CSE166 – Image Processing – Final

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`http://www-cse.ucsd.edu/classes/fa05/cse166`

11:30am-2:30pm Tue. Dec. 6, 2005.

On this exam you are allowed to use a calculator and two 8.5" by 11" sheets of notes. The total number of points possible is 55. Good luck!

Part I: Fill in the Blank (1 pt. each, 20 pts. total).

1. Hough's original parameterization blew up in the case of _____ lines.
2. The Fourier transform of a sinc function is a(n) _____ .
3. The normalization constant for the N-tap binomial kernel $h(x) = a \begin{pmatrix} N-1 \\ x \end{pmatrix}$ for $x = 0, \ldots, N-1$ is given by $a =$_____ .
4. The axes of greatest and least inertia for a shape are given by the _____ of the scatter matrix.
5. The 8-point DFT of $f(x) = \sin(\pi x/2)$ has exactly _____ nonzero value(s).
6. The 16-point FFT decomposes the problem into _____ 2-point DFTs.
7. A 2D affine transform has _____ degrees of freedom.
8. _____ component(s) of the optical flow can be measured in an aperture containing a straight edge.
9. _____ is an iterative clustering algorithm that alternates between cluster assignment and centroid re-estimation.
10. The normal form of the line $ax+by+c = 0$ is given by $\rho =$_____ and $\theta =$_____ .
11. _____ relates the posterior probability to the class conditional density.
12. The "Mexican Hat" function is another name for the _____ kernel.
13. The minimum distance classification boundary between clusters belonging to two different classes is the _____ of the line joining the two clusters.
14. True or False: convolution with `[1 -1]` improves the compressibility of piecewise constant images. _____
15. The morphological operation that removes pixels on object boundaries is called _____ .
16. Canny proposed the use of _____ -thresholding to prevent streaking in the detected edges.
17. In the HSI color space, the length of the vector extending from the axis of the cone represents the _____ and the angle represents the _____ .
18. If you fixate on an image of an American flag for 60 seconds and subsequently view a blank white screen, you will see the following three colors in place of red, white and blue: _____ , respectively.

Part II: Written problems.

1. (3 pts.) Consider the system $g(x) = \sum_{k=x-4}^{x+1} f(k)$. Determine whether this system is LSI, and show your work. If it is LSI, what is the impulse response $h(x)$? If it is not LSI, provide an intuitive explanation of why it isn't.

2. (18 pts) This problem makes use of the following image sequence. Assume that the images are equal to zero outside their boundaries. *Hint*: the numbers have been chosen in this problem to be integer at each step.

$$I(x,y,t_o) = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 4 & 2 & 0 \\ 0 & 4 & 8 & 4 & 0 \\ 0 & 2 & 4 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad I(x,y,t_o+1) = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 2 & 4 & 2 & 0 & 0 \\ 4 & 8 & 4 & 0 & 0 \\ 2 & 4 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

   (a) If $I(x,y,t_o)$ is regarded as a filter (up to a constant), what type of kernel is it?

   (b) Compute ∇I at time t_o using the centered first difference approximation $\partial/\partial x \approx [0.5, 0, -0.5]$ and $\partial/\partial y \approx [0.5, 0, -0.5]'$.

   (c) Compute $\partial I/\partial t$ with the approximation $\partial/\partial t \approx [1, -1]$.

   (d) Solve for the windowed image second moment matrix of $I(x,y,t_o)$. What is its rank? Is this a 'good' interest point?

   (e) Specify A and $\mathbf{b}$ in the matrix-vector form of the optical flow equation $A\mathbf{u} + \mathbf{b} = \mathbf{0}$, where $\mathbf{u} = [u, v]^\top$ is the optical flow vector at the center pixel.

   (f) Solve for $\mathbf{u}$.

3. (14 pts) Recall that the Gabor filter has form of a Gaussian times a complex exponential:

$$h(x) = e^{-x^2/2\sigma^2} e^{-j2\pi u_o x}$$

   Assume in this problem that x is continuous.

   (a) Specify $h_{re}(x)$ and $h_{im}(x)$ such that $h(x) = h_{re}(x) + jh_{im}(x)$.

   (b) Sketch an example of $h(x)$. Label your drawing to show what σ and u_o control.

   (c) What type of filter is $h(x)$: lowpass, bandpass, or highpass?

   (d) Sketch the Fourier transforms of the following functions (up to a constant scale factor), indicating σ and u_o in each sketch:

   - $e^{-x^2/2\sigma^2}$
   - $e^{-j2\pi u_o x}$
   - $h(x)$