Analysis of the 5 "Shot Marilyns" Paintings

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Abstract

This project looks at Andy Warhol's Shot Marilyns, which are silkscreen paintings of Marilyn Monroe with different background colors: orange, red, turquoise, blue, and egg blue. We analyzed each silkscreen portrait using various data science techniques. Since the colors were the main distinguishing factors between each painting, we started with color separation using K-means clustering for each painting, and separated the colors into five clusters. We then explored color imbalances within the images, starting off with breaking up the image into its RGB components and adjusting the colors if there was an imbalance. RGB distributions were created with kernel density plots, which resulted in unique distributions of red, green, and blue for each image. We then employed hierarchical clustering analysis to further investigate color imbalances and the distribution of colors in various regions of interest (ROI) such as the eyeshadow. Hierarchical clustering trees were also used to analyze colors of the faces and the different parts of each painting. Then for each image, conditional entropy values were found for every possible permutation of primary colors (Red-Green, Red-Blue, Blue-Green, and vice versa), and five different matrices were created to summarize the results. Three dimensional plots were created for the RGB values of all five paintings. The graphs had the color red on the x-axis, green on the y-axis, and blue on the z-axis. Two dimensional plots were also made with each combination of primary colors for every image. All graphs were greyscale, and the darkness of each point signified the intensity of whatever color was not included in the axes of the plots. The amount of points on each graph signified how much color diversity the specific portrait had. By investigating the color diversity and deeper meanings of each of the paintings, we gain an insight into Andy Warhol's artistic intentions and in the future apply these techniques to other artworks.

1 Background (Data)

The renowned pop-artist Andy Warhol was captivated by the allure of Hollywood. Marilyn Monroe was an iconic figure in Hollywood adored by many, and had an impact on many individuals well past her untimely passing at the age of 36 in 1962. At the time, Warhol was exploring silkscreen art, and decided to memorialize Monroe's influence and beauty by creating five silkscreen portraits of the actress from her promotional photo taken for the 1953 movie, Niagara. All of the portraits used the same source image, however, they varied in color based on background. The five silkscreen portraits had the background colors of orange, red, turquoise, blue, and egg blue.

The performance artist Dorothy Podber ended up shooting the red, orange, blue, and egg blue portraits by stacking the four and firing a revolver at them. The turquoise painting was not included in the stack and therefore was not shot. Nevertheless the series of silkscreens are considered to be valuable and influential art pieces that are admired to this day.

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To load the PNG images of the paintings using Python, we used the Python Imaging Library package and then used numpy to transform the image data in to arrays of RGB values, with most of the images having a fourth variable signifying alpha level. The array data was the type of data that was primarily used for this project.

The organization of the paper starts with the 'Abstract' above, then this 'Introduction and Background' section, then the 'Methodology' section, followed by the 'Analysis and Results' section, then the 'Discussion' section, and finally the 'References' section.

2 Methodology

We used Python in Jupyter Notebook and collaborated using a GitHub repository. We used packages and libraries such as NumPy, Pandas, Seaborn, MatPlotLib, IterTools, OpenCV, and Python Imaging Library. To load in digital images of the paintings, we used Python Imaging Library (PIL) and OpenCV to load the images and used NumPy to convert the images to an array. For the two- and three-dimensional plots of RGB values, we used IterTools and Pandas to center and drop duplicates of the pixels of each image and used MatPlotLib to create the plots. We used Pandas and Numpy to calculate the relative conditional entropies and used Seaborn to create heatmaps. We also used SKImage to explore color imbalances and make adjustments to the images.

3 Analysis and Results

The digital images used in this project are composed of pixels. Each pixel has unique characteristics such as the location in the image as well as the color. The color of the pixel is dependent on the three primary colors or red, green, and blue. Each primary color can take values between 0 and 255, which means the possible number of colors is 256 to the third power, which is around 17 million unique colors.

The images that we used were PNG images, which were 750 pixels in height and 750 pixels in width, so 750x750. In total, there are 562,500 pixels in each portrait of Monroe.

3.1 Color Separation

We decided to separate the colors in the Shot Marilyn paintings using K-Means Clustering, which is a type of unsupervised machine learning algorithm. We decided to use five clusters, so that we could easily compare colors across all the five paintings, but this number can also be increased or decreased depending on how many colors you want to separate for each image. Each data point is assigned to the nearest cluster, which are kept as small as they possibly can be.

Prior to extracting the top five most prominent colors for each image, we converted the image from BGR back to RGB format, since OpenCV in Python reads images in via BGR format. Following this, we also reshaped the image array to the shape (M x N, 3) where M x N is the pixels in the original image. This then allows us to perform K-Means clustering.

We created pie charts so that we can compare the prominence of the top five colors across the five Shot Marilyn paintings, as shown in Figure 1.

Figure 1: Pie Charts of Prominent Colors

As we can see from the results, as expected, the background of each image forms a significant component of the top five most prominent colors for each image. Various shades of pink also formed significant components of the colors of each of the five images due to the skin tone, as well as yellow for the hair. However, as we can see the egg blue Marilyn had the darkest shade of pink and hair whereas turquoise Marilyn the lightest shades for these pink colors. Also, the use of darker colors like black and brown in contrast to lighter backgrounds and colors like blue and orange may have been intentional to highlight Marilyn's features.

3.2 RGB Distributions

Using the seaborn package, RGB distributions for the five portraits were created with kernel density graphs. Each primary color is represented by the curve that corresponds to the actual color, so for example the red curve pertains to the red values in a pixel.

The portrait with the orange background had a high density of blue values between 50 and 100, green values between 100 and 150, and red values between 200 and 250. There were smaller peaks of blue green and blue values between 150 and 200. The portrait with the red background had a large density of blue values around 0, with smaller peaks of red and green values around 0. It had medium peaks of red, green, and blue values between 150 and 250. The portrait with the turquoise background had green and blue values that were relatively similar in density, however it had a large density of red values around 250. The portrait with the blue background had a high density of numerically small red values (50-100), a high density of moderate green values (100-150), and a high density of larger blue values (175-225). For the final egg blue portrait, all the primary colors had high densities concentrated in the higher values from about 150 to 250, with lower peaks from 25 to 100.

