Digital Image Processing

Lecture 2

The basic concepts of Digital Image Processing

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2. The basic concepts of Digital **Image Processing**

2.1. Digital Image Formation

2.2. Color Model and Image function

2.3. Spatial Relationships between image pixels

2.4. Basic features of digital images

2.1. Digital Image Formation

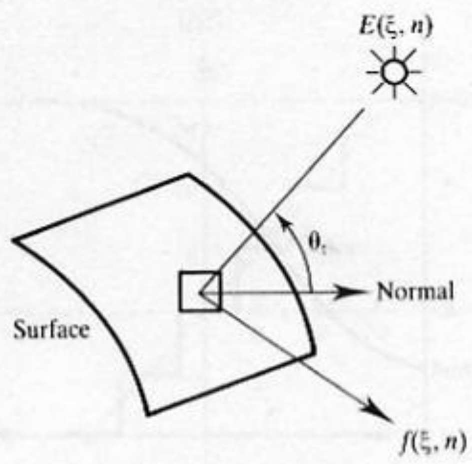


Figure 2.1 Reflection of light on an object surface.

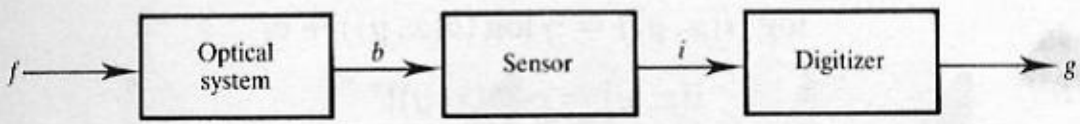


Figure 2.2 Model of a digital image formation system.

2.1. Digital Image Formation

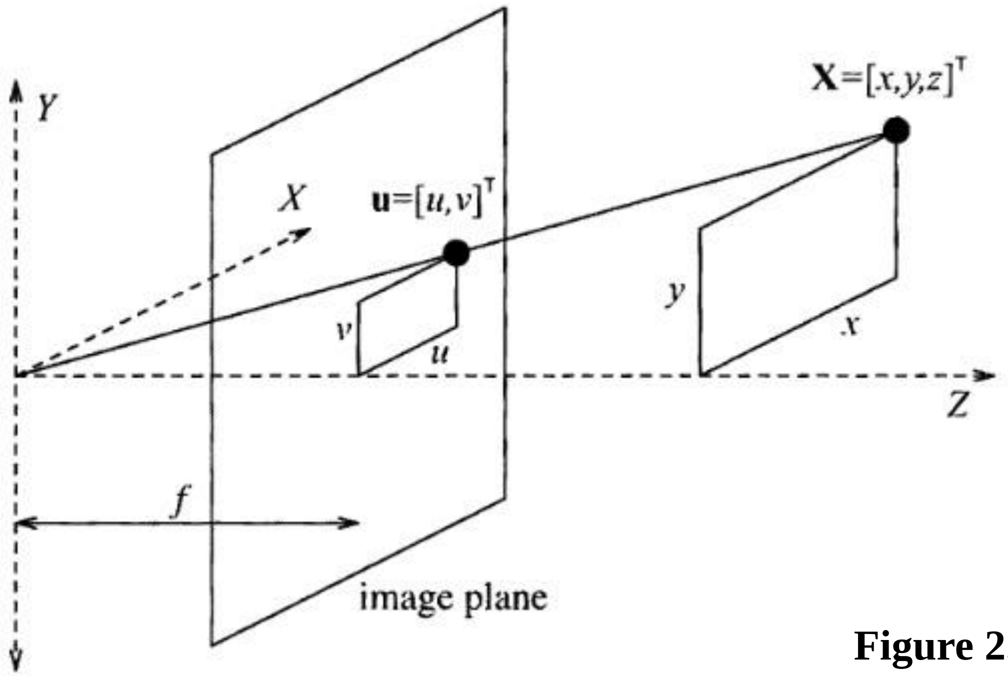


Figure 2.3. Perspective projection geometry.

