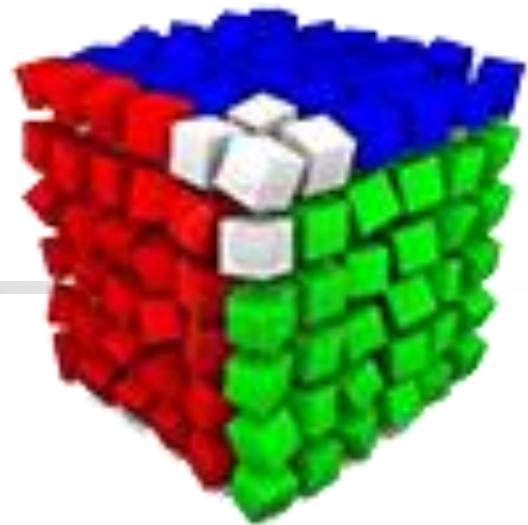


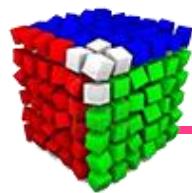
Modelos de Cores



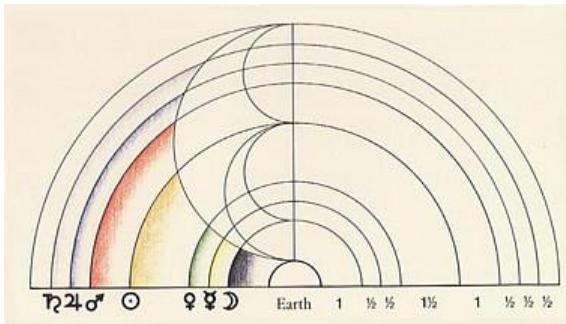
Carlos Alexandre Barros de Mello
Edward Roe



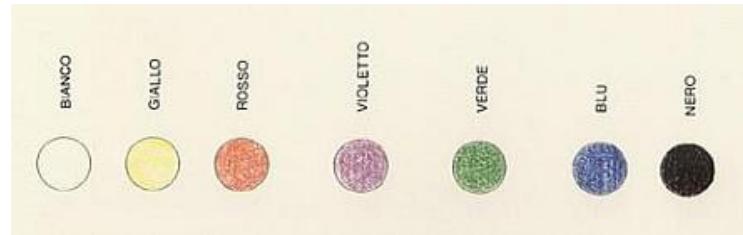
Sobre as cores....



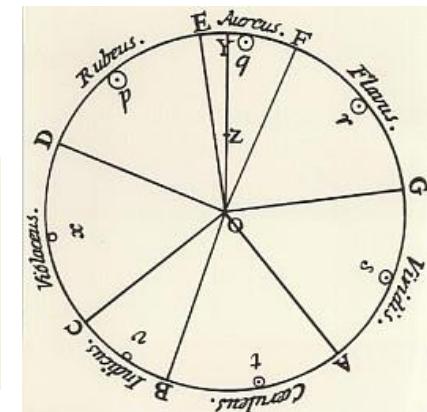
Evolução dos Modelos de Cor



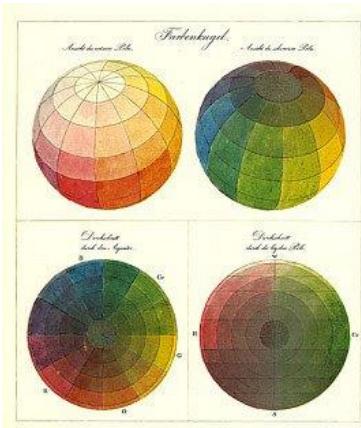
Pitágoras ~550AC



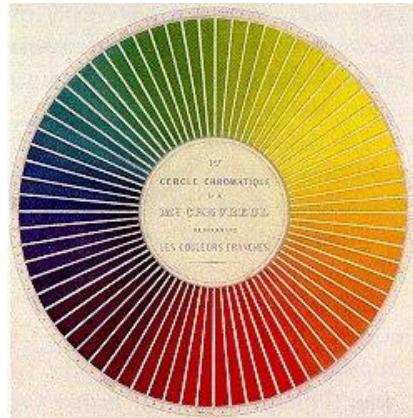
Aristóteles ~350BC



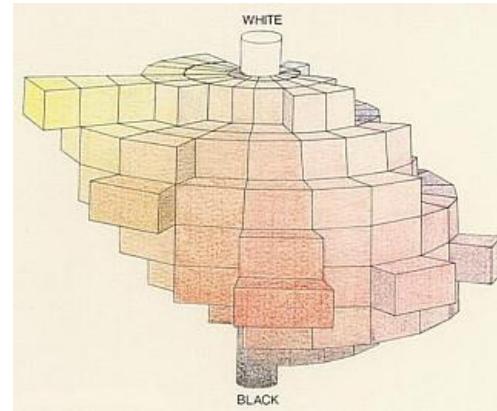
Isaac Newton - 1704



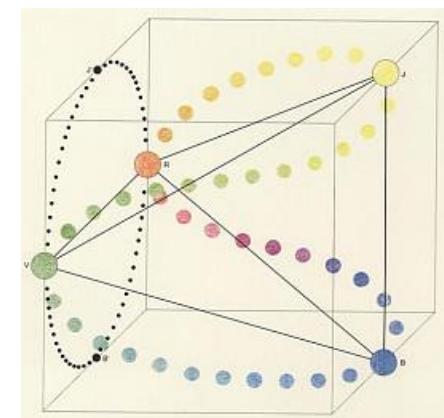
Philipp Otto Runge 1810



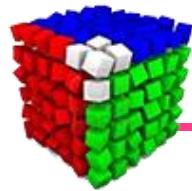
Michel Eugène Chevreul 1839



Albert Henry Munsell 1915



Michel Albert-Vanel 1983

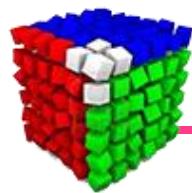


Isaac Newton

- Acreditava na teoria corpuscular da luz
- Huygens acreditava na teoria ondulatória
- Teoria de Newton foi mais aceita devido ao seu grande reconhecimento pela gravitação
- Newton fez importantes experimentos sobre a decomposição da luz com prismas e acreditou que as cores eram devidas ao tamanho da partícula de luz
- Hoje, sabe-se que a luz se comporta hora como partícula, hora como onda

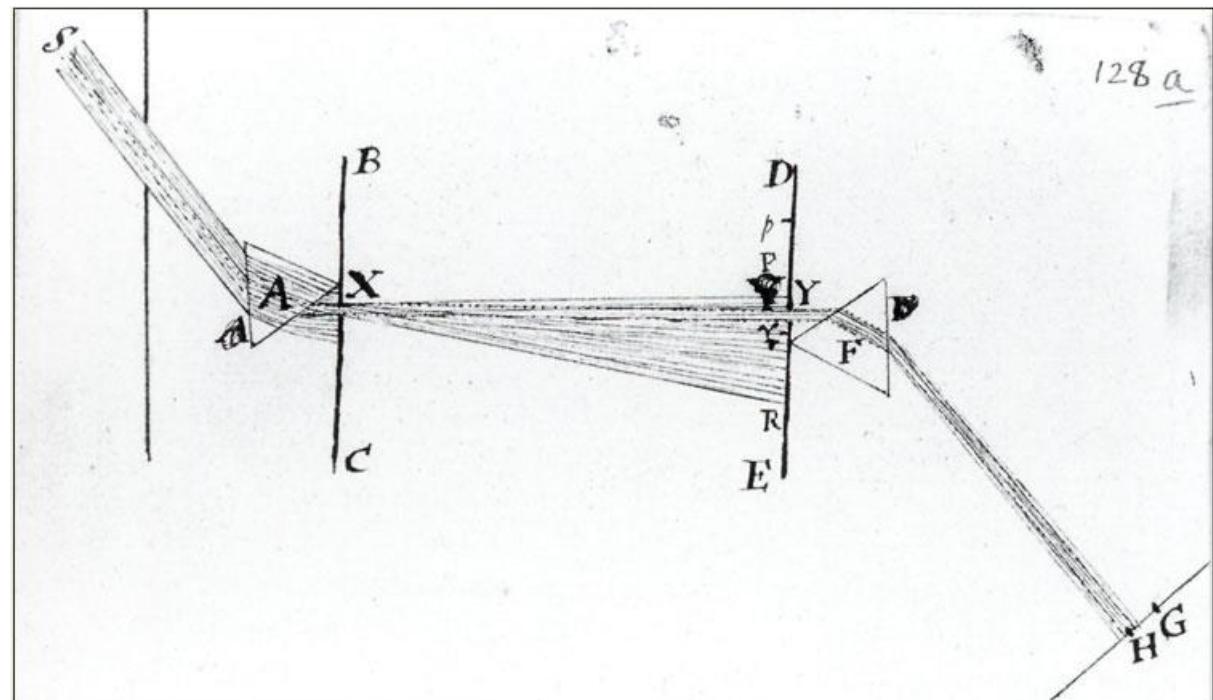
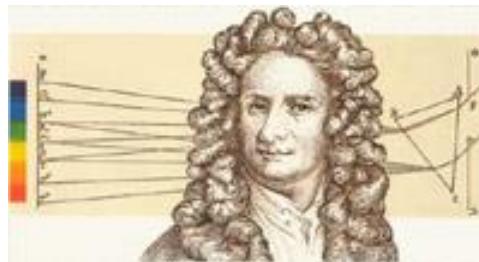
Um pouco mais sobre o assunto:

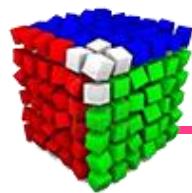
<https://www.youtube.com/watch?v=OQ6kWit51fA>



Experiência de Newton

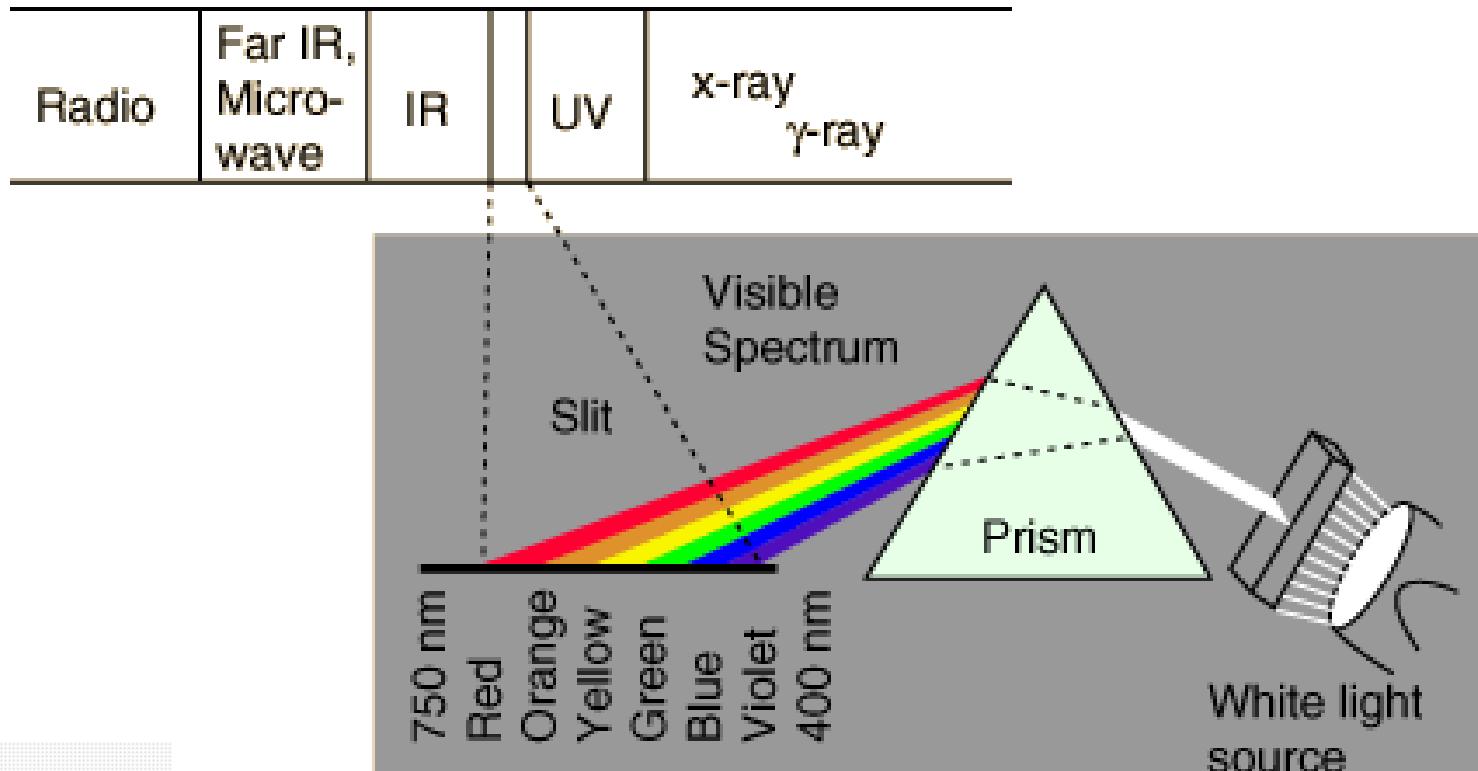
- Através de um experimento simples Newton mostrou que a luz branca era na verdade composta por outras cores

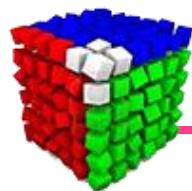




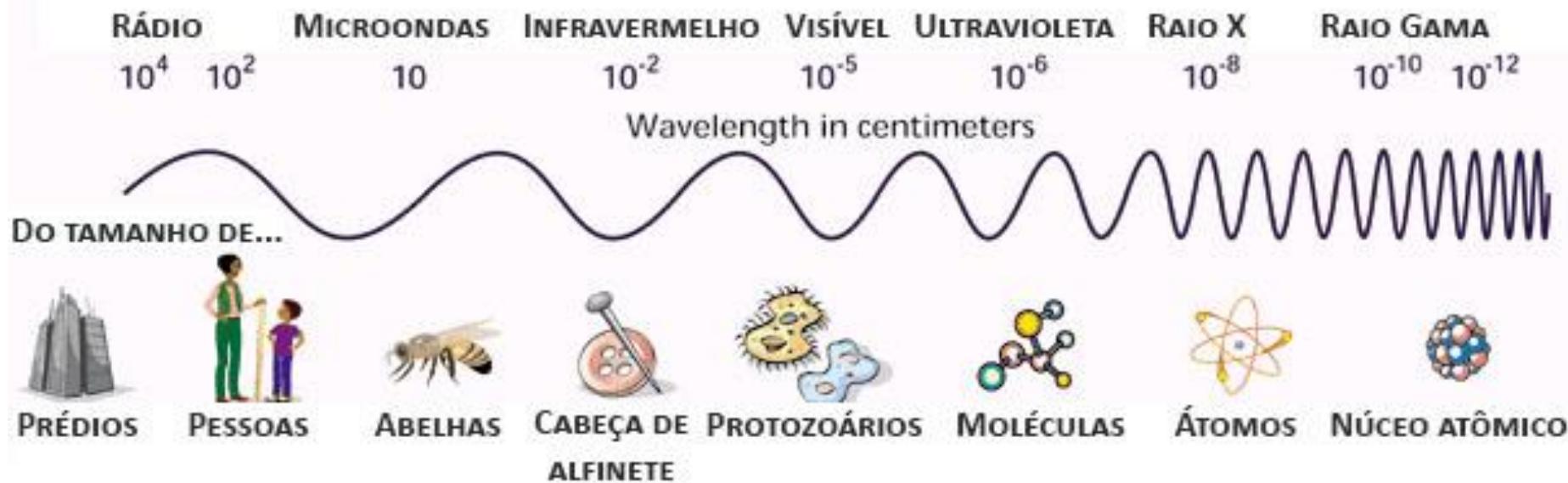
Decomposição da Luz

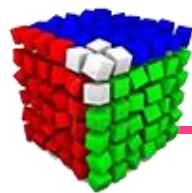
- Decomposição da luz através de um prisma



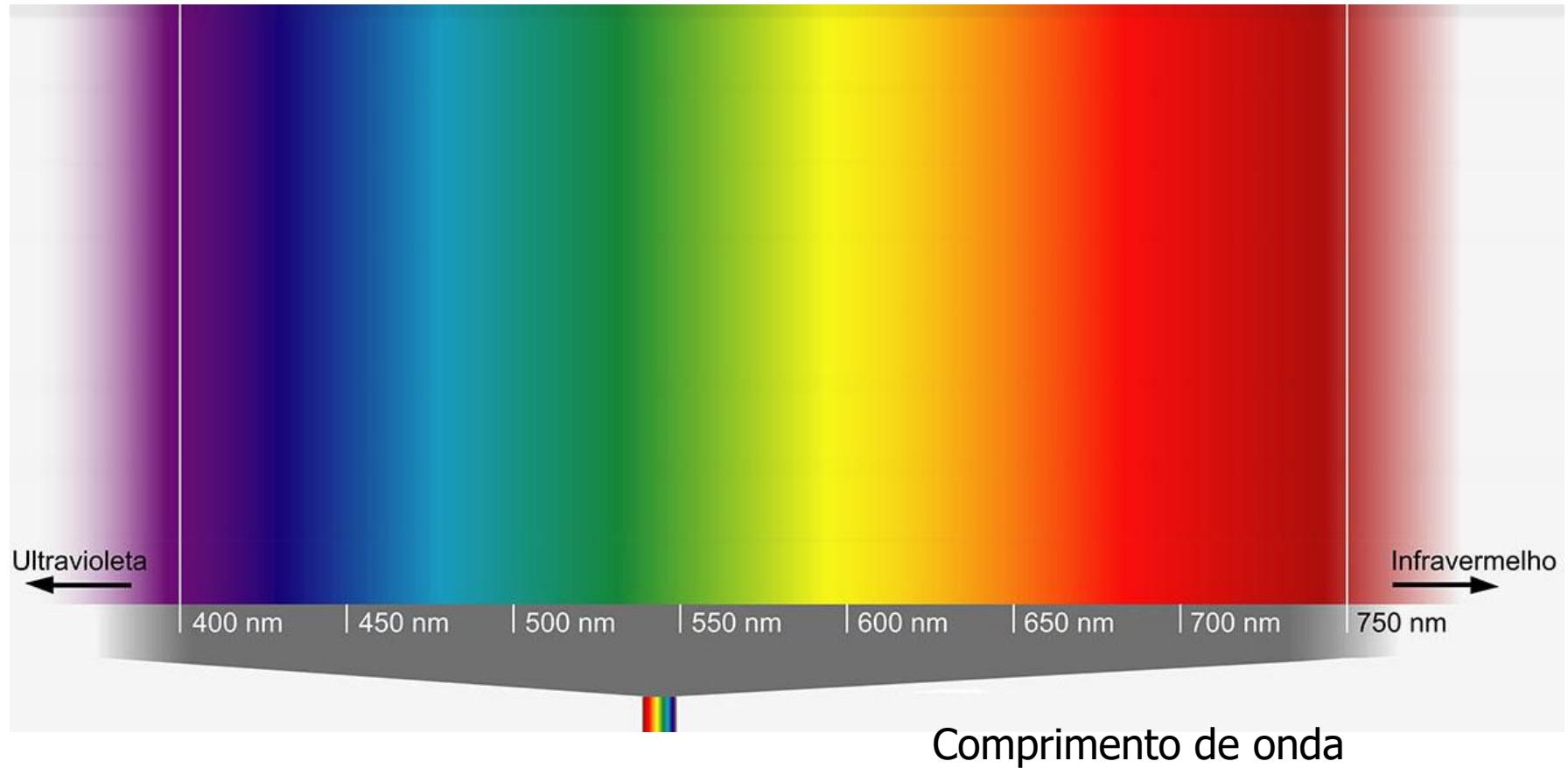


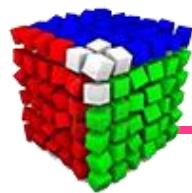
Espectro Eletromagnético





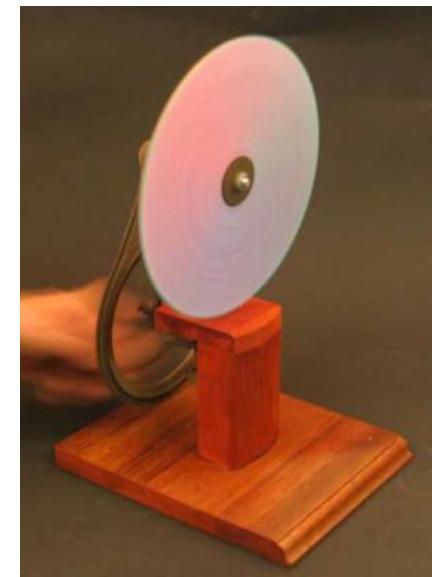
Cores do Espectro



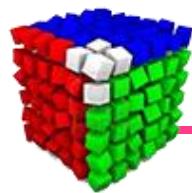


Experiências de Newton

- Newton usou 7 cores (vermelho, laranja, amarelo, verde, azul, índigo e violeta) para dividir o espectro, em analogia às 7 notas da escala musical
- Disco de Newton



