Imagens Coloridas

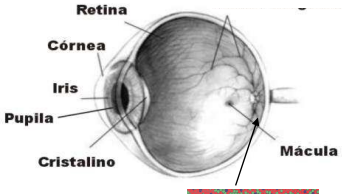
Como os computadores conseguem colorir as imagens?

Percepção de Cores

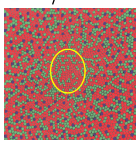
Radiações
Sinais luminosos

Sistema Visual

Sinais visuais



Fóvea ou
mancha amarela



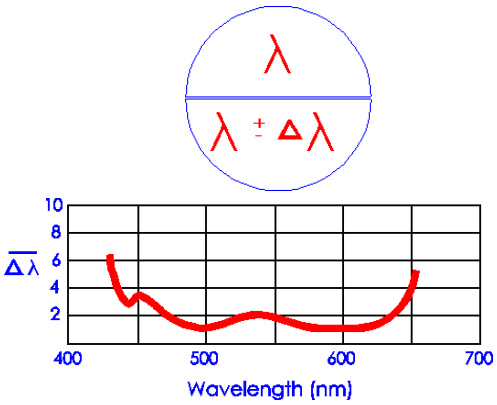
Cones sensíveis a
comprimento de onda
curto, médio e longo

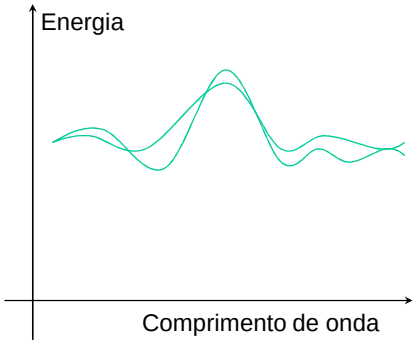
Sinais elétricos

Sensação de cores

Respostas

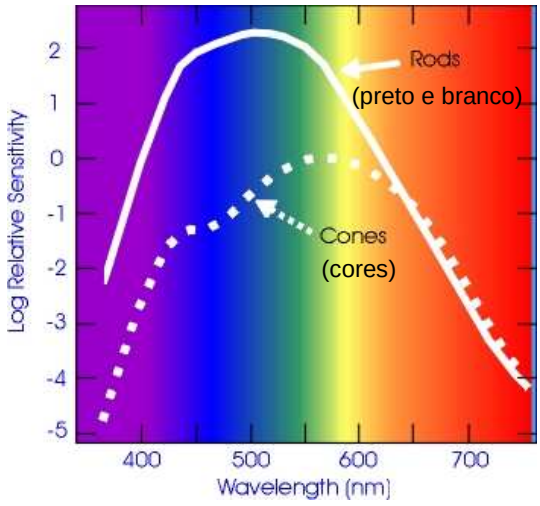
Diferenciação de Cores
Metâmeras





Distintas distribuições espectrais, porém mesma percepção colorida

Células Fotoreceptoras



Visão fotópica (diurna) : visão adaptada a altos níveis de luminância. Visão colorida.

Visão mesópica: visão adaptada a regiões de níveis intermediários.

Visão escotópica (noturna): visão adaptada a baixos níveis de luminância. Os bastonetes respondem melhor.

Células Fotoreceptoras

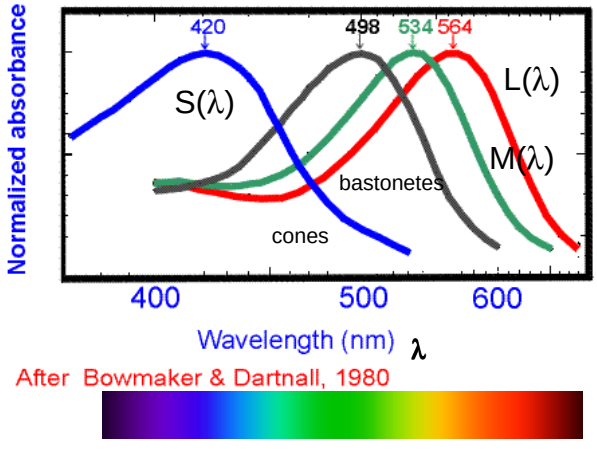
Daltonismo por ausência de cones

- **Protanopia:** ausência de cones "vermelhos" ou de "comprimento de onda longo", resultando na impossibilidade de discriminar cores no segmento verde-amarelo-vermelho do espectro.
- **Deuteranopia:** ausência de cones "verdes" ou de comprimento de onda intermédio, resultando, igualmente, na impossibilidade de discriminar cores no segmento verde-amarelo-vermelho do espectro,
- **Tritanopia:** ausência de cones "azuis" ou de comprimento de onda curta, resultando na impossibilidade de ver cores na faixa azul-amarelo.

