Washer segmentation and classification

Part 1:
The original image to be processed is shown in Figure 1 below. With the goal of classifying washer types, there are several features of the image that may be used, such as size and color of the washers.

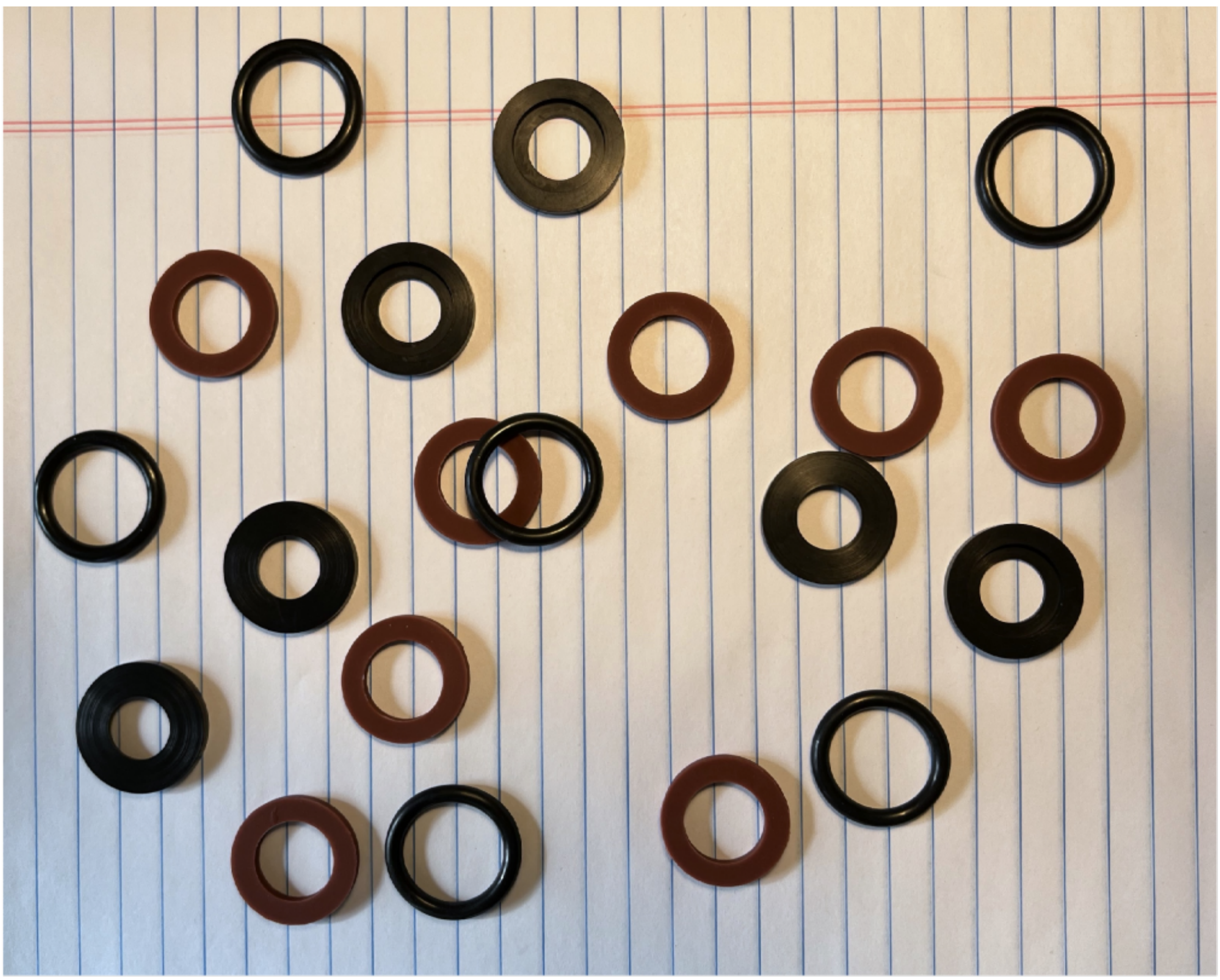


Figure 1: Original Image to be processed.

We first looked at each color channel of the original image separately (Figure 2). We tried further processing and edge detection with each color separately to see which provided the best results.

