Visual Computing Midterm
Winter 2018

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.
2. **Questions may have more than one answer. You get full points only if you choose all the correct answers.**
3. 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.
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.
6. **The number of minutes you should spend on each question is roughly equal to the number of points assigned to the question.**

1) **[1+1+1+1=4]** Assume that the maximum bandwidth of audio signal to be 75Hz. Let us consider amplitude modulation of such audio signals by multiple stations using high frequency carrier signals.

a. Which of the following cannot be the frequency of a carrier signal.
   i. 50 Hz
   ii. 100 Hz
   iii. 200 Hz
   iv. 400 Hz

b. What is the minimum gap that should exist between two carrier frequencies?
   Since the max bandwidth is 75Hz then there should be at least 2*75=150Hz gap between two carriers to avoid overlap of signals
   i. 75 Hz
   ii. 150 Hz
   iii. 200 Hz
   iv. 400 Hz

c. Not maintaining this minimum gap results in
   i. Ghosting
   ii. Amplifying
   iii. Aliasing

d. Amplitude modulation in frequency domain is equivalent to
   For amplitude modulation we multiply the signal with the carrier signal in spatial domain which equivalent of Convolving carrier frequency cosine wave with the signal
   i. Adding carrier frequency cosine wave to the signal
   ii. Multiplying carrier frequency cosine wave with the signal
   iii. Convolving carrier frequency cosine wave with the signal

2) **[1+1+1+1=4]** Consider a double-torus manifold constructed of triangles. Its genus is 2.

a. The euler characteristic of this double torus is
   e = 2-2g = 2-4=-2
   i. -2
   ii. -1
   iii. 0
   iv. 1
   v. 2

b. V (# of vertices) and F (# of faces) in this manifold is related by the following
   e = F – E + V = -2
   we can also write a equation between number of edges and number of faces. Since each face has 3 edge and each edge belongs to two face we have E=3*F/2
   By replacing this equation in above equation we get V = (F-4)/2

   i. V = (F+4)/2
   ii. V = (F-4)/2
   iii. V = 2F-2
   iv. V = 2F+2

c. Now consider a torus. What is its genus?