2.1. Digital Image Formation

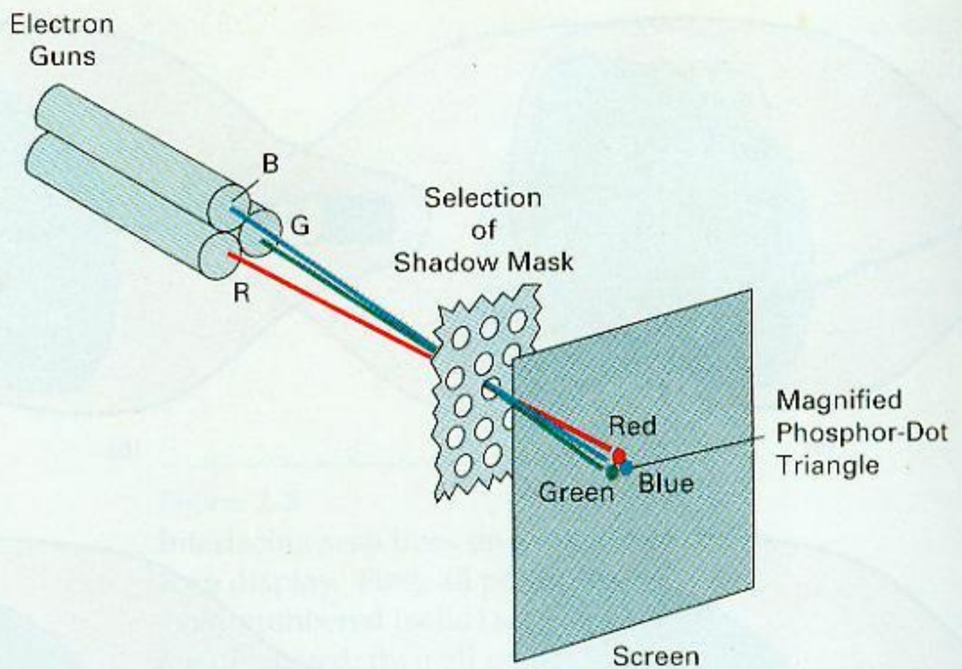


Figure 2.4.

Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color-dot patterns on the screen, are directed to each dot triangle by a shadow mask.

