AMPLIFYING COMPOSITIONAL INTELLIGENCE: CREATING WITH A PSYCHOLOGICALLY-INSPIRED GENERATIVE MUSIC SYSTEM

Toby Gifford
Queensland Conservatorium,
Griffith University.
140 Grey Street,
South Brisbane, 4101
Australia

Andrew R. Brown
Queensland Conservatorium,
Griffith University.
140 Grey Street,
South Brisbane, 4101
Australia

Robert Davidson
School of Music,
The University of Queensland.
Brisbane, 4072
Australia

ABSTRACT

We describe the *Motivator*, a newly developed Computer Assisted Composition (CAC) tool for generating variations of melodic motives. The motivator helps composers to make Gestalt switches in interpretation of multistable motives, generates variations that preserve structural tones in a given interpretation, and suggests variations that enhance the multistability of the motive. The tool has been used in the composition of *Entanglement*, a work for piano, percussion and live electronics.

1. INTRODUCTION

In Western tonal music, notes are not heard in isolation but in the context of the piece so far (and more broadly in the cultural context of the style). The function or meaning of a note depends on the context in which it appears [1, 2]. For example, the pitch C functions as tonic in C major, but as leading note in C# major. The different functions possess different qualia, and generate disparate expectations [3]. The leading tone suggests ongoing motion, perhaps tension, and creates expectation of resolution to the tonic. The tonic, on the other hand, suggests repose and resolution, and is equivocal on possible continuations.

Expectations created at a given point in a melody will thus depend on the perceived context at that point. Music theorists have long discussed metric and tonal contexts, and music perception studies, e.g. [4], have demonstrated that interpretations and expectations generated by notes, are conditioned by such contexts. The musical context of a note is multidimensional, comprising a number of distinct yet inter-related parameters. Here we focus on metre, key and harmony.

These contexts are perceptual phenomena, not present explicitly in the musical surface, but inferred from it. Patterns of musical emphasis provide evidence for certain contexts—for example (in many styles) regular recurrence of tonally stable notes hints at the downbeat, whilst a prevalence of triadic notes on strong beats suggests a particular harmony. The different musical parameters are thus intertwined.

A given passage may suggest multiple contexts for each parameter, with various configurations being mutually supportive or contradictory. Where multiple disparate configurations are mutually supportive, *perceptual multistability* may result. The notion of perceptual multistability comes from Gestalt psychology. For example, Figure 1 shows an example of a perceptually multistable image; it can be seen either as a black vase, or as two white faces. Often, only one interpretation is visible, until the alternate interpretation is explicitly pointed out. Then both interpretations are readily perceptible, though not simultaneously. Rather, one experiences a 'Gestalt switch' from one stable configuration to the other. Multistable phenomena, and corresponding Gestalt switches, are also well documented in auditory streaming [5].

Figure 1. A perceptually multistable image

Multi-stability of metric and tonal contexts is frequently evident in Western tonal music [6]. Various theorists have discussed the importance of ambiguity in music perception [7, 8], and later authors have clarified that ambiguity here should be thought of as multistability—the simultaneous strong suggestion of multiple disparate contexts, rather than simply vagueness [9, 2].

Whilst multi-stable percepts admit only one conscious interpretation at a time, several theories of music cognition suggest that multiple plausible interpretations are maintained subconsciously [10, 3] and may all simultaneously contribute to musical affect. The role of creating suitably ambiguous material in composition is attested to by many theorists [11].

2. MUSICAL AMBIGUITY

The multi-stability of music perception leads to what is more commonly called ambiguity of musical interpretation [6]. That is, there are multiple ways of interpreting a musical passage and this leads to some ambiguity about how it is heard. We are guided in our listening by musical cues as to the structure of the work.

In particular the metric and harmonic stability of notes interacts with our perceptions of metre and key.

Figure 2a. The passage in 4/4 time starting on the downbeat

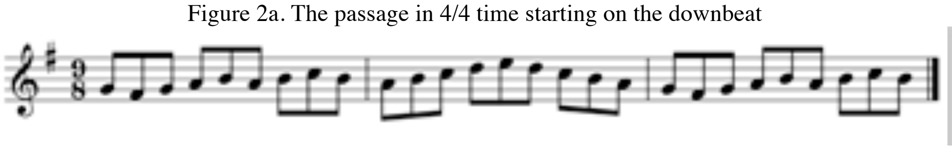

Figure 2b. The passage in 9/8 time starting on the downbeat.

