ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Department of Computer Engineering

CENG 466 Fundamentals of Image Processing Final Take Home Exam

Open Book and Open Internet

January 30, 2021, 17:00

METU Honor Code and Pledge

METU Honor Code: "The members of the METU community are reliable, responsible and honourable people who embrace only the success and recognition they deserve, and act with integrity in their use, evaluation and presentation of facts, data and documents."

"I have read and understood the implications of the METU Honor Code. To be precise, I understand that this is an open book-open Internet exam and I am allowed to use the codes, available in open sources. However, I am obliged to cite them in my references. Also, I am fully responsible to study and confirm my thorough knowledge about all the algorithms and implementation issues, in my exam paper. I am not allowed to communicate with anybody in any media to discuss, to ask help, to give help and/or to share any of my opinions, ideas, suggestions and/or solutions about the exam. I understand and accept to obey all the rules announced by the course staff, and that failure to obey these will result in disciplinary action."

Specifications About the Exam

1. **Individuality:** You are required to do your final exam **by yourself**. After you receive your exam sheet, you are not allowed to communicate with anybody in any media to discuss, to ask help, to give help and/or to share any of your opinions, ideas, suggestions and/or solutions about the exam. If there is an unclear part in the exam sheet, you can write a private e-mail to hazal@ceng.metu.edu.tr .
2. **Programming Language:** You must code your program in MATLAB or Python. You are expected to make sure your code runs successfully on department laboratory machines.
3. **Due date:** Due date of this exam is January 30, 2021, at 5:00 PM. Late Submission is **not** allowed!
4. **Newsgroup:** You must follow the OdtuClass for possible updates on a daily basis.
5. **Submission:** Each student will submit the followings:

(a) All the source codes developed for this exam, emphasizing the ones taken directly from any source of Internet.

(b) A thorough exam paper, which covers all the methods and algorithms, with referenced cites.

Submission will be done via Odtuclass. Create Final.tar.gz file that contains all your source code files and the written exam paper as a PDF file. Do not send the input and output images. Do not forget to write your names and student id's at the beginning of the scripts.

6. **Format of your exam paper:** You are required to prepare a written exam paper, which should be prepared in IEEE Conference Proceedings Template (LaTeXis recommended) provided in the following link.
https://www.ieee.org/conferences_events/conferences/publishing/templates.html

Content of Your Exam Paper

Your paper will include the answers to the three questions, given in this exam sheet. Thus, your exam paper will include three parts to answer three questions, each of which consists of the following sections:

I. Introduction

Discuss the difficulties of the problem. Discuss the possible solutions (a brief literature survey with references) available in the image processing literature. Explain, why you chose your suggested algorithm(s) among many alternatives? What is your novelty, if any?

II. Theoretical Presentation of Your Methods

Explain the techniques that you use, and the heuristics that you suggest. Provide the pseudo codes of each algorithm that you implemented. In all of the algorithms, explain how and why you select the parameter sets. For example; if you apply a convolution filter, how do you determine the size and entries of the mask? If you threshold your image, how do you identify the optimal threshold value? If you use an iterative algorithm, such as mean shift clustering, how do you select the initial parameters?

III. Experimental Results

Provide the outputs and related plots of each step of your algorithm. Clearly, state the selected parameters of your algorithm. Provide the performance measures of your algorithms. Make a complexity analysis of your algorithms. Explain the implementation issues, such as, the computation environment, used tools and languages.

IV. Conclusion

Write a critique of your suggested algorithms. What are the pros and cons of your solutions? Compare your methods with similar methods. What are the advantages and disadvantages of your solutions?

Grading Policy

1. **Grading your source codes**: We shall test your programs with similar images, which **does not** take place in the given datasets. Thus, your algorithms must be as generic as possible. We measure the performances of each algorithm by the metrics, defined on each question using the test images. The performances that we measure for each of your programs will define your programming grades.
2. **Grading your final exam:** Half of your grades will come from your written exam paper and the other half will come from our tests of your programs. Pay great attention to writing your paper clearly.
3. **Letter grading policy:** It will be decided after we complete the grading of your homework assignments and final exams. However, at least 45% will come from the final exam and 10% will come from the attendance of on-line lectures.
4. There may be a verbal exam, in case we suspect any type of correlations among the final exam papers and programs.
5. There will be a 20 point bonus in your final take-home exam.

Question 1

Consider an image dataset of street numbers. Your are asked to develop a series of algorithms and implement them for classifying the characters with loop(s) and without loop(s). Your algorithm should involve the following steps:

Input

Images given in Dataset1

Output

1. Labels of two classes: **Class1**: Loopy numerals for (0, 4, 6, 8, 9) and **Class2:** Loopless numerals for (1, 2, 3, 5, 7), associated with each image.
2. Overall performance of your algorithm in terms of correct classification performance.
3. Plots of the outputs of each step, (below).

