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

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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

In May 2022, one of Andy Warhol's "Shot Marilyn" portraits set a new auction record, selling for $195 million, as reported by the Los Angeles Times. This unprecedented sale has renewed both public and scholarly interest in Warhol's work, highlighting the enduring impact of his art on contemporary culture. The "Shot Marilyns" series holds immense value, not only monetarily but also in its profound impact on contemporary art and its reflection of societal themes. The record-breaking auction underscores its continued relevance and fascination (Vankin 2022). Furthermore, Marilyn Monroe remains an iconic figure whose image has permeated

popular culture. Her tragic life story, coupled with her enduring allure, makes her an intriguing subject for artistic exploration (Gallery 2019). Warhol's unique art style, characterized by his use of silkscreen printing and vibrant color schemes, offers a rich field for visual analysis. His method of mass-producing images and manipulating colors challenges traditional notions of art and celebrity, making the "Shot Marilyns" series a perfect case study for understanding his innovative approach (Lanchner and Warhol 2008). Through this analysis, we aim to uncover new insights into the interplay between celebrity, media, and art, enriching our understanding of both Warhol's work and Monroe's legacy.

In 1964, amidst the bustling atmosphere of Andy Warhol's studio, The Factory, a significant event led to the creation of the "Shot Marilyns" series. Warhol, deeply influenced by Marilyn Monroe's tragic death in 1962, began producing silkscreen portraits of her, capturing the iconic actress's image through repetitive, vivid depictions (Christie's 2022). The "Shot Marilyns" series features five portraits shown in Figure 1, each rendered in different color schemes.

(a) Orange Marilyn (b) Red Marilyn (c) Turquoise Marilyn

(d) Blue Marilyn (e) Eggblue Marilyn

Figure 1: The five portraits in Andy Warhol's "Shot Marilyns" series, each showcasing Marilyn Monroe in distinct color schemes: (a) Orange Marilyn, (b) Red Marilyn, (c) Turquoise Marilyn, (d) Blue Marilyn, and (e) Eggblue Marilyn. These variations exemplify Warhol's innovative use of color and his unique approach to portraiture. Image source: The Interior Review. Retrieved from https://www.theinteriorreview.com/story/2022/5/10/critically-assessing-warhols-shot-sage-blue-marilyn.

The name "Shot Marilyns" originates from an incident involving Dorothy Podber, a performance artist and frequent visitor to The Factory. One day, Podber, accompanied by Warhol's friend and photographer Bill Name, observed the Marilyn portraits lined up against a wall. She asked Warhol for permission to "shoot" them, which Warhol, interpreting it as a request to photograph the artworks, granted. Unexpectedly, Podber pulled out a revolver and fired a shot, piercing four of the five canvases through the forehead (Ghighi 2022). This act of violence not only created physical damage but also added a layer of historical intrigue and controversy to Warhol's work, further embedding it into the fabric of pop culture and art history.

In this paper, we aim to conduct a comprehensive analysis of Andy Warhol's "Shot Marilyns" series using several advanced techniques. First, we will analyze the relative conditional entropy of the pixel color distribution in RGB (red, green, blue) space to understand the variations in color across the different portraits. This will provide insights into the underlying patterns and complexity of Warhol's use of color. Next, we will create 3D scatter plots to visualize how each pixel color is distributed in the RGB space, enabling us

to observe the distinct color palettes used in each image. We will also apply K-means cluster analysis to identify and compare the primary color clusters within the portraits, highlighting different regions of interest (ROI) such as the background, hair, eyeshadow, and face. Additionally, we will focus on digitally repairing the "Blue Marilyn" using K-Nearest Neighbors to model and analyze the RGB distribution around the gunshot-damaged area. This restoration will involve capturing the gunshot region and using color distribution data to reconstruct the damaged section, preserving the artwork's integrity. Through these methods, we aim to gain a deeper understanding of Warhol's artistic techniques and the visual impact of his "Shot Marilyns" series. While our analysis strives for objectivity, we acknowledge that interpretations of art can be inherently subjective.

2 Methods

An image is composed of pixels, each containing three color components: Red (R), Green (G), and Blue (B), denoted as (R, G, B) respectively. These components determine the intensity of their respective colors, with each component represented by an integer value within the range of 0 to 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. For this study, each image in the "Shot Marilyns" series has a resolution of 960 by 960 pixels.

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 introduced by Shannon (1948).

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 examine the color dynamics in Andy Warhol's "Shot Marilyns" series. For each image, we specified 15 clusters and used the "k-means++" initialization method. This initialization method, introduced by Arthur and Vassilvitskii (2007), improves the convergence speed and accuracy of the K-Means algorithm by spreading out the initial cluster centers. This method is particularly effective in avoiding poor clustering results due to the random placement of initial centroids.

Mathematically, the K-Means algorithm minimizes the following objective function:

$$J = \sum_{i=1}^{k} \sum_{x \in C_i} \|x - \mu_i\|^2 \tag{4}$$

where k is the number of clusters, C_i is the set of points belonging to cluster i, x represents a data point, and μ_i is the centroid of cluster i. The "k-means++" algorithm initializes the centroids by first selecting one

random data point as the first centroid. Subsequent centroids are chosen based on a probability proportional to the squared distance from the nearest existing centroid. This process can be expressed as:

$$P(x) = \frac{D(x)^2}{\sum_{x' \in X} D(x')^2} \tag{5}$$

where $D(x)$ is the distance from the point x to the nearest centroid already chosen.

Using this method, we applied K-Means clustering to the entire images and specific regions of interest (ROI) in each image. The clustering algorithm grouped pixels into clusters based on their RGB values, effectively identifying the predominant colors in each image. This approach 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 ribbon visualizations. 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 Region of Interest (ROI) analysis, we targeted specific segments of the images such as the background, hair, eye shadows, and face. We began by converting the images to the HSV color space using OpenCV's conversion functions, which facilitate more effective identification and segmentation of specific color ranges. By manually determining the minimum and maximum HSV values within selected regions, we created color masks using OpenCV's masking functions to isolate these target areas. These masks highlighted the pixels that fell within the specified HSV range, effectively isolating the desired colors from the rest of the image. Once the masks were applied, we used image processing techniques to extract only the parts of the image that matched the mask, discarding the rest. This allowed us to focus on the color features of interest. The resultant ROIs were then processed and saved for detailed analysis. This method, enhanced by the precise capabilities of OpenCV and guided by best practices from Culjak et al. (2012), enabled us to highlight specific color features in Warhol's artwork, providing nuanced insights into his use of color and its variations, and ensuring accurate and efficient color segmentation and analysis.

