ICBV231 HW 3

Release Date: 01/01/2023

Submission Deadline: 14/01/2023, 23:59

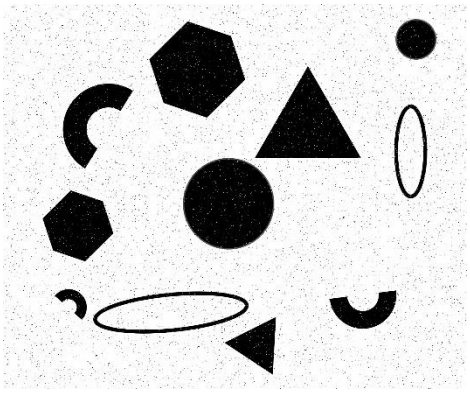
Instructions

Please read and follow these instructions carefully.

- To be able to submit your work you must first enroll in a group on Moodle.
- The assignment contains both programming tasks and a written part. The written part needs to be submitted in a single PDF file and the programming tasks must be answered in the provided Jupyter notebook. You need to submit a single zip file where:
    - The name of the file is "Assignment3-Group#.zip", where # should be replaced by your group number.
    - In the zip file put the written answers as a PDF file and the Jupyter notebook (.ipynb file) along with any additional files used by your code.
- The written assignment must be typed on the computer. Handwritten scanned documents **will not** be accepted.
- Make sure that the Jupyter notebook can be run. Before submitting, restart runtime and run all cells. In Google Colab: 1) *Runtime > Restart and run all;* 2) *File > Download .ipynb*. In addition, make sure you submit any additional files used by your code (usually image files).
- Both the PDF containing the written answers and the Jupyter notebook must contain the id numbers and the names of the submitting students.

Question 1 – Hough Transform

In this question you will implement a python code which uses Hough Transform to detect semicircles (i.e., "half" circles) in the provided **semicircles-noisy.png** image. Your code should perform the following computations:



1. **Produce an edge map from the image using an edge detector of your choice.** The edge map is a binary image, the same size as the 'semicircles-noisy' image, with a value of one in each detected edge pixel and a value of zero anywhere else. Choose the best algorithm and parameters for the edge detection (in your opinion), and explain (in written response) your choice. Plot the edge map in the provided Jupyter notebook.
2. **Detect all the semicircles in the image using Hough transform.** Define the appropriate Hough space and explain your choice (that is, explain the parameters of the Hough space, and why you chose this representation). You should define the bucket size for each of the Hough transform parameters (i.e., the number of values you scan in the range of each parameter). Explain your choices and the considerations behind it (in written response). Detect the semicircles, i.e., the local maximum points in the Hough space. Use a method of your choice for detecting the local maximum points. Explain the method you chose and any parameters you had to set for it (in written response).
3. **Plot the detected semicircles on top of the original input image** in the provide Jupyter notebook. Draw the semicircles in red.

Follow the following guidelines when answering this question:

- You cannot use any built-in OpenCV method to perform the Hough transform, you must implement your own version of the Hough transform for semicircle detection.
- You may use convolution to count the number of votes for each possible semicircle (as shown in the tutorial for template matching. It is not obligatory to use convolution, but it may significantly reduce the runtime of your algorithm.
- Note that using a constant threshold for the number of votes (to isolate maximum points) will most probably not work. You will have to find another solution for detecting the maximum points in the Hough space.
- Solutions which will succeed in detecting only the semicircles in the image, but **not the complete circles** in it, will be graded higher.
- All the plots you were asked to draw should be presented in the provided Jupyter notebook. In addition, you should provide in the PDF your written responses explaining the choices you made throughout your implementation (the methods and parameters you chose in the different steps).

