Landscapes in Social Media: A Quantitative Analysis of Color Harmony in Historical Buildings

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Abstract. Historic buildings are vital repositories of local historical memory in urban environments. Color harmony, a key aspect of urban historical landscapes, lacks comprehensive quantitative standards and detailed research, notably concerning the evaluation of color harmony in historic contexts, encompassing monochromatic, analogous, and complementary hues. Integrating quantitative color indices and assessment techniques into historic preservation strategies necessitates further exploration. This study employs semantic segmentation algorithms, image property detection, and color pattern quantification to evaluate color harmony in historical buildings. Analyzing 100 viral Instagram images, dominant colors were extracted, categorized into 12 hue-based ranges, and assessed for harmonious combinations. Analogous and complementary schemes predominate, with 1–2 color harmonies and 2–4 color ranges recommended for optimal richness without visual clutter. Our findings offer a precise method, informed by popular social media images, to guide the conservation and restoration of historic landscapes with quantified color harmony guidelines.

Keywords: Cultural Landscapes and New Technologies, Historical Landscape Renovation, Color Harmony, Color Scheme, Quantitative Analysis.

1 Introduction

Historical buildings are vessels of sacred national memories, encapsulating a city's core identity and enhancing its urban competitiveness. However, the surge of urbanization has introduced novel challenges to the preservation of these structures. Their restoration and safeguarding have long captivated scholars, generating diverse avenues for research. This study seeks

to establish a connection between intuitive color perception and the preservation of historical architecture. This involves selecting historically significant buildings that resonate with the public, using advanced theoretical calculations to quantify and evaluate their color harmony. The objective is to provide more informed guidance for protecting and restoring these timeless architectural treasures.

The historical environment can be seen as a fusion of form and color, with color a potent and immediate conduit of architectural culture and identity (Hu et al., 2017). Some researchers have advanced the notion that discerning the colors adorning historical buildings carries inherent heritage value (Pin, 2015; Garcia-Codoñer et al., 2009; Jin, 2016).

In the context of historical building restoration and urban landscape design, achieving a harmonious visual perception of historical building facades assumes paramount significance in forging a distinctive national architectural identity. As a unique and expressive element of architecture, color plays a pivotal role, underscoring the essential nature of color harmony. Burchett (2002) defines color harmony as the pleasurable response elicited when colors are juxtaposed. However, contemporary architectural color planning often leans heavily on qualitative guidelines to assess color coordination. For example, the *Guidelines for Urban Architectural Color Design* present principles and methodologies for a comprehensive approach to regulating architectural colors (Cui, 2020).

Scholars have established methods for evaluating color harmony. Xueying (2019) integrated dense hue elements based on the correlation between lightness and chroma to categorize colors with similar attributes. Haobo et al. (2022) evaluated urban color harmony using color histogram similarity. However, these studies' color harmony calculations are based solely on color similarity, revealing inherent limitations. This study strives to enhance the color coordination calculation method based on color theory, addressing the limitations of color calculation.

Regarding color system selection, the RGB color space, commonly used for digital displays, involves additive color mixing and presents challenges for statistical analysis. Although this study favors the RGB color system, it acknowledges its additive nature and the challenges this poses for data analysis. In the realm of image processing, the HSV color space is commonly used (Jiang et al., 2022), where the hue, saturation, and value components are relatively independent. Therefore, this study employs conversion from RGB to HSV for calculations.

Attaining precise architectural color coordination further demands the application of a specialized and expert color scheme. A color wheel, a staple tool in color science, embodies a circular arrangement of elongated bar-shaped color sequences in spectral order (Yaseen et al., 2018).

In this study, color harmony quantification relies on a bespoke color scheme derived from the color wheel, grounded in the HSV color attributes. These categories include:

monochromatic—enabling color variations by adjusting saturation and value, ensuring harmonious matches from a single point on the color wheel.

analogous—employing adjacent colors on the color wheel.

complementary—using colors directly opposite each other on the color wheel.

split complementary—using opposing colors on both sides of the color scheme.

triadic—employing three evenly distributed colors forming a perfect triangle on the color wheel.

tetradic—forming a rectangle on the color wheel.

square—four colors equidistant on the color wheel to create a square or diamond shape.

These approaches to color coordination contribute to enhancing the accuracy and effectiveness of the study's findings.