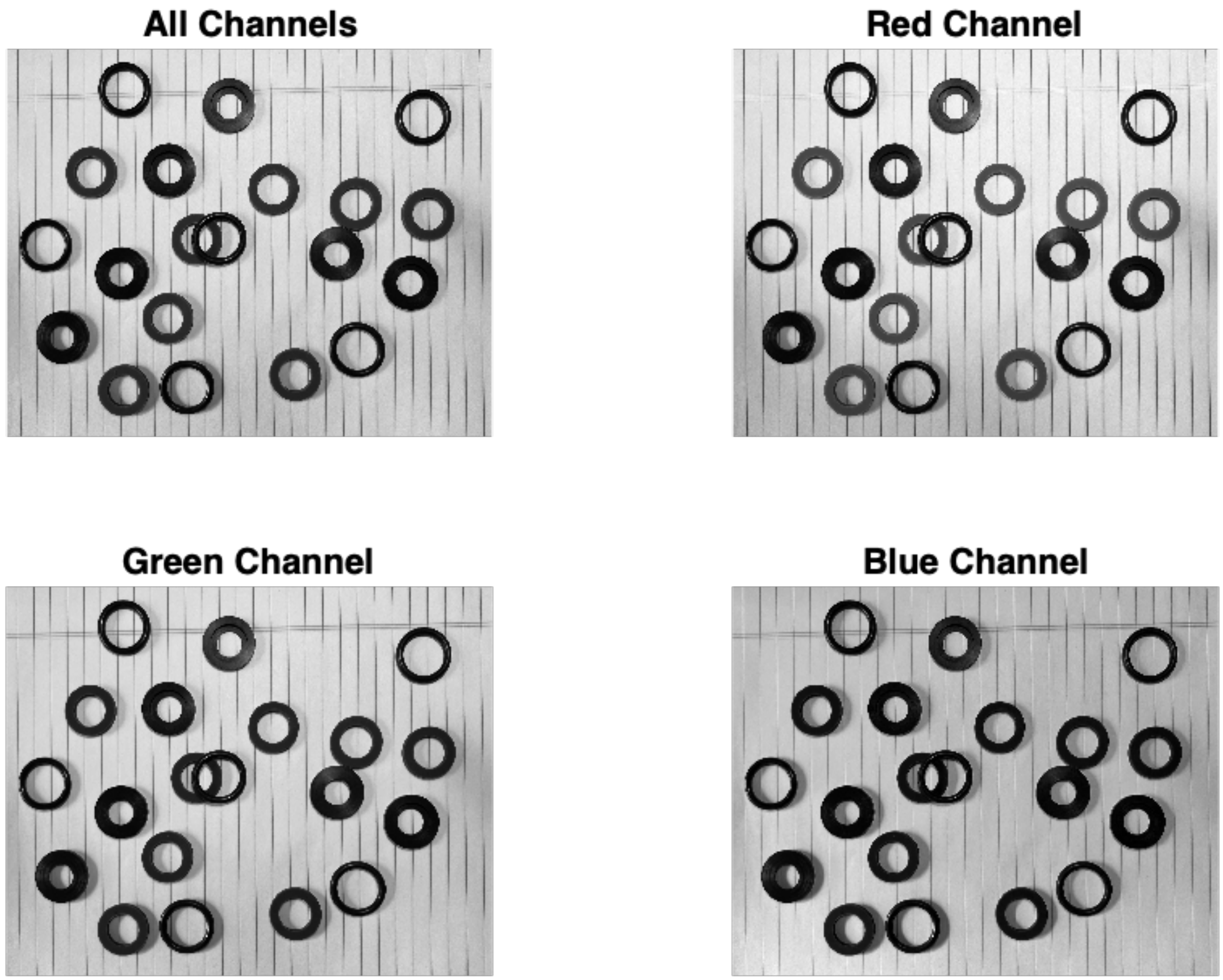


Figure 2: Color channels of the original image. The top left image is the original color image converted to grayscale.

Next, we applied a 15 x 15 median filter to each color channel and then combined those into an image (Figure 3). This reduced the background noise in the image well.

