

Describing Musical Contour with Tonality, Voicing, and Dissonance Levels

MIT Student

May 21, 2012

Abstract

This project provides a quantitative way to describe the contours of musical pieces from the western classical music repertoire. These contours describe what happens in a piece of music over time according to some measurement: either a measurement of dissonance, spacing, or tonal strength. This project normalizes many of these individual contours and combines them to get an average contour over many pieces. By studying these aggregate contour, one can determine if a musical event or feature tends to occur more often at a specific point in a piece, for instance in the very middle. This project finds that there is some trend amongst levels of dissonance in the Bach Chorales, but it is inconclusive about trends in voice spacing and tonality.

1. Introduction

Music theory is largely based on subjective observations and synthesis. Analyses that attempt to locate large-scale patterns and structures are prone to human error and bias. Often theoretical constructs are not even precisely defined. For instance, to describe a piece's contour, one would probably say that the piece follows an arc, but what does that actually mean? Can that arc be described quantitatively? While the qualitative contour has been explored countless times by music theorists, there has been little attempt at a quantitative examination.

This project provides a way to quantitatively describe a piece's contour in three ways: using levels of dissonance, using voice spacing, and using tonal strength. These features were chosen because each is associated with musical tension: dissonant chords tend to resolve to consonant ones, a large leap or wide spac-

ing tends to revert back to a more comfortable range, and the further a piece is from its original key, the "further from home" it sounds. Thus, it is reasonable to expect to see some type of arc in these three contours.

After deriving contours for individual pieces, the next step is to combine contours for similar pieces across genres, composers, time-periods, etc. This project examines these 'aggregate contours' to see if they have any significance. If they do have significance, then the aggregate contour for a genre can be used to define a metric for how well a piece fits into that genre. Thus, given the aggregate contour of the first movement of string quartets and the aggregate contour for chorales, one could compare an unknown piece to both aggregates to determine which type of piece it is more likely to be.

This project is concerned primarily with seeing if aggregate contours are meaningful.

This can be tested by developing a similarity metric for the aggregate contours, and then seeing whether a piece used to create the aggregate is more similar than a random re-ordering of the measures in that piece.

2. Methods

2.1 Corpus

This project uses the corpus of Bach Chorales. This is both reasonable and practical: the chorales are canonical works exhibiting strong tonal tendencies and the chorales happen to be readily available for analysis through the Music21 software. The project further restricts this corpus to the chorales with no additional instruments (just the Soprano, Alto, Tenor, and Bass voices) and to chorales with between 14 and 24 measures.

2.2 Quantitative Measurements

The first step in creating each contour is to determine a way to quantitatively measure levels of dissonance, spacing, and tonal strength.

Measuring Dissonance: For dissonance, this project uses a function which takes a chord, or any group of simultaneously sounding notes, and returns one if they are dissonant or zero if they are not. This function uses the `isConsonant()` method from Music21 which behaves as follows: on a two-note chord, it returns one if the two notes are a major third, minor third, major sixth, minor sixth, or perfect fifth apart; on a three-note chord, it only returns one if the chord is a major or minor chord in either root position or in first inversion.

Measuring Spacing: For spacing, this project uses a simple function that takes in simultaneous sounding notes and returns a weighted sum of the distances between them.

The weighting of the intervals must not be linear, or else the function would return the same value for chords such as [C, E, G], [C, G], or [C, F#, G]. Also, the distance between the lower two notes is weighted less than the distance between the higher notes, since the lower voices are expected to be further apart, especially in the Bach Chorales.

Measuring Tonality: Measuring tonal strength can be done by finding a key-dependent mapping of pitches to weights based on how far away the pitches are from a specified key. This is the same idea that was used by Carol Krumhansl to create a key-finding algorithm [2]. Music21 implements this algorithm with the `analyze('key')` function. The `analyze('key')` function also determines the certainty value associated with each possible key. This project uses a function which looks at a musical fragment, then calculates the certainty value that the fragment is in the piece's original key. This certainty value is subtracted from one and then scaled by a constant and returned. Subtracting the certainty from one makes the value of the tonality measurement proportional to how far away a fragment is from the original key. As with each function discussed, the output is meant to be proportional to musical tension.

