Assignment 1
Pixel Magic: Mastering Some Basic Image Processing Techniques

Homeworks Guidelines and Policies

- ***What you must hand in.*** It is expected that the students submit an assignment report (HW1_[student_id].pdf) as well as required source codes (.m or .py) into an archive file (HW1_[student_id].zip). Please combine all your reports just into a single .pdf file.
- ***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 do not use implementation tools when it is asked to solve the problem by hand, otherwise you will be penalized and lose some points.
- ***Don't bother typing!*** You are free to solve by-hand problems on a paper and include their pictures 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. Do not forget to explain your answers clearly, and provide enough discussions when needed.
- ***Appearance matters!*** In each homework, 5 points (out of a possible 100) belong to compactness, expressiveness, and neatness of your report and codes.
- ***MATLAB is also allowable.*** By default, we assume you implement your codes in Python. If you are using MATLAB, you have to use the equivalent functions when it is asked to use specific Python 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, which must be named '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 is where all assignments as well as course announcements are posted. Homework submissions are also made through Moodle.

- ***Assignment Deadline.*** Please submit your work **before the end of April 7ᵗʰ**.
- ***Delay policy.*** During the semester, students are given only 7 free late days which they can use them in their own ways. Afterwards, there will be a 20% penalty for every late day, and no more than four 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 do not hesitate to contact us through the following email addresses: **ebp.mohsen@gmail.com** and **ali.the.special@gmail.com**.

Amirkabir University
of Technology
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1. Helping a Puzzle Lover Complete Her Jigsaw Puzzle Again!   **(25+5 Pts.)**

Keywords: *Pixel Operations, Image Concatenation, Image Adjacency*

How do you focus when you want to study or work on an important project? According to numerous academic studies, playing a game or a short pastime has a considerable impact on creating concentration and enhancing focus. Following this technique, one of the members of The Image Processing and Pattern Recognition (IPPR) laboratory at Amirkabir University of Technology, has been in the habit of solving puzzles in order to improve her focus. Recently,

Figure 1: One of the puzzles that has remained unfinished in The IPPR lab.

a cleaning worker accidentally dissembled one of the puzzles while cleaning the lab. In this question, you are asked to help her complete her puzzle!

First, consider the images in the first folder as the different pieces of a puzzle. The first piece is associated to the upper-left corner of the puzzle.

a. Based on the above assumption, complete the puzzle and include the final image in your report.
b. Explain the strategy you used to obtain the width and height of the original image.
c. Based on what criteria did you decide two pieces should be placed next to each other?
    Hint: One might use the PSNR or the SSIM criterion for this purpose. However, any method used should be clearly explained.
    Note: All pieces in this puzzle are in correct direction and you don't need rotate them.

Next, consider the images in the second folder. As can be seen, here, pieces have special shape in their sides. Although it might reduce the search space when finding adjacent pieces, it would make it slightly more challenging to place pixels next to each other.

d. Complete the puzzle and include the final image in your report.
e. What was you strategy for starting to solve the puzzle?
    Hint: It is recommended to apply a clustering technique to pieces and obtain groups with similar shapes.
⭐ f. Generate a video (gif) displaying the process of completing each of the two puzzles.

Note: You are not allowed to use any built-in function to solve the puzzles or match the pieces.

2. CamScanner?! We Can Live Without It Now! (20 Pts.)

Keywords: *Pixel Operations, Pixel Processing, Image Enhancement in Spatial Domain, Rotation Matrix, Area Detection*

With the outbreak of the Coronavirus in 2020, most educational systems forced to operate online. Iranian students, however, had to encounter even more dire challenges. As well as occasional power outages and slow Internet speed, most lecturers emphasized too much on the quality of the uploaded documents, making it rather difficult for many students who had mediocre phones. As a consequence, various softwares, such as CamScanner, Genius Scan, and Scannable, became widely popular. However, as someone who already has the required image processing skills to accomplish what those softwares do, it is time for you to reduce your dependence on them.

(a)   **(b)**

Figure 2: A Good transformation which has noticeably enhanced the image quality (a) Original (b) Transformed

a) Identify the main region of the images and crop them.
   Note: Sheets (including their texts and empty spaces) should be preserved as much as possible.

b) As could be seen, some of the captured images have rotation misalignments. Rotate the images so that their angle with respect to the camera angle is close to 0. You may need to re-crop images to achieve better results.

c) The images taken are raw and not of very good quality for reading purpose. Apply some transformations you learned in class to improve their quality.
   Hint: it might be better to use techniques such as histogram equalization, linear/logarithm/power-law transformation, etc. The techniques used should be implemented.

d) Save the final images as PDF files and attach them to your report.

