Visualization of Concurrent Tones in Music with Colours

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ABSTRACT

Visualizing music in a meaningful and intuitive way is a challenge. Our aim is to visualize music by interconnecting similar aspects in music and in visual perception. We focus on visualizing harmonic relationships between tones and colours. Related existing visualizations map tones or keys into a discrete set of colours. As concurrent (simultaneous) tones are not perceived as entirely separate, but also as a whole, we present a novel method for visualizing a group of concurrent tones (limited to the pitches of the 12-tone chromatic scale) with one colour for the whole group. The basis for calculation of colour is the assignment of key spanning circle of thirds to the colour wheel. The resulting colour is not limited to discrete set of colours: similar tones, chords and keys have similar colour hue; dissonance and consonance are represented by low and high colour saturation respectively. The proposed method is demonstrated as part of our prototype music visualization system using extended 3-dimensional piano roll notation.

Categories and Subject Descriptors

H.5.5 [**Information Systems Applications**]: Sound and Music Computing—*Methodologies and techniques, Systems*; H.5.1 [**Information Systems Applications**]: Multimedia Information Systems—*Animations, Audio input/output*

General Terms

Experimentation

Keywords

music visualization, colour, concurrent tones, MIDI

1. INTRODUCTION

There are many possible ways to visualize music, but not every visualization is meaningful and of practical use, so our aim is to have a visualization that is not just to pleasing to the eye but can be used in analysis and comprehension of music, is easy to understand and is of aesthetic value. The basic idea behind our proposal is to interconnect similar aspects in music and in visual perception. In our visualization we put emphasis on modelling harmony: affinity of tones and consonance with colours. Our goal is to help understand the harmonic relationships in music, which may be sometimes difficult to comprehend for untrained people, but may be clarified using visual clues. Furthermore, it could be used in the other direction – for assistance in teaching or when creating music: i.e. play-by-colour.

Existing visualizations use colour to visualize different aspects of music, one of possibilities is to represent pitch classes with colours. To show harmonic relationships between pitch classes, they can be organized into the circle of fifths. To get the colour of a particular tone the colour wheel is assigned to the circle of fifths. This also means when we have a group of concurrent (simultaneous) tones, each tone is separately assigned to a colour. However a group of concurrent tones is not perceived by spectral pitches of tones alone, but also as whole [9, 10, 13].

As the basic assignment of colour covers only pitch classes, major and minor chords, we propose in this paper to address this deficiency with a novel method of visualizing also tone combinations (in our implementation concurrent tones). In comparison to previous methods, the proposed method takes into account also the loudness of tones, including dynamic change of the loudness of a tone from start to end (decaying of tones). The proposed method uses key spanning circle of thirds, which was proposed by Gatzsche et al. [3]. The key spanning circle of thirds is assigned to a colour wheel in which tones are represented as vectors of appropriate direction and length. The resultant colour is obtained by vector addition and is thus not limited to discrete set of colours. The demonstration of the method is part of our system for visualization of music based on MIDI input [5]. The visualization itself uses a 3-dimensional piano roll notation and allows interactive real-time observation of the resulting visualization.

The rest of the paper is organized as follows: in Section 2 relevant related previous work is reviewed, the method for assigning initial colours and calculating common colour for concurrent tones is presented in Section 3, Section 4 contains description of implementation of the proposed method as part of our music visualization system, the results are presented and discussed in Section 5 and conclusions are in Section 6.

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2. PREVIOUS WORK

Different attempts have been made at visualizing music. Basic visualizations usually include a time axis and some other value of interest on the other axis (e.g. pitch), some also include colour in their mapping. Smith and Williams [12] discussed visualizing MIDI music in 3-dimensional space and using colour to mark timbre. The comp-i system [8] tries to show the structure of music as a whole by using 3-dimensional piano roll visualization and allow the user to visually explore the underlying MIDI dataset. Music Animation Machine [6], which is also MIDI based, encompasses a number of visualizations including a basic 2-dimensional piano roll notation for visualizing structure. This visualization is additionally expanded with colours based on pitch classes using the circle of fifths. Mapping of pitch classes into hue by aligning related keys or tones into closely related colours was proposed already by Scriabin (for a historical review of mappings of pitch to colour refer to Wells [14]). Mardirossian and Chew [7] use colours based on circle of fifths for visualization in Lerdahl's 2-dimensional tonal pitch space. Bergstrom's isochord [1] visualizes consonant intervals between tones and chords and is based on Tonnetz grid. Some other visualization possibilities are summarized by Isaacson [4]. The existing visualizations using colour do not address the issue of merging of concurrent tones.

