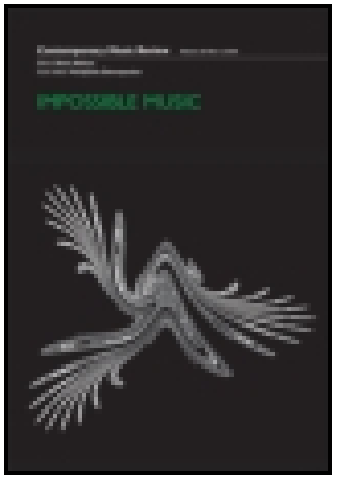

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Musical Form and Algorithmic Composition

Nick Collins

The formalization of music has not always covered so readily the form of music, particularly from a psychological angle that takes the listener into account. Some novel forms have been organizational by-products of the top-down application of grammars or probability distributions. Many works have utilized bottom-up generation of material ready for human arrangement, or accepted existing stylistic templates from music theories. Whilst material might be generated to fill particular sections, the relations between sections and between hierarchical layers, and particularly the control of musical tension through transition, have received far less attention. Algorithmic music often seems stuck in a static moment form, able to abruptly jump between composed sections but unable to demonstrate much real dramatic direction. In part, this is because such ebb and flow engages with seemingly unformalizable attributes of the human musical experience, with musical expectancy, memory and emotion. Nevertheless, since automated music has not been shy about formalizing other aspects of musical structure, and human beings are intimately involved in authoring musical systems, it would seem a highly productive avenue to explore further the possibilities of algorithmic musical form from a psychological angle.

Keywords: Musical Form; Algorithmic Composition; Macro-structure; Large-scale Works; Musical Tension

Exposition

Musical systems embody particular music theories, and these theories can extend to whichever timescales and relative arrangements of musical objects their author desires. This article will treat in particular macrostructure rather than microstructure, the traditional domain of musical form. Algorithmic and process music works have inevitably introduced novel overarching structures determining the mould for particular products or situations. Generative music raises some interesting new problems of compositional design, and some interesting new characterizations of

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form in music. Larger-scale structure provides a stimulating viewpoint from which to examine generative music, and one which has often not received the most attention either from analysts or from artists.

Indeed, this article is motivated by a suspicion that much formalized music (Xenakis, 1992) has not explicitly confronted issues of musical form. It is rare to see engagement from algorithmic composition research with larger-scale hierarchical and associative structure, directedness of transition, and interactions of content and container. Admittedly, much algorithmic work is concerned only with the generation of basic musical materials rather than self-contained pieces, and the composer retains the right to deal with larger concerns in the usual intuitive manner. Other systems are determined by extra-musical concerns, from video-game narrative to theatrical drama. In many cases, moment form (Kramer, 1978), with its concentration on the immediate scene free from outside connection, is a natural setting, particularly for more ambient music functions. And many works adopt existing well-worn stylistic templates wholesale. Nevertheless, we might also expect to see novel forms enabled by algorithmic strategies, and some great opportunities for the modelling of macrostructure and musical directivity founded in models of human audition.

This article proceeds by reviewing the musicology and psychology of musical form. Some issues of generative music itself and of large-scale algorithmic works are discussed. Various uses of form in algorithmic composition are surveyed, with an emphasis in particular on non-interactive works as presenting the most operationalized theories of form. The confluence of psychological apprehension of form and new algorithmic structures is treated, before some closing statements are made. Whilst the article will not provide definitive solutions to the modelling of form—a futile pursuit, given the huge variety of aesthetics and styles in play—I hope to convince the reader that a consideration of musical form is a productive viewpoint to take, and reveals many areas of enrichment for algorithmic composition.