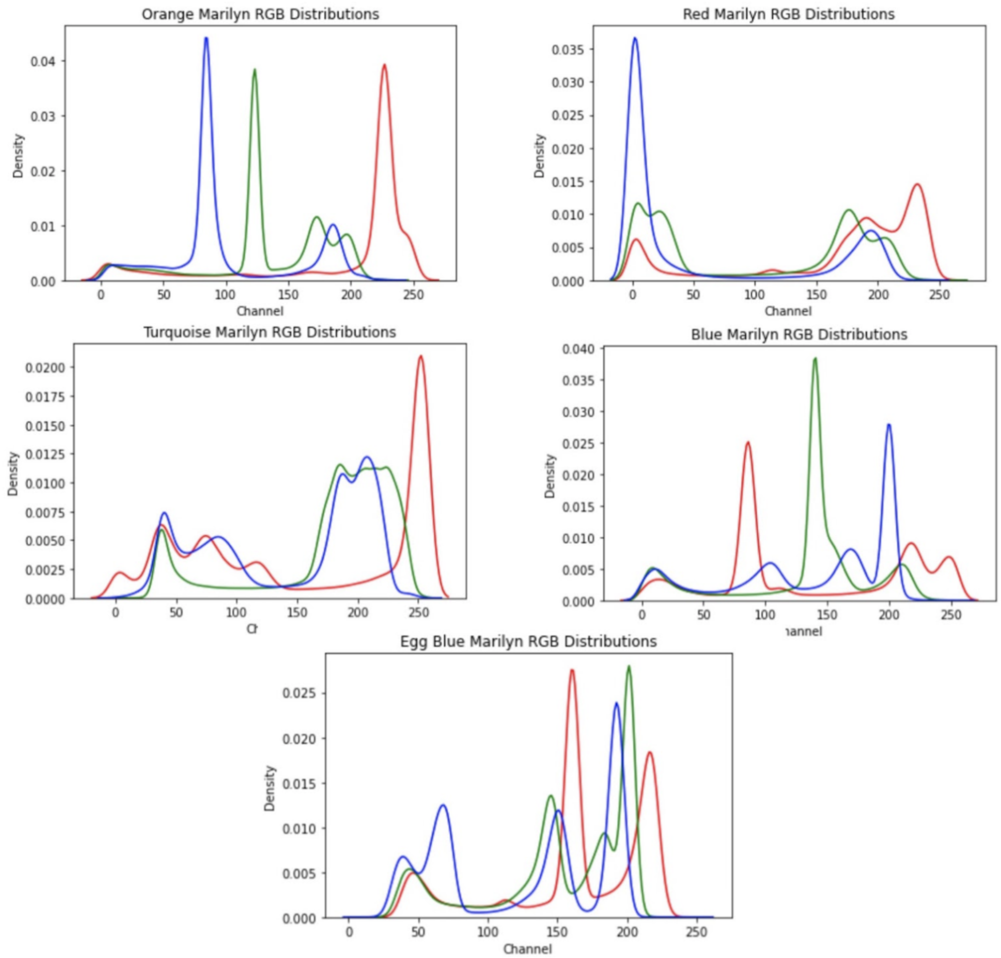

Figure 2: RGB Distributions

3.3 Plots of RGB values

We decided to center and drop duplicates of the RGB values in the Shot Marilyn paintings. This reduces the number of pixels without losing information. We made two- and three-dimensional plots that plotted distinct pixels of each painting.