2.1. Digital Image Formation

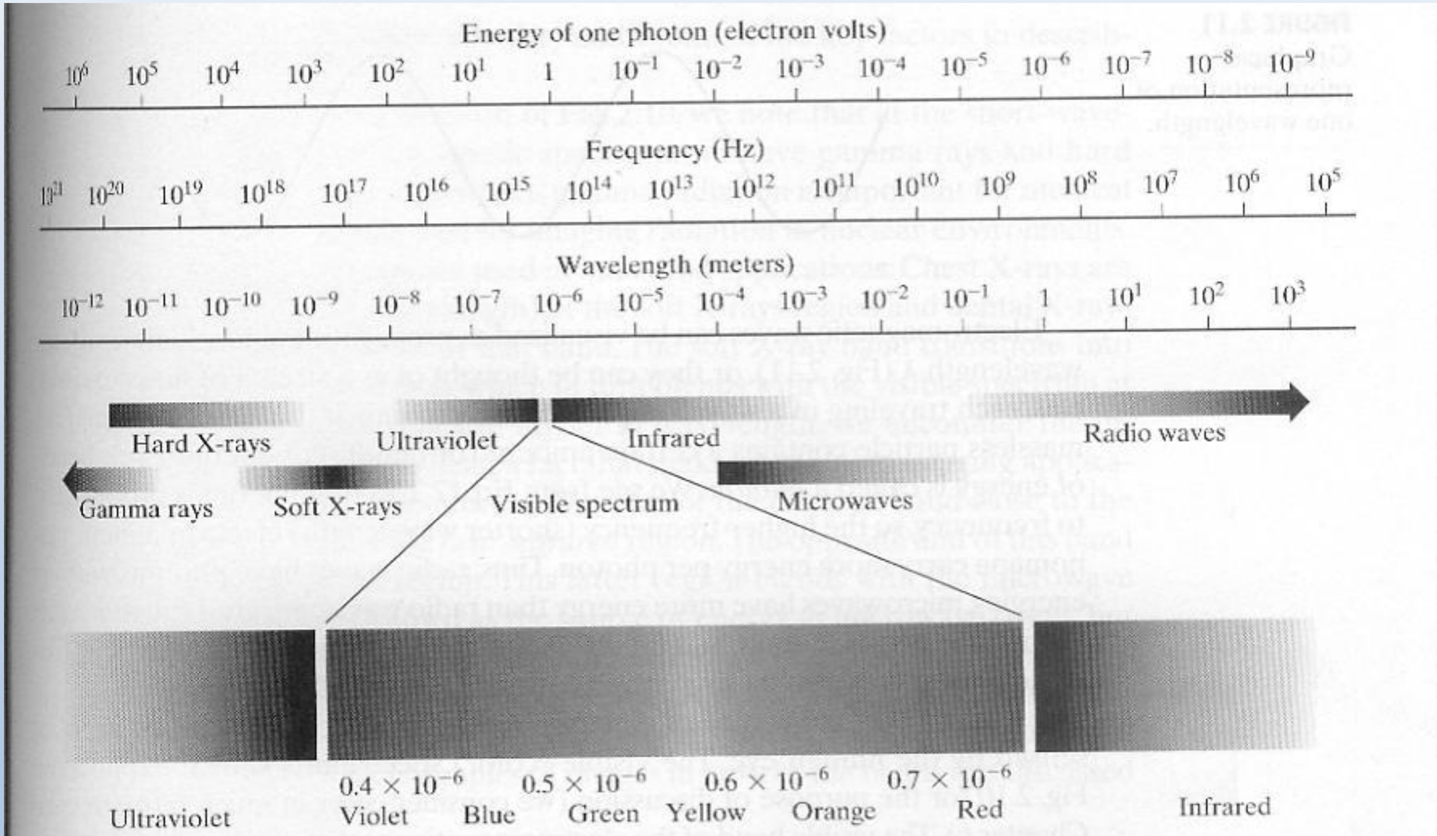


Figure 2.5. The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

2.2. Image Function & Color model

2.2.1. Image Function

2.2.2. Color model RGB

2.2.3. Color Model HSV

2.2. Image Function & Color model

2.2.1. Image Function

- **Continuous Image function**

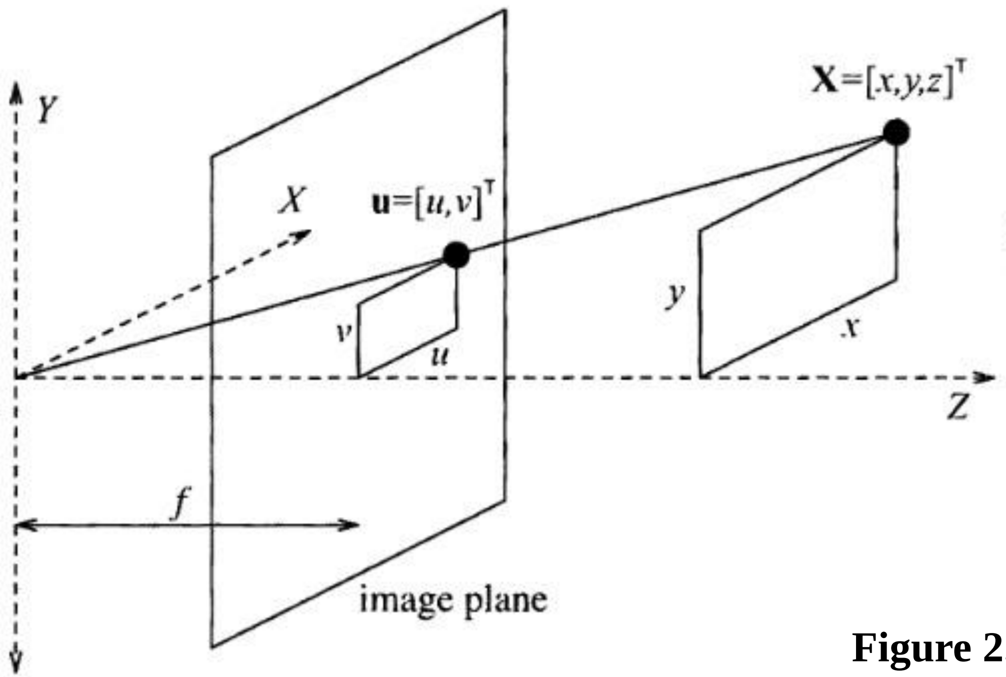
• The image function value corresponds to the brightness in the pixels.

• The image on the retina or TV camera sensor is a two-dimensional image. Calling a two-dimensional image that carries the brightness information is the intensity image.

• The intensity image is the result of a perspective projection of 3D realistic scenes.

2.2. Image Function & Color model

2.2.1. Image Function



$$u = \frac{x f}{z}, \qquad v = \frac{y f}{z}.$$

Figure 2.6. Perspective projection geometry.