<https://www.youtube.com/watch?v=b3NXsgjPSQo>

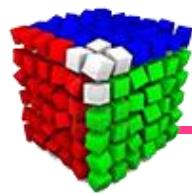


Cores - Aditivas e Subtrativas

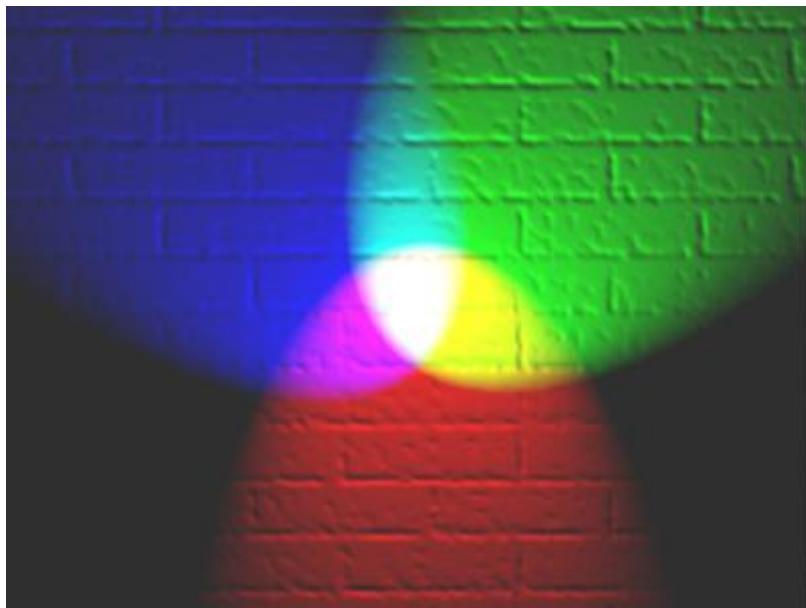
- O processo de formação **aditivo** é caracterizado pela soma de duas ou mais ondas eletromagnéticas do espectro visível, de comprimentos de onda diferentes, formando uma nova cor
- O processo de formação **subtrativo**, por sua vez, ocorre quando a luz passa por um filtro que absorve determinados comprimentos de onda e permite a passagem de outros

Cores Aditivas e Subtrativas

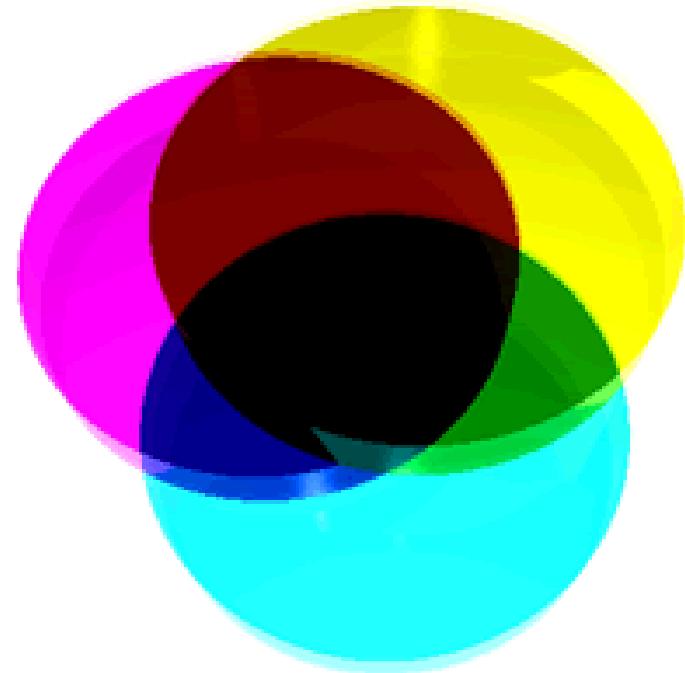




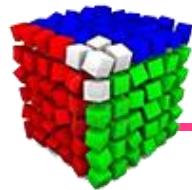
Cores - Aditivas e Subtrativas



Aditivas (luz)



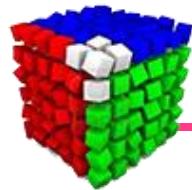
Subtrativas
(pigmentos ou filtros)



O Modelo CMY

- Modelo subtrativo
- Baseado em pigmentos
- É dependente dos dispositivos de impressão
- C - ciano
- M - magenta
- Y - amarelo

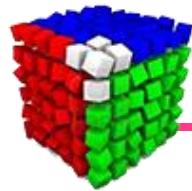




Modelo CMY ou CMYK

- O uso do pigmento preto reduz a necessidade dos outros pigmentos (ciano, magenta e amarelo)





Conversões entre RGB e CMY(K)

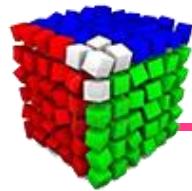
- Espaço CMY:

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

$$R = R/255$$

$$G = G/255$$

$$B = B/255$$



Conversões entre RGB e CMY(K)

- Espaço CMYK Ideal (Ford e Roberts, 1998):

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

$$R = R/255$$

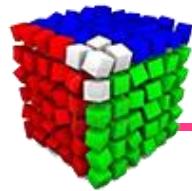
$$G = G/255$$

$$B = B/255$$

$$K = \min(C, M, Y)$$

$$\begin{pmatrix} C' \\ M' \\ Y' \end{pmatrix} = \begin{pmatrix} C \\ M \\ Y \end{pmatrix} - \begin{pmatrix} K \\ K \\ K \end{pmatrix} / (1 - K) \quad k \neq 1$$

Observe que, nesse caso, um componente sempre terá valor nulo (o que for o mínimo para K).



Conversões entre RGB e CMY(K)

- Espaço CMYK:

$$K = 1 - \max(R, G, B)$$

Se $k \neq 1$:

$$C = (1 - R - K) / (1 - K)$$

$$M = (1 - G - K) / (1 - K)$$

$$Y = (1 - B - K) / (1 - K)$$

Se $k = 1$:

$$C = (1 - R - K)$$

$$M = (1 - G - K)$$

$$Y = (1 - B - K)$$

$$R = R/255$$

$$G = G/255$$

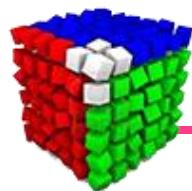
$$B = B/255$$

Exemplos:

$$(120, 40, 100)_{RGB} \Rightarrow (0, 0.67, 0.17, 0.53)_{CMYK}$$

$$(255, 255, 255)_{RGB} \Rightarrow (0, 0, 0, 0)_{CMYK}$$

$$(0, 0, 0)_{RGB} \Rightarrow (0, 0, 0, 1)_{CMYK}$$



Conversões entre RGB e CMY(K)

Cyan



C

Magenta



C+M

Yellow



C+M+Y

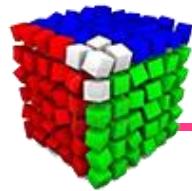
Black



C+M+Y+K

Sistemas CIE



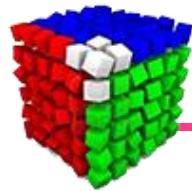


Valores Tricromáticos

- Qualquer cor C poderia ser reproduzida através das cores primárias:

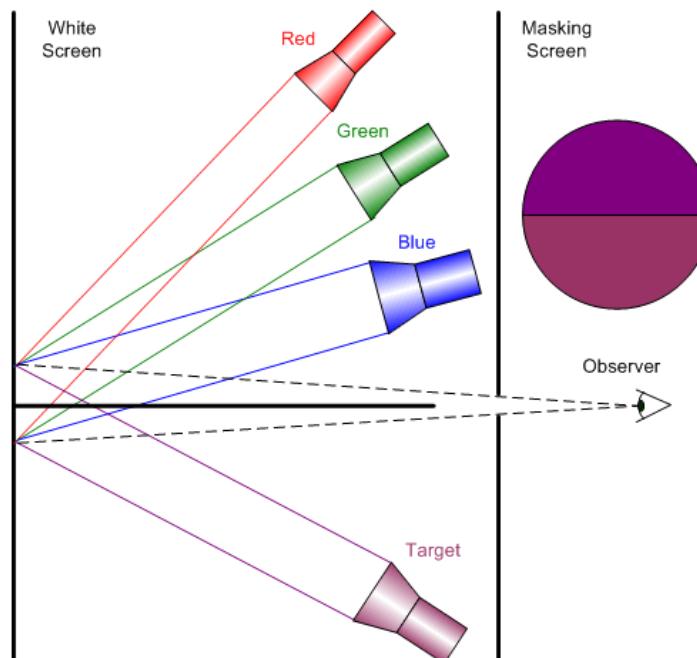
$$C = r \cdot R + g \cdot G + b \cdot B$$

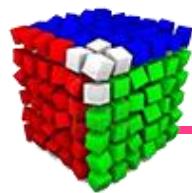
- Onde R, G e B são as três cores primárias e r, g e b são os coeficientes correspondentes



Sistema Padrão CIE-RGB

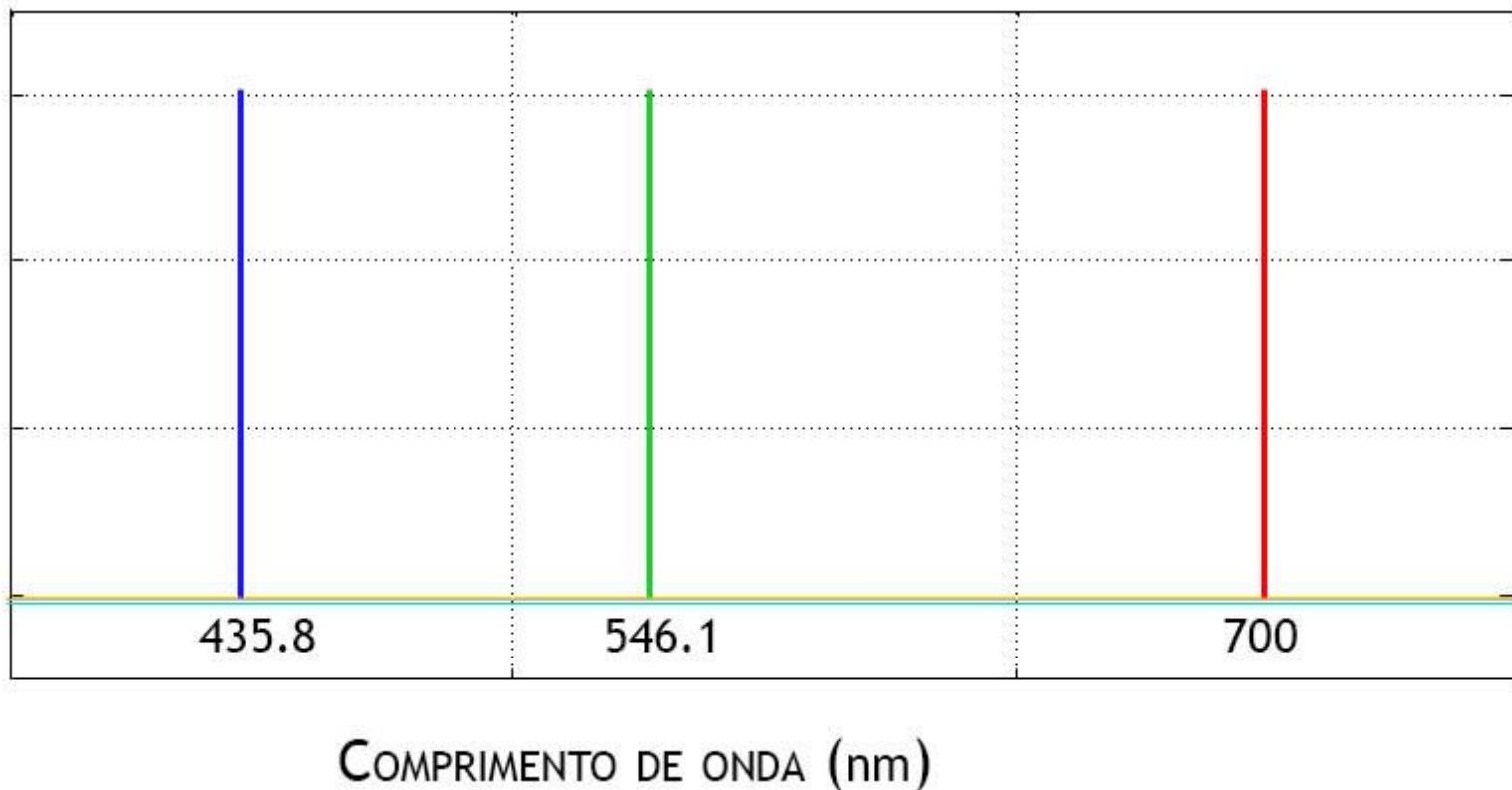
- CIE: *Commission Internationale d'Eclairage*
- Baseado em resultados experimentais
- W. David Wright e John Guild independentemente

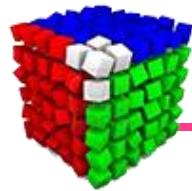




Valores Tricromáticos

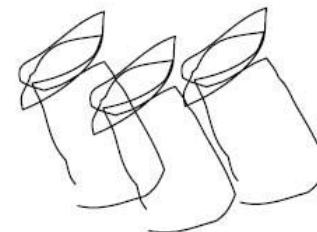
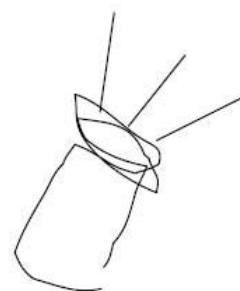
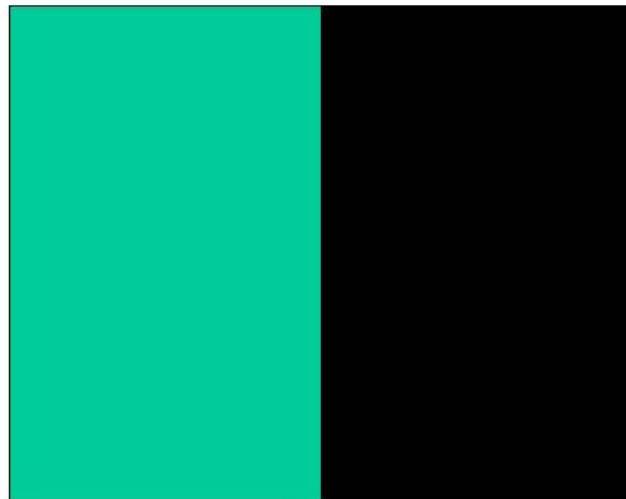
Observadores padrão CIE 1931

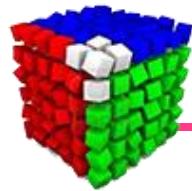




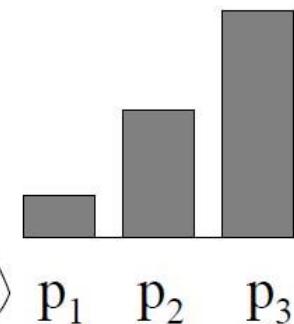
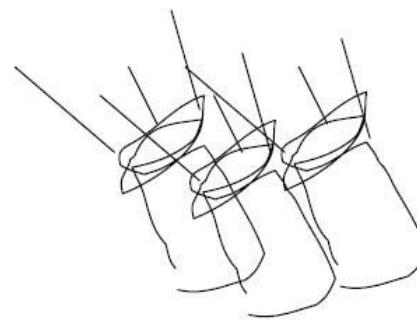
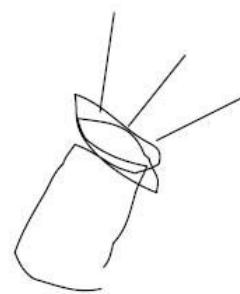
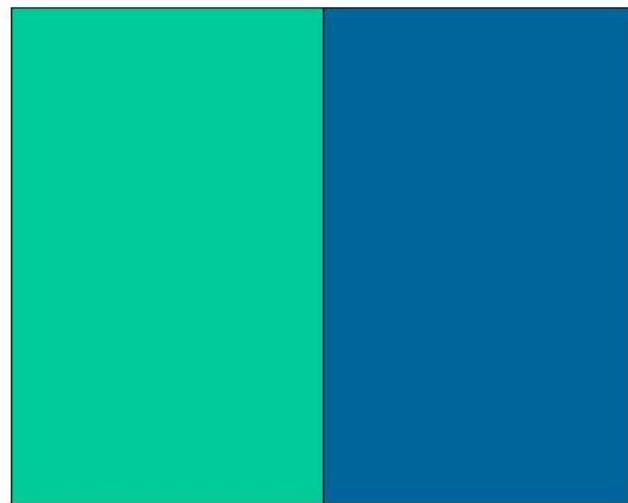
Experimentos CIE-RGB

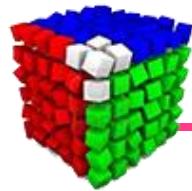
- Experimento realizado para “cada cor”



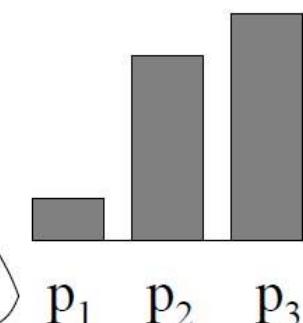
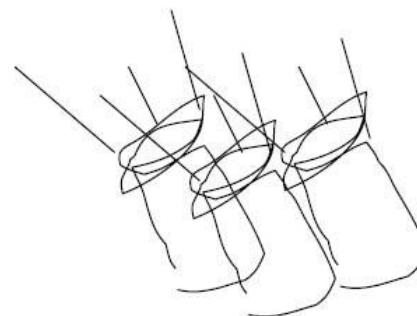
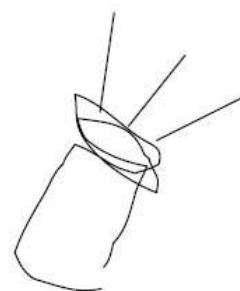
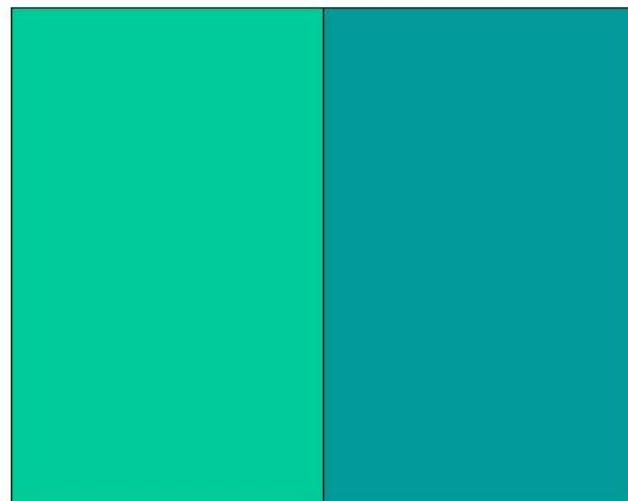


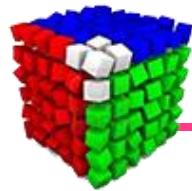
Experimentos CIE-RGB



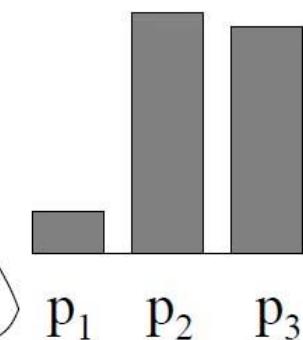
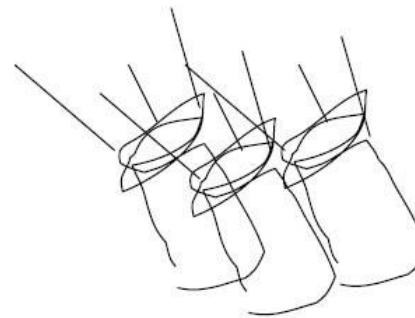
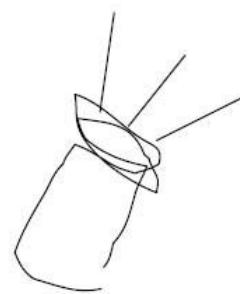
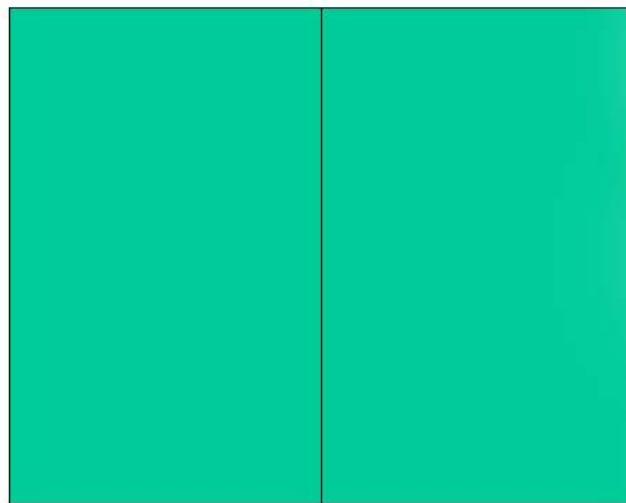


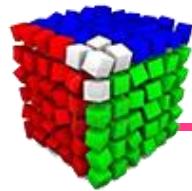
Experimentos CIE-RGB



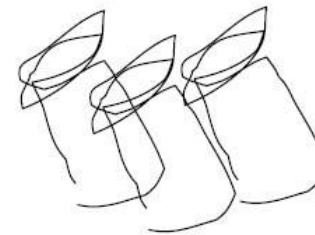
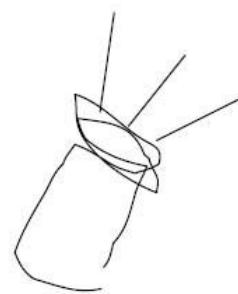
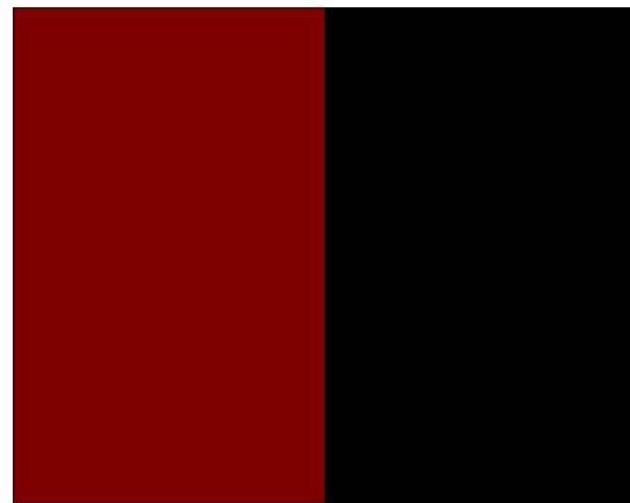