2.4 K-Nearest Neighbors Repair

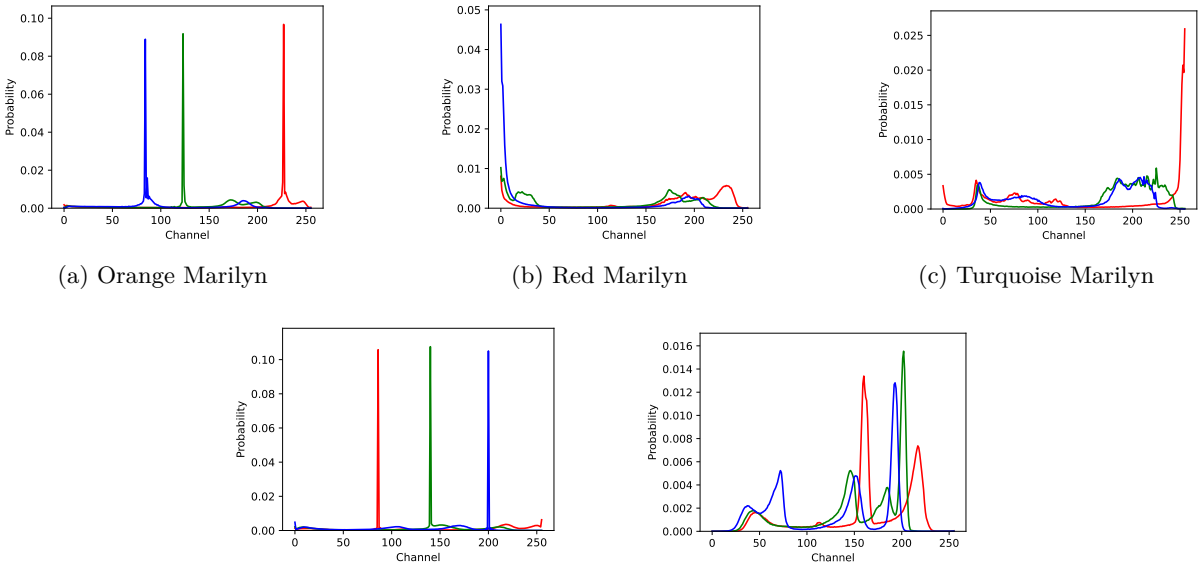
To address the damaged sections of the "Blue Marilyn" image, we employed K-Nearest Neighbors (KNN) regression for image repair. This method involves identifying the coordinates of the damaged pixels and using the surrounding undamaged pixels to predict their values. The KNN regression model, with a specified 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 titled Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn. These images are digitally encoded in the RGB color channels, which synthesize a spectrum of colors through the additive mixing of Red, Green, and Blue lights. To enhance future data visualizations, we also converted the RGB values into Hexadecimal representations. Each image measures 960 by 960 pixels, resulting in 921,600 unique data points per image, each specified by a distinct location and chromatic composition. In this additive color model, the intensity of each primary color (Red, Green, and Blue) is quantized into discrete levels ranging from 0 to 255, providing a finite palette within this cubic color space. Each pixel's color is quantified based on the RGB values, making it part of a discrete color space where the combination of these three channels can reproduce a wide array of colors.

Our initial analysis involved examining the distribution profiles of the RGB channels in the images. Figure 2 illustrates the variations in the red, green, and blue distributions across the five images. Notably, images (a) and (d) exhibit significant differences compared to the others.

In the Orange Marilyn image (a), the blue channel's highest probability density is localized within the [50, 100] range, reaching approximately 8.5%. The green channel peaks between [120, 130] with a probability



(a) Orange Marilyn (b) Red Marilyn (c) Turquoise Marilyn

(d) Blue Marilyn (e) Eggblue Marilyn

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

around 9%. Additionally, the blue channel shows another notable concentration in the [220, 240] range, with a likelihood of about 10%.

Interestingly, the green channel probabilities in image (d) closely mirror those in image (a), predominantly in the [120, 130] range. However, image (d) differs significantly in the red and blue spectra. The red channel in image (d) peaks in the [70, 80] range with an 11% likelihood, while the blue channel's highest probability is within the [190, 210] range, also accounting for an 11% probability. These differences in the red and blue channel distributions between images (d) and (a) highlight their unique color distribution attributes.

Images (b) Red Marilyn and (c) Turquoise Marilyn display highly skewed patterns. Image (b) shows a right-skewed distribution with the blue channel having the highest probability around 0.05, while the red and green channels are not as distinctive. In contrast, image (c) is left-skewed, with the red channel showing the highest probability around 0.025. Both images exhibit less distinct differences between the red, green, and blue distributions.

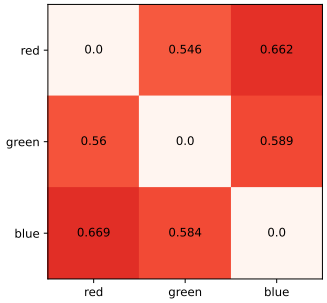
The Eggblue Marilyn image (e) presents a harmonious entanglement of the red, blue, and green channels. Each channel has a relatively similar probability distribution, with no single color dominating significantly. The red, blue, and green channels each have their highest probabilities around 0.015, indicating a balanced color distribution across the image.

This analysis reveals the diverse color distribution patterns in Warhol's "Shot Marilyns," highlighting the unique attributes and artistic techniques employed in each painting.

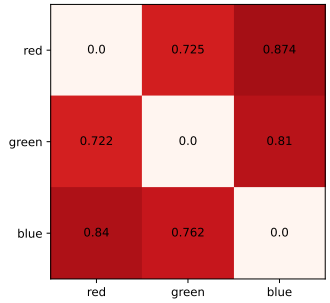
After analyzing the RGB distribution of each image, we further investigated the relationship between pairs of primary colors in the five images by calculating their relative conditional entropy (HR) (see Methods 2.1). This metric quantifies the shared information or dependency between two color channels, 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 3 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.

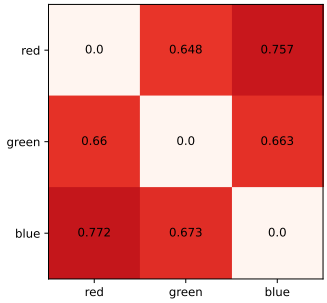
In the Orange Marilyn image (a), the HR values are relatively high between different color pairs, with the blue and red channels showing an HR value of 0.669, indicating a moderate level of independence.



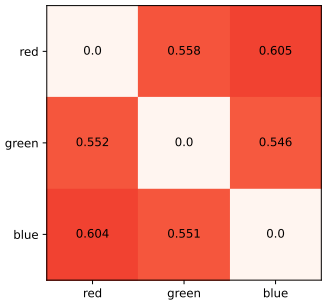
(a) Orange Marilyn Relative Conditional Entropy



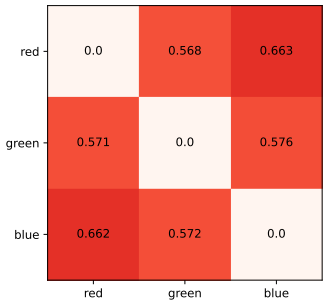
(b) Red Marilyn Relative Conditional Entropy



(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

In the Red Marilyn image (b), all the pairs has higher HR values compare to the other images which indicated red, blue, and green colors high independence each other. Notably, the HR value for the red channel relative to the blue channel is 0.874, signifying very strong independence between these two channels.

For the Turquoise Marilyn image (c), the HR values also reflect notable independence between color pairs. The HR value between the red and blue channels is 0.757, and between the blue and green channels, it is 0.673, indicating a significant level of independence among the color channels.

The Blue Marilyn image (d) exhibits moderate HR values between the color pairs. The red and blue channels showing an HR value of 0.605 and the green and blue channels at 0.546. This suggests a balanced dependency among the color channels in other images.

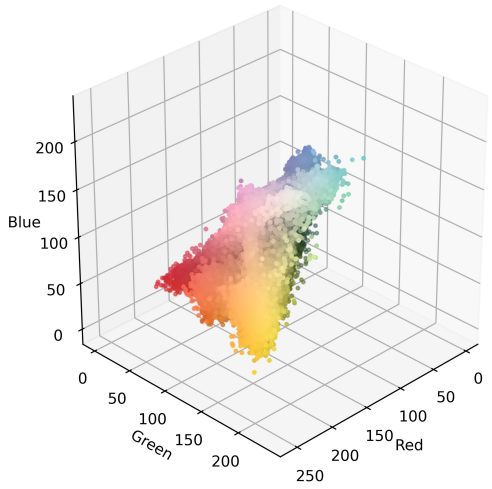
Finally, the Eggblue Marilyn image (e) shows harmonious HR values among the color pairs, with the red and blue channels having an HR value of 0.663 and the green and blue channels at 0.572. These values indicate a moderate level of independence among the color channels.

Overall, these HR values highlight the unique color relationships and dependencies within each of Warhol's "Shot Marilyns" paintings, providing insights into his use of color to create depth and visual interest.

