Amirkabir University of Technology
(Tehran Polytechnic)

Assignment 5
Practicing Basics of Image Compression and Applications of Image Morphology

Homeworks Guidelines and Policies

- ***What you must hand in.*** It is expected that the students submit an assignment report (HW5_[student_id].pdf) as well as required source codes (.m or .py) into an archive file (HW5_[student_id].zip).
- ***Pay attention to problem types.*** Some problems are required to be solved *by hand* (shown by the icon), and some need to be implemented (shown by the icon).
  Please don't use implementation tools when it is asked to solve the problem by hand, otherwise you'll be penalized and lose some points.
- ***Don't bother typing!*** You are free to solve by-hand problems on a paper and include picture of them in your report. Here, cleanness and readability are of high importance. Images should also have appropriate quality.
- ***Reports are critical.*** 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.
- ***Appearance matters!*** In each homework, 5 points (out of a possible 100) belongs to compactness, expressiveness and neatness of your report and codes.
- ***Python is also allowable.*** By default, we assume you implement your codes in MATLAB. If you're using Python, you have to use equivalent functions when it is asked to use specific MATLAB functions.
- ***Be neat and tidy!*** Your codes must be separated for each question, and for each part. For example, you have to create a separate .m file for part b. of question 3. Please name it like p3b.m.
- ***Use bonus points to improve your score.*** Problems with bonus points are marked by the icon. These problems usually include uncovered related topics or those that are only mentioned briefly in the class.
- ***Moodle access is essential.*** Make sure you have access to Moodle because that's where all assignments as well as course announcements are posted on. Homework submissions are also done through Moodle.

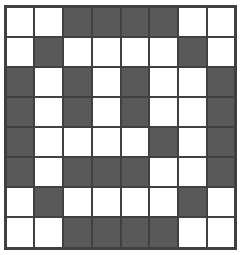
- ***Assignment Deadline.*** Please submit your work **before the end of July 9th**.
- ***Delay policy.*** During the semester, students are given 7 free late days which they can use them in their own ways. Afterwards there will be a 25% penalty for every late day, and no more than three late days will be accepted.
- ***Collaboration policy.*** We encourage students to work together, share their findings and utilize all the resources available. However you are not allowed to share codes/answers or use works from the past semesters. Violators will receive a zero for that particular problem.
- ***Any questions?*** If there is any question, please don't hesitate to contact me through **ali.the.special@gmail.com**.

Amirkabir University of Technology
(Tehran Polytechnic)

1. A Review on Fundamentals of Image Compression (20 Pts.)

Keywords: *Image Compression, Huffman Coding, Zig-Zag Ordering, Run-Length Coding, Entropy Coding, Root-Mean Square Error, Peak Signal-to-Noise Ratio*

The goal of this problem is to evaluate your fundamental knowledge of **Image Compression** techniques. First, consider the following binary image.



a. Find the runlength representation. Note that you must assume that a line always starts with "white", and specify the white runlength and then the black runlength alternatively. Put an "EOL" symbol at the end of each line.
b. Find the corresponding zig-zag ordered vector to this image.
c. We want to use a single Huffman codebook to code the white and black runlengths. Write down the probability distribution of the symbols to be coded.
d. Next, generate the Huffman code for all possible runlength symbols. You must consider "EOL" symbols as well.
e. Calculate the average number of bits per coded symbol. How does it compare with the entropy of the symbol?
f. What is the average bit rate (bits/pixel) for this method? What about the compression ratio compared to when using 1 bit for each pixel to indicate whether the pixel is black or white?

Next, assume an 8-bit gray-scale image given as below.

0	32	16	48
20	140	85	16
64	220	180	200
120	160	210	255

g. Instead of 8 bits, we would like to use 2 bits to represent each pixel. Find the value assigned to each pixel. If we intend to keep the value of each pixel between 0-255, explain how you will do such mapping.
h. Find the root-mean square error and mean-square signal-to-noise ratio for the output image you obtained in the previous part.

Now consider the following table as the initial dictionary for LZW algorithm.

Index	Entry
1	t
2	r
3	-
4	a

i. Output of the LFW encoder on a sequence is given below. Decode the sequence.

6	4	1	3	8	1	3	2	14	11	3	7	10	13	5

j. Encode the decoded sequence using the same initial dictionary. Does your answer match the sequence given above? Justify your answer.

Finally, consider a JPEG compression procedure in which instead of 8×8 image blocks, blocks of the size 4×4 are used. The coefficients generated by applying DCT on a 5×5 block of luminance value as well as the quantisation table are given below.

