

Processamento de Imagens

Introdução

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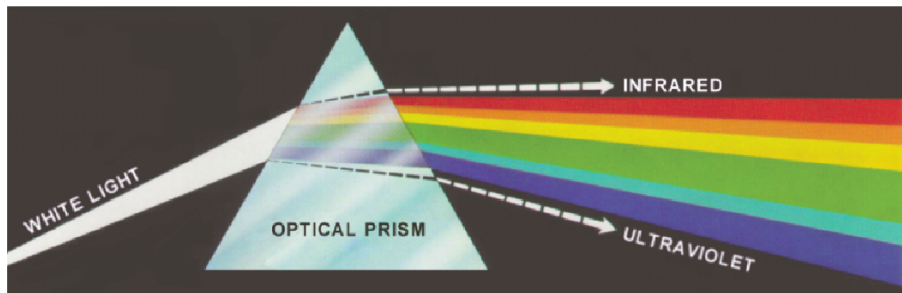
`mylene@unb.br`

12 de Abril de 2016

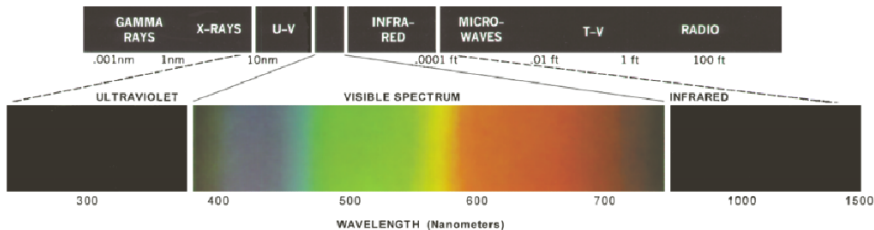
Aula 07: Cores



- Cores ou pseudo-cores
- Seres humanos são mais sensíveis a variações em cores
- Algoritmos utilizados são os mesmos, mas em algumas situações precisam ser adaptados.

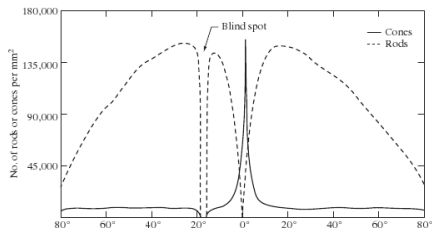
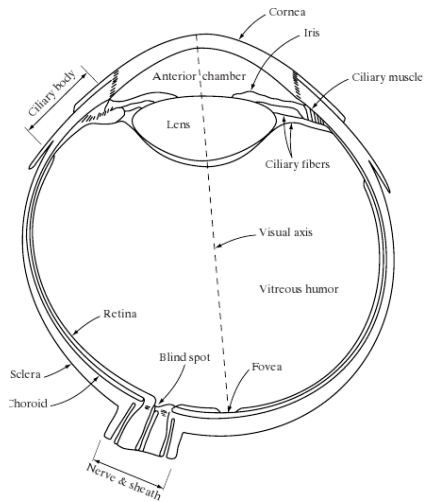


Espectro de Cores

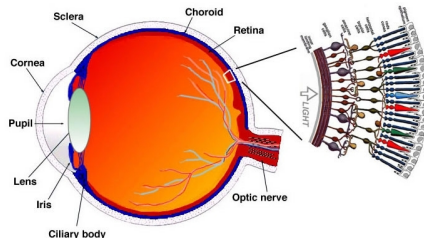


O Olho Humano

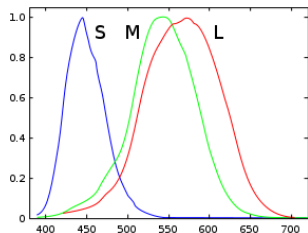
A Retina:

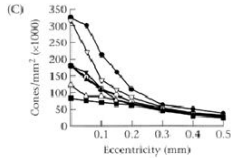
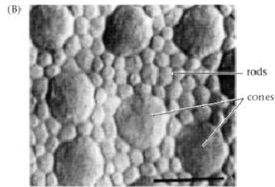
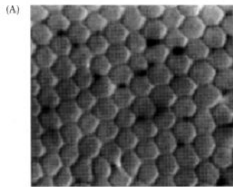


Cones e bastonetes



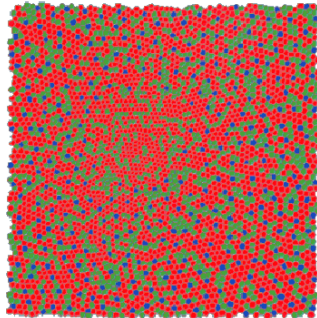
- Cones: (S, M, L) 5 milhões
 - níveis “normais” de luz,
 - permitem a percepção de luz
 - localizados no centro da retina (detalhes)
- Bastonetes – 100 milhões
 - periferia
 - níveis baixos de luz

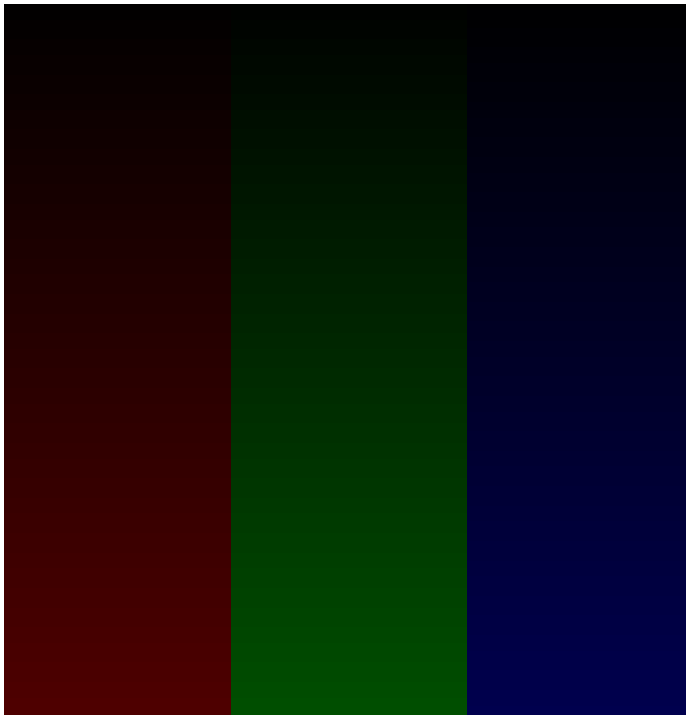


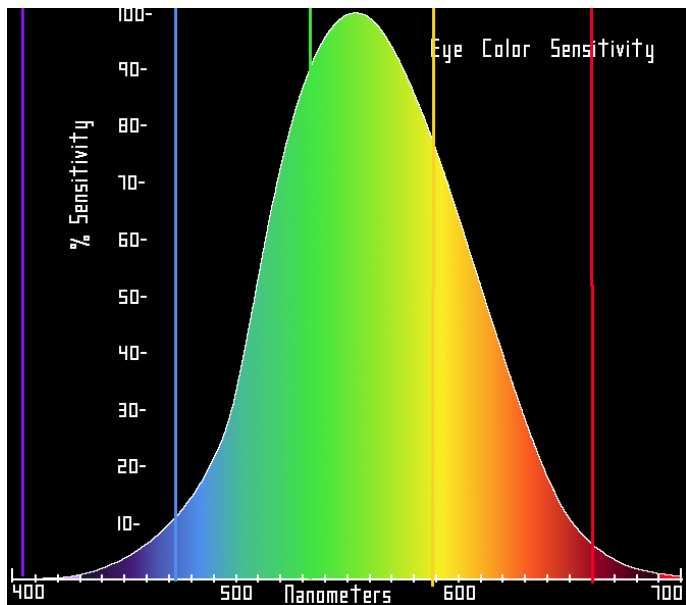


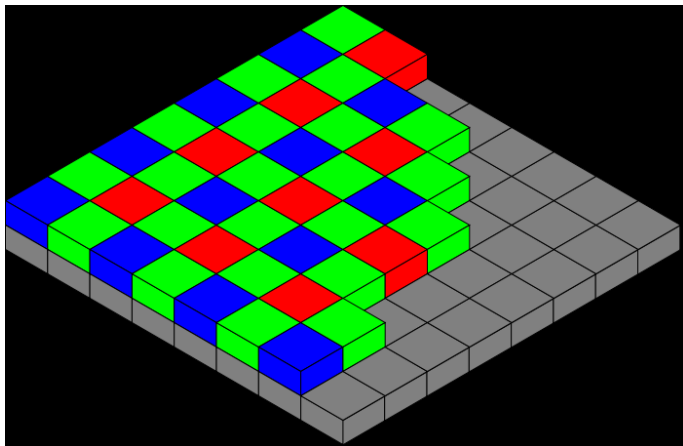
3.4 THE SPATIAL MOSAIC OF THE HUMAN CONES. Cross sections of the human retina at the level of the inner segments showing (A) cones in the fovea, and (B) cones in the periphery. Note the size difference (scale bar = 10 μm), and that, as the separation between cones grows, the rod receptors fill in the spaces. (C) Cone density plotted as a function of distance from the center of the fovea for seven human retinas; cone density decreases with distance from the fovea. Source: Curcio et al., 1990.

