

Color Quantization to Visualize Perceptually Dominant Colors of an Image

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As an alternative technique to the conventional color swatch, we adopted color quantization to present perceptually dominant colors of an image. We facilitated five digitalized paintings and extracted the color scheme of each based on their RGB values. We adopted K-means clustering analysis and created clusters with 3, 6, 9, 12, and 15 colors. The extracted colors were presented in a color swatch format as well as color quantization. Thirty design majoring students assessed each format with regard to how properly the color set represents the original image. The results showed that the judgments varied more largely when the colors were presented as color quantization than as a color swatch. In particular, an intersection point always existed, implying that a color swatch without any semantic hints is more meaningful when a color palette contains a small number.

Keywords: Color Evaluation, Representative Color, K-Means Clustering, Semantic Color Palette

이미지의 대표색을 시각화하기 위한 양자화 기법의 활용

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본 연구는 이미지를 대표하는 색을 시각화하고 대표색의 적합성을 판별하기 위한 방법으로서 이미지 양자화(Quantization) 기법을 제시하고, 이를 기존에 널리 활용되던 직사각형 형태의 색채견본 방식과 비교하여 양자화 기법이 가지는 특성과 장점을 살펴보고자 하였다. 이를 위해 다섯 개 명화의 대표색을 추출한 후, 색채 견본 방식과 양자화 방식으로 대표색들을 제시하여 사용자 대상 평가를 진행하였다. 대표색 추출에는 K-평균 군집화 기법이 활용되었으며, 각 명화 이미지에 대해 3,6,9,12,15개의 대표색을 추출하여 대표색의 개수에 따른 영향 또한 보고자 하였다. 30명의 디자인 전공자들을 대상으로 대표성의 적합도를 평가하게 한 결과, 양자화 기법으로 제시된 대표색 팔레트의 적합도 점수가 훨씬 넓은 분포를 가지고 있는 것을 확인할 수 있었다. 이를 통해 양자화 기법이 대표색의 적합성에 대해 더 분별력 높은 평가 결과를 가져다줄 수 있었다. 또한 일정 개수 이하의 대표색에서는 색채견본 방식이 양자화 기법보다 적합도 점수가 높은 반면, 대표색 개수가 일정 이상 증가하면 양자화 기법의 적합도 점수가 더 높아지는 경향성을 통해, 추출하고자 하는 대표색이 적을수록 위치 및 면적 정보가 포함되지 않은 색채견본 방식이 더 적합함을 알 수 있었다.

Keywords: 대표색 추출, 양자화, K-평균 군집화 기법

1. Introduction

Color extraction techniques from an image are widely used in various fields such as art, design, cognitive psychology and computer science. As an example in art, Lenclos' has documented endemic colors after having traveled around the world for decades (Lenclos & Lenclos, 2004). In Lenclos's study, a set of endemic colors was defined region by region, and then color applications were presented illustratively in shapes of windows or doors (Lenclos & Lenclos, 2005). In design practice, the city of Seoul proposed a color palette, called "Seoul Colors," to embody its inherent city identity (Kim, 2010). In this project, 10 Seoul Colors were defined based on the observation of over 9,800 images of representative items in Seoul.

This study purposes to compare two visualization methods to present perceptually dominant colors of an image: one is a color swatch and the other is a color quantization. Color swatch is a conventional name for a color palette because an array of color squares resembles a painter's color palette. Just as painters select a color from the color palette, users choose a color from the color swatch. Color swatch is a typical way to visually summarize color schemes in both color practice and color segmentation engineering. However, the swatch does not deliver the semantic information such as the location of the pixels that a certain color swatch represents, and the area that belongs to a color.

In this regard, we came up with an idea that color quantization can be an alternative way of visualizing a color palette; therefore, we expected to find greater utility aspect especially because it not only presents dominant colors but also illustrates semantic contents. Color quantization refers to a retrieved image that is rendered with a limited number of colors.

Through color quantization, the original image is substituted by the colors into which each pixel was classified. Hence color quantization has been utilized as a visualization technique in color segmentation studies that are aimed at abstracting or reducing the colors of an image in order to increase the computational efficiency (Sural, Qian & Pramanik, 2002; Velho, Gomes & Sobreiro, 1997). The quantized images visualize the results of color segmentation, and help to examine the excellence of a segmentation algorithm. In this study, we attempted to explore the value of color quantization as a visualization technique for perceptually dominant colors of an image, that delivers semantic information of a color swatch has.

