Visual Computing Midterm
Fall 2016
(November 23rd)

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. More than one answer can be correct.
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. For some questions, you will need the chromaticity chart attached at the end of the paper.
7. The number of minutes you should spend on each question is roughly equal to the number of points assigned to the question.
1) \[2+2+2=6\] An image has a linear histogram \(p(r) = r\). We want to transform this image so that its histogram becomes quadratic, \(p(z) = z^2\). Assume continuous images.

a. The cumulative histogram of the first image is given by
   i. \(r^2/2\)
   ii. \(r^2\)
   iii. \(r^3/3\)
   iv. \(r\)

b. The cumulative histogram of the second image is
   i. \(z^2/2\)
   ii. \(z^2\)
   iii. \(z^3/3\)
   iv. \(z\)

c. The transformation required to achieve histogram matching is given by
   i. \(z = \sqrt{r}\)
   ii. \(r = \sqrt{2z^2/3}\)
   iii. \(z = 3/2r\)

2) \[3+2+2 = 7\] \(C_1\) and \(C_2\) are colors with chromaticity coordinates \((0.3, 0.15)\) and \((0.6, 0.3)\) respectively.

a. The proportions in which these colors should be mixed to generate a color \(C_3\) of chromaticity coordinates \((0.4, 0.2)\) is
   i. \(1/2, 1/2\)
   ii. \(1/4, 3/4\)
   iii. \(2/3, 1/3\)
   iv. \(1/3, 2/3\)

b. If the brightness \((X+Y+Z)\) of \(C_3\) is 90, the brightness of \(C_1\) and \(C_2\) are
   i. \(45, 45\)
   ii. \(22.5, 67.5\)
   iii. \(60, 30\)
   iv. \(30, 60\)

c. The luminance of \(C_1\) and \(C_2\) are
   i. \(6.75, 13.5\)
   ii. \(3.375, 20.25\)
   iii. \(9, 9\)
   iv. \(6, 12\)

3) \[3+4+3 = 10\] Consider the white color \(C_1\) with chromaticity coordinates \((0.3, 0.3)\) and the color \(C_2\) with chromaticity coordinates \((0.2, 0.5)\).

a. The most likely dominant wavelength of \(C_2\) is
   i. \(550nm\)
   ii. \(515nm\)
   iii. \(490nm\)
   iv. \(610nm\)

b. The estimated saturation of this color must be less than
   i. \(70\%\)
c. Combining $C1$ and $C2$ in proportions of $3/5$ and $2/5$ creates the following color
   - i. $(0.36, 0.28)$
   - ii. $(0.24, 0.32)$
   - iii. $(0.26, 0.38)$
   - iv. $(0.38, 0.25)$

4) $[1+1+1+1+1=5]$ Consider the following color management situations
   a. Color management in printers is hard due to one or more of the following reasons.
      - i. Printer colors cannot be modeled by additive color mixture
      - ii. CIE XYZ space cannot be used to analyze printer colors
      - iii. Printers are color wise non-linear devices
   b. Gamut transformation across devices can cause one or more of the following
      - i. Shrinking of the entire 3D color gamut of the device
      - ii. Loss of brightness and vibrancy of all colors
      - iii. Incorrect reproduction of some of the colors
   c. Gamut matching across devices can cause one or more of the following
      - i. Shrinking of the entire 3D color gamut of the device
      - ii. Loss of brightness and vibrancy of all colors
      - iii. Incorrect reproduction of some of the colors
   d. If you have an application which uses 20 spot colors, which of the following color management methods would you choose.
      - i. Gamut Transformation
      - ii. Gamut Matching
   e. If your application is to show nature videos, which of the following color management methods would you use,
      - i. Gamut Transformation
      - ii. Gamut Matching

5) $[4+4 = 8]$ Match the images with the artifacts in the left and the solutions on the right.
6) \(1+1+1+2+1=6\) Two projectors overlap partially to create a bright overlap region as shown below.