Cone mosaic







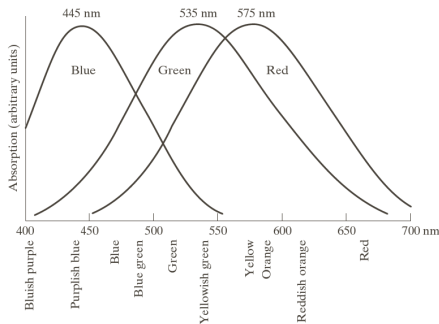


- As cores dos objetos estão relacionadas às características dos corpos
- Corpos “verdes” refletem apenas luz com comprimento de onda entre 500-570 nm
- Se a luz for acromática, o seu único atributo é a intensidade (TVs preto e branco)

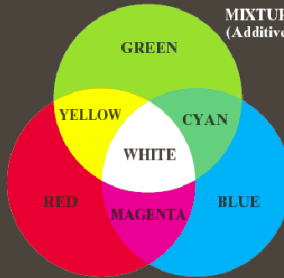
Luz Cromática:

- **Radiância** – total de energia que é emitido pela fonte de luz (Watts - W)
- **Luminância** – quantidade de energia percebida pelo observador (lumens lm)
- **Brilho** – descritor subjetivo relacionado à intensidade, sendo um dos fatores chaves na descrição de cores

- Cones e Bastonetes:
 - 65% vermelho
 - 33% verde
 - 2% azul
- Cores primárias (RGB)
- CIE (Comission Internationale de l'Eclairage)
 - Azul: 435,8 nm
 - Vermelho: 700 nm
 - Verde: 546,1
 - níveis baixos de luz



MIXTURES OF LIGHT
(Additive primaries)



MIXTURES OF PIGMENTS
(Subtractive primaries)



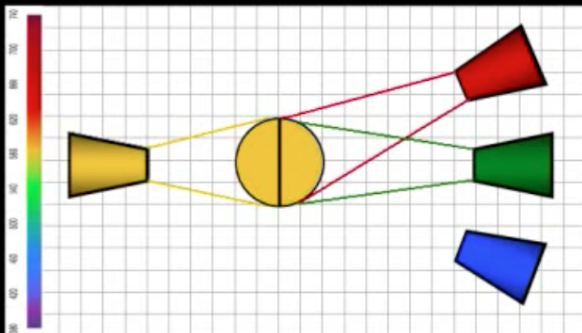
**PRIMARY AND SECONDARY COLORS
OF LIGHT AND PIGMENT**

Distinção entre Cores:

- **Brilho** (Brightness) – Noção cromática da intensidade
- **Tonalidade** (Hue)
 - comprimento de onda dominante
 - cor predominantemente percebida
- **Saturação** (Saturation)
 - pureza da luz
 - quantidade de luz branca misturada
- Saturação + Tonalidade = cromaticidade

Color Matching

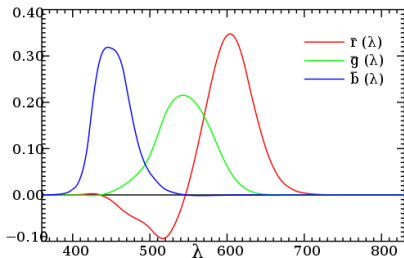
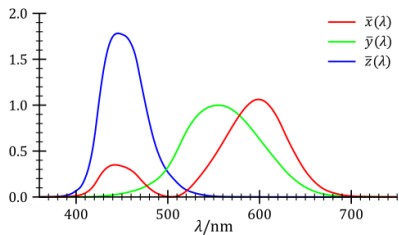
***Test
Color***



Red

Green

Blue



3 funções de casamento de cores, que podem ser entendidas como sendo curvas de sensibilidade espectral dos três detectores de luz lineares que geram os valores X, Y e Z do trí-estímulo CIE XYZ.

http://www.biyee.net/v/cie_diagrams/index.htm

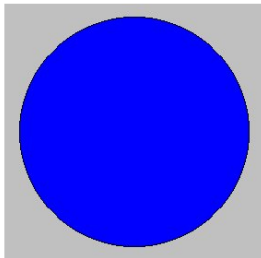
"The 1964 (ten-degree field) observer had about 50 observers but the 1931 (two-degree field) only had about a dozen. The 1964 work included a few foreign post-doctoral fellows but the early work included only Englishmen from the region near to London."

Danny Rich

CIE 1931 2-Degree Field of View



CIE 1964 10-Degree Field of View



- Tri-estímulo:

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

$$z = \frac{Z}{X + Y + Z}$$

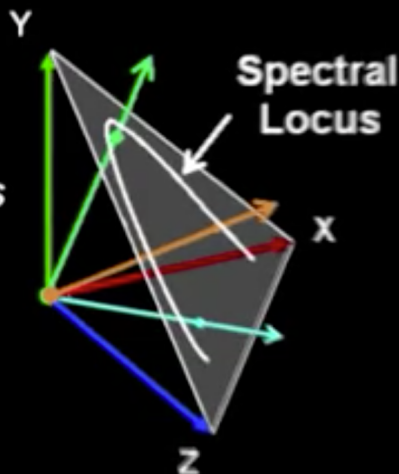
onde:

$$x + y + z = 1$$

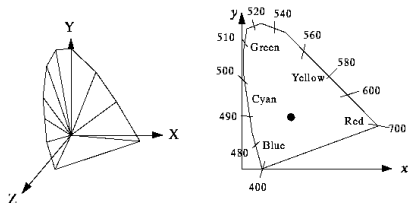
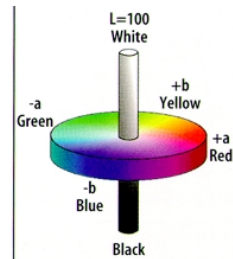
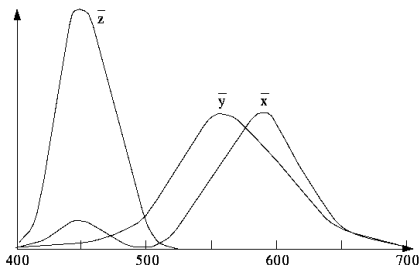
Color Space

X-Y-Z

*Series of
Tristimulus Vectors
Map Out the
Chromaticity
Diagram*



- 1931: CIE definiu 3 cores primárias (X,Y,Z)
 - derivadas das cores vermelha, azul e verde.

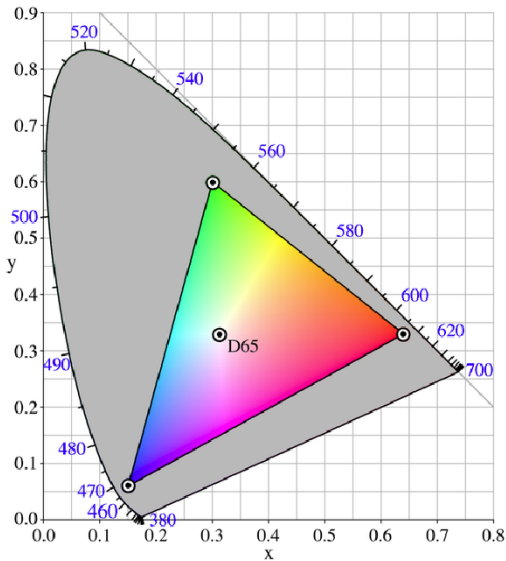
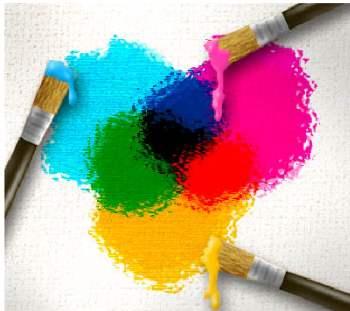
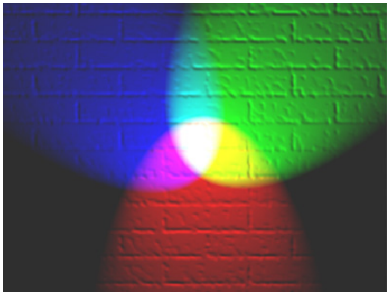


CIE Chromaticity Diagram

$$X = \int E(\lambda) \bar{x}(\lambda) d\lambda$$

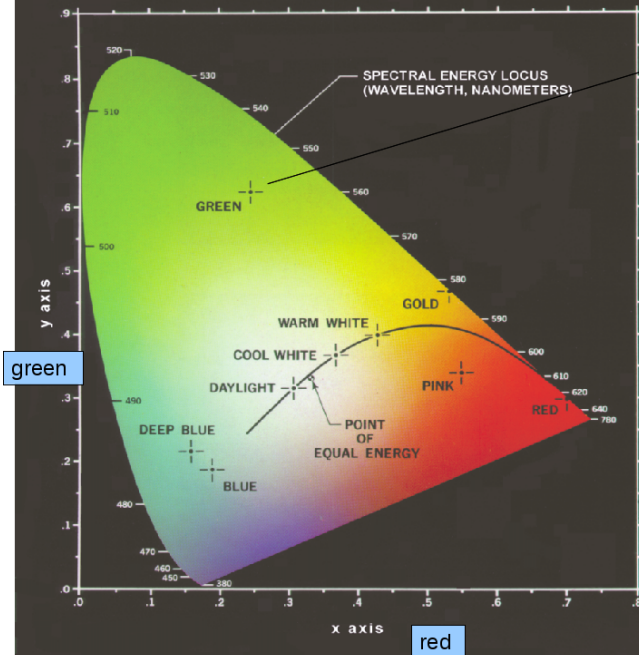
$$Y = \int E(\lambda) \bar{y}(\lambda) d\lambda$$

$$Z = \int E(\lambda) \bar{z}(\lambda) d\lambda$$



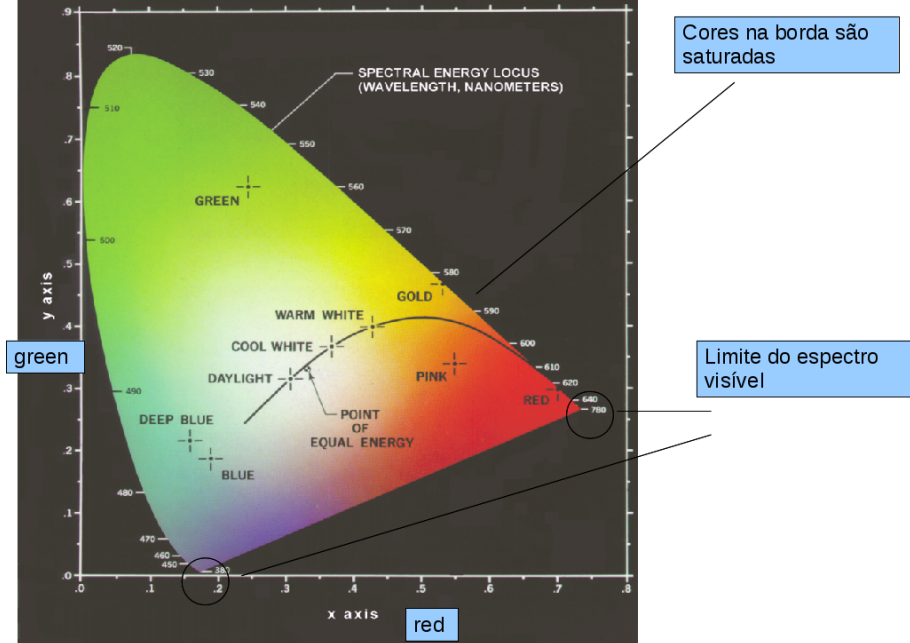
(C.I.E. CHROMATICITY DIAGRAM)