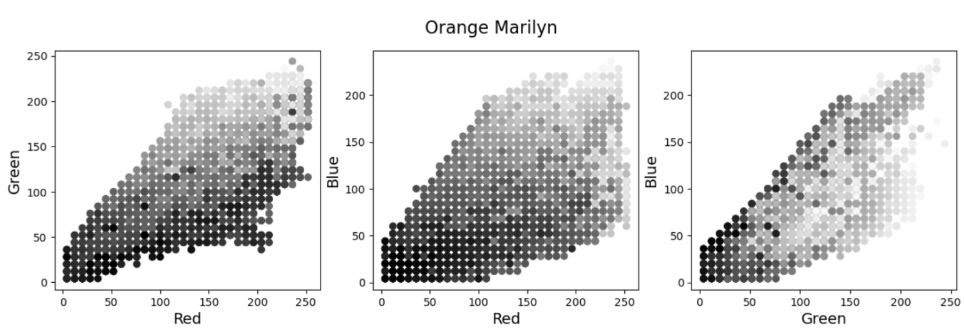

Figure 3: RGB Plot: Orange Marilyn

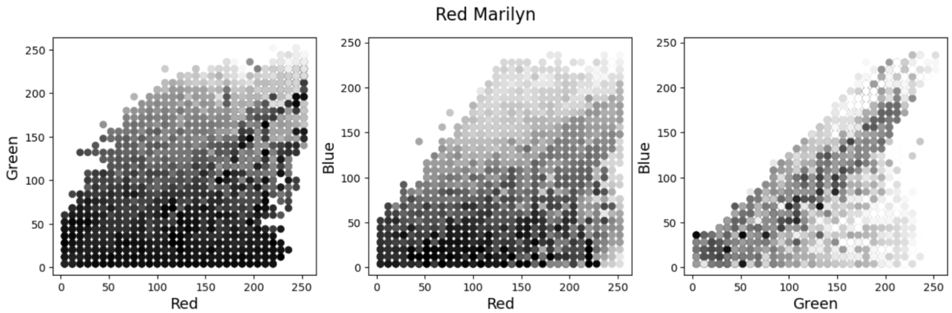

Figure 4: RGB Plot: Red Marilyn

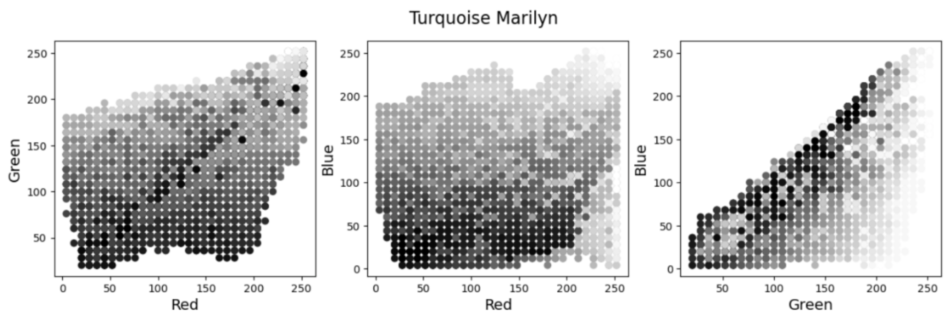

Figure 5: RGB Plot: Turquoise Marilyn

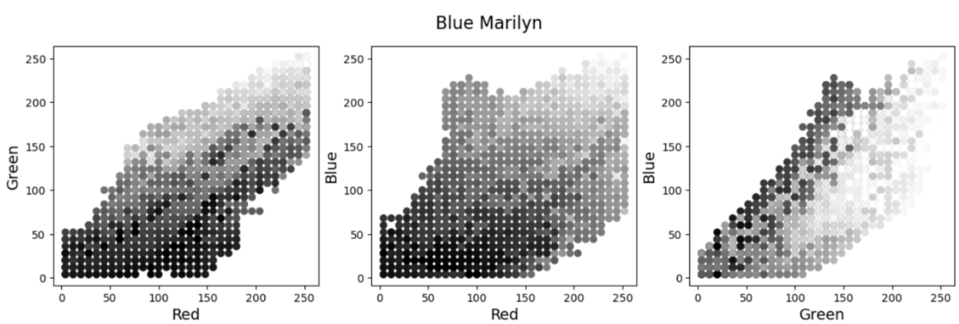

Figure 6: RGB Plot: Blue Marilyn

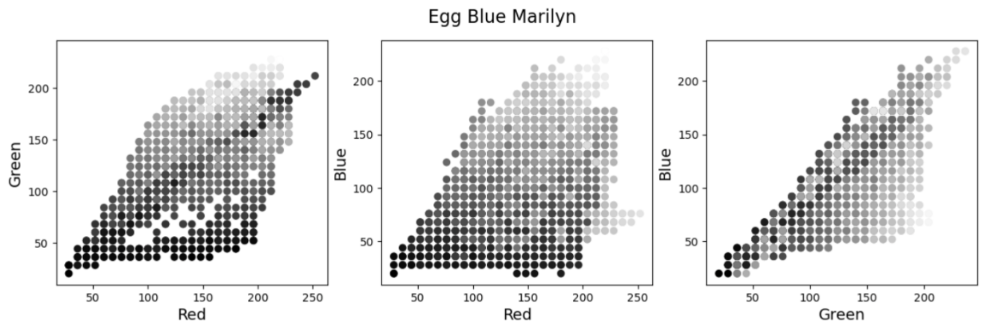

Figure 7: RGB Plot: Egg Blue Marilyn

Each point in the two-dimensional plots has a color in grayscale that represents the intensity of its red, green, or blue coordinate. The intensity ranges from low to high (white to black). For each painting, we made plots showing red vs green with blue in grayscale, red vs blue with green in grayscale, and green vs blue with red in grayscale.

The Red and Turquoise Marilyn paintings seem to have the most diversity of color since the red vs green and red vs blue plots are almost completely filled for both paintings. The Turquoise also has the most blue and green combinations out of all the other paintings. The Egg Blue Marilyn painting has the least amount of distinct points in the graphs, meaning it has the lowest diversity of colors. It also has the smallest range of values for all colors, covering values from 0 to 230 for red, 0 to 234 for Green, and 0 to 230 for blue.

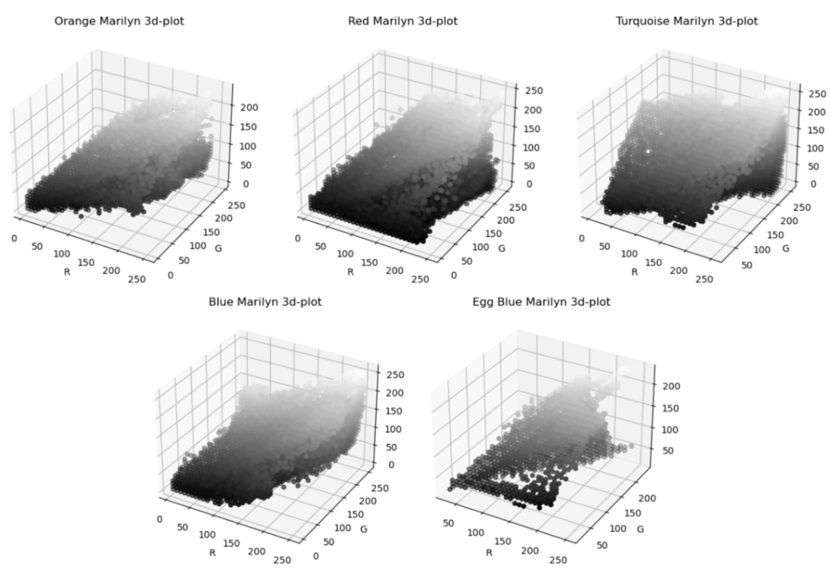

Figure 8: RGB Plot: 3D Plots

In the three-dimensional plots, we plotted the pixels with the red coordinate on the x-axis, green on the y-axis, and blue on the z-axis. Each point also has a color in grayscale representing the intensity of its blue coordinate. It appears that the orange and egg blue Marilyns have the smallest amount of points on the plots, meaning it has lower diversity of colors.

3.4 Exploration of Color Imbalance

We decided to explore the RGB components of each of the images, to see whether there was an obvious imbalance in one of them. Below are the results.