Genus number shows the number of handles which is 1 for a torus

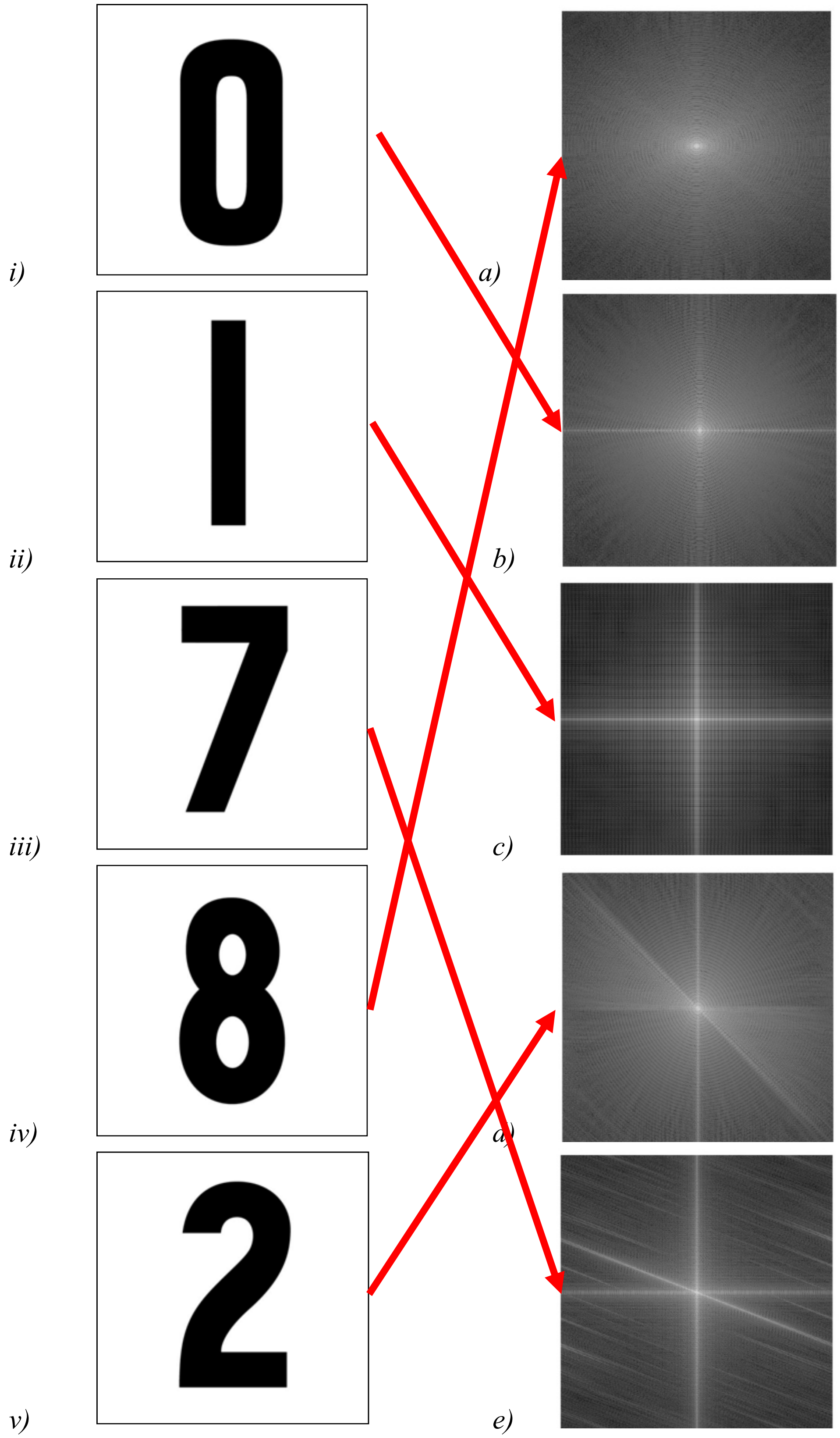
i. -2
ii. -1
iii. 0
iv. 1
v. 2

d. Is it possible to morph a double torus to the torus?

morphing a double torus to a torus without changing the connectivity of the vertices is no possible. We can not morph objects with different genus numbers.

i. Yes
ii. No

3) **[5x2=10]** Match the images from left column with the image of the magnitude of their DFT from right column.
For solving this question look at the orientation of the edges in each image. Then the DFT of the image should have same direction for the edges.


i)
ii)
iii)
iv)
v)
a)
b)
c)
d)
e)

4) **[2+3+3+2=10]** Consider a signal of 16 samples given by *x(i)= 4 + Cos(πi/4) + 3Sin(3πi/8) + 2Cos(πi/2) + 5Sin(5πi/8) + 7Cos(3πi/4) + 9Sin(7πi/8) + Cos(πi).*

For solving this question we can use the following equation

$$x[i] = \sum_{k=0}^{\frac{N}{2}} \hat{x}_c[k] cos\left(\frac{2\pi ki}{N}\right) + \sum_{k=0}^{\frac{N}{2}} \hat{x}_s[k] sin\left(\frac{2\pi ki}{N}\right)$$

xc and xs are the RX and IX and the DC component is the scalar value which is 4

a. The DC component of this signal is
   - i. 1
   - ii. 4
   - iii. 8
   - iv. 16

b. The array X_c is given by:
   - i. [4, 1, 2, 7, 1]
   - ii. [4, 1, 2, 7, 1, 0, 0, 0, 0]
   - iii. [4, 0, 1, 0, 2, 0, 7, 0, 1]
   - iv. [0, 0, 0, 0, 4, 1, 2, 7, 1]

c. The array X_s is given by:
   - i. [0, 3, 5, 9, 0]
   - ii. [0, 3, 5, 9, 0, 0, 0, 0, 0]
   - iii. [0, 0, 3, 0, 5, 0, 9, 0, 0]
   - iv. [0, 0, 0, 3, 0, 5, 0, 9, 0]

d. Consider the cosine and sine waves in *x* that make 4 cycles through the 16 samples. The amplitudes of these two waves respectively, are:
   - i. 2, 5
   - ii. 2, 0
   - iii. *1, 9*
   - iv. 0, *9*

5) **[2+2+2+1+2=9]** Consider the Laplacian filter.

a. It provides the following at any pixel in an image.

   Laplacian filter finds the second derivative of the image which shows the curvature of the image
   - i. Gradient in *x* direction
   - ii. Gradient in *y* direction
   - iii. Curvature
   - iv. Strength and direction of edges

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.

