Practice Final

1. Let X denote a continuous random variable representing the pixel brightness in an image and let $X \sim p_X(x)$. (The notation means X is distributed with probability density function $p_X(x)$).
   (a) Write down the transformation $T(.)$ for which random variable $Y = T(X)$ has a uniform distribution on $[0, 1]$.
   (b) Prove that $Y = T(X)$ has a uniform distribution.
   (c) Write down the version of $T(.)$ used in the discrete case.
   (d) What is the name of this image processing operation?
   (e) Why is it used in practice?
2. Answer the following questions in words using one or two sentences. Equations can be used only if it will help your explanation.
   (a) What is an eigenface?
   (b) How are eigenfaces used for recognition?
   (c) What mathematical technique is used to find the eigenfaces?
3. Hough Transform
   (a) Explain how the Hough Transform was used in class.
   (b) With a line parameterized by $y = ax + b$, sketch the image defining x, y, a, b and the Hough feature space.
   (c) With a line parameterized by $\rho = x\cos(\theta) + y\sin(\theta)$, sketch the image defining x, y, ρ, θ and the Hough feature space.
   (d) Which is the preferred parameterization of a line and why?
   (e) Explain the Canny edge detector and explain why it is used for Hough Transform for line detection.
4. Draw the system level diagram and explain the inputs and outputs for
   (a) image processing
   (b) pattern recognition
   (c) computer graphics
   (d) computer vision
5. Sketch the following 2D transformations of a square.
   (a) In general, what is the shape after rigid body (rotation and translation) transformation?
   (b) In general, what is the shape after an affine transformation?
   (c) Give the rotation matrix requires to rotate a square by θ degrees.
6. Image Representation
   (a) Which is larger, an 8-bit color image with R, G, and B channels or a 16-bit grayscale image?

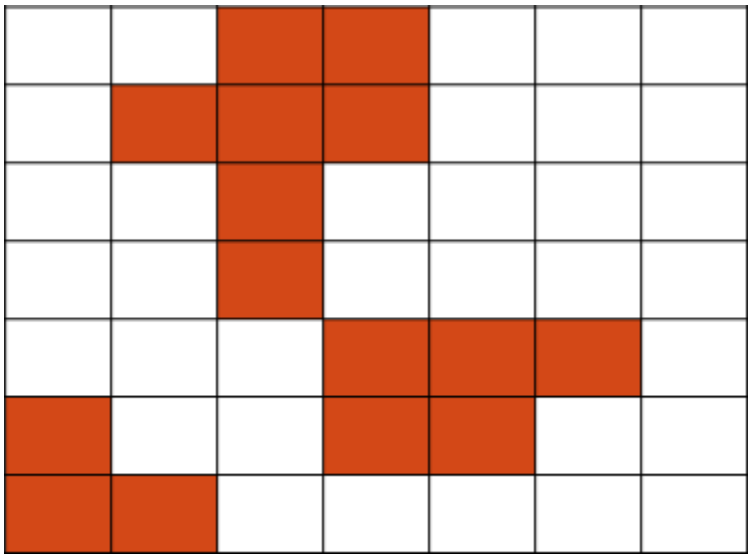

Figure 1

(b) Would you rather use the RBG image or the grayscale to represent a truly grayscale scene? Why?

7. Perform connected component labeling of of the binary image in Fig. 1. Red indicates an on pixel and white is off.
   (a) Use 4-connected neighbors.
   (b) Use 8-connected neighbors.

8. Linear Filtering
   (a) Give the filtering equation.
   (b) How can filtering be used to remove noise? What assumption is made when doing this?
   (c) What type of filter works best for removing Gaussian noise? How is the 3×3 filter implemented?
   (d) What type of filter works best for removing salt and pepper noise? How is the 3×3 filter implemented?
   (e) Why do we care about separable filters?
   (f) Why are derivative filters used?
   (g) Explain the difference between a first and second derivative filter. Which is better for lines and which for edges?
   (h) How can temporal noise be removed in video?

9. Explain the effect of the dilation and erosion operation on a binary image?

10. Cross Correlation
    (a) Explain how cross correlation can be used as an object detector.
    (b) Why is normalized cross-correlation usually used instead of just cross correlation?

11. Laplacian Pyramid

(a) Explain the procedure to produce a Laplacian pyramid.

(b) Give examples of why the pyramid is useful.

12. The following problem relates to basic feature detection.

    (a) Describe the basic algorithm for detecting good features or keypoints. Give the definition of the autocorrelation matrix.

    (b) What are the best features to match and why?

    (c) Explain the aperture problem for matching. You may want to draw a picture.

    (d) What is the most popular keypoint descriptor (we discussed this in class)? Briefly explain how it describes the a keypoint.

13. What is RANSAC and explain how it is used in image alignment.

14. The following problem deals with homography

    (a) Explain what is an induced homography.

    (b) How many unknowns are in the 3×3 homography matrix?

    (c) Derive the system of equations to estimate the homography starting with the homogenous relationship $x_2 \sim Hx_1$. Put your equations into matrix form.

    (d) How many corresponding points are required to estimate the homography?

15. Given a pair of rectified stereo images, describe how to compute the disparity. Explain how the match window neighborhood size affects the results.

16. This problem pertains to the measurement of optical flow.

    (a) What are the assumptions used to derive optical flow?

    (b) What is the aperture problem? Describe and illustrate with a diagram.

    (c) Draw the three basic types of image neighborhoods and characterize them in terms of their windowed second moment matrices (Harris matrix).

17. Background Subtraction

    (a) What is background subtraction used for?

    (b) Given a background $B(x, y, t)$ and a new video frame $I(x, y, t)$ at time t, explain how to adaptively update the background without using any more memory.

    (c) How did Stauffer and Grimson improve background estimation? What challenges in background modeling did they address?

18. Adaboost Classification

    (a) Why is the Adaboost classifier so successful for face detection?

    (b) Explain why Viola and Jones used a cascade classifier.

19. What does clustering refer to?