Teoria Tricromática

Young, Helmholtz e Maxwell

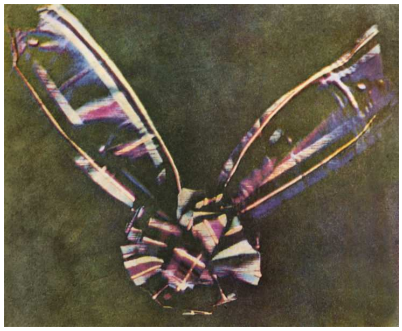
Funções de Sensibilidade Espectral



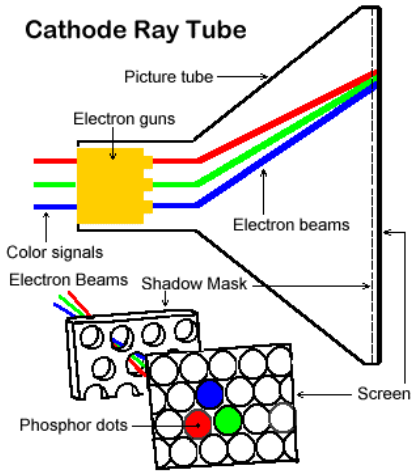
3 tipos de cones

380nm 750nm

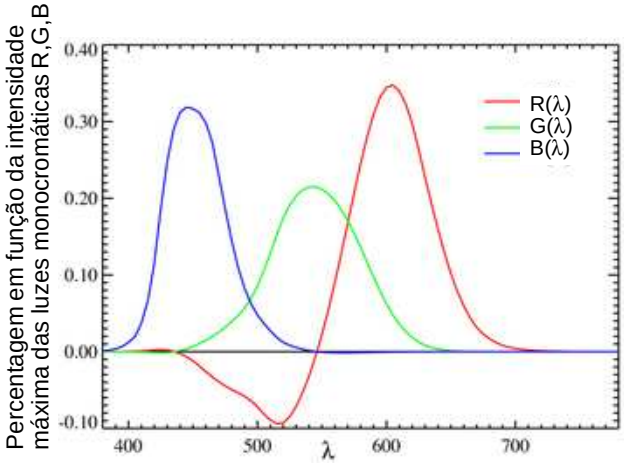
Teoria Tricromática
Mistura Aditiva



Primeira foto colorida resultante da projeção conjunta de 3 imagens (verde,vermelho e azul), James Clerk Maxwell, 1861



Teoria Tricromática
Reconstrução Espectral



$$A(\lambda) = rR(\lambda) + gG(\lambda) + bB(\lambda)$$

Teoria Tricromática

Leis de Grassman

1. Qualquer cor pode ser especificada como mistura aditiva de 3 cores independentes.
2. A cor de uma mistura aditiva não se altera quando substituirmos as cores componentes pelas suas metâmeras.
3. Se uma componente de uma mistura aditiva é alterada numa dada proporção continuamente, a cor da mistura é modificada na mesma proporção continuamente, obedecendo as leis de simetria, transitividade e linearidade.

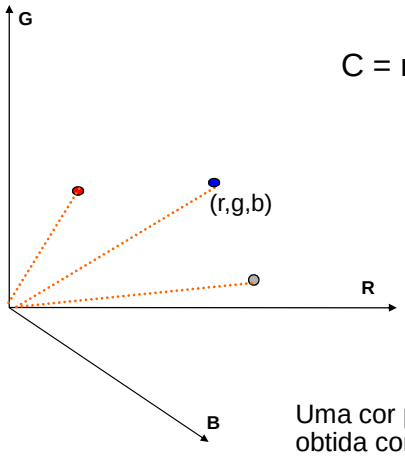
Espaço de Cores

Funções de Reconstrução Espectral com 3 cores

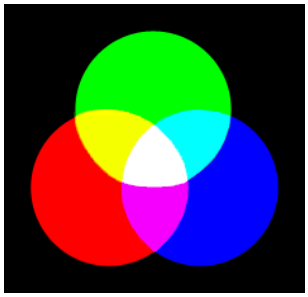
Leis de Grassman

Espaço Vetorial de Cores

Espaço de Cores RGB

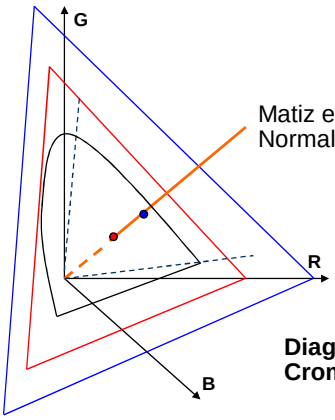


$$C = r\mathbf{R} + g\mathbf{G} + b\mathbf{B}$$



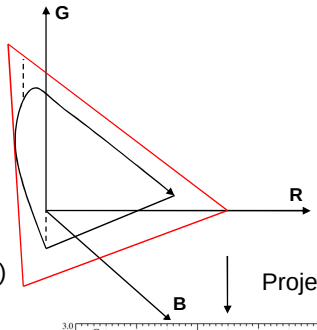
Uma cor pode ser obtida como soma ponderada de somente três tipos de radiações (primárias).

Espaço de Cores RGB



Matiz e saturação
Normalizar energia

(R/C,G/C,B/C)
C =R+G+B



Projeção

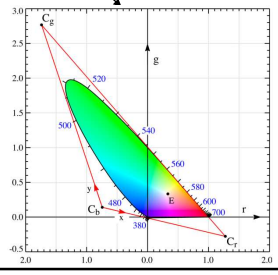
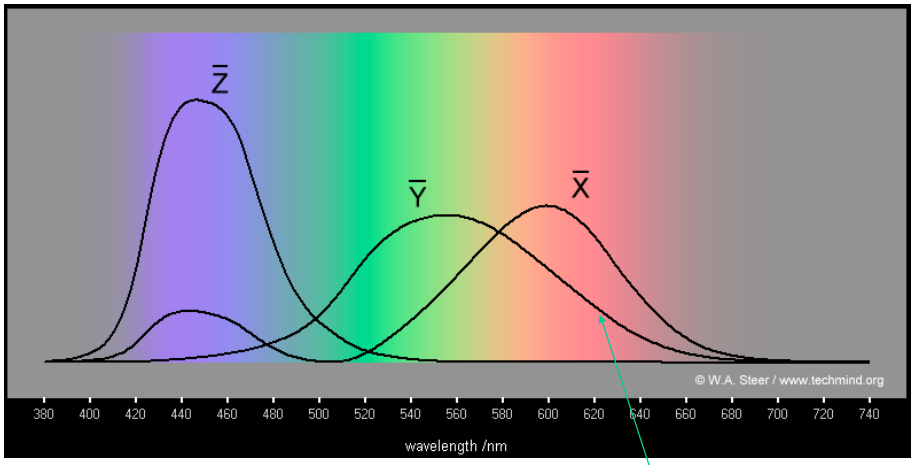