62% green
25% red
13% blue

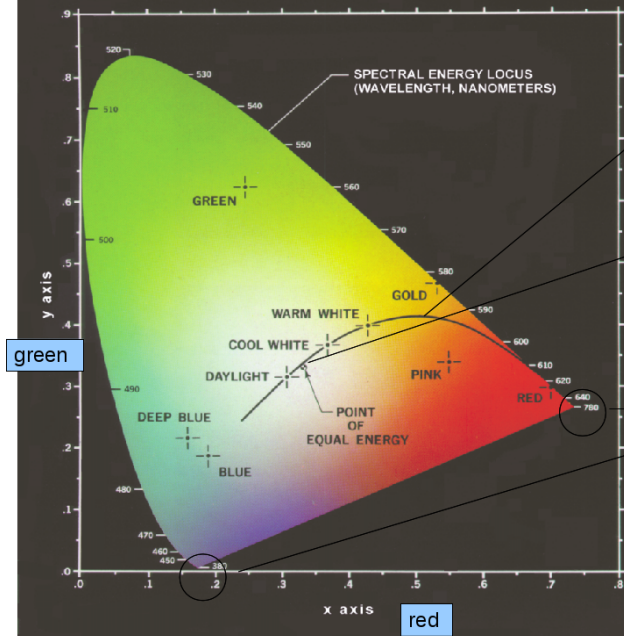


$$z = 1 - (x + y)$$

(C.I.E. CHROMATICITY DIAGRAM)



(C.I.E. CHROMATICITY DIAGRAM)



A reta de uma cor a outra mostra todas as cores que podem ser obtidas adicionando as duas cores.

Ponto de equi-energia
Proporção igual
Saturação = 0!

White



Tungsten



*Warm
White*

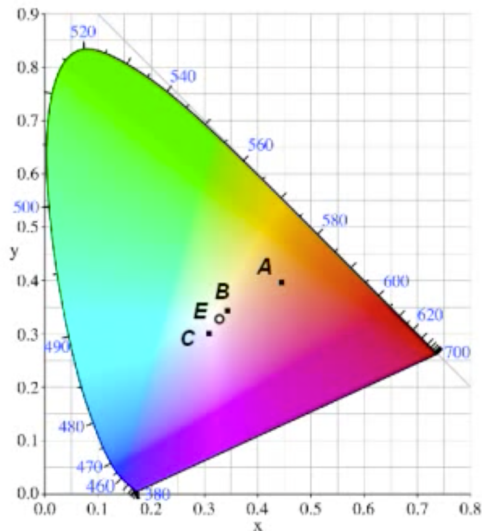


*Cool
White*

CIE Chromaticity Diagram

CIE Standard Illuminants

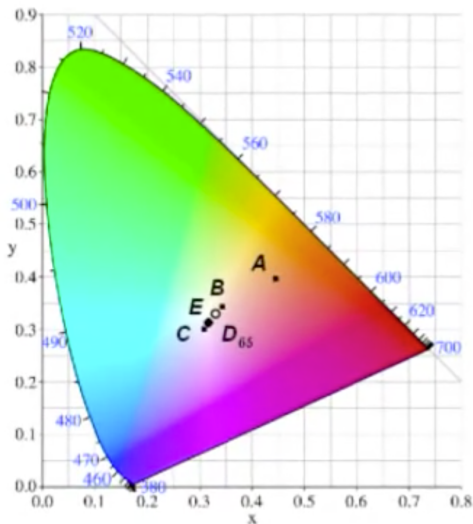
A: Tungsten
B: Direct Sun
C: Av. Daylight



CIE Chromaticity Diagram

CIE Standard Illuminants

A: Tungsten
B: Direct Sun
C: Av. Daylight
D65: Av. Day



Color Temperature



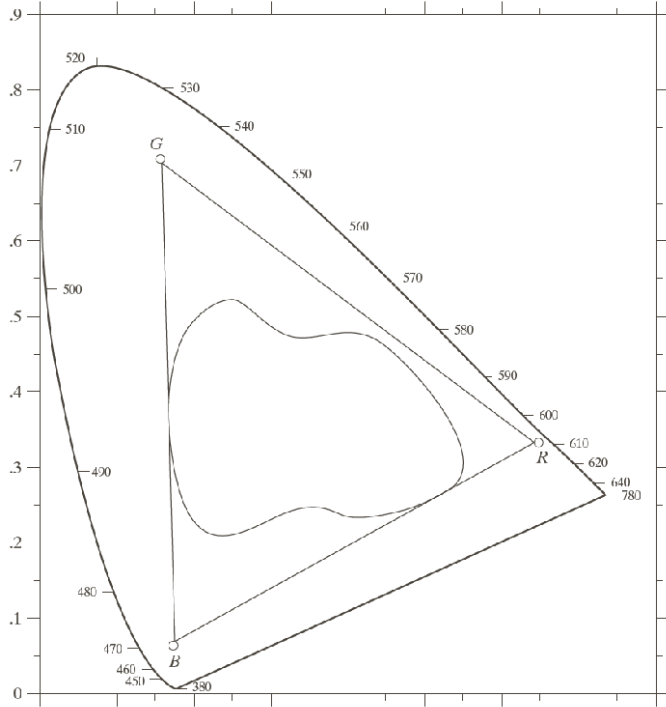
Std A
Tungsten
2856 K



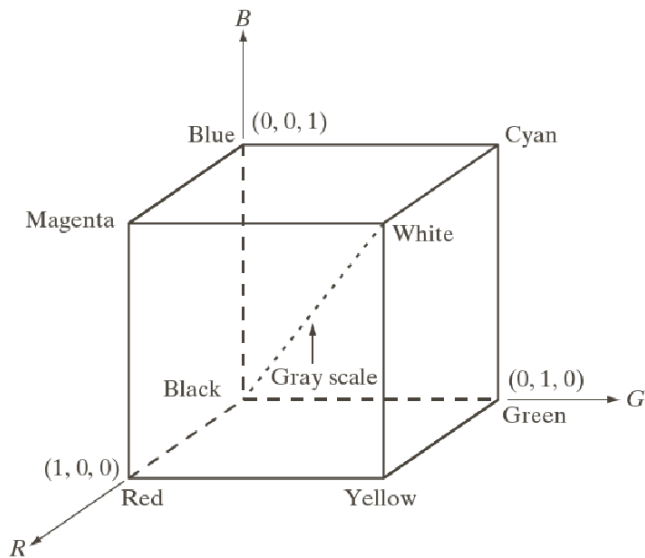
Std B
Direct Sun
4874 K

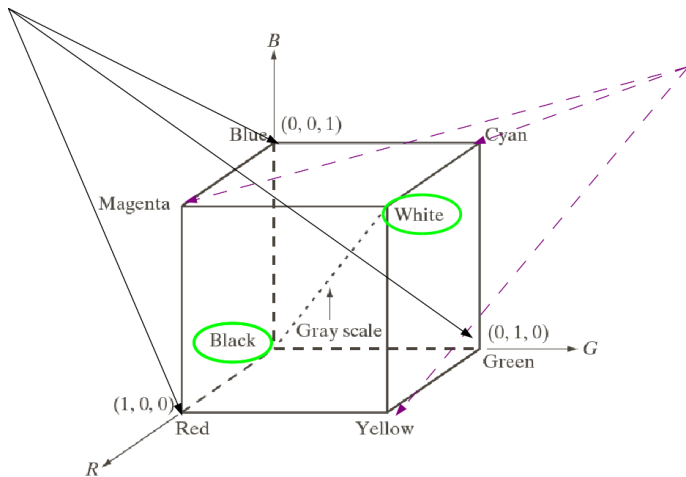


Std D₆₅
Daylight
6500 K



- **RGB** (red, green, blue)
 - monitores e câmeras
- **CMY** (cyan, magenta, yellow)
 - impressoras
- **CMYK** (cyan, magenta, yellow, black)
 - impressoras
- **HSO** (hue, saturation, intensity)
 - modelo perceptivo
 - separa a intensidade – usada por dispositivos em preto e branco (tons de cinza)



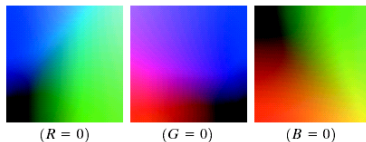
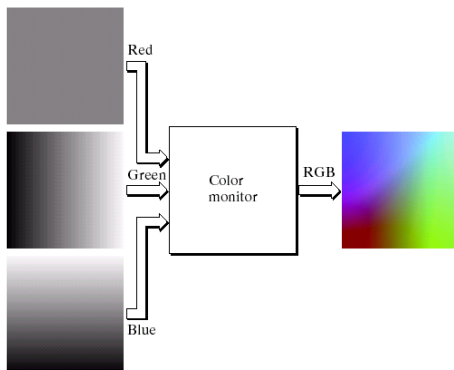


- 24 bits – 8×3 (full color) (R,G,B)
- number of colors = $(2^8)^3 = 16\,777\,216$



a
b**FIGURE 6.9**

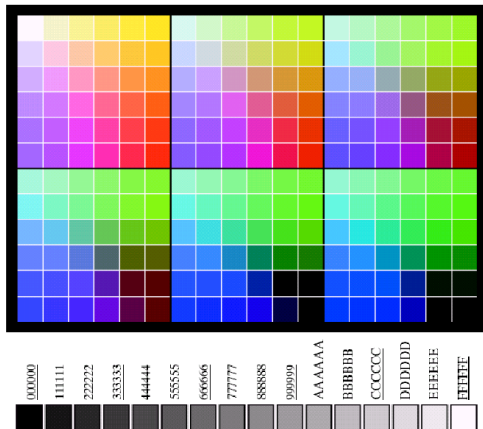
(a) Generating the RGB image of the cross-sectional color plane $(127, G, B)$.
 (b) The three hidden surface planes in the color cube of Fig. 6.8.