Specifications

Write a function *final_q1(input_file_path, output_folder)*, where the first argument is the filename of the input file. The second argument is the folder to save your outputs. Save your outputs in .png format.

Tasks

In your exam paper, clearly provide the pseudo codes of the algorithms, you implement. Also clearly explain,

- **why you preferred these algorithms,**
- **how do you select the parameters of your algorithms.**

Step 1 (10 points): Develop a generic preprocessing algorithm to enhance all the images for accentuating the numerals. Your algorithm should successfully suppress the background while emphasizing the numerals. This step may require some heuristics in addition to the available algorithms in the literature.

Step 2 (10 points): Develop a generic algorithm to find the minimum bounding box, which encloses the numerals.

Step 3 (5 points): Develop a generic thinning algorithm to find the skeleton of the numerals in each bounding box.

Step 4 (10 points): Develop a generic algorithm to label **Class1**: Numerals with loop(s) and **Class2:** Numbers without loop. This step may require some literature survey.
Print the output labels to the console at this step.

Step 5 (5 points): Measure and output the performance of your algorithm as,

$$\text{Performance} = \frac{\#\text{ of correctly labeled numerals}}{\text{total }\#\text{ of numerals in dataset1.}}$$

Question 2

Consider an image dataset of animals. Your are asked to develop a series of algorithms and implement them to segment the animals from the background. Your algorithm should involve the following steps:

Input

Images given in Dataset2

Output

1. Image overlays with segmented regions.
2. Measures of the overall performance of your algorithm by Area Fit Index (AFI).
3. Plots of the output at each step.

Specifications

Write a function *final_q2(input_file_path, output_folder)*, where the first argument is the filename of the input file. The second argument is the folder to save your outputs. Save your outputs in .png format.

Tasks

Step 1 (10 points): Over-segment your image to generated super pixels, using mean shift segmentation method.

In your exam paper, clearly explain how mean shift clustering algorithm segments an image. Also, show that if the pixel color values are assumed to be taken from a mixture of Gaussian distribution, Mean Shift clustering algorithm iteratively estimates the mean and variance of each cluster.

Step 2 (10 points): Define an attributed graph, where each node corresponds to a super pixel obtained in step 1. Develop an algorithm to determine the edge weights, which measures the similarities between each pairs of super pixels (nodes) using a texture similarity measure between the super pixels.

In your exam paper, clearly provide the method for measuring texture similarity. Also clearly explain,

- **Why you preferred this measure for texture similarity.**
- **How you compute the edge weights of the graph.**

Step 3 (10 points): Use n-cut segmentation to partition the image into animals versus background.

In your exam paper, clearly explain how n-cut clustering algorithm makes segmentation, using the spectral graph theory. Also, explain why we use the eigenvectors of the Laplacian matrix defined as below

$$(D - W)\lambda = D\lambda$$

to bipartition the graph with the minimal cut. Note that in the above equation, $W = [w_{ij}]$ is the graph similarity matrix, you obtained in step 2. The diagonal degree matrix D has entries $d_{ii} = \sum_j w_{ij}$ and λ is the eigenvector.

In your exam paper discuss

- **What is over segmentation, what is super pixel and what is texel.**
- **What should be the number of segments k in Step 3.**
- **What is the n-cut algorithms response to different number of predefined segments (k).**

Step 4 (10 points): Measure the performance of your algorithm for each image, using Area Fit Index (AFI), defined below;

$$\text{AFI} = \frac{A_r - max(A_{s(i)})}{A_r}$$

where A_r is the area of the reference object, $max(A_{s(i)})$ is the area of the maximum overlapped region, i, with reference object.

Question 3

Consider a dataset of satellite images. Your are asked to develop a series of algorithms and implement them to extract the roads. Your algorithm should involve the following steps:

Input

Images given in Dataset3

Output

Image overlays with road regions.

Specifications

Write a function *final_q3(input_file_path, output_folder)*, where the first argument is the filename of the input file. The second argument is the folder to save your outputs. Save your outputs in .png format.

Tasks

In your exam paper, clearly provide the pseudo codes of the algorithms, you implement. Also clearly explain,

- **Why you preferred these algorithms.**
- **How do you select the parameters of your algorithms.**

Step 1 (10 points): Develop a generic algorithm to enhance all the Images for accentuating the roads. Your algorithm should successfully suppress the regions other than the roads. This step of the question requires some heuristics.

Step 2 (10 points): Detect the parallel lines and or curves using Hough transform.

Recall that there is a variety of methods for implementing Hough transform. In your exam paper, provide the method and algorithm you use for Hough trams form. Also, explain why you select these specific Hough transforms for this particular problem.

Step 3 (10 points): Post process the output of step 2 to eliminate the spurious lines and curves and to complete the missing pieces. This step of the question requires some heuristics.

Step 4 (10 points): Overlay the detected roads on the original images for display.