Diagrama de Cromaticidade RG

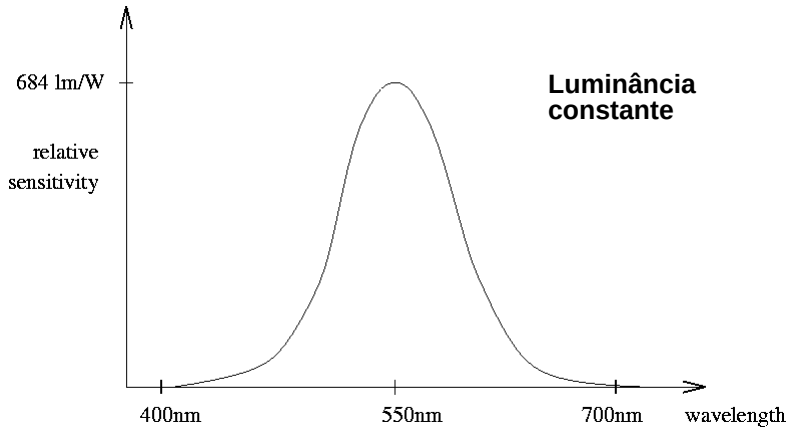
Como eliminar os valores negativos de R?

Espaço de Cores XYZ



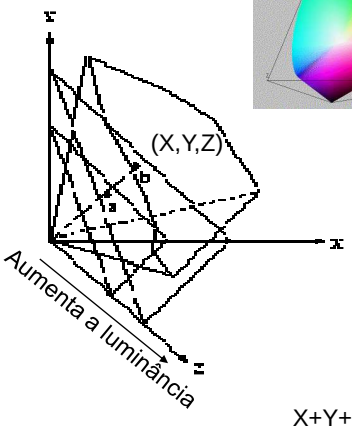
Função de eficiência luminosa

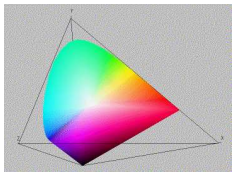
Espaço de Cores XYZ
Y : Função de Eficiência Luminosa



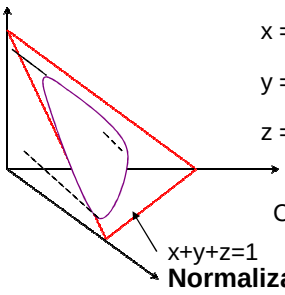
380nm 750nm

Espaço de Cores XYZ





X+Y+Z = C



$$x = \frac{X}{C}$$

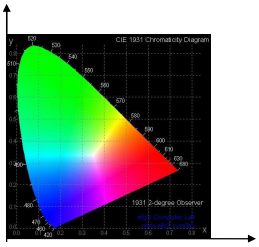
$$y = \frac{Y}{C}$$

$$z = \frac{Z}{C}$$

C=X+Y+Z

x+y+z=1

Normalização



Mudança de Espaços

XYZ ←→ RGB

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{1}{b_{21}} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{1}{0.17697} \begin{bmatrix} 0.49 & 0.31 & 0.20 \\ 0.17697 & 0.81240 & 0.01063 \\ 0.00 & 0.01 & 0.99 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Diagrama de Cromaticidade CIE

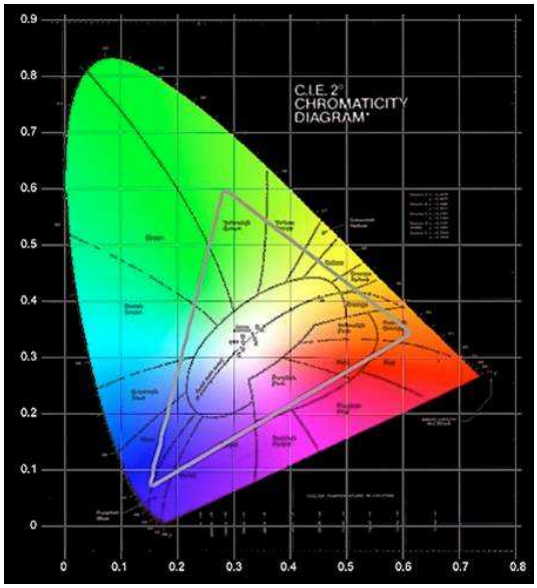
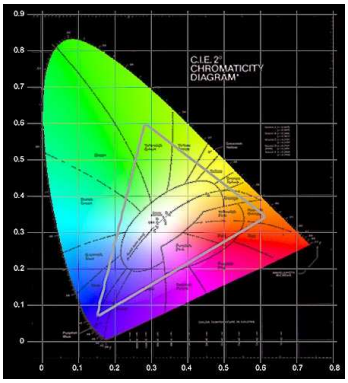