This study introduces an advanced calculation model for color harmony, leveraging prominent historical buildings as data samples from social media. By extracting dominant colors and categorizing them, it employs the optimal HSV color scheme to quantify architectural color harmony. These findings offer profound insights for the preservation and strategic planning of historical buildings.

2 Methodology

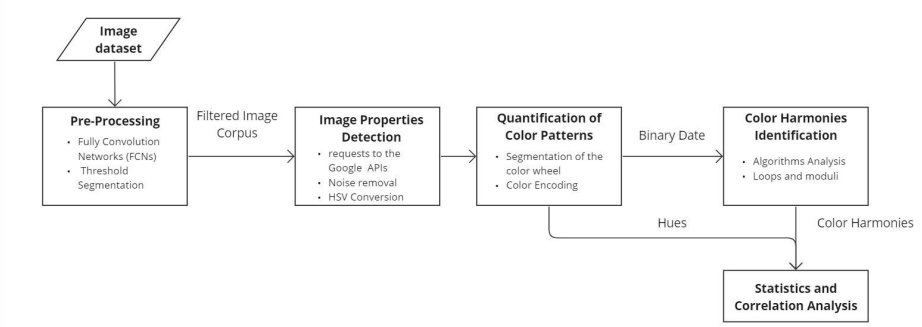

Figure 1. Method Flowchart. Source: Author, 2023.

2.1 Data Collection and Preprocessing

We compiled a dataset of 100 images of historic buildings that achieved viral popularity on Instagram, evidenced by over 3,000 likes each. With 2.05 billion monthly active users as of 2021, Instagram represents one of the largest global social media ecosystems (Statista, 2022). The phenomenon of content "going viral" indicates a surge in engagement through likes, comments,

sharing, and new followers. Our image corpus was sourced by searching Instagram under the destination tag “Historic Buildings” and capturing photos with high visibility. The compiled viral images consisted of colorful street views of various heritage sites across the United States.

To exclude the influence of extraneous colors from elements such as skies and cars, we performed semantic and threshold segmentation on the images to extract masked images containing only the building portions. We chose fully convolutional networks and the ADE20K training dataset to complete the semantic segmentation, followed by grayscale thresholding to binarize the images. This process enabled us to clean the image dataset and focus more precisely on the colors of the buildings.

Figure 2. Representative Images Collected from Instagram. Source: Author, 2023.

2.2 Image Property Detection

This study used the Cloud Vision API, a cognitive service from Google Cloud, for automated analysis of image content and extraction of relevant information. A key capability of Cloud Vision is the detection of various image properties. Using this feature, we obtained RGB color clusters representing the predominant colors in each image. To reduce noise, minor colors accounting for less than 1% of the image were filtered out, leaving only the most prominent. The raw RGB values were then converted to HSV color space to enable subsequent analysis of hue relationships and color harmonies.

2.3 Quantification of Color Patterns

Based on widely accepted color harmony principles originally defined by Munsell, Itten, and others, the color wheel can be systematically segmented into 12 equally spaced hue regions consisting of three primary, three secondary, and six tertiary colors. Leveraging this theoretical framework, we segmented the color wheel into 12 equally spaced sections based on 12 different hues.

For each image, we determined which of the 12 representative color ranges contained the hue values of the main colors from our analysis. By encoding the presence or absence of the representative colors as binary values, we constructed circular arrays in reference to the color wheel to summarize the main colors within each image. This allowed concise quantification of color patterns in a format intrinsically linked to the conceptual model of the color wheel (Niti, 2020).

Figure 3. Binary Conversion of Main Colors. Source: Author, 2023.

2.4 Color Harmony Identification

The circular color arrays can be used to programmatically identify color harmonies by analyzing the pattern of hues present. For instance, an image with an analogous color scheme will have adjacent color segments in its array, resulting in a sum of binary values of more than 1. Further, through loops and moduli, we can efficiently detect the presence of nearby or complementary colors on the wheel. The structured color encodings enable efficient automated analysis of color harmonies through algorithms, allowing faster annotation of the dataset versus manual labeling (Niti, 2020).

