Justin Gold

CSC-483: Introduction to Computer Vision

Final Report

Introduction

Planaria are a member of the flatworm group and have been attractive to many biologists in their ability to regenerate. Planaria are promising to study for advancing our understanding of the functionalities of stem cells, and they are convenient for researchers as they are cheap and abundant. Due to their small size, and relatively consistent shape, it was of interest to use computer vision to identify the main features of the worms. Thus, the goal of this project was to, given a set of images containing planaria, implement computer vision techniques to find the contours of the planaria, convert them to the frequency domain, and distinguish between a head and a tail of a planarian.

Thresholding

The first way to identify these planaria was to gain a solid image where there is a clear difference between planaria and unimportant objects. Various types of thresholding were implemented including adaptive thresholding where each pixel was thresholded based on the Gaussian weighted average of its local neighborhood, as well as where each pixel is compared to the mean of its local neighborhood minus some constant C. These are both shown in the figure below, but the most efficient thresholding method implemented used Otsu's Binarization. This method distinguishes every part of an image to be either in the foreground or the background, and finds the threshold that maximizes the separability between these two classes [1] . Using Otsu's Binarization on the planaria dataset provided the most distinguishable differences between planaria and external noise. Though the thresholding worked very well in producing well-defined black and white representations of the images, there were still noise-like objects included in the images.

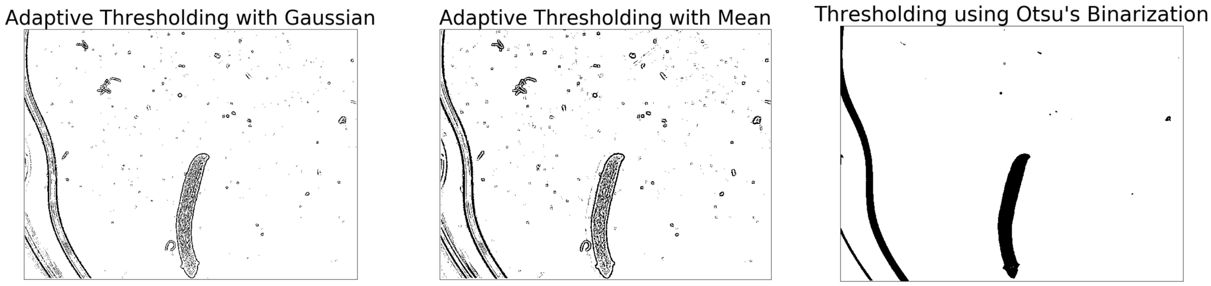


Figure 1: Various thresholding methods on a common image

Contours

With a clear black and white representation of the planaria, the contours of the thresholded images were found. However, because the thresholding was not perfect in isolating only the planaria in the images, when implementing OpenCV's contour function, contours that were not correct, including small dirt on the platform, as well as light surrounding the sides of the platform the planaria were included in the set of contours. To limit the number of contours, contours were thresholded by their length. A small contour surrounding dirt would be too small to be a planaria, so a lower bound was set. Additionally, it was typical that the outline of the entire image was captured was set, so an upper bound. However, the acceptable range could not be too narrow as the planaria had large variations in size among all the images. Thus, the final contour threshold was set to have between 200 and 1200 points. This reduced the number of contours captured for each image to mostly be in a range from 1-6, with some outliers for extremely noisy images. The following images display all of the contours found among a sample of images in the dataset.

