EE 637 Midterm Exam #2

Session 35

April 5, Spring 2002

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Instructions:

- Follow all instructions carefully!
- This is a 50 minute exam containing **two** 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.(50pt)

Consider two images $g(x,y)$ and $f(x,y)$ where x and y are the horizontal and vertical co-ordinates in inches and both functions take on postive values, are proportional to energy, and are scaled to the range $[0,1]$ with 1 representing the maximum allowed luminance. Both images are viewed at a distance of d inches, and have a length and width of $2 * d$ inches. The intention is for the two images to look the same.

To assess the fidelity of the reproduction, the following three quality metrics are used

Metric A

$$\frac{1}{4d^2}$$

$$D_a(f,g) = \int_{[-d,d]\times[-d,d]} ||f(x,y) - g(x,y)||^2 dx\, dy$$

Metric B

$$\frac{1}{4d^2}$$

$$D_b(f,g) = \int_{[-d,d]\times[-d,d]} ||(f(x,y))^{1/3} - (g(x,y))^{1/3}||^2 dx\, dy$$

Metric C

$$\frac{1}{4d^2}$$

$$D_c(f,g) = \int_{[-d,d]\times[-d,d]} ||(h(x,y) * f(x,y))^{1/3} - (h(x,y) * g(x,y))^{1/3}||^2 dx\, dy$$

where $h(x,y)$ is the impulse response of the linear space invariant filter and $*$ denotes 2-D convolution.

a) Give an example of a two images $g(x,y)$ and $f(x,y)$ which differ (primarily) at a spatial frequency of 5 cycles per degree.

b) Give an example of a two images $g(x,y)$ and $f(x,y)$ for which $D_a(f,g) > 0.1$, but which can be made to look arbitrarily similar.

c) What is the advantage of Metric B?

d) Suggest a method for choosing the impulse response $h(x,y)$.

a) $\tilde{f}_0 = \frac{\pi}{180} d f_0$

$f_0 \leftarrow$ cycles/inch
$\tilde{f}_0 \leftarrow$ cycles/deg
$d \leftarrow$ inch

$f_0 = \frac{180}{\pi d} \tilde{f}_0$

$= \frac{180}{d\pi}$ 5 cycles/deg

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$f(x,y) = 0.5$

$g(x,y) = 0.5 + 0.5\cos\left(\frac{180}{\pi} d\, 5x\right)$

b) $f(x,y) = 0.5$

$g(x,y) = 0.5 + 0.5\cos\left(\frac{180}{\pi d} \tilde{f}_0 x\right)$

$D_a = 4d^2 \cdot \left(\frac{1}{2}\right)^2 \frac{1}{4}$

$= d^2$

But in the limit as $\tilde{f}_0 \to \infty$, $f(x,y)$ and $g(x,y)$ appear to be the same because the constrast sensitivity function of the human visual system falls off above approximately 10 cycles per degree

c) By applying the power $(1/3)$, this metric better models the sensitivity of the HVS and approximates Weber's Law better than a linear metric. The values $(f(x,y))^{1/3}$ are also

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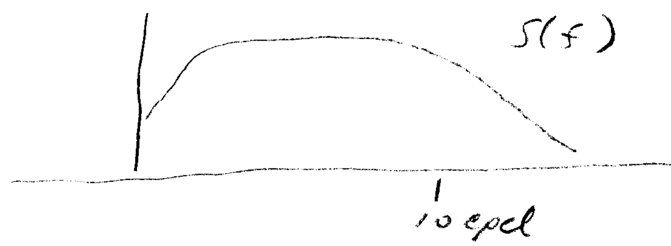
equal to L^* which is known to be approximately perceptually uniform.