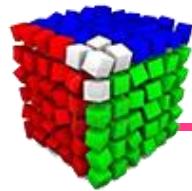
Experimentos CIE-RGB



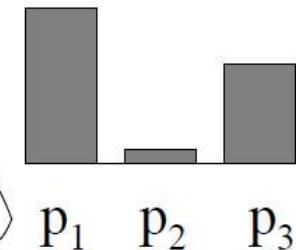
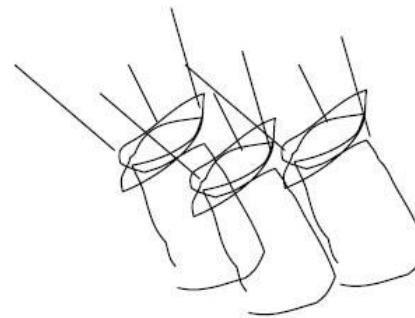
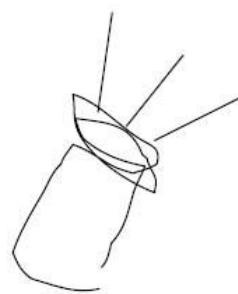
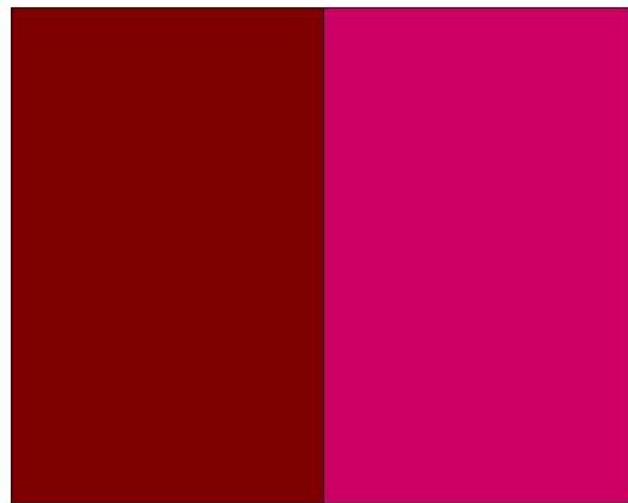


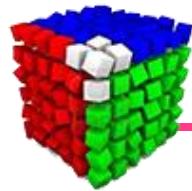
Experimentos CIE-RGB





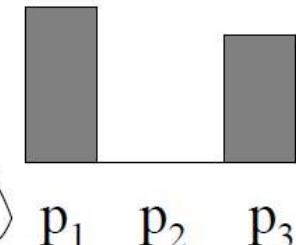
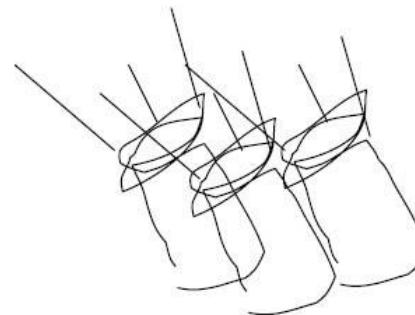
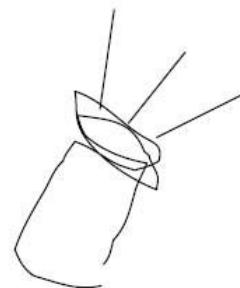
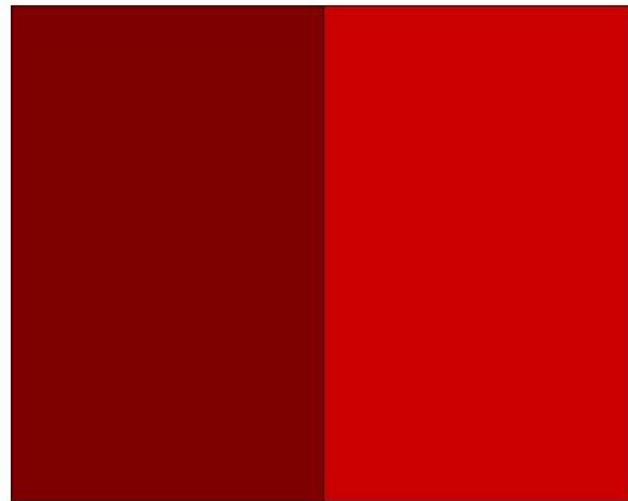
Experimentos CIE-RGB

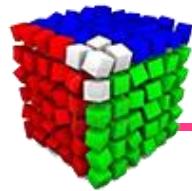




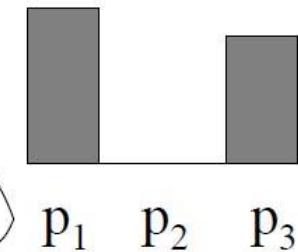
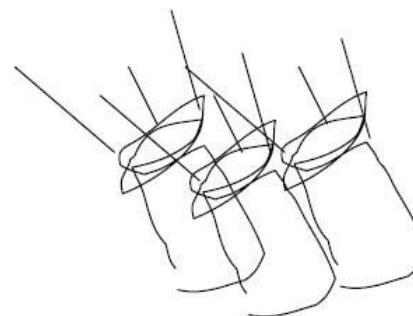
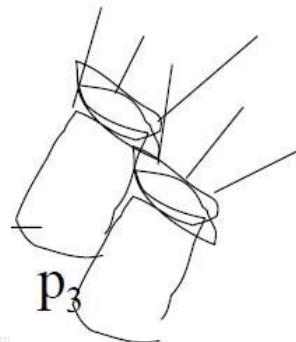
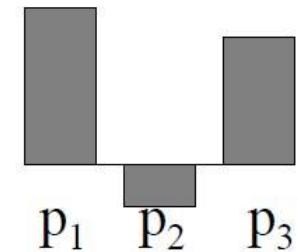
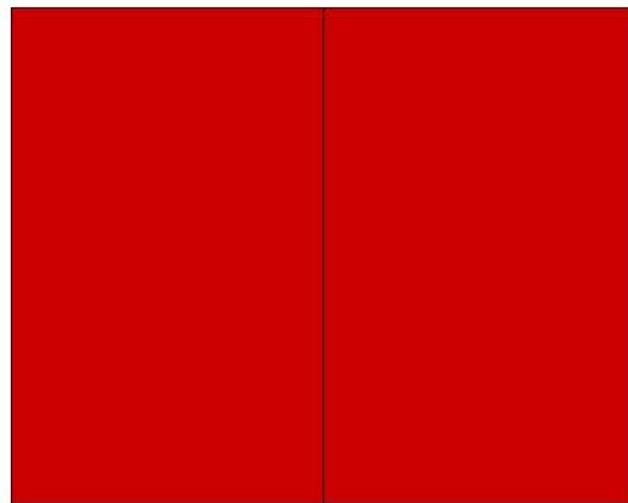
Experimentos CIE-RGB

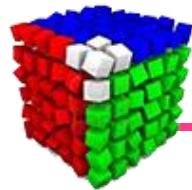
Problema....





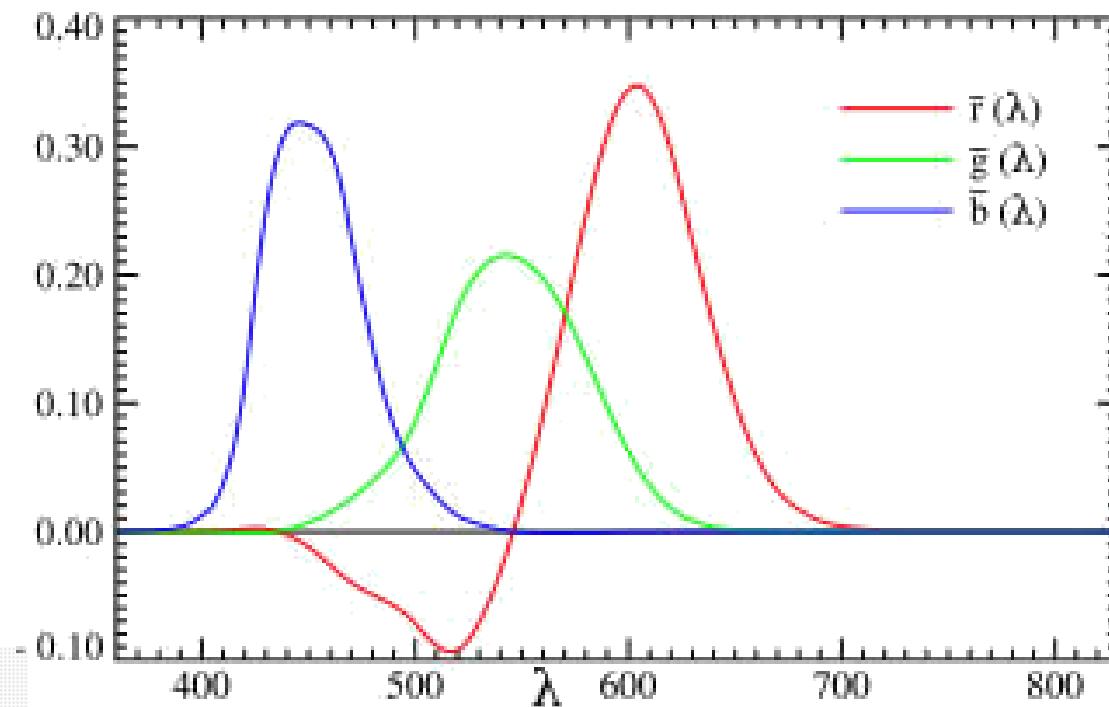
Experimentos CIE-RGB

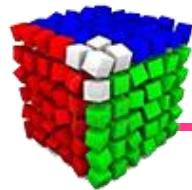




Sistema Padrão CIE-RGB

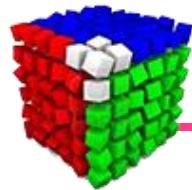
- As curvas representam as quantidades de primárias necessárias para reproduzir a cor de referência





Sistema Padrão CIE-XYZ

- Algumas cores não puderam ser reproduzidas usando apenas valores positivos no CIE-RGB
- Em 1931, a CIE definiu três novas primárias: X, Y e Z
- Somente valores positivos
- Y (luminância), X, Z (croma)



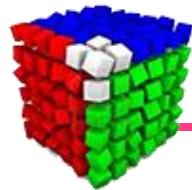
Sistema Padrão CIE- XYZ

- Coordenadas de cromaticidade normalizadas (x , y e z)

$$x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z}, \quad z = \frac{Z}{X + Y + Z}$$

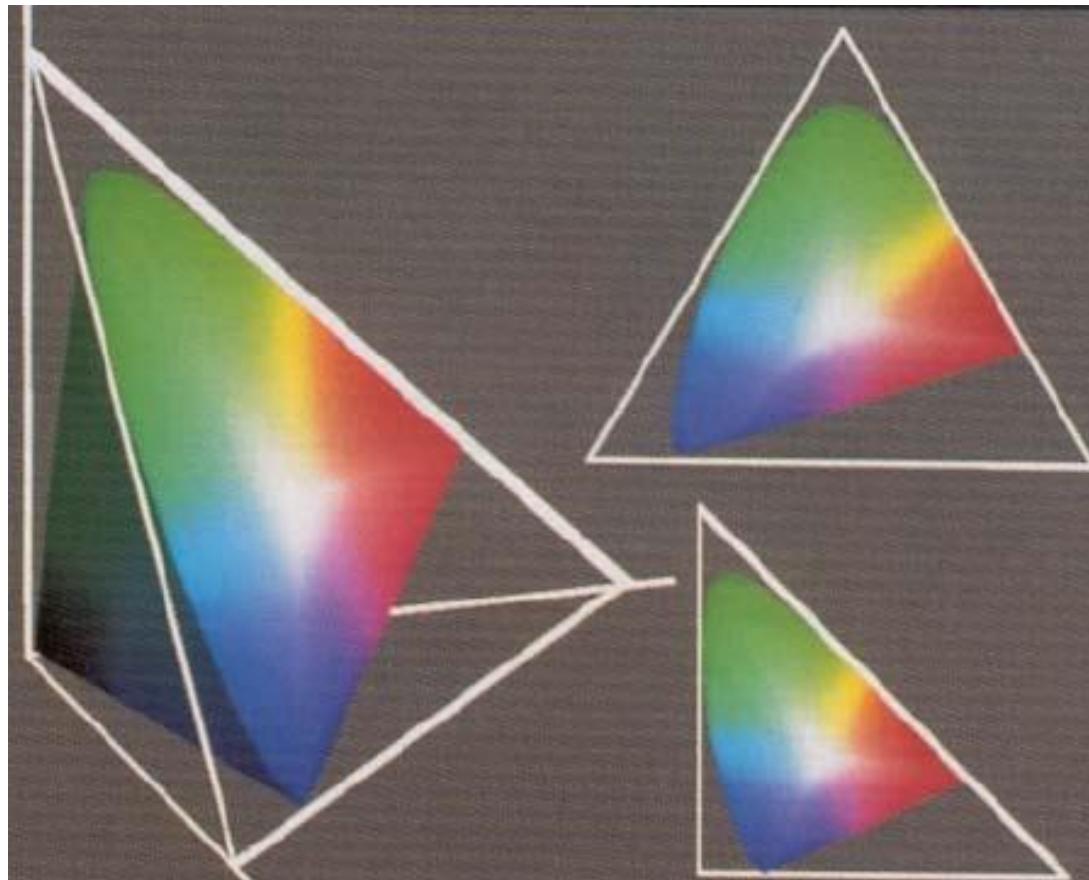
- Com $x + y + z = 1$:

$$X = \frac{x}{y}Y, \quad Y = Y, \quad Z = \frac{1 - x - y}{y}Y$$



Sistema Padrão CIE- XYZ

- Vistas do plano $X+Y+Z=1$



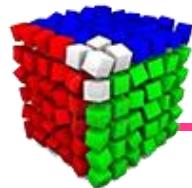
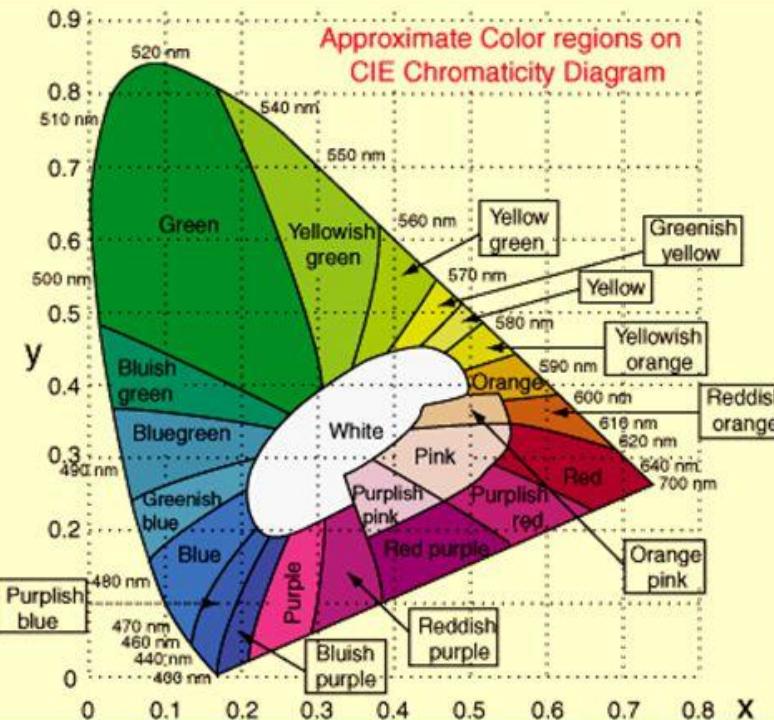


Diagrama de Cromaticidade

Interpretação do diagrama de cromaticidade CIE



Color name	Red	Green	Blue
Red	191	27	75
Pink	245	220	208
Reddish orange	216	119	51
Orange pink	240	204	162
Orange	228	184	29
Yellowish orange	231	224	0
Yellow	234	231	94
Greenish yellow	235	233	0
Yellow green	185	214	4
Yellowish green	170	209	60
Green	0	163	71
Bluish green	24	162	121
Bluegreen	95	164	190
Greenish blue	110	175	199
Blue	92	138	202
Purplish blue	88	121	191
Bluish purple	92	102	177
Purple	246	85	158
Reddish purple	196	64	143
Purplish pink	243	208	219
Red purple	175	35	132
Purplish red	209	65	136
White	255	255	255

Diagrama que caracteriza as cores por um parâmetro Y de Luminância e duas coordenadas de cores x e y que especifica o ponto no diagrama de cromaticidade.

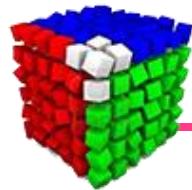
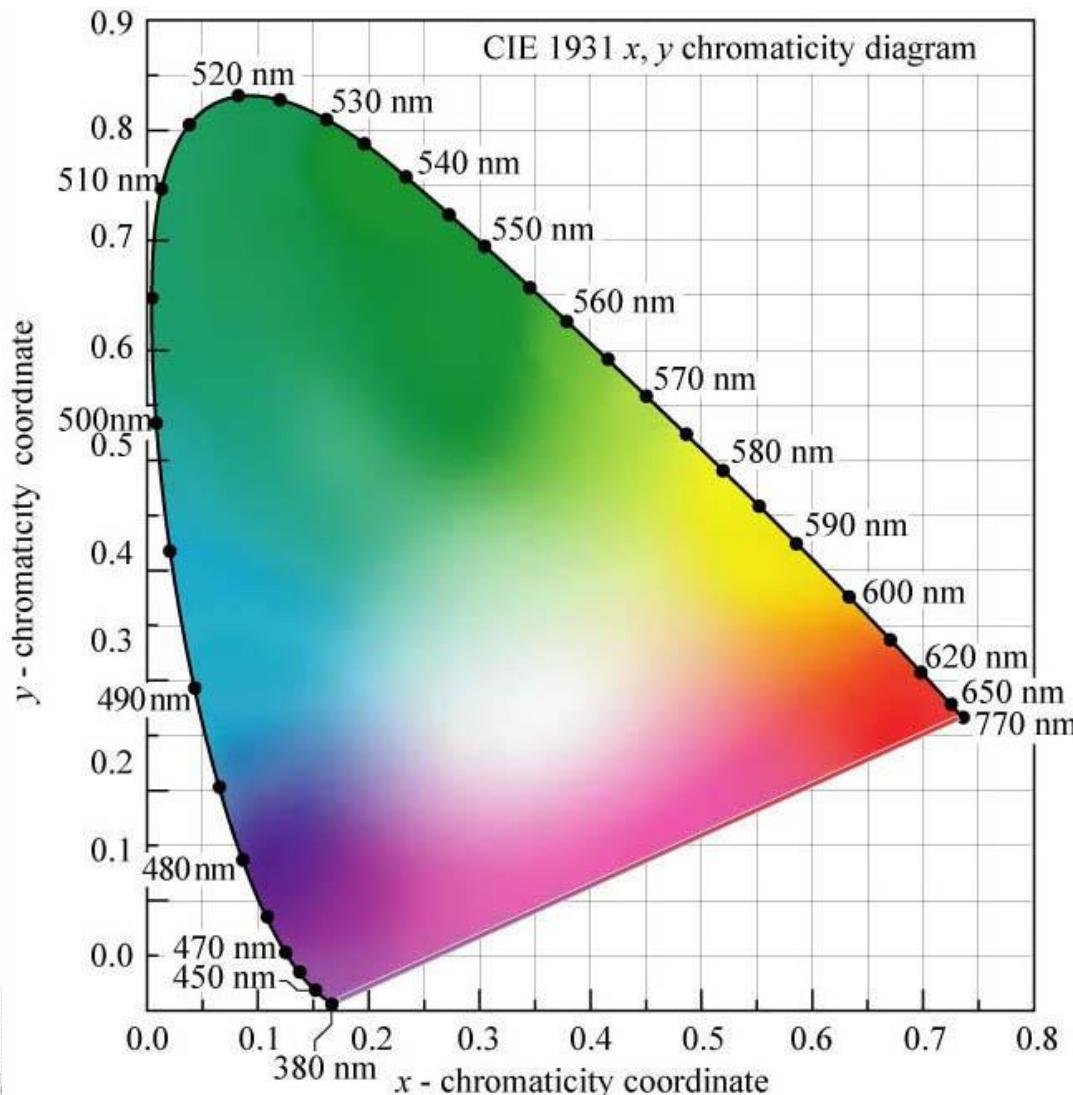