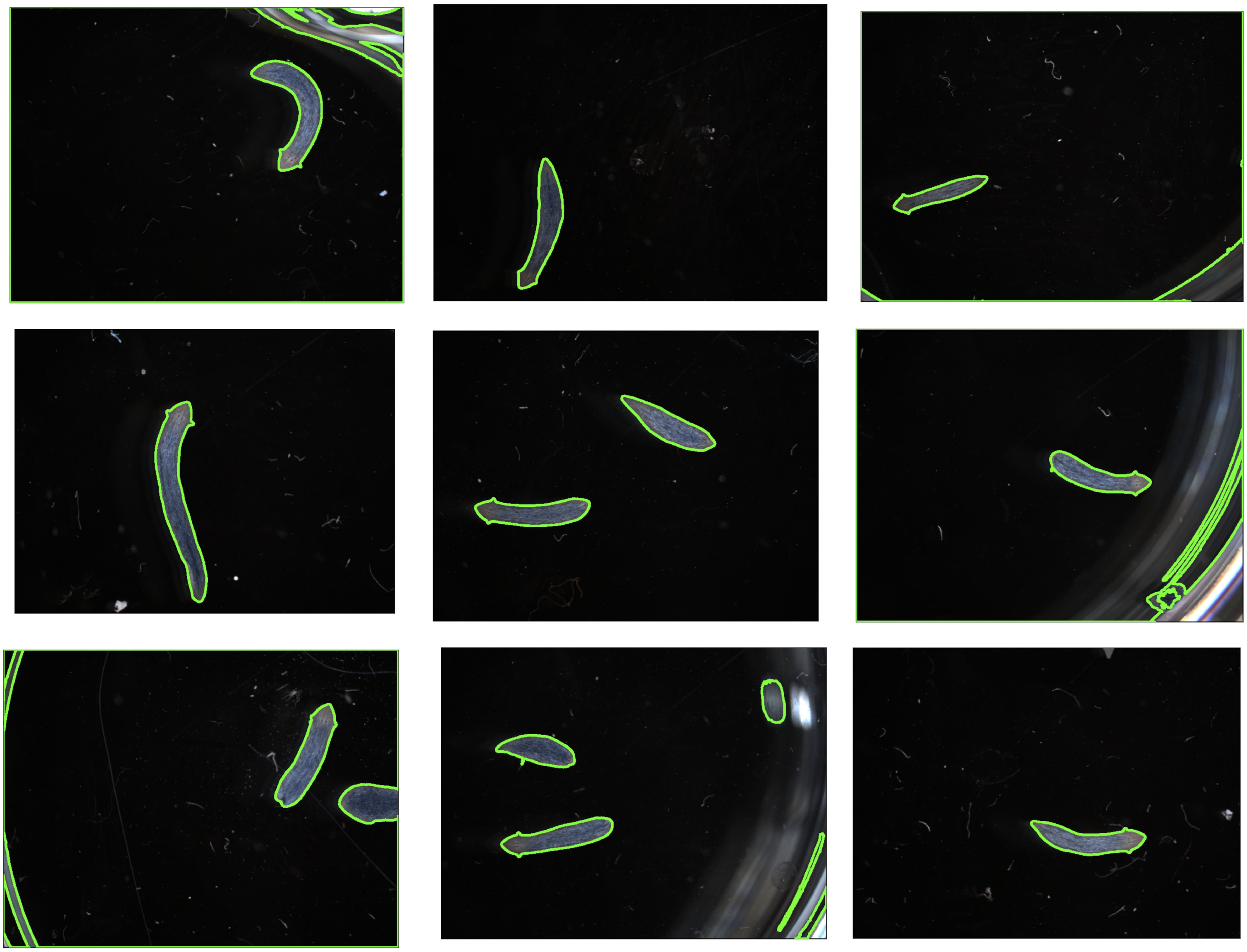


Figure 2:Finding Contours of Planaria with one and two in range

Modifying the Contours and the Fourier Transform

After iterating through the contours of the images to determine which was the correct contour for the planaria, real and imaginary components were considered to the right contours. The figure below shows three contours of planaria in the dataset as well as their real versus imaginary representation.