Figure 9: RGB Components

As we can see from the results, the orange and red Shot Marilyns have intense shades of red, and lighter shades of green and blue. The turquoise Marilyn has a deeper shade of blue on the face, as well as moderately intense shades of red and green. Blue and egg blue Marilyns on the other hand have lighter shades of red and green, but are also deeper in blue compared to the orange and red Shot Marilyns.

To get an exact idea of the RGB components in each image, we produced a table of channel statistics for each color to see if there are any imbalances.

		Max	Mean	Median	P_90	P_95	P_99
Orange Marilyn	Red	-1	192.571374	227.0	241.0	246.0	250.0
	Green	-21	133.651769	124.0	195.0	200.0	208.0
	Blue	-23	101.282130	84.0	186.0	191.0	205.0
		Max	Mean	Median	P_90	P_95	P_99
Red Marilyn	Red	-1	170.162471	195.0	236.0	239.0	243.0
	Green	-1	103.784875	125.0	203.0	210.0	219.0
	Blue	-16	57.976361	6.0	195.0	201.0	208.0
		Max	Mean	Median	P_90	P_95	P_99
Turquoise Marilyn	Red	-1	154.548519	160.0	254.0	255.0	255.0
	Green	-1	177.979045	195.0	231.0	236.0	243.0
	Blue	-1	143.148219	179.0	215.0	220.0	226.0
		Max	Mean	Median	P_90	P_95	P_99
Blue Marilyn	Red	-1	138.345559	95.0	244.0	250.0	255.0
	Green	-1	132.024606	140.0	204.0	212.0	221.0
	Blue	-1	137.156594	163.0	200.0	200.0	204.0
		Max	Mean	Median	P_90	P_95	P_99
Egg Blue Marilyn	Red	-7	162.644537	163.0	218.0	221.0	225.0
	Green	-6	152.843154	168.0	203.0	204.0	206.0
	Blue	-7	126.807339	146.0	194.0	196.0	199.0

Figure 10: Table of Channel Statistics

As we can see from the results, in the orange Marilyn painting there is an imbalance of Red, as the maximum value of red is -1 but it is between -21 and -23 for green and blue. To attempt to correct the imbalance for this image, we were interested in what would happen if we adjusted the image with the mean, maximum and median values for each channel. As we can see from the figure below, this mostly affected the saturation and brightness of the image, with the image being the lightest when we used the mean.

Figure 11: Adjusted Orange Marilyn

Then, we were curious what would happen if we kept red at the maximum value and instead used the median and mean values for blue and green.

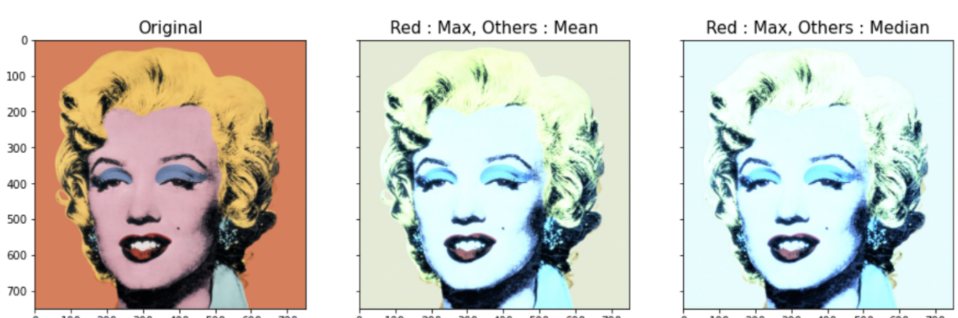

Figure 12: Adjusted Orange Marilyn: Red Kept at Maximum

As we can see, this did correct the red color imbalance somewhat however it made the image significantly more blue and green tinted.

Next, we examined the red Shot Marilyn. Looking at the table from earlier, we can see that it has an imbalance of blue as the maximum value of it is -16 compared to -1 for red and green. Like we did to the first orange painting, we adjusted the image with the maximum, mean and median values for each channel.

Figure 13: Adjusted Red Marilyn

As we can see, this gave it more of a “pop art” look as the face contrasts starkly with the contrast, and you can see the different layers. We then also kept blue at the maximum value and instead used the median and mean values for red and green.

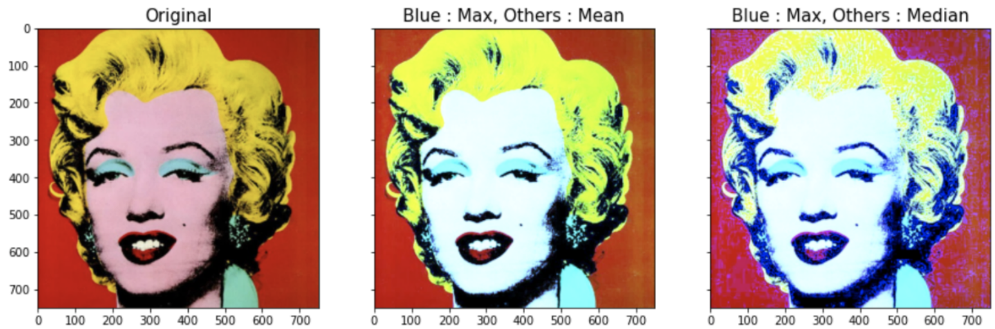

Figure 14: Adjusted Red Marilyn: Blue Kept at Maximum

Like we can see from the image above, it didn't help to correct the color imbalance, as the image now has a blue tint. Moving on to the turquoise and blue Marilyns, we did not make any adjustments because as we can see from the table, the RGB values are already balanced with a maximum of -1. For the egg blue Shot Marilyn, the table shows us that there was barely a color imbalance because the maximum values of red and blue were -7, and green was -6. However, we were still curious how significant the differences would be between the original and the adjusted images if we applied the same adjustments as before. Below is the result of adjusting the maximum, mean and median values for each channel.

As we can see from the image above, this affected primarily the brightness and saturation of the green shades in the image, and made the image as a whole appear lighter. Keeping green at a maximum and adjusting red and blue yielded the following results, making the image seem more blue tinted.