d) The function $h(x,y)$ can be choosen as the inverse CSFT of the 2-D contrast sensitivity function. So let $S(f)$ be the contrast sensitivity function of the form



$$S_2(\tilde{x}, \tilde{y}) = S\left(\sqrt{x^2 + y^2}\right)$$

$\tilde{x} \leftarrow$ cpd

$\tilde{y} \leftarrow$ cpd

$$S_3(x, y) = S_2\left(\frac{\pi}{180} d x, \frac{\pi}{180} d y\right)$$

$$h(x,y) = CSFT^{-1}\left\{S_3(x,y)\right\}$$

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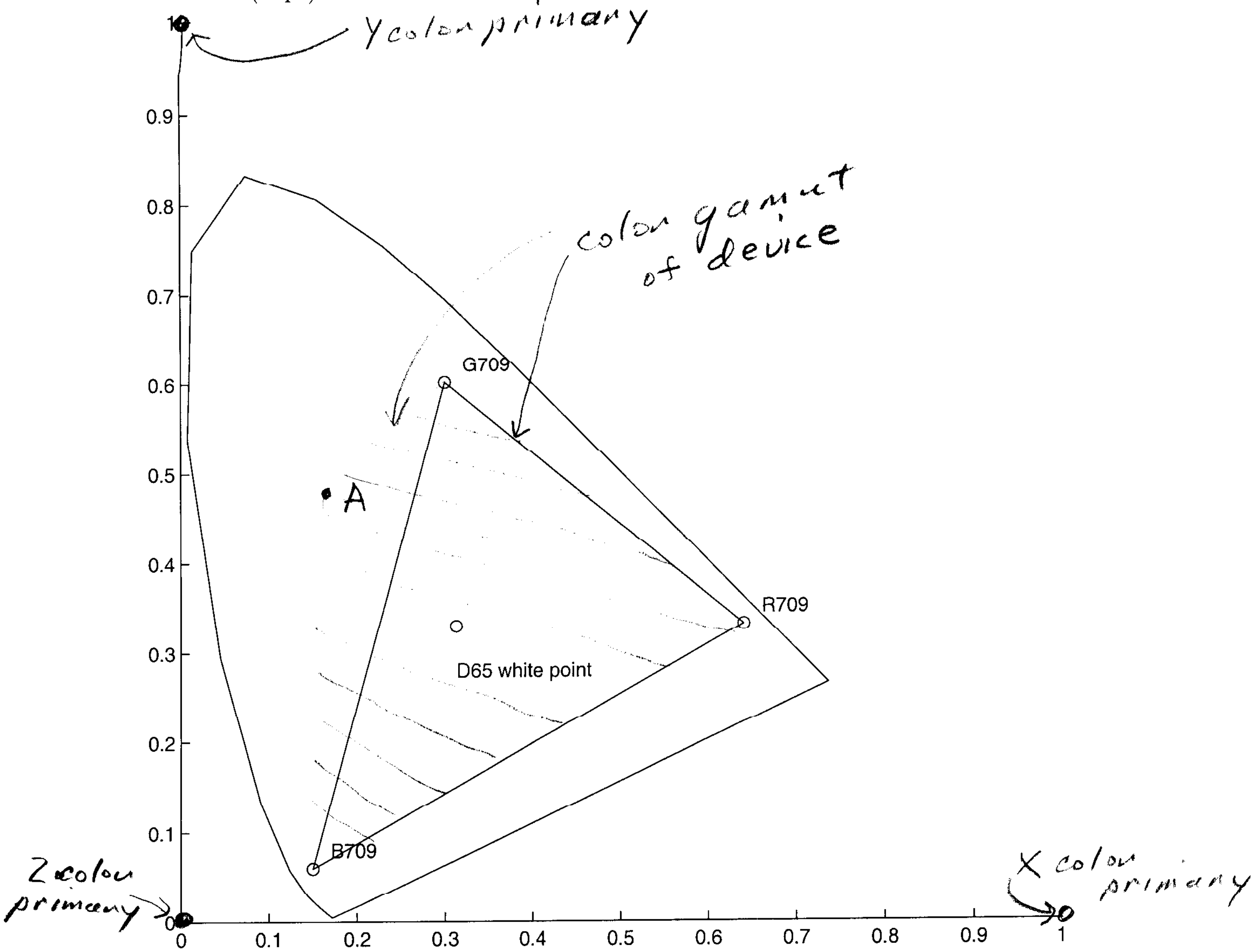
Problem 2.(50pt)



Consider an imaging rendering system with **4** primary colors corresponding to red (**R**), green (**G**), blue-green (**A**), and blue (**B**). The red, green, and blue primaries use standard 709 chromaticies, and the blue-green primary is given by

$$A = (0.7G + 0.3B) - 0.25R$$

a) Sketch and label the location of the blue-green primary on the chromaticity diagram.

b) Sketch and label the color gammut of the device.

c) Sketch and label the location of the XYZ color primaries on the chromaticity diagram.

d) Sketch and label the color gammut of the XYZ color primaries.