Number System		Color Equivalents					
Hex	00	33	66	99	CC	FF	
Decimal	0	51	102	153	204	255	

TABLE 6.1

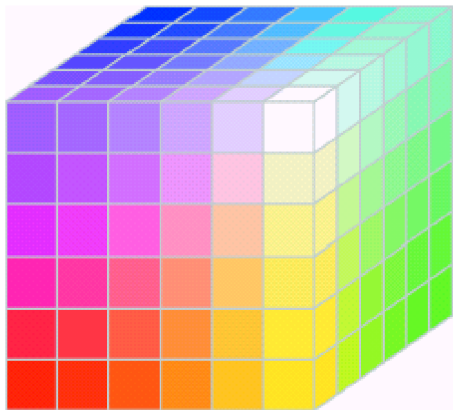
Valid values of each RGB component in a safe color.



a
b

FIGURE 6.10

(a) The 216 safe RGB colors.
(b) All the grays in the 256-color RGB system (grays that are part of the safe color group are shown underlined).

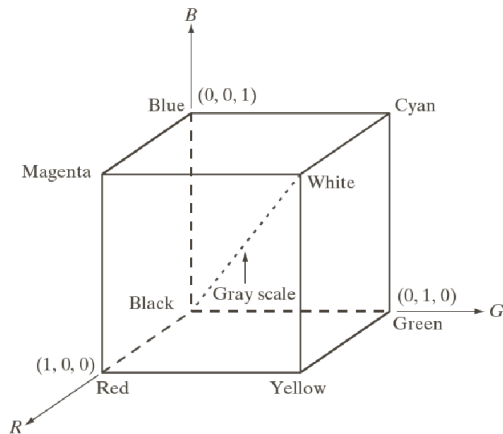


RGB safe-color cube.

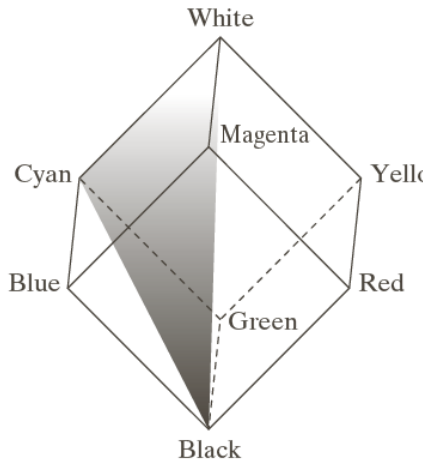
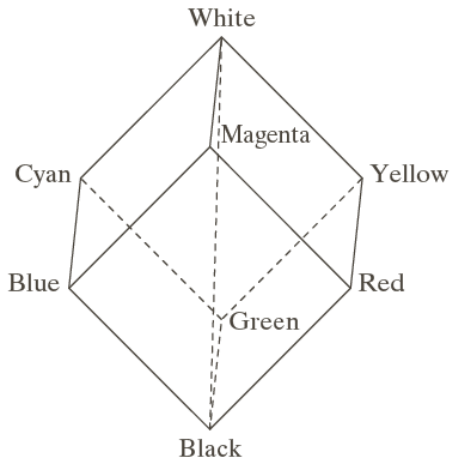
- **CMY**: Cores primárias para pigmentos

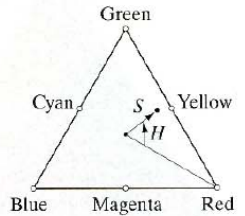
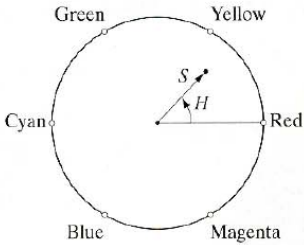
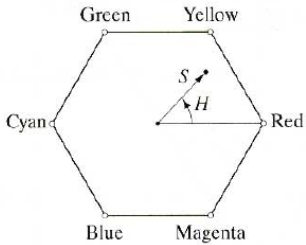
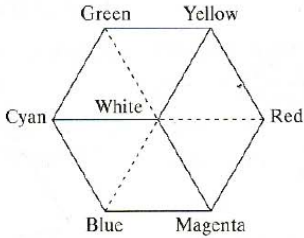
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

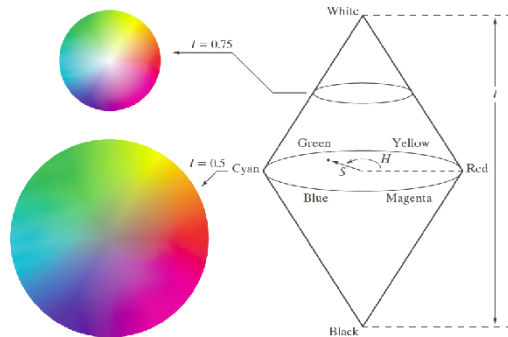
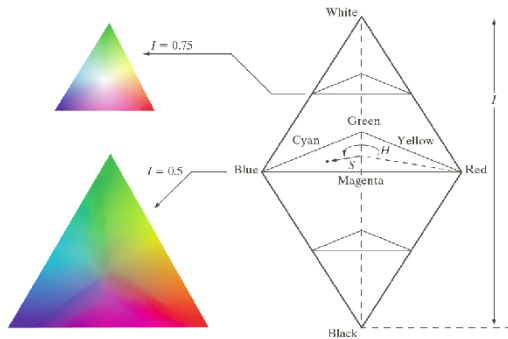
- **CMYK**: Preto é adicionado para evitar aspecto apagado do preto.



- Mais próximo da maneira como percebemos as cores:
 - Tonalidade (hue), saturação (saturation), intensidade (intensity)
- Produção e reprodução de cor
- Análise – HSI e variantes ...
- Isolamento da componente de intensidade
 - níveis de cinza







$$H = \begin{cases} 0, & \text{se } B \leq G \\ 360 - \theta, & \text{se } B > G \end{cases}$$

$$\theta = \cos^{-1} \frac{\frac{1}{2} [(R - G) + (R - B)]}{[(R - G)^2 + (R - B)(G - B)]^{1/2}}$$

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

$$I = \frac{1}{3}(R + G + B)$$

Setor RG ($0^\circ \leq H \leq 120^\circ$)

$$B = I(1 - S)$$

$$R = I \left[1 + \frac{S \cos H}{\cos(60^\circ - H)} \right]$$

$$G = 3I - (R + B)$$

Setor BR ($240^\circ \leq H \leq 360^\circ$)

$$H = H - 240^\circ$$

$$G = I(1 - S)$$

$$B = I \left[1 + \frac{S \cos H}{\cos(60^\circ - H)} \right]$$

$$R = 3I - (G + B)$$

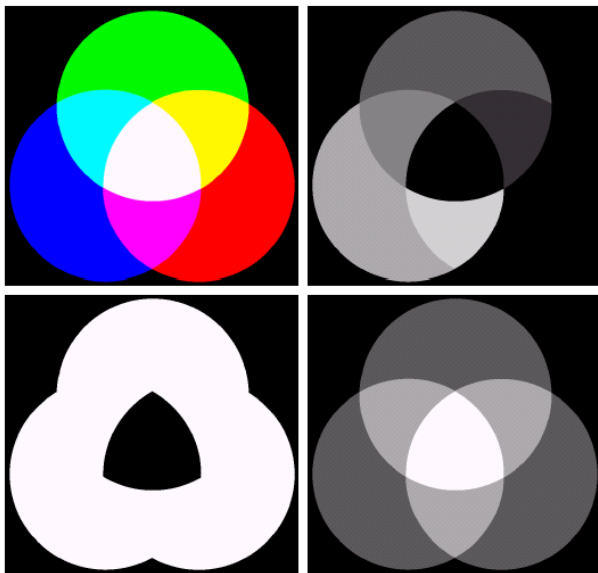
Setor GB ($120^\circ \leq H \leq 240^\circ$)

$$H = H - 120^\circ$$

$$R = I(1 - S)$$

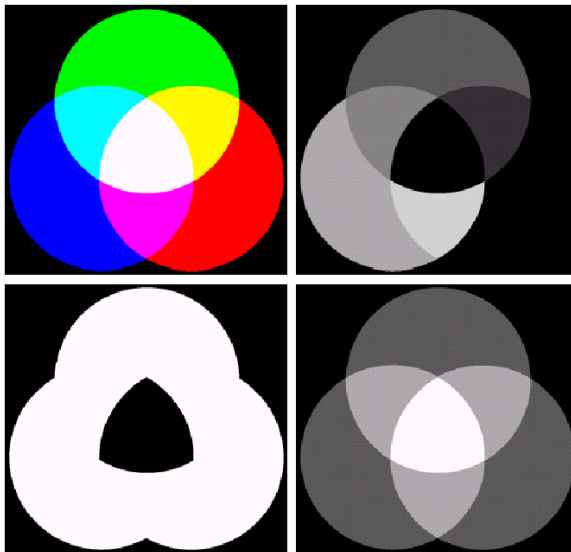
$$G = I \left[1 + \frac{S \cos H}{\cos(60^\circ - H)} \right]$$

$$B = 3I - (G + R)$$



a b
c d

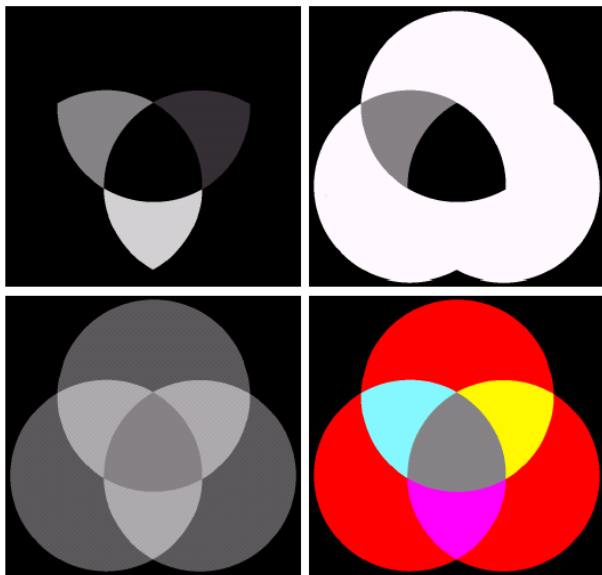
FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.



