Unveiling Color Dynamics in Andy Warhol's "Shot Marilyns": A Study on Visual Variations and Perception

A Preprint

Erick S. Arenas V
Department of Statistics
University of California, Davis
Davis, CA 95616
esarenas@ucdavis.edu

Weilin Cheng
Department of Statistics
University of California, Davis
Davis, CA 95616
wncheng@ucdavis.edu

Hengyuan Liu
Department of Statistics
University of California, Los Angeles
Los Angeles, CA 90095
hengyuanliu@g.ucla.edu

Xinhui Luo
Department of Statistics
Tufts University
Boston, MA 02155
xinhui.luo@tufts.edu

Kathy Mo
Department of Statistics
University of California, Los Angeles
Los Angeles, CA 90095
kathymo24@g.ucla.edu

Li Yuan
Department of Computer Science
Swiss Federal Institute of Technology, Zurich
8092 Zurich, Switzerland
xxxx@ethz.ch

July 20, 2024

Abstract

This study delves into the comparative analysis of five distinct versions of Andy Warhol's "Shot Marilyns," focusing on the intricacies of their color composition and distribution. Employing a range of analytical methods, including relative conditional entropy, this research investigates the unique color distributions and interrelations present in each artwork. Through the clustering of the artworks and the meticulous examination of specified regions of interest (ROIs)—namely, the backgrounds, hair, eyeshadow, and faces—we have unearthed profound insights into the constructional variances and similarities among the images. Our findings reveal that the presupposed uniformity in the coloration of certain elements stands contradicted, thereby underscoring the complexity and illusionary nature of color perception in visual art.

***K*eywords** shot marilyns · marilyn monroe · andy warhol · region of interest · python

1 Introduction

"Shot Marilyns," an illustrious artwork by the American artist Andy Warhol, stands as a testament to his exploration of celebrity culture and the commodification of images. Created in 1964, this series features multiple depictions of Marilyn Monroe, crafted in the wake of her untimely demise, thereby immortalizing her status as a cultural icon. Warhol's fascination with fame, consumerism, and the media's influence on societal perceptions is evident in his innovative use of silkscreen printing. This technique, adopted in August 1962, facilitated a production-line approach in art-making, enabling Warhol to replicate images with minor variations. The “Shot Marilyns” series, inspired by Monroe’s death in the same year, utilized this method to produce screenprints of her image, employing photo stencils and a palette of vibrant inks to transfer her likeness onto canvas. This body of work underscores Warhol’s endeavor to dissect Monroe’s persona through repetitive imagery, each variation rendered in distinct colors and compositions, allowing for diverse visual interpretations.

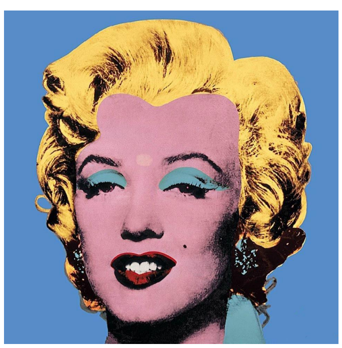
The series’ repetitive nature serves as a critique of the pervasive commodification of celebrities, transforming them into ubiquitous symbols within popular culture. Warhol’s strategic use of bright, contrasting colors aims to encapsulate Monroe’s dynamic celebrity essence, with the vivid hues underscoring her societal allure and influence. This study seeks to analyze the pixel color distribution in RGB space across the five “Shot Marilyns” images, examining the interplay between primary colors through relative conditional entropy. Such an analysis aims to reveal the underlying emotional and symbolic connotations Warhol might have intended, with color distributions potentially reflecting varied moods and themes.

In 1964, an intriguing incident further contributed to the series’ lore when Dorothy Podber, a performance artist, mistakenly received permission from Warhol to “shoot” the Marilyns, leading to an act of literal gunfire that damaged four of the five canvases. This event birthed the “Shot Marilyns,” adding a layer of physical and conceptual depth to the artwork. Part of our project involves digitally restoring the “Blue Marilyn,” focusing on the gunshot damage, by analyzing and replicating the surrounding area’s color distribution.

(a) Orange Marilyn

(b) Red Marilyn

(c) Turquoise Marilyn



(d) Blue Marilyn

(e) Eggblue Marilyn

Figure 1: Different color variations of Marilyn Monroe

2 Methods

An image comprises pixels, with each pixel containing three color components: Red (R), Green (G), and Blue (B), denoted as (R, G, B) respectively. These components define the intensity of the respective colors, with each component represented by an integer value within the range of [0, 255] in the RGB color space. Therefore, each color component is a discrete variable capable of assuming 256 distinct values. In the equations below, $Y = y$ or $X = x$ can be selected from any of the three color components, R, G, or B.