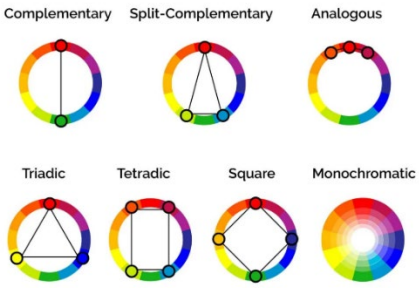

Figure 4. Explanation of Color Harmony. Source: https://www.colorsexplained.com/color-harmony/

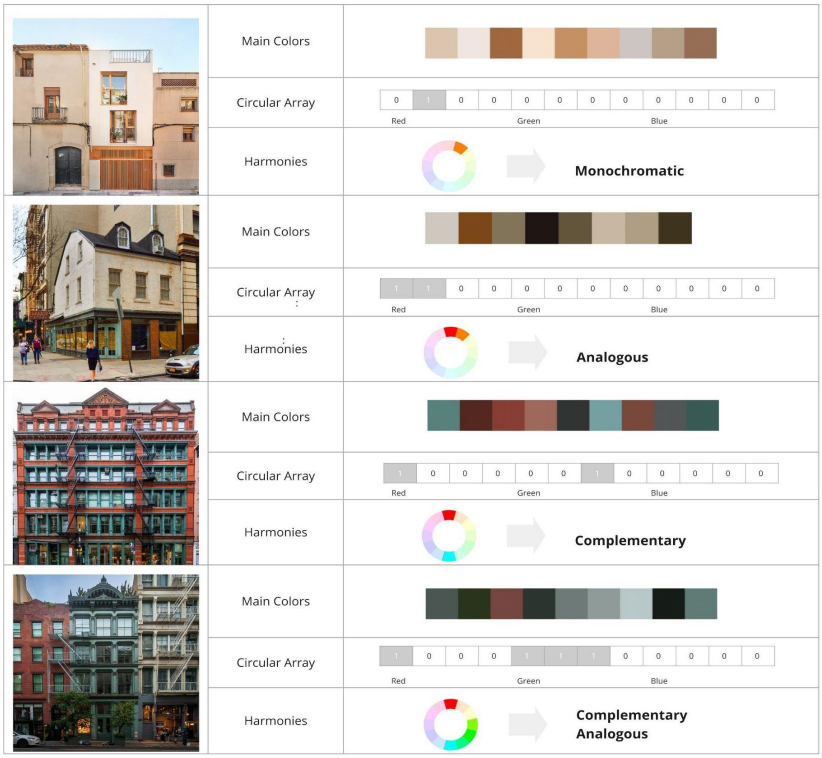

Figure 5. Demonstration of Different Color Harmony Types. Source: Author, 2023.

3 Results

3.1 Overall HSV Interval Distribution

By processing the RGB data of historical architectural images, the overall HSV distribution results of the images are first obtained. Comparing the saturation and value shows that the saturation of most images is between 0.2 and 0.4, and the value is concentrated around 0.5 (Figure 6). The images in the existing dataset show medium saturation, medium value, and medium chroma.

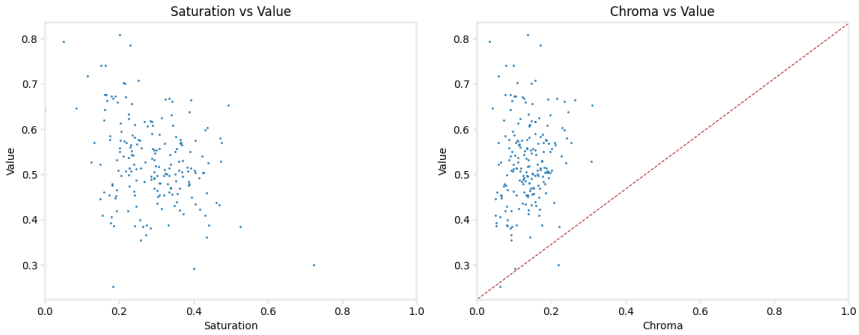

Figure 6. Analysis of Saturation vs. Value. Source: Author, 2023.

3.2 Color Harmony

According to harmony identification, the frequencies of seven kinds of color harmony were counted, and the following conclusions were obtained.

Harmony modalities are lower in building photographs with more likes, with 1–2 harmony modalities in each image. Therefore, 1–2 harmony modalities are sufficient for historical structures.

Analogous harmony appears with the highest frequency, at more than 50%, followed by complementary and monochromatic (Figure 7). Analogous and complementary harmony account for the highest proportion among all color harmony, and they often appear in the same image.