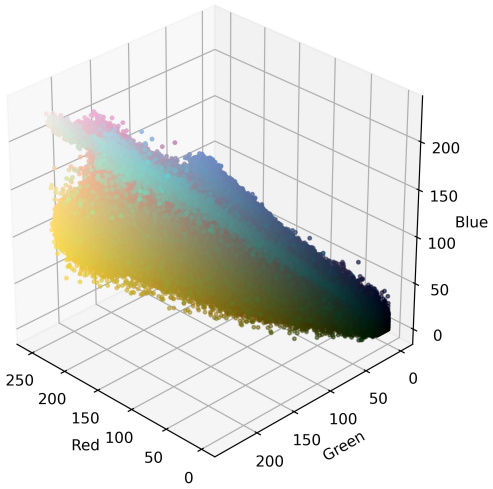
4 Data Exploration and Visualization Analysis

The figures below display the RGB space occupied by the pixels of various Marilyn paintings from four different angles. Each subplot reveals the distribution and density of pixel colors in the 3D RGB color space, providing insights into the color composition and variations within the images.

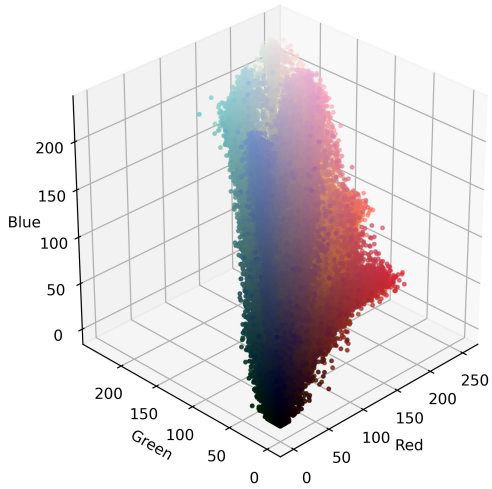
Figure 4 displays the RGB space of "Orange Marilyn" from four different angles. In (a), the density of pixels representing the background part of the image is shown, revealing a balanced mix of colors including orange, yellow, pink, red, and blue. These colors reflect the different dominant areas of the painting: the orange background, yellow hair, pink face, red lips, and blue eye shades. The shape of the 3D scatter plot in (a)



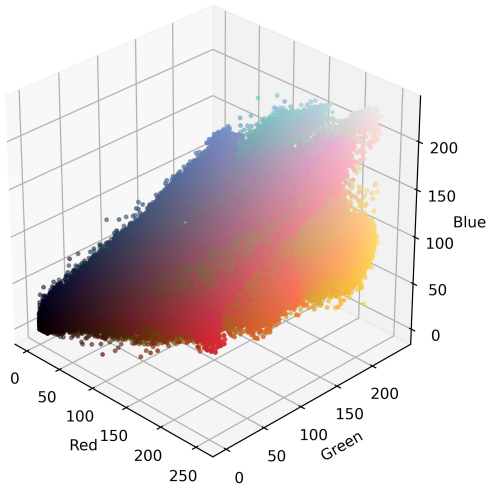
(a) Orange Marilyn RGB Space



(b) Orange Marilyn RGB Space



(c) Orange Marilyn RGB Space



(d) Orange Marilyn RGB Space

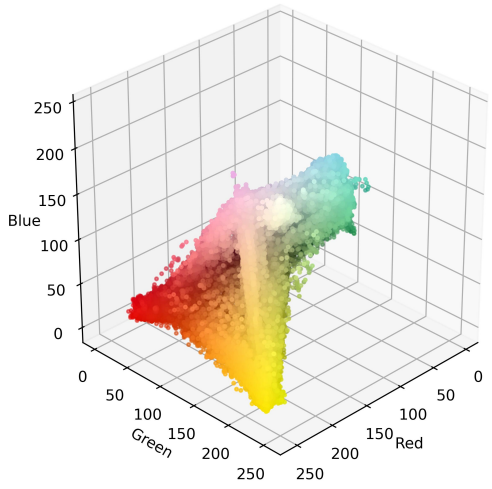
Figure 4: The RGB space occupied by the pixels for the entire image of Orange Marilyn, showing different angles: (a) 30 °elevation, 45 °azimuth, (b) 30 °elevation, 135 °azimuth, (c) 30 °elevation, 225 °azimuth, (d) 30 °elevation, 315 °azimuth. These variations highlight the color distribution within the artwork.

indicates a broad, dispersed distribution of colors, showing the diverse color use in the background and facial features.

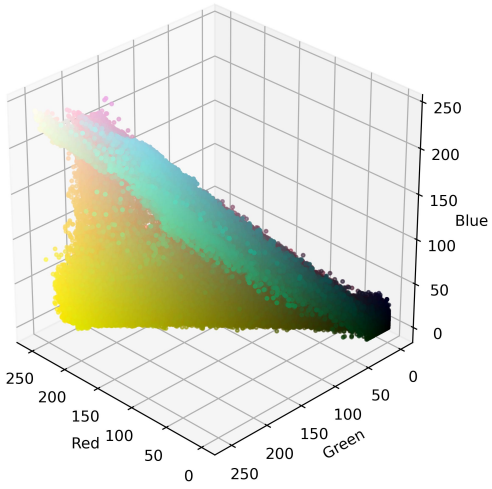
In (b), the plot illustrates how colors are distributed from darker pixels at the bottom to brighter pixels at the top, highlighting shading gradients. This gradient reflects the shading around Marilyn's facial features and hair, adding depth to the portrait. The darker pixels likely represent shadows in the hair and facial contours, while the brighter pixels correspond to highlights on her face and hair.

In (c), the concentration of the brightest pixels is evident, showing specific groupings likely related to prominent features. This highlights the intense colors used in Marilyn's lips, eyes, and other facial highlights. The plot suggests a focused clustering of bright colors, indicating areas where Warhol applied more vivid hues to draw attention.

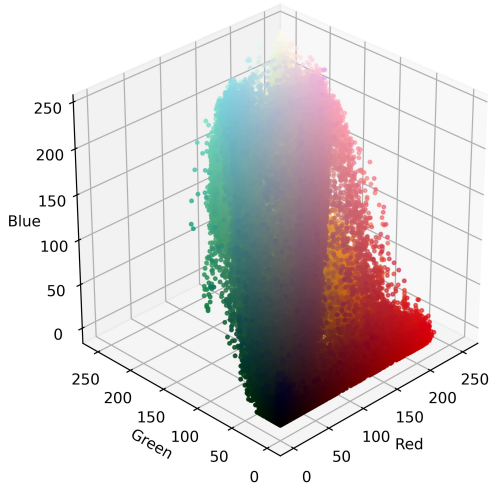
In (d), the color distribution from dark to light is presented from a different angle, allowing us to observe the distribution of colors in areas such as hair and eye shades with less red. This provides a different perspective on the artwork's color dynamics, showing how the turquoise and yellow shades in the hair and the blue in the eyes are distributed. The shapes in (b) through (d) all reflect a similar elongated form, resembling a long funnel, showing a clear gradient from dark to light colors. This consistent shape across different angles highlights the structured way Warhol applied color to create depth and contrast in the "Orange Marilyn" painting.