Diagrama de Cromaticidade



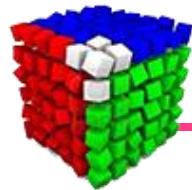
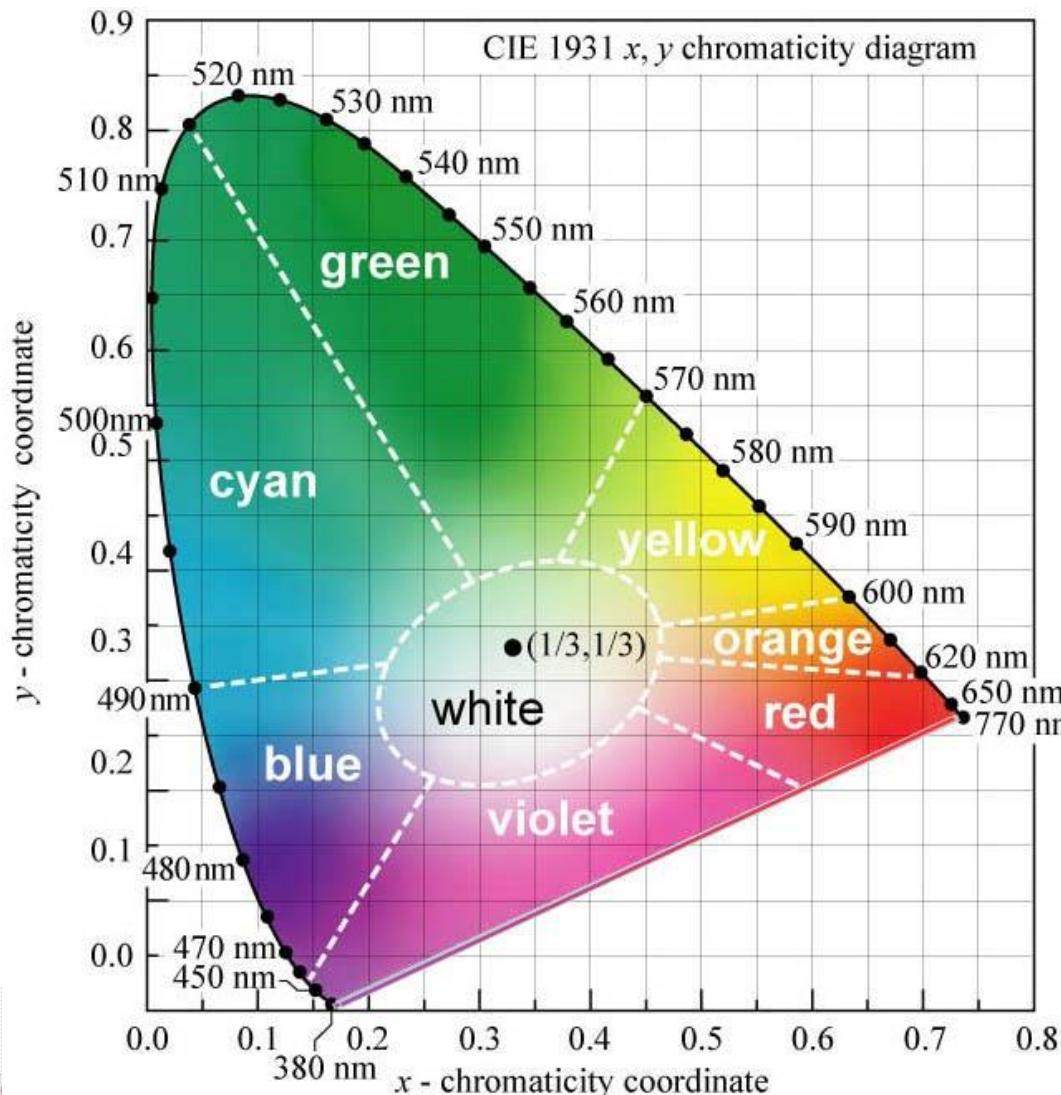


Diagrama de Cromaticidade



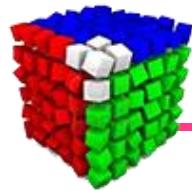
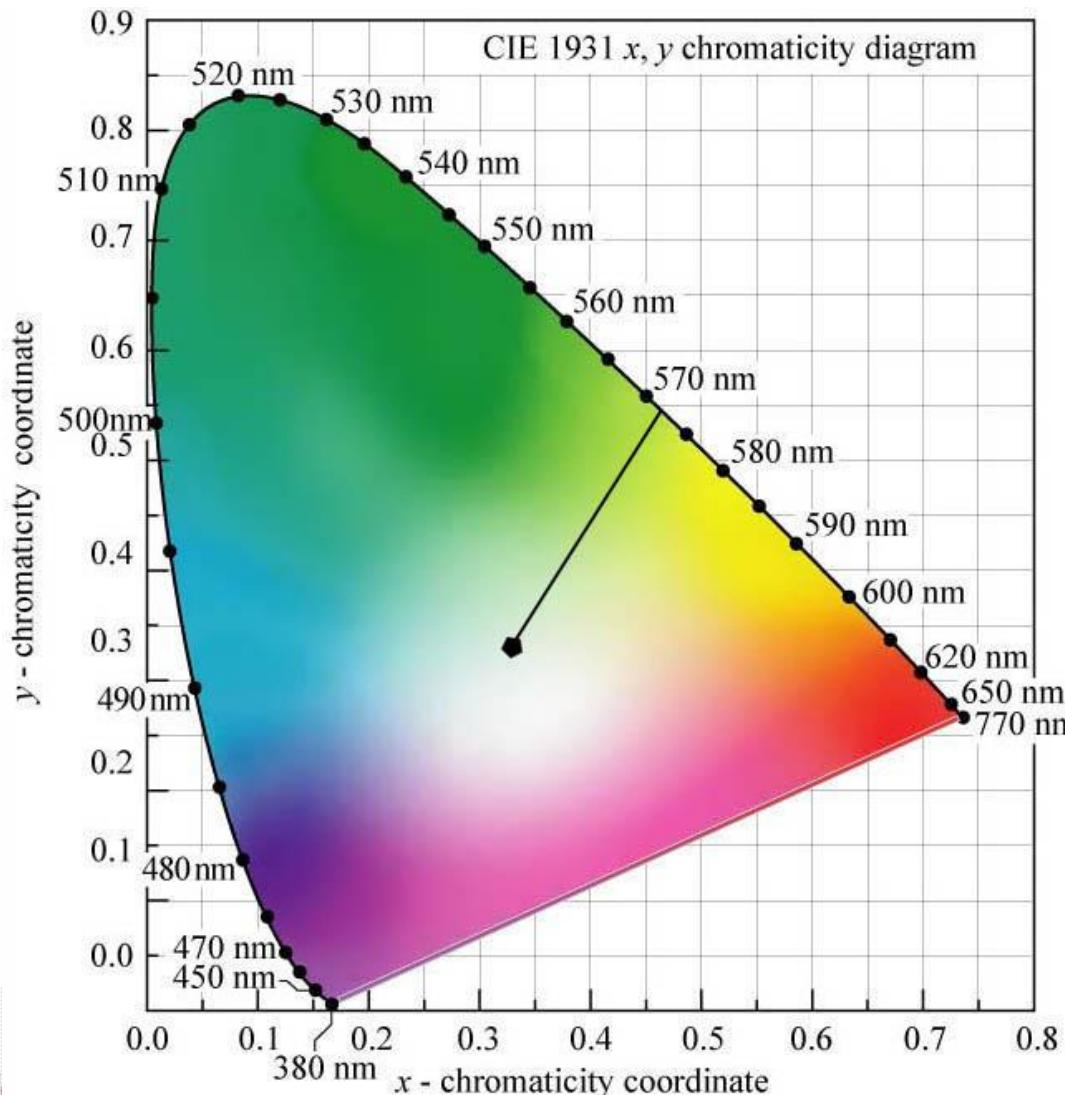


Diagrama de Cromaticidade



Saturação

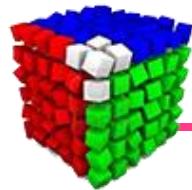
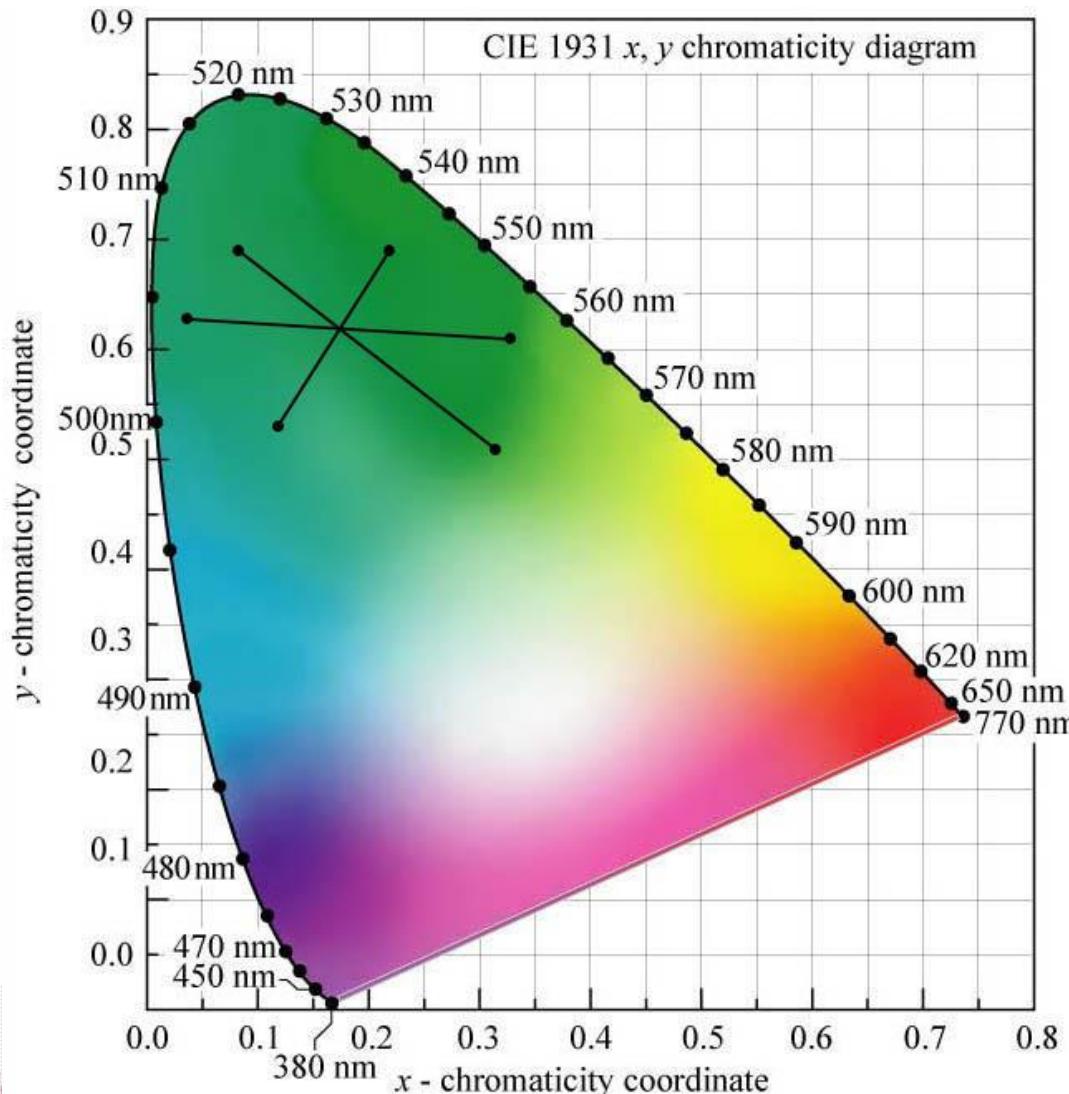


Diagrama de Cromaticidade



Metâmeros:
Cores que
parecem
iguais

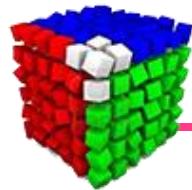
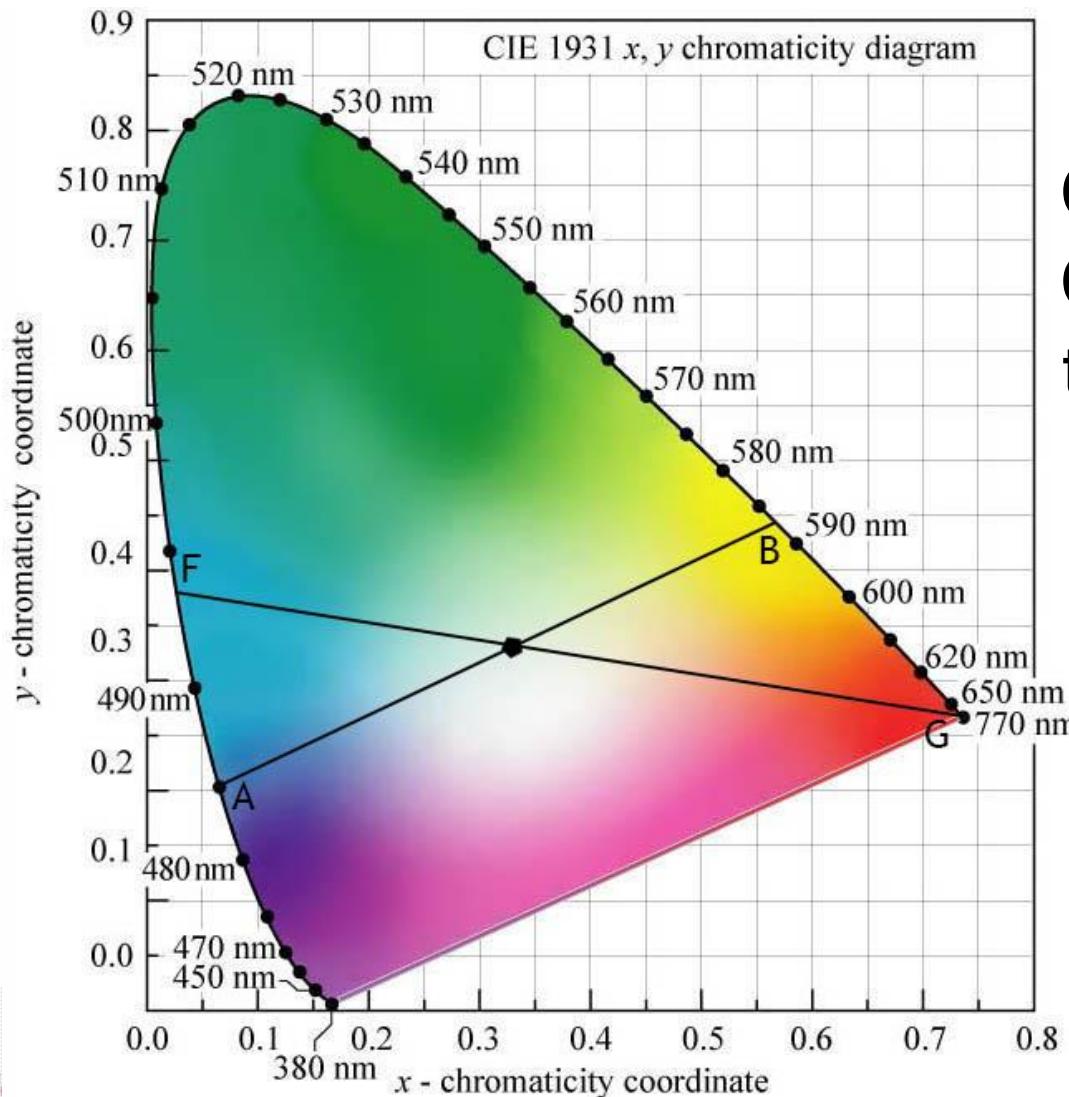


Diagrama de Cromaticidade

Cores
Complementares



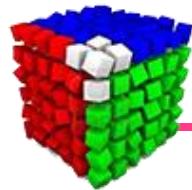
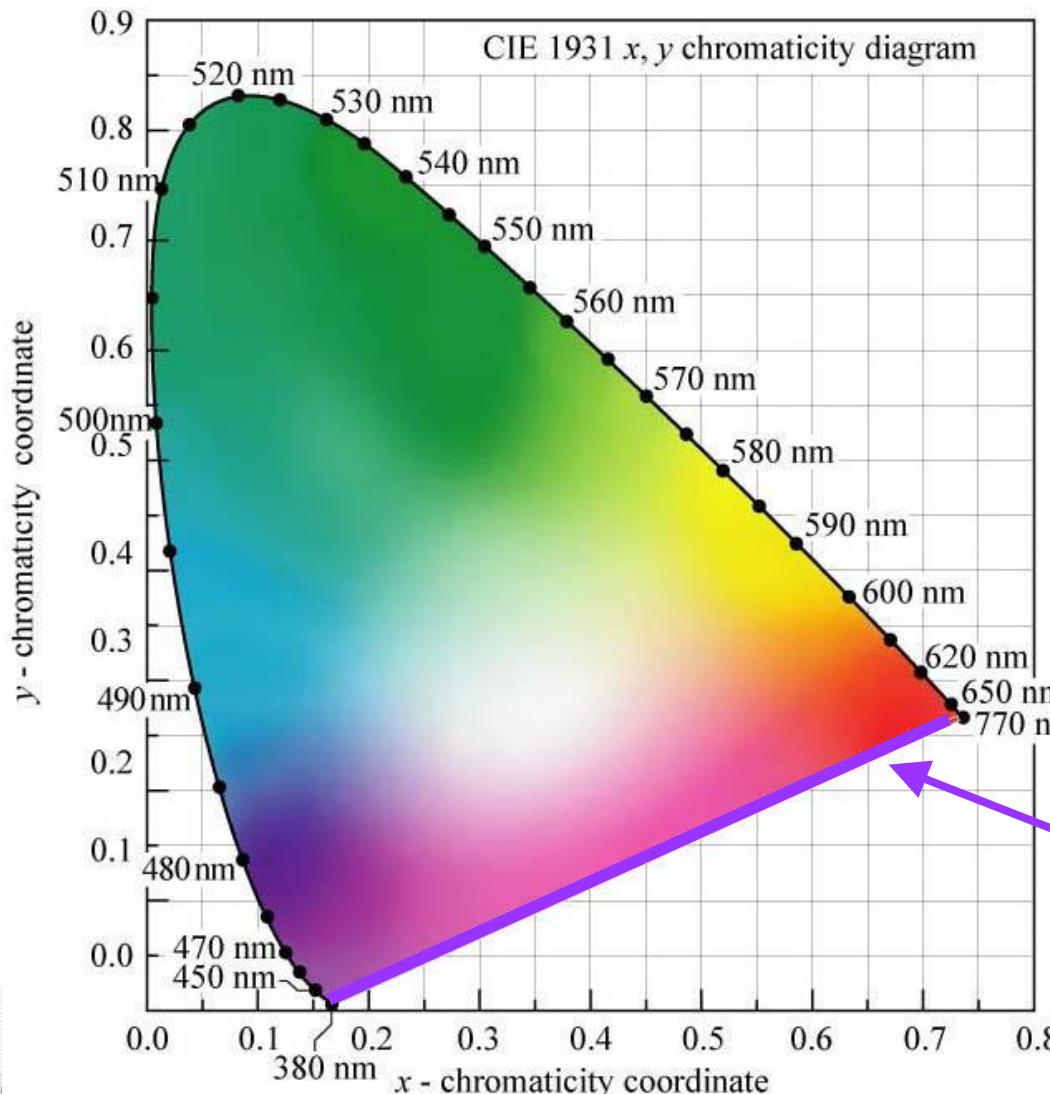
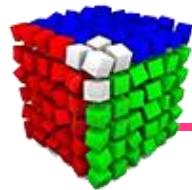


Diagrama de Cromaticidade





Conversão entre RGB e XYZ

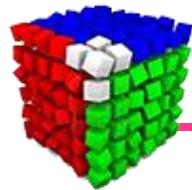
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.2405 & -1.5371 & -0.4985 \\ -0.9693 & 1.8706 & 0.0416 \\ 0.0556 & -0.2040 & 1.0572 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\text{Ex.: } Y = 0,2126 \cdot R + 0,7152 \cdot G + 0,0722 \cdot B$$

Sistema Computacional de Cores

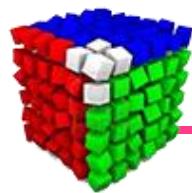




Sistema Computacional de Cores

- Cada tom (R, G e B) é armazenado em 1B
- Resolução de Cor:
 - 2 cores (1 bit)
 - 16 cores (4 bits)
 - 256 cores (8 bits = 1 byte)
 - 16 milhões de cores (24 bits = 3 bytes)

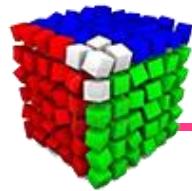
Paleta de Cores



Sistema Computacional de Cores

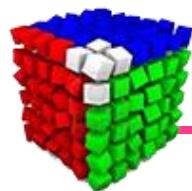
■ Sistema RGB

NUMBERS		
R 255	R 102	R 51
G 0	G 102	G 204
B 0	B 255	B 153
R 255	R 255	R 51
G 255	G 0	G 204
B 102	B 204	B 255
R 51	R 51	R 255
G 51	G 51	G 153
B 0	B 153	B 153



Tons de cinza

- Níveis de brilho
- Níveis de cinza
- Conversão de um modelo (RGB, por exemplo) para uma representação de brilho da cor
 - Ex.: $C = \lceil 0,39R + 0,59G + 0,11B \rceil$