2.2. Image Function & Color model

2.2.1. Image function

- **Digital Image Function**

\- Single spectral image function f is the defined mapping:

$$f:[0..M-1]\times[0..N-1]\rightarrow[0..L-1]$$

M, N are the number of pixels in the horizontal and vertical directions of the image.

L is the number of gray levels in the image.

2.2. Image Function & Color model

2.2.1. Image function

- **Digital Image Function**

\- Multi spectral image function f_{MUL} is the defined mapping:

$$f_{MUL}(x, y) = \{ f_1(x, y), f_2(x, y), \ldots, f_n(x, y) \}$$

$f_i(x, y)$ is single spectral image function

2.2. Image Function & Color model

2.2.1. **Image function**

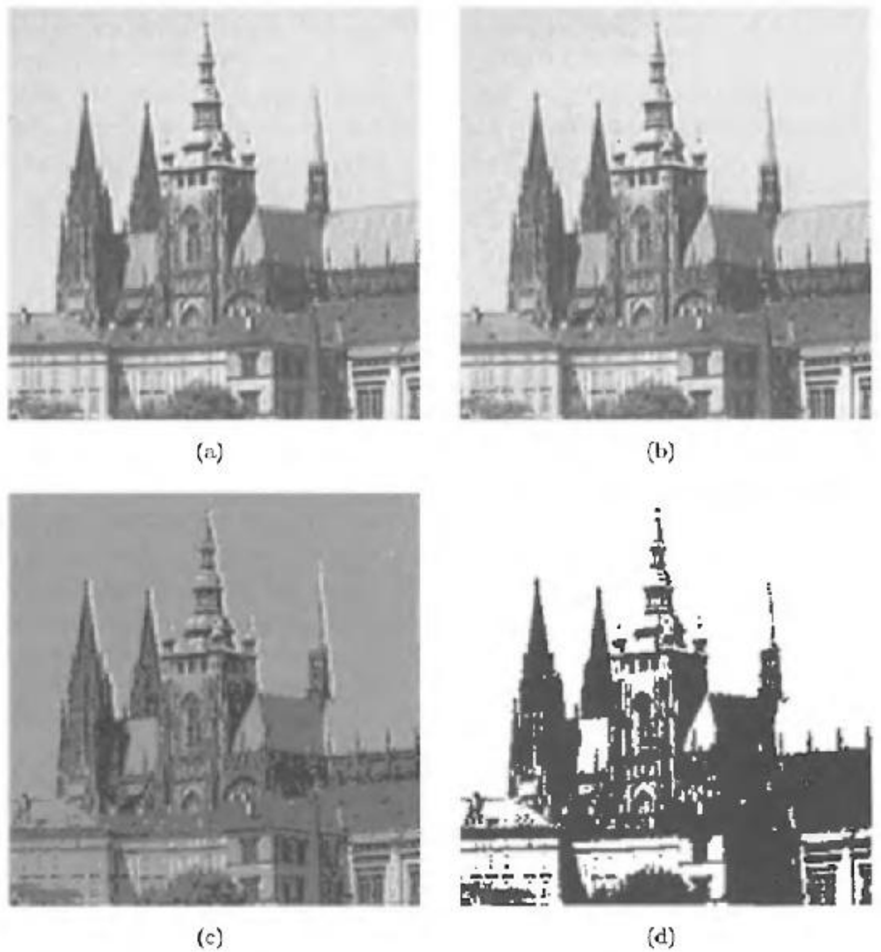


Figure 2.7. Brightness levels. (a) 64. (b) 16. (c) 4. (d) 2.

