IMAGE SEGMENTATION

A presentation by **Hans Emmanuel Hernandez** (2020-11387)

OBJECTIVES

In this activity, we implement various image segmentation techniques as a preliminary step in feature extraction. Specifically, we have the following objectives:

- Perform image thresholding to extract features
- Transform RGB information into Normalized Chromaticity Coordinates space
- Discuss the principles of image segmentation techniques
- Perform parametric segmentation
- Perform non-parametric segmentation and validate the results
- Expand results on other images

01 RESULTS AND ANALYSIS

IMAGE THRESHOLDING

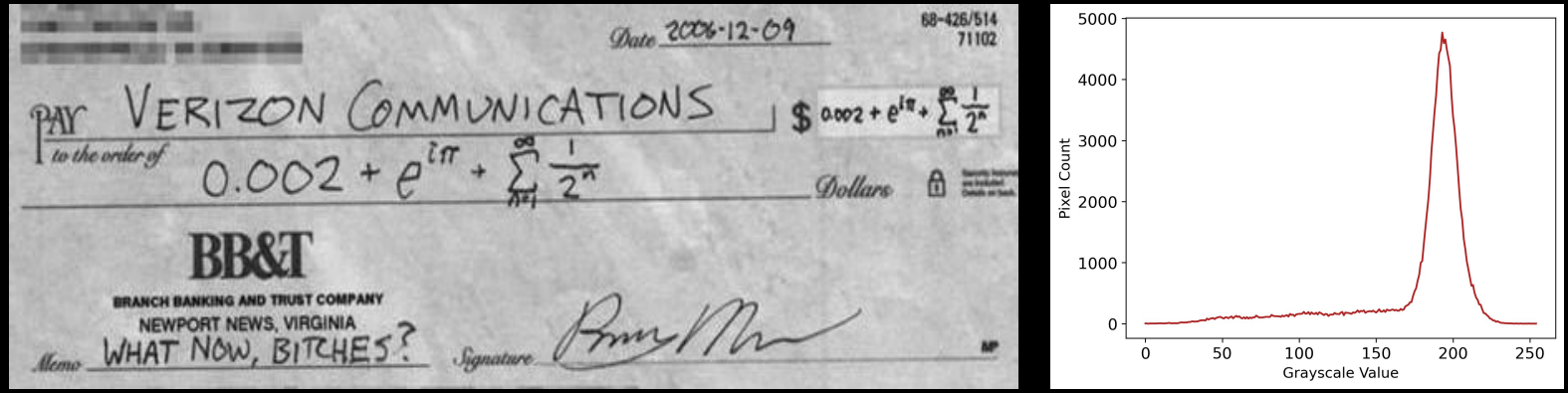
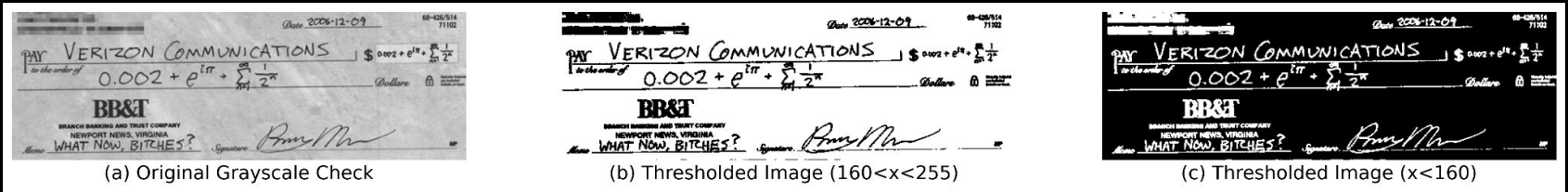


Figure 1. An image of a grayscale check with its corresponding grayscale histogram.

Looking at the grayscale histogram of the image, we can clearly see that **most of the pixels are within the range of 190-200 grayscale value.** This is to be expected since the mostly white background comprises most of the original image. To perform preliminary image segmentation, **we have to select appropriate grayscale values to threshold the image.**