Diagrama de Cromaticidade

Metâmeras



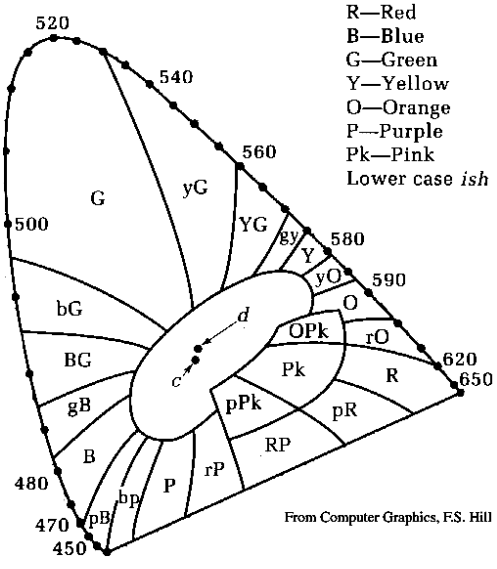
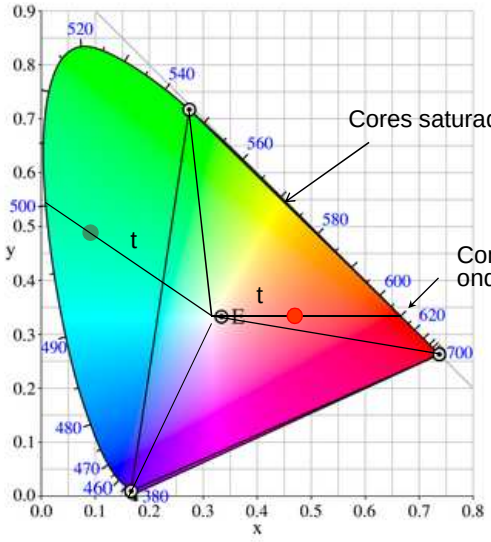


Diagrama de Cromaticidade
Saturação/Pureza de Cor



t: pureza de cor

Diagrama de Cromaticidade
Cor Complementar

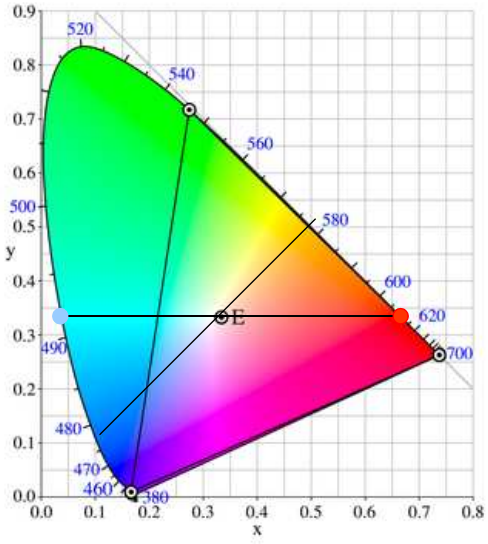
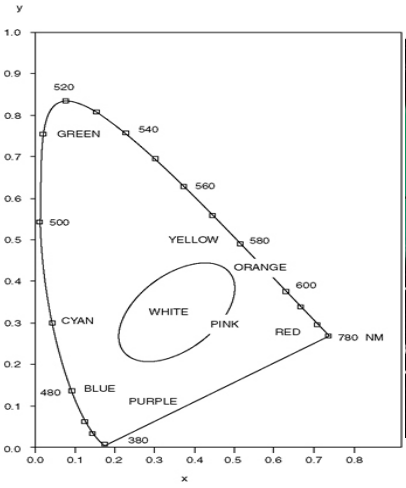


Diagrama de Cromaticidade
"Brancos"



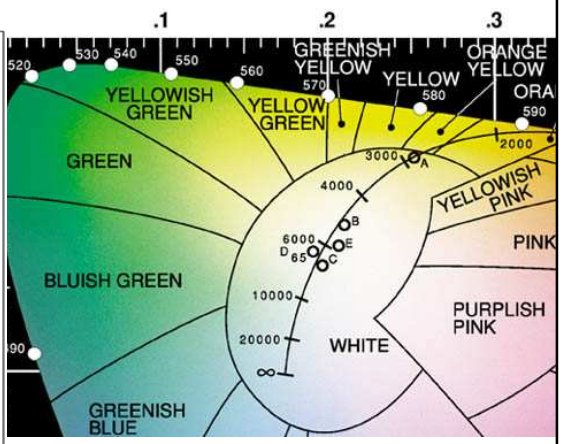


Diagrama de Cromaticidade
Branco de Referência

Nome	Temperatura	Coordenadas	Fonte
Illuminant A	2856	(0.44757,0.40745)	[Wyszecki82, p 139] [Agoston87, p. 103]
Illuminant B	4874	(0.34842,0.35161)	[Wyszecki82, p 139] [Agoston87, p. 103]
Illuminant C	6774	(0.31006,0.31616)	[Wyszecki82, p 139] [Agoston87, p. 103]
Illuminant D65	6504	(0.3127,0.3291)	[Walker98] [Agoston87, p. 103]
Direct Sunlight	5335	(0.3362,0.3502)	[Agoston87, p. 103]
Light from overcast sky	6500	(0.3134,0.3275)	[Agoston87, p. 103]
Light from north sky on a 45-degree plane	10,000	(0.2773,0.2934)	[Agoston87, p. 103]
Illuminant E	5400	(1/3,1/3)	[Wyszecki82, p 139] [Agoston87, p. 103]