Problems of Musical Form

Much historical writing on musical form has concentrated on cataloguing standard models, and traditional western theory textbooks tend to say less about the apprehension of long-term form, rather emphasising a list of known analytical templates (Berry, 1966; Cole, 1969; Kohs, 1976; Schoenberg, 1967).[1] These off-the-shelf models supposedly encapsulate common practice in particular eras, typically becoming formularized by theorists only after a bulk of examples exist, and, in many cases, being reified by later composers perhaps as more rigid models than they may originally have been intended to be (Copley & Gartland-Jones, 2005). At least this promotes their mechanizability for the algorithmic composer!

In musicology, the relation of particular works to general models has caused some sleepless nights, alongside the similar chicken-and-egg problem of form and material (Whittall, 2008).[2] Container and contents are inexorably intertwined in the analysis of form, which must find a level at which to explicate structure. This often spills into

characterizations of bottom-up (material-driven) or top-down (template-determined) construction for works. One resolution of this is provided by the recognition of an iterative design cycle in composition rather than a singular one-directional determination (Cook, 2004). As Otto Laske (1985, pp. 558–559) expresses it, 'Compositional activity is difficult to analyze because it is characterized by instantaneous changes in compositional strategy from top-down to bottom-up approaches in the material'.

Recent psychological literature has tackled the principles by which listeners might discern form. These studies have emphasized aspects of human long-term memory, the extraction of prominent cues, recognition of similarity and associative processes, the modelling of expectancy and musical tension, and the multi-scale hierarchicality of structure which supports parsing and chunking of information (Deliège, 1989; Huron, 2006; McAdams, 1989; Snyder, 2000). McAdams et al. (2004) differentiate three approaches to musical form:

1) The analytical view of musical architecture, requiring multiple listens, access to composer plans (such as a score), or some other form of out-of-time study of musical objects.
2) The denial of teleological trajectory and long-term relationship—namely, moment form.
3) The online 'in-time' listener experience solicited during the course of a work, founded in human cognitive capability.

These may of course interact—for example, in the change of long-term memory structure due to repeated listening, which impacts on the causal experience of each new run-through, or the gradual loss of attention when a listener is starved of new information. Whilst acknowledging the conceptual, compositional and analytical relevance of the first two ('out-of-time' referring to the writing of Xenakis), it is the third that will particularly influence this article, in discussing goal-directed musical motion drawing the listener on a hopefully controlled path through a form.

One healthy sceptical possibility must be raised, however, that long-term form is not tracked and that only short-term structure is appreciated by listeners (essentially expressive content within the approximately ten-to-fifteen-second/thirty-to-thirty-six-event bound of short-term memory). Tillmann & Bigand (2004) review a number of studies that seem to suggest this, particularly in regard to tonal closure and key relationships, as well as for the time ordering of segments of music. There is evidence for implicit learning of hierarchical structure in the short term, but also for the 'weak perceptual importance of global organization' (Tillmann & Bigand, 2004, p. 218), and the authors argue that listeners favour local coherence and transition. In this vein, many of the techniques raised below are of relevance to effecting coherent short-term transitions. Nevertheless, Tillmann and Bigand's case is not watertight, particularly with regard to memory for motifs, recognition of development and recurrence of sections.

Variations of Generative Music

Rule sets do not have to be mechanized; text pieces provide examples of often highly ambiguous poetic instruction lists unfit for computer determination. However, the central exemplars of generative music in this era tend to be generative music programs, for the computer is such a natural tool for the exploration of musical systems. Yet, as well as standalone musical generation programs, it is common to examine situations where human and computer interact in real time. Undeniably, humans write rule sets and programs, and it is up to them to establish the roles of any human and computer participants in musical generation. The indeterminacy where human beings are involved in live decision-making is potentially a paradigm jump greater than the entirely explicit nature of code alone (Collins, 2008). We shall deal mainly with non-interventional, non-interactive works, typically algorithmic composition computer programs, in this article, but much of what will be traced is highly pertinent to interactive algorithmic systems as well. Nevertheless, non-interactive autonomous works are extremely interesting as theories of musical form, since they must simulate auditory experience rather than directly take advantage of human feedback.

