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CS8803: Computational Aesthetics


Project 1: Color

I. Introduction

Our goal in this project is to devise an int-to-color mapping, i.e. an algorithm that takes in integers $n \leq 32$ and $k \leq n$, and outputs a corresponding color such that: 1) the combination of colors, when used for displaying level sets (e.g. terrain elevation data, population statistics, etc.), is "aesthetically pleasing"[1]; 2) colors pertaining to consecutive integers are clearly distinguishable; and 3) the algorithm is relatively easy to learn and remember.

Our approach is inspired by a sound-to-color synaesthesia based on the 12-tone scale[2], along with a modified Circle of Fifths[3] supplemented by major triads[4] to ensure that the transition among pitches (and, we conjecture, their corresponding colors) is consonant, easily distinguishable, and logically / intuitively sensible. This experiment is based on the notion that, if the correlation between color and musical scales proposed by the likes of Newton (1700), Finn (1881) and Maryon (c. 1920)[5] is to be compelling, then the aural aesthetics of the pitches' overall combination should be analogously reflected in the visual aesthetics of the corresponding colors.

II. Implementation and Motivation

Synaesthesia is an idea rich in history, long espoused by philosophers and composers alike (e.g. Aristotle, Schoenberg, et al.)[6]. For our experiment, we adopt the mapping scheme proposed by Maryon circa 1920, in which we modify the color scheme from the traditional RYB color model to the more modern RGB model:

Pitch	C	$C^\#$ / D^b	D	$D^\#$ / E^b	E	F	$F^\#$ / G^b	G	$G^\#$ / A^b	A	$A^\#$ / B^b	B
Color	Red	Orange	Yellow	Y/G	Green	G/C	Cyan	C/B	Blue	Violet	Magenta	M/R

Fig. 1*. Correlation between color and chromatic music scales by Maryon (c. 1920), as modified with the RGB color model.*

From the above, it is clear that all pairs of opposing (i.e. complementary[7]) colors, such as red vs. cyan or yellow vs. blue, correspond to the tritone, historically dubbed "the Devil's Interval"[8] for its harsh, dissonant quality. Our algorithm based on the Circle of Fifths naturally avoids these dissonant pairs by cycling through pitches that have an interval of perfect fifths (a frequency ratio of 3:2 between pitches, a.k.a. Pythagorean Intervals[9]), considered in music theory to be more stable and consonant than any other interval except the unison and the octave. The Circle of Fifths comprises the following cycle, covering all of the 12 tones in the chromatic scale:

$$(C \to G \to D \to A \to E \to B \to F^\#/G^b \to C^\#/D^b \to G^\#/A^b \to D^\#/E^b \to A^\#/B^b \to F)$$

Fig. 2. *The Circle of Fifths.*

We modify the above cycle by converting each adjacent pair of perfect fifths into a major triad. For example, the adjacent pair (G, D) is replaced by the triad (G, B, D). After conversion, the result is as follows:

$$(C \to E \to G \to B \to D \to F^\#/G^b \to A \to C^\#/D^b \to E \to G^\#/A^b \to B \to D^\#/E^b \to F\#/Gb \to$$
$$A^\#/B^b \to C^\#/D^b \to F \to G^\#/A^b \to C \to D^\#/E^b \to G \to A^\#/B^b \to D \to F \to A)$$

Fig. 3. *The Circle of Triads.*

which we informally dub the "Circle of Triads", and where the added pitches, highlighted in red, themselves constitute their own Circle of Fifths. Further, every sequence consisting of three consecutive pitches is either a major or a minor triad (for instance, C → E → G is a major triad, whereas E → G → B is a minor triad). The primary reason for our modification of the Circle of Fifths, aside from the fact that it serves as a baseline for handling a larger range of *n* in the int-to-color mapping, is that the major and minor triad each contains consonant intervals only (a major third, a minor third, and a perfect fifth) and no dissonant intervals (e.g. minor / major / augmented second, diminished / augmented fourth, and so on). In fact, there exists *no other distinct* three-pitch combination in which all the intervals are consonant. Hence we believe the Circle of Triads, played

1 The phrase is left deliberately open-ended, as part of our project's aim is to explore and make conjectures on its meaning.
2 Wells, Alan. "Music and Visual Color: A Proposed Correlation." The MIT Press (1980).
3 Clough and Myerson. "Musical Scales and the Generalized Circle of Fifths." Amer. Math. Monthly (1986).
4 *See, e.g.,* https://en.wikipedia.org/wiki/Triad_(music).
5 Wells. "Music and Visual Color" (1980). (Footnote 2)
6 Poast, Michael. "Color Music: Visual Color Notation for Musical Expression." The MIT Press (2000).
7 *See, e.g.,* https://en.wikipedia.org/wiki/Complementary_colors#Colors_produced_by_light.
8 *See, e.g.,* http://mentalfloss.com/article/77321/brief-history-devils-tritone.
9 *See, e.g., http://www.phys.uconn.edu/~gibson/Notes/Section3_2/Sec3_2.htm*.