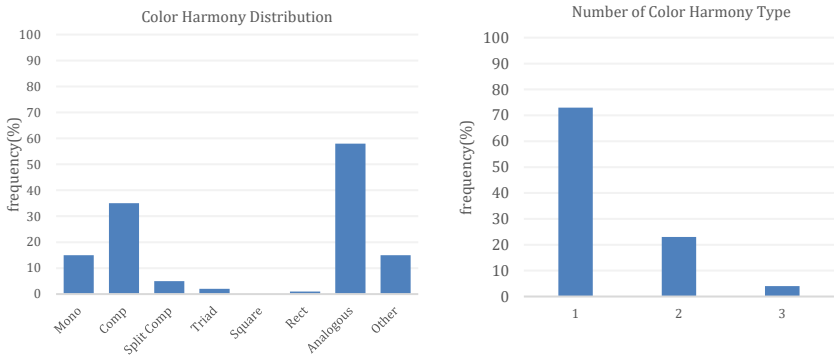

Figure 7. Color Harmony Distribution (Left) and Number of Color Harmony Type in Each Image (Right). Source: Author, 2023.

3.3 Color Range

Most of the historical architectural images have 2–4 color ranges. Fewer images are monochrome or have more than four color ranges, implying that these two types of images are less popular.

The most frequently used color ranges are red and orange (Figure 8), appearing on more than 60% of buildings.

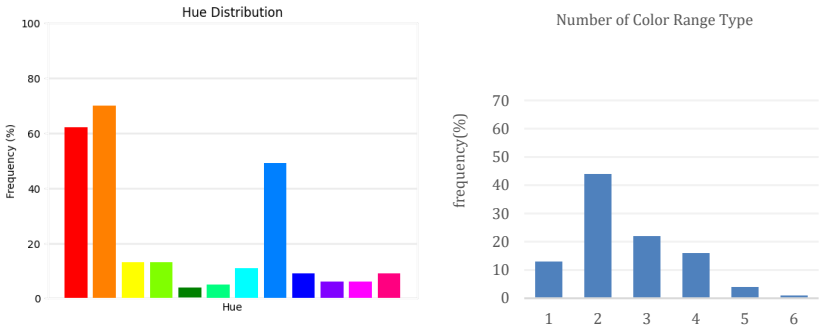

Figure 8. Hue Distribution (Left) and Number of Color Range Type (Right). Source: Author, 2023.

3.4 Correlation

The correlation study mainly aimed at the correlation measurement between color ranges, color ranges and color harmony, and color harmony (Figure 9). Because these are all two binary variables, a more appropriate Phi coefficient was selected for correlation measurement. Among them, color ranges are classified as one color every 30° in the color wheel, for a total of 12 color ranges.

	Monochromatic	Complementary	Split Complementary	Triad	Square	Rectangular	Analogous	Other
Monochromatic	1.00	-0.30	-0.09	-0.06	0.00	-0.04	-0.45	-0.16
Complementary	-0.30	1.00	0.11	-0.11	0.00	0.13	0.07	-0.32
Split Complementary	-0.09	0.11	1.00	-0.03	0.00	-0.02	0.20	-0.10
Triad	-0.06	-0.11	-0.03	1.00	0.00	-0.01	0.12	-0.06
Rectangular	-0.04	0.13	-0.02	-0.01	0.00	1.00	0.09	-0.04
Analogous	-0.45	0.07	0.20	0.12	0.00	0.09	1.00	-0.49
Other	-0.16	-0.32	-0.10	-0.06	0.00	-0.04	-0.49	1.00

	Red	Orange	yellow	Yellow-Green	Green	Cyan-Green	Cyan	Cyan-Blue	Blue	Blue-Purple	Purple	Magenta
Red (H=0)	1.00	-0.38	-0.19	0.00	-0.05	0.09	0.01	-0.02	0.10	-0.06	0.02	0.17
Orange	-0.38	1.00	0.06	-0.14	-0.20	-0.15	-0.26	-0.19	-0.33	-0.02	-0.29	-0.33
yellow	-0.19	0.06	1.00	0.29	-0.08	0.18	0.24	-0.20	-0.02	0.15	-0.10	-0.12
Yellow-Green	0.00	-0.14	0.29	1.00	0.07	0.18	0.05	-0.08	0.09	-0.10	0.15	0.09
Green (H=120)	-0.05	-0.20	-0.08	0.07	1.00	-0.05	0.25	0.00	0.11	-0.05	-0.05	0.11
Cyan-Green	0.09	-0.15	0.18	0.18	-0.05	1.00	0.51	-0.04	0.09	0.14	-0.06	-0.07
Cyan	0.01	-0.26	0.24	0.05	0.25	0.51	1.00	0.04	0.11	0.18	-0.09	-0.11
Cyan-Blue	-0.02	-0.19	-0.20	-0.08	0.00	-0.04	0.04	1.00	-0.03	-0.08	0.01	0.18
Blue	0.10	-0.33	-0.02	0.09	0.11	0.09	0.11	-0.03	1.00	0.22	0.22	0.27
Blue-Purple	-0.06	-0.02	0.15	-0.10	-0.05	0.14	0.18	-0.08	0.22	1.00	0.11	0.07
Purple	0.02	-0.29	-0.10	0.15	-0.05	-0.06	-0.09	0.01	0.22	0.11	1.00	0.36
Magenta	0.17	-0.33	-0.12	0.09	0.11	-0.07	-0.11	0.18	0.27	0.07	0.36	1.00