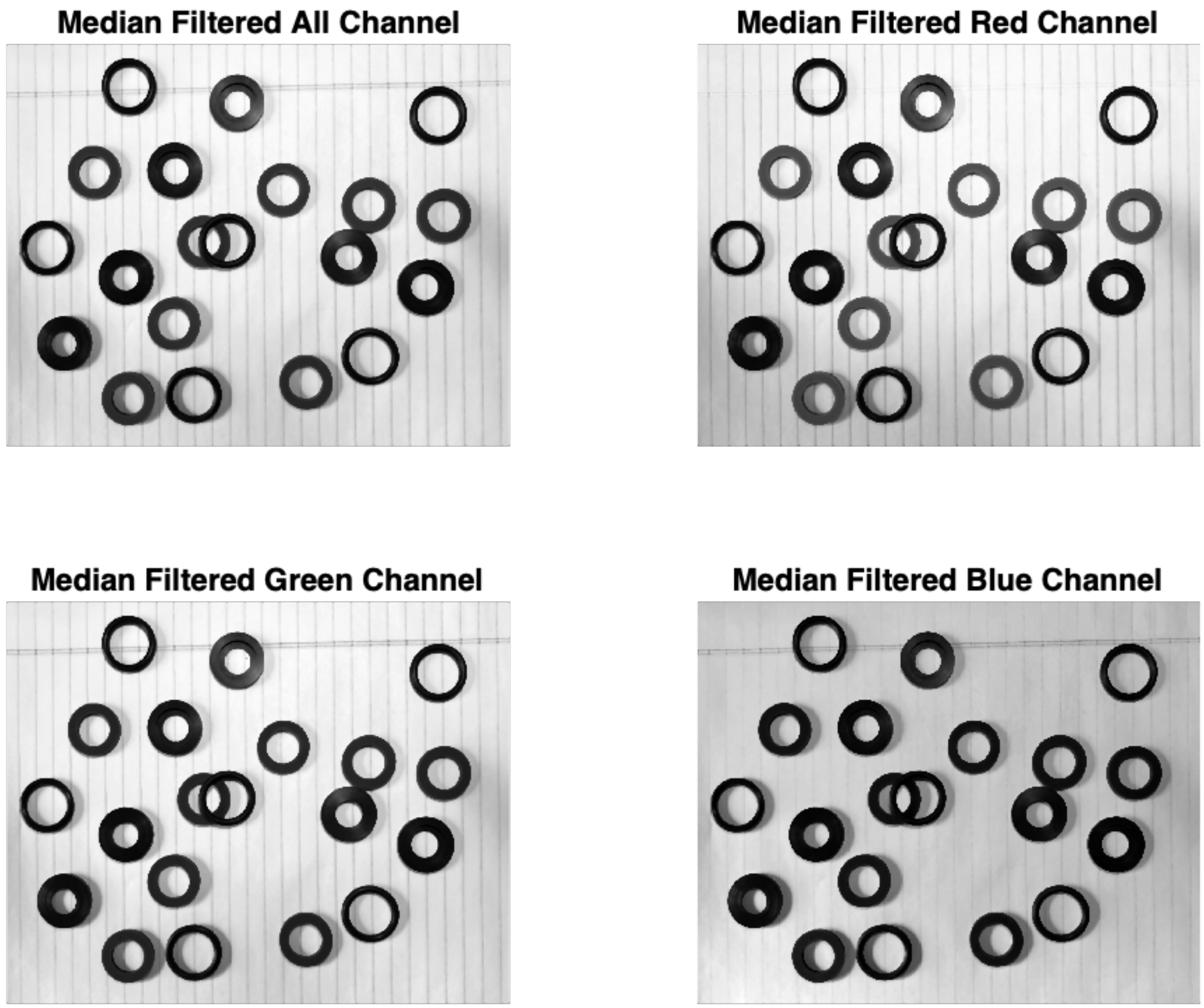


Figure 3: Median filtered images of each color channel and their composite image.

Once the image had been sufficiently preprocessed, we used Canny edge detection to isolate the washers, shown in Figure 4. We used a threshold of 0.5 and a sigma value of 10 because this provided the best output. This edge detection step is necessary for later processing that will use these circular edges.

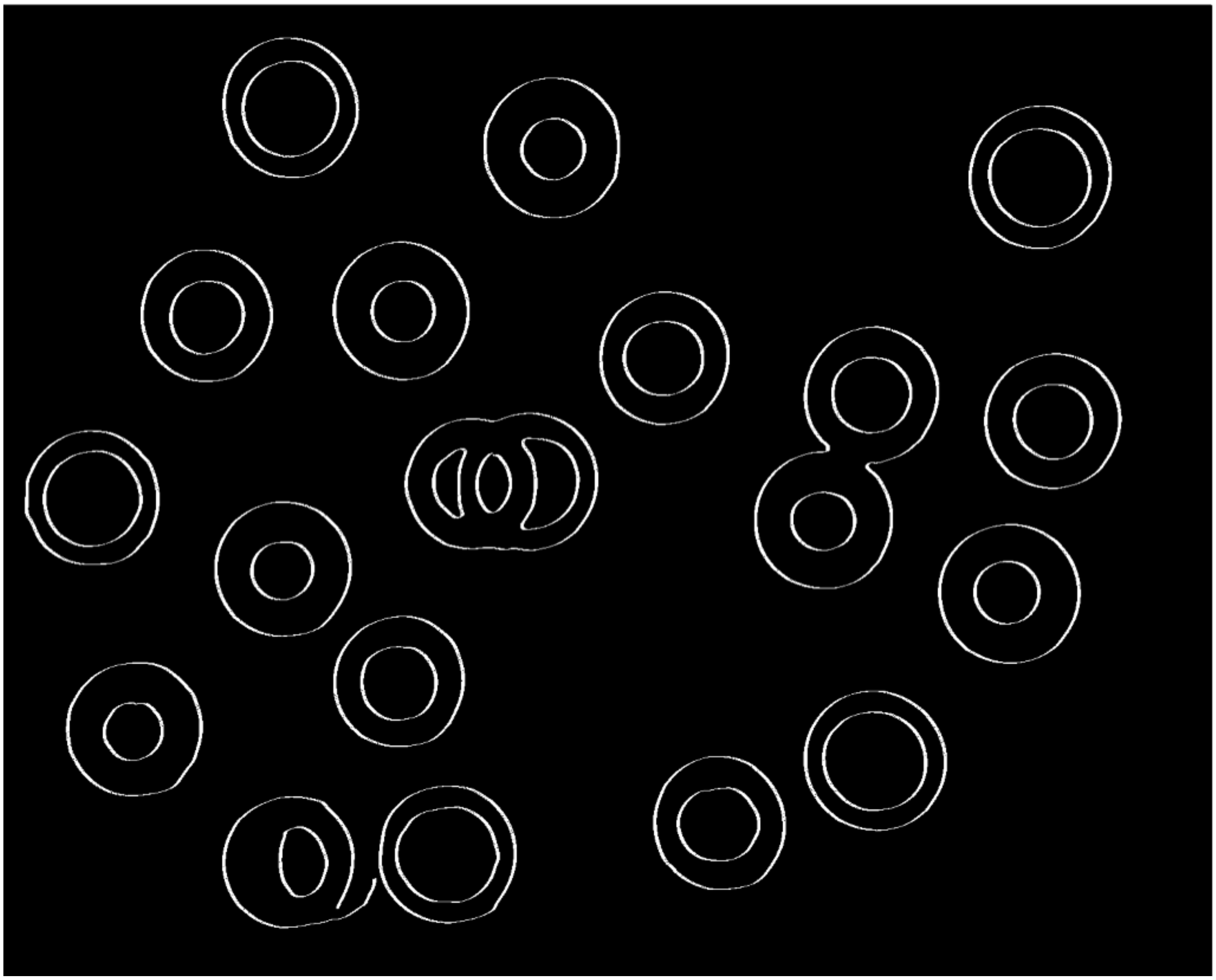


Figure 4: The Canny edge detection from the median filtered image.

