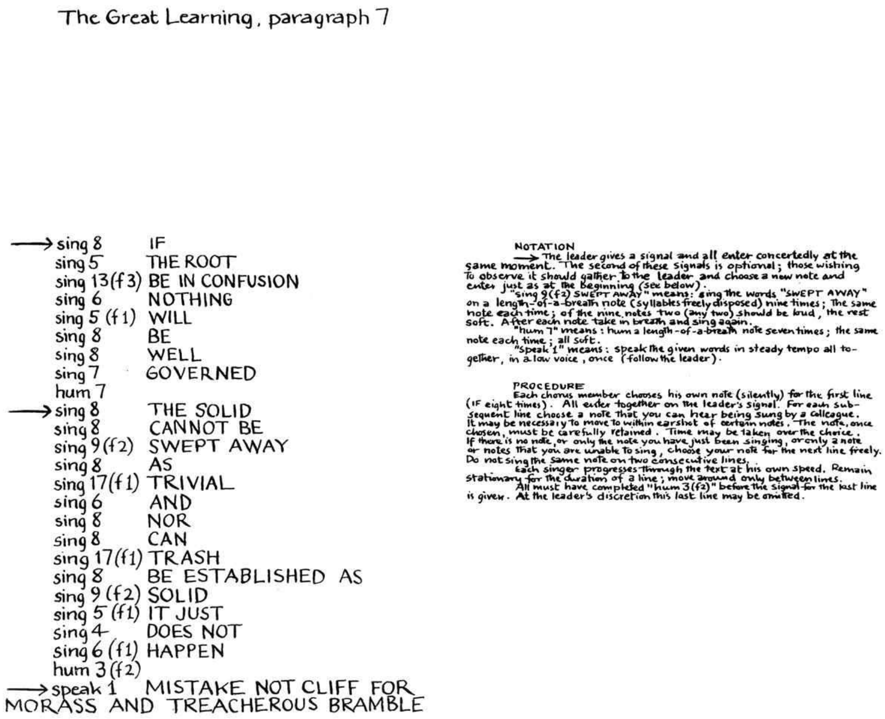
> Paragraph 7 successfully isolates the individual as the only variety-introducing factor in the piece. As in much experimental music, the score is composed in such a way as to produce a range of outputs, valuing its probabilistic properties of generation, not its specific ones. What is perceived by the listener in Paragraph 7 is an evolutionary harmonic procedure.

Other issues relating to self-organization are given by Beyls [4].

Other pieces from the 1970s also illustrate ideas of agency and emerging structure in contrasting ways, and both illustrate the idea of the evolution of a sonic structure through interactions between performers following some instructions. An example is *Telephone Matrix* by Kenneth Maue (reprinted in [11]). In this piece a number of performers (who need not be in the same performance space) are each equipped with a telephone. The piece begins with the "players" (as the performers are termed) writing down a few words and phrases, known as units. These units are then transmitted to other players by telephoning them and giving them a word or phrase; if two attempts have been made to communicate a particular unit, then the player must purge that unit from their list. When a player has a number of units that they can form into a phrase, they can then transmit that whole phrase; eventually whole sentences are formed. When a player has a full sentence, they can stop participating. When everyone has a sentence they are happy with (apart from one player, who is still calling and not being answered) the performers meet together to "compare the results of their activities".

References

1. Richard Barrett. Michael Finnissy—an overview. *Contemporary Music Review*, 13(1):23–43, 1995.



The Great Learning, paragraph 7

→ sing 8 IF
sing 5 THE ROOT
sing 13(f3) BE IN CONFUSION
sing 6 NOTHING
sing 5 (f1) WILL
sing 8 BE
sing 8 WELL
sing 7 GOVERNED
hum 7
→ sing 8 THE SOLID
sing 8 CANNOT BE
sing 9(f2) SWEPT AWAY
sing 8 AS
sing 17(f1) TRIVIAL
sing 6 AND
sing 8 NOR
sing 8 CAN
sing 17(f1) TRASH
sing 8 BE ESTABLISHED AS
sing 9 (f2) SOLID
sing 5 (f1) IT JUST
sing 4 DOES NOT
sing 6 (f1) HAPPEN
hum 3 (f2)
→ speak 1 MISTAKE NOT CLIFF FOR MORASS AND TREACHEROUS BRAMBLE

NOTATION

→ The leader gives a signal and all enter concertedly at the same moment. The second of these signals is optional; those wishing to observe it should gather to the leader and choose a new note and enter just as at the beginning (see below).

