Towards Understanding Beautiful Things: A Computational Approach for the Study of Color Modulation in Visual Art

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Abstract

This paper is a guided attempt at analyzing the aesthetics of color from the perspective of color theory. Our guides are the works of Johannes Itten, one of the most influential theorists of color aesthetics. We focus on one specific aspect of color usage in visual art, namely color modulation. To this purpose, we introduce the color palette, a novel 3D visualization of the chromatic information of an image in the HSL space. Moreover, we propose a set of simple descriptors for evaluating color modulation. Our approach is demonstrated on two case studies, which show that our measures on modulation are consistent with Itten's color theory. Ongoing work involves a thorough experimental exploration of the proposed color palette and modulation descriptors, in terms of their ability to discriminate between different artists and painting styles.

Categories and Subject Descriptors (according to ACM CCS): I.4.7 [Computer Vision]: Feature Measurement—Feature Representation

1. Introduction

The study of aesthetic quality of images has been recently receiving increased attention from the computer vision community. The computational perspective may reveal hidden aspects of aesthetics, which is a rather elusive principle.

Our study is an attempt at 'understanding beautiful things' from the perspective of color theory. We are guided by the works of Johannes Itten [Itt61] [Itt70], who is considered to be one of the most influential theorists of color aesthetics in modern times. Our focus is on modulation, which is a specific aspect of color usage in visual art, and a defining element of an artist's style. For instance, Itten highlights the extensive use of modulation by Cezanne: 'To him [Cezanne], modulating a color meant varying it between cold and warm, light and dark, or dull and intense. Such modulation throughout the picture area accomplished new, vivid harmonies. ' On the other hand, 'Matisse refrained from modulation, to again express simple, luminous areas in subjective equilibrium.'

This paper proposes a new visualization of the chromatic distribution of a given painting in the HSL space, called the 'color palette'. The 3D visualization isolates the chromatic information from spatial or structural information. In other words, we discard any shape-related information in order to focus only on the color distribution in the color space. We argue that the proposed visualization facilitates the study of color modulation and provides means for quantifying the modulation for every hue sector of the HSL space. Hue-specific modulation is measured via a set of three descriptors using first and second order statistics on the color distribution within the HSL space. Our visualization and measures on modulation are applied to two case studies, namely paintings of Mondrian and Van Gogh discussed by Itten in [Itt61] [Itt70]. These case studies show that our measures on modulation are consistent with Itten's color principles on modulation and contrast.

The remainder of the paper is structured as follows. Section 2 reviews related work while section 3 presents our proposed approach. Two case studies where paintings are analyzed with our approach are presented in section 4. The final section draws conclusions and outlines future work.

2. Related work

Since our approach focuses solely on color, this section reviews only approaches that consider color in their aesthetics analysis. The vast majority of the related work focuses on photographic images and aims at classifying them into

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high quality versus low quality photographs. This is mainly motivated by data availability, as all studies referenced here use public databases generated by on-line communities of photography amateurs such as www.dpchallenge.com or www.photo.net. Such databases provide not only the images, but also their aggregated human-generated aesthetic rankings as data source for machine learning algorithms.

The selection of features for assessing a photo's quality attempts to infer perceptual criteria that people use to judge photos. This is a challenge, because human judgment is highly qualitative. Ke et al [KTJ06] based their feature design upon interviews with professional and amateur photographers and non-photographers, as well as upon research in photography books. Nishiyama et al [NOSS11] use a model-based approach for feature selection; their approach considers the color harmony model by Moon and Spencer [MS44]. They compute the color harmony score of a photograph by aggregating the color harmony scores of small patches. Dhar et al [DOB11] propose a set of high-level attributes, defined as image cues that may be part of human-generated descriptions of high quality images. The color attribute relates to the presence of complementary hues in the image.