Mudança:
zerar todos
os valores
de tonalidade

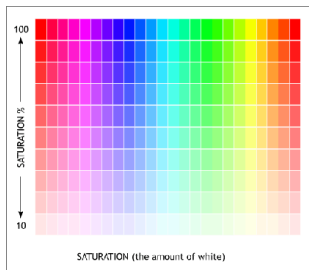
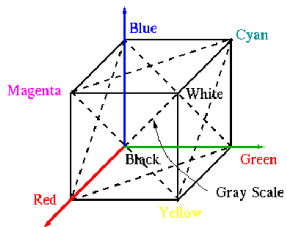
a	b
c	d

FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

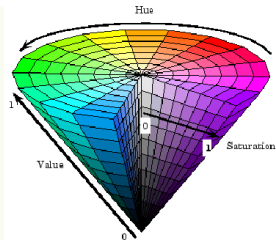
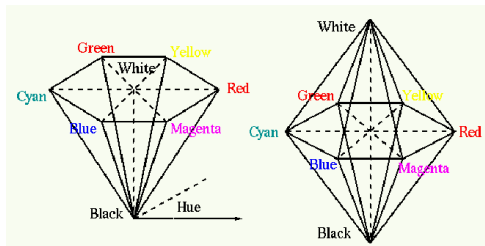


a	b
c	d

FIGURE 6.17 (a)–(c) Modified HSI component images. (d) Resulting RGB image. (See Fig. 6.16 for the original HSI images.)



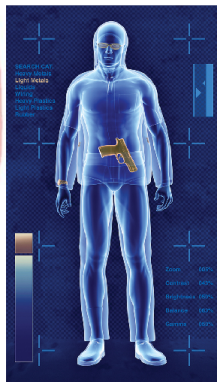
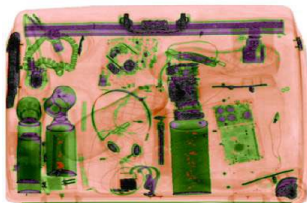
HSV



- Pseudo-cores = cores “falsas”
- Visualização humana (raio x de aeroporto)
- Fatiamento de cores
- Transformações de intensidade para cores

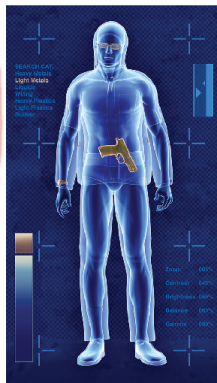
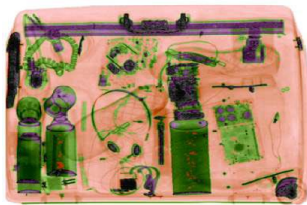
Processamento em Cores

- **Blue:** Materiais duros. Metais (blue/black), plásticos duros, ligas (alloys), etc. Ex.: armas e facas iram aparecer como uma mistura de azul ou preto. O mesmo para fios, baterias, etc.



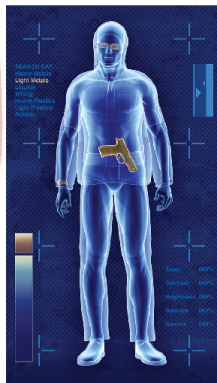
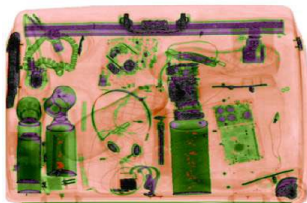
Processamento em Cores

- **Orange:** Material biológico. Tudo que natural e algumas coisas que não são. Borracha, couro, comida, dinamite e outros explosivos (exceto plástico (vai aparecer azulado)), líquidos e gels e pós de natureza orgânica.

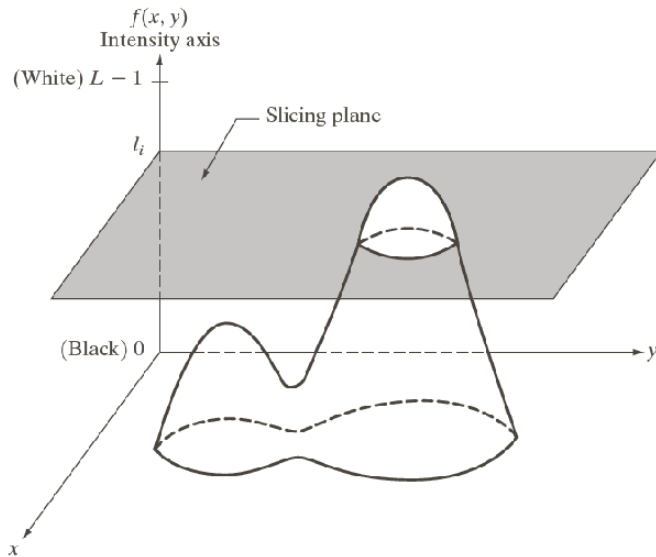


Processamento em Cores

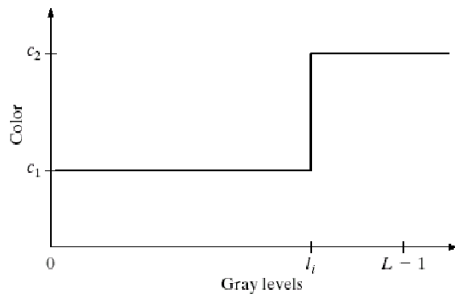
- **Green:** Plásticos e ligas nos quais a densidade não é tão grande que os faça aparecer azul ou preto. Cerâmicas (densas) – cas contrário irá aparecer como laranja.

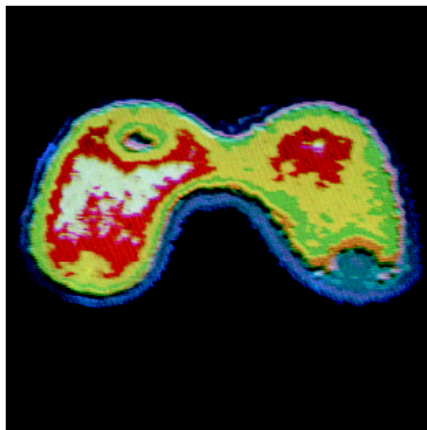
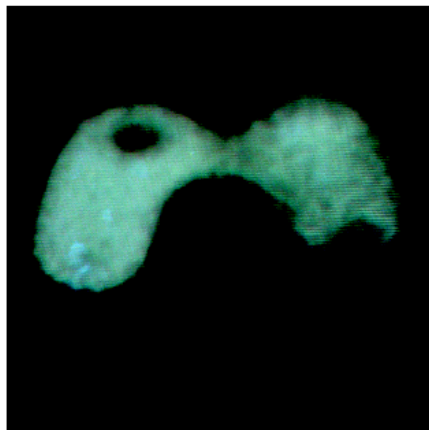


Processamento em Pseudo-Cores



$$f(x, y) \in V_k \longrightarrow f(x, y) = c_k$$





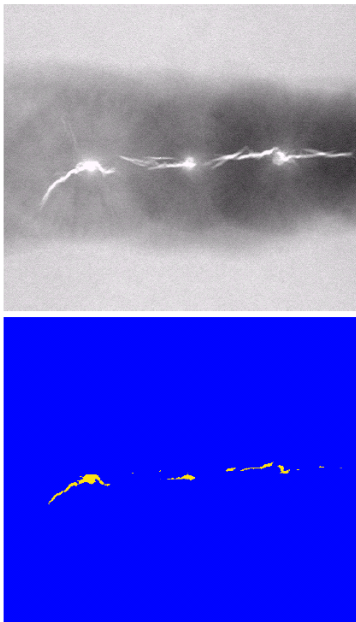
a b

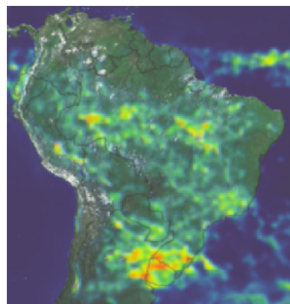
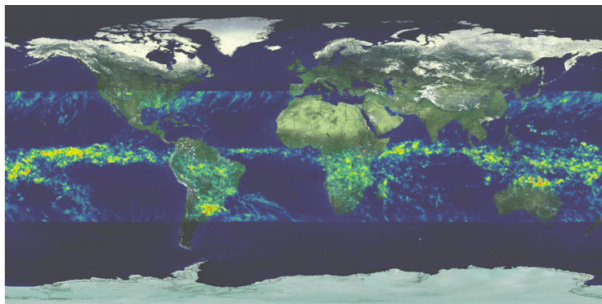
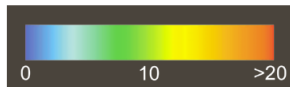
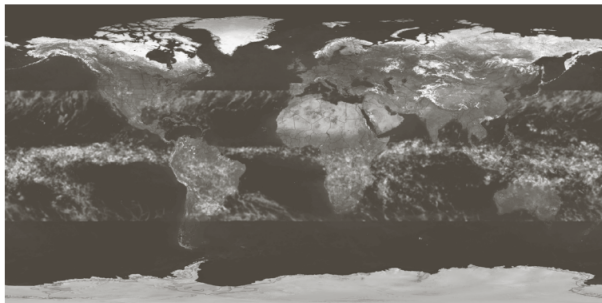
FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

a
b

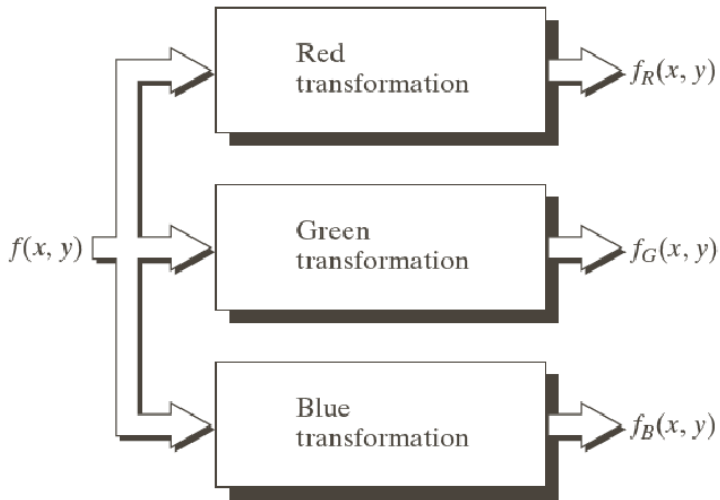
FIGURE 6.21

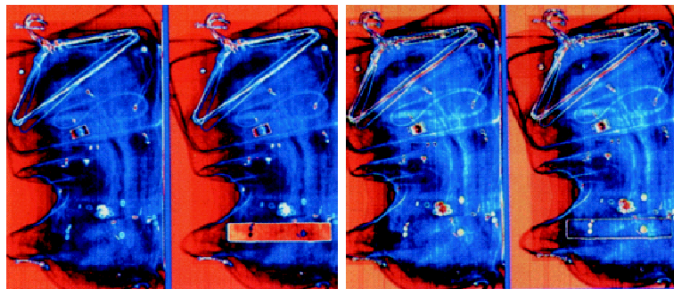
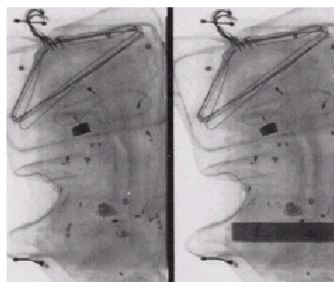
(a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)