IMAGE THRESHOLDING USING BOOLEAN OPERATIONS

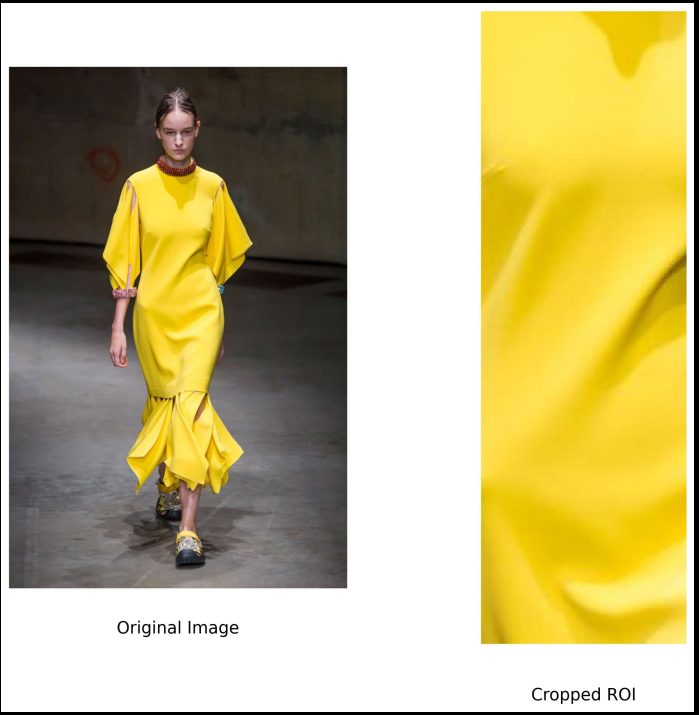


(a) Original Grayscale Check (b) Thresholded Image (160<x<255) (c) Thresholded Image (x<160)

Figure 2. Segmented images with varying thresholding conditions.

To separate the text from the background, we choose a likely threshold value from the histogram in Fig. 1. **We use boolean operations to determine the final pixel values after thresholding. If the pixel value in the image array is within the threshold condition, the pixels are set to True which corresponds to white in grayscale value. If not, they are set to False which corresponds to black.** In **(b)**, since we have set the thresholding condition as 160<x<255, **any pixel that goes out of that range is set to black in the final image. Since much of the text that we want to extract most likely falls below that range, they are automatically set to black while the rest are set to white.** In **(c)**, since we have set the thresholding condition as x<160, **most of the text is set to white while the background is set to black since it falls out of the boolean condition.**

NORMALIZED CHROMATICITY COORDINATES



Original Image

Cropped ROI

Figure 3. An image with a region of high color saturation and its cropped region of interest.

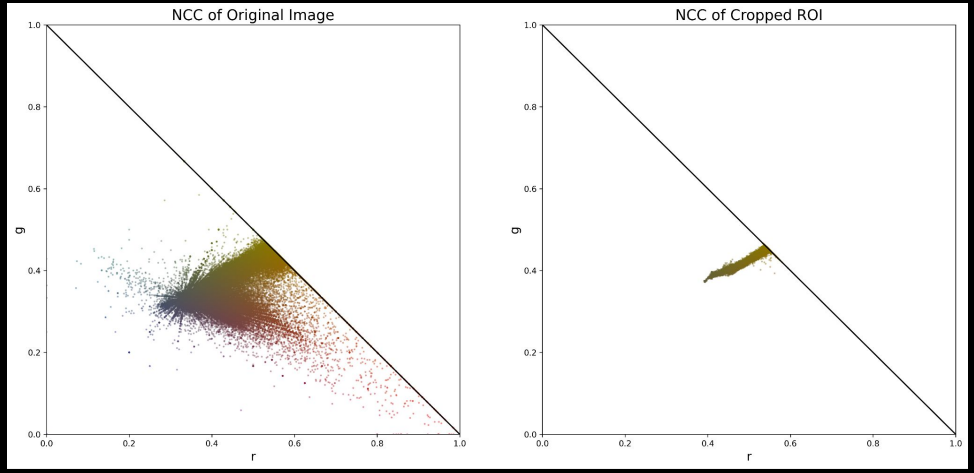


Figure 4. Scatter plot of the normalized chromaticity coordinates of the original image and its cropped ROI.

The Normalized Chromaticity Coordinates is a 2-dimensional color space that retains r, g color information and brightness. It can be seen in Fig. 4 that the original image is primarily yellow with some red, green, and blue values in the color space. The NCC of the cropped ROI is obviously much more defined as a mostly solid yellow region.

PARAMETRIC SEGMENTATION: PIXEL MEMBERSHIPS

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

Figure 5. Probability distribution function of a gaussian distribution.

