CS 111: Digital Image Processing
Fall 2016
Midterm Exam: Oct 19, 2016

Time: 1 hour 20 mins
Total Points: 80 points

Name:____

Number:____

Pledge: I neither received nor gave any help from or to anyone in this exam.

Signature:_____________________________

Useful Tips

1. All questions are multiple choice questions --- please indicate your answers very clearly. You can circle them or write out the exact choice. If your answer is ambiguous, you are not going to get any points for the answer.
2. Use the blank pages as your worksheet. Put the question number when working out the steps in the worksheet. Also, do your work clearly. This will help us give partial credit. Answer the questions you are most comfortable with first.
3. **Points are indicative of the time in minutes you should spend on the question.**
4. If you need more work sheets, feel free to ask for extra sheets.
5. Staple all your worksheets together with the paper at the end of the exam. If pages of your exam are missing since you took them apart, we are not responsible for putting them together.

Do not enter anything in the table below

Q #	Points	Points Received
1)	**8**	
2)	**10**	
3)	**9**	
4)	**4**	
5)	**12**	
6)	**8**	
7)	**8**	
8)	**7**	
9)	**10**	
10)	**4**	
Total	**80**	

1) **[2+4+2=8]** g[n] is a 1D discrete signal defined for $-2 \leq n \leq 4$. The impulse response h[n] of a linear system is another discrete signal defined for $1 \leq n \leq 6$. The response of g[n] when passed through this system is given by the convolution of g[n] with h[n] and denoted by y[n].

   a. The length of y[n] is
      i. 4
      ii. 12
      iii. 13
      iv. 14
   b. The number of samples in y[n] that are fully immersed is
      i. 0
      ii. 1
      iii. 2
      iv. 3
   c. Consider the multiplication of g[n] and h[n] in spatial domain. This is equivalent to which operation in the frequency domain.
      i. Filtering
      ii. Addition
      iii. Convolution
      iv. Multiplication

2) **[1+2+1+1+2+1+2=10]** Consider using a 512x512 image. Consider its Gaussian Pyramid using a Gaussian filter.

   a. Knowing the original image is considered as Level 0, What is the highest level in the pyramid?
      i. Level 2
      ii. Level 4
      iii. Level 8
      iv. Level 9
   b. Level *i* of this pyramid (Level *0* being the original image) can be achieved in which of the following ways.
      i. By convolving the Level *0* image with Gaussian of size $2^i x 2^i$
      ii. By convolving the Level *i-1* image with a Gaussian of size 2x2
      iii. By convolving the Level *i-3* image with a Gaussian of size 8x8
   c. We can reduce the image size of each level by a
      i. Factor of 2
      ii. Factor of 3
      iii. None at all
   d. This is possible because
      i. Each level reduces the frequency content by an octave
      ii. Some of the pixels become zero due to the processing
      iii. Nyquist sampling requirement goes down with each level
   e. If we want to use a box filter for this pyramid, what kind of artifacts will result?
      i. Ghosting
      ii. Blurring

iii. Aliasing
iv. Dimming

f. This is due to
   i. Shifting of some frequencies
   ii. Removal of high frequencies
   iii. Contrast Reduction
   iv. Leakage of high frequencies

g. Convolving with a box kernel in the spatial domain is equivalent to
   i. Multiplication with a sinc in frequency domain
   ii. Convolution with a box in frequency domain
   iii. Multiplication with a gaussian in frequency domain
   iv. Convolution with a sinc in frequency domain

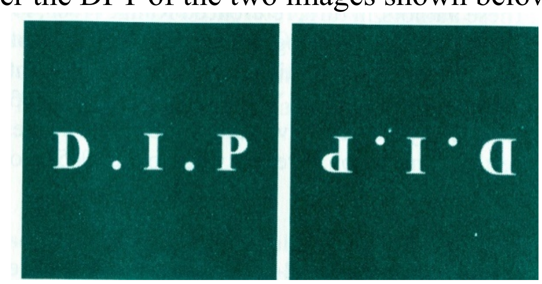
3) **[3+3+3=9]** Let $f(x,y)$ denote an image and $f_G(x,y)$ denote the image obtained by applying a Gaussian filter $g(x,y)$ to $f(x,y)$. In the photography industry an operation called *high boost filtering* generates an image $f_B(x,y) = af(x,y) - f_G(x,y)$, where $a \geq 1$.

a. You are asked to use one filter to achieve the high boost filtering. The filter you would use is
   i. $\delta(x,y) - g(x,y)$
   ii. $1\text{-}g(x,y)$
   iii. $a\,\delta(x,y) - g(x,y)$
   iv. $a - g(x,y)$

b. If $G(k,l)$ is the frequency domain response of $g(x,y)$, the frequency response of this filter is given by
   i. $\delta(k,l) - G$
   ii. $a - G$
   iii. $a\,\delta(k,l) - G$
   iv. $1\text{-}G$

c. The shape of this filter in the frequency domain is close to a
   i. Low pass filter
   ii. High pass filter
   iii. Band pass filter