   The edge is the point of transition from positive curvature to negative curvature which is the zero crossing of the second derivative.
   - i. Zero
   - ii. Zero Crossings

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.
By removing the high frequencies we can reduce the noise so we need to use a low pass filter
   i. A low pass filter
   ii. A high pass filter
   iii. A gradient filter
d. This degrades which of the following property of a good edge detector
Low pass filter will blur the image and as a result the location of the detected edges can be changed
   i. Detection
   ii. Localization
   iii. Single Response
e. By changing the size of this preprocessing filter, we can detect edges of
   i. Different Lengths
   ii. Different Resolutions
   iii. Different Contrasts

6) **[2+2=4]** We want to use Hough Transform to identify the presence of different types of conics (e.g. parabolas, circles , ellipses) in an edge image.
   a. Consider an ellipse given by equation $\frac{x^2}{a^2} + \frac{y^2}{b^2} = c$ The Hough space for identifying an ellipse is
   The unknown variables are a, b, and c. So the hough transform has three variables.
      i. one dimensional
      ii. two dimensional
      iii. three dimensional
   b. Every edge pixel will
      i. add 1 vote to multiple voxels (3D pixel) in Hough space
      ii. add multiple votes to multiple voxels in Hough space
      iii. add 1 vote to multiple pixels in Hough space
      iv. add multiple vote to multiple pixels in Hough space

7) **[1+2+2=5]** Consider the Canny Edge detector.
   a. It is a
      i. Gradient based edge detector
      ii. Curvature based edge detector
   b. The non-maximal suppression achieves which of the following in Canny edge detector
   non-maximal suppression assures to choose one point for each edge
      i. Detection
      ii. Localization
      iii. Single Response
      iv. Classification of edges based on their strengths

c. The process of double thresholding helps in

Using double thresholding we can categorize each point as non-edge, weak edge and strong edge

i. Detection
ii. Localization
iii. Single Response
iv. Classification of edges based on their strengths

8) **[2+3+3+2=10]**Consider a 2D rectangle ABCD where A=(0,0), B= (3,0), C=(3, 1) and D=(0,1). We want to apply a **2D** transformation to this rectangle which makes it a parallelopipped ABEF where E = (6,1) and F= (3,1).

a. What kind of transformation is this?

As you can see after transformation the value of x is increase proportional to value of y so we have x = x + 3y . So this is a shear

i. Scale
ii. Rotate
iii. Shear
iv. Translate

b. The 3x3 matrix **M** achieving this transformation is given by

i. [1 3 0 ; 0 1 0 ; 0 0 1]
ii. [1 0 0 ; 3 1 0 ; 0 0 1]
iii. [1 0 3 ; 0 1 0 ; 0 0 1]
iv. [1 0 0 ; 0 1 0 ; 3 0 1]

c. What additional transformation **N** we would need to apply to ABEF to get the parallelopipped A'B'E'F' where A' = (0, 0), B' = (6,0), E'= (12, 3), and F' = (6,3).

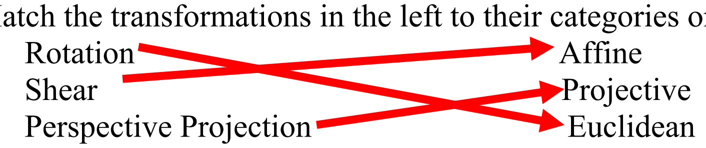
i. Rotation by 45
ii. Scale by (2, 3)
iii. Translate by (3, 2)

d. What is the final concatenated matrix in terms of **M** and **N** that will transform ABCD to A'B'E'F'?

M is the first transformation so it should be on the right. Then when we multiply NM with coordinate of each point M will multiply first

i. **MN**
ii. **NM**
iii. $\mathbf{M^{-1}N}$
iv. $\mathbf{N^{-1}M}$

9) **[3]** Match the transformations in the left to their categories on the right.



10) **[3+2=5]**Consider the following matrix [Note: 1/√2 = 0.707].

the following matrix is created by multiplication of a scale matrix and a shear matrix.

$$\begin{bmatrix} 3 & 0 & 2 & 0 \\ 0 & 1 & 2 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

a. This matrix achieves the following in the *global coordinate system*

i. x-shear of 2 following by S_x of 3

ii. S_x of 3 following by x-shear of 2

iii. z-shear of 2 following by S_x of 3

iv. S_x of 3 following by z-shear of 2

b. Consider a translation **T** of the *local coordinate system* following these transformations. The resultant transformation will be (T shows translation, S shows Scaling and H shows shear)

Because T is in local coordinate system it should be in the right side.

i. **H_xS_xT**

ii. **TH_xS_x**

iii. **TS_xH_z**

iv. **S_xH_zT**

12) [1+1=2] Consider an image with salt and pepper noise.