2.3 Deriving the Contours

Contours for Individual Pieces To determine the contour, each bar is associated with a quantitative value determined by one of the above measurements. For the dissonance contour, the value of each bar is just the sum of the measured dissonances over each chord in the bar. Each chord's dissonance score is weighted by its duration so that an eighth-note passing tone will not contribute as much as a tone-cluster which lasts the entire bar. The spacing contour is determined in the same way, but of course with spacing

measurements. The tonality measurement for a bar does not scale with the size of the input, so the tonality contour just consists of the tonality measurements for each bar. Each contour can thus be displayed as a scatterplot, where a quadratic (or higher order) regression can be applied to get a smoother shape.

Aggregate Contours An aggregate contour must account for the varying lengths of each piece. If a piece has n measures, then its individual contour can be written as $((1, f(m_1)), (2, f(m_2)), \dots, (n, f(m_n)))$, where m_i is the i^{th} bar, and f is the quantitative value for a bar, as outlined in 2.3. Each piece can be normalized to a time value of 100 by multiplying the first number of each element in the contour by $\frac{100}{n}$. Once each chorale has been normalized, one can just look at a combined scatterplot of every value. By combining the contours this way, measurements from exactly half-way through one chorale will line up in the aggregate with measurements from exactly half-way through each other chorale.

2.4 Testing the Aggregate Contours

This experiment examines how the aggregate contours relate back to the individual contours. This is done by first developing a similarity metric that compares a piece to the aggregate contour, then seeing if each chorale is closer to the aggregate than a “random chorale.” A similarity metric can be computed similarly to the χ^2 value: normalize the contour for the individual chorale, then sum the absolute values of the differences between the chorale’s observed contour values and the expected contour values at those points as predicted by the polynomial regression of the aggregate contour. The result is divided by the number of points in the contour, so as not to favor longer chorales. As outlined, this is technically a dissimilarity metric, so lower scores

mean more similarity.

To test if an individual chorale is significantly close to the contour, first calculate the similarity between the chorale’s contour and the aggregate contour. Then, shuffle the chorale’s contour, and see if it is more or less similar to the aggregate than the original contour. Repeat this process 100 times to see how often the original chorale is closer to the aggregate than the randomized chorale. If the original is closer more than 50% of the time, this experiment considers the chorale significantly related to the aggregate. Similarly, if 67% or more of the chorales are significantly related to the aggregate, this experiment considers the aggregate to be a meaningful description of the chorales.

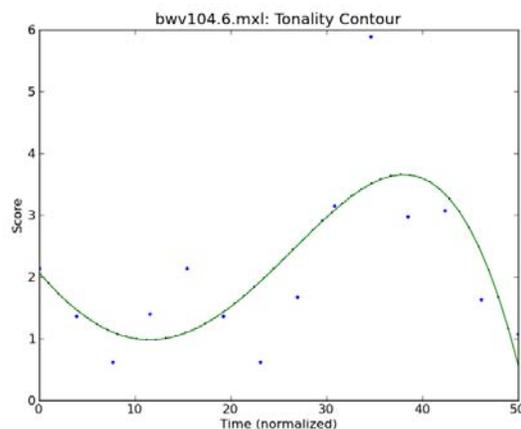


Figure 1: Tonality contour for a Bach Chorale

3. Data and Results

Figure 1 shows an example of a contour for an individual piece, Bach’s Bwv 104 no 6. Figure 2 shows the aggregate dissonance and tonality contours for the chorales. Though the scatterplots look noisy, the polynomial regressions reveal an underlying pattern.

Table 1 shows the results of the experiment: 72% of the chorales were closer to the aggregate dissonance contour than their random permutation more than half of the time. Thus, according to this experiment, the

Aggregate Contour Type	Fraction of Chorales Significantly Close to the Aggregate Contour (out of 213 considered)
Dissonance	72%
Spacing	18%
Tonality	24%

Table 1: How well the aggregate describes the individual Chorales

aggregate dissonance contour is meaningful. On the other hand, the aggregate tonality and spacing contours were only significant to

fewer than a quarter of the chorales, and thus are not meaningful across all the chorales.

