Master in Machine Learning for Health

BIOMEDICAL IMAGE PROCESSING

IMAGE SEGMENTATION

LAB EXERCISE 3 - PROJECT 1

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INTRODUCTION

In this project, we aim to improve the provided baseline segmentation system by integrating different ideas and methods. The main goal is to upgrade the performance by increasing the Jaccard Index. To do so, we have implemented several techniques, which are explained throughout this report. The whole segmentation process is listed in order, with the new techniques in bold letters.

TABLE

Technique	**Performance**
Baseline system	0.34
CLAHE	0.35
CLAHE + 2 Edge enhancements	0.51
CLAHE + 2 Edge enhancements + closing	0.53
CLAHE + 2 Edge enhancements + closing + remove small objects	0.54
Combination of images (1st and 2nd additions) + change parameter of th-segmentation	0.56
Bilateral filtering + Edge sharpening	0.58
Remove small objects + closing	0.6

PREPROCESSING

1. **Edge sharpening:** sharpen edges using the formula: **New_Im = Im + 3*(Im - gaussian (Im, sigma = 4))**. A low pass filter smoothes out the edges, then subtracting this from the original image, we get the edges. Finally, we add them (with a control parameter) to obtain a sharpened image.
2. Illumination compensation: already in the baseline, it is useful for correcting non-uniform illumination, common in retinal images where the center is often brighter than the edges.
3. **Edge sharpening:** same as before but with the illumination-compensated image.
4. Contrast enhancement: already in the baseline. It improves the contrast of the vessels within the retina area, making them more distinguishable from the background.
5. **CLAHE**: local histogram equalization to enhance contrast locally. At this point we obtain an image with a good definition of the vessels, but a very noisy background. If we apply the threshold segmentation directly to this image, the results are slightly better than the baseline, but we want to go further. We will call this **Image_1.** With the next steps, we aim to ‘cancel out’ the background noise while maintaining the definition of the vessels.

6. **Illumination compensation of image obtained in step 3.** We will call this **Image_2.**
7. **Sobel:** perform this high-pass filter to detect the edges of the image and then compute the negative. This way we will have the edges shown in dark colors while the background in light colors. We will call this **Image_sobel.**
8. **First Addition: Image_sobel + 30*Image_2 = Image_3.** With this addition (using a control parameter) we enhance the vessels from Image_2, as we obtained an image that emphasizes the darkness of the vessels in contrast to the background while maintaining a quite uniform background and avoiding noise.
9. **Second Addition: Image_1 + 2.1*gaussian(Image_3, sigma = 1.05) = Image_4.** With this addition, we can balance the noisy background from the CLAHE by adding it to a slightly blurry version of Image_3. We will get an output that maintains the dark values of the blood vessels while compensating for the local changes within the background, which will make it easier to find a good threshold that separates the background from the vessels.
10. **Bilateral filtering**: further filtering of Image_4 to get rid of the background noise and make the background as uniform as possible. With bilateral filtering, we can reduce the noise while preserving the edges. A Gaussian filter would blur the image to eliminate the noise.
11. **Weighted edge sharpening:** we can sharpen the edges of the image without overly enhancing the noise as it takes some parameters that help to do so.

SEGMENTATION

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12. **Threshold segmentation: (with <0.05*th)** Now we are able to change the value of 0.25 to 0.05, choosing a smaller threshold that selects the vessels, which is able to catch the dark values of the vessels only and not the background.