a. The median filter is considered to be the more effective in removing this noise than a low pass filter. This is because

i. Median filter retains the edges

ii. Median filter is less noisy

iii. Median filter has a smaller size

b. Median filter is a

i. Linear filter

ii. Non-linear filter

iii. Order statistics filter

13) [2+2=4] Consider applying a rotation **R**, and then a translation **T,** and then a scaling **S** in global coordinate system.

a. The corresponding transformation matrix is given by

i. **STR**

ii. **RTS**

iii. **SRT**

iv. **RST**

b. The same transformation in local coordinate system is given by

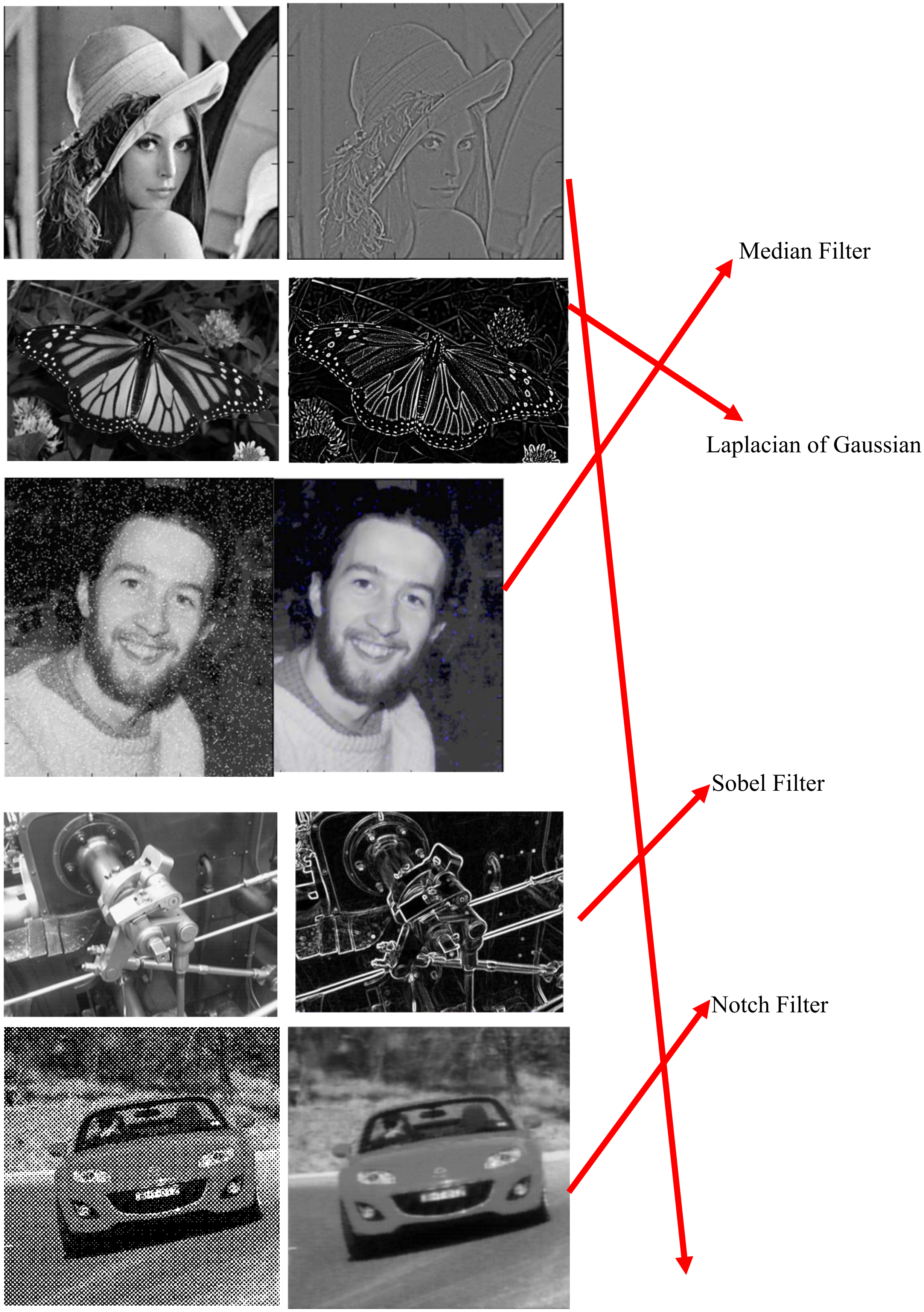
i. **STR**

ii. **RTS**

iii. **SRT**

iv. **RST**

11) **[5x2=10]** Match the results on the left to the filters on the right


Median Filter
Laplacian of Gaussian
Sobel Filter
Notch Filter

High Pass Filter