uc3m | Universidad Carlos III de Madrid

Departamento de Teoría de la Señal y Comunicaciones

Image Segmentation

Audio processing, Video processing and Computer vision

Lab exercise 3

1. Introduction

Our goal is to produce a segmented image as illustrated in Figure 1, where the image on the left shows the image to be segmented and the image on the right shows the desired result.

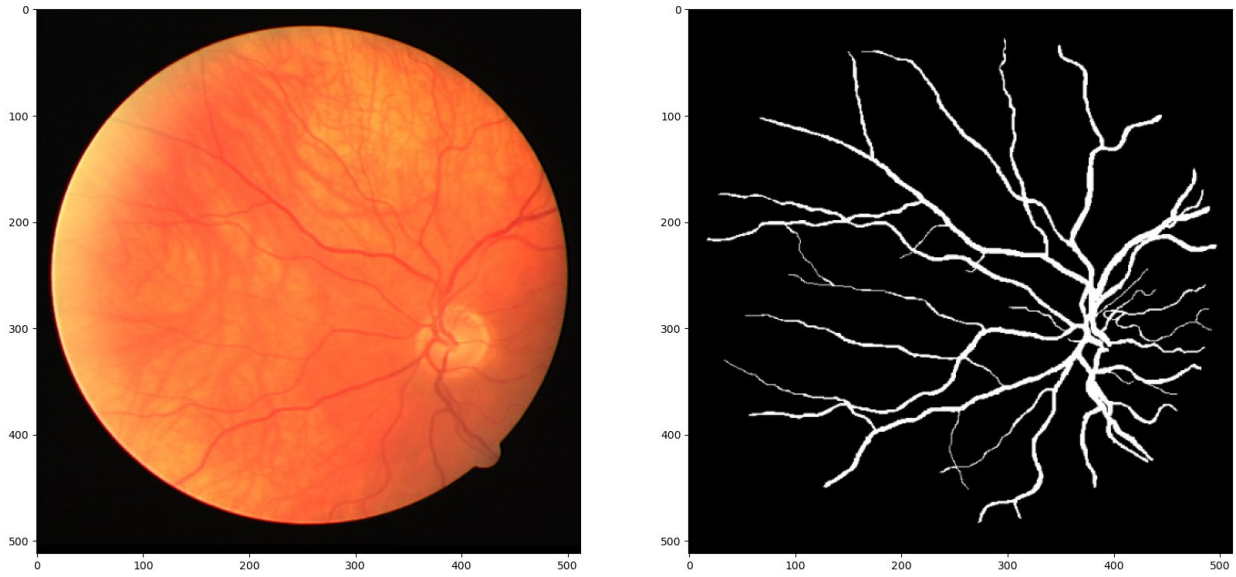


Figure 1.- Original and ground-truth segmentation result.

2. Project description

The basic block diagram of an automatic image segmentation system is as follows:

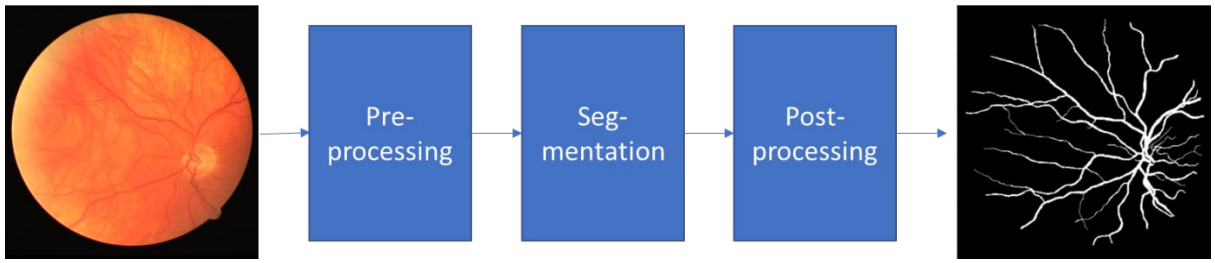


Figure 2.- Block diagram of the segmentation process

1. Preprocessing: to reduce the impact of noise or other artifacts

2. Segmentation: use of an automatic segmentation algorithm that produces a binary mask separating cells from each other and the background.

3. Post-processing: to achieve a more precise segmentation, the binary masks resulting from the segmentation can be post-processed.

2.1. Preprocessing

A Gaussian smoothing operation is a common option, but you need to pay attention to the tradeoff between the blurring of undesirable features and the preservation of the edges. Median filtering is another option.

2.2. Automatic segmentation

A wide variety of methods have been proposed for automatic segmentation. In class, we have covered the most basic approaches, which include:

1. Threshold-based segmentation: These algorithms determine one or more appropriate threshold values to separate the pixels of an image into two or more regions.
2. Clustering-based segmentation: These methods segment an image into two or more regions according to a set of predefined features, such as intensity, texture, location, and more.

