BMI/CS 567

Medical Image Analysis

Instructor: Jeanette A. Mumford

Exam I

March 6, 2018 2:30- 3:45PM

Instructions:

- **You may not use a computer on this exam**
- **You have 75 minutes to complete the exam (2:30 - 3:45PM)**
- **The exam consists of 8 problems on 11 pages. Most problems are subdivided into sections like 1(a), 1(b), etc. Make sure your exam is complete before you begin.**
- **Show all work in detail or your answer will not receive any credit. All answers without supporting work receive ZERO credit.**
- **Write neatly**
- **You can use the back of the pages as scratch paper.**
- **Do not use your own scratch paper. You may ask for approved scratch paper from the instructor.**

I pledge on my honor that I have not received or given any unauthorized assistance in this exam.

Name: _____

1. An experiment consists of flipping a coin 5 times where the probability of heads is 0.4. The probabilities of 1, 2, 3, 4 or 5 heads out of 5 are 0.2592, 0.3456, 0.2304, 0.0768 and .0102, respectively.

(a) (1 point) Write the equation for the probability distribution for the number of heads (N_H) equal to k, $P(N_H = k)$. This equation should be a function of k. Please do not list out the probabilities given above as your solution.

(b) (2 points) Plot the probability distribution for the probability of k *tails* of out the 5 flips. It is fine if your bar heights are only scaled approximately, but write the actual bar height above each bar.

Solution

(a) $P(N_H = k) = {}_5C_k 0.4^k 0.6^{(5-k)}$

(b) Heights are: 0.0102, 0.0768, 0.2304, 0.3456, 0.2592 , and 0.0778, in that order

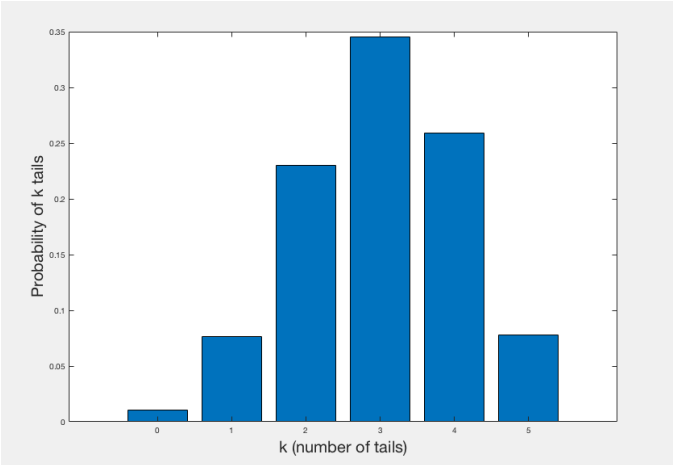


Figure 1: Solution to part b.

2. (2 points) Figure 2 displays two images of Bucky Badger, although you cannot actually see him in the image of the right panel. Given this, why do you suspect the SNR does such a bad job at describing the image quality? Why does the CNR work better in this case?

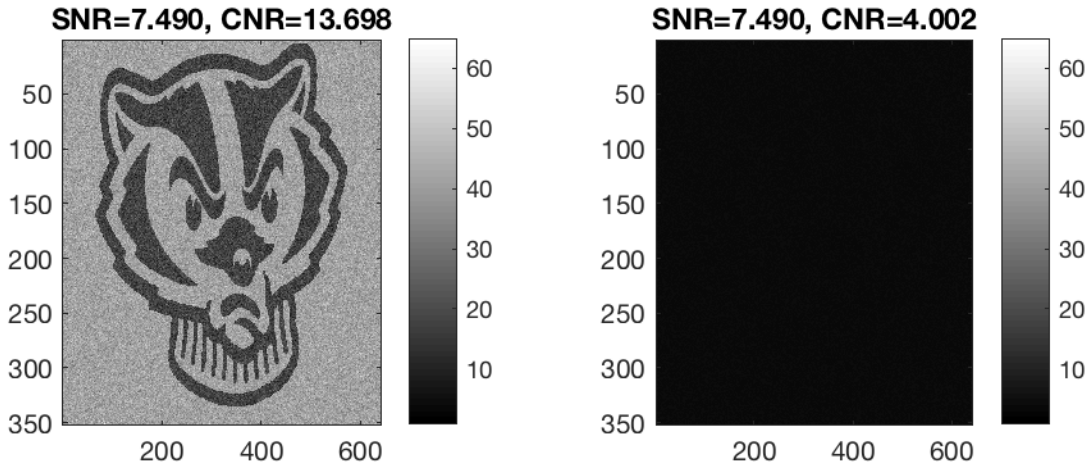


Figure 2: The titles of each image display the SNR and CNR of each image. The variance was estimated using the upper left corner pixels (1:50, 1:50), which do not include the Bucky portion of the image.