There are three notable differences between our approach and related work on aesthetic quality assessment:

1. We perform our analysis of color modulation on digital images of paintings instead of photographs. The aesthetics of photographs does not generalize well to paintings.
2. Our approach is grounded in Itten's color theory, as opposed to aesthetic rankings collected from on-line photography communities. This represents an unexplored data source for deriving computational descriptors for aesthetic analysis.
3. Our approach is designed for the study and visualization of color modulation in paintings as an aesthetic means of expression. The focus thus is different from the binary classification of images into high and low aesthetic quality.

3. Proposed Approach

3.1. Color spaces and Visualization

Color spaces can be defined as geometric frameworks for visualizing and understanding color relationships. The Itten [Itt61] color sphere contains six equally spaced parallel circles parallel to the equatorial plane, which partition the sphere into seven zones. Twelve meridians are orthogonal to these zones. The two zones between the white and equatorial zone are populated with evenly spaced tints (i.e. mixtures of pure hues with white) of each hue. Two evenly spaced shades (i.e. mixtures of pure hues with black) of each hue are found in the zones between the equatorial and black zone. Tones (i.e. mixtures of pure hues with gray) are distributed with radial symmetry inside the sphere.

The Itten sphere is not a valid metric space from a mathematical viewpoint, as it is designed for artistic maneuvers rather than for quantitative measurements. Our approach works with a metric color space that is closest to Itten sphere, namely the HSL (Hue-Saturation-Lightness) cylinder. Our approach works with digital reproductions of paintings that need to be converted from RGB to HSL.

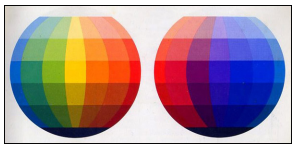

Figure 1: *The Itten Color Sphere; surface views [Itt61]*

For a given painting, our proposed visualization maps all its unique color points in the HSL space, thus obtaining the 3D 'color palette' of the painting. Extrinsic Cartesian coordinates are preferred to intrinsic cylindrical ones for the purpose of manipulating (rotating) the proposed visualization about the z axis. It is worth noting that our color mapping in the HSL space preserves Itten's partition in twelve hue sectors. Examples of 3D color palettes, with detailed views on hue sectors, are shown in Figures 3 and 4.

3.2. Measuring modulation

Itten defines modulation as the subtle, gradual, local chromatic variation of color. The presence or absence of modulation has a direct effect on the perception of contrast, regardless of the type of contrast. Let's consider the warm-cold contrast as an example. A highly modulated warm-cold contrast involves the presence of warm and cold hues, with numerous, subtle intra-hue chromatic variations. These subtle variations will attract and hold the gaze of the viewer, focusing her attention to local details of the painting. According to Turner [Tur98], '[...] the meaning of modulation is that it embodies the transitional aspect of the experience, the feeling of our attention shifting from here to there.' In contrast, a low modulated warm-cold contrast involves a limited number of hues, with bolder chromatic transitions between usually large homogeneous regions. This leads the viewer to perceive the image as a whole, and give less attention to local detail.'

We propose a set of simple quantitative descriptors for modulation that are consistent with Itten's principles, definitions and descriptive comments. To measure the modulation for a given hue sector, we consider the set of unique color points in each hue sector of the HSL space. For each of the 12 hue sectors we perform the following steps:

Step 1: Compute the average Euclidian distance p_{dist} of each color point p to its 5 nearest neighbours located in the same hue sector:

$$p_{dist} = \sum_{i=1}^{5} \frac{\sqrt{(p_{i_x} - p_x)^2 + (p_{i_y} - p_y)^2 + (p_{i_z} - p_z)^2}}{5}$$

Step 2: Compute the mean μ_{dist} of the distance p_{dist} per hue

sector:

$$\mu_{dist} = \sum_{i=1}^{N} \frac{p_{dist}(i)}{N}$$

where N is the total number of distinct color points within the given hue sector.

Step 3: Compute the standard deviation σ_{dist} of the distance p_{dist} per hue sector:

$$\sigma_{dist} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(p_{dist} - \mu_{dist})^2}$$

Step 4: Consider the number N of distinct colour points within the hue sector as a global descriptor of modulation.