Diagrama de Cromaticidade
Mistura de Cores

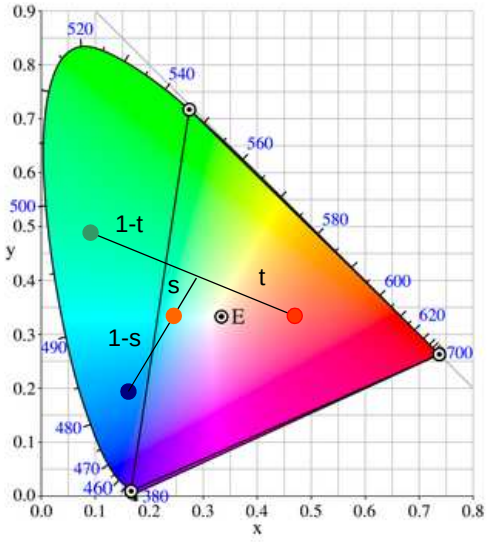
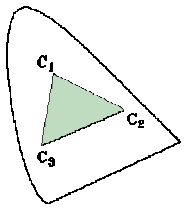


Diagrama de Cromaticidade
Gamute de Cores



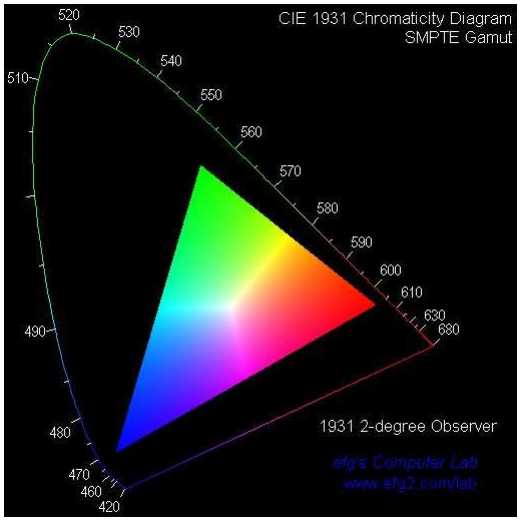


Diagrama de Cromaticidade
Gamute de Monitores

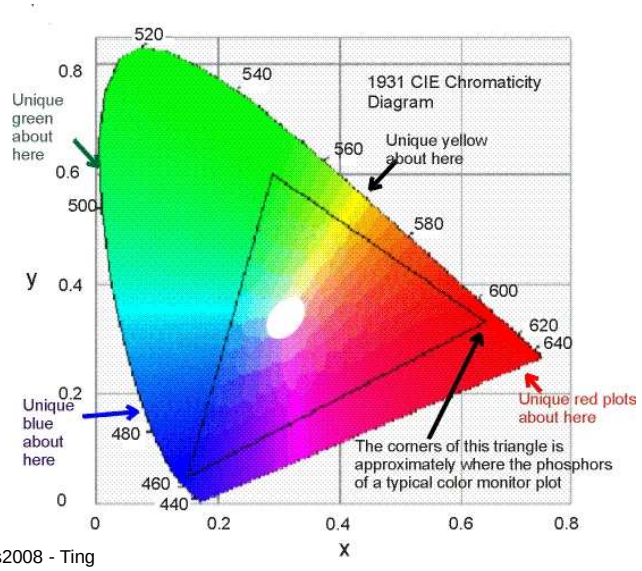
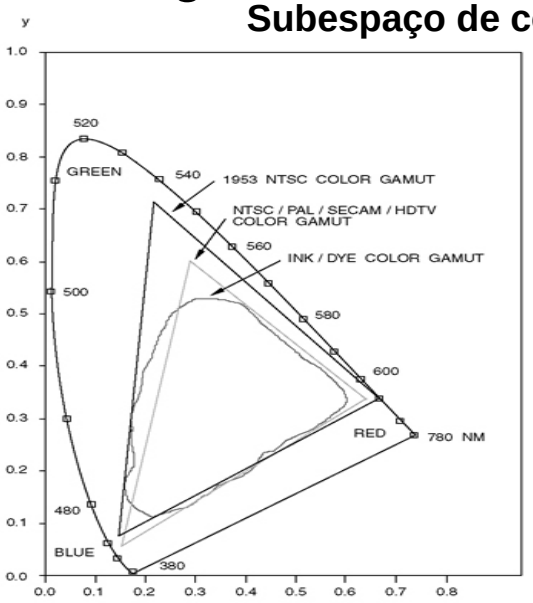


Diagrama de Cromaticidade
Cromaticidade dos Fósforos de Monitores

Nome	R	G	B	Branco
Short-Persistence	(0.61,0.35)	(0.29,0.59)	(0.15,0.063)	
Long-Persistence	(0.62,0.33)	(0.21,0.685)	(0.15,0.063)	
NTSC	(0.67,0.33)	(0.21,0.71)	(0.14,0.08)	Iluminante C
EBU	(0.64,0.33)	(0.30,0.60)	(0.15,0.06)	Iluminante D65
Dell (all monitors except 21" Mitsubishi p/n 65532)	(0.625,0.340)	(0.275,0.605)	(0.150,0.065)	9300K
SMPTE	(0.630,0.340)	(0.310,0.595)	(0.155,0.070)	Iluminante D65
P22 phosphor in NEC Multisync C400	(0.610,0.350)	(0.307,0.595)	(0.150,0.065)	(0.280,0.315)
P22 phosphor in KDS VS19	(0.625,0.340)	(0.285,0.605)	(0.150,0.065)	(0.281,0.311)
High Brightness LEDs	(0.700,0.300)	(0.170,0.700)	(0.130,0.075)	(0.310,0.320)