We perform parametric segmentation by first obtaining the PDF of the ROI by normalizing its histogram which we have already done in the 2D NCC space. Next, we determine if the pixel from the original image belongs to the PDF of the ROI. **The probability that a pixel with chromaticity r or g belongs to the ROI is just given by Fig. 5 which we assume to be gaussian.** Thus, **the pixel membership distribution is just the joint probability of r and g which is essentially just a product of the two.**

PARAMETRIC IMAGE SEGMENTATION

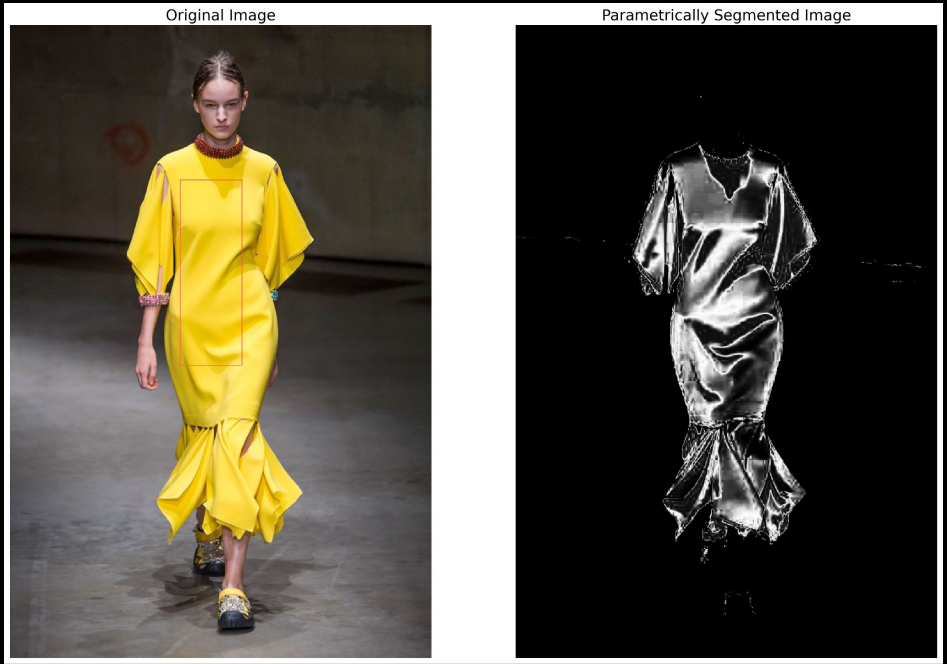


Figure 6. Resulting image after parametric segmentation. The red rectangular region highlighted in the left image represents the ROI basis.

Performing parametric segmentation on the image, we obtain a resulting segmented image that highlights the normalized yellow ROI. Interestingly enough, the algorithm was also able to pick up on the **texture and folds of the dress which can be attributed to a change in color saturation due to lighting.** It can also be said that the resulting segmented image is very smooth and rounded.

NON-PARAMETRIC IMAGE SEGMENTATION

Figure 7. Resulting image after parametric segmentation. The red rectangular region highlighted in the left image represents the ROI basis.

Unlike the previous parametric segmentation technique, non-parametric segmentation does not utilize the previous gaussian probability distribution function. Instead, it uses the very first technique we learned in image processing: **Histogram Backprojection.** First, **we calculate the 2D histogram of the ROI by mapping it into the NCC space which we have already done in the previous slides. We match the high-intensity locations of the NCC space and retain these pixel values.** As we can see in Fig. 7, **the resulting non-parametrically segmented image is highly sensitive since the algorithm is dependent on the accuracy of the ROI.**

PARAMETRIC VS NON-PARAMETRIC: CONCLUSIONS

Overall, the parametric segmentation technique was superior in extracting a cleaner segmented image with rounded and smoother edges. The parametric segmentation technique uses the joint probability of the gaussian probability distribution function to determine pixel membership to the ROI while the non-parametric segmentation technique only uses histogram backprojection to directly correlate pixel membership to the 2D histogram of the ROI. **Thus, the non-parametric segmentation technique performs better when the provided ROI is accurate to the regions we want to segment.** We can also show that the non-parametric segmentation technique is more useful **if we are interested in extracting features that directly correlate or match the provided ROI** since it retains more information in that regard. However, **if we are only interested in maximizing color extraction, we may simply use the parametric segmentation technique.**

