# Midterm Examination
# CS 534: Computational Photography

November 3, 2015

**NAME: ________________________________________**

| Problem | Score | Max Score |
|---|---|---|
| 1 | ____________ | 8 |
| 2 | ____________ | 8 |
| 3 | ____________ | 9 |
| 4 | ____________ | 4 |
| 5 | ____________ | 3 |
| 6 | ____________ | 4 |
| 7 | ____________ | 6 |
| 8 | ____________ | 13 |
| 9 | ____________ | 7 |
| 10 | ____________ | 4 |
| 11 | ____________ | 7 |
| 12 | ____________ | 10 |
| 13 | ____________ | 9 |
| 14 | ____________ | 8 |
| Total | ____________ | 100 |

1. [8] What are *four* (4) ways that you can control a camera's **exposure** (i.e., intensity or brightness value) in a photograph?

2. [8] Fill in each of the following blanks with one of "*smaller*," "*larger*," or "*same*."

   (a) [2] The smaller the f-number of a lens, the _______________ the **depth of field**.

   (b) [2] The shorter the focal length of a lens, the ________________ the depth of field.

   (c) [2] The closer the distance to the object in focus, the ______________ the depth of field.

   (d) [2] The faster the shutter speed, the ________________ the depth of field.

3. [9] Say I have a **camera** with lens focal length of 40mm, aperture f-number f/5.6, shutter speed 1/500 second, and ISO value 200.

   (a) [3] What is the diameter of the lens (in mm)?

   (b) [3] What shutter speed should I use to obtain the *same exposure* in a second photo using f/11 instead of f/5.6?

   (c) [3] What shutter speed should I use to obtain the *same exposure* in a second photo using ISO 400 instead of 200?

4. [4]  Given a **pinhole camera** with focal length 60, what are the **image coordinates** of the 3D scene point at coordinates (100, 200, 400)?

5. [3]  Does the **thin lens formula** apply to a pinhole camera for determining which scene points are in focus and which are not?  Briefly explain why or why not.

6. [4]  If I double the focal length of a camera lens and also move twice as far away from an object I focus on in a scene, what are *two* (2) things that will be different in the two images?

7. [6]  What property of the coefficients of a discrete approximation of a **Gaussian filter** ensures that

   (a) [3]  regions of uniform intensity are unchanged by smoothing using this filter?

   (b) [3]  the amount of smoothing does *not* depend on orientation of objects in the image?

8. [13] **Laplacian**

(a) [3] Define a 3 x 3 linear filter that can be used as an approximation of the **Laplacian** of an image $f(x, y)$, i.e., $\nabla^2 f = ( \partial^2 f / \partial x^2 ) + (\partial^2 f / \partial y^2 )$

(b) [3] How can this filter be used to detect **edges** in an image? That is, specify how to create a binary edge image where a pixel's value is 1 if it is at an edge, and 0 otherwise.

(c) [3] How can this filter be used to "sharpen" an image by **unsharp masking**?

(d) [4] Describe the main steps to compute a **2-level Laplacian pyramid** from an input image. Use a figure to aid your explanation, if desired.

9. [7] Say you want to **warp** an image, *I*, into a new one, *J*, by rotating *I* 45° about the origin of the image. This transformation can be described by the mapping from *I*'s (*u*, *v*) coordinates to *J*'s (*x*, *y*) coordinates as: $x = u\cos\theta + v\sin\theta$ and $y = -u\,sin\,\theta + v\cos\theta$

   (a) [4] If pixels in image *I* are all 0s except five 1s at coordinates (0, 0), (1, 1), (2, 2), (3, 3), and (4, 4) (i.e., a diagonal line of five pixels), what is the resulting image *J* after 45° rotation of just the five "1" pixels in *I* using the above transformation and using 0-order (nearest neighbor) interpolation? Use *cos* 45° = *sin* 45° = 0.7.

   (b) [3] What problem(s) does this example demonstrate?

10. [4] Use **bilinear interpolation** to compute the intensity value at point (10.2, 4.5) assuming the four nearest neighbor pixels have the following intensity values: (10, 4) has value 22, (11, 4) has value 42, (10, 5) has value 40, and (11, 5) has value 25.

11. [7] Compute

(a) [4] the **gradient** at the central pixel of the image:

| | | |
|---|---|---|
| 1 | 3 | 10 |
| 2 | 4 | 11 |
| 3 | 5 | 12 |

using the two first derivative (Sobel) filters in the *x* and *y* directions, respectively:

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

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

(b) [3] the **gradient magnitude** at this same pixel.

12. [10] Say you've detected *n* point features in image 1 and *m* feature points in image 2 and you'd like to determine the **2D translation** of image 1 so that it aligns best with image 2.

(a) [3] What is the form of the 3 x 3 homography matrix, **H**, for this special case of 2D translation? Give your answer as a 3 x 3 matrix with letters in positions for unknowns and numbers where a known constant is used.

(b) [3] What is the minimum number of corresponding points between the two images that are needed to estimate **H** in this case of a 2D translation?

(c) [4] Give two (2) benefits from incorporating the **RANSAC** algorithm as part of the computation of **H**.

13. [9] **Texture Synthesis**

(a) [6] The **Image Quilting** algorithm for texture synthesis iteratively selects and adds texture blocks to a partially-defined output texture image.

(i) [3] How is a new block selected to add at each iteration?

(ii) [3] How are seams between adjacent blocks "hidden"?

(b) [3] What additional property/term does the **Criminisi best-first filling algorithm** include to improve on the Image Quilting algorithm? Describe qualitatively; no equation(s) required.

14. [8] **SIFT Descriptor**

(a) [3] How is the SIFT descriptor made 2D orientation invariant?

(b) [3] Describe how the histogram(s) is (are) constructed for use in the descriptor.

(c) [2] What are the features contained in the descriptor’s feature vector?