

**CS 111: Digital Image Processing (Spring 2009)**

**Written Assignment 1**

**Total Points: 70**

Due: 30 April, 2009

- 1) Consider a signal blurring system. Every sample of the output signal is generated by averaging the values of the sample itself, and its left and right neighbors in the input signal. (Assume that the samples at the boundary of the input signal are zero).
  - a. Is this system linear? Prove your answer. [4]
  - b. What is the impulse response of the system? [3]
  - c. How would this impulse response change if a larger neighborhood of five samples is considered? [3]
  
- 2) Calculate the convolution of the following signals (your answer will be in the form of an equation): [4x3 = 12]
  - a.  $h[n] = \delta[n-1] + \delta[n+1]$ ,  $x[n] = \delta[n-a] + \delta[n+b]$
  - b.  $h[n] = \delta[n+2]$ ,  $x[n] = \exp(n)$
  - c.  $h[n] = \exp(-n)$ ,  $x[n] = \delta[n-2]$
  - d.  $h[n] = \delta[n] - \delta[n-1]$ ,  $x[n] = \exp(-n)$
  
- 3) In gradient-based edge detection algorithms, a gradient is approximated by a difference. Three such difference operations are shown below. This difference can be viewed as a convolution of  $f(x, y)$  with some impulse response of a filter  $h(x, y)$ . Determine  $h(x, y)$  for each of the following difference operators.
  - a.  $f(x, y) - f(x-1, y)$  [2]
  - b.  $f(x+1, y) - f(x, y)$  [2]
  - c.  $f(x+1, y+1) - f(x-1, y+1) + 2[f(x+1, y) - f(x-1, y)] + f(x+1, y-1) - f(x-1, y-1)$  [3]
  
- 4) Classify the following signals as zero-phase, linear-phase or non-linear phase [4x2 = 8]
  - a.  $x[n] = \delta[n-1] - \delta[n-4] + \delta[n-7]$
  - b.  $x[n] = \exp(-\text{abs}(n))$  (where "abs" is the absolute value function)
  - c.  $x[n] = \text{abs}(n)$
  - d.  $x[n] = n + \text{abs}(n)$
  
- 5) Assume a sequential method to generate the Gaussian pyramid where the pixels in the image are processed in a scan-line order (top to bottom, left to right). Is this system causal? Justify your answer. [3]
  
- 6) System A is an "all pass" system, i.e. its output is identical to its input. System B is a low-pass filter that passes all frequencies below the cutoff frequency without change, and blocks all frequencies above. Call the impulse response of system B,  $b[n]$ .
  - a. What is the impulse response of system A? [2]

- b. How would the impulse response of system B need to be changed to make the system have an inverted output (i.e., the same output, just changed in sign)? [2]
- c. If the two systems are arranged in parallel with added outputs, what is the impulse response of the combination? [3]
- d. If the two systems are arranged in parallel, with the output of system B subtracted from the output of system A, what is the impulse response of the combination? [3]
- e. What kind of filter is the system in (d)? [2]
- f. In this problem, system B has the ideal characteristic of passing certain frequencies "without change." How would the outputs of the systems described in (c) and (d) be affected if the low-pass filter delayed (i.e., shifted) the output signal by a small amount, relative to the input signal? [3]

7) You can blur an image using a filter B and find the horizontal gradient of an image using the filter G, where B and G are given as follows. You are also assured that both of these are linear methods.

B =

1/4	1/4
1/4	1/4

G =

-1	+1
-1	+1

- a. Prove that the method of finding the gradient is linear. (You have already proved the blurring is linear in Question 1). [4]  
**Hint:** *This has nothing to do with the filters. Think about the functions that the filters are achieving. You can give the proof in 1D.*
- b. You are asked to apply B to the image to generate a blurred image and then apply G to the result to find the gradient of the blurred image applying G. How would the output change if you apply G first and then B? [3]
- c. If you are asked to apply one single filter S, instead of two filters in succession, how would you find S? [4]
- d. If you are asked to design a single filter S that would achieve the effect of adding the blurred image and the gradient image created by applying B and G separately, how would you find S? [4]