Assignment 5
Mastering Basic Image Restoration and Compression Techniques

Please note:

1. What you must hand in includes the assignment report (.pdf) and – if necessary – source codes (.py or .m). Please zip them all together into an archive file named according to the following template: XXXXXXXX.zip
   Where XXXXXXXX must be replaced with your student ID.
2. Some problems are required to be solved *by hand* (shown by the icon), some need to be implemented (shown by the icon), and some need to be dockerized (shown by the icon).
3. As for the first type of the problems, you are free to solve them on a paper and include the picture of it in your report. Here, cleanness and readability are of high importance.
4. Your work will be evaluated mostly by the quality of your report. Don't forget to explain what you have done, and provide enough discussions when it's needed.
5. 5 points of each homework belongs to compactness, expressiveness and neatness of your report and codes.
6. By default, we assume you implement your codes in Python. If you're using Matlab, you have to use equivalent functions when it is asked to use specific Python functions.
7. Your codes must be separated for each question, and for each part. For example, you have to create a separate .py file for part b. of question 3. Please name it like p3b.py.
8. Problems with bonus points are marked by the icon.
9. If there is ***any*** question, please don't hesitate to contact us through the following email addresses:
   - Atghaei@aut.ac.ir
   - fardin.aiar@gmail.com
   - minoo.dolatabadi75@gmail.com
   - aidin.khalili@ymail.com
   - b.roshanfekr@aut.ac.com
10. Unfortunately, it is quite easy to detect copy-pasted or even structurally similar works, no matter being copied from another student or internet sources. Try to send us your own work, without being worried about the grade! ;)

1. Warming up with some Morphological Image Processing exercise (15 Pts.)

Consider the binary image and the structuring element shown below:

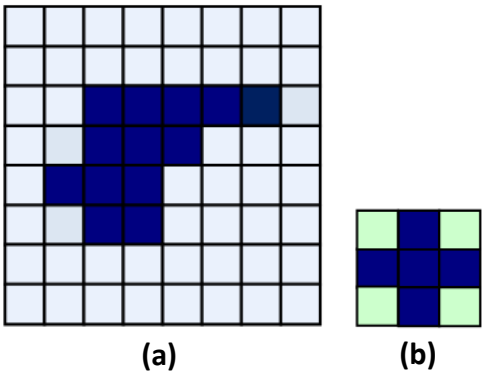
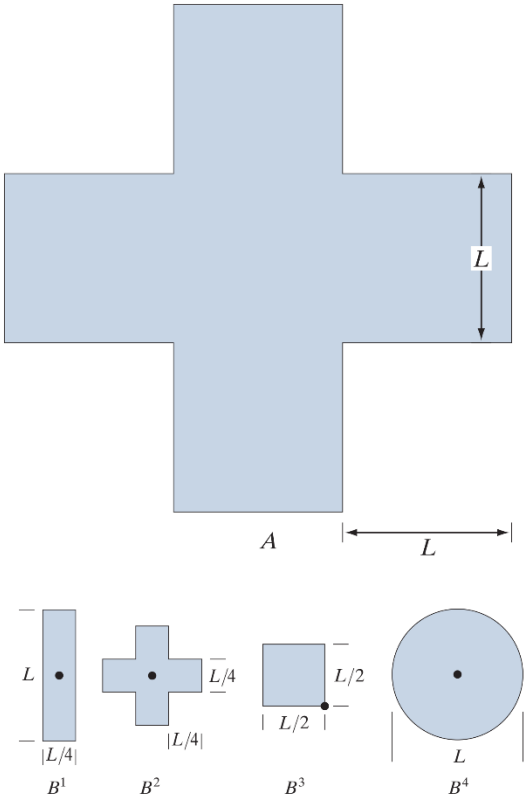


Figure 1: The binary image (a) contains a dark blue shape on a light background. The structuring element (b) is a 3x3 cross shape with dark blue and light green cells.

a) Apply the dilation operation on the binary image using the given structuring element. Show the resulting image and explain the changes compared to the original image.
b) Apply the erosion operation on the binary image using the given structuring element. Show the resulting image and explain the changes compared to the original image.
c) Perform the opening operation (erosion followed by dilation) on the binary image using the given structuring element. Show the resulting image and describe its effect.
d) Perform the closing operation (dilation followed by erosion) on the binary image using the given structuring element. Show the resulting image and describe its effect.
e) Compare and Discuss: Compare the results of each operation and explain their practical applications in image processing, such as noise removal or shape smoothing.