Diagrama de Cromaticidade

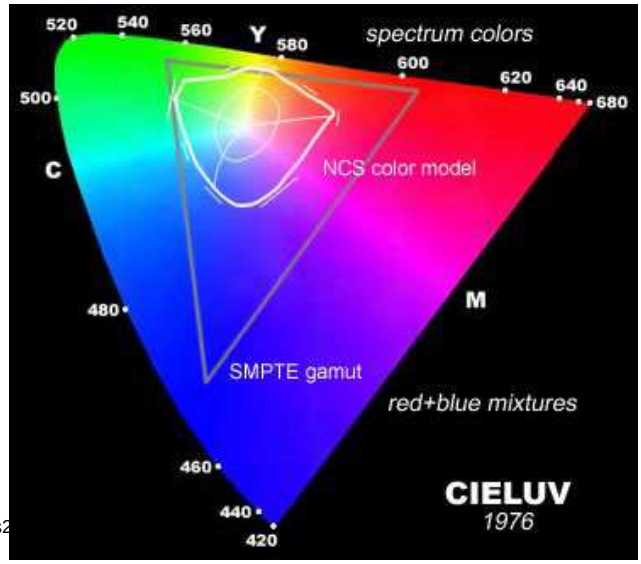
Subespaço de cores



Todas as cores de um dispositivo são reproduzíveis noutro dispositivo?

Espaço de Cores LUV

Cores perceptivamente uniforme



Mudança de Espaços
LUV ←→ XYZ

$L^* = 116\,(Y/Y_n)^{1/3} - 16$, $Y/Y_n > 0.01$

$u^* = 13\,L^*\,(u' - u'_n)$

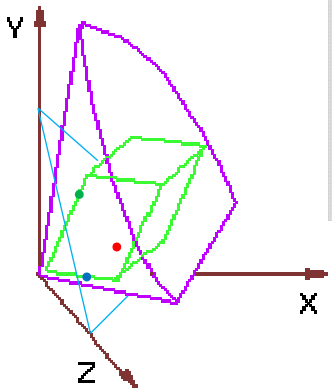
$v^* = 13\,L^*\,(v' - v'_n)$

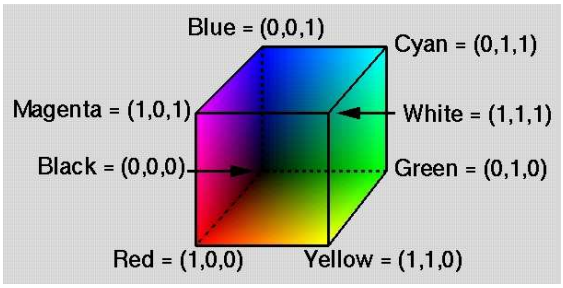
$$u' = \frac{4X}{X + 15Y + 3Z} \qquad v' = \frac{9Y}{X + 15Y + 3Z}$$

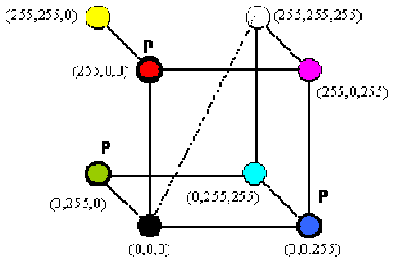
$$u'_n = \frac{4X_n}{X_n + 15Y_n + 3Z_n} \qquad v'_n = \frac{9Y_n}{X_n + 15Y_n + 3Z_n}$$

(X_n, Y_n, Z_n): branco do dispositivo

Modelo de Cor
RGB: Gamute de monitores

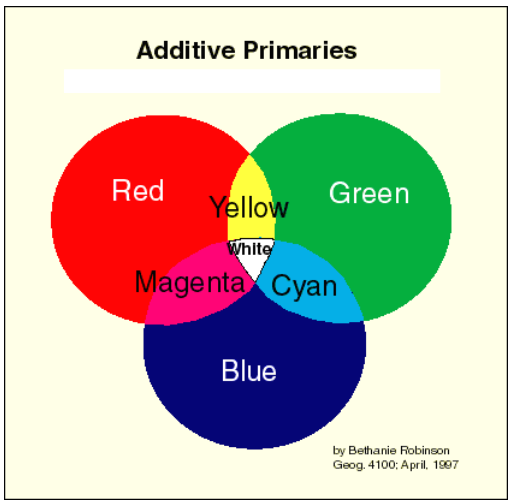






Modelos de Cor

Aditiva - Cores Primárias



Modelo de Cor

Conversão entre Dispositivos

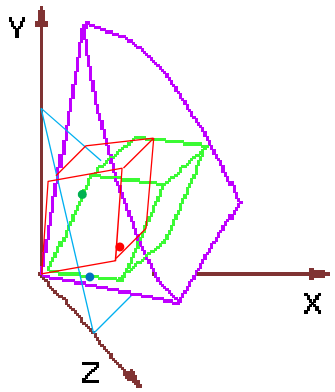
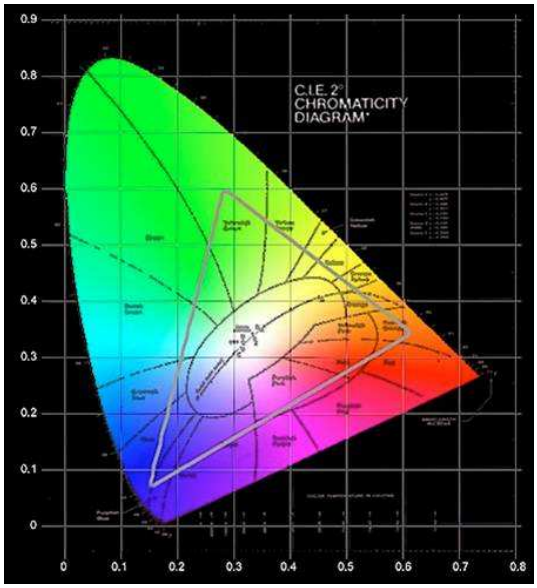


