

Istanbul Technical University
 Computer Engineering Department
 BLG 453E - Computer Vision - Fall 24/25
 Assignment I
 Due: 14.11.2024, 23.59

Notes

- You should do your own work! 🚫. Cheating is highly discouraged.
- You can use built-in Python, Numpy, and OpenCV functions until otherwise stated.
- You should write your codes in Python.
- Partial points will be given for incomplete solutions.
- Report creation is **optional**, but may be subject to bonus points if it is **well-written**. If you do not prepare a report, the codes will be expected to be well-commented.
- For your questions, do not hesitate to reach Res. Asst. Ziya Ata Yazıcı (yaziciz21@itu.edu.tr) and Res. Asst. Tuğçe Temel (temel21@itu.edu.tr).

Q1 (15 pts) - Where are the bones?

In this task, you will perform a point-wise image processing technique – **gamma correction** – on a low contrast biomedical image (CT.tif in Figure 1) to assist the radiologists, who will be inspecting the image to see the shape of the human skeleton and determine any abnormalities.

Medical images may exhibit low contrast due to variations in tissue density, sub-optimal image acquisition parameters, noise artifacts, and other factors. These challenges can hinder the accurate interpretation of diagnostic information. To address these limitations, gamma correction could be one of the options to enhance contrast and improve the overall quality of medical images.

Gamma correction is a **non-linear operation** that adjusts the contrast of an image by applying a *power-law transformation* to the pixel intensities. It's often used to compensate for the non-linear response of displays and sensors.

$$I_{\text{out}} = A \cdot I_{\text{in}}^{\gamma}$$

where:

- I_{in} is the **input intensity** of a pixel, typically normalized between 0 and 1.
- I_{out} is the **output intensity** of the pixel after gamma correction.
- γ is the **gamma value**, a positive real number that determines the nature of the correction.
- A is a **scaling constant**, often set to 1 for simplicity.

The given image will be in the TIFF format. By using the *SimpleITK*¹ library, one can import the image into the Python environment and process the data. You may also use the *OpenCV* library, but be careful about the default color format.

¹<https://simpleitk.readthedocs.io/en/release/>

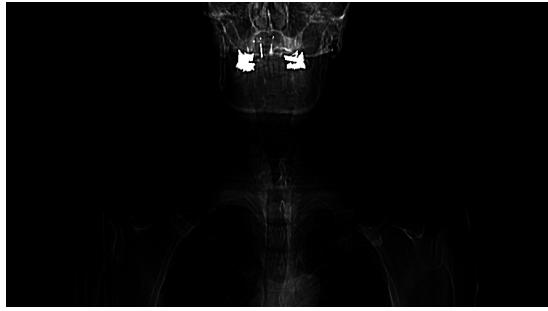


Figure 1: A low contrast image to be processed.

```
import SimpleITK as sitk
imageCT = sitk.ReadImage("<path_to_image>\CT.tif")
imageCT = np.asarray(sitk.GetArrayFromImage(imageCT))
```

Your task will be to use the pixel-wise gamma correction formula to make the **person's arms and chest** visible in the image.

Q2 (15 pts) - Glioblastoma

Similar to the Q1, the contrast enhancement process can also be applied with a linear operation. In this case, as seen in Figure 2, our brain CT image makes it difficult to examine the glioblastoma regions clearly due to its narrow intensity range. On the given CT.brain.tif image, you are expected to perform intensity 'stretching' via a piece-wise linear approach.

You can start by checking the image's minimum and maximum intensities and increasing its contrasts to the dynamic range of 8 bits.

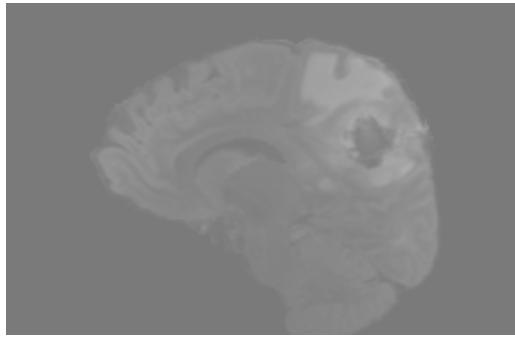


Figure 2: A low contrast sagittal brain CT to be processed.