There is no one algorithm to delimit our investigation, and whilst a variety of mathematical frameworks are pertinent, from probability theory to nonlinear dynamical systems, no single formulation can be said to summarize all works. Further, generative music is agnostic as to the style[3] and predominant carrying parameters of music. Generation may have rather modest aims, such as creating a single theme or texture, or create the grounding for a long autonomous musical workout. Generativity implies multiple versions whenever systems are not deterministic (which is certainly the case whenever humans are involved, and predominantly the case for algorithmic music engaging with any level of variability), so can bring issues of a corpus of outputs to the table. Is it the form of one exemplar, or a meta-form discerning all possible productions? Perhaps this is the nightmare of musicologists magnified!

Gottfried Michael Koenig has differentiated a model of form, from a realisation fitting that model. This concept of *potential* and *actual* form is described in the context of his *Funktionen* electronic music works, but generalizes well to describe the relationship between a program and any one run. The scope of a system to empower variation is a critical facet of generative work: 'The more closely the components of the form potential are woven together, the lesser the extent to which the various actualities differentiate with regard to one another and to the potential; the potential is then in practice the form itself' (Koenig, 1971, p. 51).

It might seem straightforward to overload a listener with an autonomous generative system through sheer fecundity. However, the perceptible variety of outputs from a given system is usually quite constrained compared with the mathematical space, and significantly expanding this from the user's point of view is a goal of current research in computational creativity. Furthermore, each production

is usually a short piece, not in itself constructed with issues of long-term form in mind.

Lifetimes of Larger Works

Problems of form are less pressing for vignettes; short works simply demand less sustained attention, less negotiation with long-term memory. As Schoenberg (1967, p. 179) notes, 'Large forms develop through the generating power of contrasts. There are innumerable kinds of contrast; the larger the piece, the more types of contrast should be present to illuminate the main idea'.

Algorithmic music enables extended forms; in the extreme, it is possible to plot infinite duration works (Collins, 2002). Larger expanses of time are often invoked by installation works running over extended periods, or by programs constantly streaming algorithmic music over the Internet. Whilst the audience may drop in and out, works such as Jem Finer's *Longplayer* or Leif Inge's *9 Beet Stretch* stream on; only automation by machine guarantees these performances! It is arguable what coherence the listener can extract overall from such extended work—though 1000 years versus 24 hours is the difference between impossible and plausible for continuous human observation—but the conceptual engagement with time beyond human scales is important to many artists, in the same way that moment form can support access to the eternal (Kramer, 1978). If a critique of these two deterministic works might be levelled, it is that the perceptual variety of experience on offer is not as profound as their claims to huge duration (just as LaMonte Young's Manhattan room installation and John Cage's 639-year organ work might not be enough musical material to keep a human engaged for a lifetime, whatever their philosophical import).

Seeking out generative systems that can support individual productions carrying more developed long-term structure may help to solve (or possibly magnify) the problem of available listener time. These systems might be intended to run just once for a continuous production which cannot be pre-rendered (per evening, per lifetime). Or they may exemplify more highly crafted models of musical form, to be utilized in the study of composition. Algorithmic engagement with aspects of large-scale structure and associated cognitive processes of memory and affect are necessary steps in the algorithmic composition research programme.

The Development of Musical Form in Algorithmic Music

I noted earlier some suspicion that longer-term form was not a main focus of algorithmic composition research to this point. Eduardo Miranda refreshingly introduces the issue of musical form early on in his book on computer composition (Miranda, 2001, pp. 8–19), and considers the listener's perspective with regard to the unfolding of a musical piece. Yet none of the examples considered in his book point to macrostructure. He states that 'algorithmic composition software tends to support the bottom-up approach whereas computer-aided composition software tends to

support the top-down approach … composers tend to combine both approaches' (Miranda, 2001, p. 10). He exemplifies the top-down angle by Paul Whalley's *Tangent* (pp. 186–187), which allows the creation of passages by a choice of generating rules, but does not significantly engage with musical form *per se*. The other main example of top-down construction he gives is the musical grammar (also covered, for example, in Ames [1987] and Roads [1985]), typically invoked without relation to the cognitive reality of any ensuing music.