Solution: By inspection of the range of grayscale values of the right image, it is clear that the variance is much smaller than the left image, which is inflating the SNR. Likewise, the mean is very small. Due to the low contrast in the right image, the CNR metric is much better at describing image quality.

3. (2 points) Write an equation that could be used to rescale image values that currently range from the values of A to B to range between -5 and 10.
Solution: $\rho' = \frac{\rho - A}{B - A} 15 - 5$

4. (2 points) Using the standard definition of convolution, what impact would the following kernel have when convolved with an image?

0	0	0
0	0	1
0	0	0

Solution: Image will be shifted 1 pixel to the right

5. Figure 3 shows the plot of a Sigmoid based ITF.

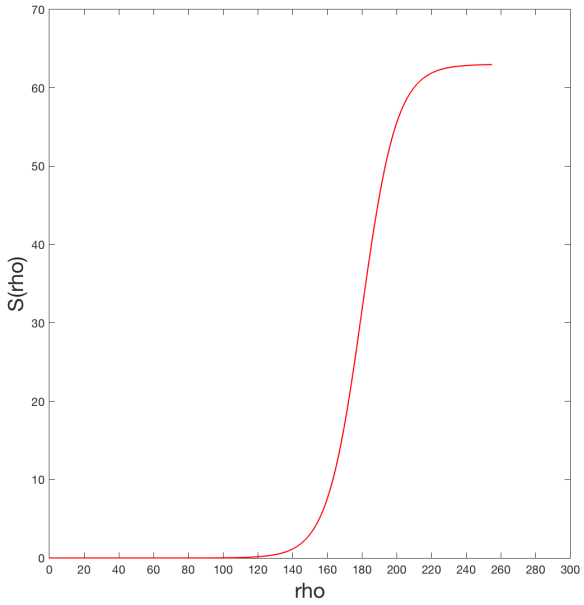


Figure 3: Sigmoid function for problem 5.

(a) (1 point) What are the image depths (in bits) of the input and output images.

(b) (2 points) Write out the equation for a windowing function in that closely approximates the Sigmoid function in Figure 3

Solution (a): Input has an 8 bit depth and output has a 6 bit depth
(b):

$$\rho' = \begin{cases} 0, & 0 \leq \rho < 130, \\ -\frac{63}{70}130 + \frac{63}{70}\rho, & 130 \leq \rho < 200, \\ 63, & 200 \leq \rho \end{cases} \tag{1}$$

6. For the following image use the length of the gradient, as defined by the forward difference kernels in both directions to find the edges of the image. Be sure to include your work so partial credit can be given and use zero padding.

0	0	0	0	0
0	0	0	0	0
0	1	-2	1	0
0	0	0	0	0
0	0	0	0	0

(a) (1 point) How does the central difference relate to the forward and backward difference kernels?
Solution (a): The central difference is the average of the forward and backward differences.

(b) (1 point) Write out the kernels used. Use the forward kernel in the x-direction that corresponds to $\rho(i+1,j) - \rho(i,j)$ and in the y-direction that corresponds to $\rho(i,j+1) - \rho(i,j)$.
Solution (b):
X-direction

0	1	0
0	-1	0
0	0	0

Y-direction

0	0	0
1	-1	0
0	0	0

(Continued on next page)

(c) (1 point) Write out your convolution result in each of the x and y direction, below. Note that the next pages of the exam have numerous empty grids for you to put your work, but please display your final solution on the grids below If you need more grids I have extras printed out.

Solution, part(c)