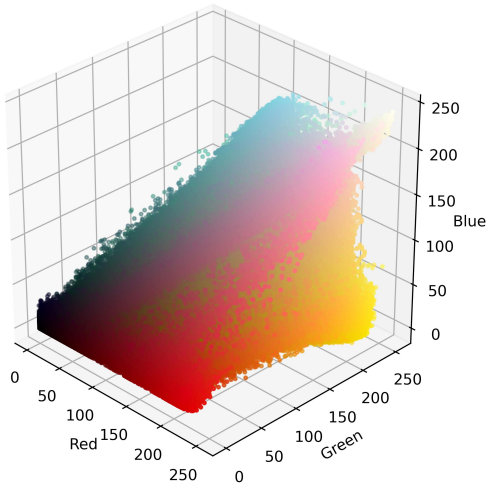
(a) Red Marilyn RGB Space



(b) Red Marilyn RGB Space



(c) Red Marilyn RGB Space



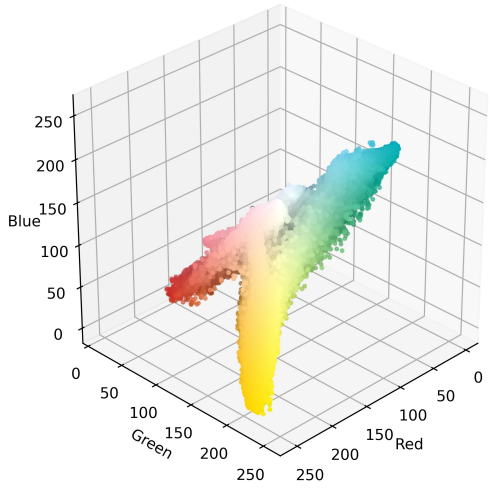
(d) Red Marilyn RGB Space

Figure 5: The RGB space occupied by the pixels for the entire image of Red Marilyn, showing different angles: (a) 30 °elevation, 45 °azimuth, (b) 30 °elevation, 135 °azimuth, (c) 30 °elevation, 225 °azimuth, (d) 30 °elevation, 315 °azimuth. These variations highlight the color distribution within the artwork.

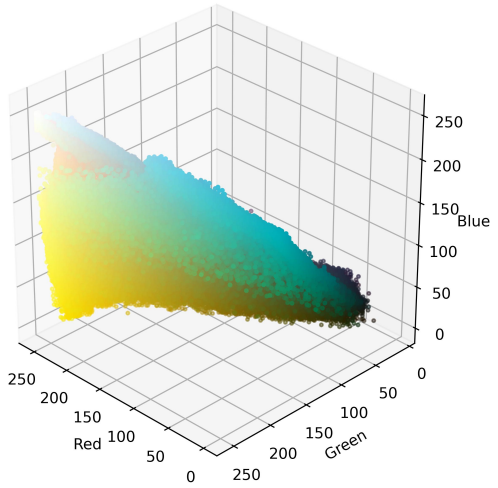
Figure 5 displays the RGB space of "Red Marilyn" from four different angles. The red color represents the background of the portrait. The yellow color of Marilyn's hair is brighter than "Orange Marilyn," along with her eye shadow and clothes.

In (a), the colors and shape of the figure is similar to the corresponding image for "Orange Marilyn." However, there is a much larger prominence of orange, creating a concave shape at the lower left. The longer stretches of yellow and blue correspond to the brighter shades of these colors in this portrait, compared to "Orange Marilyn."

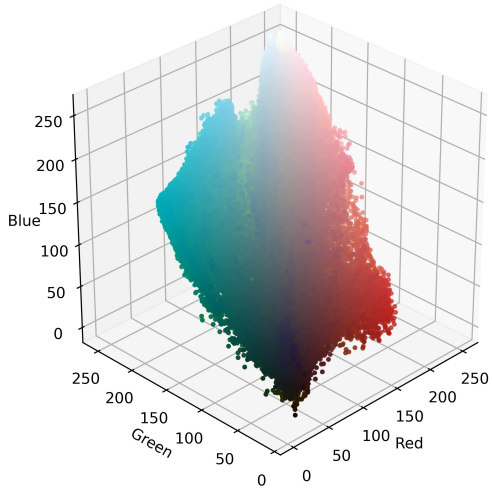
The shapes in (b) through (d) all reflect a similar elongated form as seen in "Orange Marilyn," but with a more spread-out appearance, resembling a long and thick funnel. This shape shows a clear gradient from dark to light colors, indicating that the colors are brighter, bolder, and more impactful than in "Orange Marilyn." This consistent shape across different angles highlights the structured way Warhol applied color to create depth and contrast in the "Red Marilyn" painting.



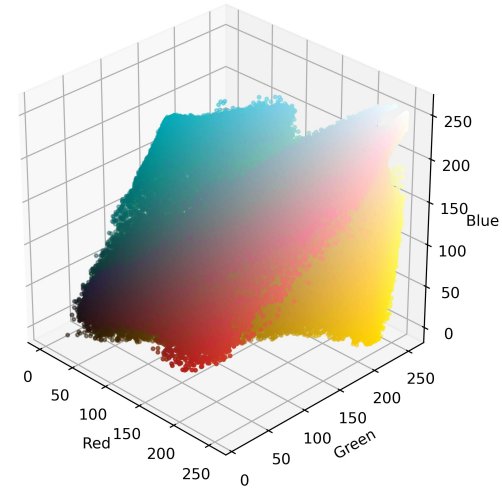
(a) Turquoise Marilyn RGB Space



(b) Turquoise Marilyn RGB Space



(c) Turquoise Marilyn RGB Space



(d) Turquoise Marilyn RGB Space

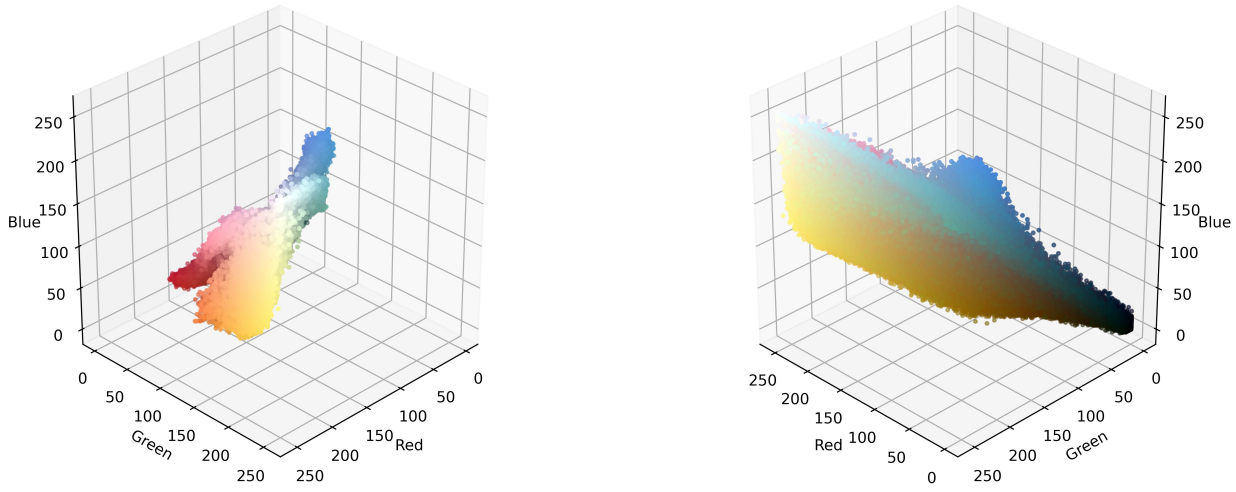
Figure 6: The RGB space occupied by the pixels for the entire image of Turquoise Marilyn, showing different angles: (a) 30 °elevation, 45 °azimuth, (b) 30 °elevation, 135 °azimuth, (c) 30 °elevation, 225 °azimuth, (d) 30 °elevation, 315 °azimuth. These variations highlight the color distribution within the artwork.

Figure 6 displays the RGB space of "Turquoise Marilyn" from four different angles. The turquoise color represents the background. The color of Marilyn's hair, skin, and eye shadow are the brightest of all five portraits. There is also a distinct lack of color to the right of her neck. This is all showcased in the RGB space.

Unlike the previous two portraits, the shape image (a) for "Turquoise Marilyn" lacks a prominent amount of orange color, creating an upside down "V" shape.

Image (b) through (d) are similar to the previous "Shot Marilyn's," just with lighter shades of color. The wide shapes for each one resemble "Red Marilyn."

The shapes in (a) through (d) reflect a similar elongated form, resembling a long and wide funnel, showing a clear gradient from dark to light colors. This highlights how the colors are brighter in "Turquoise Marilyn," emphasizing the structured application of color by Warhol to create depth and contrast.



