Practice Midterm 2

CMSC 426

The midterm will cover material up to and including stereo geometry (but not stereo matching). The midterm will be cumulative, covering everything up to this point, including material covered in the first midterm. However, there may be an extra emphasis on material not covered in the midterm. The previous practice midterm can serve as a review for that material; here I'll only discuss new topics. But you should think of both practice midterms as providing preparation for the second midterm.

Here are some topics it will be helpful to master for the midterm:

- Interactive Segmentation with Min Cut
  - How you can represent image as a graph.
  - Understand how to create edge weights.
- Background subtraction and Kernel Density Estimation (KDE)
  - The main point here is to understand how to use samples to create a probability distribution. This is also relevant to image segmentation using mincut. It includes:
    - How to form a histogram, and use this to estimate probabilities.
    - How smoothing this with a Gaussian (or equivalently, placing a Gaussian at each sample point) creates a smoother distribution (this is KDE).
- Texture
  - Understand what is meant by a Markov process.
  - Understand how SSD can be used to find locations in a sample that match a template.
  - Understand the overall structure of the Efros and Leung synthesis algorithm.
- Mosaicing
  - Blob detection. What does the filter for a blob detector look like? How is non-maximum suppression done in blob detection (the filter output must be larger than at neighboring locations and scales).
  - SIFT descriptors. How are they constructed?
  - RANSAC. RANSAC for detecting lines, as an example. RANSAC as used in the mosaicking project.
- Geometry
  - 2D Transformations. How to represent rotation, translation, and scaling using matrices. How to represent affine transformations. How to solve for a similarity or affine transformation using a matrix inverse.
  - Perspective Projection. How 3D points turn into 2D image points. Vanishing points and the horizon.
  - The Epipolar Constraint. Depth from 2 images. Rectification.

Practice: The goal of this is to give you samples of the sorts of questions and topics that will come up in the midterm. Some of these questions may be a bit more involved or more vague than those that I would ask in a real midterm. It is very likely that there will be at least one question on the midterm that is quite similar to a practice question.

1. Kernel Density Estimation: Suppose that four pixels in an image are known to be part of the background. They have intensities of 3, 7, 3 and 12.
    a. Build a histogram of these intensities. Using the histogram, what would you estimate is the probability that a new background pixel will have an intensity of 5? What about an intensity of 3?
    b. Use KDE, with a Gaussian that has a sigma of 1, to estimate the probability that a new background pixel will have an intensity of 5.
2. Markov Models: Explain how you could use a sample of text, such as "The rain in Spain falls mainly in the plane" to generate a new text string, using different order Markov models, following the example of Shannon.
3. RANSAC: Suppose an image contains n points. You wish to find a square that matches as many points as possible. We say that a square matches a point if the point is within 3 pixels of one of the sides of the square. Explain as precisely as you can how you would do this using RANSAC.
4. SIFT: Consider the 5x5 image below. Find the image gradient of the 3x3 inner square (the points in bold face). Construct a histogram of the direction of the image gradients.

1	1	1	1	0
2	**2**	**2**	**1**	0
3	**3**	**2**	**1**	0
4	**3**	**2**	**1**	0
4	3	2	1	0

5. 2D Transformations:
    a. Give a matrix that rotates objects by 45 degrees counterclockwise and scales them by a factor of 2.
    b. Suppose S is a matrix that performs a similarity transformation. Applying S to the point (1,1) takes it to the point (4,2). Applying S to the point (2,2) takes it to the point (5,5). What is S?
    c. Construct an affine transformation that will stretch objects by a factor of 2 in the diagonal direction. That is, it will take the point (1,1) to (2,2), for example.
6. Perspective Projection
    a. Suppose we have a camera with a focal point at (0,0,0) and an image plane at z=1. If there is a point in the world at (16,8,4), where will it appear in the image?
    b. Suppose we have a camera with a focal point at (0,0,0) and an image plane at z=2. If there is a point in the world at (16,8,4), where will it appear in the image?

   c. Suppose we have a camera with a focal point at (0,0,0) and an image plane at x=1. If there is a point in the world at (16,8,4), where will it appear in the image?
   d. Suppose we have a camera with a focal point at (3,7,2) and an image plane at x+z = 6. If there is a point in the world at (16,8,4), where will it appear in the image?
7. Vanishing points: Suppose we have a camera with a focal point at (0,0,0) and an image plane of z = 1.
   a. There is a line whose location is described by the equations, y = -4, x+2z = 3. What is its vanishing point?
   b. There is a line whose location is described by the equation y + z = -1, x + 2z = 3. What is its vanishing point?
8. Suppose we take two pictures. In the first, the camera has a focal point at (0,0,0) with an image plane of z=1. In the second, the focal point is at (0,1,1) and the image plane is z = 2. Give an example of conjugate epipolar lines in the two images. That is, give a pair of lines, one in each image, so that every point in line 1 matches some point in line 2.