Course name: Research Skills: Image Analysis

Course code: 880877-M-3

Take-home Assignment
Academic Year: 2021-2022, Blok 3.

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This Individual Assignment is worth 100 points and is 40% of your grade. For questions or clarifications regarding the assignment, please post your queries on Canvas. You may use any packages in Python of your choice.

You will submit code in a Jupyter notebook (*.ipynb) file. Please use the answer sheets provided.

At the top of your file, please reference to any code, methods, ideas that are not your own or not provided in this course. Remember that these codes must be publically available and free to use. Please also include any special instructions that are required to run your code.

Students are NOT encouraged to use any specific (Generative AI) tool to generate code. Using the output of Generative AI tools without referring to them with a statement in your submission file will typically be deemed plagiarism. If there is any doubt about plagiarism, the case will be referred to the exam committee.

This assignment is due on **26 March 2023**.

# 1 Image smoothing in the spatial and frequency domain

You are provided with a color image in (XXXXXX_rgbimage.jpg) in "Files/assignment/files/XXXXX.zip" where XXXXX is your SSID. These images were taken by your course coordinator's child at 4 years old.

1. (5 points) Convert the color image which you have been provided to grayscale. Display the image with a gray colormap and an appropriate title.
   **Points breakdown**: 3 points for converting the color image to gray, 2 points for displaying your image.
2. (5 points) Add 10% salt and pepper noise to the grayscale image.
3. (5 points) Denoise the noisy image by performing a Gaussian blur with 'sigma=1' in the spatial domain. Display your denoised image.
   **Points breakdown**: 3 points for denosing the image, 2 points for displaying your image.
4. (5 points) Convert both the "clean" grayscale image (output of Q1.1) and noisy image (output of Q1.2) to the frequency domain and display the two FFT spectrums (FFT magnitude).
   **Points breakdown**: 2 points for converting to the frequency domain, 3 point for displaying the FFT spectrums.
5. (5 points) Denoise the noisy image by performing a Gaussian blur with 'sigma=1' in the frequency domain. Convert your denoised solution back to the spatial domain. Display your denoised image.
   **Points breakdown**: 2 points for denoising. 2 points for converting your solution to the spatial domain, 1 point for displaying the image.
6. (10 points) Compare the time taken to run Gaussian blur operations in the spatial domain vs the frequency domain the following 6 values of 'sigma' - 1, 2, 16, 32, 64 and 128. Plot the time taken vs

sigma for both spatial and frequency domain in the same plot. Briefly comment on your plot. When 'sigma' is larger, the kernel is larger. Which domain is preferred for larger kernels?
**Points breakdown**: 3 points for running the operations in the spatial domain. 3 points for running the operations in the frequency domain. 1 point for the plot. 2 points for your comment on the plot and answering the question.

# 2 Extracting vessels from raw fundus images

You are provided with a color image (XXXXXX_vesselimage.jpg) and the corresponding binary segmentation mask (XXXXXX_vesselmask.jpg) in "Files/assignment/files/XXXXX.zip" where XXXXX is your SSID. The binary image is the manual annotation results. These images are cropped from images in the High-Resolution Fundus (HRF) Image Database [1].

1. (5 points) Load the color image (XXXXXX_vesselimage.jpg). Using subplots, display each color channel separately.

2. (5 points) Convert the color image to HSV and display the hue, saturation and value channels.

3. (20 points) Segment the vessels to obtain a binary image where pixels representing the vessels are set to 1. You should compare two different image segmentation algorithms. You can apply morphological operations on these images.
**Points breakdown**: Maximum of 10 points for each method. Comparing two thresholding algorithms only counts for 1 method. Report the steps you took to compute two image segmentation algorithms as comments in your code. Display the results of image processing at each step with appropriate titles.
For each method: Full (10) points if each method successfully segments all the large vessels, most of the smaller vessels and none of the background. Show the results for each step you took. If the vessel shapes are slightly distorted or a 10% of the background is segmented or 50% of the smaller vessels are missing, you will get a maximum of 7 points each. If you make an attempt and the results are poor, you can get a maximum of 5 points each.

4. (5 points) Overlay your segmentation solutions with the binary mask (manual annotation results).

5. (5 points) Compute the Dice or Jaccard score between your solution and the binary mask.

# 3 Processing a binary image of segmented vessels

You are provided with a binary image of vessels (XXXXXX_vesselmask.jpg) where XXXXX is your SSID.

1. (2 points) Remove smaller vessels (less than 8 pixels wide) with morphological opening.

2. (3 points) Apply morphological thinning to obtain a 1 pixel thin centerline of the vascular network.

3. (5 points) Find overall length of the vascular network in the image after thinning.

4. (5 points) Find the length of the vascular network which is wider than 40 pixels. In other words, fin d Hint: You can apply a medial axis transforms to compute the width of the vessel for the pixels of the skeleton

5. (5 points) Computer orientation of the vascular network in the image after thinning. Display the orientation distribution of the vascular network in a polar (rose) plot.

6. (5 points) Compute the length and orientation of each branch (e.g. with the sknw package (https://github.com/Image-Py/sknw)).