"sing 9(f2) SWEPT AWAY" means: sing the words "SWEPT AWAY" on a length-of-a-breath note (syllables freely disposed) nine times; The same note each time; of the nine notes two (any two) should be loud, the rest soft. After each note take in breath and sing again.

"hum 7" means: hum a length-of-a-breath note seven times; the same note each time; all soft.

"speak 1" means: speak the given words in steady tempo all together, in a low voice, once (follow the leader).

PROCEDURE

Each chorus member chooses his own note (silently) for the first line (IF eight times). All enter together on the leader's signal. For each subsequent line choose a note that you can hear being sung by a colleague. It may be necessary to move to within earshot of certain notes. The note, once chosen, must be carefully retained. Time may be taken over the choice. If there is no note, or only the note you have just been singing, or only a note or notes that you are unable to sing, choose your note for the next line freely. Do not sing the same note on two consecutive lines.

Each singer progresses through the text at his own speed. Remain stationary for the duration of a line; move around only between lines.

All must have completed "hum 3(f2)" before the signal for the last line is given. At the leader's discretion this last line may be omitted.

Fig. 1. Paragraph 7 from Cardew's *Great Learning*.

2. Peter J. Bentley, editor. *Evolutionary design by computers.* Morgan Kaufmann, 1999.
3. Peter J. Bentley and David W. Corne, editors. *Creative Evolutionary Systems.* Morgan Kaufmann, 2001.
4. Peter Beyls. Musical morphologies from self-organizing systems. *Interface*, 19:205–218, 1990.
5. Pierre Boulez. *Orientations.* Faber and Faber, 1986.
6. Anthony R. Burton and Tanya Vladimirova. Generation of musical sequences with genetic techniques. *Computer Music Journal*, 23(4):59–73, Winter 1999.
7. John Cage. *Cartridge Music.* Peters Edition, 1960. EP6703.
8. Cornelius Cardew. *The Great Learning.* Matchless Publications, 1971.
9. Paul Griffiths. *Modern Music: the Avant-Garde since 1945.* Dent, 1981.
10. Colin G. Johnson. Genetic algorithms in visual art and music. *Leonardo*, 35(2):175–184, 2002.
11. Rogerr Johnson, editor. *Scores: An Anthology of Modern Music.* Schirmer, 1981.
12. Richard Kostelanetz, editor. *Conversing with Cage.* Omnibus Press, 1998.
13. Leigh Landy. *What's the Matter with Today's Experimental Music?* Harwood Academic Publishers, 1991.
14. K. McAlpine, E. Miranda, and S. Hoggar. Making music with algorithms: A case-study system. *Computer Music Journal*, 23(2):19–30, 1999.
15. Eduardo Reck Miranda. Cellular automata music: An interdisciplinary project. *Interface*, 22:3–21, 1993.
16. Eduardo Reck Miranda. Granular synthesis of sounds by means of a cellular automaton. *Leonardo*, 28(4):297–300, 1995.
17. Eduardo Reck Miranda. On the music of emergent behaviour: What can evolutionary computing bring to the musician? In *Workshop Proceedings of the 2000 Genetic and Evolutionary Computation Conference*, 2000.
18. Artemis Moroni, Jonatas Manzolli, Fernando J. von Zuben, and Ricardo Gudwin. Vox populi: evolutionary computation for music evolution. In Bentley and Corne [3].
19. Gary Lee Nelson. Sonomorphs: An application of genetic algorithms to the growth and development of musical organisms. In *Proceedings of the Fourth Biennial Art and Technology Symposium*, pages 155–169. Connecticut College, March 1993.
20. Gary Lee Nelson. Further adventures of the Sonomorphs. Conservatory of Music Report, Oberlin College, 1995.
21. Michael Nyman. *Experimental Music: Cage and Beyond.* Schirmer, 1974. (second edition by Cambridge University Press, 1999).
22. Karlheinz Stockhausen. *Stockhausen on Music.* Marion Boyars, 2000. Edited by Robin Maconie.
23. Trevor Wishart. *On Sonic Art.* Harwood Academic Publishers, 1996. second edition, revised by Simon Emmerson; first edition 1985.
24. Iannis Xenakis. *ST/4 for string quartet.* Boosey and Hawkes, 1962. 080262.
25. Iannis Xenakis. *Formalized Music: Thought and Mathematics in Composition.* Indiana University Press, 1971.