A historical survey of algorithmic composition reveals many systems that have not concentrated on form to any great degree either. Lejaren Hiller writes that 'the concept of hierarchy was little used in the early development of computer music algorithms … I felt this lack' (Hiller, 1981, p. 86), and that 'hierarchical structure is the fundamental architectural principle that makes a musical work into a coherent whole' (Hiller, 1981, p. 84). Whether or not hierarchy is all there is to the psychology of musical form, his solution is a program called *PHRASE*, which 'can be used to compose themes, motives and phrases, and, even more importantly, to imitate and combine these phrases in a number of ways' (Hiller, 1981, p. 84). Yet this is transformation of relatively short-term materials (as combinations of notes), and not an algorithmic model of long-term form. Hiller seems to display his prerogative as human composer to impose forms, appropriating round or rondo. Indeed, the default assumption in most work in this field is that of composer intervention on the level of form, or imposing certain template structures at higher level from standard music theoretic models.

Charles Ames in his 1987 review writes that 'where the Urbana school tended to focus on local qualities implemented in the form of stylistic rules, the Europeans emphasized global qualities of musical passages, as quantified by statistical distributions' (Ames, 1987, p. 173). He interprets Iannis Xenakis' aims as those of 'aggregate effect' rather than thematic relationship or sequential control.[4] And although he claims 'increased machine participation in decisions affecting large-scale compositional form' for the period 1976–1986 (Ames, 1987, p. 179), no example is given relating to the perception of that form aside from James Tenney's *Bridge* (1983/4). This work utilizes Tenney's gestalt theory of clangs, though the overall 8-, 13- and 21-minute sections seem to derive from human exigency. For most other works, manual human intervention is again the order of the day, or else researchers tackle more constrained musical tasks such as melody generation or harmonization, with the simple adoption of stylistic templates when daring to go any further.

It's not a bad tactic to providing larger-scale form, to work from a pre-existing style model, as historically developed by composers and theorists in a cultural survival of the fittest! It is possible to piggyback, to 'templagiarise' an existing work (as coined by Doug Hofstader in Cope, 2001) or to dip into any one of the catalogues of forms for abstract reductions. It is even possible to begin to consider the automatic extraction of musical form templates using music information retrieval algorithms (Kuhl & Jensen, 2008). The problem here is that the psychological dimension, especially as pertaining to the interaction of materials and the template, is not always so well algorithmized.

Modelling the Listener in Algorithmic Music Construction

Reviewing much of the rest of the algorithmic composition literature leaves one similarly lacking in large-scale examples that significantly treat psychological form. One exception is provided by Giuseppe Englert (1989), who invokes form readily ('For a large-scale work realized with complex means, we can imagine a 'mega-form' divided into 'mega-sections' [p. 134]), but then turns to a basic low-frequency sinusoidal function as an activity determinant over time. A very recent attempt appeared at the closing stages of this article going to press; Fredrik Hedelin (2008) takes an ultimately top-down approach based on modelling the abstract musical form and its constituents at various timescales. His worthy aim is to consider the listener and the musical context during construction, though he does not review the psychology literature, grounding his work in his own musical analysis.

What is needed is some bridge between formal structure and perception. This is provided by attempts to integrate listening models, or at least models of musical tension and memory, into algorithmic composition; published examples tend to concentrate on affect.

