An Integrated Music Chromaticism Model

DIONYSIOS POLITIS and DIMITRIOS MARGOUNAKIS
Dept. of Informatics, School of Sciences
Aristotle University of Thessaloniki
University Campus, Thessaloniki, GR-541 24
GREECE
{dpolitis,dmargoun}@csd.auth.gr

Abstract: - The evolutional course of music through centuries has shown an incremental use of chromatic variations by composers and performers for melodies’ and music sounds’ enrichment. This paper presents an integrated model, which contributes to the calculation of musical chromaticism. The model takes into account both horizontal (melody) and vertical chromaticism (harmony). The proposed perceptually based measures deal with music attributes that relate to the audience’s chromatic perception. They namely are: the musical scale, the melodic progress, the chromatic intervals, the rapidity of melody, the direction of melody, music loudness, and harmonic relations. This theoretical framework can lead to semantic music visualizations that reveal music parts of emotional tension.

Key-Words: - chromaticism, harmonic relations, emotional tension, perception of music chroma, chromatic index, chromatic intervals, music visualization

1 Introduction

The concept of chromaticism, which first emerged in ancient Greek music, has undergone numerous changes until today. However, although the concept is firmly established in musical consciousness, its definition has not yet absolutely ‘crystallized’ [1].

Although Bach in the 18th century used chromatic harmony, it was the romantic composers of the 19th century who used it more and more. Wagner wrote music which was very chromatic: there were lots of sharps and flats and it kept modulating to different key areas. He is also famous for his very chromatic Tristan chord. Chromatic music is full of tension because it leaves the audience wondering which key the music is in and also adds color, drama and excitement to the music.

The study of several aspects of chromaticism in music resulted in the modeling of a theoretical framework that calculates the factors of music chromaticism by the writers. The model, which is shown in Fig. 1, covers most of the attributes that affect the emotional background of a musical piece (melodic / harmonic structure, rhythm, and expressivity). According to Seashore, the means for conveying emotions in music relate to timing, dynamics, timbre and pitch [2]. The proposed model does not take into account the music dimension of timbre. From the era of Pythagoras [1] till nowadays several systems regarding computational music analysis have been presented by researchers [2]. All of them use specific properties of sound to model their analysis. There are have been also recorded efforts on emotional modeling of music context [3] [4].

![Fig. 1. The factors that affect music chromaticism in a framework.](image-url)

As Fig. 1 shows, the scale, in which a musical piece is written to, comprises the first benchmark in analyzing the chromatic nature of musical pitch. Moreover, the calculation of horizontal and vertical chromatic relations prerequisites the knowledge of the music piece’s scale. Each scale (or mode) bears a scale index (SI), which determines the inherent chromaticism of the scale according to its intervallic structure. For example, a music piece in Hijaz / Rast (SI = 2.096) is naturally more chromatic than one written in C-Major (SI = 1.286). More about the chromaticism of musical scales and the calculation of SI can be found in [3]. Aspects of horizontal and vertical chromaticism will be discussed throughout this paper, since calculations...
can be directly applied to music notation. Chromatic aspects that occur during live performances (timing and dynamics) are not presented here.

2 Horizontal Chromaticism
Horizontal chromaticism deals with the chromatic phenomena that are produced through the progress of the melodic line. This kind of chromaticism has been thoroughly explored and presented in the past [4],[5]. Horizontal chromaticism is defined by (1) the intervallic relations between the notes in the melody, and (2) the direction of those intervals.

2.1.1 Intervallic Chromaticism
An extended study on chromaticism of intervallic nature has been presented in the past. The interested reader is prompted to refer to [3],[4] and [5] for a comprehensive description. Intervallic chromaticism is expressed by a running variable $\chi$. In general, the value of $\chi$ is greater at times when music produces greater chromatic phenomena of intervallic nature. Fig. 2 demonstrates an example graph of $\chi$ over time.

Fig. 2. An exemplar graph of $\chi$ over time for an analyzed musical file.

2.2 Directional Chromaticism
Directional chromaticism refers to the arrangement of notes in a musical phrase, not to their very pitch. Directional chromaticism is expressed by a running variable $\chi_d$. A short mention of the special segmentation algorithm concerning this kind of chromaticism has been made in [3]. In this paper we will add notes for the elucidation of the metrics for directional chromaticism. This chromatic dimension is included in the model because of the following proposition.

Proposition 1. The notes of a musical phrase create a different chromatic tension when they do not follow the purely ascending (or purely descending) pattern of the scale.