To summarize, our proposed definition of modulation relates this concept to hue sectors. Modulation is described via a set of three scalar descriptors:

- average distance μ_{dist} of a color point to its five closest neighbours. This is a measure of the spatial closeness of color points in a given hue sector. Low values for μ_{dist} indicate subtle color transitions and thus high modulation, whereas high values indicate more abrupt transitions, thus low modulation.
- the standard deviation σ_{dist} of the distance of a colour point to its five closest neighbours. This is a measure of the variation of the spatial closeness across the hue sector, i.e. of how modulation varies inside the considered sector.
- the total number N of distinct color points within the hue sector. This is a global measure of modulation, and it is useful to provide context for the interpretation of μ_{dist} and σ_{dist} values.

For instance, consider an extreme hypothetical case where a hue sector contains only five very close color points. In this case, μ_{dist} will be low (estimating high modulation) and σ_{dist} will be high (estimating uniform modulation). However, a low value for N is a stronger estimator for low modulation, and overrides the estimations of μ_{dist}.

4. Case studies

This section analyzes two paintings in terms of their color modulation characteristics. Both paintings were discussed by Itten in [Itt61] [Itt70]. Let us first consider 'Composition 1928' by Piet Mondrian, shown in Figure 2(a). Mondrian's painting style employs contrast of proportion and contrast of hue. He works with a very limited number of fundamental colors: yellow, red, blue, white and black. According to Itten, '[Mondrian's] feeling for clean design leads him to an unadorned, visually strong, geometrical, elemental realism of form and color.'

Second, let us discuss 'Cafe at Evening' by van Gogh, shown in Figure 3. Van Gogh's chromatic style features strong colors and simultaneous contrast between yellow-orange and blue-violet. Itten discusses Van Gogh's preference for 'using texture as a means of rhythmicizing and intensifying colors'. Textured colors are highly modulated.

Hue Sector	μ_{dist} $*10^3$	σ_{dist} $*10^3$	N
Red	0.93	2.5928	327
Yellow	1.897	3.94	190
Blue	0.166	0.497	599
Blue-Violet	0.77	2.63	125

Table 1: *Modulation measures for 'Composition 128' by Mondrian. The four hue sectors with the highest numbers of color points are shown only*

Hue Sector	μ_{dist} $*10^3$	σ_{dist} $*10^3$	N
Red	0.25	0.78	5214
Red-Orange	0.16	0.16	8345
Orange	0.07	0.09	18377
Blue	0.09	0.57	11507

Table 2: *Modulation measures for 'Cafe at Evening' by Van Gogh. The four hue sectors with the highest numbers of color points are shown only*

As shown in Table 1, Mondrian's minimalist style is reflected in high values for μ_{dist} (which estimate low modulation) in all hue sectors, except for blue, which is slightly textured. In contrast, we obtain much lower values for μ_{dist} for all hues in Van Gogh's case (see Table 2). The number N of distinct color points per hue is also much higher in Van Gogh than in Mondrian.

A visual comparison of the color palettes corresponding to the two paintings (see Figures 2, 3) reveals the sparseness of Mondrian's palette in contrast with the compactness and continuity of Van Gogh's palette. Intuitively, one may associate high modulation to a smooth, continuous 3D colour palette, and low modulation to a sparse 3D palette.

5. Conclusion

This paper proposes a new approach for the computational analysis of color aesthetics. Unlike previous work, this analysis was performed on digital reproductions of paintings instead of photographs. Our proposed approach is grounded in Itten's color theory, which represents a complete and comprehensive framework for aesthetic analysis of visual art. To the best of our knowledge, this is the first attempt of translating Itten's principles of color theory into a computational approach for the quantitative analysis of aesthetic elements in images. We introduce the color palette, a novel visualization of chromatic information in the HSL space. Moreover, we propose a set of simple quantitative descriptors for color modulation. Two case studies on paintings exhibiting high and low color modulation show that our descriptors are consistent with Itten's principles and explanations on modulation. Future work involves further exploration of the pro-

