Midterm: March 24th 2021

CSE 527 Introduction to Computer Vision, Spring 2021

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Submission of your midterm: When you finish all questions, please rename your midterm as follows*:*

FirstName_LastName_SBUID_midterm.pdf

(**NOTE:** you may first need to save your midterm as PDF). Or, in case your submission is in photos or words, please zip them and name the package as

FirstName_LastName_SBUID_midterm.zip*.*

After this, please upload your midterm to Blackboard (only PDF or ZIP file will be accepted). The submission link will be available 10 minutes prior to the midterm. Good luck!

Name:

ID:

Name on your left:

Name on your right:

There are 100 points in the exam. **You will be graded out of 100**.

Use your time wisely. Most questions require brief answers.

1	
2	
3	
4	
5	
6	
7	
Total	

1. (10=2*5 points) **Planar Transformations.** How many degrees of freedom do the following 2D image transformations have?

(a) Translation

(b) Euclidean

(c) Similarity

(d) Affine

(e) Perspective

2. (17 points) **Planar Transformations.** The planar facade of a building is captured in an image taken by a camera. Assume this plane corresponds to the world coordinate frame's **X**=0 plane, and scene point (**Y, Z**) on the building facade projects to image pixel coordinates (**u, v**).

(a) (6 points) What is the planar projective transformation that describes the relationship between (**Y, Z**) and (**u, v**)? Give your answer using homogeneous coordinates.

(b) (2 points) How many degrees of freedom does this transformation have?

(c) (2 points) How many point correspondences are required to determine this transformation?

(d) (3 points) Would having more correspondences than your answer to (c) be helpful in any way? If no, briefly explain why not. If yes, explain how they could be used.

(e) (2 points) Give one invariant of a planar projective transformation.

(f) (2 points) Give one invariant of a planar affine transformation that is not an invariant for a planar projective transformation.

3. (15 points) **Edge and Corner Detection.**
(a) (5 points) Show how an approximation to the first derivative of an image can be obtained by convolving the image with the kernel [1 -1] where the image is defined as [56 64 79 98 115 126 132 133]. Ignore computing a value for the border pixels (in other words, your result will be 7 values). In addition to showing the result of the convolution, indicate where edges would be detected and why.

(b) (5 points) What property do the weights of following kernels need to satisfy in order to obtain an appropriate output value for regions of constant intensity if
i. The kernel is approximating a first derivative.

ii. The kernel is approximating a second derivative.

iii. The kernel is approximating a Gaussian.

(c) (5 points) When would detecting corners be more appropriate than detecting edges as an initial step in an application using computer vision?

4. (12 pts) **Basic Filtering**. Suppose that you have an image of *m* rows and *n* columns.

(a) (3 points) How many multiplications will you perform if you convolve it (in the most efficient way that you know) with a 5 x 5 Gaussian filter?

(b) (3 points) How many multiplications will you perform if you convolve it with a 5 x 5 mean filter? What is the form of that filter? (Assuming not using Sliding Window Algorithm)

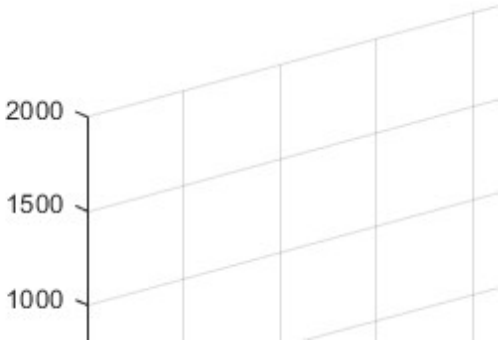
(c) (3 points) The filter kernel $1/A$ [1 4 6 4 1] is to be used for approximating Gaussian smoothing. What value should A be?

(d) (3 points) Can repeated convolutions of an image with the kernel [0.5 0.5] be used to obtain the same result obtained using the kernel in (c)? If yes, write down how many convolutions are needed and explain how to get the result? If no, explain why not.

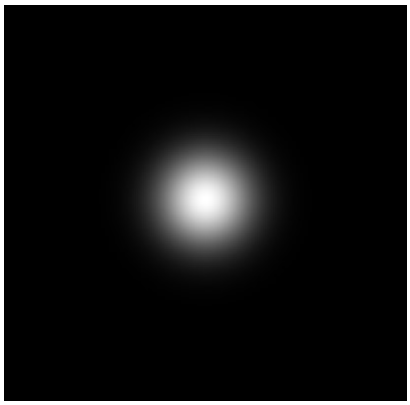
5. (11 points) **Fourier Filtering**.