Diagrama de Cromaticidade CIE



Modelos de Cor

Conversão de cores = mudança de bases

$$(R_1,G_1,B_1) \xrightarrow{M_1} (X,Y,Z) \xleftarrow{M_2} (R_2,G_2,B_2)$$

$$M_1 = \begin{pmatrix} x_{r,1}C_{r,1} & x_{g,1}C_{g,1} & x_{b,1}C_{b,1} \\ y_{r,1}C_{r,1} & y_{g,1}C_{g,1} & y_{b,1}C_{b,1} \\ z_{r,1}C_{r,1} & z_{g,1}C_{g,1} & z_{b,1}C_{b,1} \end{pmatrix} \begin{pmatrix} x_{r,2}C_{r,2} & x_{g,2}C_{g,2} & x_{b,2}C_{b,2} \\ y_{r,2}C_{r,2} & y_{g,2}C_{g,2} & y_{b,2}C_{b,2} \\ z_{r,2}C_{r,2} & z_{g,2}C_{g,2} & z_{b,2}C_{b,2} \end{pmatrix} = M_2$$

1. As luminâncias máximas das 3 cores são conhecidas: $Y_{r,1}$, $Y_{g,1}$ e $Y_{b,1}$

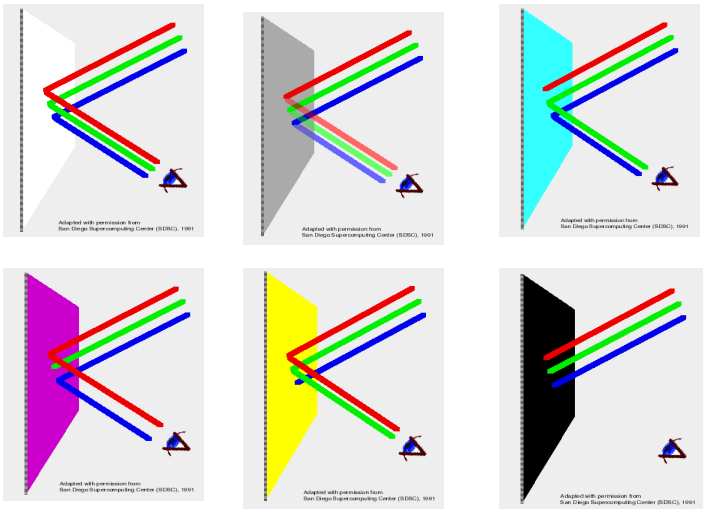
$$C_{r,1} = \frac{Y_{r,1}}{y_{r,1}} \qquad C_{g,1} = \frac{Y_{g,1}}{y_{g,1}} \qquad C_{b,1} = \frac{Y_{b,1}}{y_{b,1}}$$

2. A cor de referência branca é conhecida (X_w,Y_w,Z_w)

$$\begin{pmatrix} x_{r,1} & x_{g,1} & x_{b,1} \\ y_{r,1} & y_{g,1} & y_{b,1} \\ z_{r,1} & z_{g,1} & z_{b,1} \end{pmatrix}^{-1} \begin{pmatrix} X_w \\ Y_w \\ Z_w \end{pmatrix} = \begin{pmatrix} C_r \\ C_g \\ C_b \end{pmatrix}$$

