High-Speed Atomic Force Microscopy to Reveal the Structural Dynamics of the Amyloid-β Aggregation Pathways

The morphological characteristics and aggregation of Amyloid-β in this brain has a considerable influence on the risk of Alzheimer's disease. In recent years, many studies have been conducted to characterize the morphology of Amyloid-β using AFM (Atomic Force Microscopy). This assignment aims to characterize Amyloid-β fibers from AFM images, in particular by calculating the *mean diameter* and *tortuosity* of these fibers.

In order to calculate the *mean diameter* d_m of the fibers, a method based on the combination of skeletonization and distance map calculation is proposed and the *tortuosity* τ is defined as follow:

$$\tau = l_m/l \in [0; 1] \tag{1}$$

with l the total length of the fiber and l_m the length of a straight line connecting the two ends of the fiber. The tortuosity of a straight line is thus equals to 1. A good approximation of tortuosity can be obtained by calculating the length of the skeleton l_s for l and the maximum Feret diameter $F_{\max}$ for l_m. Equation (1) is then written:

$$\tau = F_{\max}/l_s \tag{2}$$

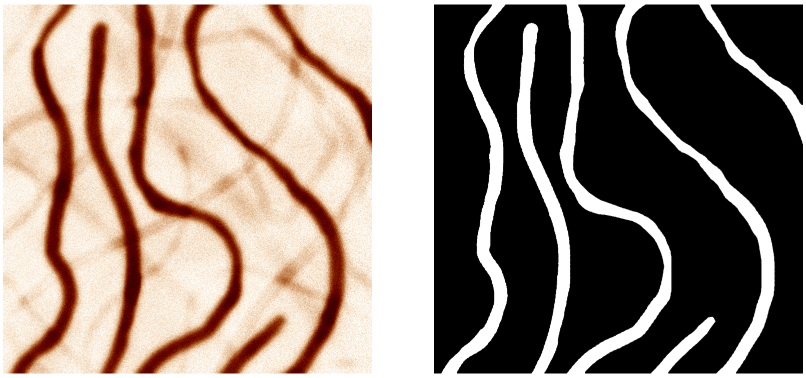

Figure 1: AFM image of Amyloid-β fibers and corresponding segmented binary image.

Instructions

- The student has at his disposal a AFM image named `amyloid_b_afm.png` and a corresponding binarized image named `amyloid_b_bw.png`.
- If the student is having difficulty with the image processing and segmentation portion of the assignment, he or she can use the proposed binary image to answer the following questions.

Question 1 (5 points)

Propose a method and code a function that turns the AFM image into a binary image in order to isolate every Amyloid-β fiber visible on the image.

Question 2 (2 points)

Propose a method and code a function that returns the number of fibers. The functions `skimage.measure.label` (Python) or `bwlabel` (MATLAB) could be found useful.

Question 3 (2 points)

For each fiber, compute the corresponding skeleton. The functions `skimage.morphology.skeletonize` (Python) or `bwskel` (MATLAB) could be found useful.

Question 4 (2 points)

For each fiber, compute the corresponding distance map. The functions `scipy.ndimage.distance_transform_edt` (Python) or `bwdist` (MATLAB) could be found useful.

Question 5 (5 points)

Propose a method to calculate the *mean diameter* of each fiber. You can use the skeletons and the distance maps previously computed. You should find a value of about 30 pixels.

Question 6 (4 points)

Propose a method to calculate the *tortuosity* of each fiber.

Appendix

Figure shows an example of the application of the `skimage.measure.label` and `bwlabel` functions to a binary image.

1	1	1	0	0	0	0	0
1	1	1	0	1	1	0	0
1	1	1	0	1	0	0	0
1	1	1	0	0	0	1	0
1	1	1	0	0	0	1	0
1	1	1	0	0	0	1	0
1	1	1	0	0	1	1	0
1	1	1	0	0	0	0	0

1	1	1	0	0	0	0	0
1	1	1	0	2	2	0	0
1	1	1	0	2	0	0	0
1	1	1	0	0	0	3	0
1	1	1	0	0	0	3	0
1	1	1	0	0	0	3	0
1	1	1	0	0	3	3	0
1	1	1	0	0	0	0	0

Figure 2: Left: Digital representation of a binary image. Right: Output provided by the `bwlabel` or `skimage.measure.label` functions applied to the same binary image.