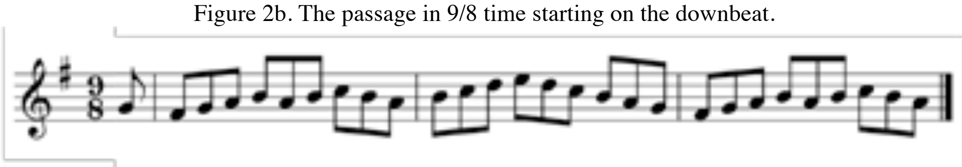

Figure 3. The passage in 9/8 time shifted back one eighth note.

Figure 4a. The passage in 4/4 with implied harmony.

Figure 4b. The passage in 9/8 with implied harmony.

Figure 4c. The passage in 9/8, metrically offset, with implied harmony.

The metric 'dissonance' of particular rhythmic interpretations is discussed by London [2:80] and we will extend an example of his here to demonstrate our approach to algorithmic interpretation.

The passage notated in Figure 2 can be interpreted as being metrically organised in many ways. Figure 2a shows the passage grouped in 4/4, while Figure 2b shows it grouped in 9/8. In addition, there are possibilities that the passage could be heard time shifted to varying degrees. The regularity of the rhythm makes this especially possible and a performer could achieve this effect by accenting appropriate notes. In particular the 9/8 interpretation could be assumed to start with an anacrusis and then the passages would be grouped with an even more frequent occurrence of ascending or descending three-note groupings, as shown in figure 3.

In addition to the rhythmic grouping differences, our closure interpretation also takes account of implied harmonic movement which, in turn, depends on key. The likely key and then harmonic progressions of each likely metric interpretation are computed. Examples of such harmonic analysis are shown as chord symbols in Figures 4a, 4b and 4c.

These examples show that different metric groupings and time shifts impact on the harmonic interpretation. Of these examples figure 4b seems the most convincing. It's implied harmonies seem most conventional, with tonic and dominant chords on down-beats and following a tonic-dominant-tonic pattern. It incorporates a dominant seventh and avoids the 6th coloration found in figure 4c; reinforcing its conventionality.

Figure 4a seems to be harmonically most uninteresting, and 4c is quite acceptable if slightly less conventional. We show below how these assessments can be measured algorithmically and will next discuss how and why structural tones are identified as step toward generative variations of selected interpretations.

3. STRUCTURE

Form is an important aspect of music theory. Music is structured through time, and music theory has traditionally been concerned with analysing this structure. Schenker [12] described musical structure as a top-down hierarchy rooted in the overall form, with lower levels understood as a nested series of elaborations. Each level of this hierarchy consists of an increasingly detailed series of *structural tones*.

In practice, Schenkerian analysis infers this hierarchical structure in a bottom-up fashion, starting from the actual musical surface, and recursively classifying notes as either structural or ornamentary, with only the structural tones 'transformed' to the next higher level.

3.1. Closure

Closure, or stability, is a fundamental notion in music perception, playing a complementary role to *tendency,* or process.

Figure 5. The closure scores for each note in the passage (lower values = greater closure).

Compositionally, closure relates to the pattern of tension and resolution, or “the general configuration of relaxation and quiescence. Melodically speaking, relaxation is associated with the decline in tension which is effected … when a progression descends at its close” [7:139].

Notions of melodic closure have long been discussed in tonal music theory, in relation to tonal stability, rhythmic repose and (implied) harmonic cadence [13]. Meyer [7], adopting a psychological perspective, married these with the Gestalt conception of closure as perceptual completion, and argued that as repeated (and nested) passage of musical structures move from incompletion to completion they create aesthetic effect.