Q3 (30 pts) - Hidden Paths Underneath

Digital Subtraction Angiography (DSA)² is a specialized imaging technique used primarily to visualize blood vessels by subtracting the background structures such as bones and tissues from the images. This is achieved by capturing **two** sets of X-ray images: one before the injection of a contrast agent (mask) and another after the contrast agent is introduced into the bloodstream (contrast). The mask image, which includes the static anatomical structures, **is digitally subtracted from the contrast image**, leaving only the enhanced visualization of **blood vessels** (Figure 3).

²https://en.wikipedia.org/wiki/Digital_subtraction_angiography

DSA is commonly used to diagnose and treat vascular conditions, including aneurysms, stenosis, and arterial blockages, providing high-resolution images of blood flow dynamics and vessel anatomy.

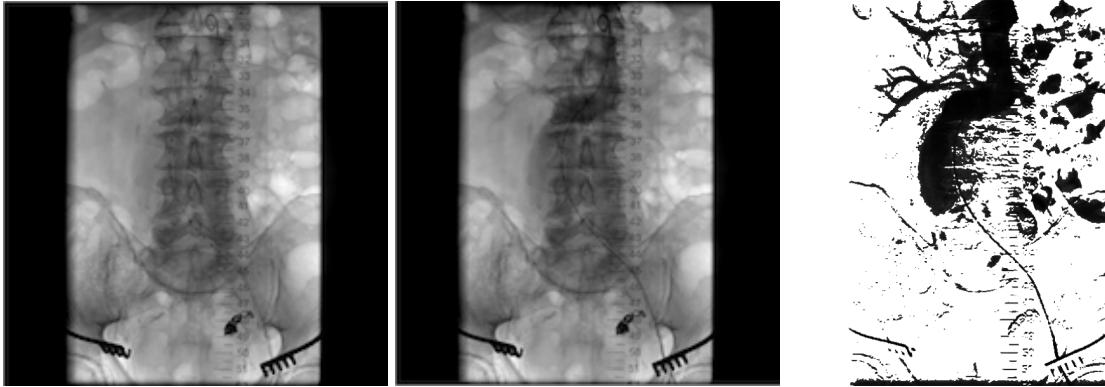


Figure 3: The mask (left), the contrast (middle), and a **sample output** (right) images for digital subtraction angiography.

Your task is to perform the image processing part of the method to help vascular doctors visualize the patient's **blood vessels** to diagnose and treat the patient correctly. However, you should be very precise in your results! The vascular structure should be detected in detail as a **binary mask**. For this purpose, you may need to apply some image processing operations you learned in classes to improve the visualization.

Q4 (40 pts) - Focus Stacking

Focus Stacking is a digital image processing technique that enhances the depth of field (DoF) in photographs, particularly in macro and macro-like photography, where achieving a sufficient DoF can be challenging. By combining **multiple images** taken at **different focus distances**, focus stacking allows for the creation of a **single** image where **all desired elements are in sharp focus**, from the nearest foreground to the farthest background.

In this task, you will be working on a small real-scenario project in a biomedical research lab. You are given two images of a zebrafish (Figure 4), each taken from a different focal length via an autonomous microscopy system, and two fluorescence microscopy images (Figure 5) that show a biomolecule that emits a radioactive signal in red color.

Your task is to stack two images of the zebrafish so that they become a single, fully sharp image from head to tail. Also, you should place the biomolecules in the stacked image so researchers can easily observe the subject in a single image. The sample result can be seen in Figure 6.

At first glance, it can be thought that keeping the left and right halves of the images and combining them in a single frame might get the result. However, there are a few points to consider:

- Due to the focal length changes of the microscope objective lens, the subject's location in the image also changes. **Therefore, the images should be aligned first!** Please do a further search about the methods.
- Unfortunately, due to a malfunction in the microscopy system, **the images are not in the same shape**.
- **The biomolecule images have a dark background.** Thus, directly assigning the intensity values of the biomolecule image to the focus-stacked zebrafish would not work. What can be done only to get the reddish colors and assign them to the stacked image?