POSTPROCESSING

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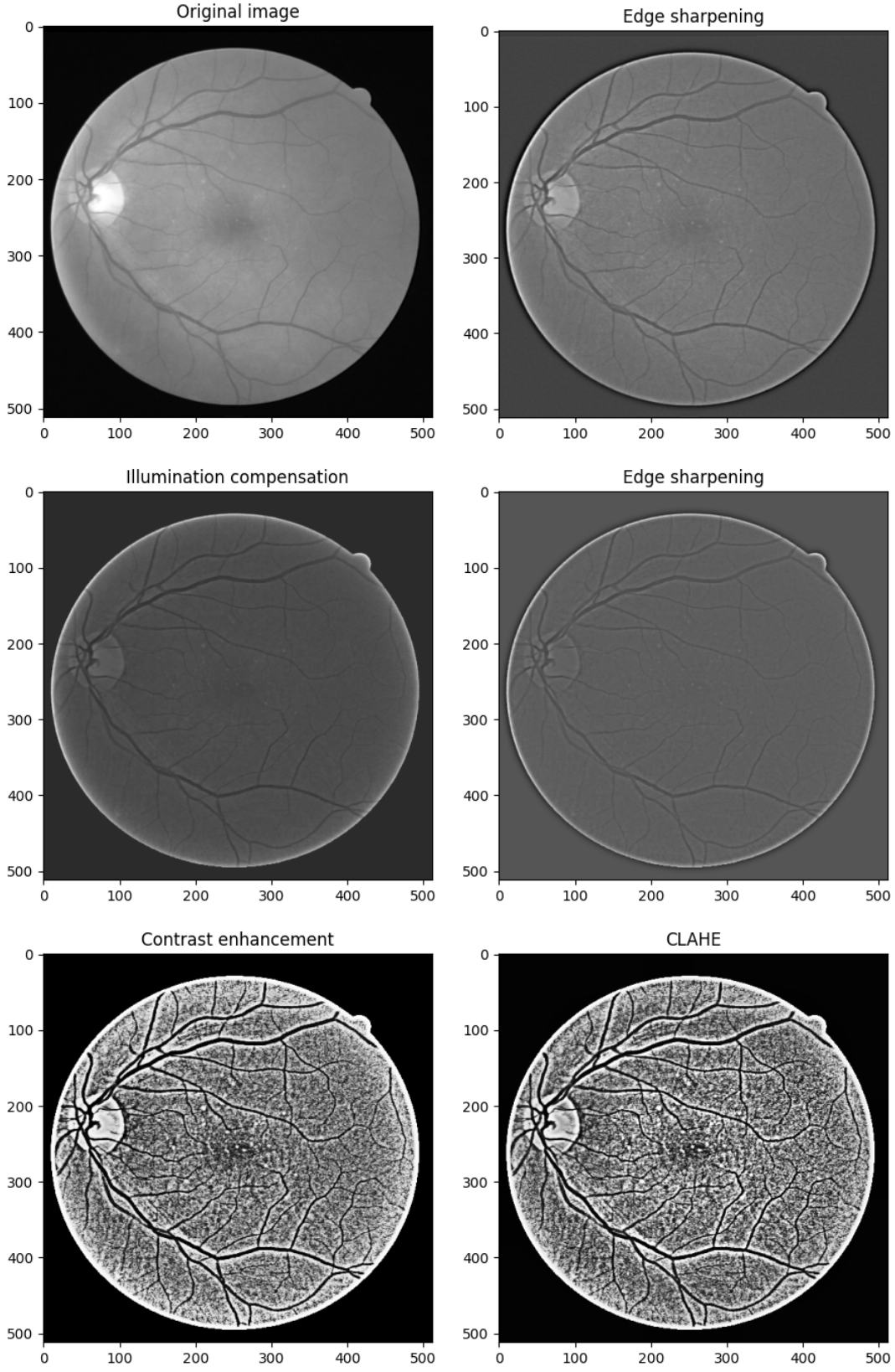
13. Remove small objects: already in the baseline but we change the min_size = 12.
14. **Closing** (square of 3): morphology operation used for getting rid of the small holes of the obtained image, and cleaning up artifacts in the segmented image.
15. **Remove small objects** with min_size = 35 (again) to get rid of bigger objects.
16. **Closing** (square of 2): perform closing again to clean the image further.

DISCUSSION OF RESULTS

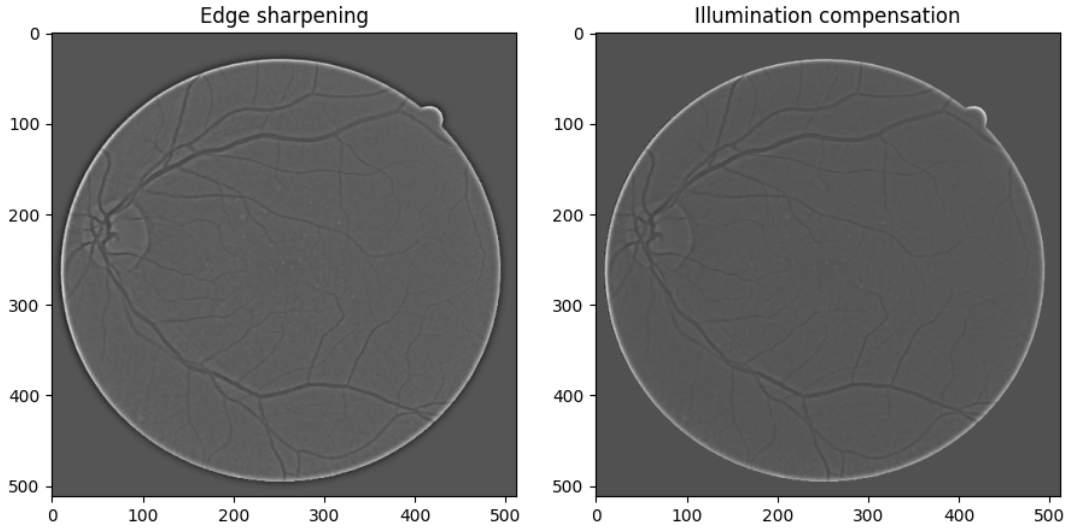
The final results of the Jaccard Index showed an average similarity of 0.60 throughout the 80 images with their GT masks. It is worth noticing that this index changes quite a bit among images, some showing indexes as high as 0.65 and others as low as 0.41, as it is difficult to find techniques that work properly for all images. Overall, the methods we implemented brought the index of all images up, so we can conclude that they are somewhat efficient.