After the edges had been isolated, we used the circular Hough transform to find the center and radius of each washer. We ran two separate Hough transforms; the first was for the small circles, which isolated the inner circle of each washer, and the second was for the large circles, which isolated the outer circle of each washer, shown in Figure 5.

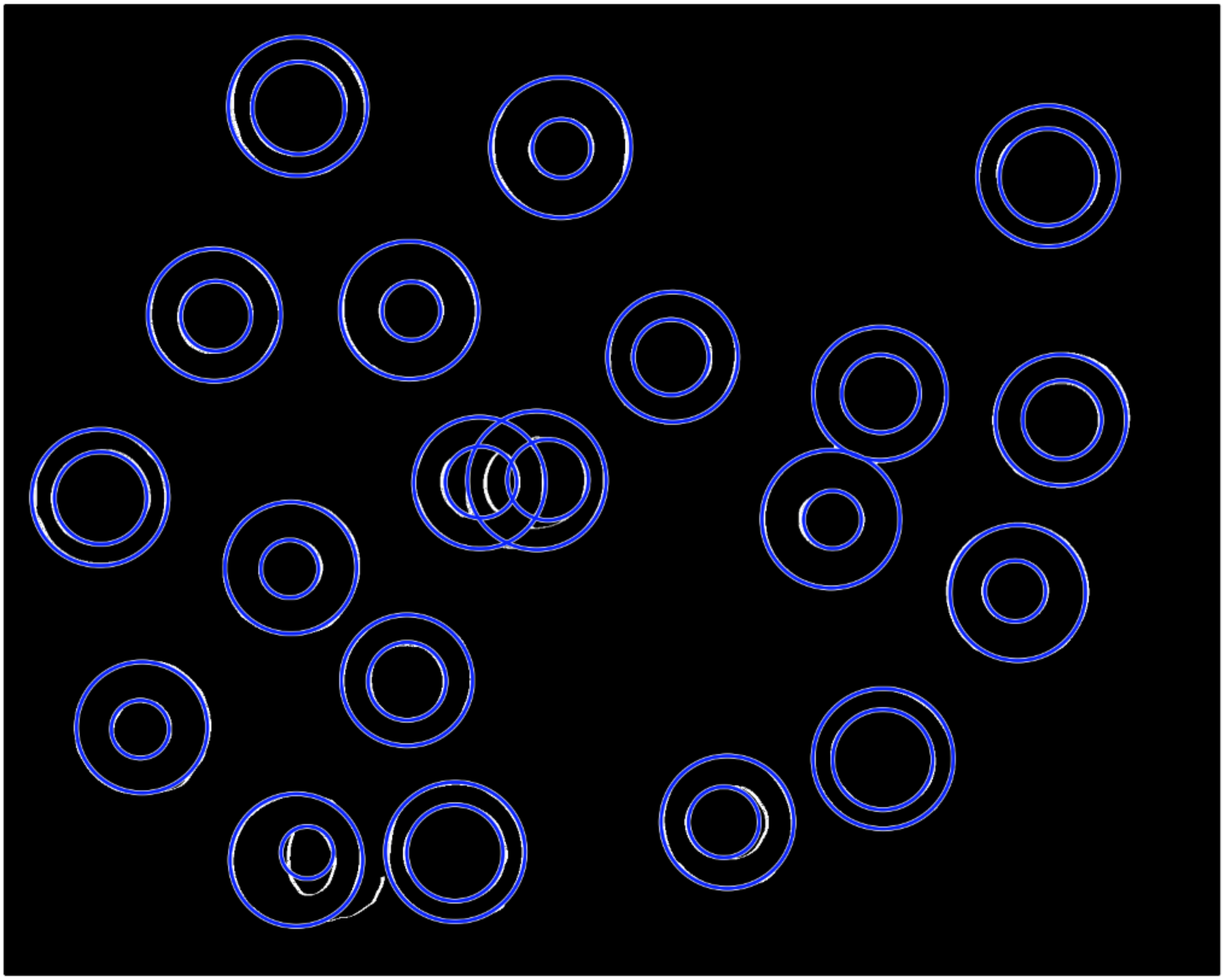


Figure 5: The circular Hough transform was used to find the inner and outer circles of each washer.

Once the inner and outer circles had been found, we had to match them up with each other to identify each individual washer. To accomplish this, we used the dsearchn() function in Matlab, which used the nearest neighbor method to match centers of each inner and outer circle. This allowed us to perform further calculations of each washer.

To sort the washers, we first separated them by color. We found that only using the red and blue color channels provided the greatest contrast between the red and black washers from the median filtered image shown in Figure 6.