sequentially, tends to maintain consonance (some might even consider it reminiscent of Impressionism[10]), and is arguably even more aesthetically pleasing than the Circle of Fifths.[11]

In order to translate these sounds to colors, we begin by referencing the mapping in *Fig. 1* to approximate each of the 12 distinct pitches to a specific hue, h, in the Lch color space so that neighboring colors are equidistant from each other. Specifically, we let the pitch C correspond to $h_0 = 0°$ (red), and each semitone thereafter is assigned $h_i = h_{i-1} + 30°$ (e.g. $C^{\#}/D^{b} = h_1 = 30°$, …, B = $h_{12} = 330°$). Next, we associate an integer k to each successive pitch in *Fig. 3* (e.g. C = 1, E = 2, …, A = 24), and fix increasingly larger values of L along with smaller values of c as k becomes greater. The int-to-color map, then, outputs each of the Lch values as follows:

$L = 100 * k / n$ *//100 = max lightness*
$c = 140 + 20 – (140 * k / n)$ *//140 = max chromaticity, 20 = an offset value*
$h = [((k-1) / 2) * 210] \% 360$ *if k is odd, else* $[120 + [((k-2)/2) * 210]] \% 360$
//210 = hue difference for perfect fifths,120 = major third, 360 = max hue

The above algorithm as it relates to the hue is a mathematical model of the Circle of Triads as translated to color schemes via the mapping in *Fig. 1*. Our reason for adjusting the lightness and chromaticity as per above is to model the way in which musical notes generally sound thinner and airier the higher the frequency gets. Additionally, although *Fig. 3* only contains a total of 24 pitches, the above algorithm can be generalized for any reasonable value of k up to 32 and possibly beyond: for any $k > 24$, the algorithm effectively extends the Circle of Triads by beginning an additional cycle (this will, of course, increase the total number of duplicate pitches, but the adjustment of L and c values as detailed above helps ensure distinctness of colors within a reasonable range, analogous to the way in which octaves are composed of distinct notes despite having the same pitch).

Results and Future Work

Fig. 4. *Color map for n = 12 and 32, respectively.*

Fig. 4 shows the result of our algorithm for two different values of n. The reader is invited to experiment further with the code provided herein. With few exceptions at the darker end of the spectrum, the adjacent colors appear easily distinguishable from one another.[12] As for whether the color palette is aesthetically pleasant, we cannot draw definitive conclusions other than to say that we attempted to faithfully base this model on one specific idea of correlation between music and color, as well as incorporate well-established theories of consonance in a somewhat creative fashion. This model in no way implies that dissonance lacks aesthetic merit[13], and may very well run counter to various other (non-musical) conceptions or intuitions of beauty.[14] We do conjecture that acceptance of the above color palette as visually “consonant” will not be nearly as universal as that of the corresponding Circle of Triads as auditorily consonant, a fact suggesting we have plenty of work ahead of us.

In fact, this experiment has been particularly useful for opening our eyes to areas of future work we previously did not envision. One possible area may be to explore the effect of certain types of dissonance and their resolutions (e.g. dominant seventh tritone “strict resolution”[15]) on the corresponding color schemes, since much of the emotional impact of music hinges not just on consonant harmonies strung together, but rather on the numerous and sometimes unexpected ways in which dissonances are utilized, in cadences and otherwise. Another area might involve research on how best to implement some of the current research findings on color aesthetics, for example one by Schloss and Palmer (see Footnote 14), to help improve the existing model.

10 *See, e.g.,* https://www.britannica.com/art/Impressionism-music.
11 The enclosed audio files, Circle_of_Triads_01 and Circle_of_Triads_02, respectively illustrate the arpeggio and chord progressions.
12 We initially considered “zig-zagging” between fluctuating levels of lightness and/or chromaticity to render adjacent colors even more distinguishable, but decided at length to preserve the original model due to its correspondence with musical notes, esp. with respect to the persistent “darkness” of the pitches’ sounds at the lower frequencies and the their “gradual” ascent towards lighter sounds.
13 Indeed, some of the greatest artistic works of the modern era (e.g. Stravinsky’s “Rite of Spring” or the many paintings of Jackson Pollock) are decidedly “dissonant.”
14 For recent examples of research study on the topic of perceived aesthetics of color combinations, ***see*** Schloss and Palmer. “Aesthetic Response to Color Combinations”. Springerlink (2010); *see also* Madden, Hewitt and Roth. “Managing Images in Different Cultures: A Cross-National Study of Color Meanings and Preferences.” Journal of International Marketing (2000).
15 *See* https://en.wikipedia.org/wiki/Dominant_seventh_chord#Voice_leading.