2.1 Entropy Calculation

The probability of a specific color component, $P(Y = y)$, is determined by dividing the number of pixels with color coordinates corresponding to that component by the total number of color components in the entire image. The following equations illustrate the calculation of entropy, conditional entropy, and relative conditional entropy

The entropy of a color component Y is defined as:

$$H(Y) = -\sum_{y=0}^{255} P(Y = y) \cdot \log(P(Y = y)) \tag{1}$$

The conditional entropy of Y given X is given by:

$$H(Y|X) = \sum_{x=0}^{255} P(X = x) \cdot H(Y|X = x) = -\sum_{x=0}^{255}\sum_{y=0}^{255} P(X = x, Y = y) \log_2 \left(\frac{P(X = x, Y = y)}{P(X = x)} \right) \tag{2}$$

The relative conditional entropy is calculated using the following formula:

$$HR(X|Y) = \frac{H(X|Y)}{H(X)} \tag{3}$$

2.2 K-Means Clustering Analysis

In the clustering analysis, we applied K-Means clustering to analyze the color dynamics in Andy Warhol's "Shot Marilyns" series. For each image, we performed K-Means clustering using the sklearn library, specifying the number of clusters (n_clusters) as 15, the initialization method (init) as "k-means++"[ ].(Benefits of using k-means++) The clustering algorithm grouped pixels into clusters based on their RGB values, effectively identifying the predominant color in each image. This method allowed us to quantify and visualize the distribution of colors, revealing the underlying color patterns and variations within the artworks. The resulting clusters were then analyzed to understand the prominence of specific colors across the series, as depicted in the corresponding bar charts and ribbons. These visualizations highlight the distinctive color schemes employed by Warhol, providing insights into his artistic technique and color usage.

2.3 ROI Extraction

In our study of ROI analysis, we employed a method to ROI from the images in the "Shot Marilyns" series include background, hair, eyeshadow and face. This process involved converting the images to HSV color space to better identify and segment specific color ranges. We determined the minimum and maximum HSV values within selected image regions manually. These values were used to create a color mask, which isolated the target color regions. The masked image was then processed to remove unwanted areas, and the resulting ROI was saved and analyzed. This method enabled us to focus on specific color features in the artwork, providing detailed insights into Warhol's color use and variations.

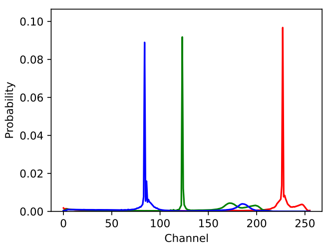
2.4 K-Nearest Neighbors Repair

To address the damaged sections of the "Blue Marilyn" image, we employed K-Nearest Neighbors (KNN) regression for image repair. This method involves identifying the coordinates of the damaged pixels and using the surrounding undamaged pixels to predict their values. The KNN regression model, with a specified number of neighbors, was trained on the undamaged pixels' RGB values. The model then predicted the RGB values for the damaged pixels, effectively restoring the affected area. This approach allowed us to maintain the image's visual consistency by leveraging the spatial color information of the undamaged regions. The repaired images were subsequently saved and analyzed to ensure the accuracy and aesthetic integrity of the restoration process.

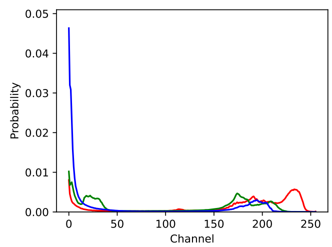
3 Data Description

Our study utilized a dataset comprising five images, each retrieved via URL links provided by "The Interior Review" website [1]. The images, titled Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn, are digitally encoded in the RGB color model. This model synthesizes a spectrum of colors through the additive mixing of Red, Green, and Blue light. The intensity of each primary color is quantized into discrete levels, ranging from 0 to 255, offering a finite palette within this cubic color space. The dimensions of each image are 960 by 960 pixels, totaling 921,600 unique data points per image, each specified by a distinct location and its chromatic composition.