David Cope has managed to firmly associate his name with dedicated work in automated composition, even if a few controversies over his level of disclosure of the exact techniques remain.[5] EMI is claimed to take account of motives of 8–10 notes, phrases and sections (Cope, 2001, p. 128). Most notable in this context is Cope's modelling of musical tension through SPEAC—statement, preparation, extension, antecedent, consequent—(following Schenker), chiefly employed for marking up the sense of tension and resolution of melodic lines and chords. Cope tags material at each of EMI's hierarchical levels, and uses this context of musical tension in recombinance from his database: 'Hierarchical groupings of identifiers show tension at larger and larger levels using the same procedures' (Cope, 2001, p. 133). Whilst also dependent on the template work, this principle of coherent flow is a more significant engagement with the problem of the listener.[6]

In her PhD thesis, Morwaread Farbood (2006) presents a multi-parametric model of musical tension, combining existing models of harmonic tension, melodic expectation and psychoacoustic loudness with basic pitch, onset time and tempo attributes. The weightings for these factors are determined by fitting experimental data and checking generalization performance. Multiple versions of her computer-assisted composition environment *Hyperscore* are presented, utilizing various manifestations of a user-defined high-level tension curve. Although no final tension model is integrated into the system, and the model components are themselves hardly a proven and sufficient framework given limitations in the experiments and individual components, the potential of this approach to reflect the likely experience of a listener to any generated music is well conveyed.

The psychological literature offers then models of musical tension and expectancy (Huron, 2006; Narmour, 1999) that may prove productive in incorporating the future listener into the composition system. The associated notion of musical affect

has been tackled in a number of projects. Perhaps the first algorithmic composition system to make an explicit link with emotion was WOLFGANG (Riecken, 1992), even if the 'emoting potentials' themselves are not adequately described and seem to derive from some basic hard-coded heuristics. Birchfield (2003) expresses well an aim to create 'outputs that contain intelligible structure and can sustain large-scale forms' in a listener-oriented generative system engaging emotion and form, though the realisation and evaluation is less than convincing. Further recent examples relate more to the psychology literature, and include the generation of music for video games with a particular affect (Eladhari et al., 2006; Livingstone & Brown, 2005) as well as the induction of user-specific fitness functions grounded in data gained from an emotional quiz (Legaspi et al., 2007). High-level affective descriptors can then determine the form, with systems tending to focus on styles following specifically common practice western harmonic systems, where there is more psychology research to draw upon. Much interesting ground remains to be covered.

Novel Forms of Generative Music

Although the previous section treated systems engaging with conventional musical forms, it is productive to consider the psychological affect of novel forms and, before novelty is taken for granted, whether there are any innately algorithmic forms. The factory view of a generative system as churning out new products is not in itself new, for composers hardly write only one work. The richness of the human system, learning and developing in style in interaction with culture, has certainly not been adequately captured by machine, though promises much as a research goal!

Open form and indeterminacy are just ways of invoking where and whose human effort is applied. For autonomous generative programs, the indeterminacy is in the random number seed, and for interactive music systems, in the specification of allowable action. Interactive negotiation of form is also not new; improvisation is the most ancient of musical arts. This is not to deny that new twists are possible through the construction of interactive musical machines (see the Robert Rowe article in this issue). Even to sidestep the machines and concentrate on rules, there are plenty of situational adventures. A number of ensembles (such as the fabulously named Halal Kebab Hut) have continued to explore ways in which human beings can be the agents for the performance of rule-based systems. The joy of live coding is also explored elsewhere in this issue.

Returning to generative music programs, the following list presents a few possible contenders for novel structural ramifications investigated in systematic composition and mathematical music:

1) Self-similar structures; recursive definitions, fractal music;
2) Stochastic music, information theoretic constructions;
3) Emergent form (as a by-product of complex lower level activity);
4) Artificial musical grammars.

There is always plenty for analysts to write about, and they may challenge existing schemas, but a question mark remains over the end-user experience. Whilst conceptual brilliance may pay art critics' salaries and underwrite some aspects of grand art, it is not enough for the average audience stuck listening to a work in a concert hall. To what extent should such novelties directly reflect human processing constraints? No one seeks to deny the inspirations of novel territory, but in the conveyance of large-scale form, a delicate psychological trick as it is, much more is at stake.