Result convolution with $K_{x:forward}$

0	0	0	0	0
0	1	-2	1	0
0	-1	2	-1	0
0	0	0	0	0
0	0	0	0	0

Result convolution with $K_{y:forward}$

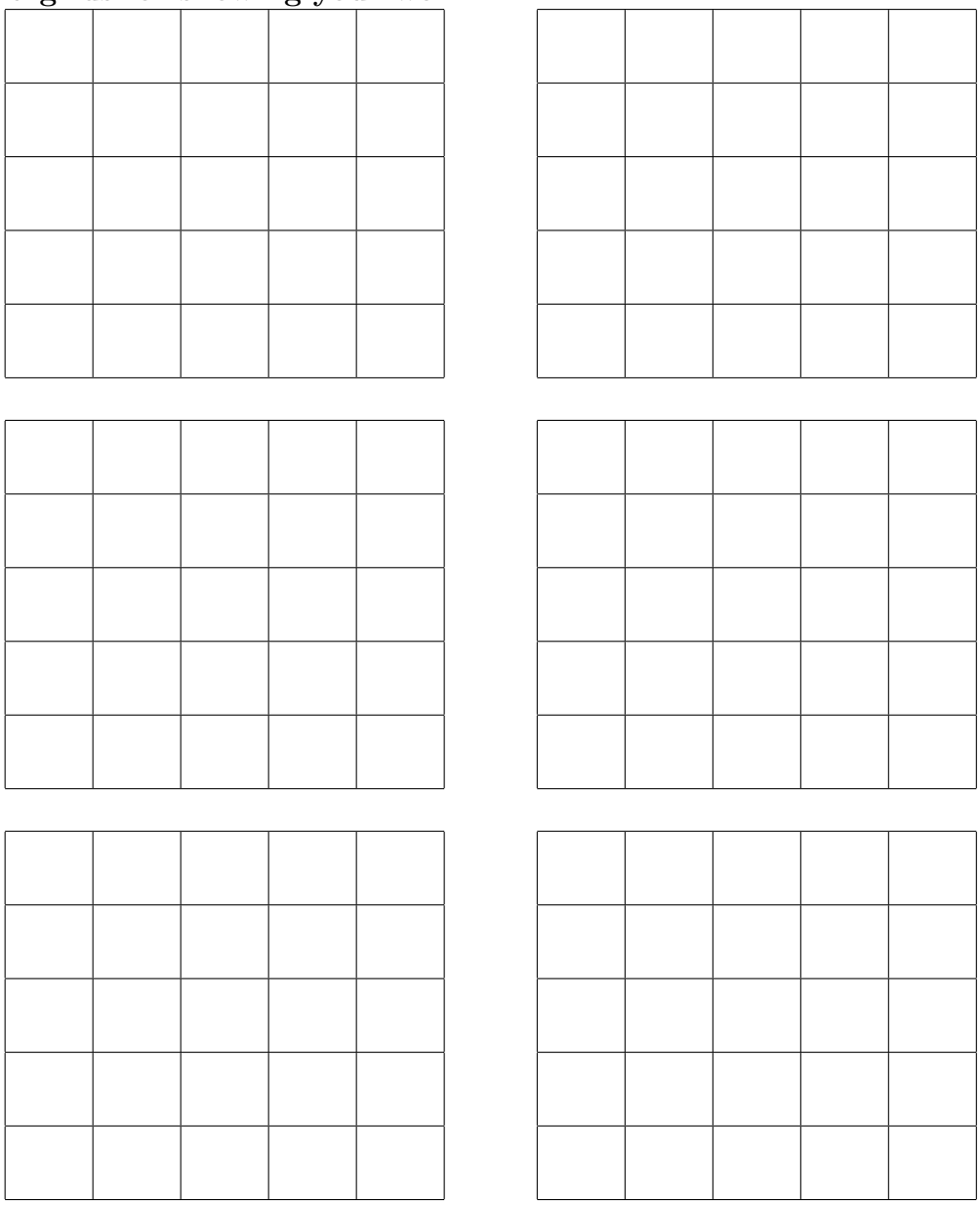
0	0	0	0	0
0	0	0	0	0
1	-3	3	-1	0
0	0	0	0	0
0	0	0	0	0

(d) (1 point) Write your final answer (length of the gradient) below.

Solution, part(d)

0	0	0	0	0
0	1	2	1	0
1	$\sqrt{10}$	$\sqrt{13}$	$\sqrt{2}$	0
0	0	0	0	0
0	0	0	0	0

extra grids for showing your work



7. (2 points) Describe a scenario in which you would want to reduce an 8 bit image to a 6 bit image and a scenario in which you would *not* want to reduce the image depth.
Solution: You only want to reduce to 6bit for displaying the image in MATLAB. Generally you don't want to reduce image depth, since you lose resolution

8. (2 points) I'm reading a DICOM file into MATLAB using `fopen` and `fseek`, specifically using `fpointer = fopen('My_IMAGE', 'r');` and `fseek(fpointer, 4000, 'bof')`. What does 4000 represent and how would you figure that value out so you could read in the image?

Solution: The 4000 refers to the size of the header. To compute this you'd either need to find the size of the header directly, or subtract the size of the image from the size of the DICOM file. The latter was the approach used in class.