(a) Blue Marilyn RGB Space

(b) Blue Marilyn RGB Space

Figure 7 displays the RGB space of "Blue Marilyn" from four different angles. The blue represents the background of the portrait. The colors representing Marilyn's hair and skin are darker than all of the previous portraits. The smaller shapes in image (a) through (d) are similar to "Orange Marilyn." The colors in each RGB space are less spread out, while the shades of color themselves are darker than the previous portraits.

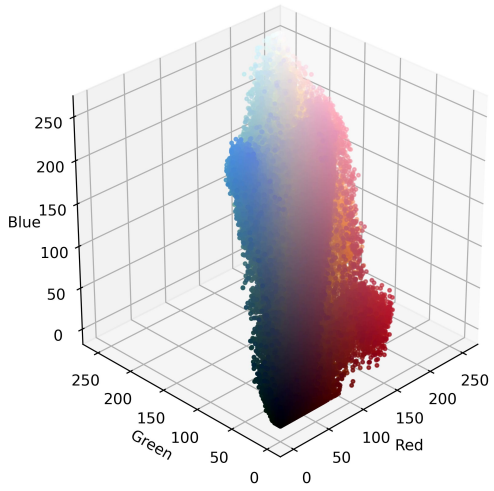
Figure 8 displays the RGB space of "Eggblue Marilyn" from four different angles. The eggblue color is from the background of the portrait. The images of this figure show that the colors Warhol used for this portrait were darker than any of previous four.

In (a), the pixels are closer together, creating a smaller shape. There are also small vibrant pixels of white on the top of the shape, representing Marilyn's teeth.

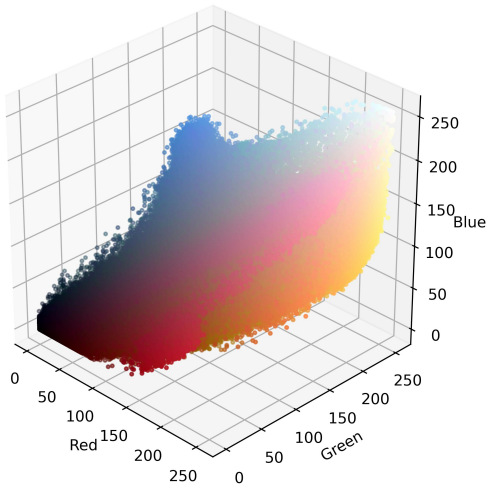
The funnel shape in image (b) is relatively narrow, especially when compared to "Red Marilyn." This shows how subdued the colors are when compared to the previous portraits.

In (c), the plot emphasizes the concentration of the brightest pixels, showing specific groupings likely related to Marilyn's lips, eyes, and other highlighted features. This view shows the backside of (a), reaffirming the significant presence of egg blue pixels. The yellow and pink pixels are prominently visible, highlighting the extensive use of these colors in the hair and facial features. While the overall shape and distribution of colors remains the same as the other portraits, this image stands out because of the scattering of bright white in the shape. These represent Marilyn's teeth and are prominent because of the contrast with the darker colors of the portrait. Image (d) is similar to (c), albeit the prominence of the bright white color is smaller.

Overall, these shapes and color distributions highlight how Warhol used color to create depth and contrast in the five "Shot Marilyn" portraits. The different angles reveal the prominence of each background color and the varying shades of Marilyn's features, showcasing Warhol's strategic use of color. The detailed analysis of

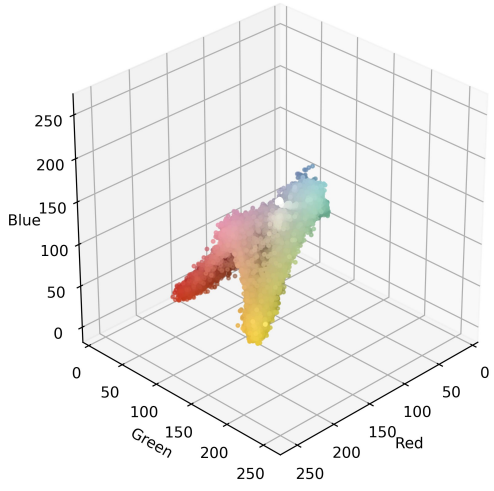


(c) Blue Marilyn RGB Space

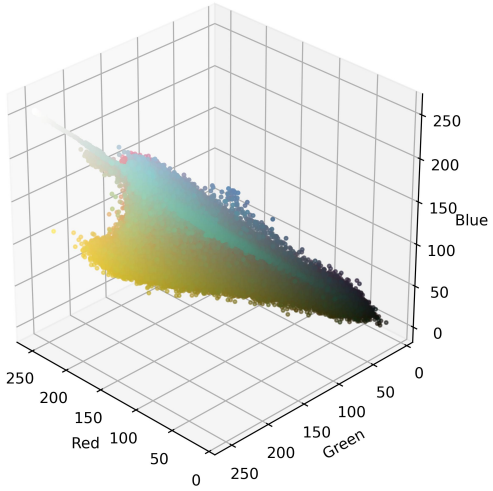


(d) Blue Marilyn RGB Space

Figure 7: The RGB space occupied by the pixels for the entire image of Blue Marilyn, showing different angles: (a) 30 °elevation, 45 °azimuth, (b) 30 °elevation, 135 °azimuth, (c) 30 °elevation, 225 °azimuth, (d) 30 °elevation, 315 °azimuth. These variations highlight the color distribution within the artwork.



(a) Eggblue Marilyn RGB Space

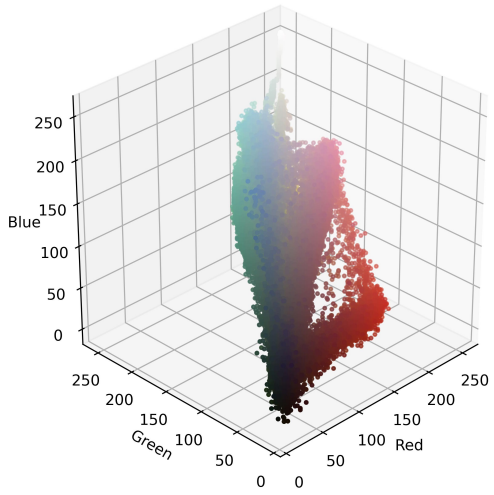


(b) Eggblue Marilyn RGB Space

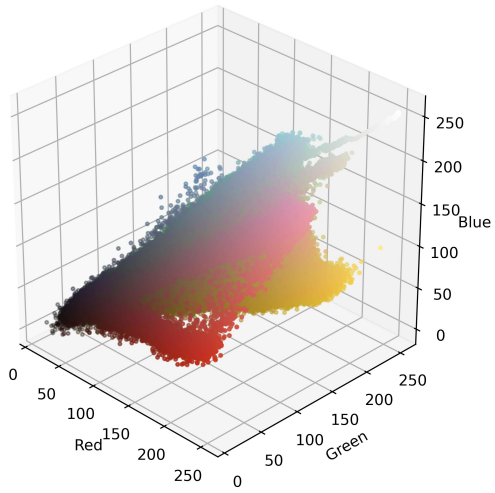
each angle provides insights into how specific colors dominate different parts of the painting and contribute to its overall visual impact.

5 Clustering based on Whole Images

Figure 9 showcases the clustered bar representation of pixel distribution across various Marilyn paintings. The Orange, Blue, and Eggblue paintings each exhibit a prominent clustered bar, indicating a strong concentration of pixels within a specific color range for their respective backgrounds. This signifies a high degree of uniformity and consistency in the background hues of these paintings. In contrast, the Red Marilyn painting displays a dual-pronged approach with two distinct, yet prominent bars. These bars represent the pixels

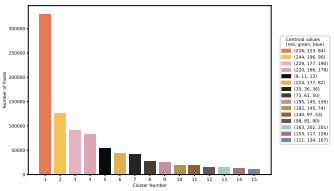


(c) Eggblue Marilyn RGB Space

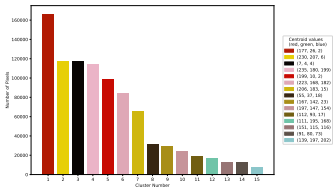


(d) Eggblue Marilyn RGB Space

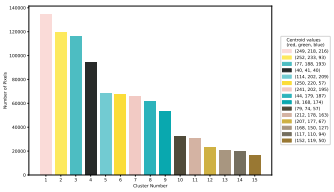
Figure 8: The RGB space occupied by the pixels for the entire image of Eggblue Marilyn, showing different angles: (a) 30 °elevation, 45 °azimuth, (b) 30 °elevation, 135 °azimuth, (c) 30 °elevation, 225 °azimuth, (d) 30 °elevation, 315 °azimuth. These variations highlight the color distribution within the artwork.