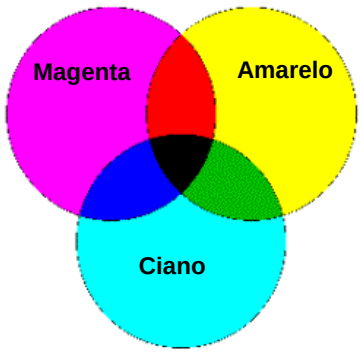
Modelo de Cor

Mistura Subtrativa



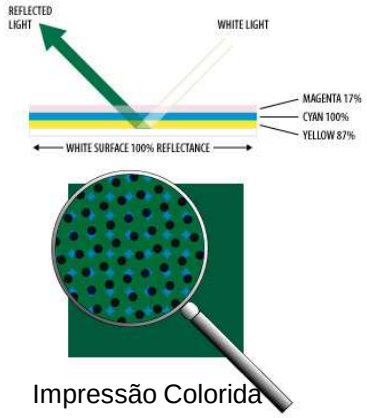
Modelo de Cor

Subtrativa - Cores Primárias



Modelos de Cor

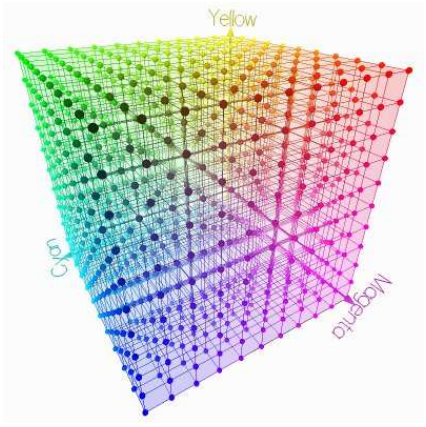
Mistura Subtrativa



Impressão Colorida

Modelo de Cor

CMY: Gamute de Impressoras

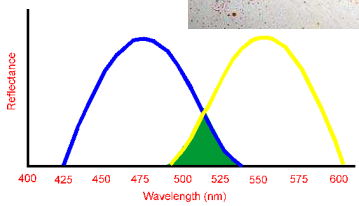


$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

Modelos de Cor

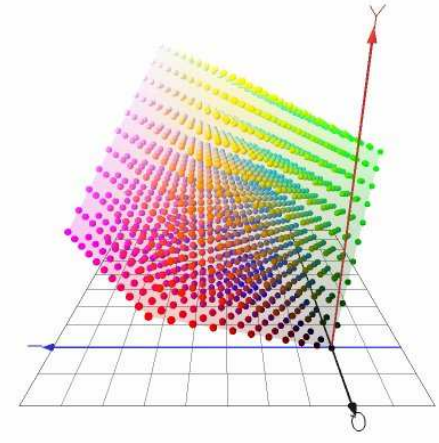
Mistura Subtrativa

Tintas



Modelo de Cor

YIQ: Sistema de televisão NTSC

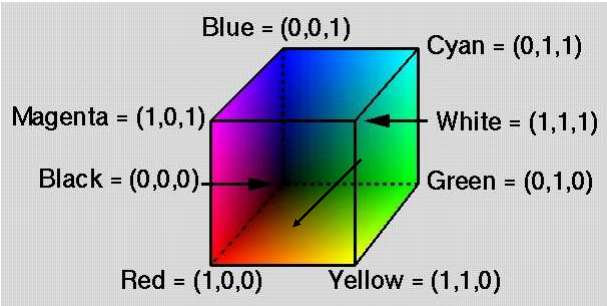


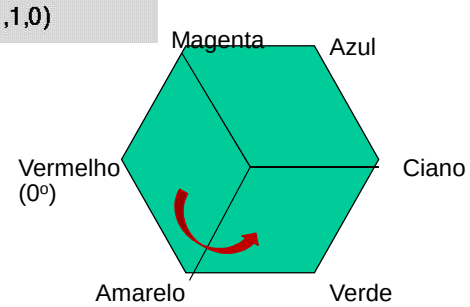
I : faixa laranja - azul
Q: faixa verde violeta
Y: luminância

$$\begin{pmatrix} Y \\ I \\ Q \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

Modelo de Cor

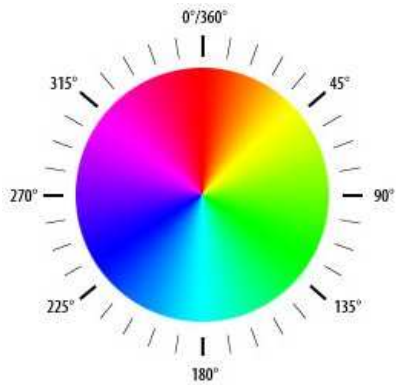
HSI: Gamute orientado a usuário





Modelo de Cor

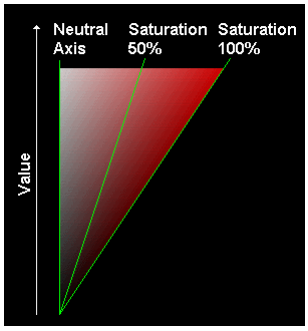
HSI



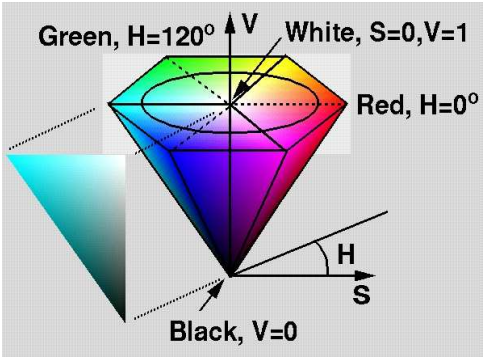
Matiz: comprimento de onda

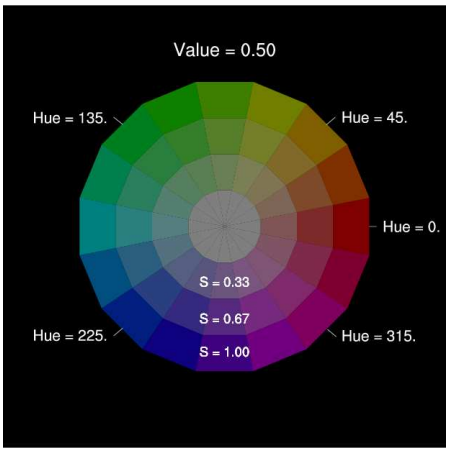
Saturação: pureza da “cor”

Intensidade: brilho da cor

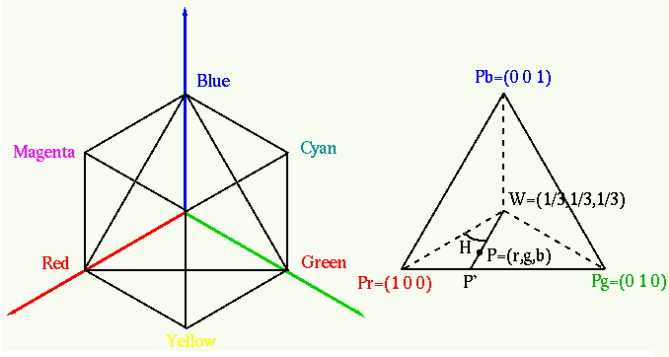


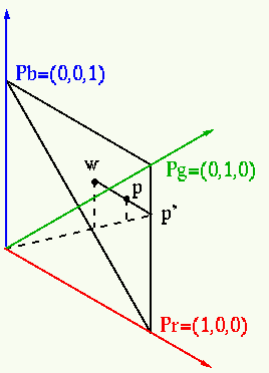
Modelo de Cor
HSI





Modelo de Cor
RGB → HSI





$I = 1/3 (R+G+B)$

$r = R/I$; $g = G/I$; $b = B/I$

$H = \cos^{-1}((0.5*((R-G)+(R-B))) / ((R-G)^2 + (R-B)*(G-B))^{0.5})$

$S = 1 - (3/(R+G+B)) *\min(R,G,B)$

Se S=0, H é indefinido