Tons de cinza

- Exemplos de conversão



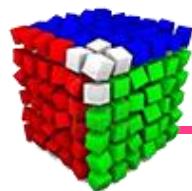
Original



Média



Pesos



Tons de cinza

- Exemplos de conversão



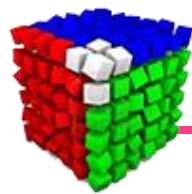
Red



Green

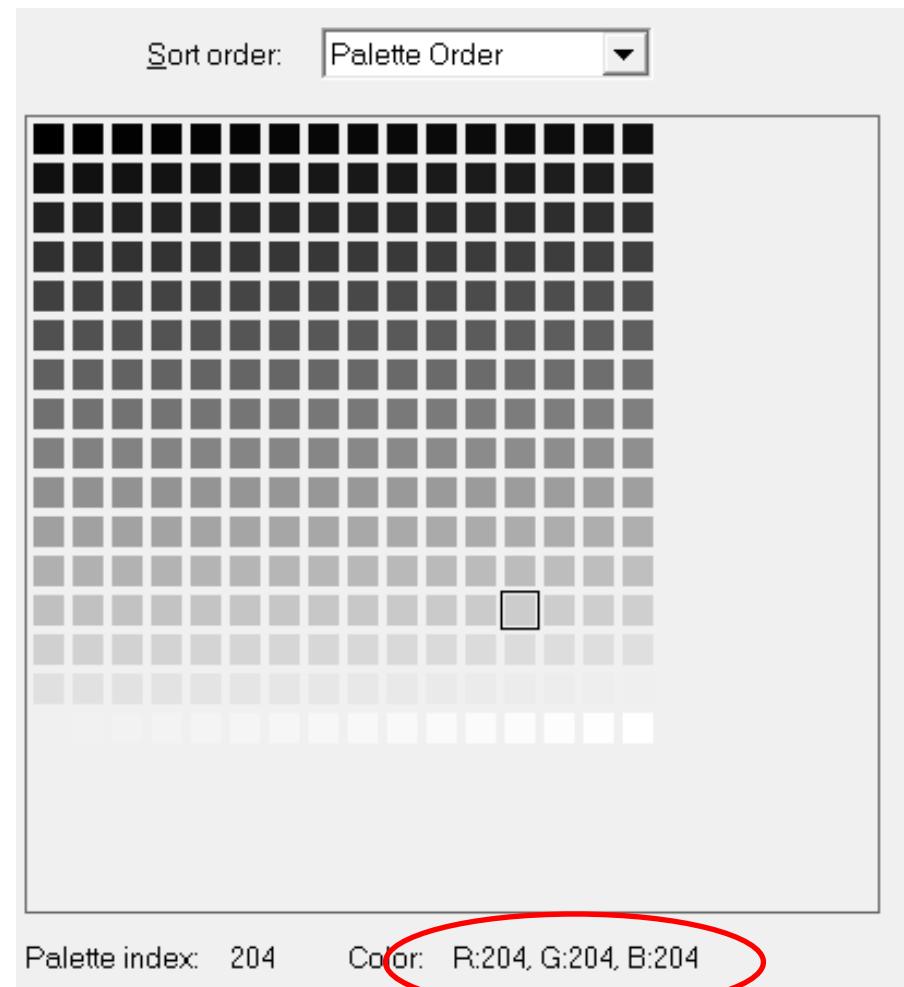


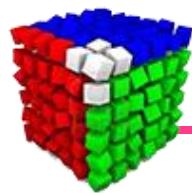
Blue



Tons de cinza

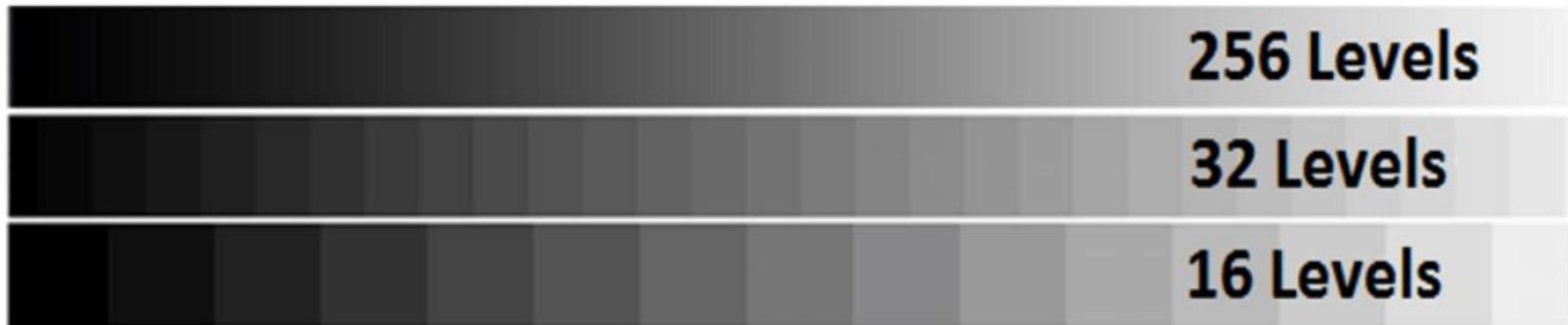
- Tons de cinza
(no RGB)

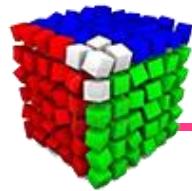




Tons de cinza

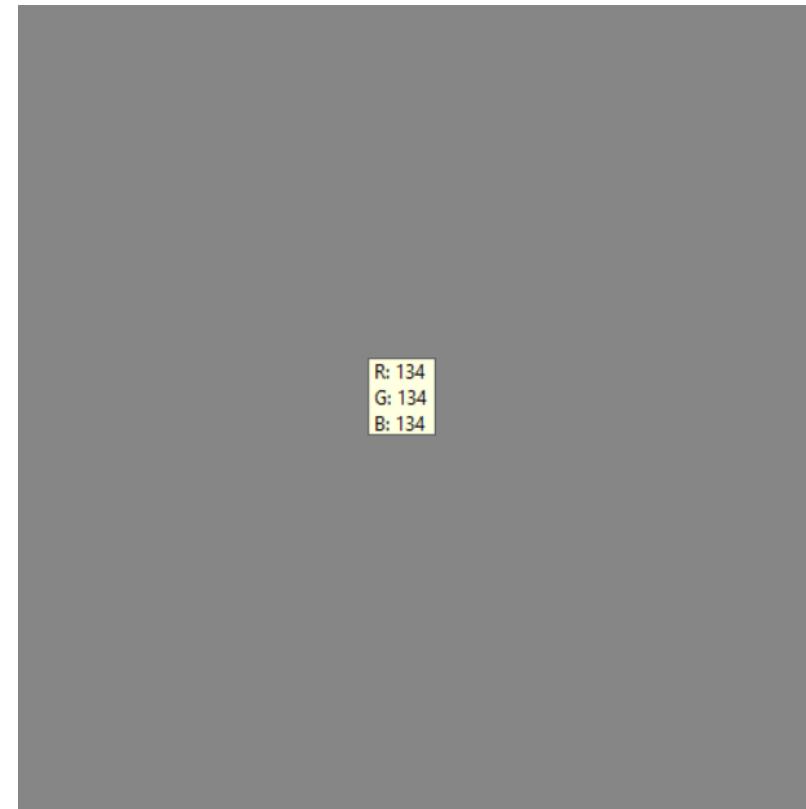
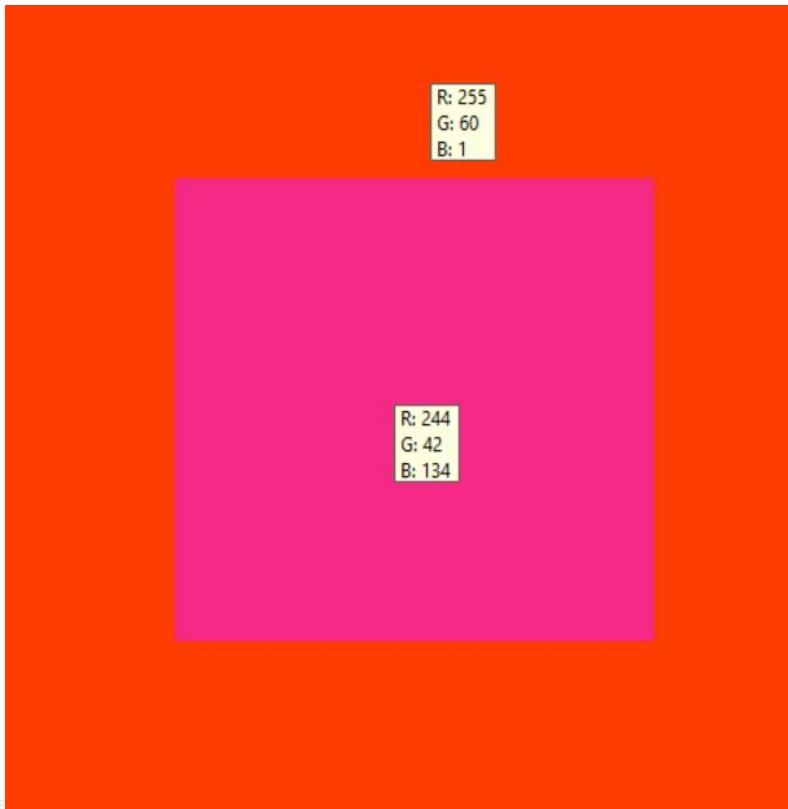
- Tons de cinza (no RGB)

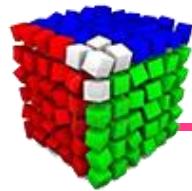




Tons de cinza

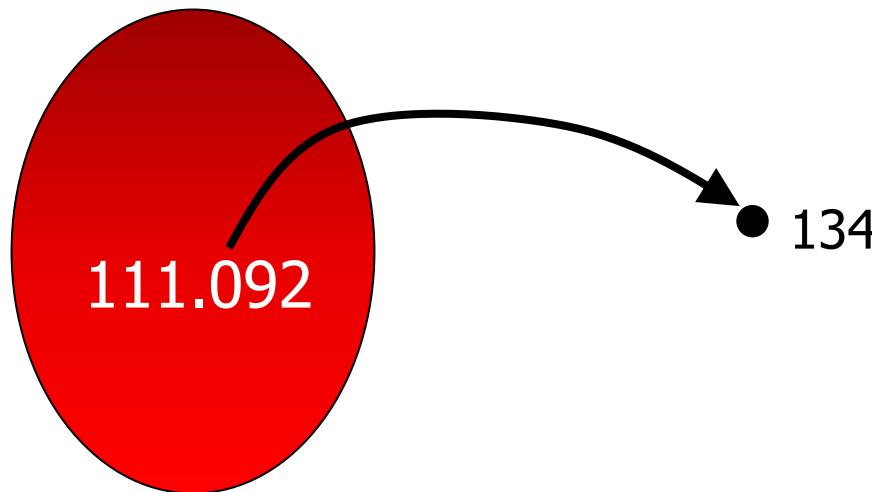
■ Cores metaméricas

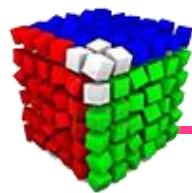




Tons de cinza

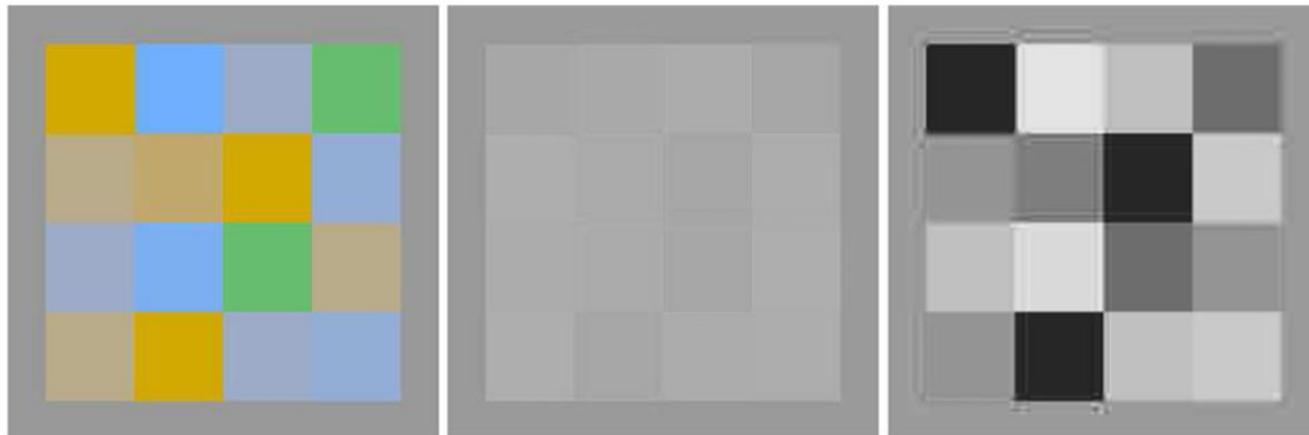
- Cores metaméricas
 - Diferentes cores são mapeadas em um tom apenas
 - Nesse caso anterior, 111.092 cores (RGB) são mapeadas no tom de cinza 134





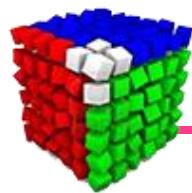
Tons de cinza

- Tema ainda em estudo e desenvolvimento
 - A new perspective on decolorization: feature-preserving decolorization, Orhan Akbulut
 - Signal, Image and Video Processing (2021)
 - <https://doi.org/10.1007/s11760-020-01802-4>



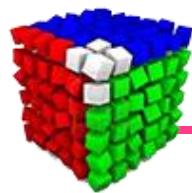
Modelos de Interface





Modelos de Interface

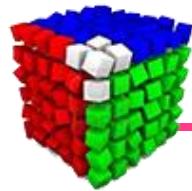
- Os modelos de interface, ou baseados na percepção, são modelos que são caracterizados, no geral, por componentes que descrevem a matiz, saturação e luminância da cor
- Dificilmente, uma pessoa entende uma cor em um modelo como o RGB



Modelo de Munsell

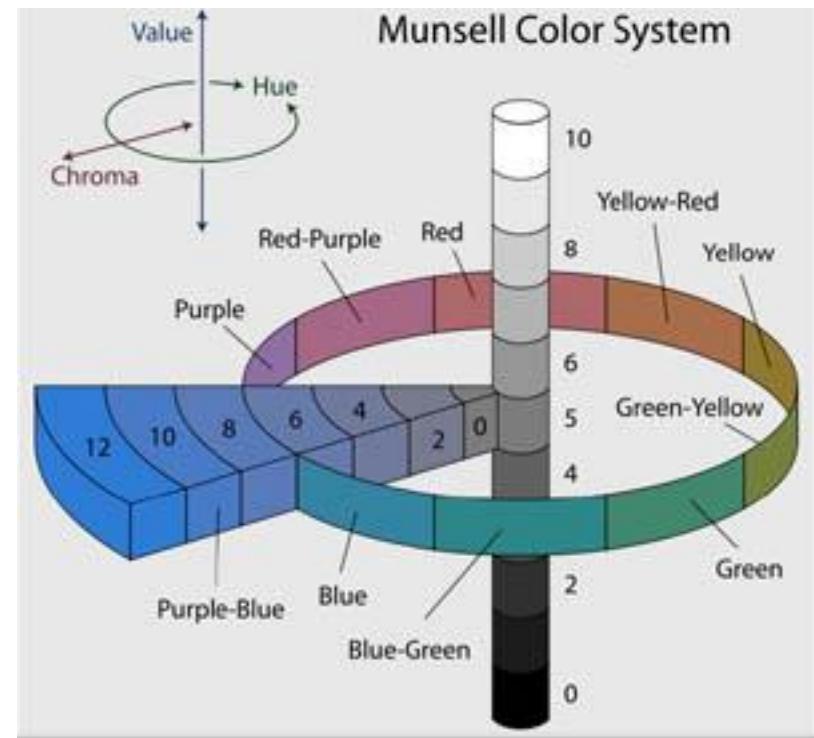
- Tentativa inicial em criar um sistema preciso para descrever cores numericamente
- O Matiz (Hue) é representado em uma ordem natural de cores na forma circular:

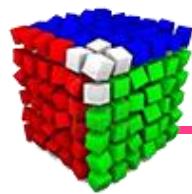




Munsell

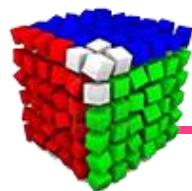
- A Saturação (*Chroma*) é o grau de distância de uma cor qualquer a cor neutra localizada no centro do círculo
- O Brilho (*Value*), representado pelo eixo perpendicular ao círculo, indica a intensidade de luz refletida de uma cor





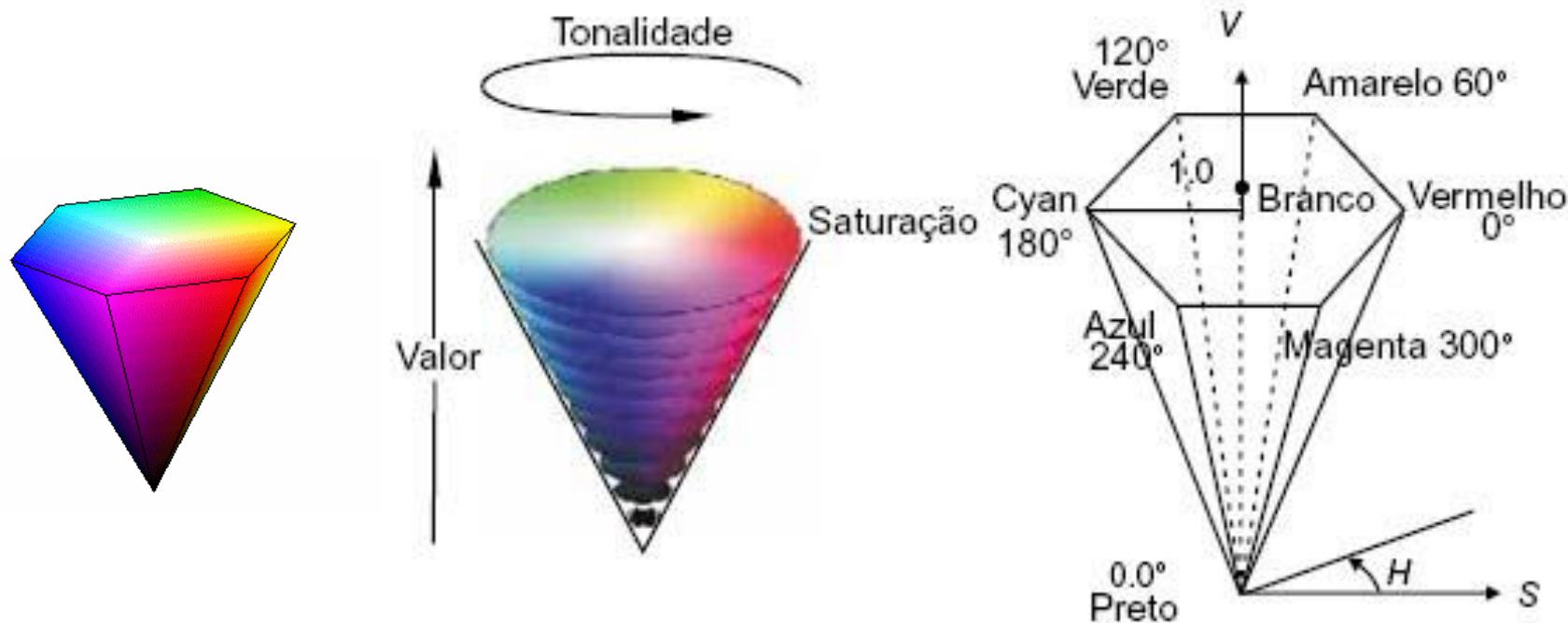
Modelo HSV

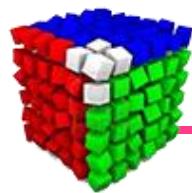
- HSV:
 - *Hue* (Matiz)
 - *Saturation* (Saturação)
 - *Value* (Luminância)
- Desenvolvido em 1978 por Alvey Ray Smith
- Orientado ao usuário - baseado na maneira com que o artista descreve e mistura as cores



Modelo HSV

- Representações do modelo





Modelo HSV - Conversões

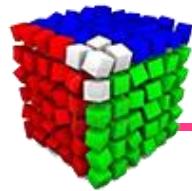
- HSV RGB

$$H = \begin{cases} 60 \frac{(G - B)}{(M - m)}, & M = R \text{ e } G \geq B \\ 60 \frac{(G - B)}{(M - m)} + 360, & M = R \text{ e } G < B \\ 60 \frac{(B - R)}{(M - m)} + 120, & M = G \\ 60 \frac{(R - G)}{(M - m)} + 240, & M = B \end{cases}$$

$$S = \begin{cases} \frac{(M - m)}{M}, & M \neq 0 \\ 0, & M = 0 \end{cases}$$

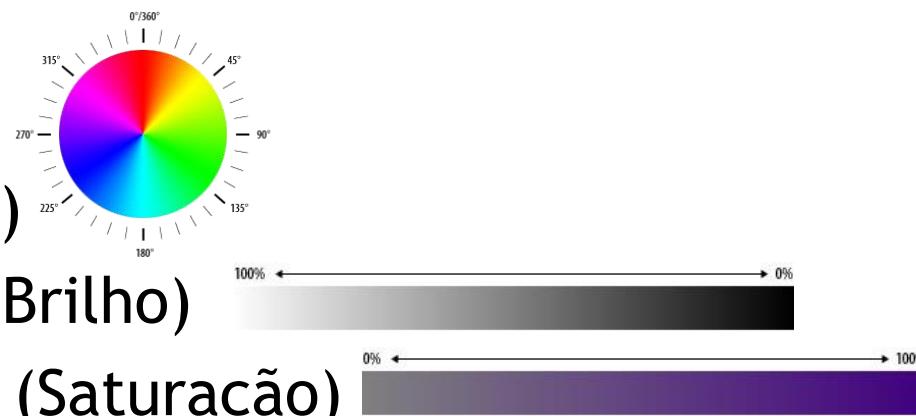
$$\boxed{\begin{aligned} m &= \min(R, G, B) \\ M &= \max(R, G, B) \end{aligned}}$$