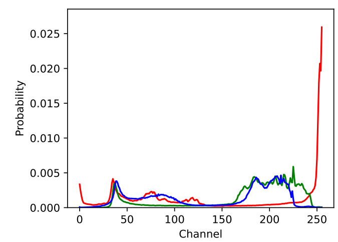
4 Data Exploration and Visualization Analysis



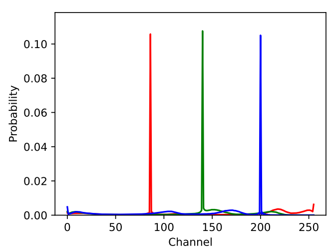
(a) Orange Marilyn RGB Distributions



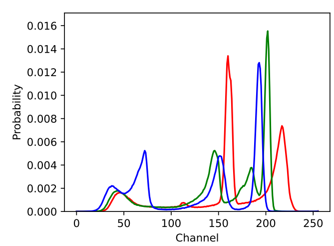
(b) Red Marilyn RGB Distributions



(c) Turquoise Marilyn RGB Distributions



(d) Blue Marilyn RGB Distributions

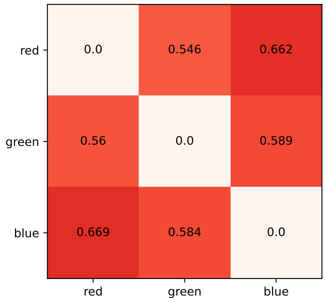


(e) Eggblue Marilyn RGB Distributions

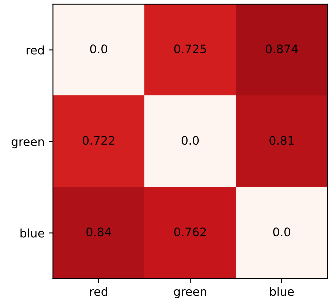
Figure 2: Distributions of values of Red, Green, and Blue channels for five images with all pixels

Our initial analytical procedure involved scrutinizing the RGB channels of the images and assessing their distribution profiles. Figure 3 delineates the variation in the red, green, and blue distributions across the five images. Notably, images (a) and (d) display pronounced disparities when contrasted with the others. For instance, in the (a) Orange Marilyn image, the blue channel's most significant probability density is localized within the [50, 100] interval, reaching an estimated 8.5%. The green channel's peak probability lies between [120, 130], at around 9%. Similarly, a notable concentration for blue is observed in the [220, 240] range with a likelihood of approximately 10%.

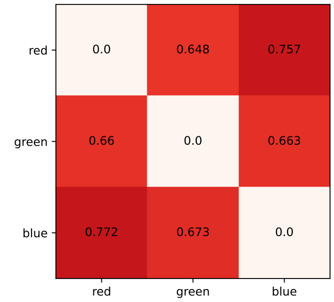
Intriguingly, image (d) mirrors the (a) Orange Marilyn in terms of green channel probabilities, predominantly in the [120, 130] range. However, it diverges markedly in the red and blue spectra. Image (d) features a red channel probability apex in the [70, 80] interval, representing a 11% likelihood, while its blue channel's highest probability is within the [190, 210] range, also accounting for a 11% probability. The divergence in the red and blue channel distributions between images (d) and (a) accentuates their unique attributes in the collective color distribution.



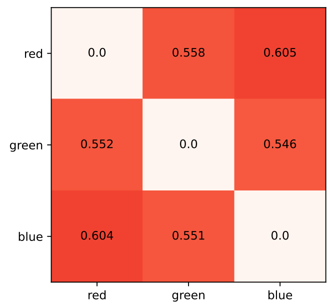
(a) Orange Marilyn Relative Conditional Entropy



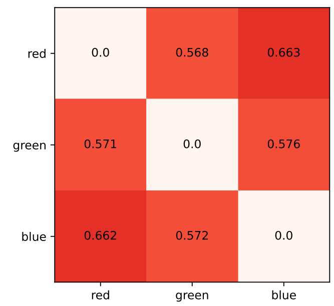
(b) Red Marilyn Relative Conditional Entropy



(c) Turquoise Marilyn Relative Conditional Entropy



(d) Blue Marilyn Relative Conditional Entropy



(e) Eggblue Marilyn Relative Conditional Entropy

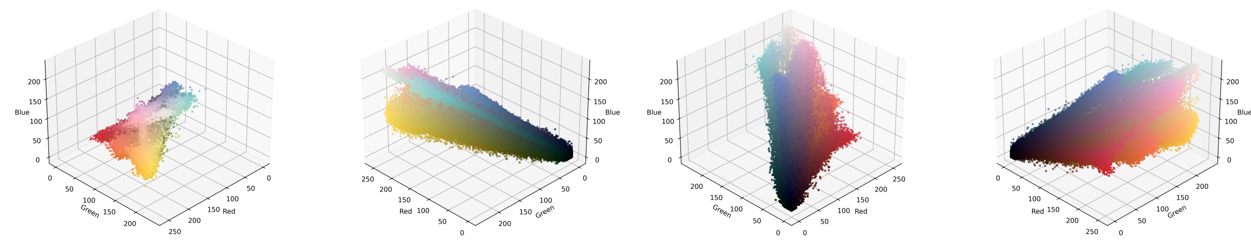
Figure 3: The relative conditional entropy values among the red, green, and blue coordinates of pixels