This means that two melodic sequences that contain exactly the same notes in a different order do not bear the same chromaticism of directional nature. Directional chromaticism is open to criticism, since it does not fully comply to the main definition of chromaticism as “the use of pitches not present in the diatonic scale” [6]. It does, however, comprise a deviation from the basic diatonic organization of the scale [7]. Moreover, this deviation also affects the emotional intensity of a music part. For these reasons, the authors claim that directional chromaticism should be considered together with intervallic chromaticism in the model. Concerning the metrics, directional chromaticism bears, of course, lower weight than its intervallic counterpart. Next, we demonstrate the calculation of horizontal chromaticism with a short example.

Fig. 3 shows an example for a musical phrase. This particular segment (from Tchaikovsky’s “The Nutcracker”) encompasses both intervallic and directional chromaticism. The piece is written in D Major scale ($SI = 1.286$). The melodic line under examination is shown in the upper stave of the figure.

According to the rules of chromatic analysis [4], the intervallic chromaticism in this example is the result of the fourth sharpened note (G#), which creates two chromatic intervals (a semitone and a 1 ½ tone) with the adjacent notes. The rest of the melodic intervals belong to the scale and, therefore, retain (or restore) the $SI$ of the melody.

Fig. 3. Upper stave: (m. 119-121) from Tchaikovsky’s “The Waltz of the Flowers” (from The Nutcracker). Lower stave: the purely ascending rearrangement of the segment’s notes. The factors that affect music chromaticism in a framework.

However, apart from the intervallic chromaticism, there is also chromaticism of directional level in the segment. This becomes apparent if there is a rearrangement of the notes in a
purely ascending form (lower stave). The comparison between the lower and the upper staff reveals the intervallic deviations from the expected range of the scale. These deviations are marked in Fig. 3. Each notes of the example in Fig. 3 is given a sequential number, e.g. 1:E\textsuperscript{5}, 2:F\textsuperscript{#5}, 3:G\textsuperscript{5}, 4:G\textsuperscript{#5}, 5:B\textsuperscript{5}, 6:A\textsuperscript{5}, 7:G\textsuperscript{5}, 8:A\textsuperscript{5}, 9:B\textsuperscript{5}, 10:C\textsuperscript{#6}, 11:D\textsuperscript{6}. The perceptual differences are counted in semitones. In order to calculate the average indexes of intervallic and directional chromaticism, partial indexes for each note should be assigned. The indexes for the 11 notes of the music sequence and their averages are shown in Table 1. The first note of the segment is the calculation base and its indexes value would de facto be \( \chi_i = SI \) and \( \chi_d = 0 \). Thus, it is not taken into account for the segment’s averages’ calculation.

Table 1. Calculated indexes of horizontal chromaticism for the melodic segment of Fig. 3.

<table>
<thead>
<tr>
<th>( \text{n} )</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>( \chi_i )</th>
</tr>
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<tbody>
<tr>
<td>( \text{E} )</td>
<td>1.286</td>
<td>1.286</td>
<td>1.286</td>
<td>1.338</td>
<td>1.334</td>
<td>1.311</td>
<td>1.311</td>
<td>1.311</td>
<td>1.311</td>
<td>1.286</td>
<td>1.286</td>
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<tr>
<td>( \text{D} )</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
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<td>0</td>
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</table>

3 Vertical Chromaticism

Most of the time, chromatic pitches change the harmony of a given musical passage. Chromatic harmony means harmony (chords), which uses notes that do not belong to the key the music is in (they are not in the key signature). One of the following categories:
- Secondary Dominants
- Borrowed Chords (Mode Mixture)
- The Neapolitan Sixth Chord
- Augmented Sixth Chords
- Altered Dominants
- Linear Harmony

Concerning chromatic harmony, things are more complicated since chromaticism depends on inflected chords (regarding the music scale). A value of chromaticism for each chord should be separately calculated in order to achieve chromatic evaluation. A rather simple way to calculate \( \chi_h \) (harmonic chroma) would be the ratio of the altered notes in the chords of a segment to the total amount of the segment’s notes (eq. 1). Another, still simple but more accurate, way would be the ratio of the altered chords in a segment to the total amount of the segment’s chords (eq. 2). In both cases, notes that belong to the melodic line are not taken into account. These simple approaches can reveal some preliminary clues about the chromatic harmony of a musical piece.

\[
\chi_{hl} = \frac{\#_{\text{alt}}}{\#_{\text{tot}}} \quad (1)
\]

\[
\chi_{ch} = \frac{\#_{\text{alt}}}{\#_{\text{tot}}} \quad (2)
\]

In Fig. 5 we can see the meters 5-7 from Tchaikovsky’s “The Waltz of the Flowers”, part of the *Nutcracker*. This segment contains no melodic intervallic chromaticism as it is obvious from the melodic line. However, the flattened B in meter 6 creates chromaticism in the chordal level. Equations 1 and 2 for this segment result in 0.1 and 0.22 respectively. By listening to the segment, one could possibly feel that the emotional tension of the chromatic phenomenon affects more than 10% of the segment implied in the first equation. Thus, the chord approach is considered to be more accurate.