3. ASSIGNING COLOURS TO CONCURRENT TONES

3.1 Basic Assignment

The perception of consonance and dissonance is related to ratios of frequencies [2, 11]. In order of rising dissonance the most consonant intervals between two tones are unison (ratio of 1:1), followed by octave (1:2), perfect fifth (2:3), perfect fourth (3:4), major third (4:5), minor third (5:6) etc. Tones with simple ratios are also perceived similar. Perfect fifth can be used to generate 12 tones of the chromatic scale, which can be joined into the circle of fifths where tones which sound consonant when played together are near each other and the most dissonant are on opposing sides (Figure 1). When mapping tones to colour we want to map similar tones to similar colours and in colour wheel the colours that are perceived similar are likewise close together and complementary are on opposing sides, so we can assign the colour wheel to the circle of fifths. The sound of concurrent tones can be anything from consonant to dissonant. Consonant tone combinations are pleasing to the ears and are therefore represented by saturated colours and dissonant are unsaturated or grey. For this purpose we take a colour wheel that has zero saturation in the centre of the wheel and increases to the outside.

3.2 Calculating colours

A tone is represented by a vector from centre in the direction of the tone in the circle of fifths. The length of the vector is proportional to the loudness of the tone. When two or more tones sound concurrently, the tones which belong to the same pitch class, are represented as one vector of length, which corresponds to the loudest tone in the given pitch class. The colour of concurrent tones is calculated by vector addition. The resulting vector length is normalized by diving it with maximum resultant length, which could be

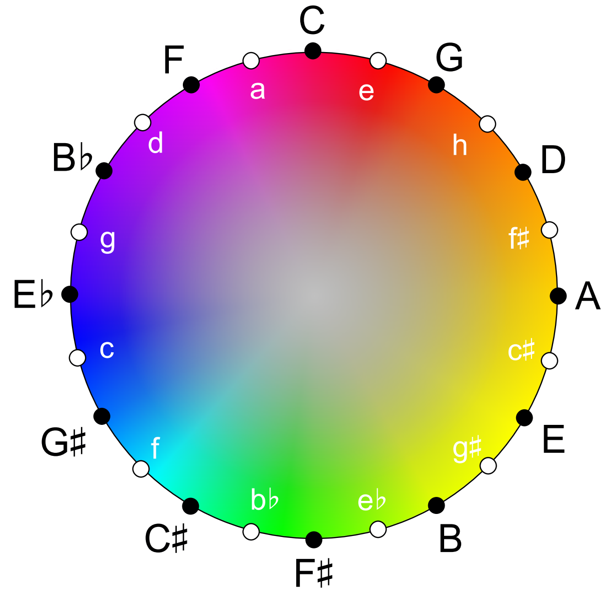


Figure 1: Key spanning circle of thirds assigned to the colour wheel. A particular tone is represented by a radius vector pointing in the direction of circle of fifths denoted by majuscule letters.

obtained by addition of given vectors, that is when all vectors would be collinear. The direction of the resulting vector in the colour wheel determines the hue and the length determines saturation.

3.3 Solution for problematic intervals

The resulting colours are consistent with expectations regarding saturation and hue of pairs of tones that are very consonant or very dissonant, for example: large saturation for interval of unison, octave, perfect fifth and minimal saturation for tritone and minor second. But for combinations of tones which are an interval of major or minor third apart, the resulting saturation is poor although they are not perceived dissonant. The reason for this is that the angle between such tones is from 90 to 120 degrees in the circle of fifths. This is the consequence of circle of fifths showing relationships of 2:3 and 3:4, but not 4:5 and 5:6. To solve this problem the key spanning circle of thirds [3] is used instead of circle of fifths. The key spanning circle of thirds contains two circles of fifths that are slightly rotated in correspondence to each other (pitch classes in original circle of fifths are shown in majuscule letters and that of the contorted circle of fifths in minuscule letters) (Figure 1). Left and right neighbour of a particular tone in this circle are the minor and major third of the tone. Viewing from the viewpoint of keys in the key spanning circle of thirds the parallel major and minor keys are close together (for example C-major and a-minor). The initial setup of colour wheel and key spanning circle of thirds is presented in Figure 1. The setup is not fixed and the circle could be rotated arbitrary or inverted.