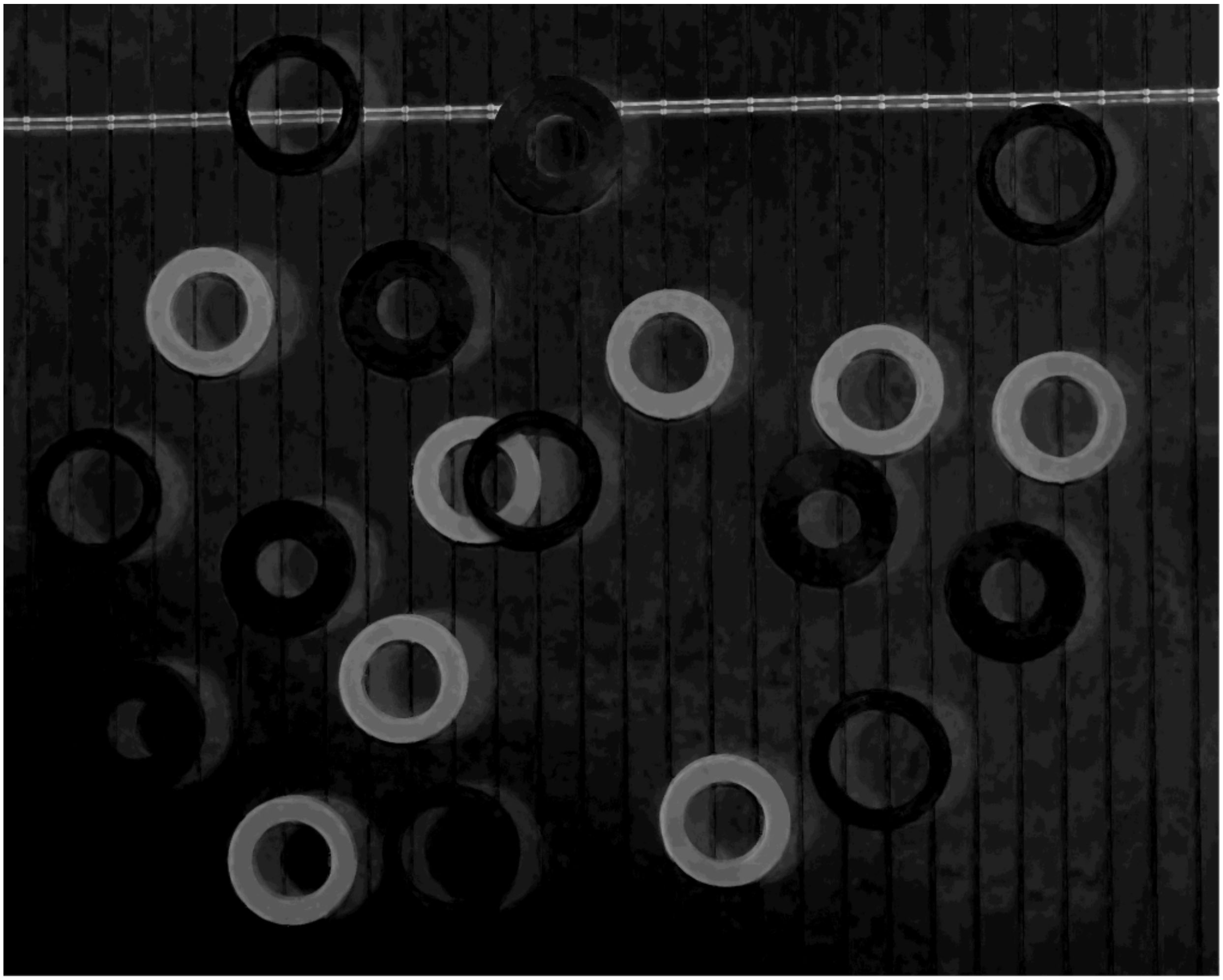


Figure 6: The red and blue components of the median filtered image.

To classify washers by color, we created a mask for each one using the result of the Hough transform. We did this by finding all pixels located at a distance from the center of each washer that was in between the inner and outer radius. Each washer was assigned a unique mask value, which is displayed in Figure 7.