ANNEX: GRAPHICAL SUMMARY

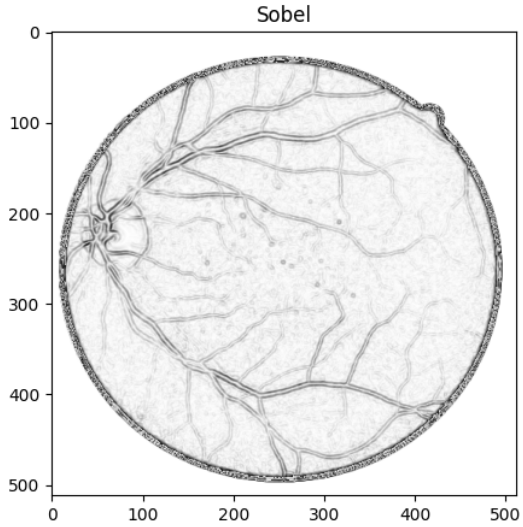
Obtaining Image_1:



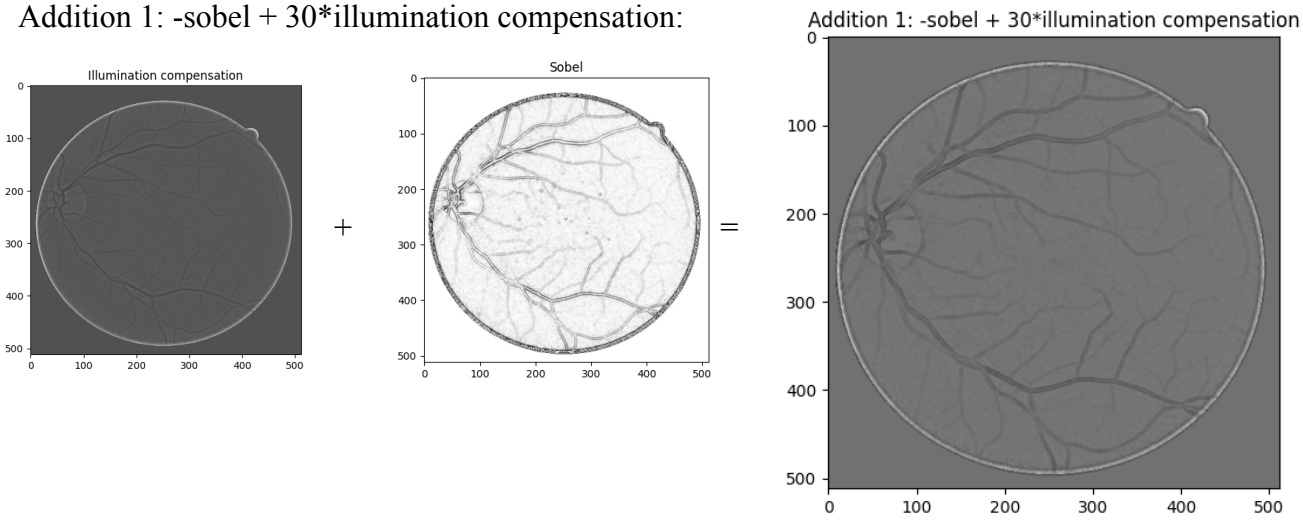
Illumination compensation of Image from second edge sharpening:



