CSC 476/676 Computer Vision Mid-term Take-home Exam

Due March 28th (Sunday) end of the day

Total points: 100 pts

Your name _____
AU ID_____

1. **The exam is open book; open notes. But you must submit your own independent work!**
2. **No discussion is allowed in the exam**. Copying from each other is strictly forbidden. **Copying lines of code from the Internet is strictly forbidden and will be considered cheating.**
3. But be careful of how you time yourself. You do not have to finish the questions in order. Pick up the easiest questions first to work on.
4. **Please write in clear font and you can use extra papers.**
5. **For the short answer questions, please directly answer them in this word document.**
6. **For programming questions, please submit a zipped folder of images and .ipynb as well as as link of Google CoLab.**
7. **Please write equations clearly with equation editor.**
8. **You can insert photos and drawings directly to the word document. But please make sure your writing/pictures are clear and easy to read.**

Short Answers

1. (5pts) Under what conditions will a line viewed with a pinhole camera have its vanishing point at infinity?

2. (15pts)

   (A) What is the Fourier transform of the 8×1 vector [1,-1,1,-1,1,-1,1,-1]?
   Please show how you drive the answer.

   B) If I take every second sample (show the result), what is the Fourier transform of that signal ?

   C) Is there any "aliasing" going on above ? Explain in words.

3. (5pts) What is the pinhole camera geometry and the camera matrix P for a pin-hole camera? In other words, how do I relate 3D world points (X,Y,Z) to a 2D image point (x, y) through pin-hole camera projection? Please draw an illustration as well as derive the equations.

4. (15pts) The binary image below is an image of a 3 pixel thick vertical line.

0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0

A) Show the resulting image obtained after convolution of the original with the following approximation of the derivative filter $[-1, 0, 1]$ in the horizontal direction.

B) How many local maxima of the filter response do you obtain?

C) **Suggest a filter which when convolved with the same image would yield a single maximum in the middle of the line. Demonstrate the result of the convolution on the original image.**

5. (5pts) Using lens maker's formula to solve this.
When an object is held in front of a convex lens of focal length 5.0cm a real image forms at a distance of 15cm from it.

   What is the object distance u?

6. (5pts) What is the effect of the sigma parameter of a Gaussian, on the appearance of the image that has been convolved with a Gaussian?

   What about the derivative of Gaussian filter and the effect of sigma on filtered images?

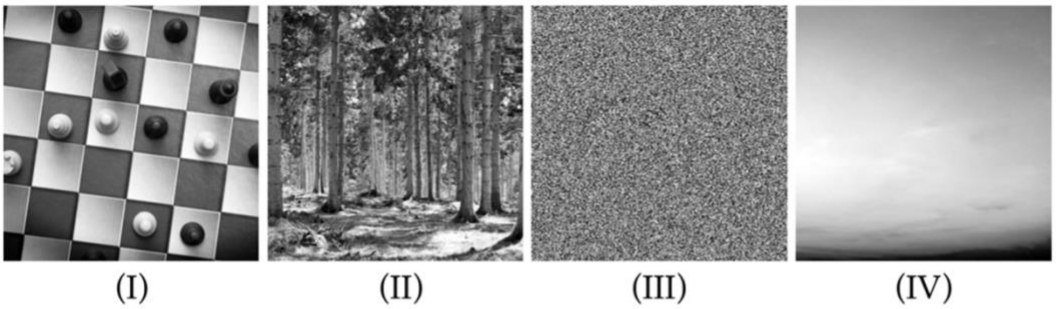
7. (5pts) Say I am at a pixel (r, c), where r is the row index and c is the column index. How can you find the difference between pixels to the right of me and pixels to the left of me, i.e. between pixels (r, c-1) and (r, c+1), using a filter?

   What about the difference between pixels below/above me, i.e. (r+1, c) and (r-1, c)?