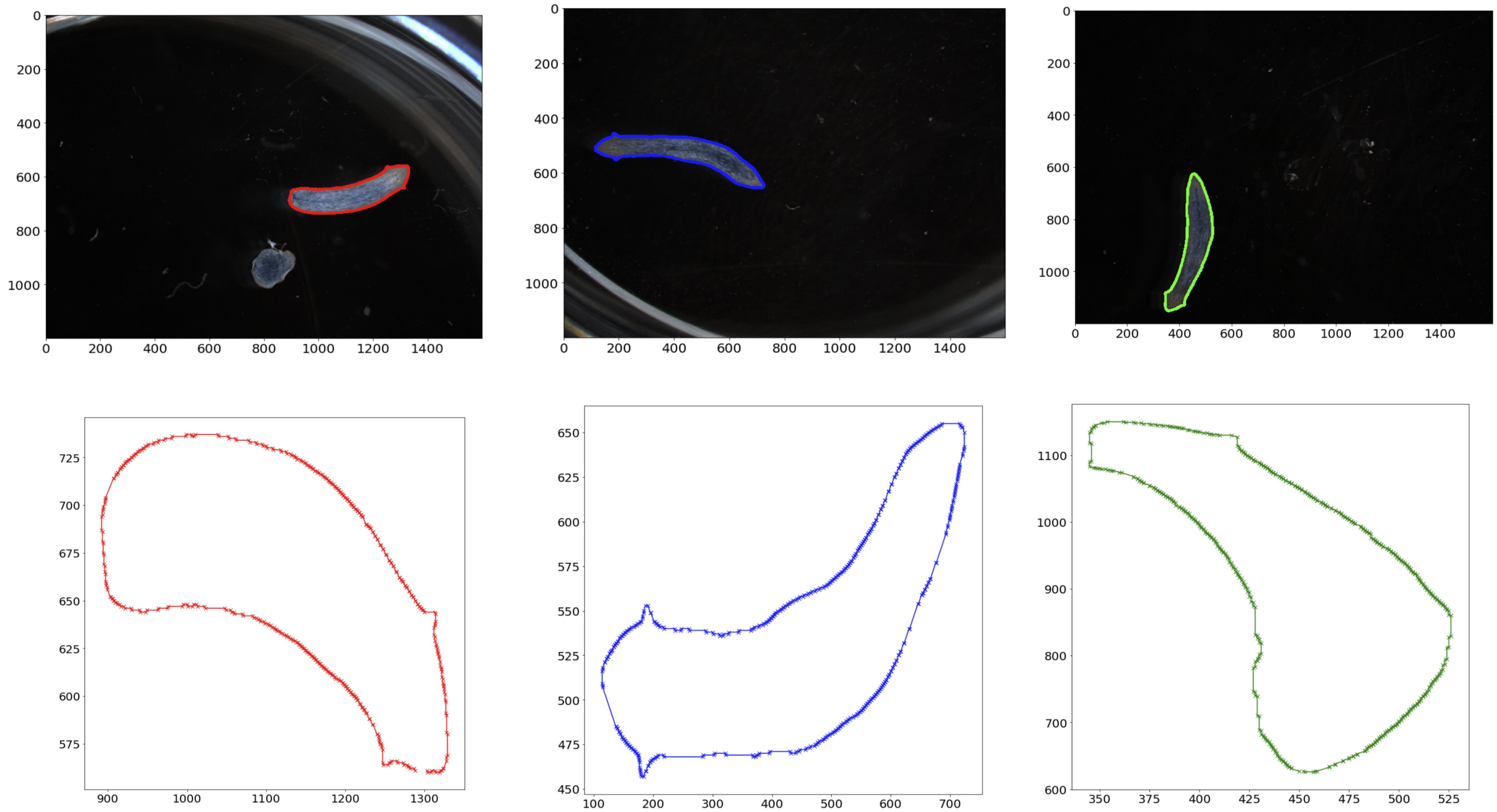


Figure 3: Contours of planaria (top row) and their real and imaginary components (bottom row)

Clearly, the contours of the planaria oriented horizontally are inverted along the x-axis in their real versus imaginary components, and the contour oriented vertically is inverted along the y-axis in its real versus imaginary representation. Additionally, all of these contours are out of center. To revert this to reflect the orientation of the planaria in the actual images, the Fourier Transform was considered for all of these contours. The contours in the frequency spectrum are shown in Figure 4.