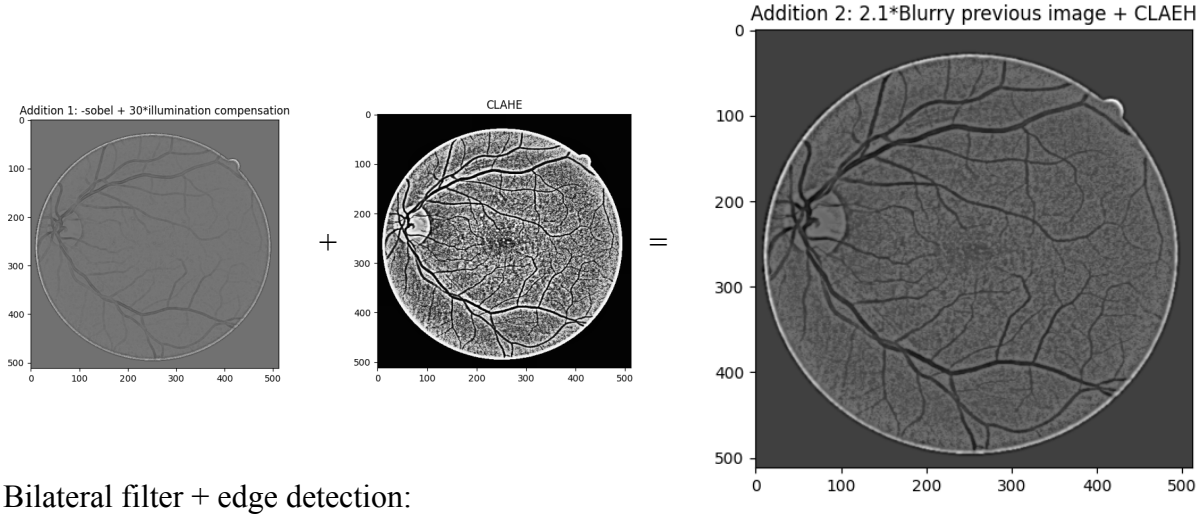
Perform the negative Sobel:



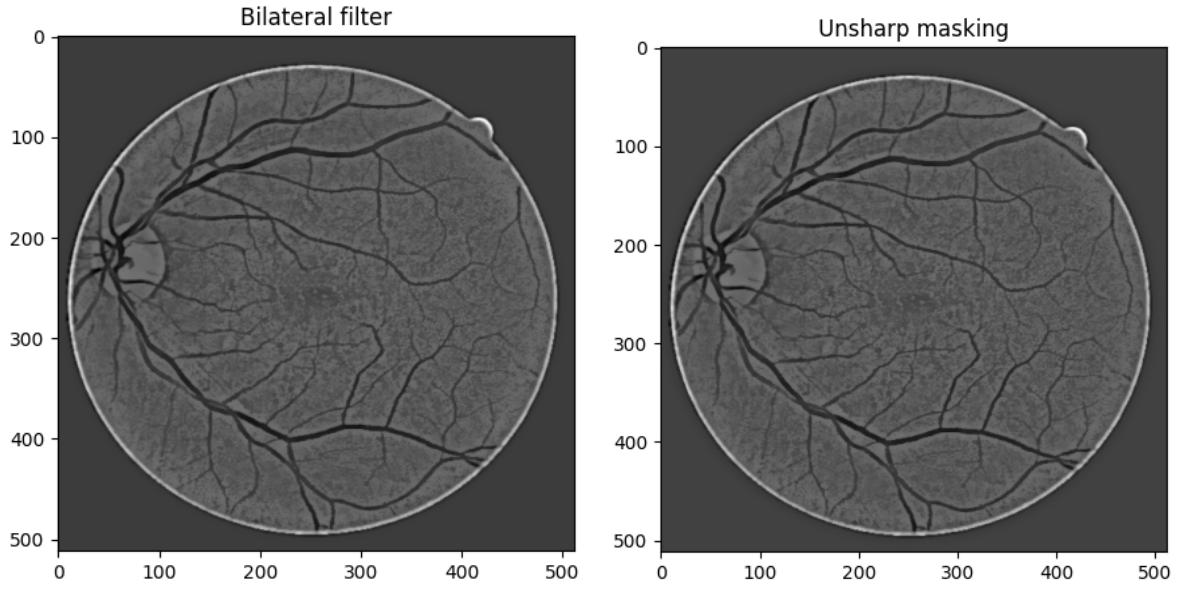
Addition 1: -sobel + 30*illumination compensation:



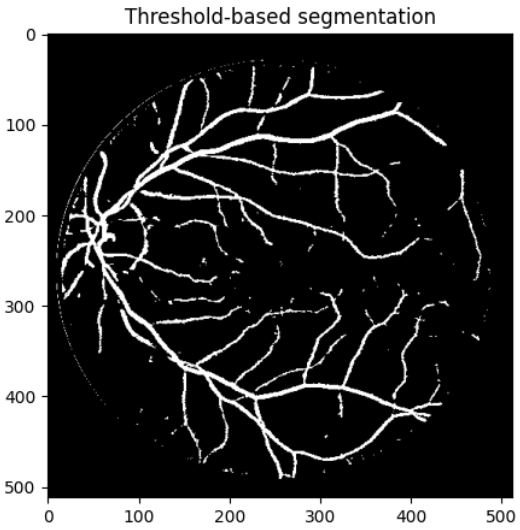
Addition 2:



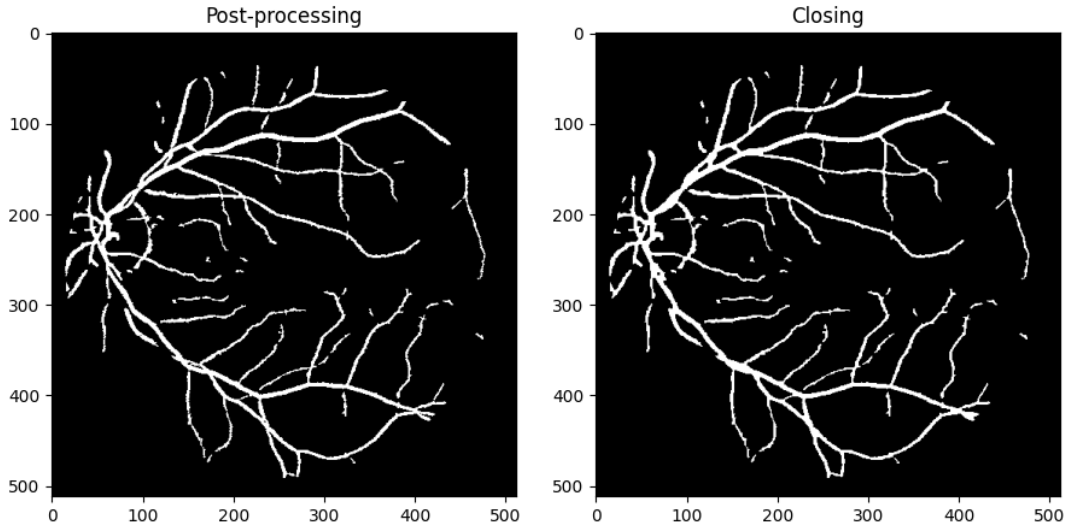
Bilateral filter + edge detection:



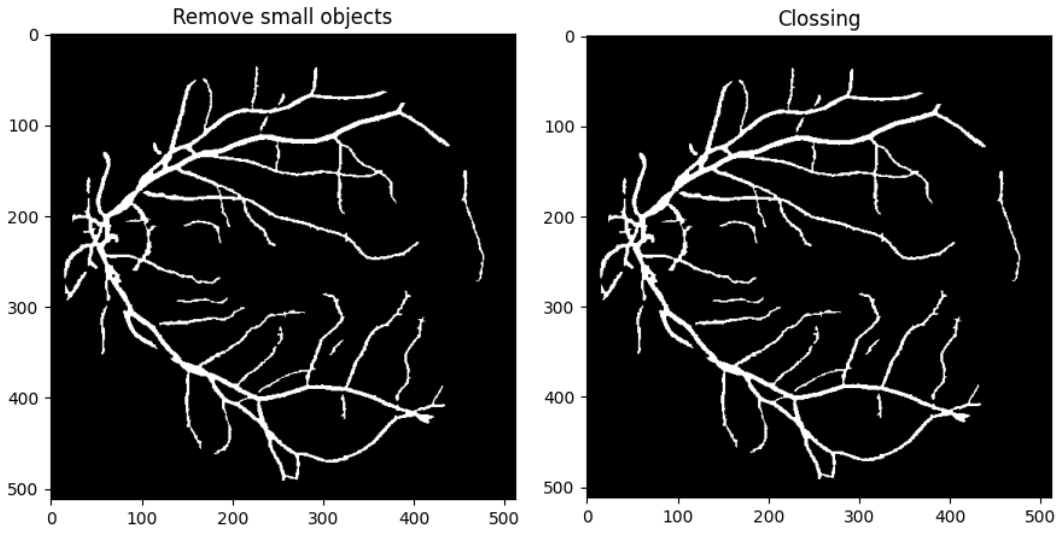
Threshold segmentation:



Remove small objects + closing:



Remove small objects + closing:



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