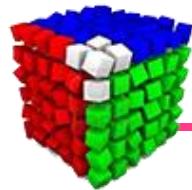
$$V = M$$



Modelo HSL

- HLS:
 - *Hue* (Matiz)
 - *Lightness* (Brilho)
 - *Saturation* (Saturação)
- Modelo alternativo para o HSV
- Desenvolvido por Gerald Murch da Tektronix
- Fácil de ser utilizado
- Definido por um hexágono duplo





Modelo HSL

- HLS

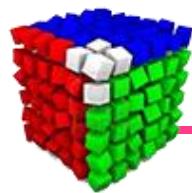
$$L = \frac{M + m}{2}$$

H calculado como antes.

$$S = \begin{cases} \frac{(M - m)}{(M + m)}, & 0 < L \leq 0.5 \\ \frac{(M - m)}{2 - (M + m)}, & L > 0.5 \end{cases}$$

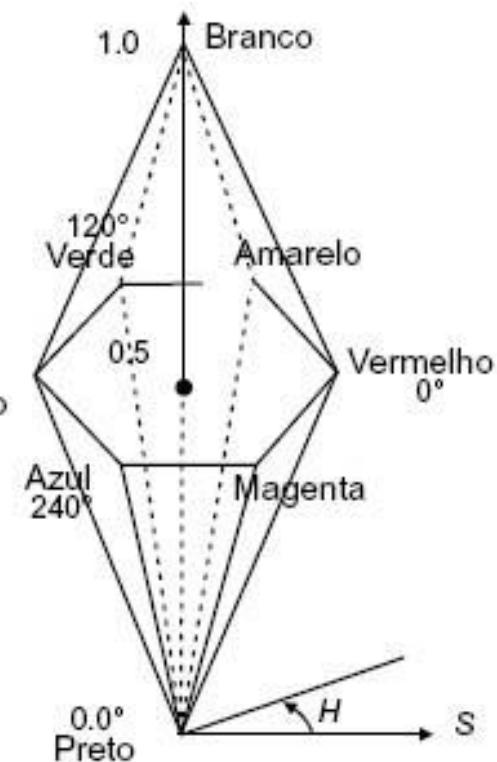
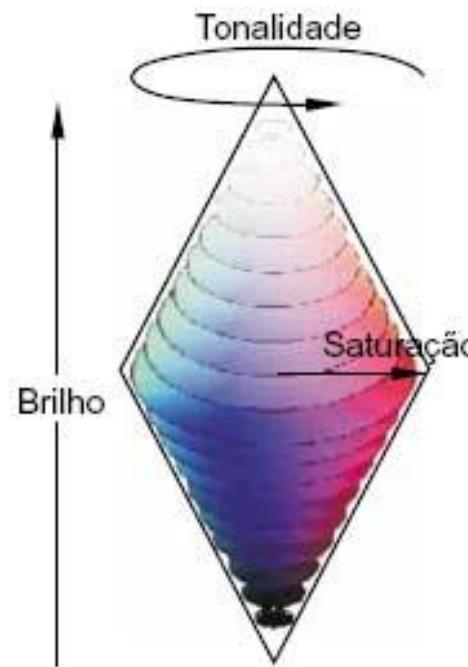
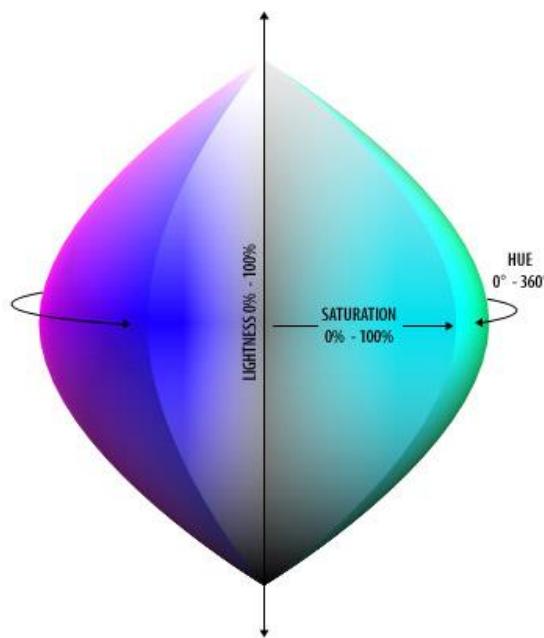
$$m = \min(R, G, B)$$

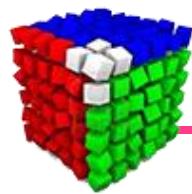
$$M = \max(R, G, B)$$



Modelo HSL

- Representações do modelo





Modelo HSI

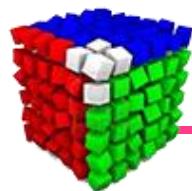
- HSI
 - *Hue* (Matiz)
 - *Saturation* (Saturação)
 - *Intensity* (Intensidade)

$$H = \begin{cases} \cos^{-1}(\alpha), & B \leq G \\ 360^\circ - \cos^{-1}(\alpha), & B > G \end{cases}$$

$$S = 1 - \frac{3 \min(R, G, B)}{R + G + B}$$

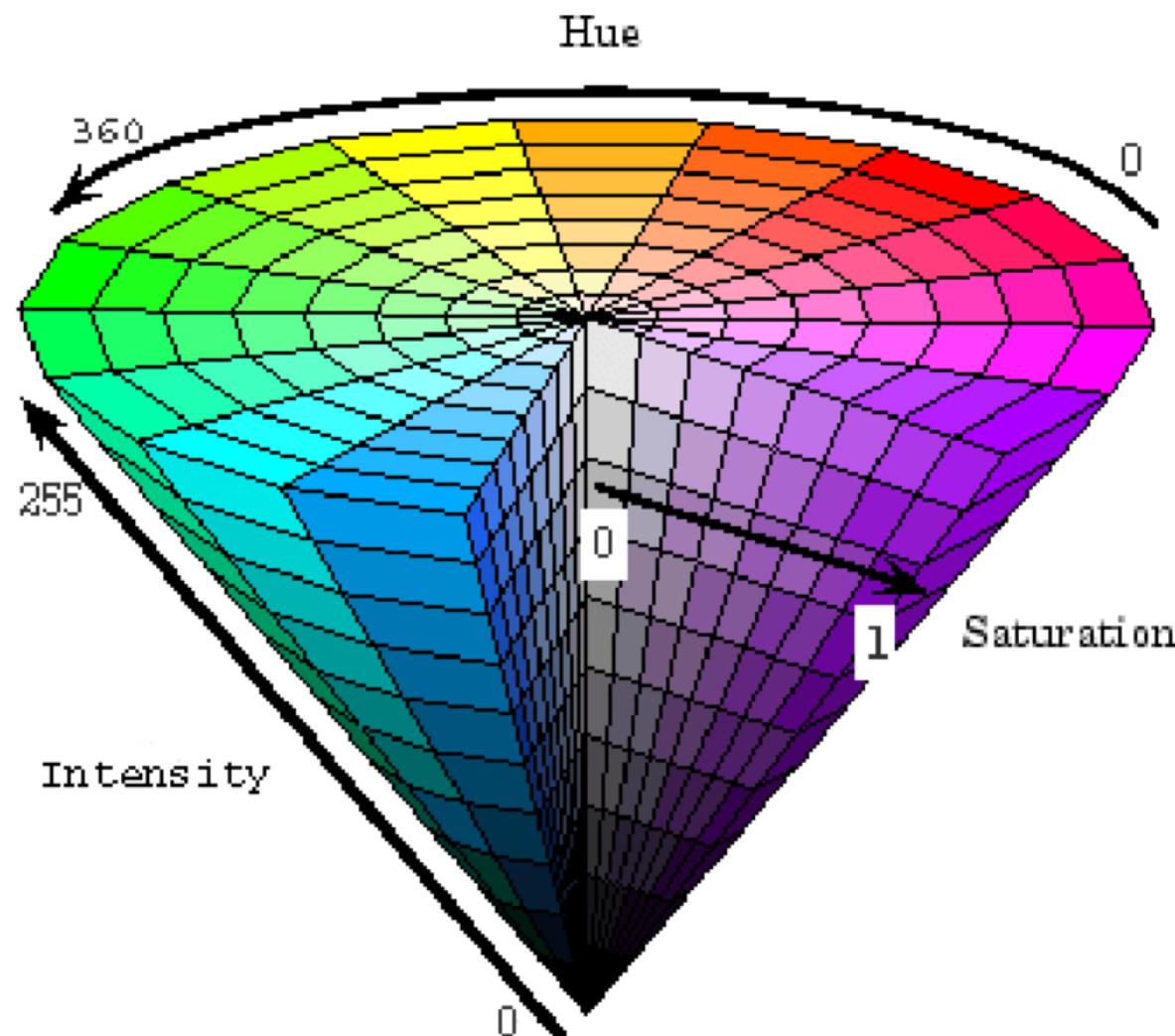
$$I = \frac{R + G + B}{3}$$

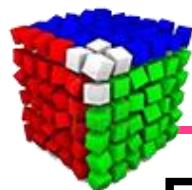
$$\alpha = \frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}$$



Modelo HSI

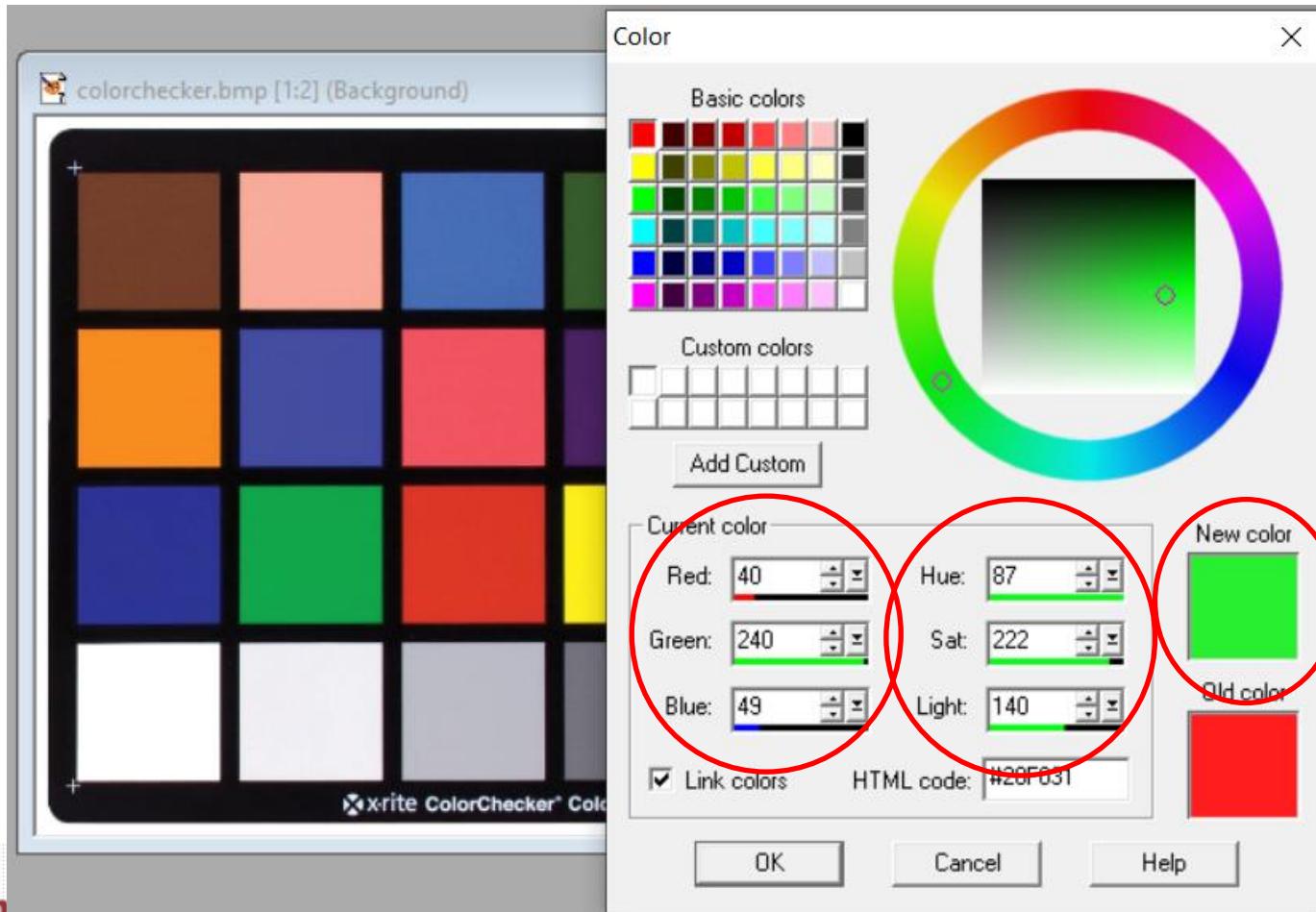
- HSI

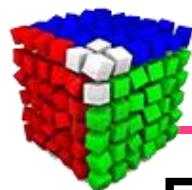




No Computador....

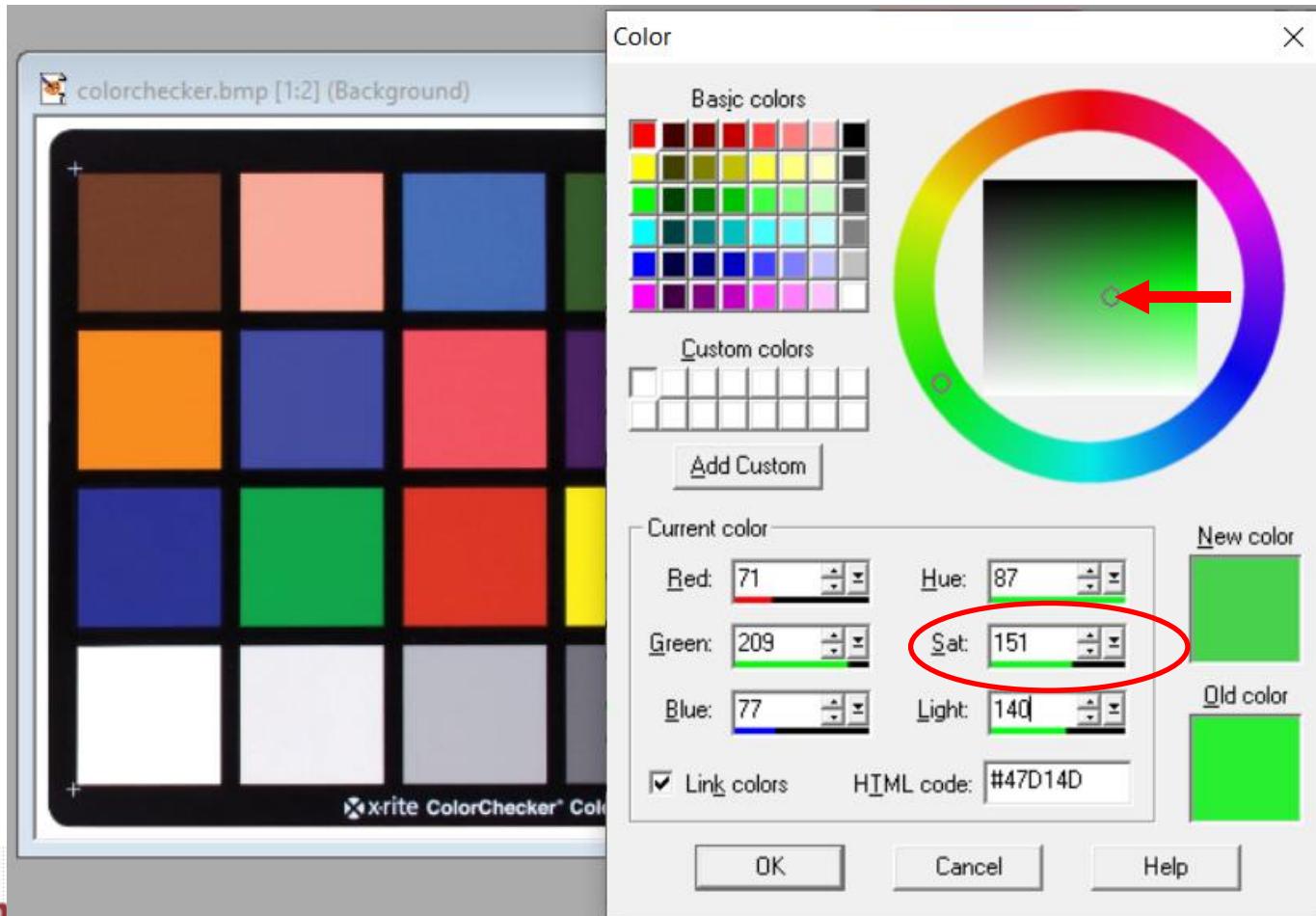
■ Exemplo:

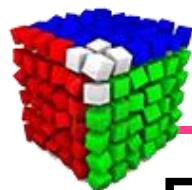




No Computador....

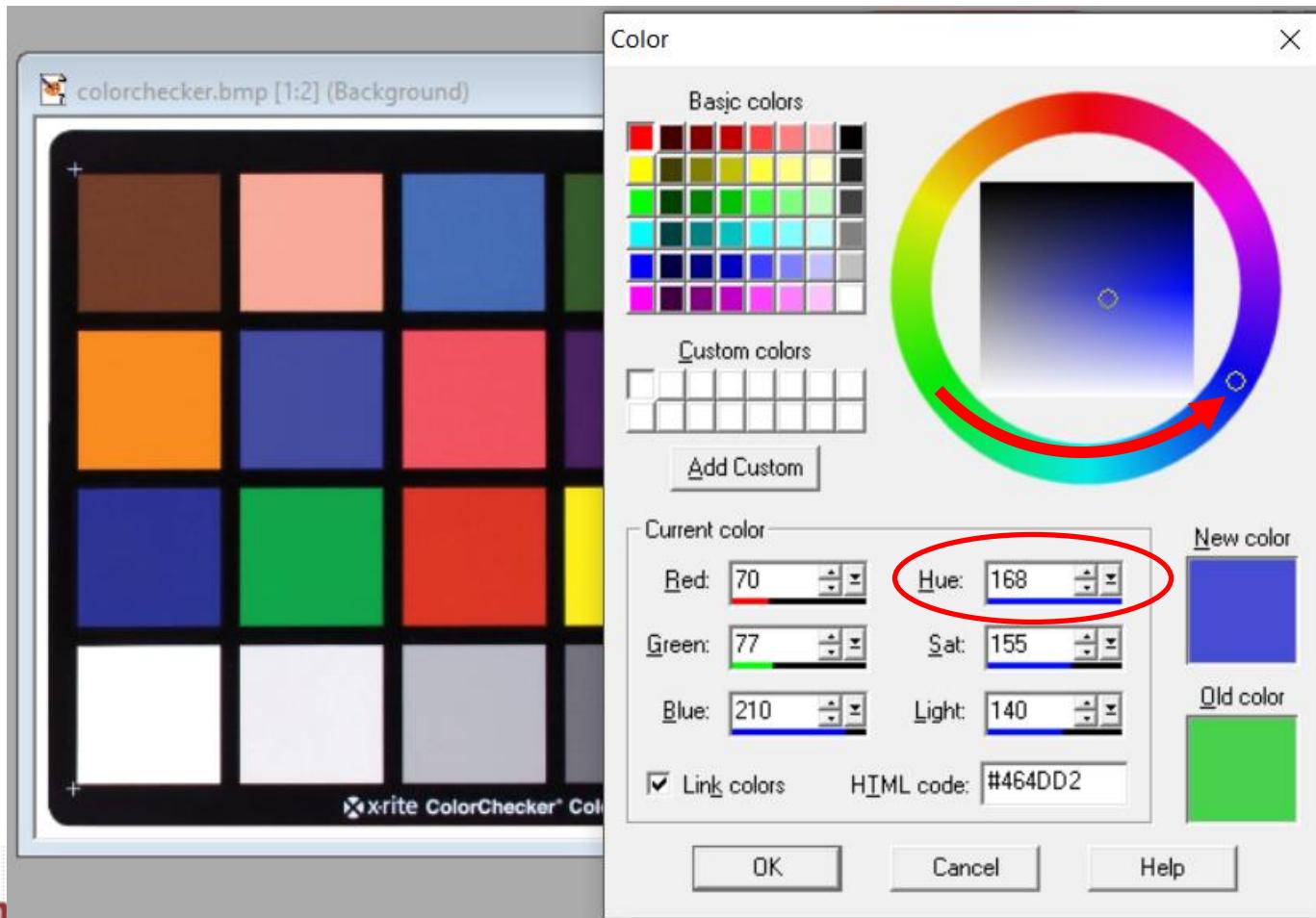
■ Exemplo:

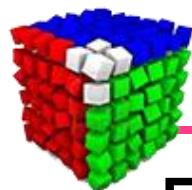




No Computador....