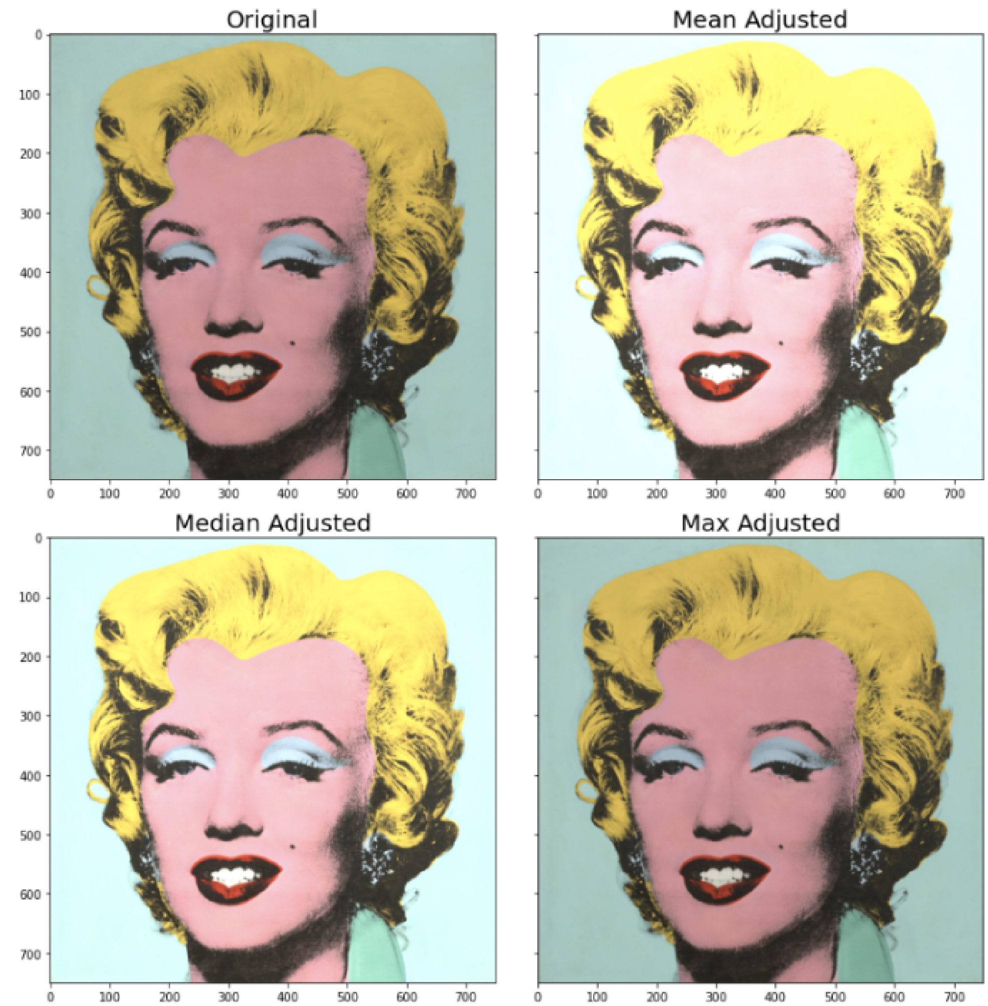

Figure 15: Adjusted Egg Blue Marilyn

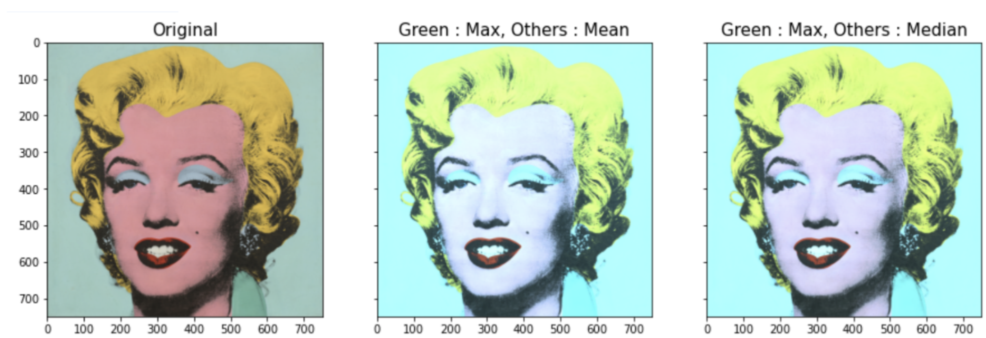

Figure 16: Adjusted Egg Blue Marilyn: Blue Kept at Maximum

Overall though there does appear to be a color imbalance judging for the numerical values presented in the table, these are not starkly apparent to the human eye and don't appear to make the image visually unappealing. Thus, we can infer that Andy Warhol was intentional in the shades and colors that he used, selecting ones that make the image visually appealing and stand out.

3.5 Hierarchical Cluster Analysis

In order to further explore the color imbalance of the five paintings, we used hierarchical cluster analysis. This approach involves the clustering of the pixels via agglomerative clustering, where each pixel starts in its own cluster and then pairs of clusters are merged until they all belong to the same cluster. This is illustrated in the dendrograms below for each respective Marilyn.