Following the introduction of circle of thirds the calculating of resultant colour is modified: if a pair of tones is encountered, where the second tone is a major third apart from first and the first tone is louder or equally loud then the second tone is represented by a vector pointing to the tone

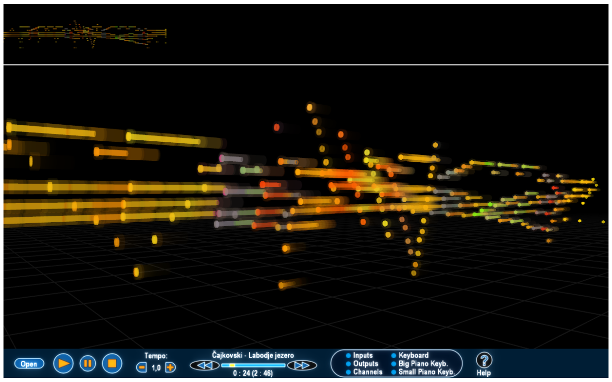


Figure 2: Screenshot of the main window of our system for visualization of music showing coloured 3-dimensional piano roll of Tchaikovsky's Swan Lake demonstrating calculated concurrent colours.

of the same name in the contorted circle of fifths instead of the original circle of fifths. If the second tone is louder, then the angle between two circles is linearly interpolated. In case of more tones, each tone is tested against all others and converted to appropriate vector before the resultant vector is calculated. In this way we attain consistent results such that consonant intervals including major and minor third result in saturated colours and dissonant intervals have low saturation. Related chords have similar hues.

4. SYSTEM DESCRIPTION

The method for calculating colour of concurrent tones is part of a system we developed for visualization of music [5]. The base of the system is a 3-dimensional piano roll notation (the dimensions are time, instruments and tone pitch) expanded with colours for harmonic relations (Figure 2). Loudness of tones is shown as transparency. The piano roll notation enables us to visualize the structure of the music and observe the calculated colours for the whole duration of a composition. The system uses MIDI as input, which is sufficient since the calculation of colours uses only the 12 pitch classes of the chromatic scale. Using MIDI also eliminates the problem of tone extraction from sound recording. The MIDI data itself can contain tones that have frequencies in between the standard pitch classes – in that case the colour computation algorithm rounds them to the nearest pitch class, but the actual pitch is drawn in the piano roll notation.

Because the resulting colour of concurrent tones is calculated for a given moment in time and changes in loudness of input tones affect the resulting colour, the music would have to be sliced in small time slices and the colour calculated for each one. Most of the time changing of loudness is continuous; an important exception being the beginning of the tone. Therefore the colours are calculated at boundaries as such sudden change of tone loudness (events like note-off, note-on and explicit change of loudness of a MIDI channel) and interpolated linearly in between.

The visualization is dynamic and runs in real-time, allowing live input. The resulting 3-dimensional object can be interactively observed and studied.

5. RESULTS

No formal studies have been conducted with our visualization system yet, but the feedback from users has been positive.

The main purpose of our visualization is to visualize harmonic relationship in music with colour but structure can be seen as well and together they can give us greater insight into nature of a musical piece. Consonant dyads (e.g. C and G) have saturated colours and dissonant (e.g. C and C♯, C and F♯) have low saturation. Major triads have hues corresponding to hue between the root tone of the chord and its fifth, minor triads have hues that correspond to hue of minor third of the root (e.g. Am chord corresponds to hue of C), but an augmented triad is dissonant and has therefore zero saturation (grey), to name a few examples.

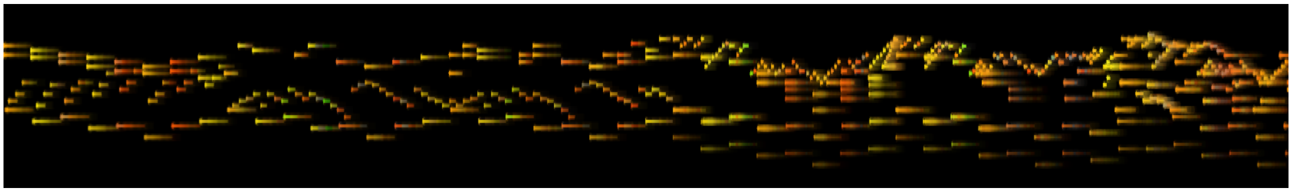
Examples from visualizations of excerpts of classical pieces are presented in Figure 3. The visualizations are viewed from side with time flowing from left to right and vertical axis representing pitch (depth represents instruments, but is omitted for clarity in the examples). An example of chord progression can be seen in the initial part of visualization of Pachelbel's Canon in D major (D, A, Bm, F♯m, G, D, G, A) depicted in Figure 3(a). Resulting colour hues are centred around colour hue of D (orange in current assignment), which is a consequence of tonality of the piece being D major. An example of modulation can be seen in the excerpt in Figure 3(a) where we can observe transition from A major to D major to B♭ major then back to D major and then to G major. An example of dissonant intervals can be seen as grey areas in Tchaikovsky's Swan lake (Figure 2), where dissonance is caused by tritone interval. Dissonant intervals are unstable and cause tension, so they are resolved, which can be seen as saturation of colour increases in tone combinations afterwards.