2.3. Post-processing

The result of the automatic segmentation stage is a binary mask that separates blood vessels from the rest.

To improve the result of the segmentation, it can be postprocessed by applying one or more morphological operations.

3. Evaluation

The metric used for the evaluation of the proposed segmentation system will be the Jaccard Index (JI). It measures the degree of similarity between two regions, in this case two segmentation masks:

- A: the ground-truth (GT) mask, determined by experts
- B: the mask predicted by our automatic system.

The formulation of the JI is as follows:

$$JI(A,B) = \frac{|A \cap B|}{|A \cup B|}$$

i.e., the cardinality of the intersection of both sets divided by the cardinality of their union.

JI takes values between 0 and 1. The closer to 1, the better the segmentation.

4. Database

- The database provided for this exercise consists of 80 images of size 512x512.
- There are two types of images:
  - The retina color images
  - The ground-truth segmentation

5. Goal

You have access to a baseline segmentation system, and your task is to improve it. Please note that machine learning-based techniques are not permitted for this task.

You goal is two-folded:

- Improving a baseline threshold-based segmentation method
- Implementing a clustering-based segmentation method.

The primary objective is to enhance the baseline system by integrating successful ideas and maintaining a record of the improvements in a table.

To improve your system's performance, you should look at the results and learn from the errors. It may be helpful to implement an automatic procedure to show the images exhibiting the worst results.

Avoid spending excessive time on overfitting the parameters of your system to our dataset. Instead, explore different approaches.

6. Implementation and submission

Your code must implement the different stages of the system: pre-processing, automatic segmentation and post-processing. The software has to be properly documented.

The headers of the provided functions cannot be modified, as they will be used for evaluation. Your system has to work just updating the folders containing the images and the masks.

6.1. Project submission

For the evaluation of the project, you must submit:

1. The software implemented according to the Python scripts provided, properly structured and commented. If you have used some source of external software, you have to include it in your submission (and properly describe it in the project report).
2. A brief project report (2 pages maximum, excluding the cover, references, and the graphic summary), including:
   - Brief introduction (one paragraph; it is just a formality)

- Table including each proposed technique and the obtained results. The idea is to start with the baseline results (provided with the lab exercise) and adding new entries indicating the techniques that allowed you to improve the baseline results. Example:

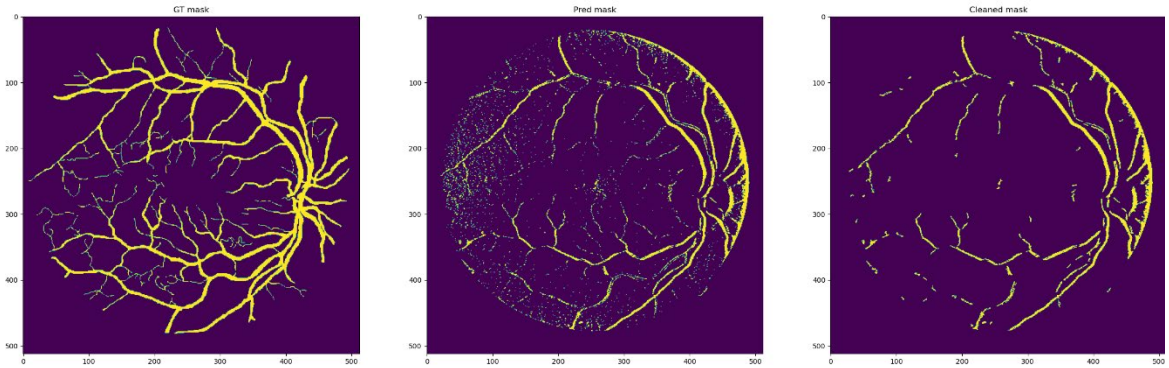
Technique	Performance (IoU)
Baseline system	0.37
Technique #1	0.39
Techniques #1 and #2	0.41
Techniques #1, #2 and #3	0.43

- A brief description of the proposed techniques. The student must provide relevant information about the system (excluding the description of known methods or algorithms – those than can be found in papers and books). In other words, you only need to describe why you believe that a given technique is going to work well. For example: you do not have to describe *k-means*, but you need to describe your feature space. Example:

  "Remove_small_objects (morphological operation): it improves the segmentation masks by removing noise. Increases the IoU"

- Discussion of results
- References
- Annex: Graphical Summary of your work, i.e., a sequence of images illustrating the image evolution through your system, from the original image to the segmented image. This image sequence must illustrate the effect and contribution of each of the proposed techniques. Example:

  Morphology operation: remove_small_objects



Deadline for submission through “Aula Global” (Python code and report): Sunday, Oct. 20, 2024.

6.2. Evaluation

The evaluation of the lab is structured as follows:

- 50%: performance
- 40%: report
- 10%: code

6.2.1. Original contributions

All the original contributions will be valued positively.