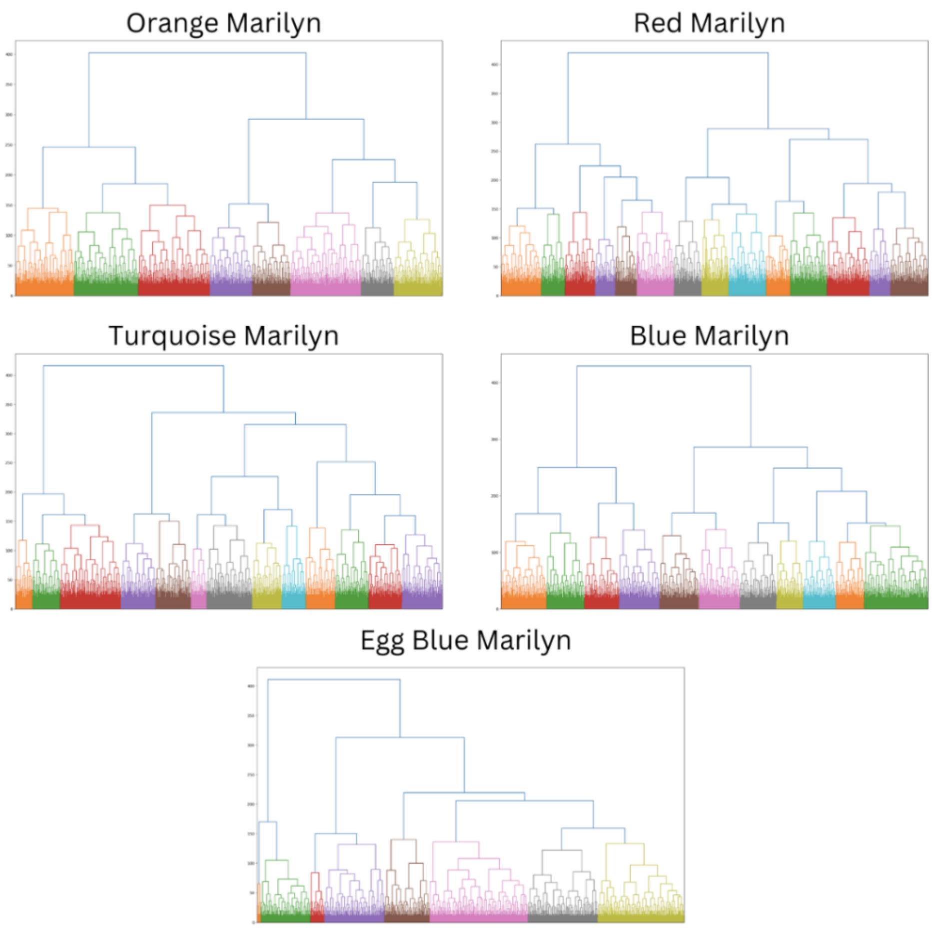

Figure 17: HCA Tree

Figure 18: Orange Marilyn Clusters

$$d(P(i), P(j)) = \sqrt{(r(i) - r(j))^2 + (g(i) - g(j))^2 + (b(i) - b(j))^2}$$

All of the agglomerative clustering is done with the linkage criteria being the maximum distance between the color elements, known as complete linkage.

From these respective HC trees, we can isolate the specific clusters in order to identify specific regions of interest we are interested in, mainly the eyeshadow region of Marilyn's eyes, and the background as a baseline of which to compare the five paintings. As seen in Figure 18, the layers of all sixteen clusters of the orange Shot Marilyn, in this we are able to see which regions of the paintings are separated into which clusters. Here the fourth cluster contains, mainly the background for the painting, and the eyeshadow is captured within the twelfth cluster.