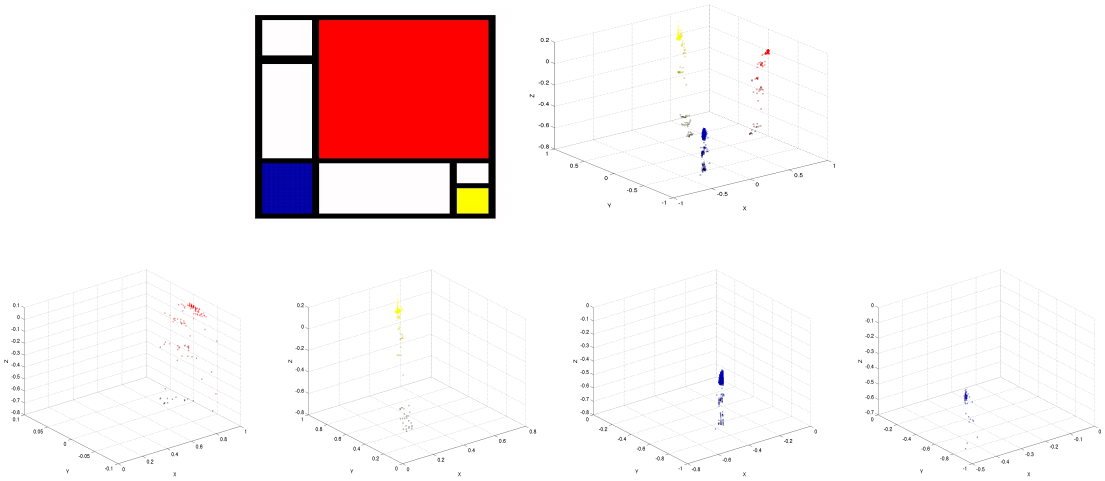

Figure 2: *'Composition 1928' by Mondrian.Top row: image and its color palette; Bottom row: red hue sector of color palette; red-orange hue sector of color palette; orange hue sector of color palette; blue sector of color palette*

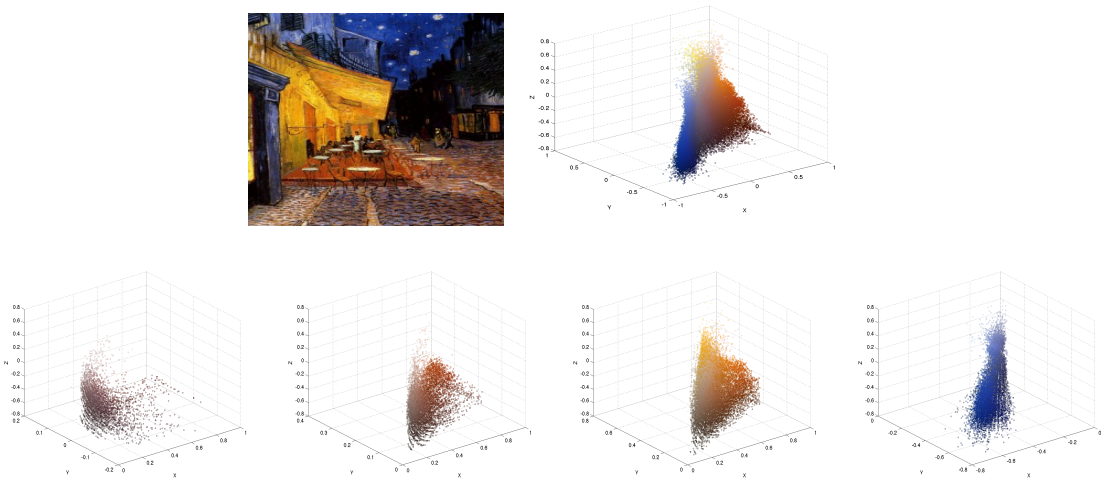

Figure 3: *'Cafe at evening' by Van Gogh.Top row: image and its color palette; Bottom row: red hue sector of color palette; red-orange hue sector of color palette; orange hue sector of color palette; blue sector of color palette*

posed color palette, in terms of its ability to discriminate between different artists and painting styles.

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