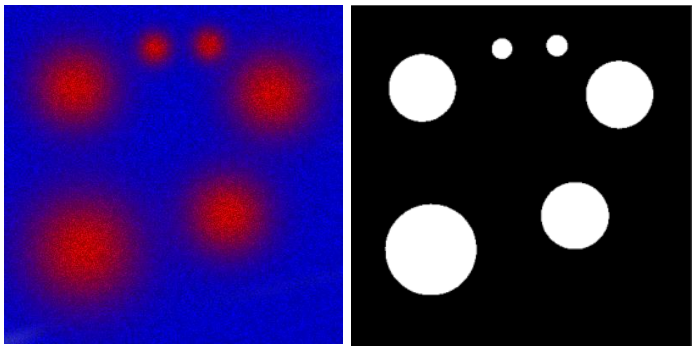
Question 2 – Curvature

Write an expression for the Frenet frame of the following regular curve: $\alpha(t) = \frac{1}{2}\big(\cos(2t), \sin(2t)\big)$. That is, write an expression for its tangent vector $T(t)$, its normal vector $N(t)$, and its curvature $\kappa(t)$, for every value of the parameter t. At last, write the Frenet equation.

Question 3 – Segmentation and Relaxation Labeling

In this question you will implement a segmentation system that breaks down RGB images into visually coherent regions. In the "world" the images were taken from, objects tend to reflect varying levels of red and background tends to reflect varying levels of blue. Because images in this world tend to be noisy, it is not possible to perform segmentation based solely on identification of the pixel colors.

The figure below shows a possible image in this "world" (left) and a desired result for its segmentation, encoded by brightness levels (right):



Develop a Relaxation Labeling algorithm for the correct segmentation of this image ('blobs.png'). Implement your result in the provided Jupyter notebook. Your algorithm should get as input an RGB image and return a 2D segmentation array in which the value of each cell represents the label of the corresponding pixel. You may add additional parameters as input to your algorithm, and in this case, you must provide a written explanation for your choice. Use your algorithm to segment the 'blobs' image, and plot your result encoded by brightness levels. Explain (in written response) the computational steps of your algorithm, and any parameters you may have set. In particular, provide comprehensive explanation for how the different components of the relaxation labeling network are defined.

You **must not** use smoothing methods to reduce the noise of the input image. It is recommended to use a compatibility function that takes into account the distance of the neighbor from the tested pixel (e.g., using a Gaussian function). When computing the support for each labeling, you must consider an environment of at least 41*41 pixels around the tested pixel (for pixels in the edges of the image, which have less than 41 neighbors, you may consider only the intersection of this environment with the image environment).

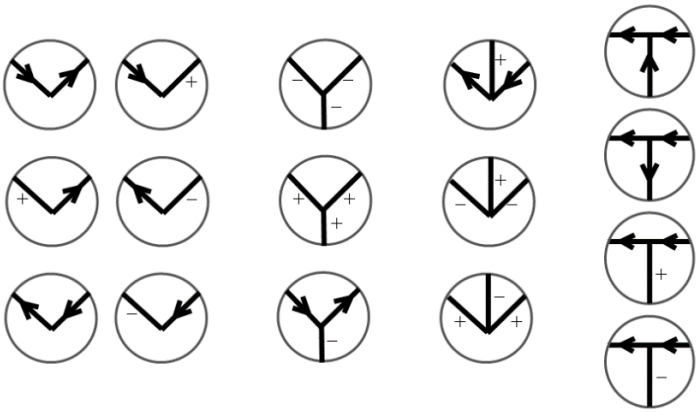
Tip: avoid unnecessary loops in your code and try to implement the computations as matrix multiplications.

Note: Exceptional answers in terms of originality or performance will reward you with bonus points.

Question 4 – Line Drawing Interpretation

In 1982, Sweden issued a series of new stamps that describe special objects. One of these stamps is described in the image to the right. Your task is to discover whether it is possible to interpret the object presented in this stamp, in the sense of producing a consistent labeling of its different edges. If it is not possible, explain why. If it is possible, provide a consistent labeling of the edges.

For your convenience, below is the junctions catalog developed by Huffman and Clowes for line drawing interpretation (left) and an enlarged diagram of the object (right) for you to mark your labeling in case you think a consistent labeling exists.



Question 5 – Reading Material

Answer the following question in writing and keep your answer short. This question refers to *Laws of Organization in Perceptual Forms* by Max Wertheimer, 1923.

a) In class, the concept of *common fate* was mentioned. What is the additional name Wertheimer suggested for this concept?

b) List all the lows of perceptual organization mentioned in the article, and explain each of them in one sentence.