f) Let A denote the set shown shaded in the following figure, and B refer to the structuring elements shown (the black dots denote the origin). Sketch the result of the following operations:
   I. $(A \ominus \mathrm{B}^4) \oplus \mathrm{B}^2$
   II. $(A \ominus \mathrm{B}^1) \oplus \mathrm{B}^3$
   III. $(A \oplus \mathrm{B}^1) \oplus \mathrm{B}^3$



2. Applying Image Morphological Operations for Filtering Images (35 Pts.)

Morphological operations in image processing are a set of non-linear techniques that focus on the structure or shape of objects within an image. These methods involve using a small shape or template, known as a structuring element, which is moved across the image and compared with the surrounding pixels at each location.

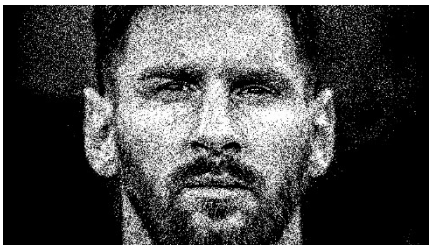
The objective of this task is to help you become familiar with fundamental morphological operations applied to binary images.

a) Load the image "barcode_binary.jpg" and write code to apply binary image dilation and erosion. Use an arbitrary structuring element for testing, and display the resulting images.

b) Repeat the steps from part (a) using morphological opening and closing operations instead. Compare the results from parts (a) and (b), and discuss how each method performs in terms of noise reduction.

Although morphological operations on binary images may seem trivial at first, they play a crucial role in various basic image processing and computer vision tasks—particularly as preprocessing steps. In this exercise, you'll explore and become familiar with one of these operations.

c) Removing Undesirable Details using Image Morphology is useful when the goal is to eliminate unwanted elements—often appearing as small dots or circular artifacts—surrounding the main object in an image. Load the image "leo.jpg" and apply morphological operations to remove these unwanted regions, particularly those around the head.



3. Hit or Miss algorithm (15 Pts.)

Sketch the result of applying the hit-or-miss transform to the image below, using the SE shown. Indicate clearly the origin and border you selected for the structuring element.

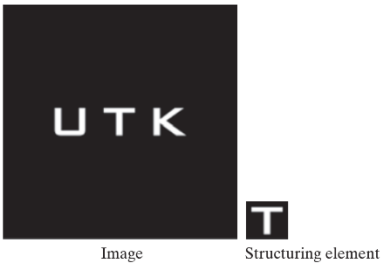


Image Structuring element

4. Offline signature feature extraction for signature recognition (35 Pts.)

Signature verification is the process of determining whether a given signature is authentic or forged. As signatures remain one of the most widely used methods of authorization globally, signature verification has broad applications across many areas of daily life. The core challenge lies in verifying whether a specific signature genuinely belongs to an individual. Offline verification relies on extracting global, statistical, geometric, and topological features from signature images.

A signature image can be seen as a collection of points distributed within a defined area, characterized by unique shape patterns. Global features help capture the spatial distribution of these points, providing meaningful insights into the overall structure of the signature.

For the provided signature images, perform the following feature extraction tasks using morphological operations and image processing techniques:

a) Skeleton of the signatures
b) End points of the signatures
c) Junction points of the signatures
d) Upper and lower envelopes of the signatures

You will be provided with a dataset of signature images, which includes both genuine and forged samples from multiple individuals. For each signature, extract the four specified features: skeleton, end points, junction points, and upper/lower envelopes. Next, evaluate the consistency of these features across the genuine signatures of each individual—specifically, assess whether the features consistently appear in approximately the same locations.

Finally, use the extracted features from the first five genuine signatures of each person as a reference to distinguish between authentic and forged signatures belonging to the same individual.

(a) (b) (c)

Figure 2: The image shows three samples of a person's signature for comparison: (a) and (b) are genuine (authentic) signatures from the same individual. (c) is a forged version of that person's signature.

Good Luck