Fig. 5. Meters 5-7 from Tchaikovsky’s “The Waltz of the Flowers” (from *The Nutcracker*).

However, if we try to read into the actual chromaticism that a single altered note of a chord creates, then we realize that four coexistent auditory relations should be examined. Three of them are actually written in the music notation, while the
fourth one is subconscious and is perceived by the listener’s music cognition.

The arrows in Fig. 6 denote the four aforementioned relations, which will be then discussed using the terms of the model in Fig.1. In this example, only monophonic melodic progression and harmonic triads are used in order for the discussion to be more comprehensible. The music phrase of Fig. 6 is considered to belong in a music piece written in C major.

**Fig. 6.** Vertical chromatic relations.

**Positional Chromaticism.** As it can be seen in Fig.6, the first two relations under consideration concern the intervals that are created by the altered note of the chord and the corresponding notes of its adjacent chords. Relations 1 and 2 are horizontal. Consequently, the same chromatic index $\chi$, which is used for calculating the chromaticism of the melodic line, can be used as a metric of positional chromaticism.

**Chordal Chromaticism.** The third relation pertains to the association between the melodic note and the accompanying chord. Two cases can be distinguished here: (a) both the chord and the melodic note belong to the scale of the musical piece and, therefore, comprise a non-chromatic tetrad, and (b) the melodic note is chromatic in regard of the accompanying triad. In case (a) no more harmonic chroma is added, and the value of chromaticism is zero. In case (b), where the accompanying triad is non-chromatic, chromaticism is caused only because of the melodic note. This note, however, affects already the index of intervallic chromaticism (see section 2.1) at the horizontal level of the melody. Therefore, the greatest chromatic weight in this case is accredited in melodic indices. At the chordal level, an extra chromatic value is added, which is equal to the difference of semitones between the chromatic note and the corresponding nonchromatic note of the accompanying chord (considered to be in the same octave). There are two more cases of chromaticism in a chord: (c) some note of the accompanying chord is chromatic in regard of the triad that is created by the melodic note and the other two notes of the accompanying triad, and (d) two or more notes out of the complete tetrad are chromatic. Both of these cases fall into the category of perceptual chromaticism, which is explained below.

**Perceptual Chromaticism.** Finally, the fourth relation is associated with musical expectancy and is very important since it affects emotional responses. The benchmark for the comparison in this case is not written in the music score. It is rather “stored” in the mind of the listener. Perceptual chromaticism is measured in semitones of difference between the chromatic chord and the chord that the listener would rather expect (a non-chromatic chord comprised with notes of the scale). In the example of Fig. 6, the expected chord (IV) is shown under the bass stave. Its perceptual chromaticism is $\chi^p = 1$. It should be noted here that the closest non-chromatic chord containing the rest of the chord notes (except for the altered one) is considered as the expected one. In our example, where both II and IV are suitable, the choice of the IV chord is stronger since it belongs to the basic harmonic pattern (I-IV-V).

If two or more notes of the chord are chromatic, then the calculated perceptual chromaticism should be greater. Therefore, the equation for measuring perceptual chromaticism ($\chi^p$) of a chord is:

$$\chi_p = \frac{\text{#ch_notes} \times \sum_{i=1}^{\text{#ch_notes}} \text{Dif}_i}{\text{Dif}_i}$$

where:
- $\text{#ch_notes}$: the total amount of chromatic notes in the chord
- $\text{Dif}_i$: the semitones’ difference between the chromatic note and its counterpart in the expected non-chromatic chord

Example of chords, which are built on the degrees of the scale and are used in rock and popular music, are the augmented sixth chord and the Neapolitan chord [8]. These chords are
presented in Fig. 7. According to eq. (3), both of them bear a chromatic perceptual index $\chi_p$ equal to 4.

Fig. 7. An Italian sixth is moving to V at the first meter, while a Neapolitan resolves to the V at the second meter.

4 Conclusions
An integrated model has been developed that takes into account all the factors, which create emotional tension because of musical chromaticism, has been presented. The applied metrics on musical pieces can result to useful data for representing musical chromaticism in semantic visualizations.Calculating musical chromaticism can be a tool for in-depth music analysis.

References