2.2. Image Function & Color model

2.2.1. Image Function

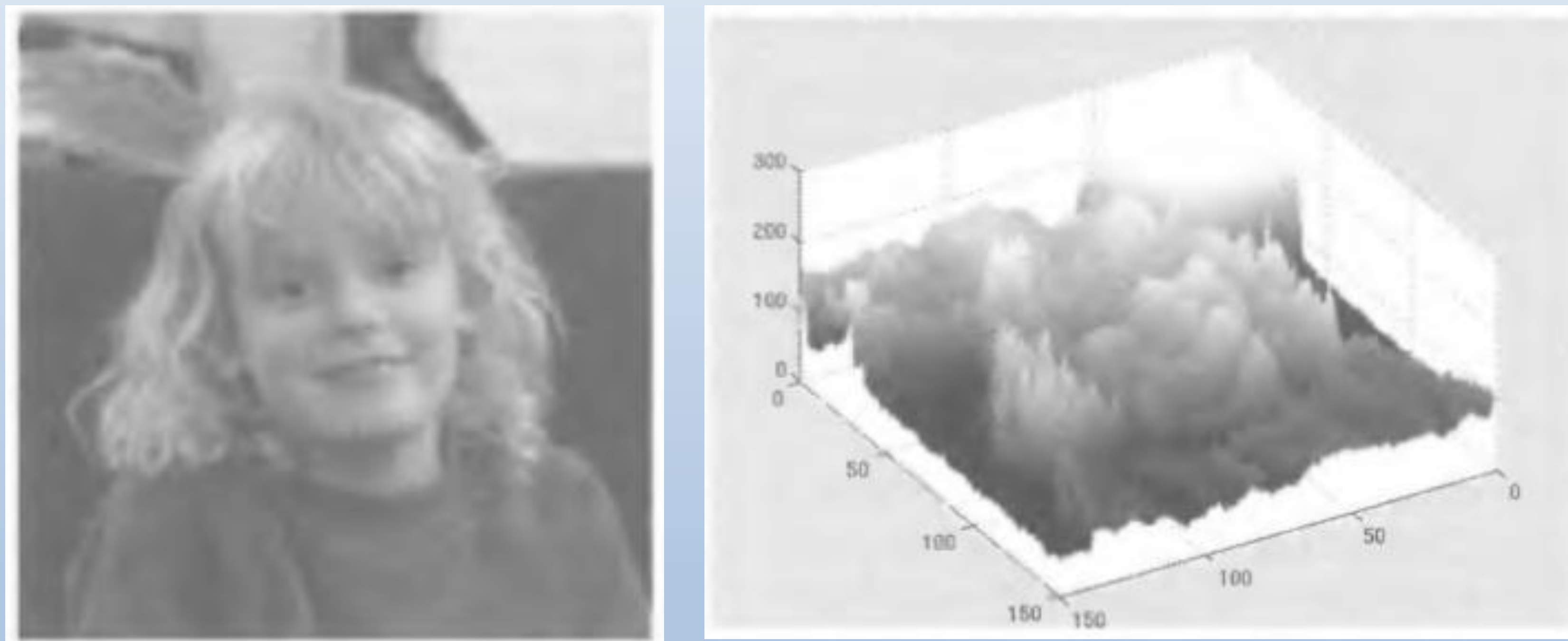


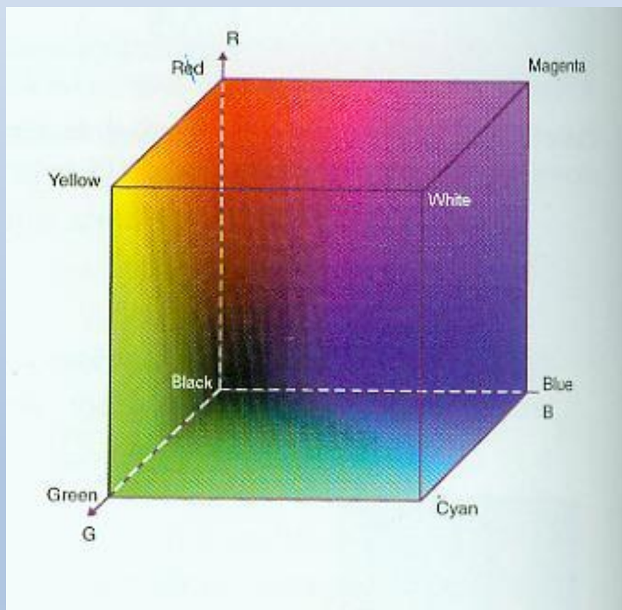
Figure 2.8. Semantic gap

2.2. Image Function & Color model

2.2.2. RGB Color Model

The color values at the pixel are composed of a triple of value (R,G,B),

R,G,B є [0..255].



