EE 637 Midterm

March 31, Spring 2004

Name: Key

Instructions:

- Follow all instructions carefully!
- This is a 50 minute exam containing **four** problems.
- You may **only** use your brain and a pencil (or pen) to complete this exam. You **may not** use your book, notes or a calculator.

Good Luck.

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Problem 1.(34pt)

Let $X(m,n)$ be a 2-D random field (i.e. random process) where m indexes the column number and n indexes the row number. Assume that the samples of $X(m,n)$ are i.i.d. Gaussian random variables with mean 0 and variance 1,

Let $Y(m,n)$ be given by

$$Y(m,n) = X(m,n) + \sum_{(k,l)>0} h(k,l)Y(m-k,n-l)$$

were the ">" operation is based on the use of raster ordering (i.e. the non-symmetric half plane), and the coefficients $h(k,l)$ are chosen so the filter is stable.

a) Calculate the power spectral density $S_x(e^{j\mu}, e^{j\nu})$ for $X(m,n)$.

b) Calculate an expression for the frequency response $H(e^{j\mu}, e^{j\nu})$ of the system.

c) Calculate the power spectral density $S_y(e^{j\mu}, e^{j\nu})$ for $Y(m,n)$.

d) Calculate $E[Y(m,n)|Y(k,l)$ for $(k,l) < (m,n)]$.

a) $S_x(e^{j\mu}, e^{j\nu}) = 1$

b) $H(e^{j\mu}, e^{j\nu}) = \dfrac{1}{1 - \sum_{(k,l)>0} h(k,l)\, e^{-j\mu} e^{-j\nu}}$

c) $S_y(e^{j\mu}, e^{j\nu}) =$

$$\left| \frac{1}{1 - \sum_{(k,l)>0} h(k,l) e^{-j\mu} e^{-j\nu}} \right|^2$$

d) $E\left[Y(m,n) \mid Y(k,l)\ (k,l) < (m,n) \right]$

$$= \sum_{(k,l)>0} h(k,l)\, Y(m-k, n-l)$$

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Problem 2.(20pt)

Consider the following main program and subroutine.

Main Routine:

$ClassLabel = 1$
Initialize $Y_r = 0$ for $r \in S$
For each $s \in S$ in raster order {
  if($Y_s = 0$) {
    ConnectedSet($s, Y, ClassLabel$)
    $ClassLabel \leftarrow ClassLabel + 1$
  }
}

Subroutine:

ConnectedSet($s_0, Y, ClassLabel$) {
  $B \leftarrow \{s_0\}$
  While B is not empty {
    $s \leftarrow$ any element of B
    $B \leftarrow B - \{s\}$
    $Y_s \leftarrow ClassLabel$
    $B \leftarrow B \bigcup \{r : r \in c(s) \text{ and } Y_r = 0\}$
  }
  return(Y)
}

Also consider the following binary image

0	1	0	0	1
1	0	0	1	1
0	1	1	0	0
0	1	1	0	0
0	1	0	0	1

a) Calculate the output when the binary image is process by the main routine using a 4-pt neighborhood. Wright your result in the table below.[1]

1	2	3	3	4
5	3	3	4	4
6	7	7	8	8
6	7	7	8	8
6	7	8	6	9

b) Calculate the output when the binary image is process by the main routine using an 8-pt neighborhood. Wright your result in the table below.[2]

1	2	1	1	2
2	1	1	2	2
1	2	2	1	1
1	2	2	1	1
1	2	1	1	3

[1]Pixels on the image edge should be consider to have only 3 neighbors, and pixels in image corners should be considered to have only 2 neighbors.

[2]Pixels on the image edge should be consider to have only 5 neighbors, and pixels in image corners should be considered to have only 3 neighbors.

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Problem 3.(12pt)

A color image is transformed to XYZ coordinates and stored as a color raster TIFF image using the C-subroutines provided in class. It is then read, transformed to sRGB, and displayed on a monitor with calibrated sRGB input. What defects would you expect to see in such an image? Be specific.

There will be contouring artifacts in dark regions due to the 8-bit quantization of the XYZ data stored in the TIFF format. In addition, some colors can fall outside of the sRGB gamut, and will be lost.

6pt - contouring in darkness
3pt - linear luminance data
3pt - 8bit quantization

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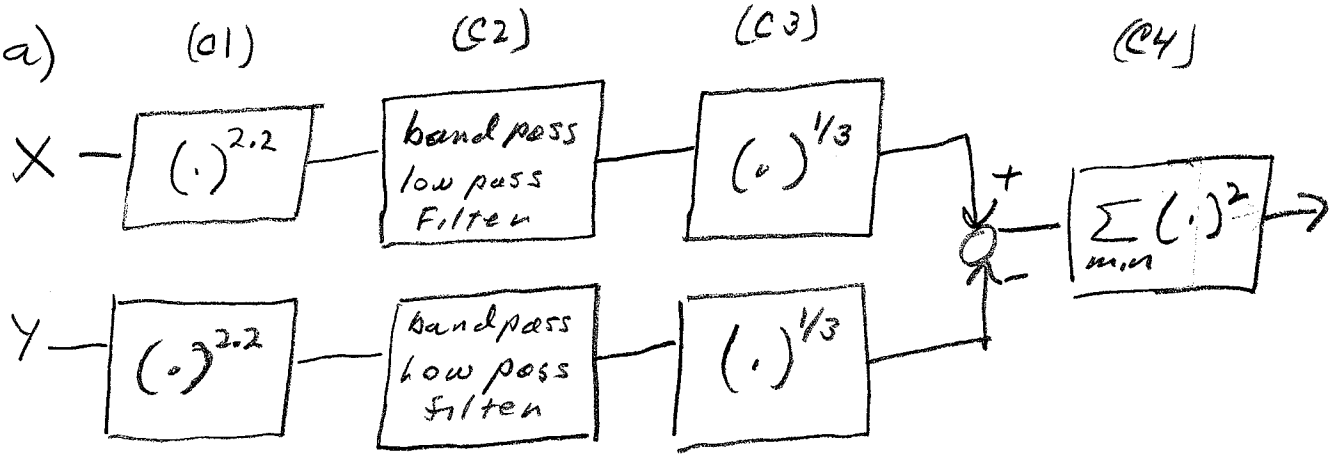
Problem 4.(34pt)

Specify a system based on a simple image fidelity model for achromatic images. The systems should:

- Have two inputs consisting of two γ-corrected images, with $\gamma = 2.2$.
- Account for the MTF of the human visual system.
- Account for perceptual sensitivity to contrast.
- Have a single scalar output.

a) Give a block diagram for this system, and specify each block's operation.
b) Explain why each major component is required. When appropriate, give examples of what would go wrong if a component was not used.
c) Give examples of an application where this system might be useful.

(2a)



(2b) (C1) This component converts to linear coordinates. Without this component the linear filter would cause tone shifts.

(C2) This component remove high spatial frequencies that are not visible.

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(C3) This component adjusts for the visual systems sensitivity to contrast. Without this component, dark regions will be under represented.

(C4) This component integrates together the squared error.

10 c) Image coding, halftoning
In both cases it is often necessary to determine the visual difference between an original and processed image.