3) 150	4) 40	5) 16	6) 11
7) 25	8) 20	9) 9	10) 7
11) 12	12) 10	13) 6	14) 2
15) 8	16) 6	17) 4	18) 1

k. Find the values assigned to each pixel after performing quantisation.
l. Assume the quantised table is transmitted as a one dimensional vector. In what order will it be transmitted, and why? Write down the ordered vector.
m. Find the run length encoding of the vector in the previous part.
n. What kind of additional compression techniques can be used when several such spatially neighboring 4×4 blocks are transmitted? Justify your answer.

4	15	20	35
16	14	28	45
18	24	32	50
23	25	41	60

2. Yet Another Application of Morphological Operators: Image Filtering (20 Pts.)

Keywords: *Grayscale Image Morphology, Image Morphological Filtering, Morphological Noise Reduction, Morphological Edge Detection*

A more complicated application of **Image Morphology** in grayscale images is **Image Filtering**, where the goal is to apply different types of filtering, e.g., smoothing filter, using a combination of **Morphological Operations**. In this problem, your task is to examine some of these operations, and compare their results.

a. Load the image displayed in part (a) of Figure 1, and apply morphological 2nd derivatives using dilation and erosion.
b. Repeat part (a) with opening and closing.
c. Repeat part (a) with dilation, erosion, opening, and closing. Compare the results obtained in part (a), (b), and (c), and comment on the performance of each strategy in **Edge Detection**.
d. Load the image displayed in part (b) of Figure 1, and apply morphological gradient using dilation and erosion.
e. Repeat part (d) with opening and closing.
f. Repeat part (d) with dilation, erosion, opening, and closing. Compare the results obtained in part (d), (e), and (f), and comment on each method's performance in **Edge Detection**.
g. Load the image displayed in part (c) of Figure 1, and apply morphological smoothing using dilation and erosion.
h. Repeat part (g) with opening and closing. Compare the outputs you obtained, and comment on the performance of the two approaches in **Noise Reduction**.

(a) **(b)** **(c)**

Figure 1 Input images of this problem, showing Joe Biden riding and falling off a bike. (a) Part a to c. (b) Part d to f. (c) Part g and h.

3. Implementation of a Morphology-Based Hypermarket Cash Register (45 Pts.)

Keywords: *Image Morphological Operations, Image Binarization, Image Logical Operations, Image Thresholding, Hit and Miss Transform, Opening Top-Hat, Boundary Detection, Region Filling*

A hypermarket has decided to utilize a smart system capable of calculating customers' cart totals, so as to control and verify the price calculated by the cashier and prevent human errors. This system captures images from the top view of the items placed on the register conveyor belt, and then applies image processing techniques to first remove the background and then categorize each item based on its size.

We aim to make use of morphological operations to accomplish this task. In the test phase, an image has been captured from several items on the conveyor belt (Figure 2). The price of each item is also displayed in Figure 3. As expected, these prices might not be still the same on the date you are reading this!

Figure 2 A top view image of the items on the register conveyor belt.

In each part, you are asked to extract details from the given image using image morphological operations. You must support your answers with enough explanation and display the results of morphological operations you performed on the image.

a. How many items are there on the conveyor belt?
b. Calculate the number of Tiny cakes purchased.
c. What is the total amount of money spent on drinks (of any type)?
d. Calculate the total number of items produced by Mihan.
e. Calculate the total cost of the cart.

Figure 3 Price of the selected items (As of Khordad, 29th!).

In a real-world scenario, the same items have been purchased by a customer, though with different quantities of products. This time the captured image of the items has become more complicated, creating a more realistic problem, Figure 4.

Figure 4 The items are now placed with different angles and may contain overlapping.

f. Count the total number of the selected items.
g. Find the number of potato chips bought.
h. Determine the cost of ice creams (of any type) in the cart.
i. Calculate the cost of all edible items.
j. Calculate the total cost of the cart.

4. Some Explanatory Questions (10 Pts.)

Please answer the following questions as clear as possible:

a. Why is it preferred to convert the image color space (RGB to $Y'C_BC_R$) in JPEG standard?
b. Assume we want to use morphological operations to shift the pixels of an image by *m* pixels to the right. Is it possible? If the answer is yes, how? And if no, why?
c. What would be the final result of continuously applying opening on an arbitrary image? What about closing?
d. Is it possible to perform erosion using hit-and-miss? Explain.
e. Imagine you want to determine a connected component given one point of this component. How might you use conditional dilation to accomplish this task?

Good Luck!
Ali Abbasi