2. Extraction of perceptually dominant colors

2.1. Color extraction techniques

With regard to the color extraction of perceptually dominant colors, both subjective judgment and quantitative analysis techniques are considered equally relevant. Color artists subjectively define which colors are more representative. More objectively, computational techniques are utilized to create a set of colors. To obtain perceptually dominant colors through mathematical calculations based on the numerical values of image pixels, techniques for splitting-based algorithms or partitional cluster analysis have been frequently adopted (Hu & Lee, 2007). The splitting-based algorithms group the color space into separate groups and different criteria can be used. The partitional clustering groups the color spaces into k number of desired clusters in order to extract a set of colors in a size of k. A successful quantitative technique should have strong reliability and high validity.

In this study, we identified the R, G, and B

values of each pixel of an image and conducted K-means clustering analysis. K-means clustering is the simplest and most widely used clustering analysis to segregate an image by color scheme (Lin & Hanrahan, 2013). It aims to minimize the sum of squared distances between all pixels and the cluster centroid to classify the pixels into k number of clusters is defined as follow:

$$\arg \min_S \sum_{i=1}^k \sum_{X \in S} \|X - \mu_i\|^2$$

For initial centroids, k pixels that are the farthest from one another in the RGB space were selected. The cluster centers were updated after every pixel was assigned to a certain cluster using the formula presented above.

2.2. Selection of paintings to extract colors

We searched for well-known paintings from Post-Impressionist artists because they were influenced by Impressionism but evolved toward a more distinctive technique. They accepted Impressionists' objective color capturing. Moreover, they endeavored to express ambiguous and symbolic meaning with strong colors (Janson & Janson, 2004). Each painting contains a wide range of hue, and the different hues are visualized in vivid tones. Consequently, we anticipated that the pixels of digitalized Post-Impressionist paintings would be distributed widely within the sRGB space and, therefore suitable for an exercise of extraction

of perceptually dominant colors.

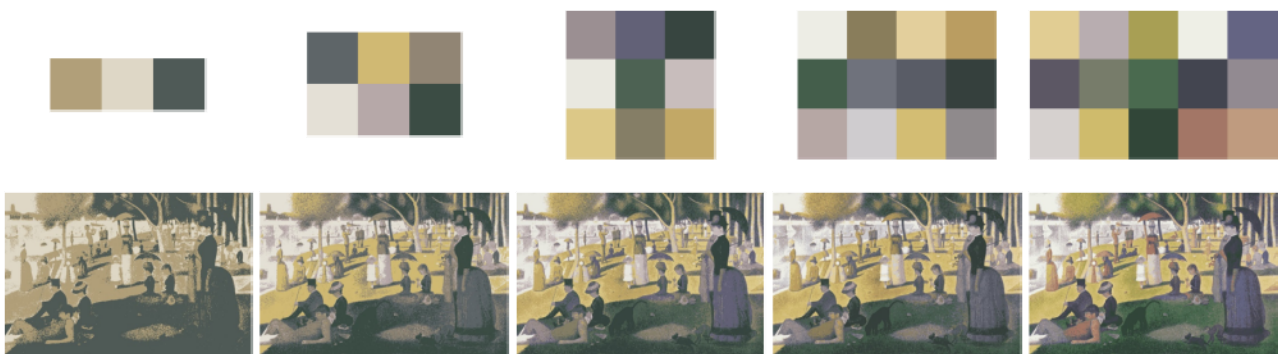


<Figure 1> The selected five Post-Impressionism paintings for color extraction.

The selected paintings are shown in Figure 1 clockwise from top left: “Café Terrace at Night” by Vincent Van Gogh, “Colored Landscape with Aquatic Birds” by Jean Metzinger, “Spirit of the Dead Watching” by Paul Gauguin, “A Sunday Afternoon on the Island of La Grande Jatte” by Georges-Pierre Seurat, and “The Joy of Life” by Henri Matisse (Figure 1). We collected the paintings in JPEG format from Wikipedia.org.