Currently broken chords may pose a problem to the visualization because the calculation of colour is limited to concurrent tones. The problem could be solved by extending the analysis to broader group of tone concerning time dimension.

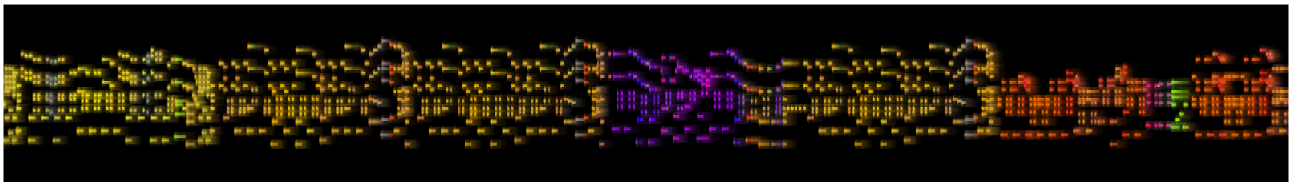
Although presented examples are classical compositions, the visualization also works for other genres such as folk music, popular music, jazz etc. (additional examples are presented in the accompanying video). In music, which uses a lot of dissonant intervals, we can see colours of low saturation, but problems outlined in connection with broken chords make the results sometimes to colourful.

6. CONCLUSIONS

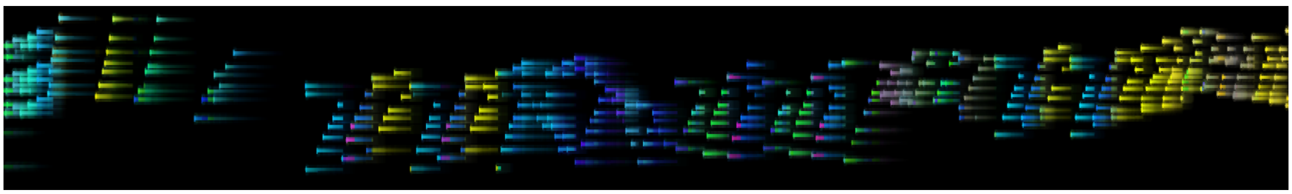
Visualizing music in a meaningful and intuitive way is a challenge. In this paper we focused on visualizing harmonic relationships between tones and colours. Related existing visualizations map tones or keys into a discrete set of colours. As concurrent (simultaneous) tones are not perceived as entirely separate, but also as a whole, we presented a novel method for visualizing a group of concurrent tones with one colour for the whole group. The method takes a group of tones of the 12-tone chromatic scale as input and the resulting colour is not limited to a discrete set of colours. The basis for calculation of colour is the assignment of key spanning circle of thirds to the colour wheel. In this way we map similar tones and keys with similar colour hue. Dissonance is represented with low saturation and consonant tone com-



(a) Excerpt from Pachelbel's Canon in D major



(b) Excerpt from Strauss's An der schönen blauen Donau



(c) Excerpt from Debussy's Clair de Lune

Figure 3: Examples of visualization of classical compositions.

binations have high saturation. Because loudness of tones influences the perception of concurrent tones, it is also taken into account in the proposed method.

The method is implemented as part of our prototype music visualization system using MIDI input. We have shown that the method works relatively well and could be used to help visualize harmony in music. However, in some cases there are still problems. Major and related minor chords are differentiated but have very similar colours, failing to represent a psychological difference. Sometimes resulting colours may be too saturated. Another limitation of the method is that it is based on the pitches of the 12-tone chromatic scale. The visualization could be improved by taking into account a broader time range in addition to concurrent tones, as human perception is not limited to a moment in time.

The colour model and our visualization system strive to establish a unity of perception of two distinct senses, creating a form of synaesthesia. In consequence, it enables easier understanding of music and thus colours may be used also to facilitate learning of music.

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