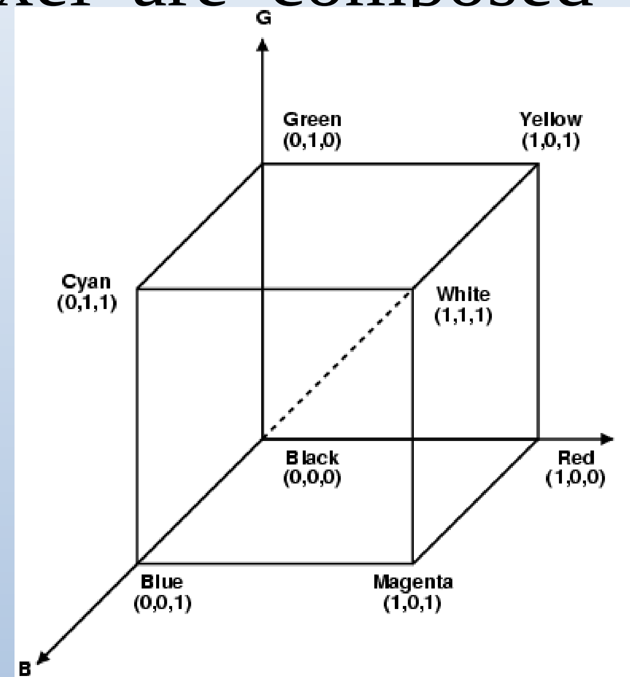


Figure 2.9. RGB Color model

2.2. Image Function & Color model

2.2.3. HSV Color Model (Hue, Saturation, Value)

The color values at the pixel are composed of a triple of value(H,S,V).

H ϵ [0..360),

S,V ϵ [0..1].

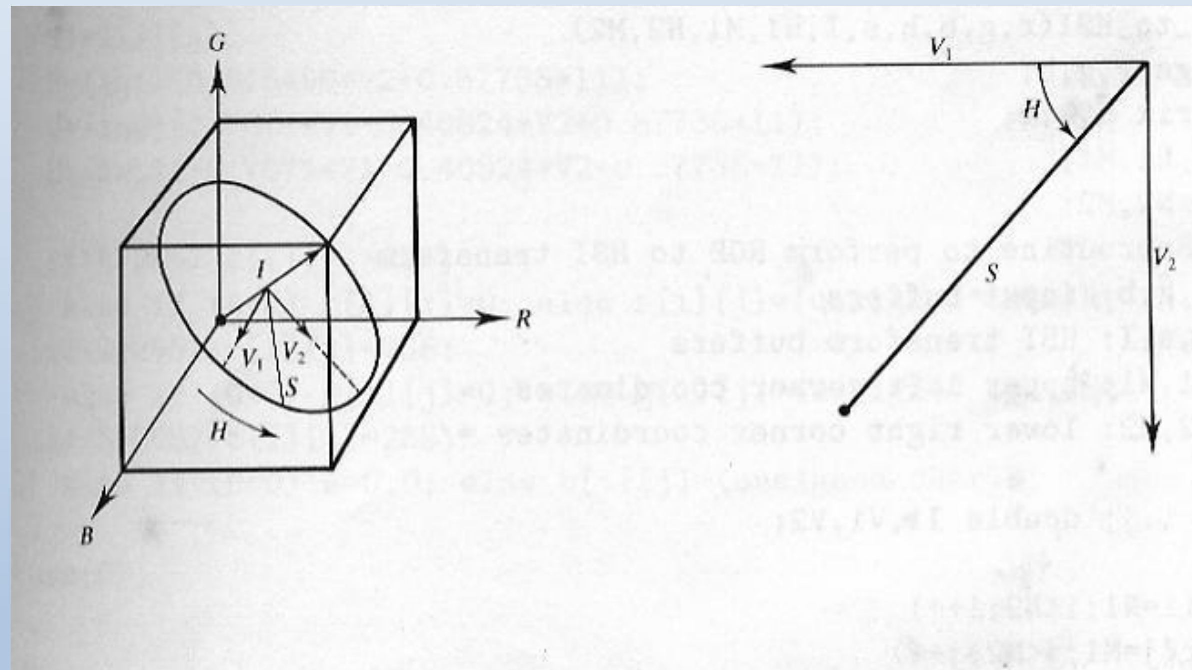


Figure 2.10. HSV Color model

2.2. Image Function & Color model

2.2.3. HSV Color Model (Hue, Saturation, Value)

RGB → HSV

$$\begin{bmatrix} V \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \sqrt{3}/3 & \sqrt{3}/3 & \sqrt{3}/3 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} \\ 2/\sqrt{6} & -1/\sqrt{6} & -1/\sqrt{6} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$H = \tan^{-1}(V_2/V_1)$$

$$S = \sqrt{V_1^2 + V_2^2}$$

HSV → RGB

$$V_1 = S \cos H$$

$$V_2 = S \sin H$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \sqrt{3}/3 & 0 & 2/\sqrt{6} \\ \sqrt{3}/3 & 1/\sqrt{2} & -1/\sqrt{6} \\ \sqrt{3}/3 & -1/\sqrt{2} & -1/\sqrt{6} \end{bmatrix} \begin{bmatrix} V \\ V_1 \\ V_2 \end{bmatrix}$$