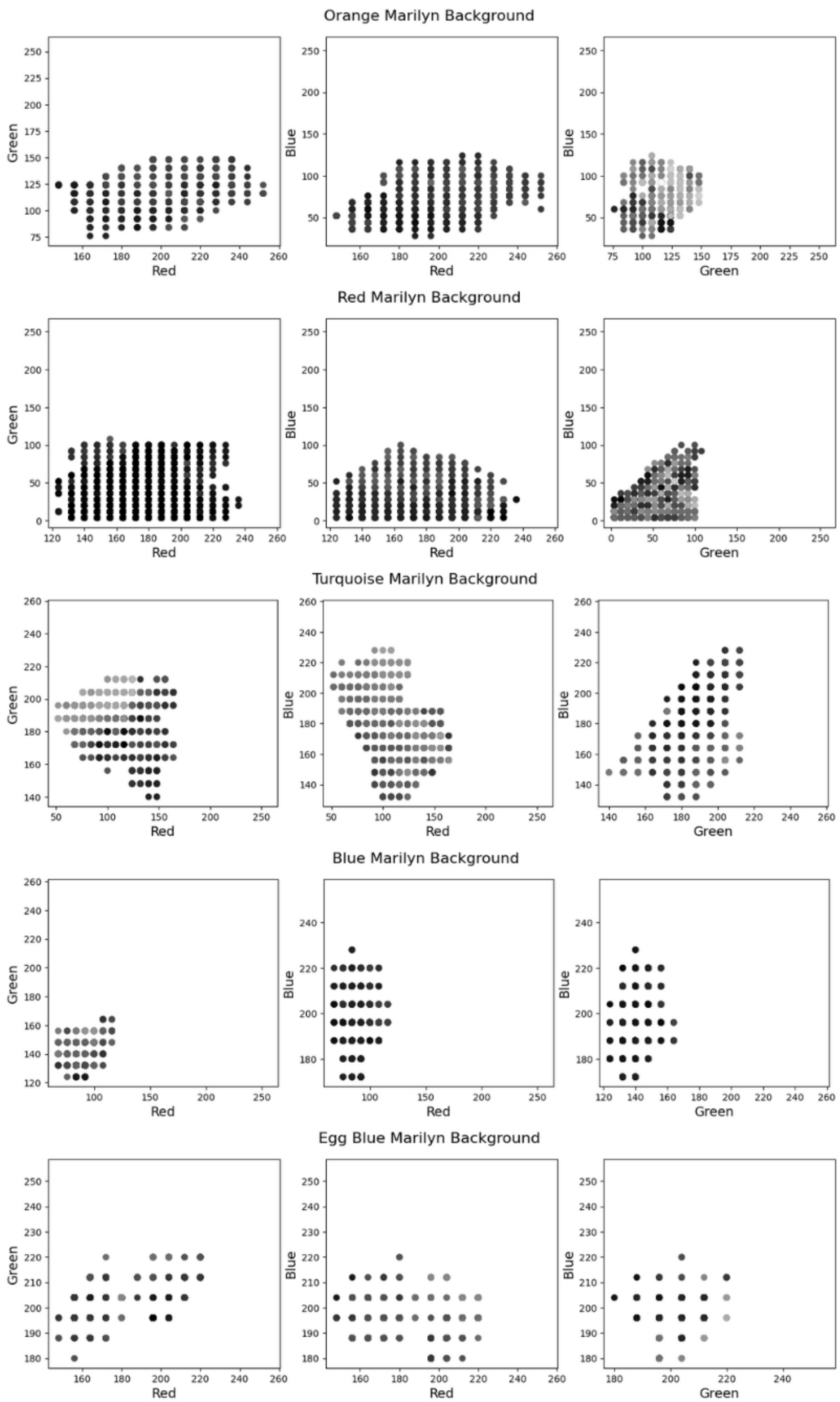

Figure 19: Background Clusters

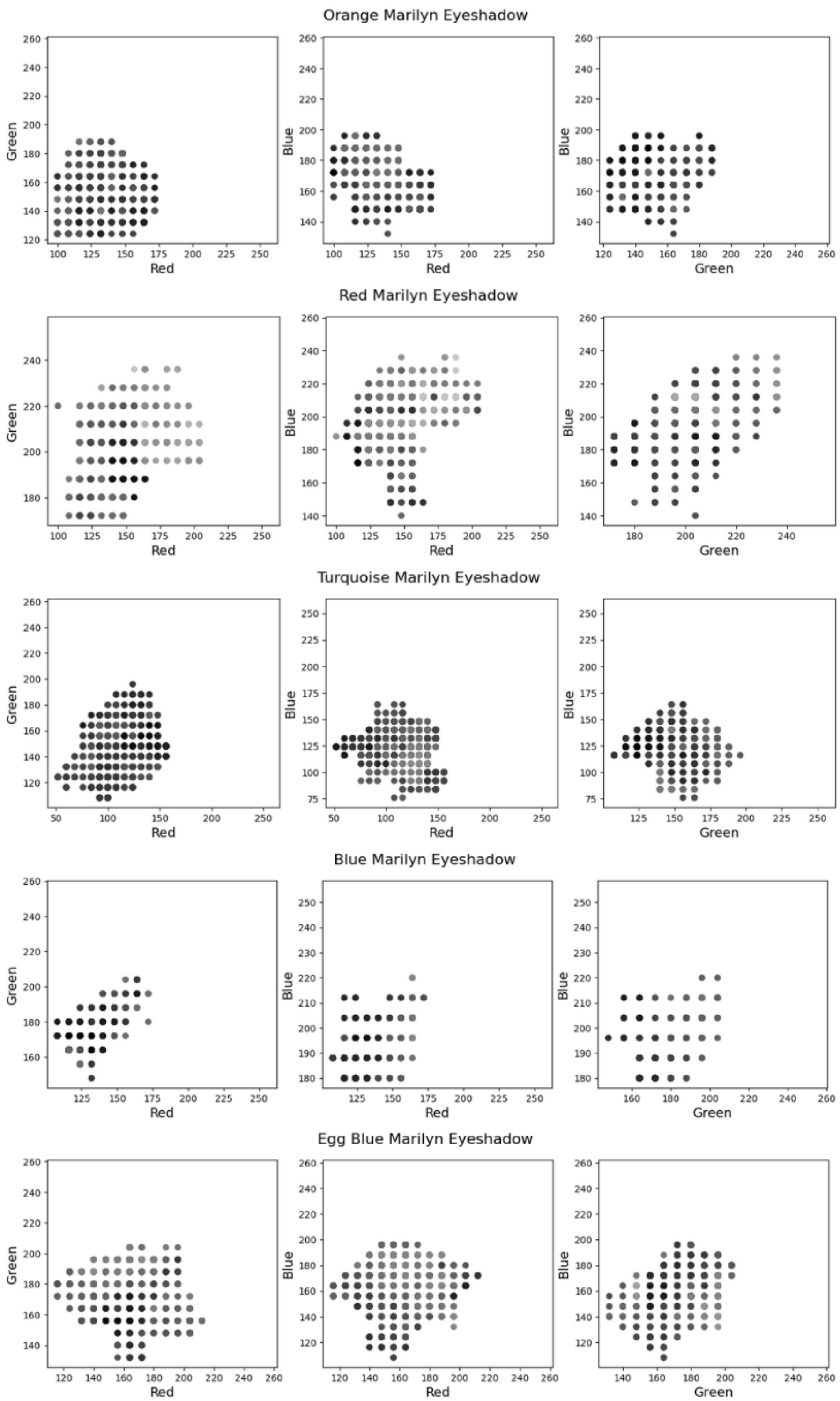

Figure 20: Eyeshadow Clusters

The eyeshadow RGB values taken from the regions of interest convey how the eyeshadow of the paintings does not seem to vary much in terms of the distributions of the colors. The red Shot Marilyn's eyeshadow does seem to contain a wider distribution compared to the other four Marilyns, which is consistent with the findings of the overall RGB Plots on the whole painting. From this we can surmise that Warhol used the same paint for the eyeshadow on each painting. However, sometimes the clusters would not be too accurate in selecting all of the regions of interest from the painting, as the colors were often very similar to colors in different regions. For instance, the cluster containing the eyeshadow of the egg blue Shot Marilyn contained parts of the background as well, since the colors used were so similar in RGB values. Thus the accuracy of the edge or boundary regions were not accurate representations of the RGB values in those regions, thus skewing the overall distribution in Figure 20.

3.6 Relative Conditional Entropy

Digital images are composed of pixels that are defined by color components, (r, g, b). Each component is an integer from 0 to 255 and describes the amount of red (R), green (G), and blue (B) in each pixel. We found the relative conditional entropies between the red, green, and blue values of all pixels of the five Shot Marilyn paintings using the following equations.