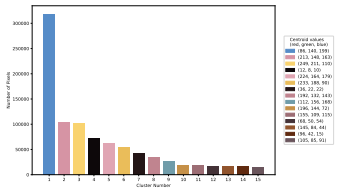
(a) Orange Marilyn Cluster Bar Plot



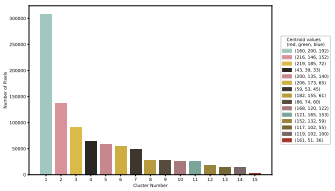
(b) Red Marilyn Cluster Bar Plot



(c) Turquoise Marilyn Cluster Bar Plot



(d) Blue Marilyn Cluster Bar Plot



(e) Eggblue Marilyn Cluster Bar Plot

Figure 9: xxx.

comprising both the background and the lips, underscoring the intentional use of red to emphasize both these elements. Meanwhile, the Turquoise Marilyn painting reveals a more complex picture, with four clustered bars grouped under the conceptual umbrella of "Turquoise." These bars encompass the colors of the background, eye shadows, and collar, suggesting a broader color palette within this designated category. However, upon closer inspection, it becomes evident that the actual color distribution within this "Turquoise" grouping is far from uniform, revealing inconsistencies that add depth and complexity to the painting.

An interesting pattern emerges in the clustering of colors, particularly with regards to yellow or golden hues, as the hair color pixels are segmented into 3 to 4 distinct clusters, reflecting variations in tone and shading. Similarly, the colors depicting the face are classified into three groups, highlighting the nuanced use of hues to capture the intricacies of facial features.

Examining the centroid values for the Orange, Blue, and Eggblue paintings, it becomes clear that the higher the prominence of one RGB color, the less evenly distributed the color becomes. For example, in the Orange painting, the centroid values for the first cluster are (226, 123, 84), indicating a strong emphasis on the red color. In contrast, the second and third clusters exhibit a more balanced distribution of RGB values, with no other clusters displaying a similar orange color as the first cluster. This suggests that the heavy emphasis on a single color in the first cluster results in a higher concentration of that color, leading to a greater number of pixels in that cluster.

In the Blue painting, the centroid values for the highest cluster are (86, 140, 199), with a notable emphasis on the blue color. The remaining clusters show a more even distribution of centroid values, with only cluster number nine having a similar color scheme to the first cluster. Similarly, in the Eggblue painting, the first cluster has centroid values of (160, 200, 192), with green being the dominant color. This concentration of a single color results in most pixels being concentrated in that cluster, with only cluster eleven displaying a similar color to the first cluster.

For the Red painting, the first cluster has centroid values of (177, 26, 2), with a higher concentration of red. Other clusters with a significant number of pixels also contain a substantial amount of red, leading to a more even distribution between clusters. The same pattern is observed in the Turquoise painting, where the cluster bars have either an even amount of red and green or green and blue, resulting in a more uniform distribution of the cluster bars.

(a) Orange Marilyn Clustered Ribbon

(b) Red Marilyn Clustered Ribbon

(c) Turquoise Marilyn Clustered Ribbon

(d) Blue Marilyn Clustered Ribbon

(e) Egg Blue Marilyn Clustered Ribbon

Figure 10: Clustered Color Ribbons Depicting Dominant Color Distribution Across Warhol's "Shot Marilyns"

Figure 10 presents the clustered ribbons for each of the five Marilyn images, revealing the dominant colors and their distribution across the entire image. The ribbons visually represent the clustering of pixels based on their color similarities, providing insights into the overall color dynamics within each painting.

In the Orange Marilyn image (a), the ribbon is dominated by a large orange section, reflecting the uniformity of the background color. This is followed by smaller segments of yellow, pink, and black, indicating the presence of these colors in the hair, face, and shadows, respectively. The remaining smaller clusters represent more subtle variations in the image's color palette, highlighting the simplicity and consistency of color usage in this painting.

The Red Marilyn image (b) shows a prominent red section, emphasizing the bold background color. This is contrasted with significant yellow and black sections, representing the hair and shadows, along with pink segments for the facial tones. Compared to the Orange Marilyn, the Red Marilyn displays a more varied and complex color distribution, with a greater emphasis on contrast and depth. The presence of the black section in both ribbons indicates the shared use of dark tones for shadowing, but the proportions and placements differ, suggesting a distinct approach to color composition.

In the Turquoise Marilyn image (c), the ribbon displays a more varied color palette, with prominent sections of turquoise, yellow, and black. The turquoise section reflects the background color, while the yellow and black represent the hair and shadows. This image shows a broader range of hues compared to Orange and Red Marilyn, indicating a more intricate composition. The turquoise color, in particular, is unique to this image and plays a central role in defining its visual impact.

The Blue Marilyn image (d) is dominated by a large blue section, corresponding to the background color. This is followed by significant segments of pink, yellow, and black, representing the face, hair, and shadows. Compared to the other images, Blue Marilyn has a more balanced use of hues, with the blue background being complemented by well-defined areas of other colors. The distribution of these colors suggests a clear distinction between the different elements of the image, similar to the structure observed in the Red Marilyn but with a cooler overall tone.

Finally, the Egg Blue Marilyn image (e) shows a harmonious distribution of colors, with a large section of egg blue, followed by pink, yellow, and black segments. This ribbon highlights the balanced and cohesive color scheme used in the painting, with each color contributing to the overall composition without overpowering the others. Compared to the other images, Egg Blue Marilyn shares similarities with both Blue and Turquoise Marilyn in terms of color harmony but stands out due to its softer, more pastel-like palette.

Cross-comparisons between the ribbons reveal distinct color strategies across the five Marilyn images. For instance, both Red and Orange Marilyn feature strong, bold background colors (red and orange, respectively), but the Red Marilyn uses a wider range of contrasting colors, resulting in a more dynamic visual effect. In contrast, Turquoise and Blue Marilyn share a more balanced distribution of colors, but the unique presence of turquoise and blue as dominant colors sets them apart from the others. Egg Blue Marilyn, with its more subdued and harmonious palette, offers a softer contrast compared to the bold and striking colors in Red and Orange Marilyn.

Overall, these clustered ribbons illustrate the distinct color strategies employed in each of Warhol's "Shot Marilyns" paintings, showcasing his deliberate use of color to create visual impact and evoke different perceptions in the viewer. The analysis of these ribbons provides a deeper understanding of the color dynamics at play, revealing both the uniformity and complexity of Warhol's color choices across the series.

6 Clustering based on Region of Interest (ROI)

a) Orange Marilyn b) Red Marilyn c) Turquoise Marilyn d) Blue Marilyn e) Eggblue Marilyn

Figure 11: Region of Interest (ROI) - Backgrounds

Figure 11 presents five versions of the "Marilyn" image, each with a different background. For each of the five backgrounds, the colors appear to be solid. However, the backgrounds range from solid colors to subtle gradients, creating varying visual effects. Notably, the region of interest (ROI) did not capture any color from the eyeshadow for the turquoise, blue, and egg blue versions of Marilyn. This indicates that the background color and the eyeshadow color are distinct from each other.