NON-PARAMETRIC IMAGE SEGMENTATIONS

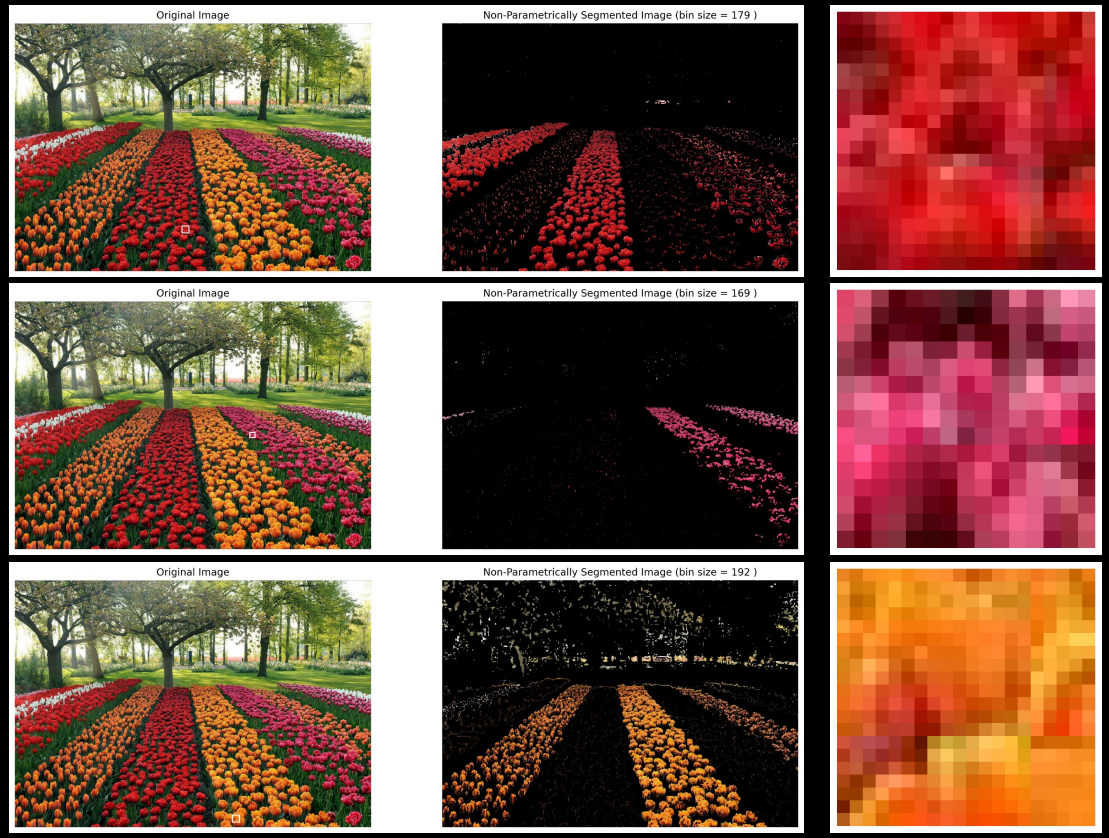


Figure 8. Non-parametric segmentations using various colored ROIs from an image of a tulip garden.

As we can see in Fig. 8, **the non-parametric segmentation technique was able to segment the image given various colored ROIs with a high degree in sensitivity.** Since each ROI greatly varies in saturation, the algorithm also resulted in displaying a wider range of each respective color. **This is mostly visible in the red ROI at the top wherein even the pink tulips were segmented.** This is also apparent for the orange ROI at the bottom wherein some parts of the trees and the background were segmented.

02 REFLECTION

REFLECTION

Overall, this was a great activity!

Image segmentation is a very cool introduction to feature extraction using computational techniques. I especially enjoyed constructing the normalized chromaticity coordinates space since I was able to grasp how to map the standard RGB channels into 2D. I also enjoyed non-parametric segmentation over parametric segmentation since you can introduce scaling factors for the bin size to really see the effects during segmentation.

Besides that, I believe that my results are accurate and stayed true to the topic, with additional cross references and analyses. I also cross-validated my results with my peers. However, if I was given more time, I would implement these image segmentation techniques on more complex images like satellite data and space data.

SELF-GRADE

Technical Correctness: 35/35

I believe that my results are correct through math, research, and through validation with my peers and with my instructors.

Quality of Presentation: 35/35

I believe that the quality of my powerpoint is up to par with the course expectations. I constructed the figures as instructed, and exported my data accordingly.

Self-Reflection: 30/30

I believe that I have acknowledged and reflected upon the activity well enough. I also have complete citation on the next slide.

Initiative: 10/10

I went above and beyond with my data presentation, and included extra analyses for the activities.

REFERENCES

[1] Aguila, N. (2021, December 28). Fixation on the Segmentation Part 2: How to do Image Segmentation with Python. *Medium*.https://towardsdatascience.com/fixation-on-the-segmentation-part-2-how-to-do-image-segmentation-with-python-b29e40c2b46c

[2] Garcia, F. (2023, June 17). Color Image Segmentation using Python (Part 2) - Flippy Garcia - Medium. *Medium*. https://medium.com/@flippygarcia/color-image-segmentation-using-python-part-2-a0db05b6554a

[3] *Gaussian Distribution*. (n.d.). http://hyperphysics.phy-astr.gsu.edu/hbase/Math/gaufcn.html

[4] *OpenCV: Image Thresholding*. (n.d.). https://docs.opencv.org/4.x/d7/d4d/tutorial_py_thresholding.html