Let C and D be two of the three fundamental colors, R, G, and B. The entropy of the color C within the image is given by:

$$H(C) = -\sum c = 0^{255} P(C = c) log(P(C = c))$$

The entropy of the color C conditioned on the color D is given by:

$$H(C|D) = -\sum_{d=0}^{255}\sum_{c=0}^{255} P(C = c, D = d) log \frac{P(C = c, D = d)}{P(D = d)}$$

Finally, the relative conditional entropy is given by:

$$HR(C|D) = \frac{H(C|D)}{H(C)}$$

The relative conditional entropy of color C given color D, HR(C|D), is a measure of association between the colors that only takes values between 0 and 1. A relative conditional entropy of 0 means that the values of C are determined by the values of D and a relative conditional entropy of 1 means that the values of C and D are independent. After calculating the relative conditional entropies, we created a heatmap matrix for visualization.

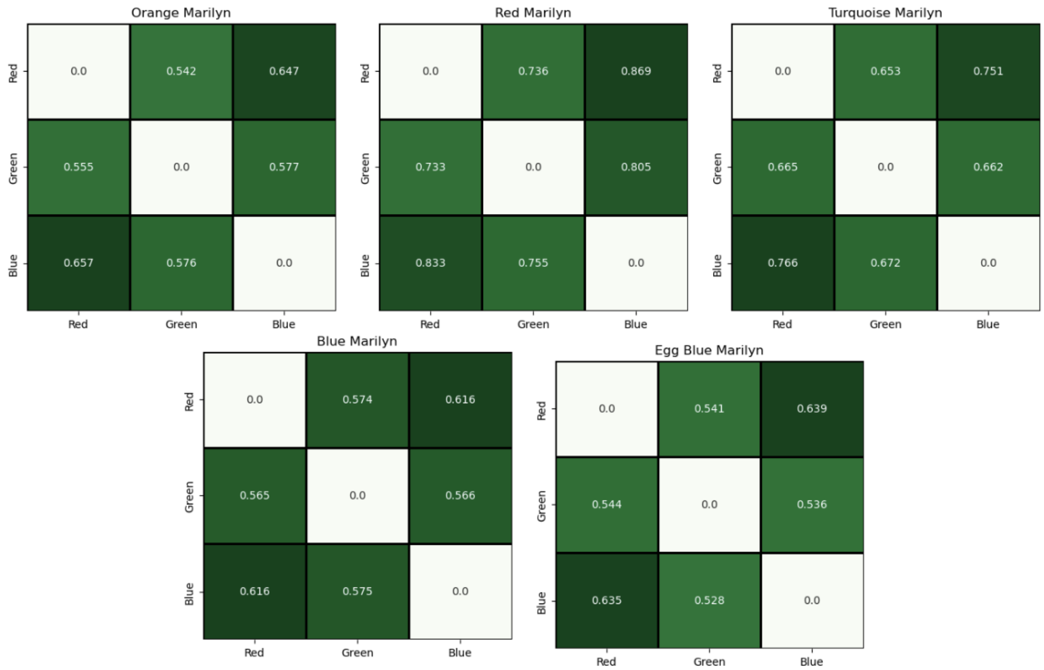

Figure 21: Conditional Entropy Heatmap

The Red Marilyn painting has the highest relative conditional entropies across all colors. The other paintings had relative conditional entropies ranging from about 0.5 to 0.7 while the Red Marilyn had values ranging from 0.7 to 0.87.

4 Conclusion

Every variant in Warhol's Shot Marilyns has many intentional nuances in terms of color, which were explored in-depth throughout this project.

Through color separation we found that the background colors of each portrait represented a large make-up of the color blocking. In addition, Monroe's features may have been influenced by the color of the background since the color of the features differ from portrait to portrait, presumably to complement the background color.

When observing the RGB distributions of each portrait, the graphs differed quite a bit as the densities of the primary colors varied for each painting. It is worth noting that despite some of the background such as turquoise and egg blue being somewhat similar, the RGB distributions look quite different. This may be due to the background color itself, but also the subtle differences in color of Marilyn's features for each portrait.

We also created two-dimensional and three-dimensional greyscale RGB plots which plotted pixels from each portrait. The number and spread of pixel points on the plots signified the color diversity of each painting, and through the two dimensional plots we found that the Red and Turquoise Marilyn paintings had the most diversity, while the Egg Blue had the least amount of diversity. Through the three-dimensional plots, our results were consistent with the two-dimensional plots however the Orange Marilyn also had low color diversity.

We then explored color imbalances by splitting the reds, greens, and blues and created visuals for each painting. A table of channel statistics was then created, and from the table we observed color imbalances. To adjust for these imbalances, we used the mean, median, and max values of each channel and and outputted the resulting image in an attempt to fix the color imbalance. When applying this technique to all the portraits, we found that the corrected images usually looked more tinted, saturated, or desaturated, and did not serve to make the image more visually appealing. Therefore we conclude that corrections of the color imbalances were not necessary. We further explored color imbalances using hierarchical cluster analysis with agglomerative clustering, where each pixel starts in its own cluster and then pairs of clusters are merged until they all belong to the same cluster. We found that in the orange Shot Marilyn, the fourth cluster contained mainly the background of the painting and the twelfth cluster contained the eyeshadow. We also used Regions of Interests (ROI) to investigate specific parts of the image. With this, focusing on the eyeshadow, we found that the color of this region of interest does not seem to vary much in terms of the distribution of colors across all five paintings. However, we did see that the red Shot Marilyn had a wider distribution of colors in its eyeshadow in comparison to the other paintings, which we also found from the RGB plots.

Lastly, we found the conditional entropy values for every possible permutation of primary colors (R-G, G-R, R-B, B-R, etc) and outputted a conditional entropy matrix for each portrait. Based on the results, we concluded that the Red Marilyn painting had the highest relative conditional entropy values at 0.7-0.87.

Overall, we can use this information to analyze paintings and other various works of art on a deeper level in order to understand the distribution of colors the original artist used to create their works. In addition these methods of color analysis could possibly be helpful in determining differences between various versions of the same painting by the same artist, or even determining forgeries or explaining differences between original works and copies.

Acknowledgments

Thank you to Dr. Fushing Hsieh and Shuting Liao.

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