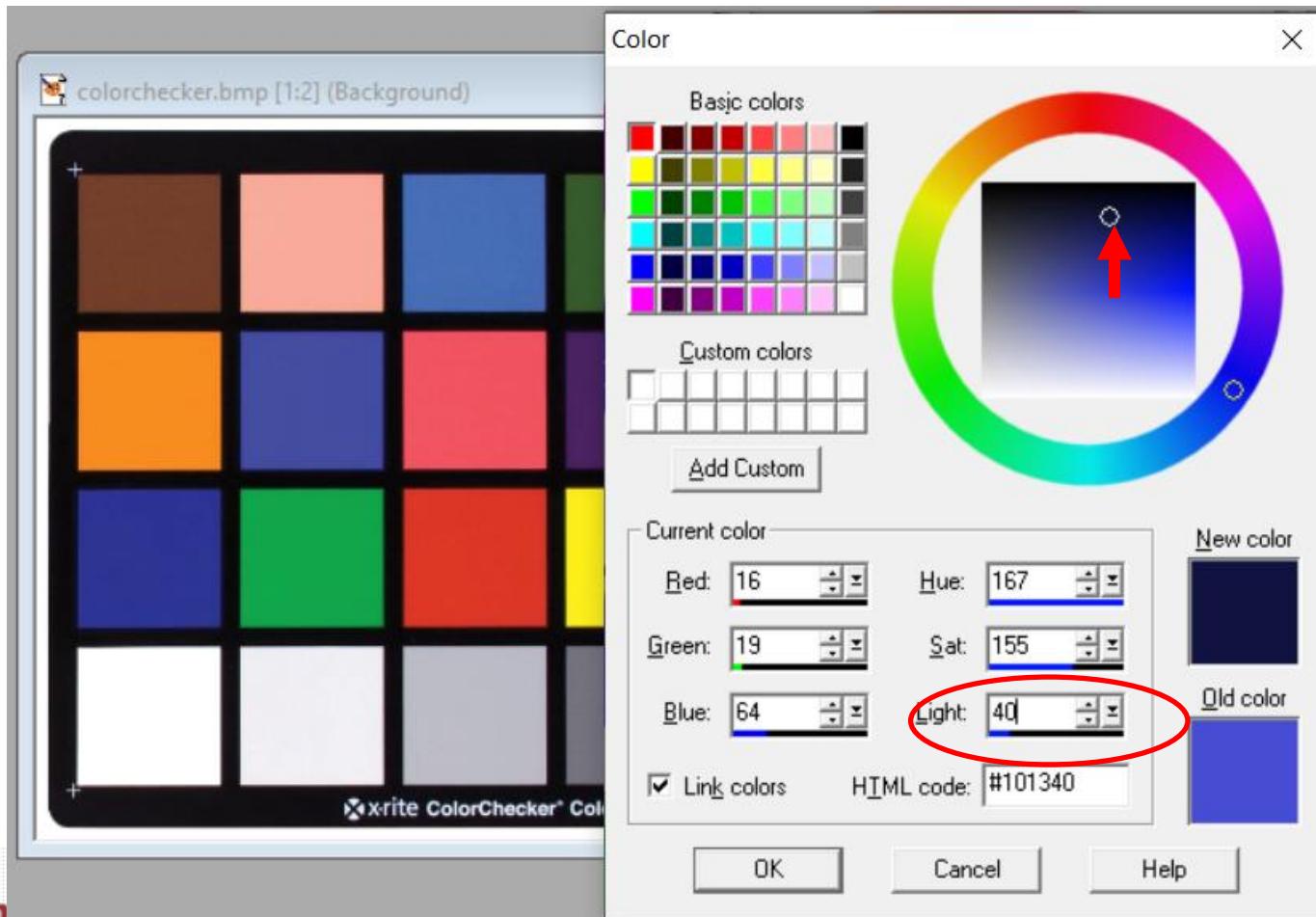
■ Exemplo:





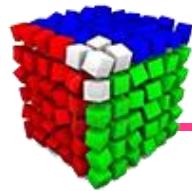
No Computador....

■ Exemplo:



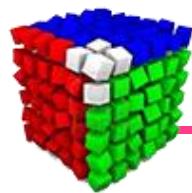
Modelos Uniformes





Modelos Uniformes

- Em 1976, o Comitê Internacional de Iluminação criou dois modelos de cor ditos *uniformes*, ou seja, a distância euclidiana entre duas cores nesses modelos tendem a ter a mesma diferença perceptual
- Nomeados de $L^*u^*v^*$ e $L^*a^*b^*$, mais conhecidos como CIE-LUV e CIE-LAB (ou Luv e Lab), esses modelos são derivados do modelo padrão CIE-XYZ e são bastante utilizados em aplicações de processamento de cor, principalmente quando cores similares são analisadas



CIE L*u*v*

- Modelo uniforme para misturas aditivas de cores

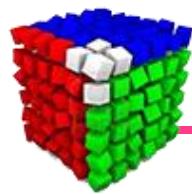
$$L^* = \begin{cases} 116 * \sqrt[3]{\frac{Y}{Y_n}} - 16, & \frac{Y}{Y_n} > 0,008856 \\ 903,3 * \frac{Y}{Y_n}, & \frac{Y}{Y_n} \leq 0,008856 \end{cases}$$

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

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

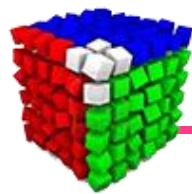
$$u' = 4X/(X + 15Y + 3Z) \quad u'_n = 4X_n/(X_n + 15Y_n + 3Z_n)$$

$$v' = 9Y/(X + 15Y + 3Z) \quad v'_n = 9Y_n/(X_n + 15Y_n + 3Z_n)$$



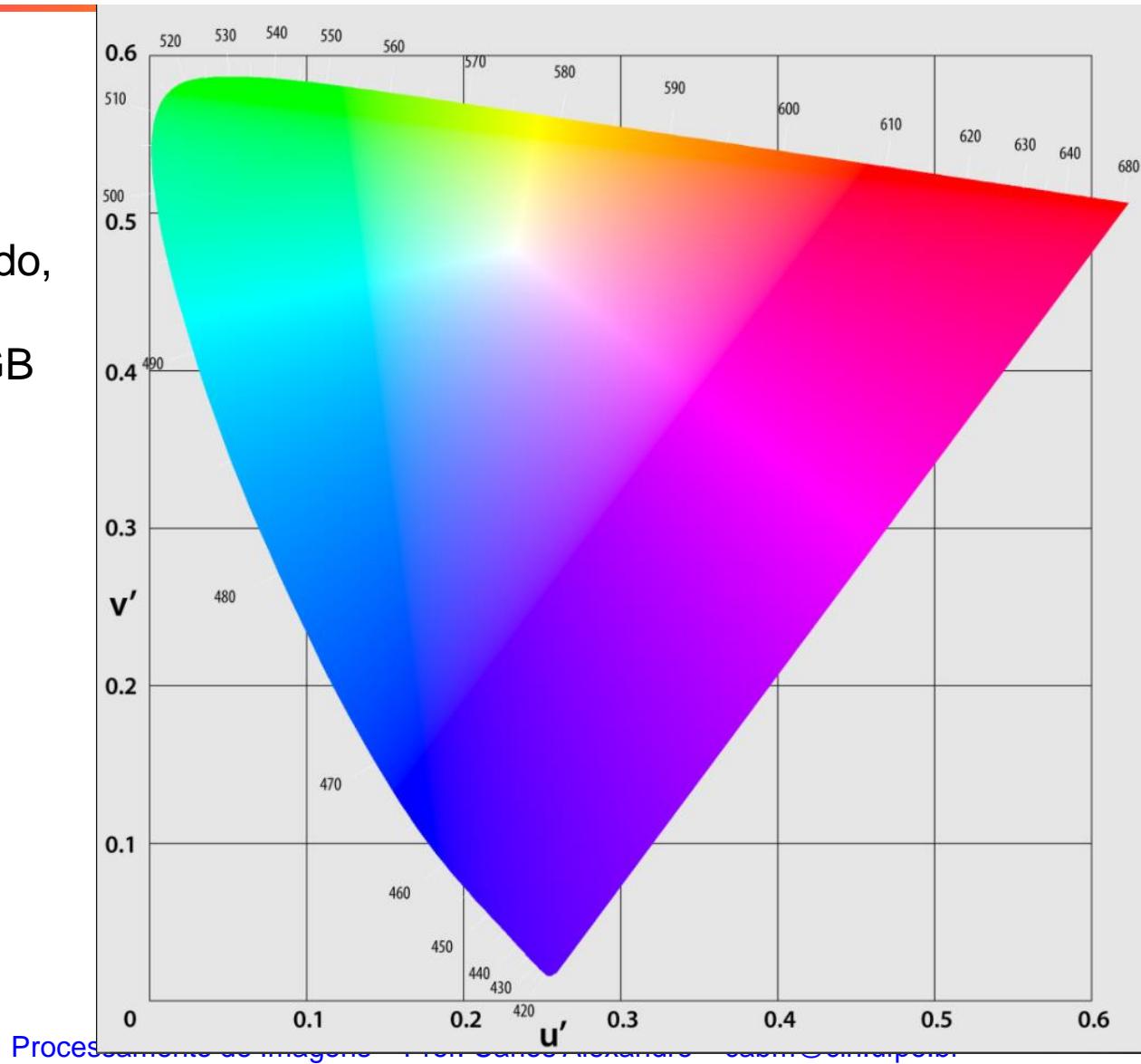
CIE L^{*}u^{*}v^{*}

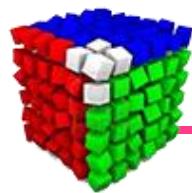
- u^{*} e v^{*} estão no intervalo ±100%
- 0 ≤ L^{*} ≤ 100%
- (X_n, Y_n, Z_n) representa a cor branca de referência



CIE L*u*v*

Diagrama aproximado,
afinal, tem que ser
apresentado em RGB





CIE L*a*b*

- Modelo uniforme para misturas subtrativas de cores

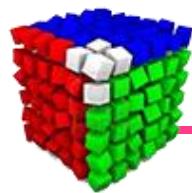
$$L^* = \begin{cases} 116 * \sqrt[3]{\frac{Y}{Y_n}} - 16, & \frac{Y}{Y_n} > 0,008856 \\ 903,3 * \frac{Y}{Y_n}, & \frac{Y}{Y_n} \leq 0,008856 \end{cases}$$

$$a^* = 500 \left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right) \right]$$

$$b^* = 200 \left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right) \right]$$

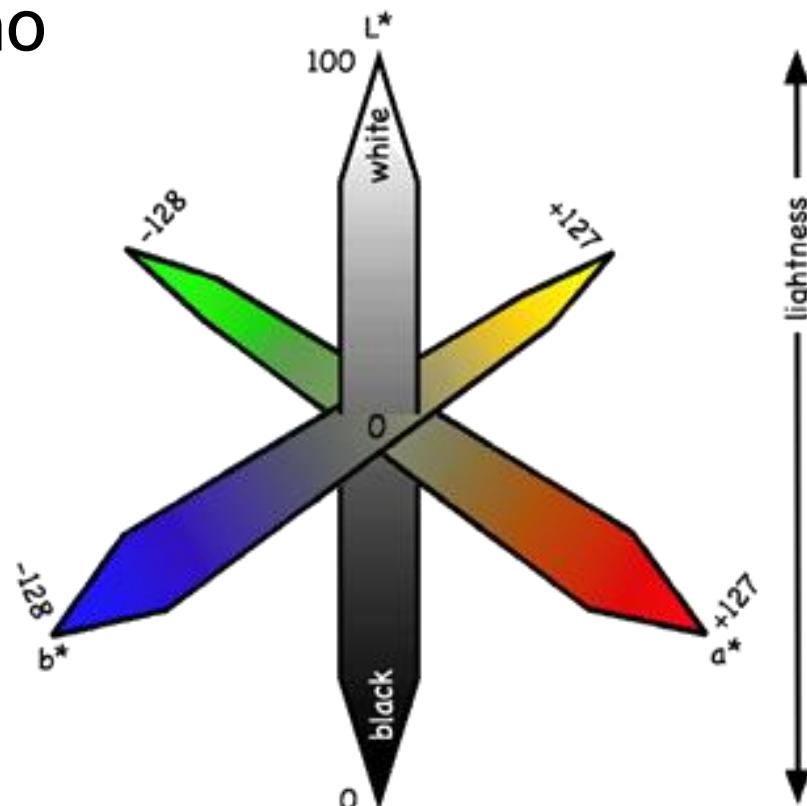
$$f(t) = \begin{cases} \sqrt[3]{t}, & t > 0,008856 \\ 7,787t + \frac{16}{116}, & t \leq 0,008856 \end{cases}$$

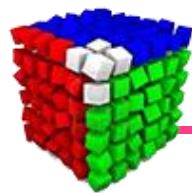
Como antes, (X_n, Y_n, Z_n) é a cor branca de referência.



CIE L*a*b*

- Canal L*: luminância
- Canal a*: verde e vermelho
- canal b*: azul e amarelo

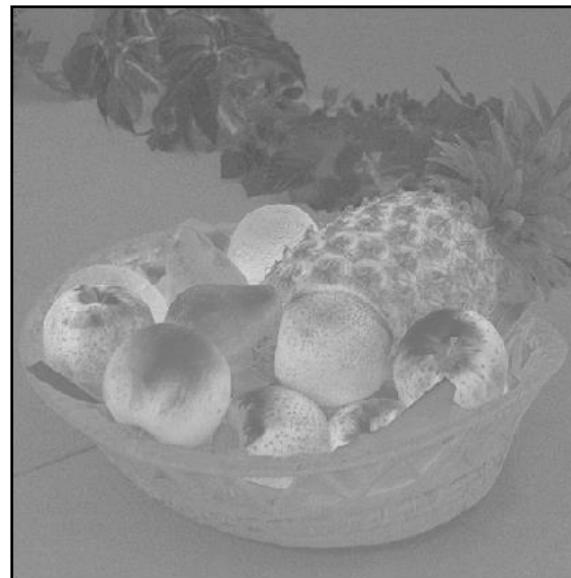




CIE L*a*b*



L^*

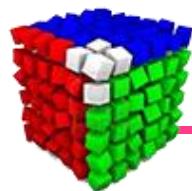


a^*



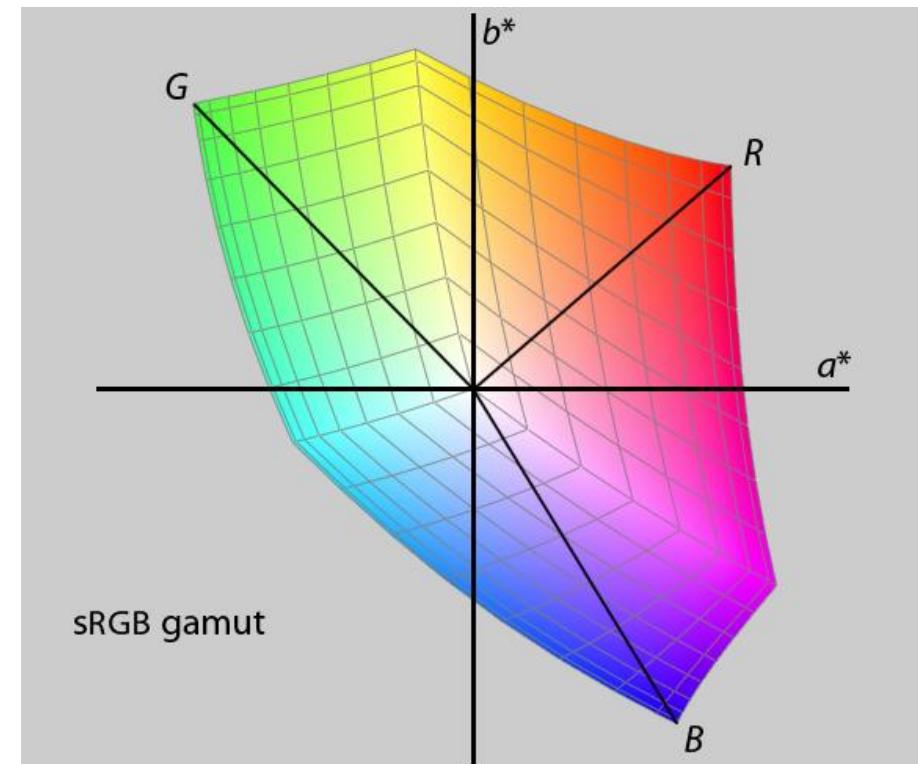
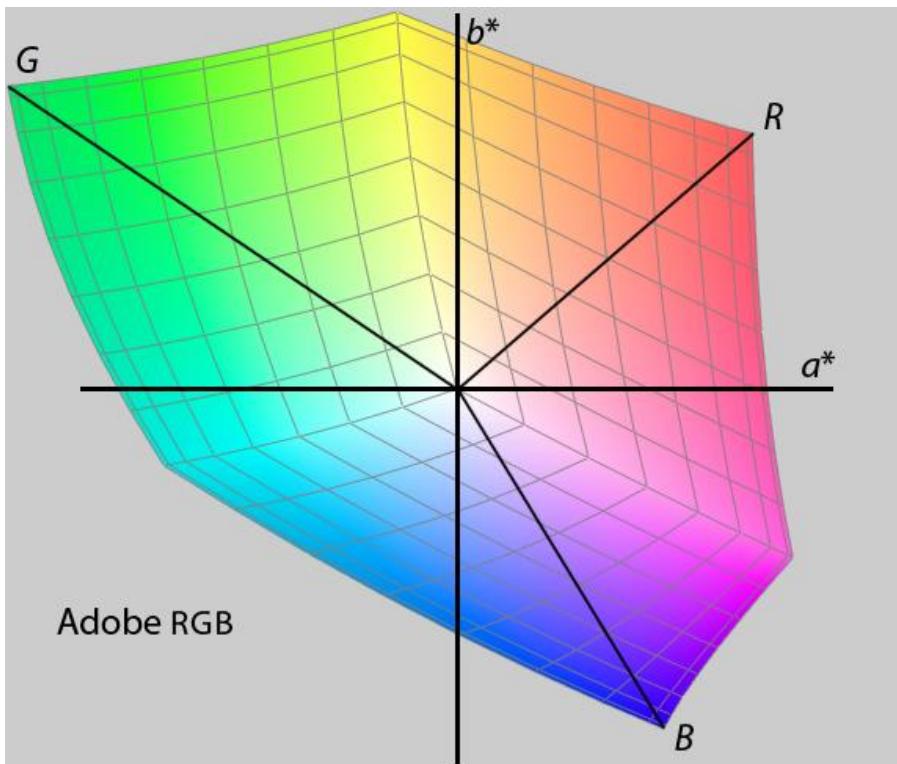
b^*

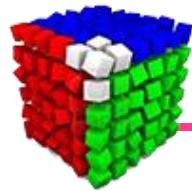
- Obs.: contraste de a^* e b^* aumentado de 40%



CIE L*a*b*

- Visualização RGB no L*a*b*





Diferença entre Cores

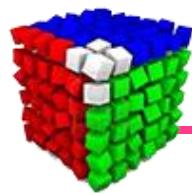
Distância Euclidiana:

$$\text{ColorDist}_{\text{Lab}}(\mathbf{C}_1, \mathbf{C}_2) = \|\mathbf{C}_1 - \mathbf{C}_2\|$$

$$= \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

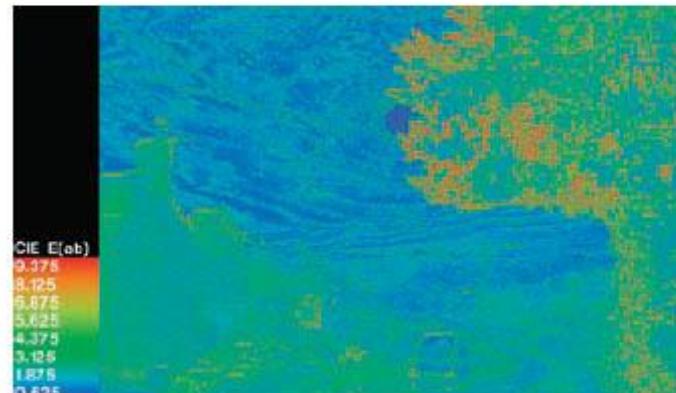
$$\mathbf{C}_1 = (L_1^*, a_1^*, b_1^*)$$

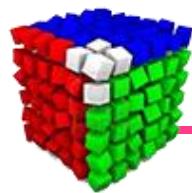
$$\mathbf{C}_2 = (L_2^*, a_2^*, b_2^*)$$



Diferença entre Cores

- Exemplo da utilização da distância - Compressão de imagens





Usando o CIE L*a*b*



Canais L*a*b*

Imagen original

Inversão do canal a*

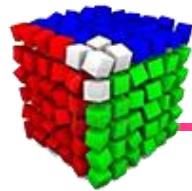


Inversão do canal b*



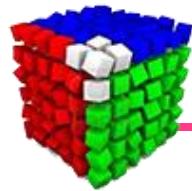
Modelos Baseados em Diferenças Cromáticas





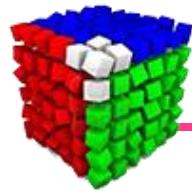
Diferenças Cromáticas

- Os modelos aqui apresentados têm suas transformações fundamentadas em operações de subtração entre as componentes do modelo RGB
 - Podendo, claro, serem utilizados outros modelos como base



Modelo $I_1 I_2 I_3$

- A ideia do modelo é que a operação de subtração entre as componentes do RGB seja responsável por anular os efeitos de reflexão provenientes do tipo da superfície de um objeto
- Por sua vez, a normalização de cada uma dessas subtrações é responsável por anular os efeitos de reflexão dados pelo formato do objeto