2.3. Extracting colors into color swatches and color quantizations

We converted each pixel of the five JPEG images into RGB values, based upon which we performed K-means clustering. We deliberately increased the number of partitions from 3 to 6, 9, 12, and then 15 because we intended to observe whether the tendency would be influenced by the visualization method between color swatch and color quantization. Moreover, we looked into the range between 3 and 15;



<Figure 2> Five color swatches and Five quantizations of “A Sunday Afternoon on the Island of La Grande Jatte”

because, in the practice of color design, the numbers of colors of a color palette are frequently 3 (Kobayashi, 1991), 5 (Adobe Color CC), or 10 (Kim, 2010). Also, we expanded the number up to 15 to reveal the saturation of satisfactoriness at a certain number.

After each clustering process, the centroid updating process repeatedly modified its clusters, and we took the centroid values of RGB of each cluster. Then, the color palette was presented in two different formats. In total, we visualized 10 alternatives—5 color swatches and 5 color quantizations—for each of the paintings. Figure 2 shows the 10 alternatives of “A Sunday Afternoon on the Island of La Grande Jatte”. In this way, a total of 50 stimuli were prepared.

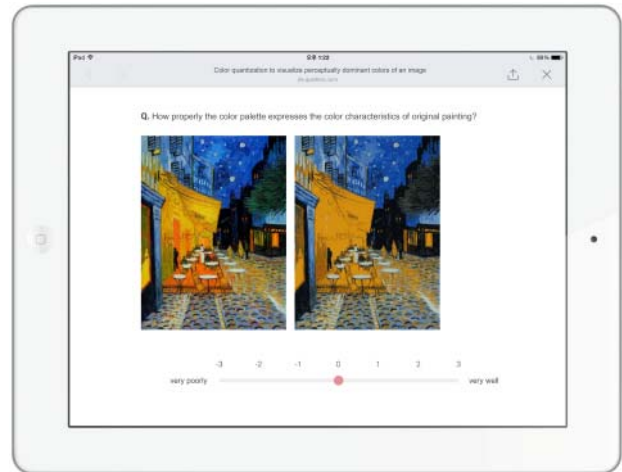
3. Evaluation of color quantization in comparison with color swatch

3.1. Subjects

We recruited 30 college students, which consisted of 14 males and 16 females. Their average age was 25.33 years with standard deviation of 2.63, and all majored in industrial design. All passed Ishihara’s color blindness test and were proven to have normal color vision.

3.2. Procedure

In order to avoid device-dependent color reproduction, we used an iPad 2 to present the stimuli. We displayed an original painting that measured 70.67mm horizontally. The vertical length of paintings varied between 48.10 and 96.72mm. As presented in Figure 3, to the right of the original painting, we randomly presented either a color swatch or a color quantization.



<Figure 3> Presentation of test stimuli

Throughout the evaluation, there was only one question about the adequacy of color palette: how properly the color palette expressed the color characteristics of original painting. The subjects rated the palette on a 7-point Likert scale that ranged between -3(very poorly) and +3(very well). The test was conducted under a fluorescent lighting with illuminance of 500 lx and the correlated color temperature of approximately 5500 K.

4. Result

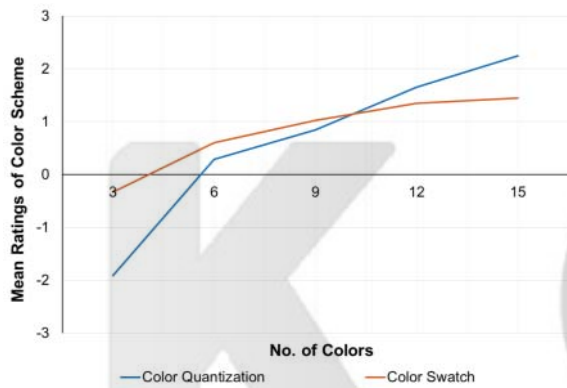
Based on the subjects’ ratings, we averaged the ratings along with the increase of number of colors. The average and standard deviation for each alternative are listed in Table 1.