2.2. Image Function & Color model

2.2.3. HSV Color Model (Hue, Saturation, Value)

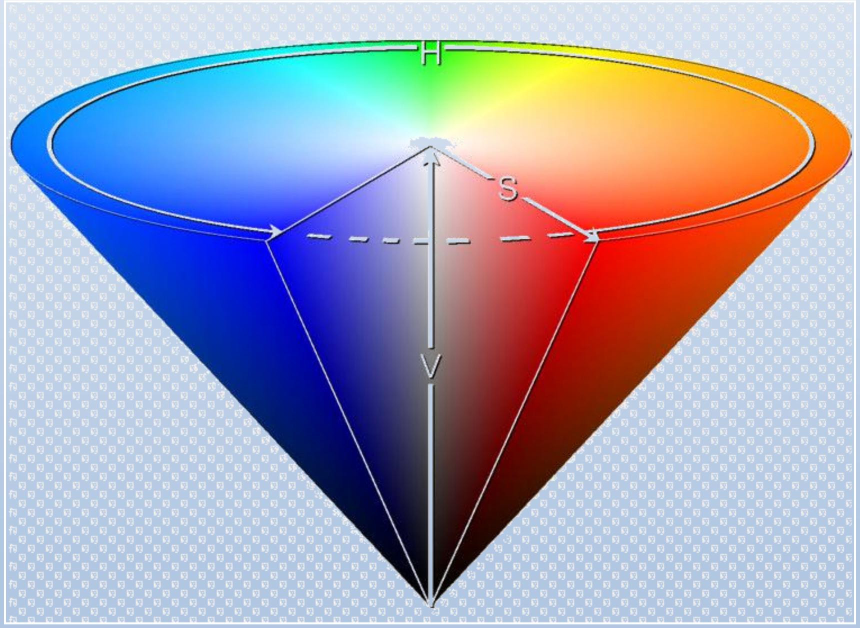
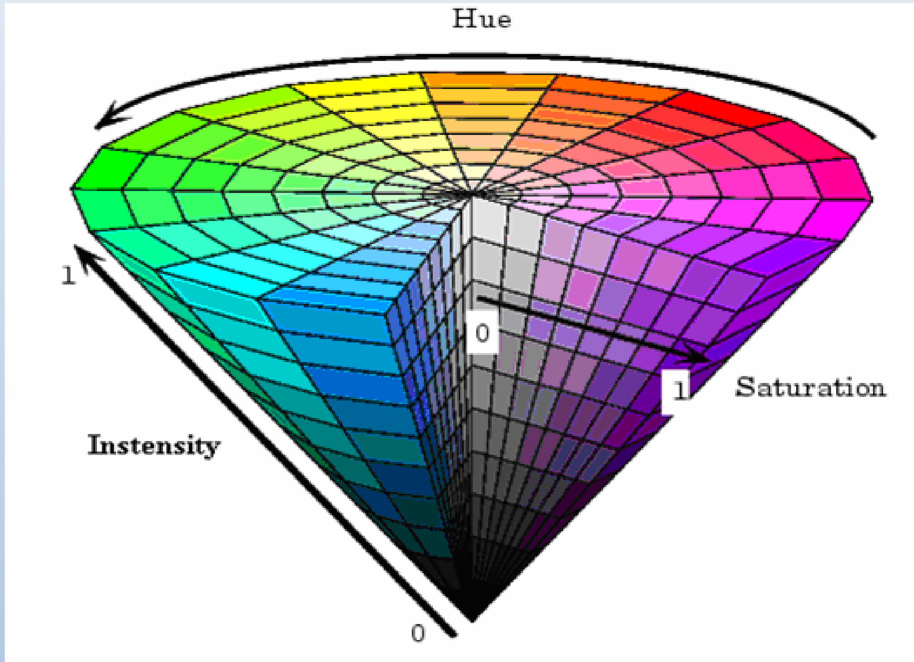