Figure shows an example of the application of the `skimage.measure.label` and `bwlabel` functions to a binary image.

Figure shows an example of the application of the `scipy.ndimage.distance_transform_edt` and `bwdist` functions to a binary image.

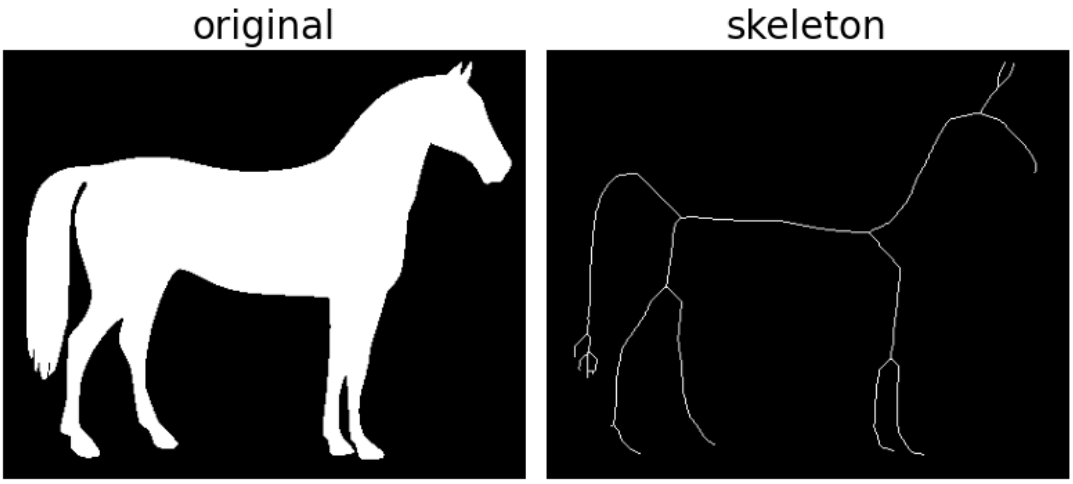

Figure 3: Left: Digital representation of a binary image. Right: Output provided by the `bwskel` or `skimage.morphology.skeletonize` functions applied to the same binary image.

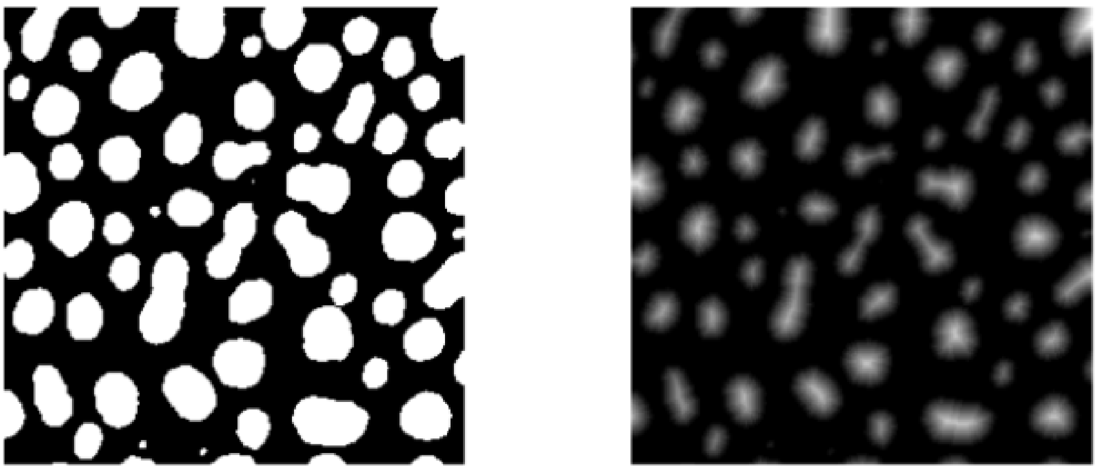

Figure 4: Left: Digital representation of a binary image. Right: Output provided by the `bwdist` or `scipy.ndimage.distance_transform_edt` functions applied to the same binary image.