<Table 1> Ratings for each alternative

No. of colors	Color Quantization		Color Swatch	
	Mean	SD	Mean	SD
3	-1.91	1.29	-0.33	1.94
6	0.29	2.02	0.61	1.75
9	0.85	1.79	1.03	1.62
12	1.66	1.67	1.35	1.59
15	2.25	1.48	1.45	1.46

Then, we plotted the results as shown in the Figure 4. The average rating is positively correlated with the number of colors, as we

have already anticipated. Then we focused on different shapes and inclinations between these two positive correlations. The orange line indicates that the average rating on the color swatches looks fitting better to a logarithmic curve than to a straight line. The determinant coefficient, R^2 of a logarithmic regression model for the orange line was slightly larger(0.39) than the R^2 of when a straight linear regression was applied(0.35). This implies that a color swatch can have a minimum number of colors that is sufficient to cover the perceptually dominant colors of an image.



<Figure 4> Mean ratings of Color Scheme

In this study we presume that the number could be around 10, because the mean ratings between color number of 9, 12, and 15 are statistically not different. Apparently, however, this number is limited to this study, i.e. viewing the 5 Post-Impressionistic paintings in approximately 1024 x 768 pixels.

With regard to the different inclinations, we observed the ratings on the color quantization varied more than the ratings on the color swatch. In Figure 4, the orange line varies between -0.44 and +1.00, while the blue line varies between -2.07 and + 1.81. The discrepancies indicate differences between the best and poorest averages, and they are 1.44 and 3.88, respectively.

<Table 2> Average discrepancies between the lowest rating and the highest rating

Artist	Average discrepancies between the lowest rating and the highest rating(N=30)	
	color swatch	color quantization
Gogh	1.67	4.07
Matisse	1.13	4.17
Metzinger	2.93	4.07
Gauguin	0.60	3.33
Seurat	2.10	3.81

The tendency that the discrepancy between the poorest and best ratings on the color quantization was larger than the discrepancy of ratings on the color swatch was always observed in all 5 paintings, as summarized in Table 2. This implies that color quantization enabled the subjects to make a clearer distinction when they judged whether the colors in the color quantization are adequate or inadequate to represent the given image than the colors in the color swatch. For example, when 3 colors were presented, the subjects' judgment of the color quantization was two times more negative than their judgment of the color swatch. In fact, when the number of color scheme was 3, the mean difference between the color quantization and the color swatch was statistically significant [paired-samples t-test, $t(149) = 9.20, p < .01$]. On the contrary, when 15 colors were presented, their judgment of the color quantization was two times more positive than their judgment of the color swatch. In this case, the mean difference was statistically significant, too [paired-samples t-test, $t(149) = -5.05, p < .01$].

In addition, there always existed an intersection point where the average rating on the color quantization crosses over the average rating on the color swatch. As illustrated in Figure 4, we found an intersection point at when the number of colors was 10.11. This tells that when the number of color schemes was less than approximately 10, color swatch has advantage over color quantization. In this study,

we do not yet conclude that 10 is a magic number because the image resource was limited to the 5 paintings of Post-Impressionism.

5. Discussion and future work

5.1. Discussion and conclusion

Color quantization has been a conventional technique to evaluate the quality of color segmentation. In this study, we tried to explore whether color quantization could be facilitated as an alternative method to color swatches when presenting perceptually dominant colors, such as a color scheme of an image. We anticipated that the color quantization would have advantage because it illustratively provides where each color scheme comes from. Also, we expected any benefit from the color quantization as it contains a semantic information where as a color swatch, the conventional way of presenting a color scheme, is just an array of squares.

In this study, we conducted a user test and found our assumption was partially supported. Based on the analysis of the five Post-Impressionistic paintings, we found that people can make more distinctive judgments when the color scheme was presented in the form of a color quantization than in the form of a color swatch. This indicates that the color quantization is particularly useful when people's opinion needs to be magnified. At the same time, we confirmed that a color swatch is an efficient visualization technique that can sufficiently describe the color characteristics of an image especially when the number of color scheme is relatively small.

5.2. Limitations and next steps

In this study, the comparison between the

color quantization and the color swatch was made using five Post-Impressionist drawings. Although the five drawings were carefully selected, a more robust conclusion will be drawn when a study includes a larger pool of images. And the age range of participants was limited to 20s. It is required to verify the method with various age groups.

As future study, more effort should be made in order to extract perceptually dominant colors rather than the density based averaging, as we adopted k-means cluster analysis in the current study. As already mentioned in some recent studies (Hu & Lee, 2007; Lin & Hanrahan, 2013; Yang, et al, 2008), advanced techniques with an emphasis on human perception are expected. Theories and empirical findings related to color saliency should be incorporated in the computational method.

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