Looking at the "Orange Marilyn" features a gradient of orange shades, transitioning from a deep, saturated tone to a lighter hue. This gradient adds depth, making the background more dynamic. "Red Marilyn," on the other hand, has a solid red background, offering a bold and uniform appearance that directs attention to the silhouette. "Turquoise Marilyn" and "Blue Marilyn" both have backgrounds with smooth color transitions. These gradients provide a calming effect, as the colors gradually shift from more saturated to lighter tones. Finally, "Egg Blue Marilyn" uses a light pastel blue with a very subtle gradient, contributing to a soft and serene atmosphere. this one includes wei pharagraph Figure 12, breaks down these backgrounds into clustered ribbons, which highlight the subtle variations within each color. Even the seemingly uniform red background

(a) Orange Marilyn

(b) Red Marilyn

(c) Turquoise Marilyn

(d) Blue Marilyn

(e) Egg Blue Marilyn

Figure 12: Background Clustered Ribbon

in "Red Marilyn" reveals slight differences when analyzed closely. The gradient backgrounds, such as those in "Orange Marilyn" and "Blue Marilyn," show clear transitions between different shades, emphasizing the fluidity of the color shifts.

In Ribbon (a), we can see that the background for the Orange Marilyn is mostly composed of orange with a subtle gradient at the end of the bar, but it is primarily one color.

For Ribbon b), we observe the ribbon for the Red Marilyn background, which shows a more diverse variation of red compared to the orange background. This is noticeable in the background extract itself, which at first glance appears to be a single red color. However, upon closer examination, you can see areas where the color is brighter and others where it is darker.

For Ribbon c), we see the ribbon for the Turquoise Marilyn. In this case, there is also a diverse variation of turquoise color, with the grouping more divided between bright and darker colors. This is noticeable in the background itself, where the lower part is darker and the upper part is lighter.

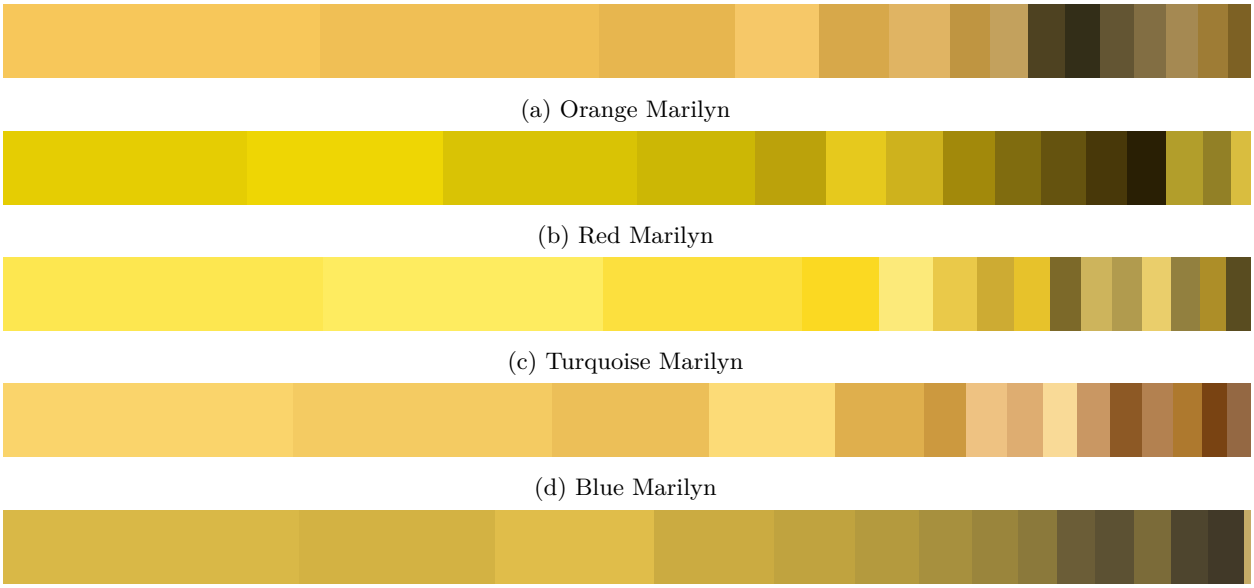
For Ribbon (d), we see the ribbon for the Blue Marilyn. Interestingly, this ribbon has one more prominent color than the other gradients. When we look back at the background itself, this is quite noticeable and makes the background appear flatter since there is only the presence of one color compared to the others.

For Ribbon (e), we see the result for the Egg Blue Marilyn ribbon, where one color is more prominent but still has a good amount of variation. This one is harder to see in the background itself. It looks like a flat color, but there is still some variation in brightness. The backgrounds with more range variation, add more depth to the picture, making it look like there is some type of lighting. Specifically, in the Turquoise Marilyn, the higher range makes it look like there is some type of lighting in the background. In contrast, the Blue Marilyn appears very flat and looks more like a painting. The analysis reveals that the choice and treatment of background colors significantly affect the overall impact of the image. While uniform backgrounds like in "Red Marilyn" create a bold, focused effect, gradient backgrounds introduce depth and tranquility. The clustered ribbon analysis further emphasizes the complexity within each color choice, even when the variation appears minimal to the naked eye. These insights demonstrate how color and gradient manipulation can alter the perception of identical images, highlighting the importance of these elements in visual art.

Figure 13 presents the Region of Interest (ROI) focused on the hair across the five versions of Marilyn: Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn. This analysis isolates the hair to emphasize how Warhol's use of color and shape varies between each version. The variations in brightness and hue across the different images reveal how some of the hair appears brighter, while others fade into darker or blurrier tones, reflecting the different artistic treatments applied to each version. Additionally,

a) Orange Marilyn b) Red Marilyn c) Turquoise Marilyn d) Blue Marilyn e) Eggblue Marilyn

Figure 13: Region of Interest (ROI) - Hair



(a) Orange Marilyn

(b) Red Marilyn

(c) Turquoise Marilyn

(d) Blue Marilyn

(e) Egg Blue Marilyn

Figure 14: Hair Clustered Ribbon

the shape of the hair differs slightly across the images, with some versions featuring more defined curls or waves, while others appear softer and more blended. The black areas between the strands of hair resemble shadows, which were not extracted in this analysis, contributing to the overall depth and dimensionality of the hair in each painting. This shadow-like effect adds to the complexity of Warhol's depiction, highlighting the interplay between light, color, and form in his portrayal of Marilyn.

Figure 14 provides a detailed breakdown of the hair colors through clustered ribbons for each image. These ribbons visually represent the range and distribution of colors within the hair, offering insights into the complexity and depth of Warhol's color choices.

In Ribbon (a) for "Orange Marilyn," the hair color is primarily composed of warm yellows and oranges. The gradient transitions from lighter to darker tones, with a smooth progression that adds depth and dimension to the hair. The presence of subtle darker shades towards the end of the ribbon suggests shadows or darker strands, contributing to a dynamic visual effect.

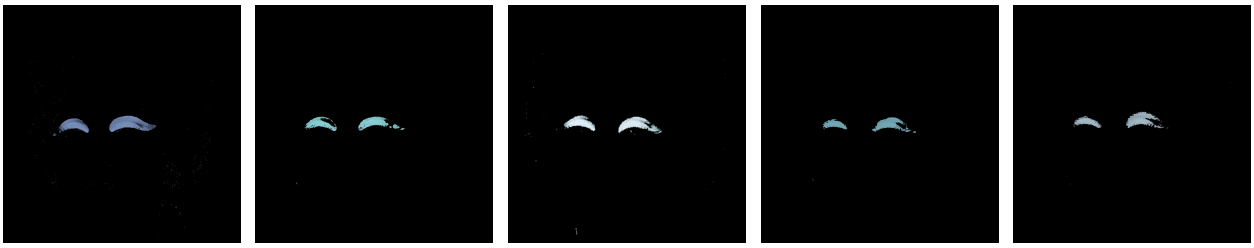
Ribbon (b) for "Red Marilyn" shows a different approach, with the hair colors skewing more towards vibrant yellows and greens. This variation creates a more vivid and lively appearance, with the transitions between colors being more abrupt than in "Orange Marilyn." The darker tones are more concentrated in specific areas, creating a contrast that adds intensity to the hair's appearance.