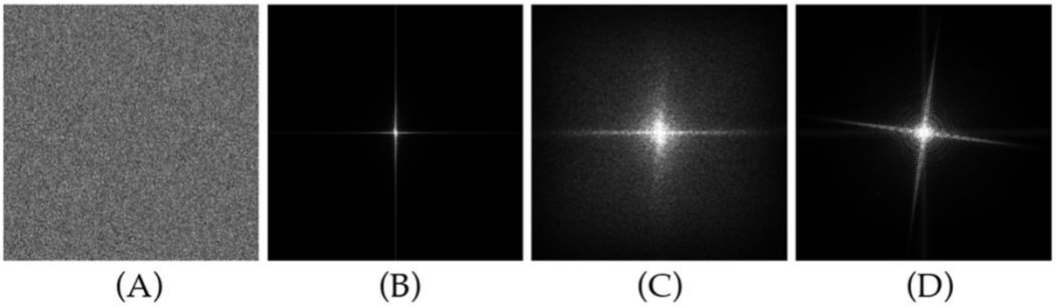
8. (5pts) Say you want to illustrate both the finer and coarser details in an image, separately. Describe a process that allows you to produce 3 "detail" images (i.e. images that only show the sharp detail of the image), the first one being very fine, the second a little coarser, and the third even more coarse.

   Feel fere to explain this with both English and Equations.

9. (5pts) Match the corresponding Fourier transform images with real images.



(I) (II) (III) (IV)



(A) (B) (C) (D)

10 (5pts) How can you find patterns in an image (e.g. let's say you're looking for a plus sign in images) in an image using a filter? You can show examples and write down specific methods.

Would a 3x3 filter work for any image, i.e. where the plus signs appear at different sizes and orientations? Explain why it would/wouldn't.

11 (5pts) Describe an algorithm that remove ONLY objects moving with a particular velocity in a video. Suppose the moving object has the velocity (vx,vy) and the sequence of the moving images can be described as:

$$f(x, y, t) = f_0(x - v_x t - v_y t)$$

It is preferred you describe it with both texts and math equations. When you write down equations, please explain in words what your equations mean and how it helps solving the problem.

Long answers (Programming Questions) (please submit a Google Colab link

Question 1 (10pts) Basic image processing with Python. Write Python code to do the following.

1. Read in an image into Python as a matrix, and write down its dimensions. For instance, you can use Georgetown.jpg in the folder.
2. Convert the image into grayscale. You can use the image attached in the exam folder.
3. Find the darkest pixel in the image, and write its value and [row, column] in your answer sheet. Hint: Convert to a vector first, and use `numpy.flatten`.
4. Use the function `numpy.sum` and a logical operator measuring equality to a scalar, to determine and write down how many pixels in the grayscale image equal the value 6.
5. Consider a 31x31 square (a square with side equal to 31 pixels) that is centered on the darkest pixel. Replace all pixels in that square with white pixels (pixels with value 255). Do this with loops.
6. Now use the code you wrote above to find one of several pixels with value 6. Find which of those pixels are at least 15 pixels away from the border of the image in any direction (not including the 6-valued pixel itself). You can use loops. Let's call these 15-away 6-valued pixels `inds` (you don't have to call them this in your code).
7. Write code to *randomly* choose one of the `inds` pixels.
8. Now consider another 31x31 square, but this time gray (e.g. with pixel values 150). Take the image with the white square in it. Replace the randomly chosen pixel from above, and the 31x31 square in the image that's centered on this pixel, with the gray square. This time you are NOT allowed to use loops. Note that you shouldn't run into border issues because of the 15-away code you wrote above.

9. Make a new figure, display the modified image (which includes both a white square and gray square), and save it to a file using pyplot. `savefig(gcf, 'new_image.png').`

Question 2 (15pts)

a) Implement an algorithm to sharpen a blurred image. You can get a blurred image by filtering an original image with a low-pass filter or shoot an image in low light or without focus. You are not allowed to use OpenCV or existing sharpening operators. Hint: You can do this via filtering in space domain or manipulating the image's Fourier Spectrum. You can find the blurred image in the attached folder. Display your results and compare the methods. Please return a sharpened color image. Compare your results with Photoshop.

b) Take a blurry or noisy image (shooting in low light is a good way to get both) and try to improve their appearance and legibility using Python code. Hint: To deblur, you can do a de-convolution such as inverting the convolution process. To remove noises, consider a median filter. Comment on the effects of your methods on the images.