How perceptible are any of these variations on variation? It is interesting that one of Xenakis' original motivations in the 'Crisis of Serial Music' article of 1955 was to criticise integral serialism on perceptual grounds. Yet Xenakis went on to attempt the conceptual unification of all timescales through common formulas (for example, with GENDYN), an approach which, whilst pure in deed, bears little psychological reality; there is only one timescale as the conduit of real listener experience, and diverse timescales are in no way equivalent!

The composer's disregard for perceptual criteria (favouring item 1 or 2 over 3 in our earlier list) pervades contemporary music, of course, and though we might carefully tread around some marvellous conceptualizations, it is hard to resist pointing out the odd flaw. For example, the subdivision of time into bracketed sections based on recursive proportions (as per John Cage) is rather weak. Subjective time depends on information content in short-term memory, not on objective perception of some carefully precise time spans outside the perceptual present. Recursions resisting hierarchic chunking of 5^5 elements will overpower human memory. If a piece will only be presented once, will it survive long in the ecology of memory if it pays little heed to human capability?

Yet this psychology aside, which no doubt to some composers seems to threaten dumbing down rather than marvellous vistas, it is always tempting to speculate grand new angles in meta-form-space, the space of systems which generate large-scale structure. Formalization often allows extrapolation from existing form-models into probabilistic generalizations: '"form" is no longer the personal manner in which the musical material is presented or the listener's perception is guided; rather, it is the rationally discernible, reproducible effect, detached from the composer, of an organized system imposed on arbitrary material' (Koenig, 1989, p. 403). Generative music seems so perfectly poised to exploit listening modes where the eternal now or eternal change are invoked, how could you not desire an eternal listener?

Coda

In reviewing the materials on algorithmic composition in preparation of this article, it was refreshing to approach them with the idea of large-scale form in mind; it helped to focus anew on composers' proposals and achievements. Consideration of

musical form is useful in drawing attention to modelling the human experience of music at all levels.

Much of the discussion herein has been related to investigations of form in music psychology, because this seems like the best bet for operational principles which allow the generation of works with comprehensible structure. The psychology literature is itself incomplete, particularly regarding many aspects of motivic construction and longer-term memory. Even if remaining slightly sceptical about the perception of any longer-term formal structure, the modelling of such facets of music as tension, resolution and affect seem replete with potential to enrich the local flow of algorithmic music.

It might even be speculated that generative music provides a way of running psychology experiments in form; novel structures can be tested with a guarantee that the subjects haven't heard them before.

Finally, how can a machine entertain its own sense of form and proportion? What worth are a machine's aesthetics unless tightly coupled to the eventual human experience? The composer must be willing to commit to a formal model of form in their system. Some practical suggestions might include continuous thematic dominance charts, tension lines as blackboard information for genera, parameter envelopes for tension model weightings, and the like. The hard work of psychological experiment, as per Farbood's thesis and other projects, may be the price of creating the most effective automatic composition engines.

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Notes

[1] The current *Oxford Dictionary of Music* definition of form (Kennedy, 2008) further settles on a small number of form categories biased to standard classical models!

[2] Both are caused by the choice of description level in theorizing about data, and can be further resolved by acknowledging the continuous evolution of human knowledge over time as models are reified and refined.

[3] The problems of categories will be avoided for now, in case we exhaust ourselves in epistemology before we get very far. Marvin Minsky on data-driven style might be quoted (see my review of Leigh Landy's book accompanying Collins, 2008).

[4] And Xenakis was a notorious tweaker of the output of algorithms!

[5] The destruction of his own databases as recounted in his latest book on creativity, and the lack therefore of complete reproducibility for EMI to allow independent confirmation of the extent of human manipulated to machine encoded production, is telling. However, many of his smaller LISP programs are available from his website.

[6] The drawbacks here are a dependency on Schenker's model for tonal music, and a failure to acknowledge that different material might be 'tense' for different combinations of factors.

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