Transformações: Intensidade de Cores





a
b c

FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)

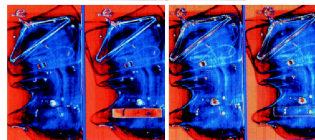
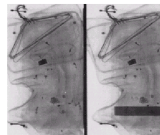
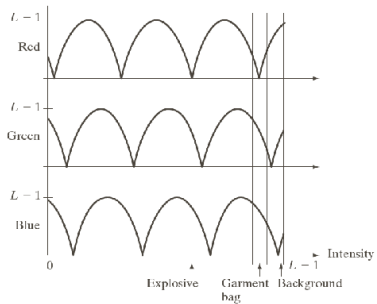
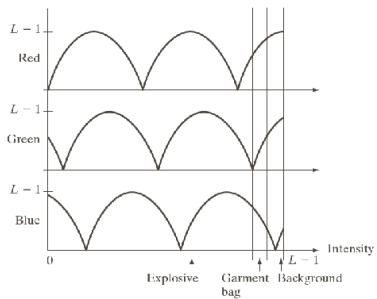
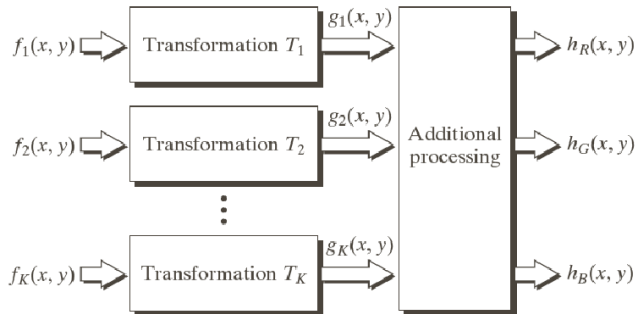


FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transfer in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)

Combinando Imagens em Várias Bandas



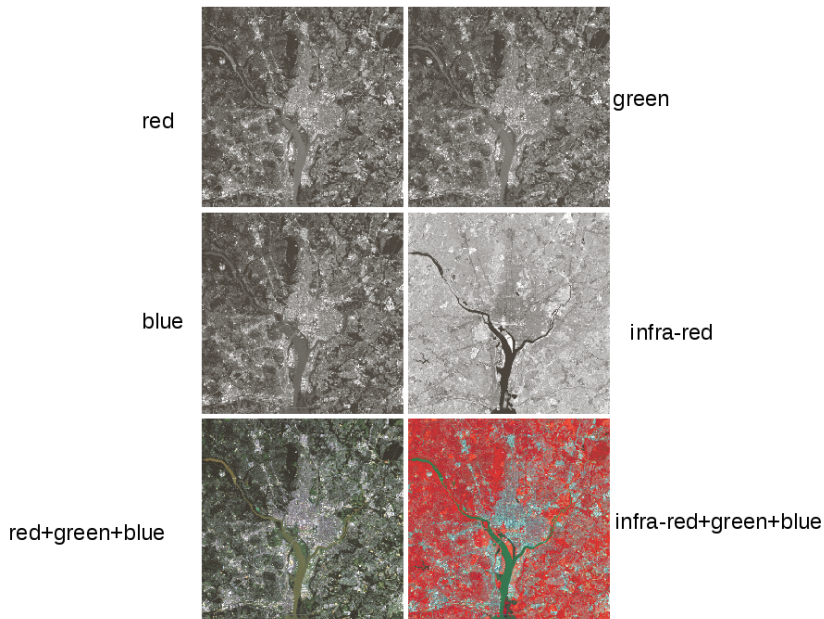
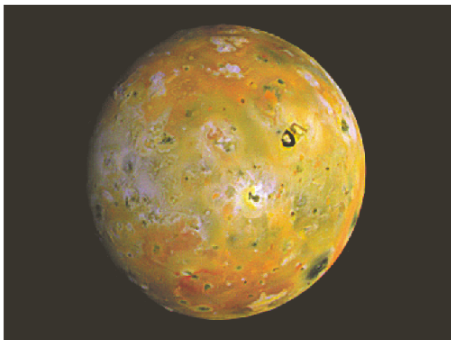


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

a b
c d
e f



a
b

FIGURE 6.28
(a) Pseudocolor
rendition of
Jupiter Moon Io.
(b) A close-up.
(Courtesy of
NASA.)

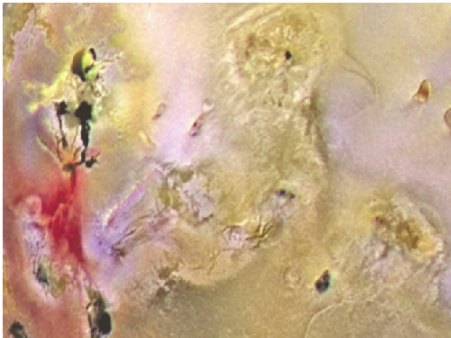
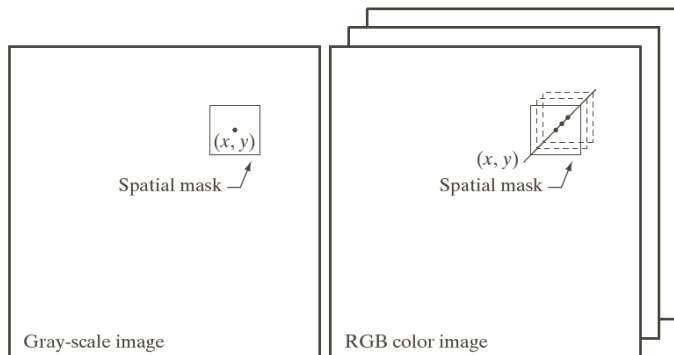


Imagem obtida
combinando imagens
de sensores com
várias bandas.

Processamento em Cores'



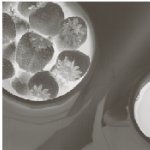
$$g(x, y) = T[f(x, y)]$$



Full color

Imagem colorida e suas componentes em vários espaços de cores.

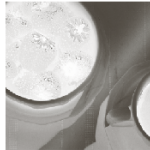
CMYK



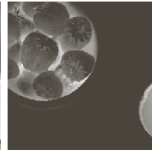
Cyan



Magenta



Yellow



Black

RGB



Red



Green



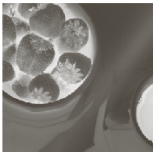
Blue



Imagem colorida e suas componentes em vários espaços de cores.

Full color

CMYK



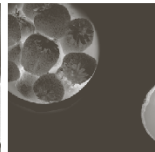
Cyan



Magenta



Yellow



Black

RGB



Red

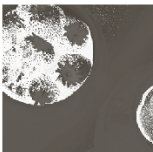


Green



Blue

HSI



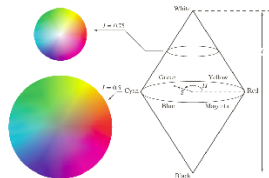
Hue



Saturation



Intensity



- Exemplo de transformação:

$$g(x, y) = k \cdot f(x, y)$$

- HSI

$$i(x, y) = s_3(x, y) = k \cdot r_3(x, y)$$

$$h(x, y) = s_1(x, y) = r_1(x, y)$$

$$s(x, y) = s_2(x, y) = r_2(x, y)$$

- Exemplo de transformação:

$$g(x, y) = k \cdot f(x, y)$$

- RGB

$$r(x, y) = s_1(x, y) = k \cdot r_1(x, y)$$

$$g(x, y) = s_2(x, y) = k \cdot r_2(x, y)$$

$$b(x, y) = s_3(x, y) = k \cdot r_3(x, y)$$

- Exemplo de transformação:

$$g(x, y) = k \cdot f(x, y)$$

- CMY

$$c(x, y) = s_1(x, y) = k \cdot r_1(x, y) + (1 - k)$$

$$m(x, y) = s_2(x, y) = k \cdot r_2(x, y) + (1 - k)$$

$$y(x, y) = s_3(x, y) = k \cdot r_3(x, y) + (1 - k)$$

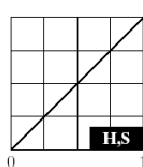
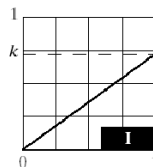
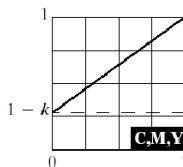
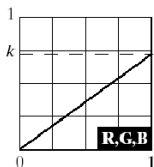
a	b
c	d
e	

FIGURE 6.31

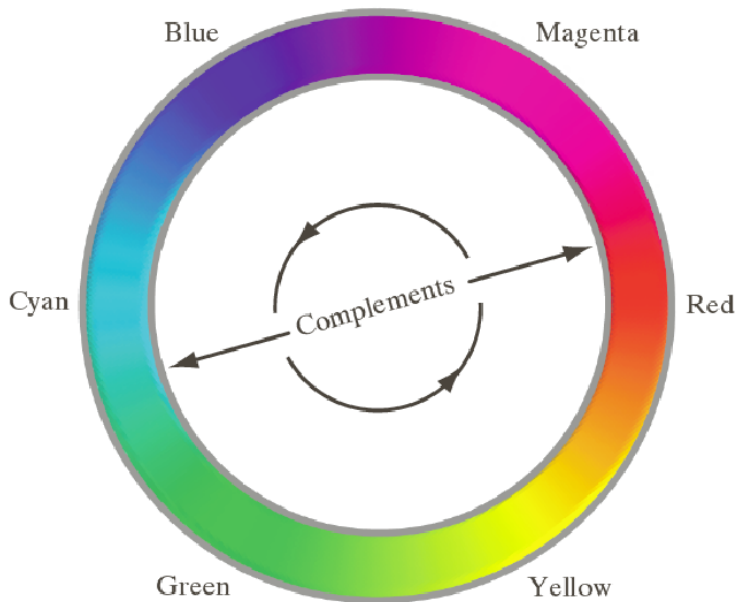
Adjusting the intensity of an image using color transformations.