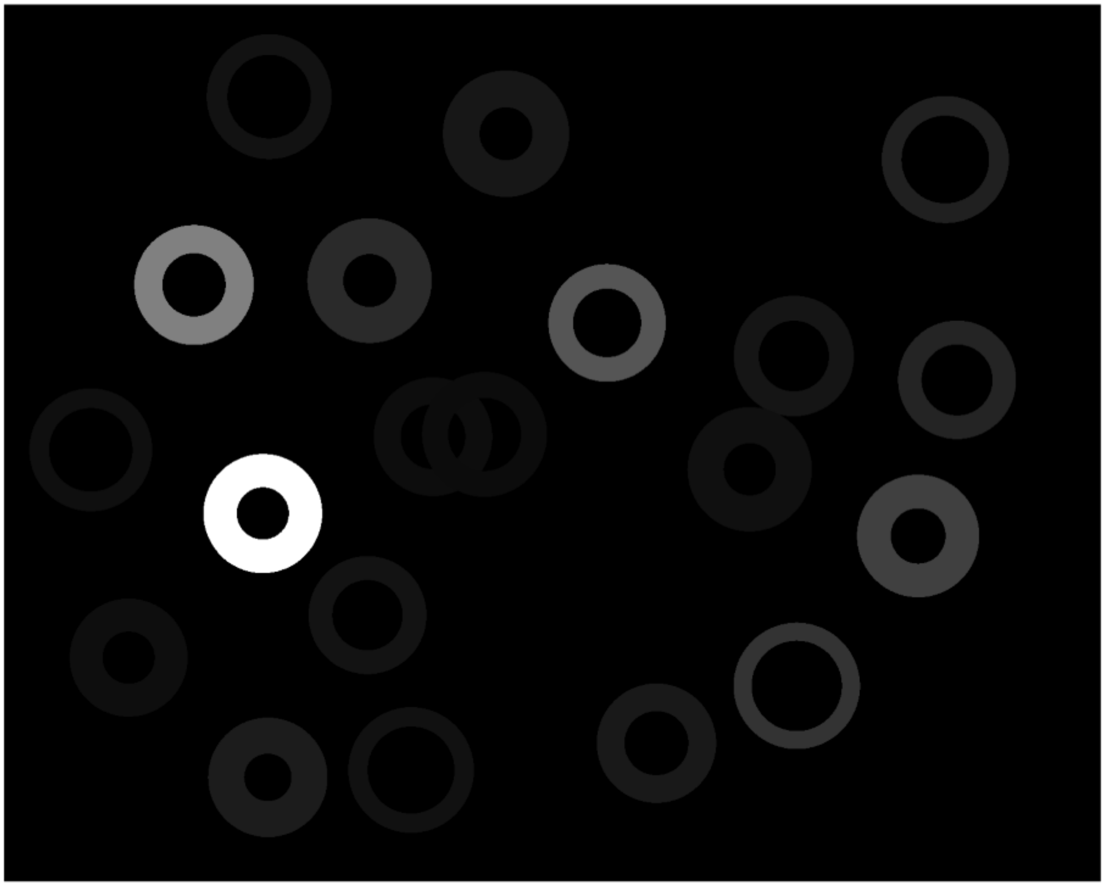


Figure 7: The segmented washer image where each washer has a mask with a unique value.

We used these mask locations to sort by color. The locations of each mask was applied to the red and blue channel image (Figure 6), and the median value was taken for each washer mask. The red washers in the original image produced a much greater response than all of the black washers. These washers were all classified as type B.

To sort washer types A and C, we used the radii of the washers. Type A are much narrower than C, so the inner and outer radius are more similar. We found the proportion of the outer radius divided by the inner radius for each washer. We determined a cutoff value of 2 provided perfect distinction between washer types A and C. The final washer classification for Part 1 is shown in Figure 8.

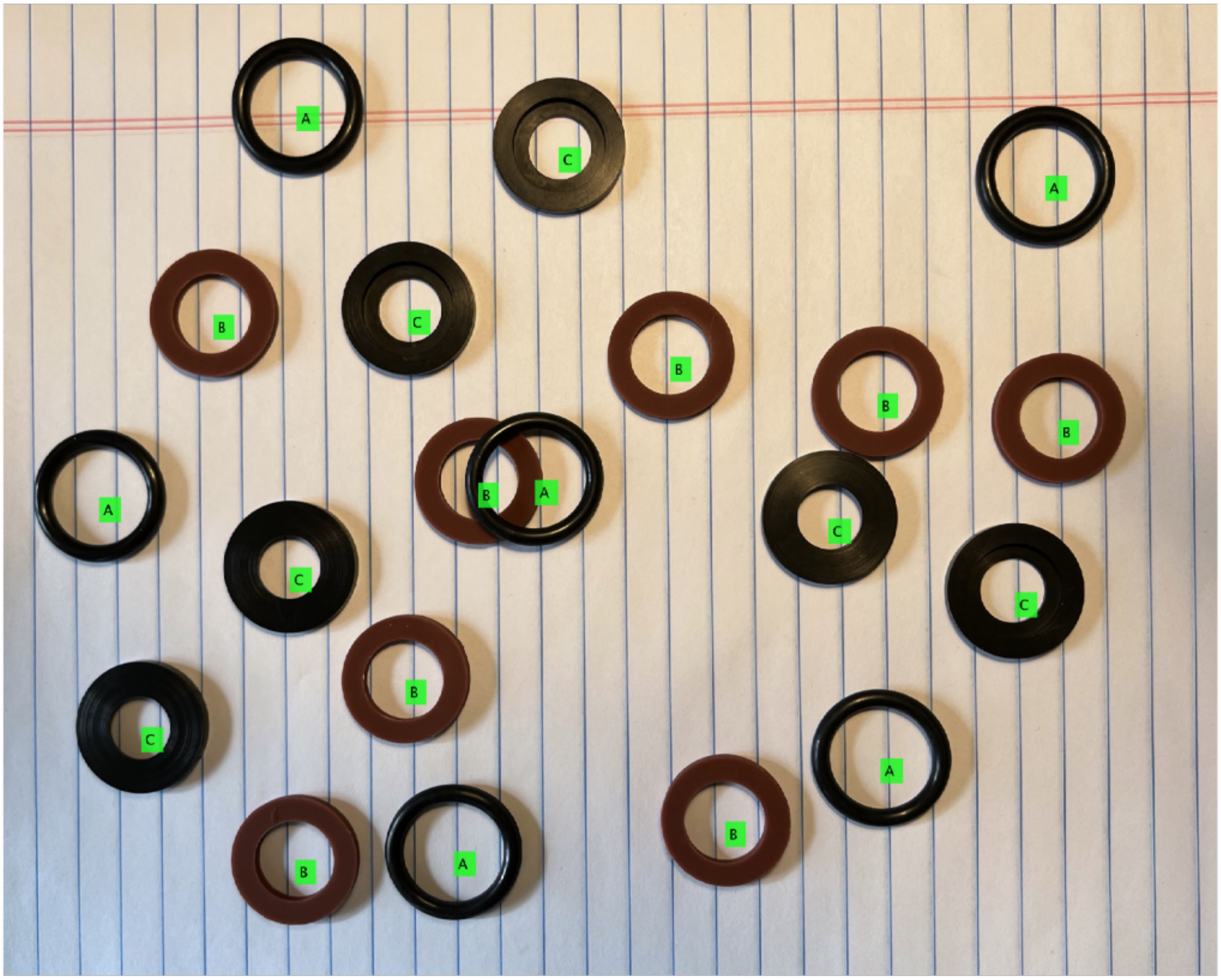


Figure 8: Washer classification of the input image.