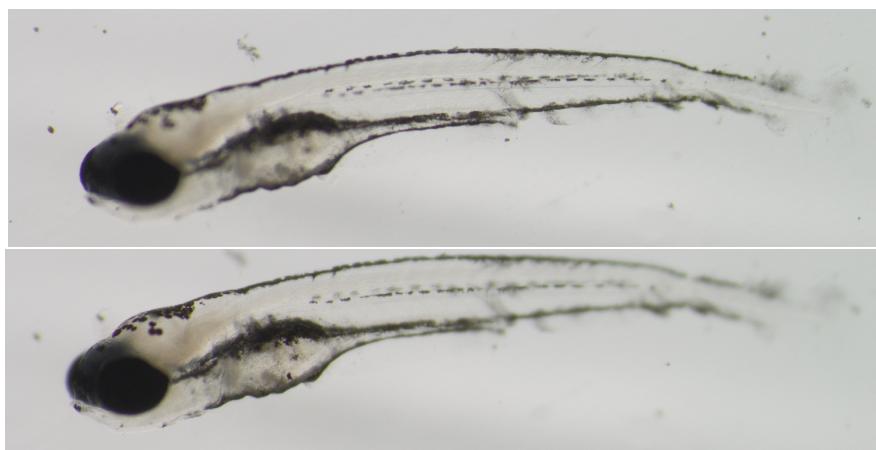


Figure 4: The zebrafish images where the right of the image is sharper (top) and the left of the image is sharper (bottom).

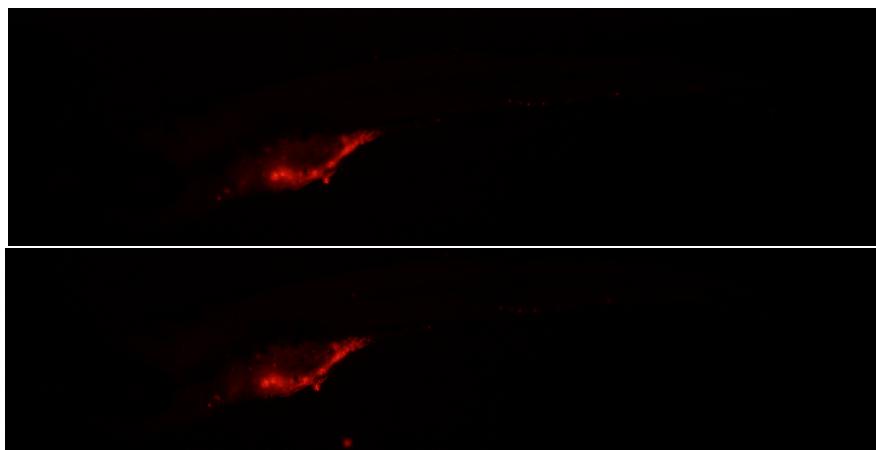


Figure 5: The red color emitting biomolecule images taken from the same order as Figure 4.

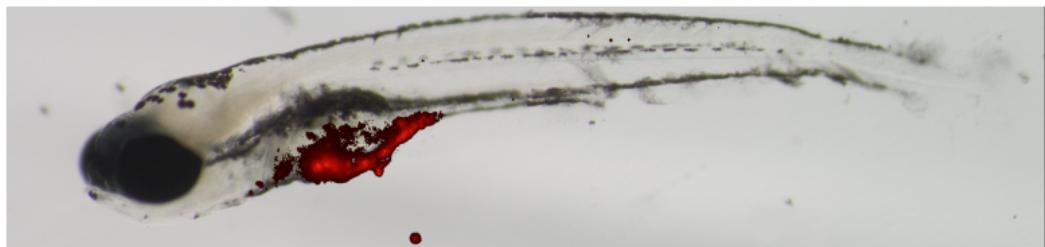


Figure 6: The focus stacked and biomolecule included the output image.