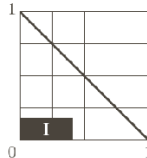
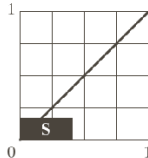
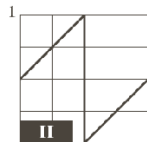
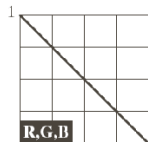
(a) Original image. (b) Result of decreasing its intensity by 30% (i.e., letting $k = 0.7$).

(c)–(e) The required RGB, CMY, and HSI transformation functions. (Original image courtesy of MedData Interactive.)



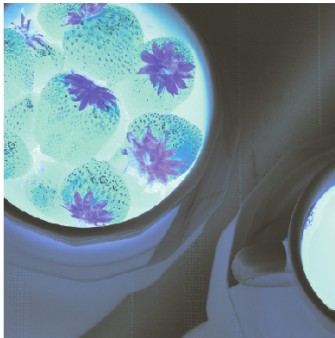
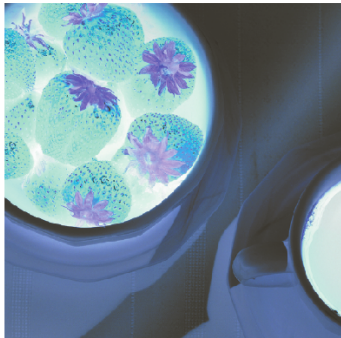
Círculo de Cores





a	b
c	d

FIGURE 6.33
Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.

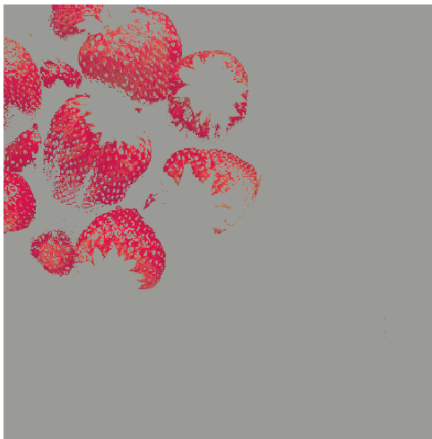


- Separação de objetos da cena
 - As cores de interesse devem se destacar do pano de fundo
 - A região de cores é utilizada como máscara

$$s_i = \begin{cases} 0,5 & \text{se } [|r_j - a_j| > \frac{W}{2}]_{1 \leq j \leq n}, \\ r_i, & \text{caso contrário} \end{cases}$$

$$s_i = \begin{cases} 0,5 & \text{se } \sum_{j=1}^n (r_j - a_j)^2 > R_0^2, \\ r_i, & \text{caso contrário} \end{cases}$$

$$i = 1, 2, \dots, n.$$



a b

FIGURE 6.34 Color-slicing transformations that detect (a) reds within an RGB cube of width $W = 0.2549$ centered at $(0.6863, 0.1608, 0.1922)$, and (b) reds within an RGB sphere of radius 0.1765 centered at the same point. Pixels outside the cube and sphere were replaced by color $(0.5, 0.5, 0.5)$.

- Modelos de Cores independentes de dispositivo
 - Scanner, display, impressora, etc.
 - Color profiles
 - Sistemas de gerenciamento de cores – CIE $L^*a^*b^*$ ou CIELAB

$$L^* = 116 \cdot h\left(\frac{Y}{Y_W}\right) - 16$$

$$a^* = 500 \left[h\left(\frac{X}{X_W}\right) - h\left(\frac{Y}{Y_W}\right) \right]$$

$$b^* = 200 \left[h\left(\frac{X}{X_W}\right) - h\left(\frac{Z}{Z_W}\right) \right]$$

- X_w , Y_w e Z_w são os valores do branco de referência (CIE standard D65)
 - Color-métricas, Uniformes perceptualmente, Independentes do dispositivo
 - Representa todo o espectro visível

$$L^* = 116 \cdot h\left(\frac{Y}{Y_w}\right) - 16$$

$$a^* = 500 \left[h\left(\frac{X}{X_w}\right) - h\left(\frac{Y}{Y_w}\right) \right]$$

$$b^* = 200 \left[h\left(\frac{X}{X_w}\right) - h\left(\frac{Z}{Z_w}\right) \right]$$

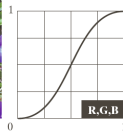
$$h(q) = \begin{cases} \sqrt[3]{q}, & q > 0,008856 \\ 7,787q + 16/116, & q \leq 0,008856 \end{cases}$$



Flat



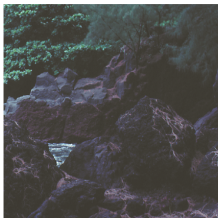
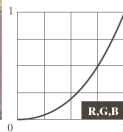
Corrected



Light



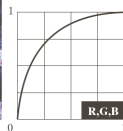
Corrected



Dark



Corrected



Balanceamento de Cores para imagens CMYK



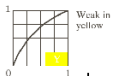
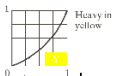
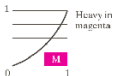
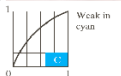
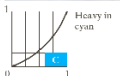
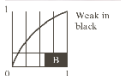
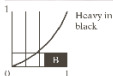
Original/Corrected

clarear

+ cyan
 $+(G+B)=-R$

-cyan
 $-(G+B)=+R$

escurecer



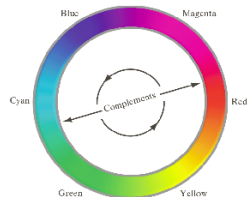
+ magenta
 $+(R+B)=-G$

- magenta
 $-(R+B)=+G$

+ amarelo
 $+(G+R)=-B$

-r amarelo
 $-(G+R)=+B$

Cyan = G+B
Magenta = R+B
Yellow = R+G

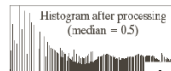
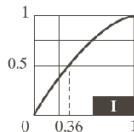
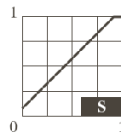
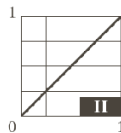


- Técnicas semelhantes às do cap.3
- Não podem ser aplicadas nas cores de forma independente
 - Artefatos: cores falsas.
- Hue (tonalidade) deve ser preservada

original



Processamento da intensidade



Aumento da saturação p compensar perdas de cor



- Considere a vizinhança S_{xy}

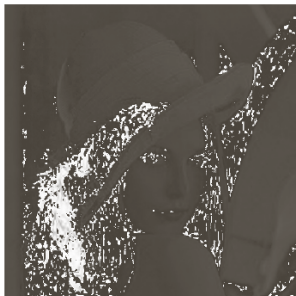
$$\bar{x}(x, y) = \frac{1}{k} \sum_{(x, y) \in S_{x, y}} c(x, y)$$

$$\bar{x}(x, y) = \begin{bmatrix} \frac{1}{K} \sum_{(x, y) \in S_{x, y}} R(x, y) \\ \frac{1}{K} \sum_{(x, y) \in S_{x, y}} G(x, y) \\ \frac{1}{K} \sum_{(x, y) \in S_{x, y}} B(x, y) \end{bmatrix}$$



a	b
c	d

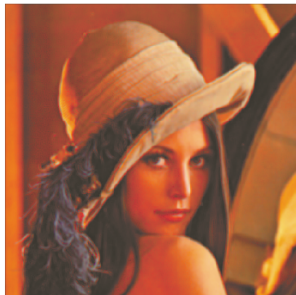
FIGURE 6.38
(a) RGB image.
(b) Red
component image.
(c) Green compo-
nent. (d) Blue
component.



HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.

Suavização com Máscara 5×5

No RGB



Diferença absoluta



Apenas a componente I do HSI

$$\nabla^2[\mathbf{c}(x, y)] = \begin{bmatrix} \nabla^2[R(x, y)] \\ \nabla^2[G(x, y)] \\ \nabla^2[B(x, y)] \end{bmatrix}$$

No RGB



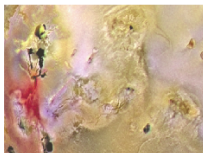
Diferença absoluta



Apenas a componente I do HSI

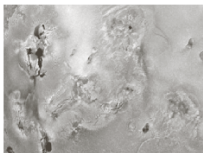
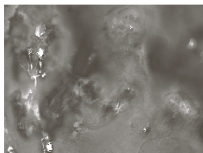
Segmentação por Cores

original



H

S

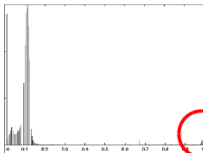


I

Máscara binária gerada de S



Produto da máscara com H



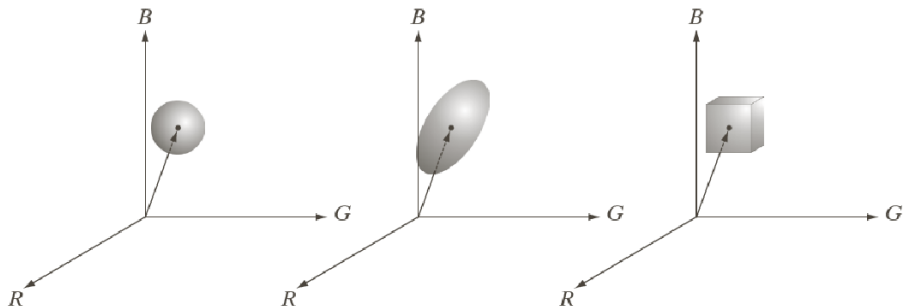
Limiar 0,9 aplicado ao produto

Histograma do produto.