a. We would like to reduce the brightness in the overlap region using a blending operation. The width of the blending function should be
   i. \(D/2\)
   ii. \(D\)
b. Consider a linear blending function. Then, the blending function of the projector 1 (in blue) and projector 2 (in red) are given by (iv).

c. Linear blending functions are not
   i. Continuous
   ii. Gradient Continuous
   iii. Curvature Continuous

d. A blending function that can alleviate this problem is
   i. Step function
   ii. Cosine function
   iii. Spline function

e. Such a function in the case of projectors would look like [i]
7) \[2+3+3+2=10\] Consider a 2D rectangle ABCD where A=(0,0), B=(2,0), C=(2,1) and D=(0,1). We want to apply a 2D transformation to this rectangle which makes it a parallelogram AEFD where E=(2,4) and F=(2,5).

a. What kind of transformation is this?
   i. Scale
   ii. Rotate
   iii. Shear
   iv. Translate

b. The 3x3 matrix M achieving this transformation is given by
   i. \[
   \begin{bmatrix}
   1 & 2 & 0 \\
   0 & 1 & 0 \\
   0 & 0 & 1 
   \end{bmatrix}
   \]
   ii. \[
   \begin{bmatrix}
   1 & 0 & 2 \\
   0 & 1 & 0 \\
   0 & 0 & 1 
   \end{bmatrix}
   \]
   iii. \[
   \begin{bmatrix}
   1 & 0 & 0 \\
   2 & 1 & 0 \\
   0 & 0 & 1 
   \end{bmatrix}
   \]
   iv. \[
   \begin{bmatrix}
   1 & 0 & 0 \\
   0 & 1 & 0 \\
   2 & 0 & 1 
   \end{bmatrix}
   \]

c. What additional transformation N we would need to apply to AEFD to get the parallelogram A’E’F’D’ where A’=(1,2), E’=(3,6), F’=(3,7), and D’=(1,3).
   i. Rotation by 45
   ii. Scale by (1,2)
   iii. Translate by (1,2)

d. What is the final concatenated matrix in terms of M and N that will transform ABCD to A’E’F’D’?
   i. MN
   ii. NM
   iii. M⁻¹N
   iv. N⁻¹M
8) \[2+1+2+3+3=11\] Consider a camera with focal length of 15mm and a square sensor of \(2cm \times 2cm\) with a resolution of 5000x5000. The principal axis does not pass through the center of the image plane but is slightly shifted by 0.3mm in both horizontal and vertical direction. The camera is translated by 2mm in X, Y and Z direction each. Further, it is rotated by 45 degrees around the Z axis.

\[
\begin{align*}
\text{a. The pixel pitch (size in one direction) of the camera is} & \quad\\
\text{i. } & 4\mu m \\
\text{ii. } & 2.5\mu m \\
\text{iii. } & 2\mu m \\
\text{iv. } & 1.5\mu m
\end{align*}
\]

\[
\begin{align*}
\text{b. The pixel shape is a} & \quad\\
\text{i. Square} & \\
\text{ii. Rectangle} & \\
\text{iii. Rombus} & \\
\text{iv. Parallelepiped}
\end{align*}
\]

\[
\begin{align*}
\text{c. The focal length of the camera is pixels is given by} & \quad [\text{you will get full scores for this question}]\\
\text{i. } & 15000 \text{ pix} \\
\text{ii. } & 25000 \text{ pix} \\
\text{iii. } & 10000 \text{ pix}
\end{align*}
\]