In order to utilise closure in the Motivator, we created a real-time measure of the ‘level of closure’. Numerous factors contribute to the overall sense of closure in Meyer’s theory. Completion of pattern (melodic, harmonic and rhythmic) is a key component. Additionally the local dynamics of various musical parameters, without reference to prior patterning, is attributed with closural power:

> “Closure, the arrival at relative stability—is the result of the action and interaction among the several parameters of music. Because melody, rhythm, harmony, texture, timbre, and dynamics are relatively independent variables, some may act to create closure at a particular point in a work, while others are mobile and on-going” [7:81].

Whilst, as Caplin [13] notes, the precise mechanisms of such parametric closure are not clearly described, Myer’s student Eugene Narmour articulated a more explicit theory of parametric closure. Narmour’s *conditions of closure* included a number of simple properties of note-to-note transitions: movement from a short to long duration, movement from a point of weak to strong metric emphasis, movement from dissonance to consonance, a change in registral direction, and movement from a large interval to a small interval.

3.2. Closure Evaluation of Musical Passages

To assess the level of closure at each point in the musical passage we use a weighted sum of Narmour’s conditions of closure. Given the step-wise motion and rhythmic consistency of this music the main influences on closure, or stability, are the metric emphasis and the tonal stability (measured with reference to the implied harmony). Figure 5 shows the example passage with the closure scores below each note. Because of the way we choose to calculate these (for implementation) lower scores are more closed.

This scoring process allows the identification of structural tones; those notes with particularly low scores. Varying the threshold value will change the number of structural tones. For example, a threshold of 0 will indicate 3 structural tones, while a threshold of 1 will nominate 5 tones, and a threshold of 2 allows 8 structural tones to be identified. Our generative variation processes, described in more detail later, are designed to use the specified structural tones as a skeleton around which variations are created.

Any number of the interpretations of the analysed motif can be used as the basis for closure evaluation and subsequent variation generation. Each interpretation can be the basis for multiple variations.

We suggest that these variations can present the composer with constructive creative possibilities that s/he may not have otherwise considered because of the psychological tendency to resist a Gestalt switch.

To facilitate the use of these processes by composers, we have implemented these analytical and generative processes in a system called The Motivator.

4. THE MOTIVATOR

The Motivator is a Computer Assisted Composition tool. It performs both generative and analytic functions aimed at assisting the composer to make Gestalt switches in their interpretation of a motive, and to facilitate the creation of tonal and metric ambiguity in their composition.

The benefit of this tool lies in the difficulty of simultaneously perceiving two (or more) contradictory contexts. As described above, human cognition tends to structure sensory stimulus into one coherent configuration, even whilst subconsciously tracking other configurations. Thus, where the composer may overlook opportunities for various plausible contexts, the computer is less blinkered by a dominant interpretation.

4.1. Functionality

The motivator has several analytic and generative functions:

1. Analyse a motive by estimating metre, key and harmony to provide coherent configurations of these contexts.
2. Identify structural notes of the motive, assuming a given configuration.
3. Create variations of a motive that maintain its structure in a given context.

The composer supplies a motive, which the Motivator analyses without regard for the notated key, metre or harmony. Instead, it searches over possible context configurations for plausible and coherent interpretations. The most plausible are presented back to the composer, notated in the key, metre and harmony of the configuration. The system is also able to generate variations that respect the selected interpretation.

4.2. Analysis: Estimation of coherent configurations

For each of the musical parameters under consideration (metre, key and harmony), the system has an estimation algorithm that finds plausible values for this parameter, given a particular configuration of values for the remaining parameters. Then, to find the most coherent overall configurations, a search over this multi-dimensional space is performed.

The metre estimation technique draws on our previous work in metre induction [14]. The key estimation technique is a variant of Bellman's [15] approach. The harmony estimation technique draws on Jansen & Povel's [16] work. All three techniques are similar in that they accumulate evidence through emphasis placed on strong pitches or beats, where the emphasis is determined by the assumed values of the remaining parameters.

4.3. Structure: Identification of stable notes

Having estimated the most plausible and coherent configurations of context, the system is also able to identify stable tones. These tones are taken to outline the structure of the motive, and act as a skeletal representation. Different configurations and closure thresholds will lead to different skeletons, highlighting interesting possible re-interpretations to the composer.