4) **[2+2=4]** Consider the DFT of the two images shown below.



d. The amplitude plot of these two images are
   i. Related by a scale factor
   ii. Related by a shift
   iii. Identical to each other

iv. Flipped

e. The phase plot of these two images are
   i. Related by a scale factor
   ii. Identical to each other
   iii. Related by a shift
   iv. Flipped

5) **[2+4+4+2=12]** Consider a signal of 16 samples given by $x[n] = 8 + 7Cos(\pi n/4) + 6Sin(3\pi n/8) + 5Cos(\pi n/2) + 4Sin(5\pi n/8) + 3Cos(3\pi n/4) + 2Sin(7\pi n/8) + Cos(\pi n)$.

f. The DC component of this signal is
   i. 0.5
   ii. 1
   iii. 8
   iv. 36

g. The array RX is given by
   i. [8, 7, 5, 3, 1]
   ii. [8, 0, 7, 0, 5, 0, 3, 0, 1]
   iii. [0, 0, 0, 0, 8, 7, 5, 3, 1]
   iv. [8, 7, 5, 3, 1, 0, 0, 0, 0]
   v.

h. The array IX is given by
   i. [0, 0, 0, 6, 0, 4, 0, 2, 0]
   ii. [0, 6, 4, 2, 0]
   iii. [0, 6, 4, 2, 0, 0, 0, 0, 0]
   iv. [0, 0, 6, 0, 4, 0, 2, 0, 0]

i. Consider the cosine and sine waves in *x* that make 4 cycles through the 16 samples. The amplitudes of these two waves are respectively
   i. 5, 4
   ii. 5, 0
   iii. *7, 2*
   iv. 0, 2

6) **[4+4=8]** Consider the 1D signals $x_1[n] = 3\delta[n-2] - 2\delta[n+1]$; $x_2[n] = 5\delta[n-3] + 2\delta[n+1]$; $h[n] = 3\delta[n-4]+1.5\delta[n-2] – \delta[n+1]$

a. The value of $x_1[n] * h[n]$ is
   i. $4.5\delta[n-2] + 2\delta[n+1]$
   ii. $9\delta[n-6] + 4.5\delta[n-4] - 6\delta[n-3] - 6\delta[n-1] + 2\delta[n+2]$
   iii. $6\delta[n-6] - 3\delta[n-3] + 9\delta[n-2] – 6.5\delta[n] - 3\delta[n+3]$
   iv. $-6\delta[n-6] + 3\delta[n-3] - 9\delta[n-2] + 6.5\delta[n] + 3\delta[n+3]$

b. The value of $x_2[n] * h[n]$ is
   i. $15\delta[n-7] + 7.5\delta[n-5] + 6\delta[n-3] - 5\delta[n-2] + 3\delta[n-1] - 2\delta[n+2]$
   ii. 0
   iii. $6\delta[n-5] + 3\delta[n-3] + 15\delta[n-1] - 2\delta[n] + 7.5\delta[n+1] - 5\delta[n+4]$
   iv. $-6\delta[n-5] - 3\delta[n-3] - 15\delta[n-1] + 2\delta[n] - 7.5\delta[n+1] + 5\delta[n+4]$

7) **[2+2+2+2=8]** Consider the Laplacian filter.

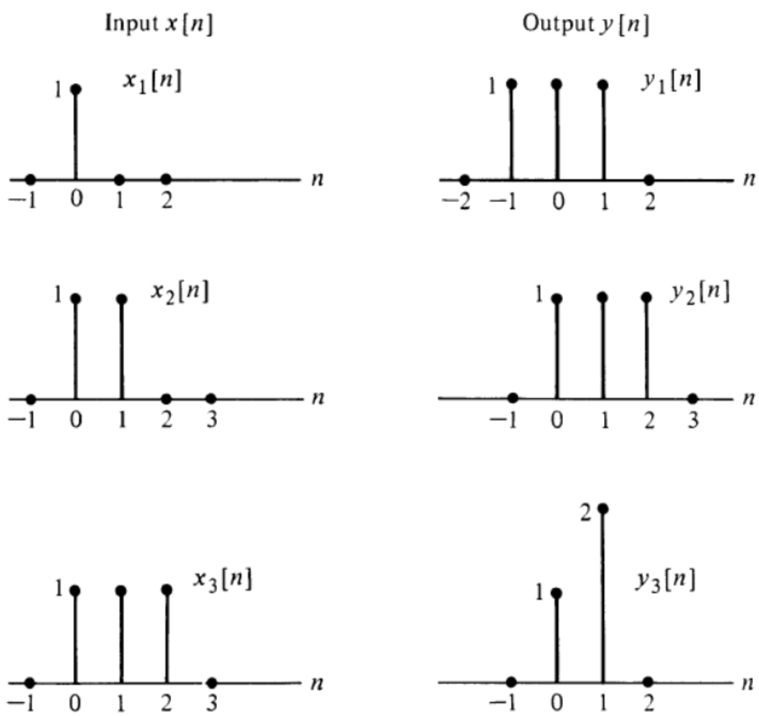
a. It provides the following at any pixel in an image.
   i. Gradient in *y* direction
   ii. Gradient in *x* direction
   iii. Strength and direction of edges
   iv. Curvature

b. Consider an image on which the Laplacian filter is applied for edge detection. An edge in the image corresponds to the following in the filtered image.
   i. Zero Crossings
   ii. Zeros
   iii. Maxima
   iv. Minima