In Ribbon (c) for "Turquoise Marilyn," the hair colors exhibit a broader range of yellows, with a gradual transition from light to darker tones. The ribbon shows more subtle variations compared to the previous images, with a smoother blend of colors. This approach gives the hair a softer and more cohesive appearance, with less emphasis on stark contrasts.

Ribbon (d) for "Blue Marilyn" reveals a distinct shift in color dynamics, with the hair incorporating more browns and beiges alongside the yellows. The color transitions are more pronounced, creating a layered effect that gives the hair a textured and multi-dimensional look. The darker tones are more prominent in this ribbon, adding depth to the overall appearance.

Finally, Ribbon (e) for "Egg Blue Marilyn" shows a balanced distribution of yellows and greens, with a noticeable presence of darker shades towards the end of the ribbon. The smooth gradient and subtle shifts in color create a harmonious and natural appearance, reflecting a careful manipulation of light and shadow to add depth to the hair.

These clustered ribbons highlight the distinct approaches Warhol used to depict the hair in his "Shot Marilyns" series. Each image's hair color treatment significantly impacts the overall mood and perception of the artwork, with some versions emphasizing vibrancy and contrast, while others focus on harmony and subtlety. The analysis of hair color distribution provides a deeper understanding of Warhol's artistic choices, showcasing how his manipulation of color can alter the impact of a visual element across different versions of the same subject.



a) Orange Marilyn b) Red Marilyn c) Turquoise Marilyn d) Blue Marilyn e) Eggblue Marilyn

Figure 15: Region of Interest (ROI) - Eyeshadow

(a) Orange Marilyn

(b) Red Marilyn

(c) Turquoise Marilyn

(d) Blue Marilyn

(e) Egg Blue Marilyn

Figure 16: Eyeshadow Clustered Ribbon

Figure 15 presents the Region of Interest (ROI) focused on the eyeshadow across the five versions of Marilyn: Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn. This analysis isolates the eyeshadow to highlight how Warhol's use of color varies between each version. The differences in hue and intensity reveal Warhol's diverse artistic approaches, ranging from subtle tones to bold contrasts, which contribute to the overall mood and visual impact of each painting. Notably, within these eyeshadows, there are areas of black in the middle of the brow bone that we did not extract. These black areas represent

shadows cast by the eye bone, adding depth and dimension to the eyeshadow and further enhancing the visual complexity of Warhol's work.

Figure 16 displays the distribution of eyeshadow colors through clustered ribbons for each image, offering insights into Warhol's nuanced use of color.

In Ribbon (a) for "Orange Marilyn," the eyeshadow consists primarily of darker blue tones, transitioning from lighter to darker shades, which adds depth and contrast against the orange background.

Ribbon (b) for "Red Marilyn" features softer, pastel-like blues and greens, creating a gentle transition that contrasts with the bold red background.

In Ribbon (c) for "Turquoise Marilyn," the eyeshadow shows a range of brighter turquoise and teal hues, blending smoothly for a cohesive appearance.

Ribbon (d) for "Blue Marilyn" uses muted blues and greys, resulting in a more subdued and blended eyeshadow effect that complements the overall cool tone of the image.

Finally, Ribbon (e) for "Egg Blue Marilyn" displays a harmonious gradient of blues and greys, creating a serene and gentle appearance.

This analysis highlights how each eyeshadow color differs across the series, with "Orange Marilyn" featuring darker tones and "Turquoise Marilyn" showcasing brighter hues. Warhol's varied techniques in depicting eyeshadow across the "Shot Marilyns" series contribute uniquely to the mood and perception of each artwork.

a) Orange Marilyn b) Red Marilyn c) Turquoise Marilyn d) Blue Marilyn e) Eggblue Marilyn

Figure 17: Region of Interest (ROI) - Face

(a) Orange Marilyn

(b) Red Marilyn

(c) Turquoise Marilyn

(d) Blue Marilyn

(e) Egg Blue Marilyn

Figure 18: Face Clustered Ribbon

Figure 17 presents the Region of Interest (ROI) focused on the face across the five versions of Marilyn: Orange Marilyn, Red Marilyn, Turquoise Marilyn, Blue Marilyn, and Eggblue Marilyn. This analysis highlights the variations in how Warhol depicted Marilyn's face across these versions, emphasizing differences in skin tones, shading, and contrast. The differences in hue and tone across the various versions reflect Warhol's artistic choices in conveying different moods and interpretations of Marilyn's iconic visage.

Upon closer examination, we observe that the face in the Turquoise Marilyn c) version has many small black noise spots, which might be due to the image appearing overexposed, resulting in uneven colors. Additionally, for the Blue Marilyn d), the gunshot wound in the middle of the forehead, which was not repaired with the correct color, is clearly visible. This contributes to the presence of many black clusters in the ribbon for Blue Marilyn. Furthermore, when extracting the face from all five images, we noticed that Eggblue Marilyn (e) is also exhibit some noise in their faces, which we believe might be due to shadows on these versions.

Figure 18 shows the clustered ribbons representing the distribution of face colors in each version. These ribbons provide a visual summary of the color palette Warhol employed for Marilyn's face, revealing the range and distribution of tones used.

In Ribbon (a) for "Orange Marilyn," the face is rendered in a range of pinks, transitioning into darker shades towards the edges. This suggests a smooth gradation in skin tone, with an emphasis on maintaining a soft, warm complexion.

Ribbon (b) for "Red Marilyn" showcases a lighter range of pinks, with the face appearing more uniformly bright. The lighter tones dominate, creating a softer and more ethereal representation compared to the other versions.

Ribbon (c) for "Turquoise Marilyn" shows a range of pinks that transition into darker, almost brownish shades, reflecting the greater contrast in the face of this version. The darker tones suggest more pronounced shadows, adding depth and dimension to the face. However, some noise is evident, possibly due to the presence of shadows.

Ribbon (d) for "Blue Marilyn" exhibits a more diverse range of pinks, with significant contrasts between light and dark areas. The presence of dark shades, particularly due to the gunshot wound on the forehead, adds to the dramatic and intense appearance of the face, with more black color clusters visible in the ribbon.

Finally, Ribbon (e) for "Eggblue Marilyn" displays a balanced range of pinks with some subtle transitions into darker tones. The overall effect is soft, yet there is enough contrast to define the features clearly, though some noise is also present, likely due to shadows.

This analysis of the face in Warhol's "Shot Marilyns" series reveals how Warhol used varying shades and tones to create different visual effects and moods, with each version of Marilyn's face offering a unique interpretation. The presence of noise and black spots in certain versions adds an additional layer of complexity, further enhancing the distinctiveness of each portrayal. # Repair Gunshot of Image

Despite considerable efforts to restore the damaged areas, a noticeable trace of the gunshot between Blue Marilyn's eyebrows persisted. To ensure a thorough and authentic restoration, we began by isolating the affected region. The image was cropped and magnified to focus on the damaged area, facilitating a seamless repair. We utilized the K-Nearest Neighbors (KNN) algorithm to replenish the RGB values within this region, carefully mimicking the original color distribution across all channels. A detailed explanation of this process is provided in Method 2.4.

By applying K-Nearest Neighbors to the RGB values of the damaged area, we achieved a flawless restoration, as illustrated in the image (B). The previously marred region now seamlessly integrates with the surrounding artwork. Through the K-Nearest Neighbors approach, which sampled the RGB values based on their original distribution in the gunshot-affected region, we successfully restored the image to its pre-damage state, eliminating the visible evidence of the "shot" in the Marilyn series.

7 Disuccsion

Conclusion and Future Work

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(a) Original image (b) Repaired image

Figure 19: The comparison between the original image and repaired image: (A) Original image, (B) Repaired image

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