4.4. Variation: Generation of motive variations

The variation algorithm operates by retaining the stable notes of the motive, and regenerating ornamentary notes via the generative technique described below. Note that stable notes vary between interpretations. So, the composer can both generate variations that retain the original structure of the motive in that context, and also generate variations that hint at other plausible structures.

4.5. Generative Technique

Having discarded ornamentary notes, the variation technique needs a way to 'connect the dots' again, i.e., to regenerate notes between structural tones. The generative technique we use builds on our work developing generative music techniques inspired by studies in music perception. Many of these process are outlined elsewhere [17]. We provide summaries of the techniques here for convenience.

- Proximity using Gaussian distribution
- Range constraint and 'elastic' intervals
- Goal seeking and directed random walk
- Continuation, repetition and saturation
- Hierarchical grouping and entrainment
- Metric contextuality and constraints

The structural tones are used as both seeds for goal seeking and random walk processes that gap-fill between these tones.

5. CONCLUSION

In this paper we have described how music perception is inclined to make Gestalt switches in interpretation of musical passages that are, in turn, conditioned by musical contexts. To assist composers to achieve these switches of perspective and to take advantage of additional implicative contexts, we have developed the *Motivator*, a newly developed Computer Assisted Composition (CAC) tool for generating variations of melodic motives. This system analyzes the multistable characteristics of motives according to possible contexts and selects likely interpretations, generates variations that preserve structure within a given interpretation, and suggests variations that enhance the multistability of the musical passage. We have used the tool for the composition of *Entanglement*, a work for piano, percussion and live electronics that has helped to demonstrate the veracity of these techniques and the usability of the system in a compositional context.

6. REFERENCES

[1] Cadwallader, A."Foreground motivic ambiguity: Its clarification at middleground levels in selected late piano pieces of Johannes Brahms," *Music Analysis*, vol. 7, no. 1, pp. 59–91, 1988.

[2] London, J. *Hearing in Time*. Oxford: Oxford University Press, 2004.

[3] Huron, D. *Sweet Anticipation: Music and the psychology of expectation*. Cambridge, MA: The MIT Press, 2006.

[4] Deutsch, D. *The Psychology of Music*. San Diego: Academic Press, 1999.

[5] Sterzer, P., A. Kleinschmidt, and G. Rees, "The neural bases of multistable perception," *Trends in Cog. Science*, vol. 13, no. 7, pp. 310–318, 2009.

[6] Karpinski, G. S. "Ambiguity: Another listen," *Music Theory Online*, vol. 13, no. 8, 2012.

[7] Meyer, L. B. *Emotion and meaning in music*. Chicago: The University of Chicago Press, 1956.

[8] Lerdahl, F. and R. Jackendoff, *A Generative Theory of Tonal Music*. Cambridge: The MIT Press, 1983.

[9] Agawu, K. "Ambiguity in Tonal Music: A Preliminary Study," in *heory, Analysis, and Meaning in Music*, A. Pople, Ed. Cambridge: Cambridge University Press, 1994, pp. 86–107.

[10] Jackendoff, R. *Languages of the mind: Essays on mental representation*. Cambridge, Mass. ; London: MIT Press, 1992.

[11] Stein, D. "Introduction to Musical Ambiguity," in *Engaging Music: Essays in Musical Analysis*, D. Stein, Ed. New York: Oxford University Press, 2005, pp. 77–88.

[12] Schenker, H. *Neue musikalische theorien und phantasien: Der Freie Satz*. Vienna: Universal Edition, 1956.

[13] Caplin, W. "The classical cadence: Conceptions and misconceptions," *Journal of the American Musicolog. Soc.*, vol. 57, no. 1, pp. 51–118, 2004.

[14] Gifford, T. "Improvisation in Interactive Music Systems," PhD Thesis, Queensland University of Technology, Brisbane, 2011.

[15] Bellmann, H. "Categorization of Tonal Music Style," PhD, Griffith University, Brisbane, 2012.

[16] Jansen, E. and D.-J. Povel, "The processing of chords in tonal melodic sequences," *Journal of New Music Research*, vol. 33, no. 1, pp. 31–48, 2004.

[17] Brown, A. R., T. Gifford, and R. Davidson, "Psychology-Inspired Techniques for Generative Melodies," *Computer Music Journal*, Submitted.