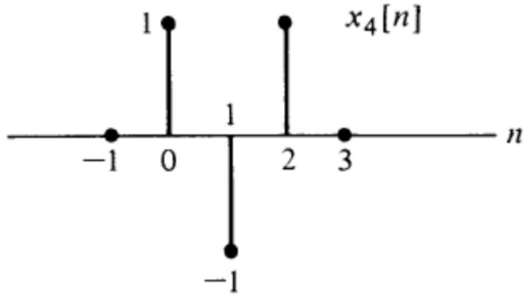
c. If the image is noisy, what kind of filter should be applied to the image before applying the Laplacian filter.
   i. A high pass filter
   ii. A low pass filter
   iii. A gradient filter

d. By changing the size of this preprocessing filter, we can detect edges of
   i. Different Contrasts
   ii. Different Lengths
   iii. Different Resolutions

8) **[4+3=7]** Consider the following input signals x_1, x_2 and x_3 and their response when passing through a linear but NOT sift invariant system, y_1, y_2 and y_3.



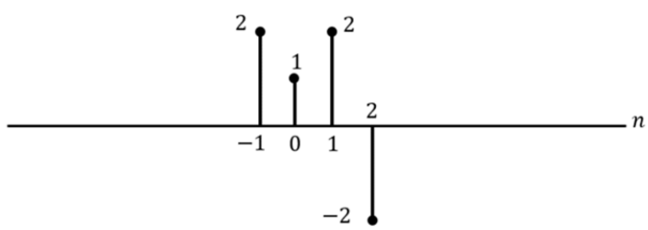
a. The following function x_4 can be expressed as a linear combination of x_1, x_2 and x_3 as



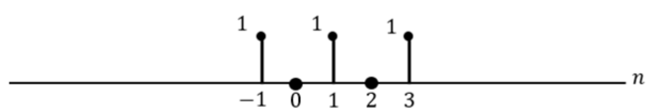
- *i.* $x_4 = x_1 - x_2 + x_3$
- *ii.* $x_4 = x_1 - 2x_2 + 3x_3$
- *iii.* $x_4 = 2x_1 + x_2 + 2x_3$
- *iv.* $x_4 = 2x_1 - 2x_2 + x_3$

b. Therefore, due to the law of superposition, the output y_4 of the function x_4 is given by

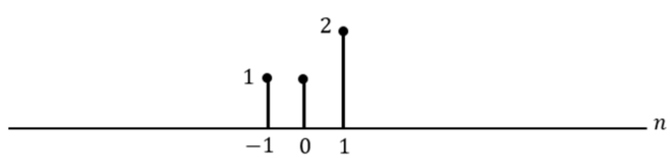
- *i.* *Correct answer*



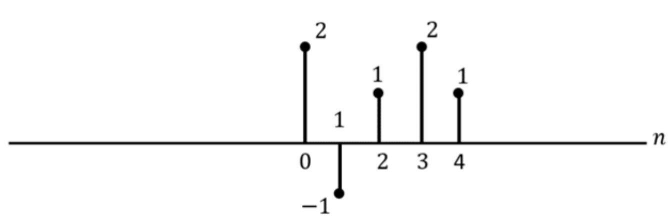
- *ii.*



- *iii.*



- *iv.*



9) **[3+3+4=10]** We want to use Hough Transform to identify the presence of different types of conics (e.g. parabolas, hyperbolas, ellipses) in an edge image.

a. Consider a parabola given by equation $y = ax^2+bx+c$. The Hough space for identifying parabolas is
   i. one dimensional
   ii. two dimensional
   iii. three dimensional
   iv. four dimensional

b. The parabola in space corresponds to the following in the Hough space
   i. Parabola
   ii. Sphere
   iii. Line
   iv. Plane

c. The general equation of the entity corresponding to the parabola in the Hough space is given by
   i. $ax+by = c$
   ii. $ax+by+z=c$
   iii. $y^2 = 4ax$
   iv. $x^2 + y^2 + z^2 = 1$

10) **[1+1+2=4]** Consider a Canny edge detector.

a. Canny edge detector depends on a
   i. Gradient based operator
   ii. Curvature based operator

b. Canny edge detector removes spurious edges by
   i. Hysteresis
   ii. Non-maxima Suppression
   iii. Low pass filtering
   iv. Finding zero crossings

c. Canny edge detector removes streaking or broken edges by
   i. Hysteresis
   ii. Non-maxima Suppression
   iii. Low pass filtering
   iv. Finding zero crossings