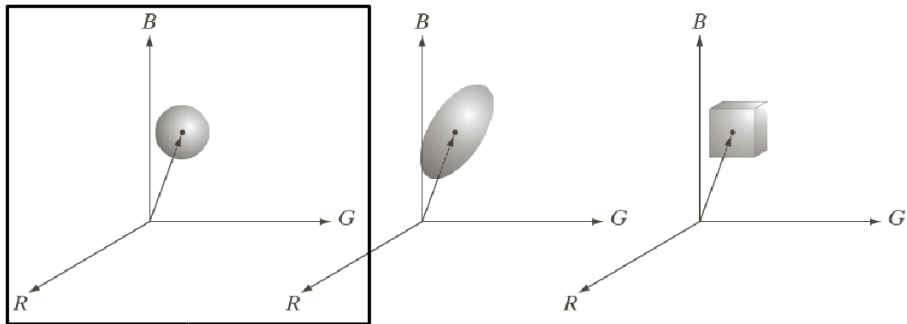
a b
c d
e f
g h

FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (c). (g) Histogram of (f). (h) Segmentation of red components in (a).

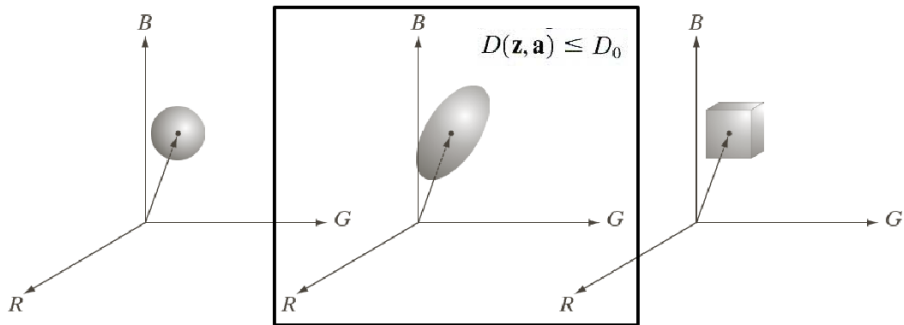
$$D(\mathbf{z}, \mathbf{a})$$



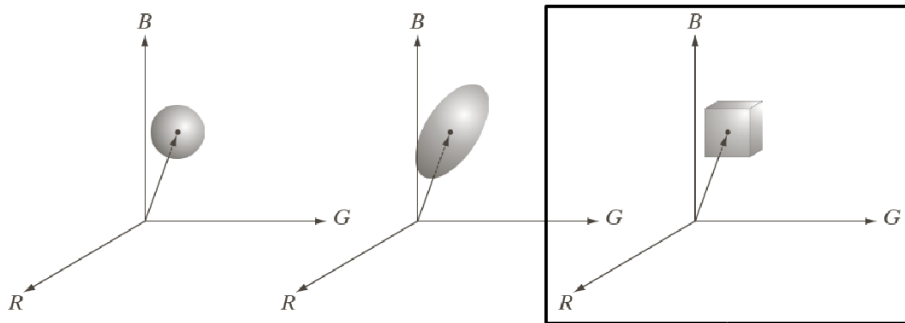
$$\begin{aligned} D(\mathbf{z}, \mathbf{a}) &= \|\mathbf{z} - \mathbf{a}\| \\ &= \left[(\mathbf{z} - \mathbf{a})^T (\mathbf{z} - \mathbf{a}) \right]^{\frac{1}{2}} \\ &= \left[(z_R - a_R)^2 + (z_G - a_B)^2 + (z_B - a_B)^2 \right]^{\frac{1}{2}} \end{aligned}$$



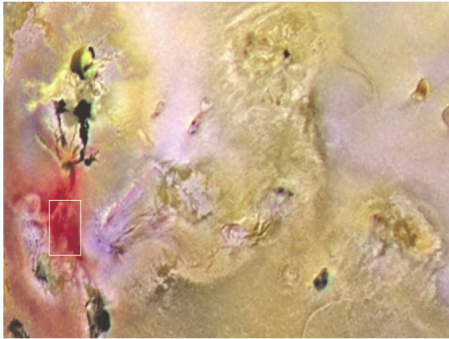
$$D(\mathbf{z}, \mathbf{a}) = \left[(\mathbf{z} - \mathbf{a})^T \mathbf{C}^{-1} (\mathbf{z} - \mathbf{a}) \right]^{\frac{1}{2}}$$



$$D(\mathbf{z}, \mathbf{a}) \leq D_0$$

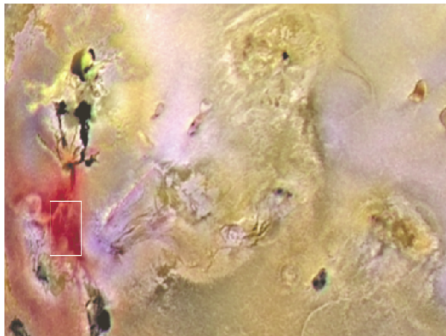


Mais simples.



- σ_R indica o desvio padrão da componente vermelha.
- Dimensões do cubo no plano R:
 $(a_R - 1,25\sigma_R)$ a $(a_R + 1,25\sigma_R)$
- original e máscara de segmentação

Comparando com o resultado anterior



Utilizando o RGB



Utilizando o HSI



Decompondo Imagens Coloridas

R

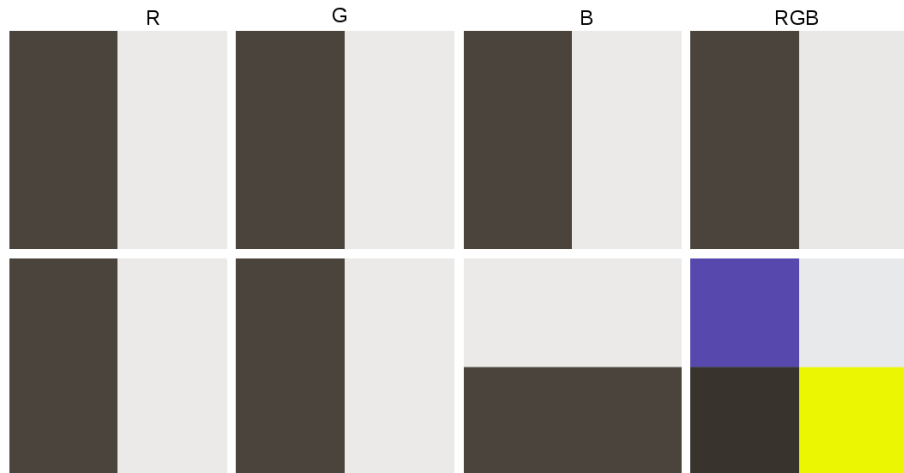
G

B

RGB



Decompondo Imagens Coloridas



$$\begin{aligned}\mathbf{u} &= \frac{\partial R}{\partial x} \mathbf{r} + \frac{\partial G}{\partial x} \mathbf{g} + \frac{\partial B}{\partial x} \mathbf{b} \\ \mathbf{v} &= \frac{\partial R}{\partial y} \mathbf{r} + \frac{\partial G}{\partial y} \mathbf{g} + \frac{\partial B}{\partial y} \mathbf{b}\end{aligned}$$

$$\begin{aligned}g_{xx} = \mathbf{u} \cdot \mathbf{u} &= \left| \frac{\partial R}{\partial x} \right|^2 + \left| \frac{\partial G}{\partial x} \right|^2 + \left| \frac{\partial B}{\partial x} \right|^2 \\ g_{yy} = \mathbf{v} \cdot \mathbf{v} &= \left| \frac{\partial R}{\partial y} \right|^2 + \left| \frac{\partial G}{\partial y} \right|^2 + \left| \frac{\partial B}{\partial y} \right|^2\end{aligned}$$

$$g_{xy} = \mathbf{u} \cdot \mathbf{v} = \frac{\partial R}{\partial x} \frac{\partial R}{\partial y} + \frac{\partial G}{\partial x} \frac{\partial G}{\partial y} + \frac{\partial B}{\partial x} \frac{\partial B}{\partial y}$$

Direção de máxima taxa de variação:

$$\theta = \frac{1}{2} \tan^{-1} \left[\frac{2g_{xy}}{(g_{xx} - g_{yy})} \right]$$

Valor da máxima taxa de variação em (x, y) e na direção:

$$F(\theta) = \left\{ \frac{1}{2} [(g_{xx} + g_{yy}) + (g_{xx} - g_{yy}) \cos 2\theta + 2g_{xy} \sin 2\theta] \right\}^{\frac{1}{2}}$$

$$F(\theta) = F(\theta + \pi)$$



Gradiente
calculado
Individualmente
e somado.



Gradiente
calculado
Nos 3 planos



diferença

Gradiente calculados
individualmente em R, G e B.



a b c

FIGURE 6.47 Component gradient images of the color image in Fig. 6.46. (a) Red component, (b) green component, and (c) blue component. These three images were added and scaled to produce the image in Fig. 6.46(c).

- Modelos discutidos são válidos

- Modelos discutidos são válidos
- Mas diferentes cores podem ser atingidas de maneira não uniforme
- Sensores CCD são sensíveis a ruídos em baixos níveis de iluminação



Componentes R, G
e B de uma imagem
corrompida com
ruído Gaussiano
(média 0 e variância
800)



Hue



Saturation



Intensity

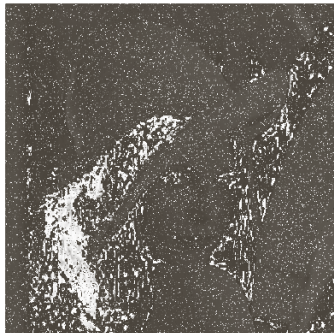


Componentes H, S e I da imagem anterior – ruído Gaussiano (média 0 e variância 800)

Componente G
corrompida
com ruído sal e
pimenta.



Hue



Saturation



Intensity