After analyzing the RGB distribution of each image, we further investigated the relationship between pairs of primary colors in the five images by calculating their relative conditional entropy (HR) (See Methods 2.1). This metric quantifies the shared information or dependency between two color channels, with lower HR values indicating stronger dependencies and higher values suggesting greater independence. HR ranges from 0 to 1, where 0 signifies complete dependency and 1 represents total independence.

Figure 4 presents the HR values for nine color pairs in each of the five images: Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn. As expected, comparing a color to itself yields a conditional entropy of zero. High HR values for different color pairs indicate minimal dependency between them. For instance, in the Red Marilyn image, the HR value for the Red channel relative to the Blue channel is 0.874, signifying strong independence between the Red and Blue channels.

5 Clustering based on Whole Images

Next, we visualized our RGB color data in a 3D space, plotting each color pair for the entire image. Following figures will present a series of 3D scatter plots from four distinct angles, with each dot representing a single pixel. These visualizations illustrate the distribution of pixel colors in the RGB space, highlighting the relationships between red, green, and blue coordinates. Viewing the data from multiple perspectives provides a comprehensive understanding of the color dynamics, revealing intricate patterns and dependencies within the images.



(a) Orange Marilyn RGB Space Angle 1 (b) Orange Marilyn RGB Space Angle 2 (c) Orange Marilyn RGB Space Angle 3 (d) Orange Marilyn RGB Space Angle 4

Figure 4: The RGB space occupied by the pixels for the entire image of Orange Marilyn

Figure 4 displays the RGB space occupied by the pixels of the entire image of Orange Marilyn from four different angles. Each subplot reveals the distribution and density of pixel colors in the 3D RGB color space. In (a), we observe a concentrated cluster of colors, indicating a dominant presence of certain hues. In (b), the distribution spreads more horizontally, highlighting the range of green and blue values. Plot (c) shows a vertical spread, emphasizing the interplay between red and blue, while (d) combines these perspectives, showcasing a broader color distribution and illustrating the complex color dynamics present in the image. These multiple viewpoints allow for a comprehensive understanding of the color relationships within the artwork.

The following is a reference to the whole figure above, type this in .Rmd:

`Figure \ref{fig:orange_marilyn_scatter}`

It will show as:

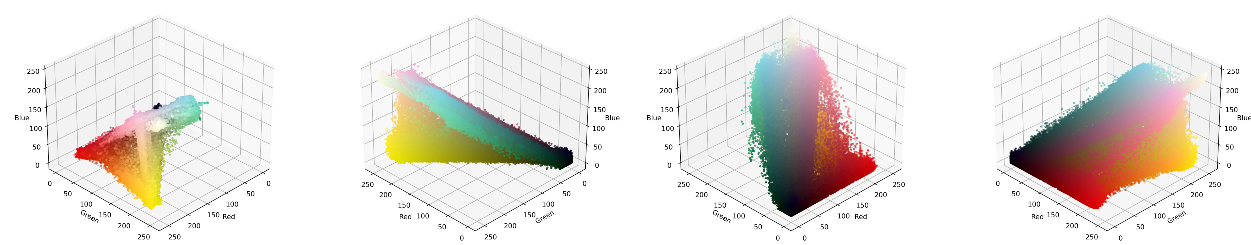
Figure 4

To reference a subplot:

`Figure \ref{fig:4_2_orange_marilyn_original_scatter}`

It will show as:

Figure 4b



(a) Red Marilyn RGB Space Angle 1 (b) Red Marilyn RGB Space Angle 2 (c) Red Marilyn RGB Space Angle 3 (d) Red Marilyn RGB Space Angle 4

Figure 5: The RGB space occupied by the pixels for the entire image of Red Marilyn

The following is a reference to the whole figure above, type this in .Rmd:

`Figure \ref{fig:red_marilyn_scatter}`

It will show as:

Figure 5

To reference a subplot:

`Figure \ref{fig:4_7_red_marilyn_original_scatter}`

It will show as:

Figure 5c

6 Clustering based on Region of Interest (ROI)

7 Repair Gunshot of Image

8 Disuccsion

9 Conclusion and Future Work