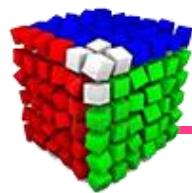


Modelo $|l_1|l_2|l_3$

$$l_1 = \frac{(R - G)^2}{(R - G)^2 + (R - B)^2 + (G - B)^2}$$

$$l_2 = \frac{(R - B)^2}{(R - G)^2 + (R - B)^2 + (G - B)^2}$$

$$l_3 = \frac{(G - B)^2}{(R - G)^2 + (R - B)^2 + (G - B)^2}$$



Modelo $h_1 h_2 h_3$

- Motivado por três questões:
 - Nenhum uso de operações de divisão e multiplicação para diminuir o custo
 - Cores próximas das cores acromáticas ($R = G = B$) são suprimidas no modelo, salientando as diferenças
 - Anular os efeitos de reflexão na superfície de objetos

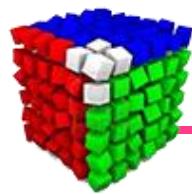
$$h_1 = R - G$$

$$h_2 = G - B$$

$$h_3 = B - R$$

Outros Modelos



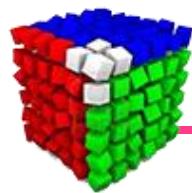


Modelo $I_1 I_2' I_3'$

$$I_1 = \frac{R + G + B}{3}$$

$$I_2' = \frac{R - B}{2}$$

$$I_3' = \frac{2G - R - B}{3}$$

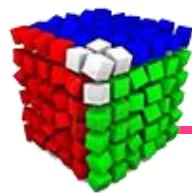


Modelo YO₁O₂

$$Y = 0,2857R + 0,5714G + 0,1429B$$

$$O_1 = R - G$$

$$O_2 = 2B - R - G$$



Modelo R_hG_hB_h

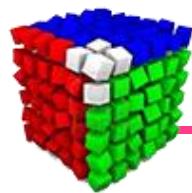
- Combinação não-linear entre os modelo de cor RGB e h₁h₂h₃ com a intenção de compor um modelo de cores com informações de cores acromáticas e de diferenças cromáticas

$$R_h = \alpha \left(\frac{R}{3} \right) + 2 * max(0, R - G)$$

$$G_h = \alpha \left(\frac{G}{3} \right) + 2 * max(0, G - B)$$

$$B_h = \alpha \left(\frac{B}{3} \right) + 2 * max(0, B - R)$$

$$\alpha = \min(R, G, B) / \max(R, G, B)$$

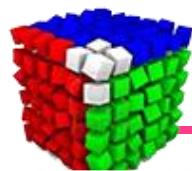


Modelo LgC

- Duas componentes apenas
 - Componente acromática L
 - Unificação das componentes de cromaticidade

$$L = 0,299R + 0,587G + 0,114B$$

$$gC = \sqrt{(R - G)^2 + (G - B)^2 + (B - R)^2}$$



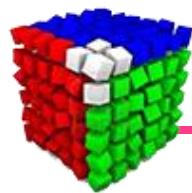
Pantone



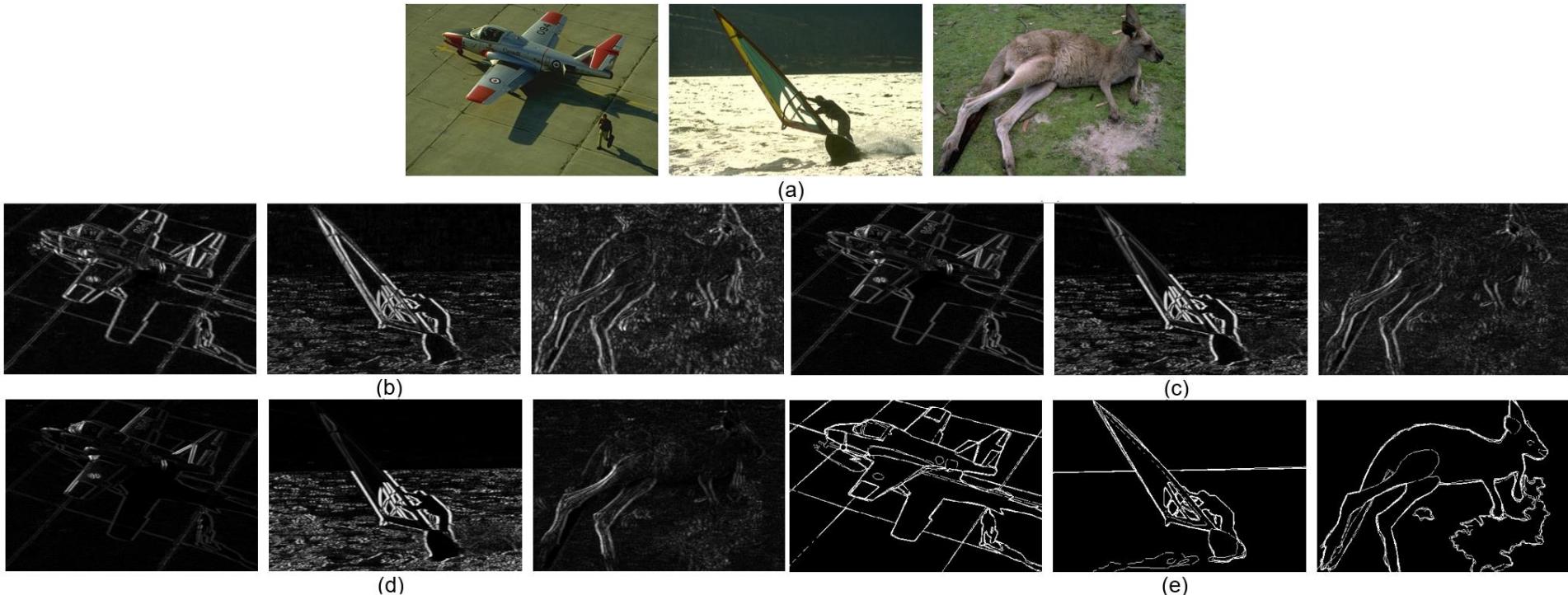
<http://finephoto.com.br/rgb-ou-cmyk/>

Aplicações





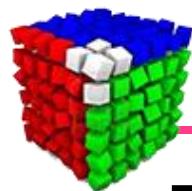
Detecção de Bordas



(a) Imagens originais e bordas detectadas usando os modelos:
(b) Lab, (c) RGB e (d) XYZ. (e) Padrão ouro.

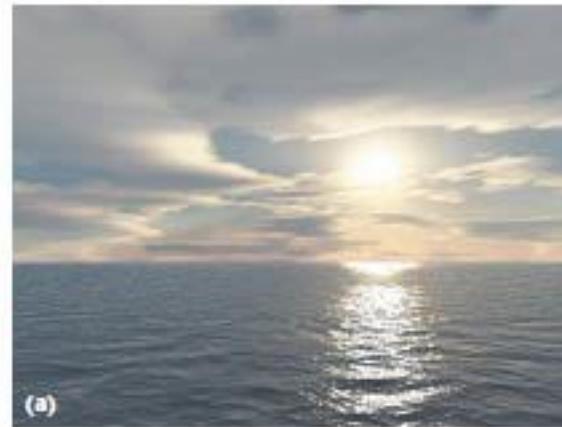
Sugestão de leitura:

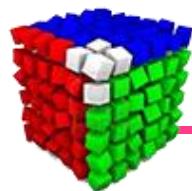
On the Influence of the Color Model for Image Boundary Detection Algorithms based on Convolutional Neural Networks, IEEE IJCNN, 2019
DOI: 10.1109/IJCNN.2019.8851701



Transferência de Cor

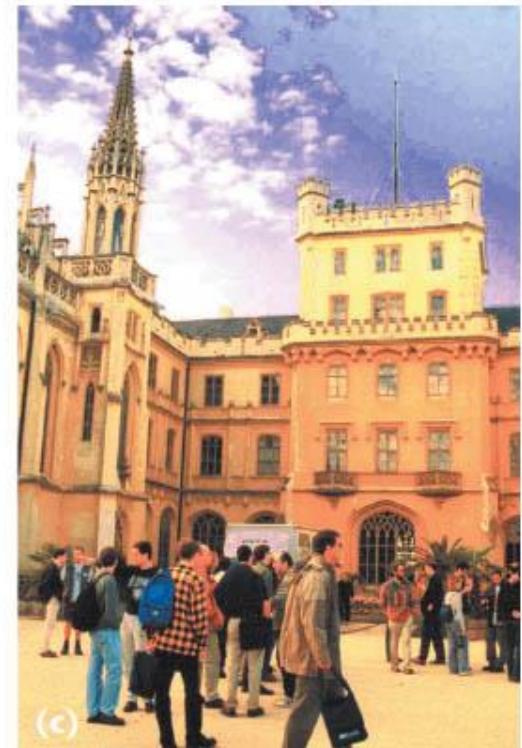
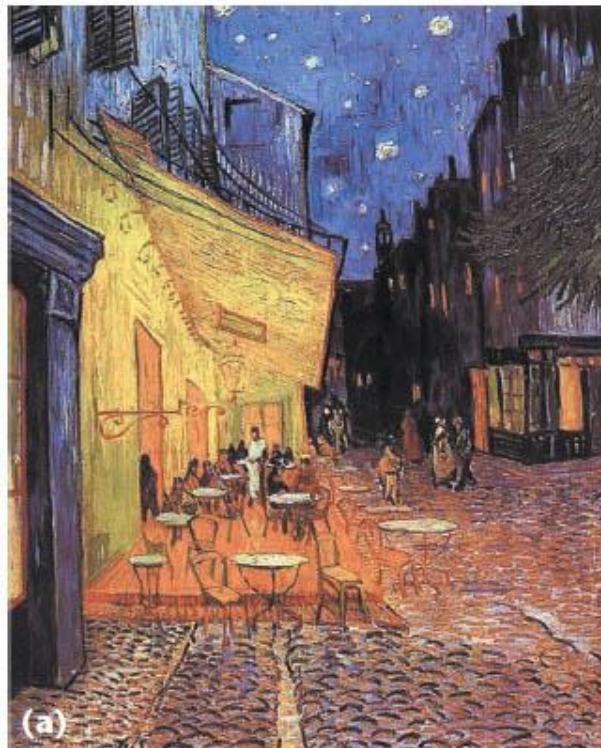
- Transferência de cor entre imagens
 - Proposto por Reinhard *et al.*
 - Utiliza o espaço $l\alpha\beta$
 - Utilizar o canal acromático l para comparação entre imagens
 - Transferir informação cromática dos canais α e β

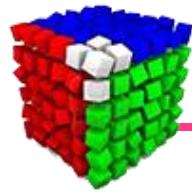




Transferência de Cor

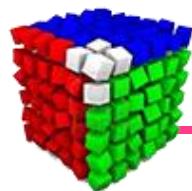
- Outro exemplo





Colorização

- Colorização de imagens em tons de cinza
- Desenvolvido por Welsh *et al.*
- Baseado no trabalho de Reinhard *et al.*

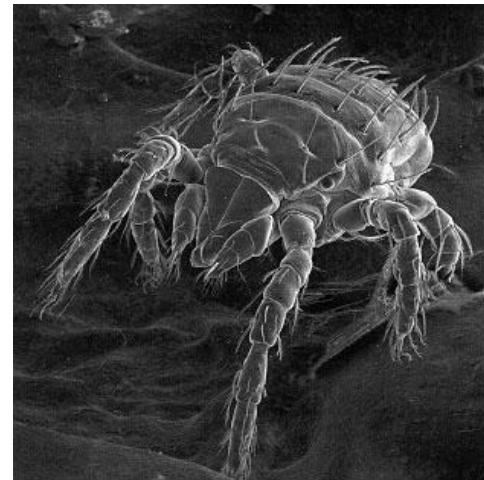


Colorização

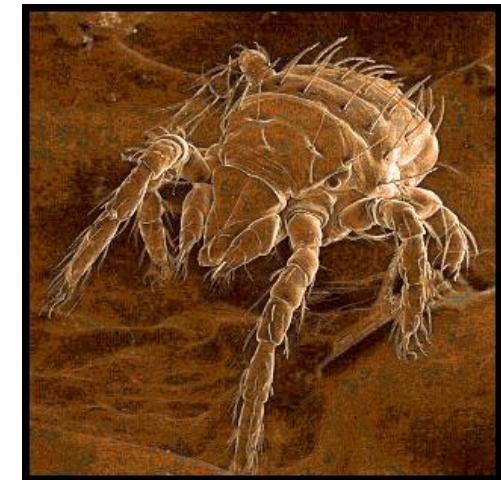
- Colorização de imagens em tons de cinza



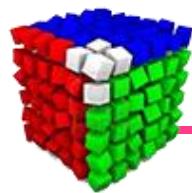
Fonte



Destino



Resultado



Colorização



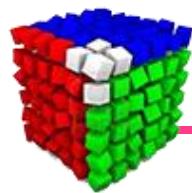
Fonte



Destino



Resultado



Colorização



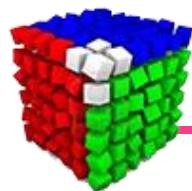
Fonte



Destino



Resultado



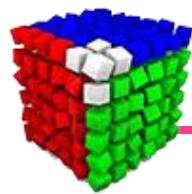
Conversão para Tons de Cinza

- Conversão para tons de cinza
- Utilizar o canal l (do modelo $l\alpha\beta$)



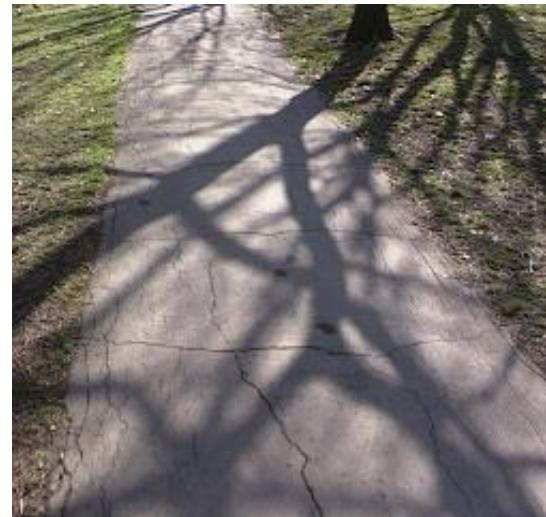
Mudança de Sistemas de Cor

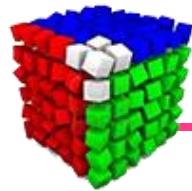
Exemplo de Aplicação



Problema....

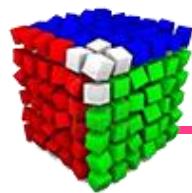
- Um veículo autônomo precisa detectar o caminho na imagem abaixo
- Observe o elemento “sombra”....





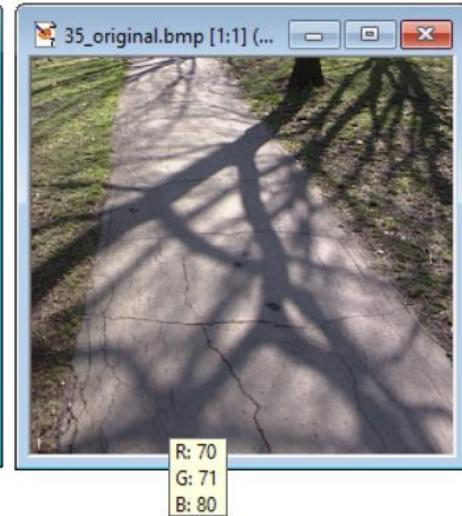
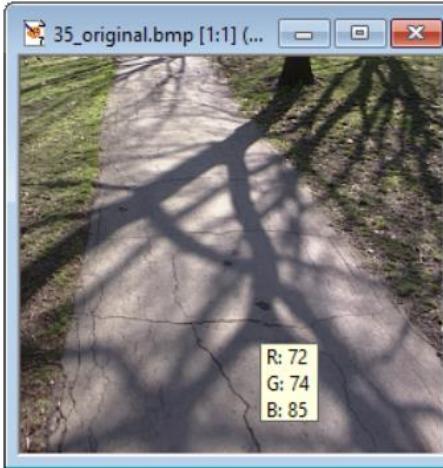
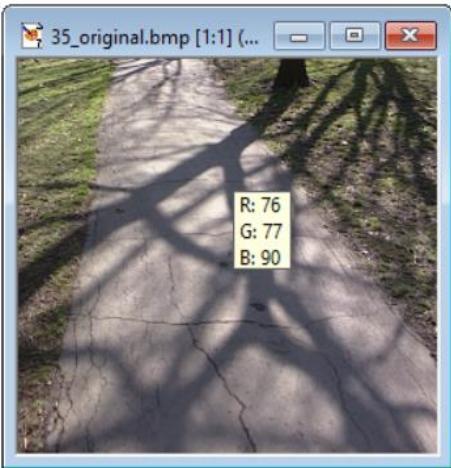
Problema....

- Apesar de termos um caminho “marrom” e uma grama “verde” nas laterais, a sombra gera um novo elemento de difícil identificação
 - A sombra se caracteriza por escurecer tanto o caminho quanto a grama
 - Esse escurecimento não gera apenas um “marrom escuro” ou “verde escuro”



Problema....

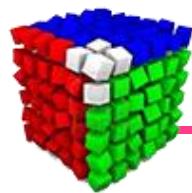
- Vamos analisar, no RGB, os tons de sombra no caminho....



Suponha então que vamos considerar como “sombra” no caminho a seguinte condição:

$$(70 < r < 80) \& (70 < g < 80) \& (80 < b < 90)$$

Os pixels que satisfizerem essa condição serão convertidos para branco....

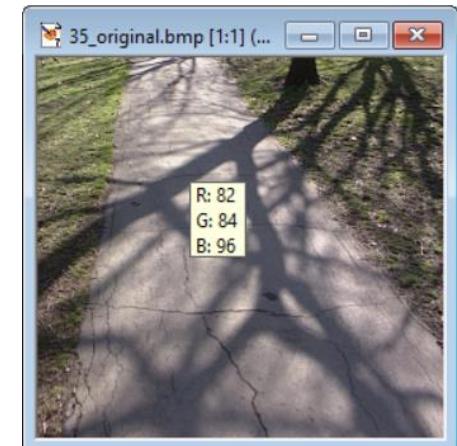


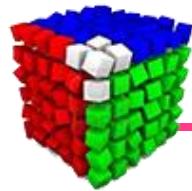
Problema....

- Resultado:



Porque há
elementos fora
dessa faixa...



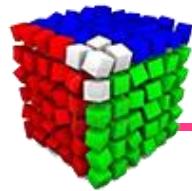


Problema....

- Vamos converter a imagem de entrada para o sistema HSV
- Tomando o componente H

Componente H convertido para RGB para visualização (mas H é uma matriz de valores para o computador)

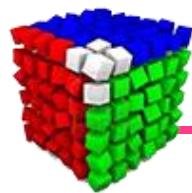




Problema....

- Nova condição:
 - Serão convertidos para branco (1) as células de H que satisfizerem:
 - $0,6 < H < 0,8$

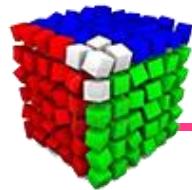




Problema....

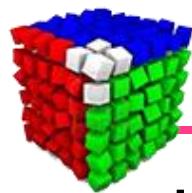
- Comparação:





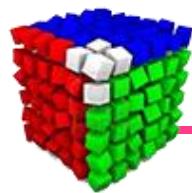
Considerações finais

- Muitos problemas podem ser resolvidos ou simplificados com uma mudança no modelo de cor
- Em geral, isso não acarreta acréscimo no custo computacional
- Normalmente, o custo na conversão de um sistema para outro é $O(1)$



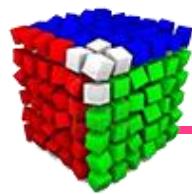
Sugestões de leitura

- Underwater image restoration by color compensation and color-line model
 - Signal Processing: Image Communication, Dez, 2020
 - <https://doi.org/10.1016/j.image.2021.116569>
- QHSL: A quantum hue, saturation, and lightness color model
 - Information Sciences, Out 2021
 - <https://doi.org/10.1016/j.ins.2021.06.077>
- QIRHSI: novel quantum image representation based on HSI color space model
 - Quantum Information Processing, Dez, 2021
 - <https://doi.org/10.1007/s11128-021-03337-0>



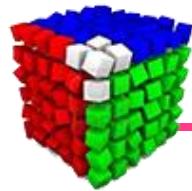
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- R. C. Gonzalez e R. E. Woods, “*Digital Image Processing (3rd Edition)*”. Prentice Hall, 2007.
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- E. Reinhard, E. A. Khan, A. O. Akyüz, G. M. Johnson, “Color Imaging: Fundamentals and Applications”, A K Peters/CRC Press; Har/Cdr edition, July 22, 2008.
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- T. Welsh, M. Ashikhmin, K. Mueller, “Transferring Colors to Greyscale Images”, ACM Transactions on Graphics, vol. 21, no. 3, 2002.
- D. Ruderman, D. L. Cronin, T. Welsh and C. C. Chiao, "Statistics of Cone Responses to Natural Images: Implications for Visual Coding". J. Optical Soc. Of America, vol 15, no. 8, 2036-2045, 1998.
- C. Poynton, “*Frequently Asked Questions About Color*”.
http://www.poynton.com/notes/colour_and_gamma/ColorFAQ.html, 2006.
- Munsell - <http://munsell.com/about-munsell-color/>



Referências

- Sistemas de cores no Colab:

- <https://colab.research.google.com/drive/1Mm-9OjLoUZPcVGxbY42RySYqwhGamaWP>