Our classification was 100% accurate as all washers were classified correctly.

Quantitative performance analysis

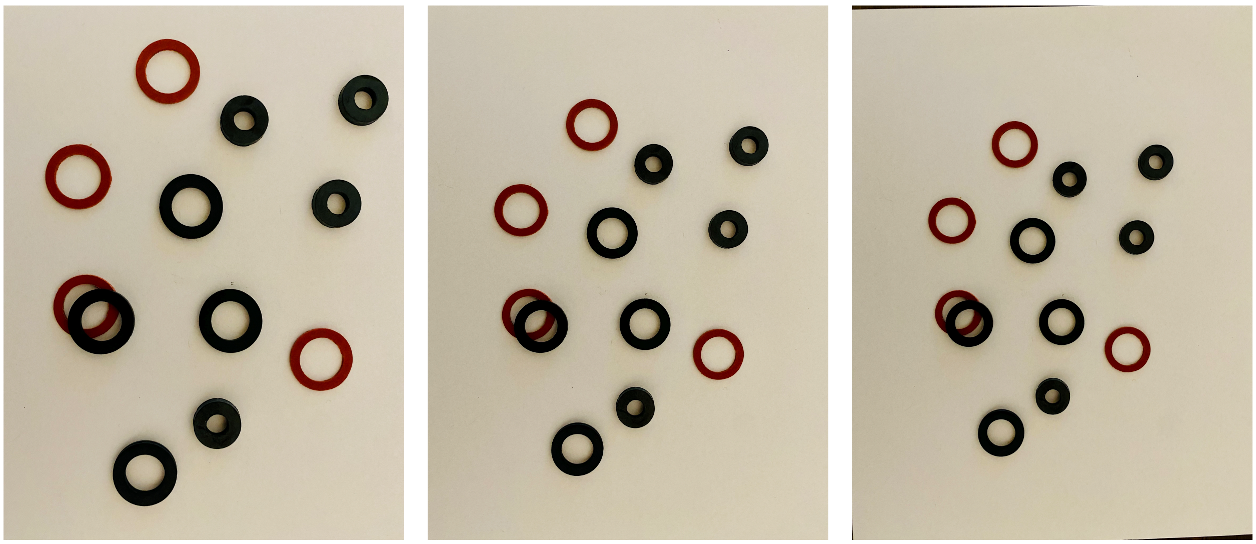
		Classification		
		A	B	C
Reference	A	6	0	0
	B	0	8	0
	C	0	0	6

Part 2:

Image acquisition:

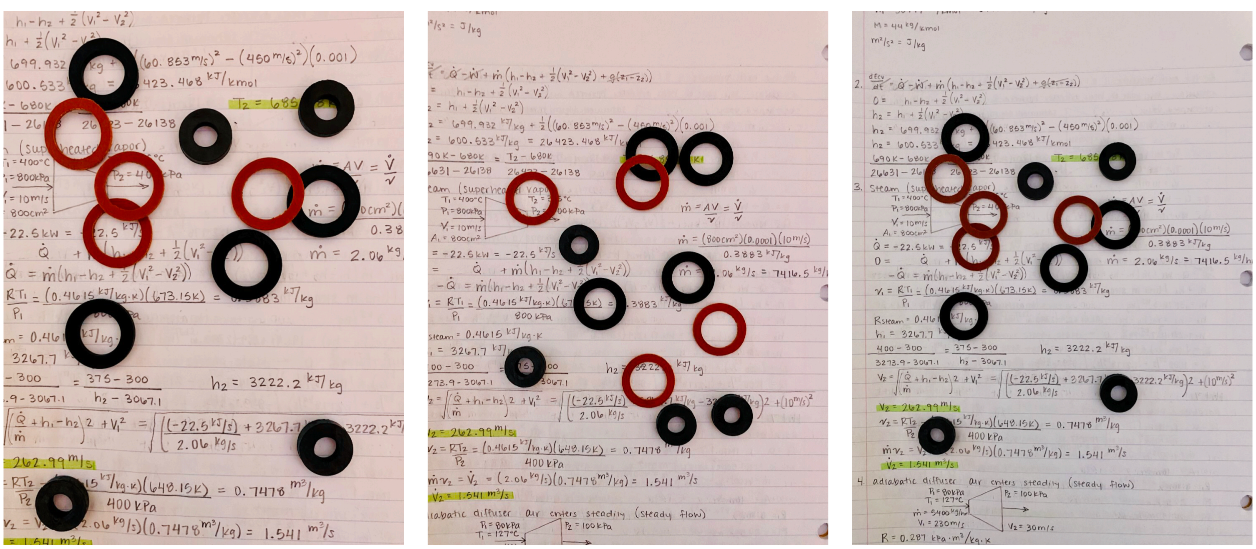
Here are all the 6 images we have collected are listed below:

washers in simple background



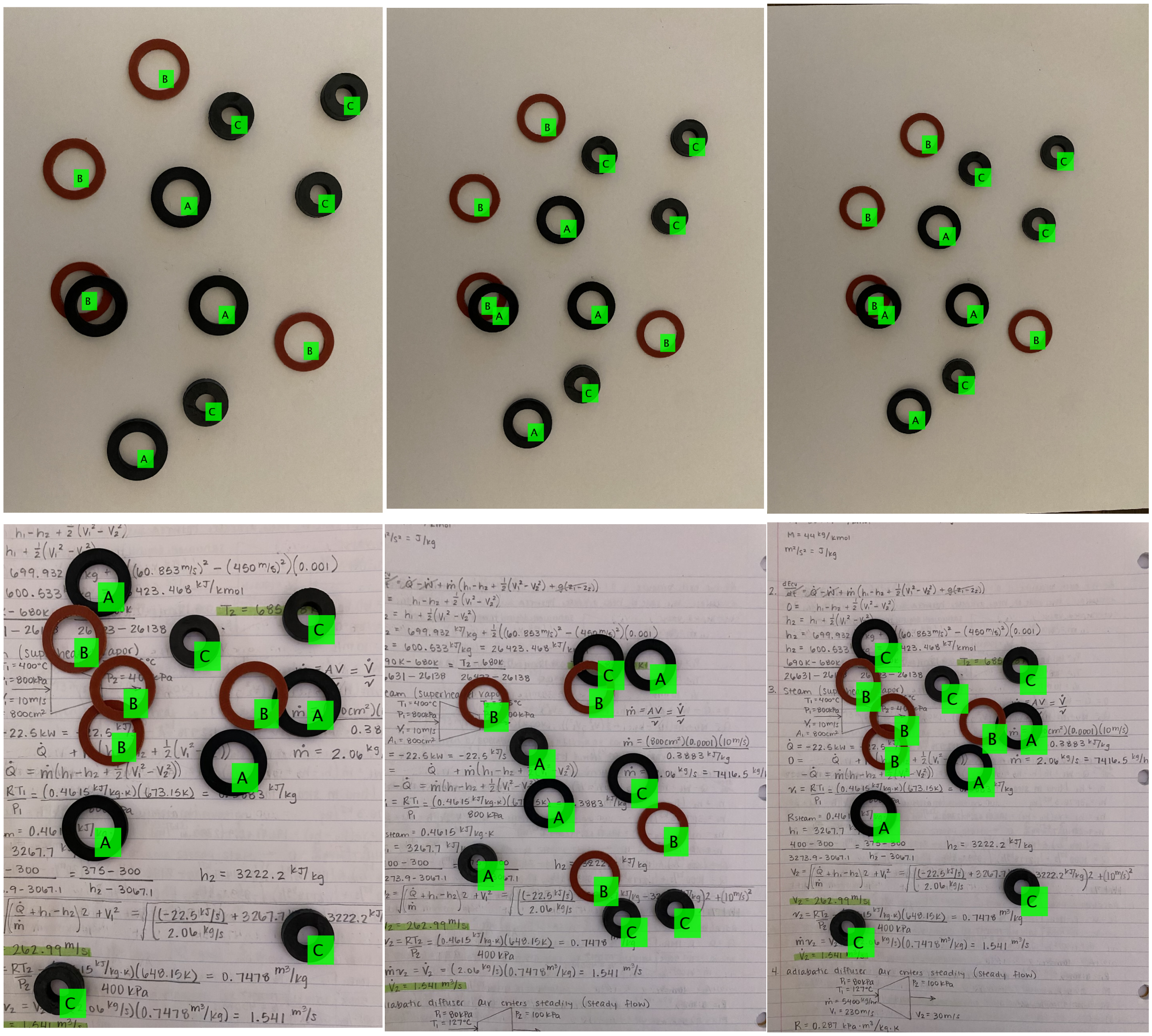
Increasing scale from left to right

Washers in challenging background



Increasing scale from left to right

Classification results:



Quantitative performance analysis (for images collected)

		Classification		
		A	B	C
Reference	A	20	0	3
	B	0	24	0
	C	2	0	22

Accuracy:

- For class A: (20/24)= 83%
- For class B: (24/24)= 100%
- For class C: (22/24)= 92%
- Overall: (20+24+22)/(3*24)= 92%

Form the classification result, we can say that our algorithm is highly effective on the collected images. Only modification we did with respect to what we have for part 1 are as follows:

Radius range for hough transformation:

Unlike part 1, we did hough transformation in three stages. For the first stage, we have selected the radius range based on the higher dimension of the inout image to care of the different scaling. Next we split the overall radius range and applied the hough transformation twice to collect the inner and outer radius of the washers.

Two stage classification:

For classifying washer type B, we have used color feature of the masked objects since the red objects provide highest color response (see table 2). Table 2 is obtained for one of the collected image. For classification, we have computed similar table for all the 6 images. But, for classifying type A and C, we used outer to inner radius response since both these washer type are of same color.

Table 2: Classification decision list for 'W6.png'

Number	Type	X_center	Y_center	Inner radius	Outer radius	Median RB values
1	C	440.036288243	408.876216704	17	48	0
2	C	638.835919867	916.123405154	18	49	0
3	C	635.996719738	362.172999096	16	50	0
4	A	505.832389487	617.678392290	31	61	0
5	C	273.085327316	306.127095389	30	64	0
6	A	268.629464760	732.436295716	30	56	0
7	C	205.338222368	1018.62320985	16	48	0
8	B	298.342143185	566.143502086	33	56	15
9	B	225.573384791	403.601919518	36	60	15
10	A	638.003058998	511.904265868	33	61	0
11	B	321.832755212	488.820150937	36	60	15
12	B	541.843525620	508.986279830	38	65	15

Conclusion:

Overall, this project was the most interesting problem so far throughout the semester. While trying the algorithm, which firstly made based on the provided image, on the collected images, we faced several problems due to different scales and contrast.