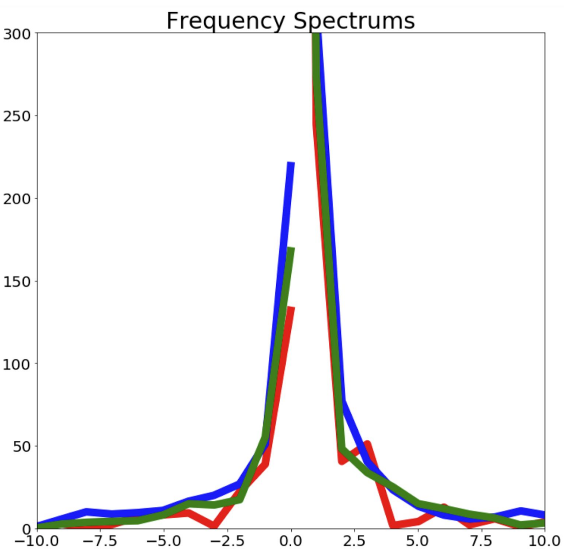


Figure 4: Frequency spectrums of the sample contours

As shown in the figure, all of the contours appear to be similar. While they differ in how smooth they are, they all share the same shape. They have one peak at roughly 0 Hz, and decrease in magnitude extremely rapidly to approach 0 by about 7.5 Hz. The Inverse Fourier Transform was then implemented on these frequency spectra, with their highest frequency component removed. The effect of this is shown in Figure 5.

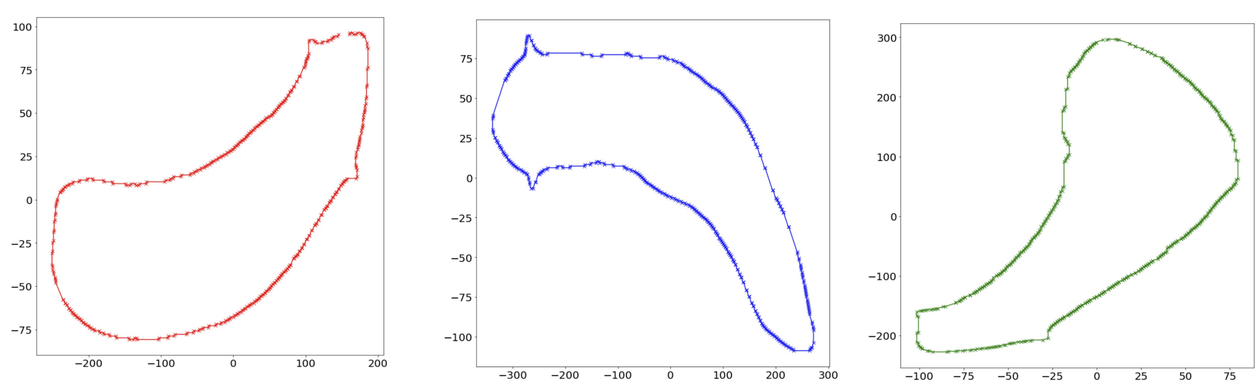
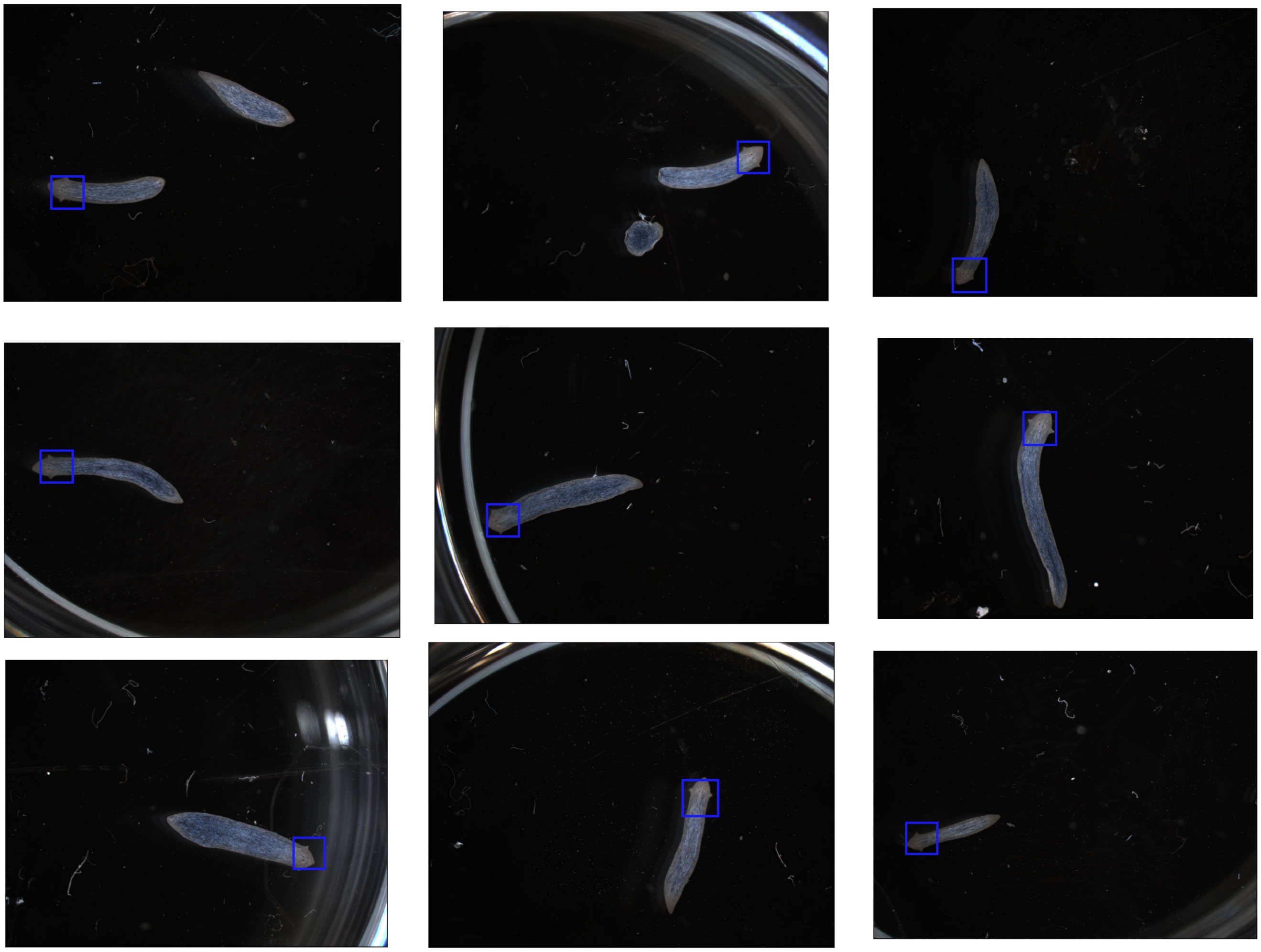