Consider a color formed by

$$[\mathbf{R}, \mathbf{G}, \mathbf{A}, \mathbf{B}] \begin{bmatrix} r \\ g \\ a \\ b \end{bmatrix}$$

e) Is the color specification for $[r, g, a, b]$ unique for all colors in the gammut of the device, not unique for all colors in the gammut of the device, or never unique? Be specific and justify your answer.

f) What is the potential advantage of using 4 primary colors rather than 3?

d) See diagram

b) See diagram

c) $\underbrace{[\vec{X}, \vec{Y}, \vec{Z}]}_{X,Y,Z \text{ color primaries}} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$

$\vec{X} \Rightarrow X=1, Y=0, Z=0 \Rightarrow x = \dfrac{X}{X+Y+Z} = \dfrac{1}{1+0+0} = 1$

$y = \dfrac{Y}{X+Y+Z} = \dfrac{0}{1+0+0} = 0$

$\vec{X} \Rightarrow (x, y) = (1, 0)$

$z = \dfrac{Z}{X+Y+Z} = 0$

Similarly

$\vec{Y} \Rightarrow (x, y) = (0, 1)$ $\quad \vec{Z} \Rightarrow (0, 0)$

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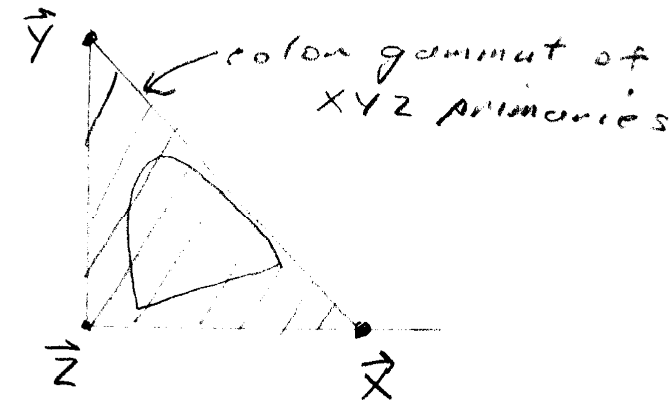
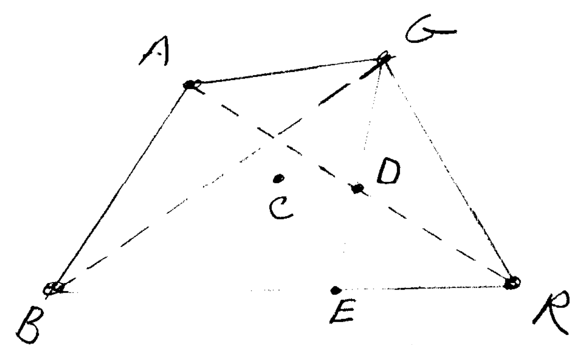
d)



e) Never unique

The color gammut forms a trapazoid of the form



Consider and color "C" in the gammut of the device. The color C falls in the triangle ARB or the triangle BGR. Therefore, the color C may be formed by a positive combinations of primaries ARB or primaries BGR. This arguement similarly holds for any color in the

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gammut of the device that does <u>not</u> fall on the line $\overline{AR}$ or the line $\overline{BG}$.

Consider the color D that falls on the line AR. D may be formed by a combination of AR or by a combination of GE. Since E may be formed by a combination of BR, this means that D may be formed by a combination of GBR. So the color specification is not unique.

A similar arguement holds for the intersection of lines BG and AR.

f) 4 color primaries can be used to increase the color gammut of the device.