\[
\begin{align*}
\text{d. The intrinsic parameter matrix of the camera is given by} & \quad [\text{you will get full scores for this question}]\\
\text{i. } & \begin{bmatrix} 15000 & 0 & 0; 0 & 15000 & 0; 300, 300, 1 \end{bmatrix} \\
\text{ii. } & \begin{bmatrix} 15000 & 0 & 300; 0 & 15000 & 300; 0, 0, 1 \end{bmatrix} \\
\text{iii. } & \begin{bmatrix} 25000 & 500 & 0; 0 & 25000 & 500; 500, 500, 1 \end{bmatrix} \\
\text{iv. } & \begin{bmatrix} 25000 & 0 & 500; 0 & 25000 & 500; 0, 0, 1 \end{bmatrix} \\
\text{v. } & \begin{bmatrix} 10000 & 300 & 0; 0 & 10000 & 0; 300, 300, 1 \end{bmatrix} \\
\text{vi. } & \begin{bmatrix} 10000 & 0 & 300; 0 & 10000 & 300; 0, 0, 1 \end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\text{e. The extrinsic parameter matrix is given by} & \quad\\
\text{i. } & \begin{bmatrix} \sqrt{2}/2, \ -\sqrt{2}/2, & 0; 0, \sqrt{2}/2, \ 0; 0, 0, 1 \end{bmatrix} \\
\text{ii. } & \begin{bmatrix} \sqrt{2}/2, \ \sqrt{2}/2, & 0; \ -\sqrt{2}/2, \ 0; 0, 0, 1 \end{bmatrix} \\
\text{iii. } & \begin{bmatrix} \sqrt{2}/2, \ -\sqrt{2}/2, & 0; \ \sqrt{2}/2, \ 0; 0, 0, 1 \end{bmatrix} \\
\text{iv. } & \begin{bmatrix} \sqrt{2}/2, \ -\sqrt{2}/2, & 0; \ \sqrt{2}/2, \ 0; 0, 0, 1 \end{bmatrix}
\end{align*}
\]

9) \[2+2+2+2=8\] Consider two cameras \(C_1\) and \(C_2\) whose image planes are parallel to each other and perpendicular to X-axis. The up-vector is the Z-axis. The center of projection of both cameras lie on the Y axis and separated by a distance by a distance \(t\).

\[
\begin{align*}
\text{a. The epipoles of } C_1 \text{ and } C_2 & \quad\\
\text{i. are given by } & [1, 0, 1] \text{ and } [0, 1, 1] \\
\text{ii. are same and given by } & [0,1,0] \\
\text{iii. are same and given by } & [1,0,0] \\
\text{iv. are given by } & [1, 0, 0] \text{ and } [0, 1, 0]
\end{align*}
\]

\[
\begin{align*}
\text{b. The epipolar lines in both the cameras will be} & \quad\\
\text{i. Parallel to Y axis}
\end{align*}
\]
ii. Parallel to X axis
iii. Converging to one point

c. The correspondences across two cameras will have the
   i. Same y coordinate
   ii. Same x coordinate
   iii. Different x and y coordinates

d. If we rotate the image planes by 90 degrees to make them perpendicular to
   the Y-axis, the epipolar lines will be
   i. Parallel to Y axis
   ii. Parallel to X axis
   iii. Converging to one point

10) [3+2=5] Consider a stereo setup with two cameras C1 and C2. Let the fundamental
    matrix be F = [1, 3, 1; 1 2 0; 0 -2 1]. (Notice that there is a typo in P10 of the
    epipolar written notes. For the epipolar line, the slope and offset are \(-f_1/f_2\)
    and \(-f_3/f_2\) respectively. You can verify it by applying \(l' = Fp\) and you will
    get most of the credits if you did this question wrong)

   a. Consider the point (2, 1) in C1. The line in C2 on which its correspondence
      lies is given by
      i. \(6y+4x-1 = 0\)
      ii. \(y+6x+4 = 0\)
      iii. \(6x+4y-1=0\)
      iv. \(6x+y+4 =0\)

   b. Which of the following points corresponds to (2,1) in C2?
      i. (1/2, -1/2)
      ii. (-1/2, 1/2)
      iii. (-2, 1/2)
      iv. (2, 1/2)

11) [1+2=3] Consider a double-torus manifold constructed of triangles. Its genus is 2.

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

   b. V (number of vertices) and F (number of faces) in this manifold is related by the
      following (Notice the relation: \(2E = 3F\))
      i. \(V = (F+4)/2\)
      ii. \(V = (F-4)/2\)
      iii. \(V = 2F-2\)
      iv. \(V = 2F+2\)
CHROMATICITY CHART FOR USE IN QUESTION 7