Figure 5: Inverse Fourier Transform of the contours

The contours are now all centered and have the correct orientations to how they were in their original images.

Head Detection

The final test conducted was detecting the head of a planaria. The method that was used to do so was based on the observed main difference between the head and the tail of the planaria being the protruding ears on the sides of the head. Other than this, the planaria has a relatively consistent shape. To leverage this feature common to the planaria, I found the top and bottom halves of the contour of the planaria and subtracted each corresponding point of the top half from the bottom half. A maximum in the displacement between the two halves would indicate that either one or both of the ears were found. To implement this, the orientation of the planaria's contour was first found. If the planaria was faced mostly vertically, the ears would indicate a maximum displacement along the x-axis. If the planaria was faced mostly horizontally, the ears would be located at the maximum y displacement. After finding the orientation, it was possible to divide the planaria into a top and bottom half, and check for a maximum displacement along the x or y axis based on its orientation. However, a maximum could have appeared somewhere in the body of the planaria. Thus, maximum displacements were only considered on the ends of the contour. Because the contour did not indicate the direction it started from, the contour could have started at either the head or tail of the planaria. Thus, both ends of the contours were considered, and whichever end had the greatest displacement was labeled as the head. The results of implementing this on a sample of the images in the dataset are shown below.



Conclusion

The contour detection and head detection of planaria worked well for most of the images in the dataset. In many images there were distinct and accurate contours around the planaria, and the head region was properly detected. However, the contour detection was not perfect as the thresholding would occasionally eliminate the planaria from the image, so the contour could not be found. Additionally, the head detection was not perfect as the displacement of the planaria's tail was occasionally greater than the displacement of the planaria's ears, and the tail would be detected.

Works Cited

[1] Otsu, Nobuyuki. "A threshold selection method from gray-level histograms." *IEEE transactions on systems, man, and cybernetics* 9.1 (1979): 62-66.