3. Helping Janbo Become More 2023! (18+3 Pts.)

Keywords: *Shapes & Lines Drawing, Text Writing, Template Matching, Object Counting*

Many stores use accounting and warehousing software to issue invoices to their customers. These softwares are typically based on an HTML-based format in which the general structure is specified and a module prepares the invoice for printing by filling in table tags such as <td> (sample project).

Figure 3: Some sample items

The invoice system of one of the branches of Janbo company has been failing to work properly and they have asked you to set up an invoice system based on image processing so that they could continue their operation. You are given images of items and their corresponding details.

a) Create a purchase invoice template based on image processing techniques. This format should include the date, time, Janbo logo, product table (line number, product name, product image, and product price), and a poem by Hafez with a contact number at the end. Display the created blank template.

b) Generate a random invoice with 5, 10, and 20 products, and display the results.
Note: The old price of the products should be considered.

c) Implement a function which receives the photo and the new price of the items in the store (in the form of a list) and counts the number of each item and calculate the new price of that invoice. Use the invoices generated in the previous section as the input of this function (as an image) and display the results. You can use the image of the product according to the image of the invoice to count the goods.

Note 1: There is no 'number' field in this system, and if a product is bought twice, it will be displayed in two separate rows

Note 2: You are not allowed to use photoshop or other tools to create template as well as object matching and counting.

Note 3: Three bonus points will be given to a good-looking and attractive design as well as a low invoice storage size.

4. When An Image Reveals Secrets   (13 Pts.)

Keywords: *Message Encryption, Custom Color Channel, Pixel Operations, Image Steganography*

Using images to transfer hidden messages is known to be one of the oldest active fields in the field of digital image processing. There are different types of hiding a secret message in an image; from hiding a separate image into another image to concealing a secret code into an image. In this section, a unique image for each of the students is given, each containing their student number.

Figure 4: A seemingly normal image which contains a secret message

a) Calculate the average PSNR/MSE measure of your image with respect to other images. Are the images numerically similar?

b) The following pseudo code is related to image decoding and message extraction. Implement a function to receive the encrypted image and output the message as well as the `hidden_channel` displayed. Extract the hidden message from your image and include it in the report.

```
img_b, img_g, img_r = ImageChannelSeparator(encoded_img)
first_hidden_channel = AddImage(img_b,img_r)
hidden_channel = SubtractImage(first_hidden_channel,img_g)
msg = EmptyString
for pixel in hidden_channel:
    msg += pixel mod 2
Message = EmptyString
for byte in ConvertBinsToBytes(msg, len_of_bin=8):
    Message.AddChar(ConvertByteToChar(byte))
```

c) Write a function which takes an image and a message as input and generates the encoded image so that the message can be extracted using the above function.

d) Encrypt your email address and student number using the above function and image `source.jpeg` and send it along with your report.

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5. From Simple Pixel Counting to Complex Remote Sensing **(10 Pts.)**

Keywords: *Image Masking, Image Thresholding, Satellite Images*

Environmental protection is indeed a crucial responsibility of every government and nation. In 1990, the U.S. approved and implemented a two-decade program for the protection and restoration of the Colorado River, with an estimated cost of $96M. Now the goal is to evaluate the success of this program based on satellite images and remote sensing.

(a)   (b)
Figure 5: Satellite images taken from Colorado River (a) 1990 (b) 2010

a) Count the number of pixels indicating water regions, and estimate the water volume based on the color range of the areas. How much has the volume of the water increased in the region?

b) Based on the extracted regions in the images, generate a binary mask for each of the images and separate them from their original image. Set the background of the new image to red. Include the masks in your report.

c) Using the masks produced in the previous section, calculate and display the regions of the river in which the level of the water has increased.

6. Some Explanatory Questions   (9 Pts.)

Please answer the following questions as clear as possible:

a) Does histogram smoothing have the same effect in different color spaces (RGB, CMYK, YUV, and HSV)? Is the time complexity of the algorithm the same? Prove your answer.

b) What is the feature pyramid and what is its application in image processing?

c) If you shoot two different images with the same resolution and settings with your phone, their storage size may vary. What is the reason?

d) Does histogram smoothing always improve the quality of images? If yes, explain why. If no, give an example.

e) Does a healthy human eye always perceives the environment in color?

f) Explain the .png storage format and explain how it stores and transmits transparency.

g) Why is it normally recommended to make use of image quality enhancement techniques after applying geometric transformations including cropping or rotation?

Good Luck!
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