(a) (8=4*2 points) The four images below are Fourier Transforms of some filters. Choose below the images which filters you think they are and why. (Assuming horizontal is X-axis and vertical is Y-axis)

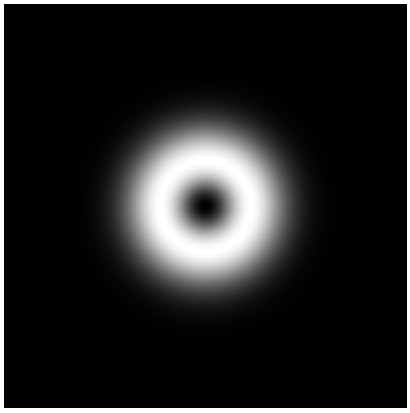
Candidate filters include: (1) Gaussian, (2) Box, (3) Derivative of Gaussian along X, (4) Derivative of Gaussian along Y, (5) Laplacian of Gaussian.



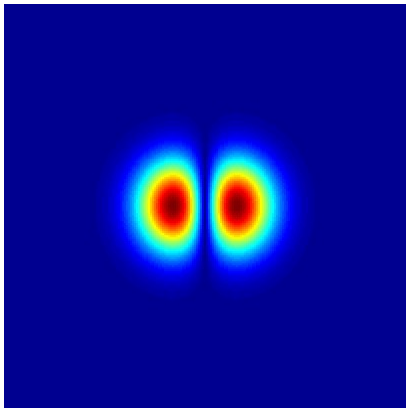
(i)



(ii)



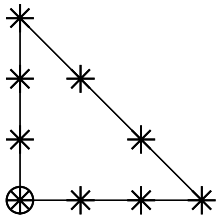
(iii)



(iv)

(b) (3 points) Which of these filters might cause aliasing?

6. (15 points) **Generalized Hough Transform.** Suppose we are given a binary image and want to detect upright right triangles with side length 4 pixels in the orientation shown below: (a right angle is an angle of exactly 90°)



(a) (4 points) How many dimensions are there in the Hough parameter space for this problem? What are they?

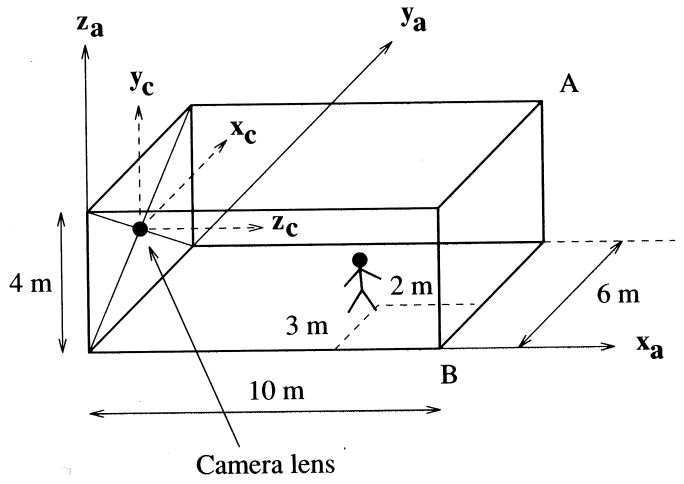
(b) (7 points) Assuming the reference point for the triangle is the bottom-left corner (shown with a circle in the template above), a ”1” in the input image at coordinates (10, 13) will ”vote for” what points in the parameter space? Give your answer in terms of a figure showing the coordinates of the points.

(c) (4 points) How would your solution be generalized if we want to detect triangles in a range of sizes, e.g., we want to detect upright right triangles with side lengths 3,4, ..., 20?

7. (20 pts) **Image Formation.** A surveillance camera is embedded in one of the walls of a room as shown in the figure. The optical axis of the camera is perpendicular to the wall, and the lens center is in the plane of the wall. The focal length of the lens is 0.05 meters. The **x-z** plane of the camera is parallel to the **x-y** plane of the world coordinate system. The image plane is behind the wall.

(a) (3 points) Find the **image plane coordinates** of the room corner A.

(b) (4 points) A person of 2 meters tall is standing at distance of 3m by 2m from the corner B, as shown in the figure. Find the **image plane coordinates** of the head.



(c) (6 points) If the image sensor has dimension 24mm vertical by 32mm horizontal and it has 480 rows and 640 columns with the principal point at position (300,250) what are the **pixel coordinates** of the answers for (a) and (b)?

(d) (3 points) Which coordinate transformations do you need to perform in order to solve this problem?

(e) (4 points) If the person is moving at a speed of 0.2m/sec parallel to the image plane at her current depth, what is the minimum shutter speed necessary to avoid motion blur?