Figure 9. Results of Correlation Measurement Between Different Objects. Source: Author, 2023.

The Phi coefficient between red (H=0) and monochromatic is -0.432 (Figure 9), indicating a low correlation between the two. This shows that red

historical buildings are generally not monochromatic and often have other colors.

The Phi coefficient between cyan blue and complementary is 0.616 (Figure 9), indicating a high correlation between them. Therefore, few historical buildings are entirely cyan blue, but cyan blue can be used as a contrasting color of red to form visual conflict as decoration in the renovation of historical buildings (Figure 10), which is consistent with the conclusion of the last point. Additionally, the Phi coefficient between blue and split complementary is 0.569 (Figure 9). This indicates that compared with cyan blue, blue is more likely to form split complementary than complementary harmony.

Figure 10. Red Historical Buildings Using Cyan Blue as a Complementary Color. Source: https://urlzs.com/PDnZS, https://urlzs.com/aSwm7.

The Phi coefficient between magenta and triad is 0.45 (Figure 9). Magenta is thus more commonly used in historical buildings with the other two colors, forming triadic harmony.

The Phi coefficient between orange and blue and between orange and magenta is -0.33 (Figure 9), suggesting that orange is not suitable to appear on the same historical building facade as magenta or blue.

The Phi coefficient between cyan and cyan green is 0.51 (Figure 9). The high correlation indicates that they often appear together on historical buildings.

The Phi coefficient between magenta and purple is 0.36 (Figure 9), indicating that these two colors are also commonly used together.

3.5 Complementary

Among the architectural images with complementary color, 60% have analogous color to achieve visual balance. More than half of the historic buildings have two harmony modalities.

In the architectural images with complementary color, red–cyan and orange–cyan blue are the most common color combinations, whereas yellow and green are rare.

Table 1. Other Types of Complementary Color Harmony.

Color harmony types	Frequency(%)
Analogous	65.71%
Split Complementary	8.57%
Rectangular	2.85%

Source: Author, 2023

3.6 Analogous

In the images containing analogous colors, the most frequently used color range types are 2, 3, and 4, each accounting for more than 27%.

One type of harmony modality is the most prevalent in images with analogous colors, followed by two types of harmony modalities.

Table 2. Frequency of Analogous Color Range Types.

Number of color range types	Frequency(%)
2	32.76%
3	31.03%
4	27.59%
5	6.90%
6	1.72%

Table 3. Frequency of Analogous Color Harmony Types.

Number of color harmony types	Frequency(%)
1	53.45%
2	39.66%
3	6.90%

Source: Author, 2023

4 Discussion

This study has introduced an effective and precise methodology for assessing color harmony in historical landscapes, using popular images from social media as a valuable reference point. These insights contribute to a deeper understanding of color harmony preferences in historical landscapes and offer practical guidance for enhancing the visual integrity of historic buildings.

In this research, we focus on the colors of historic buildings that have gone viral on Instagram. We can expand the application and subdivision of categories in the future, such as in discussion of the interior colors of historical buildings, the colors of historical buildings in different countries, and landscape colors from an aerial view.

5 Improvements

Our research's subsequent enhancements include:

Analyzing cool and warm color schemes.

Extending our methodology to the red–yellow–blue (RYB) color system. Color harmony is defined within the RYB color wheel in certain contexts. Although we currently use RGB converted to HSV, future work will involve applying our method to the RYB system and comparing its accuracy with RGB.

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