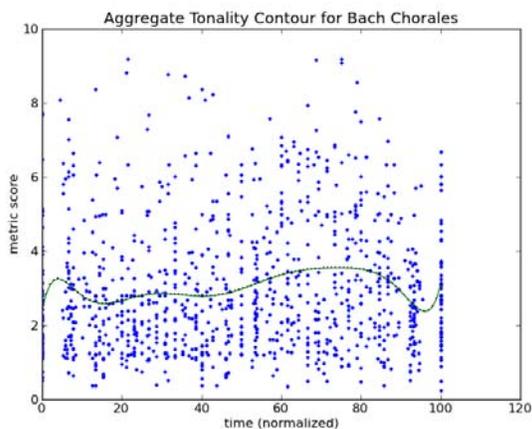
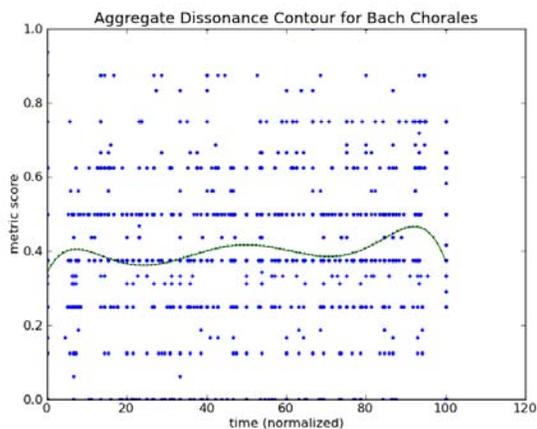


Figure 2: Aggregate Dissonance and Tonality Contours

4. Further Research

Even though tonality and spacing contour trends did not seem to extend over all chorales, some trends seemed to exist amongst large groups of them. Thus, future research may try to group chorales together based on their contours.

If the contours for individual piece's are sufficiently meaningful, then they could be used to add to the feature extraction repertoire of Music21 [1]. To get just a few data points out of the larger contour, one could classify a piece based on the number of peaks, or the temporal location of those peaks. A good motivation for contour as a musical feature is found in figure 3, the tonality contour for the second movement of Haydn's string quartet Op 17 no 2. From the contour, you can easily distinguish the minuet from the trio, since the trio is in the dominant key and thus scores higher under the tonality metric. It is easy to see how extracting features from this contour may give a way to quantitatively determine form.

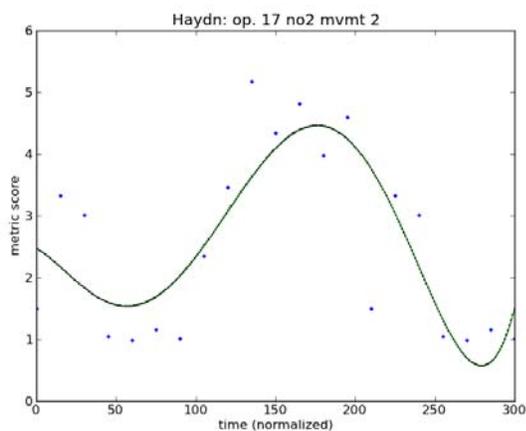


Figure 3: The Tonality Contour for the Minuet and Trio of Haydn’s String Quartet Op. 17 no. 2

References

- [1] C. Ariza, M. Cuthbert, and L. Friedland: “Feature extraction and Machine Learning on Symbolic Music using the `music21` Toolkit,” *Proceedings of the International Society for Music Information Retrieval Conference (ISMIR 2011)*
- [2] C. Krumhansl: *Cognitive Foundations of Musical Pitch*. Oxford University Press, Oxford, 1990.

MIT OpenCourseWare
<http://ocw.mit.edu>

21M.269 Studies in Western Music History: Quantitative
and Computational Approaches to Music History
Spring 2012

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.