Figure 2.11. HSV Color model and rainbow color

2.2. Image Function & Color model

2.2.3. HSV Color Model (Hue, Saturation, Value)



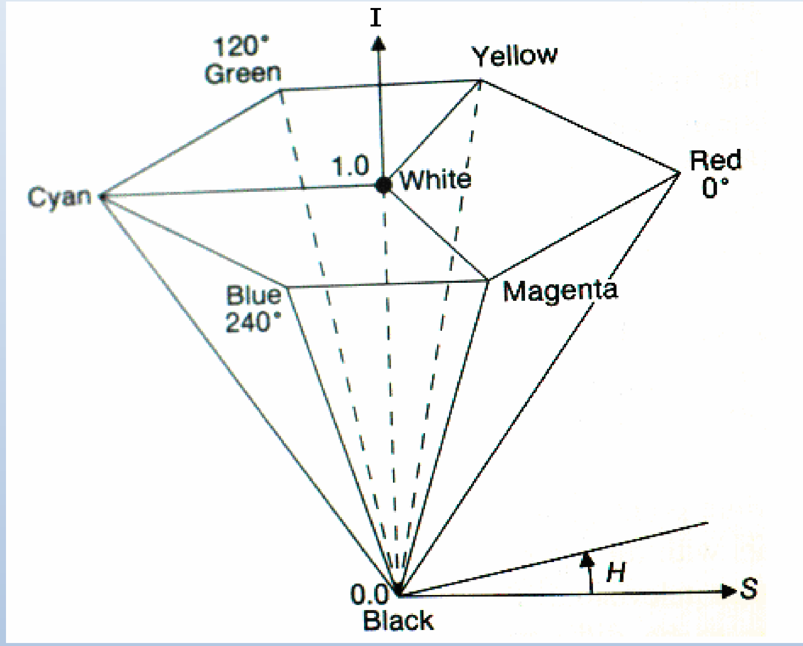


Figure 2.12. HSV Color model and Color Quantization

2.2. Image Function & Color model

2.2.3. HSV Color Model **(Hue, Saturation, Value)**

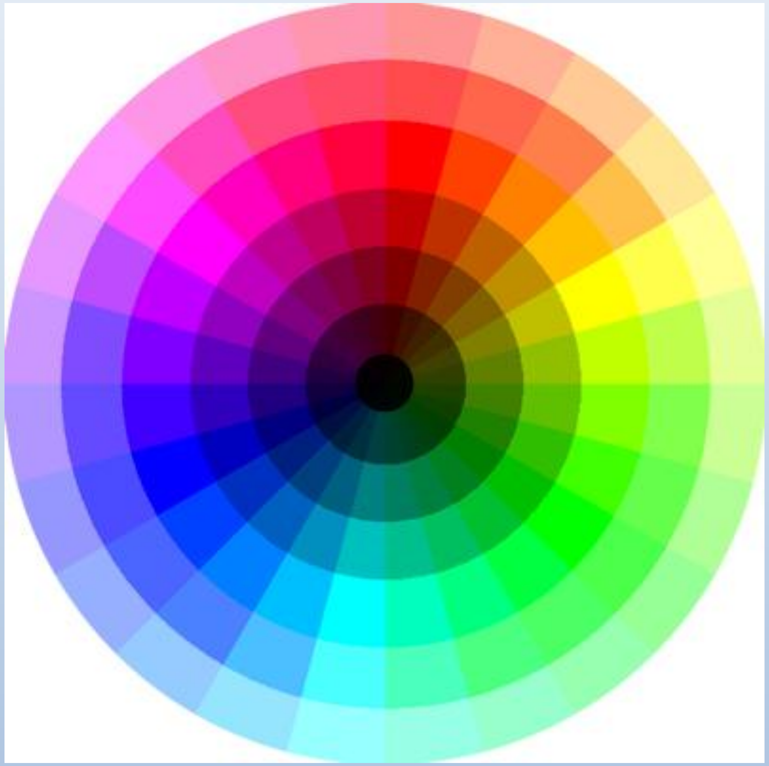


Figure 2.13. HSV Color model and Variations of Hue and Saturation at specified Value.

2.2. Image Function & Color model

2.2.3. HSV Color Model **(Hue, Saturation, Value)**

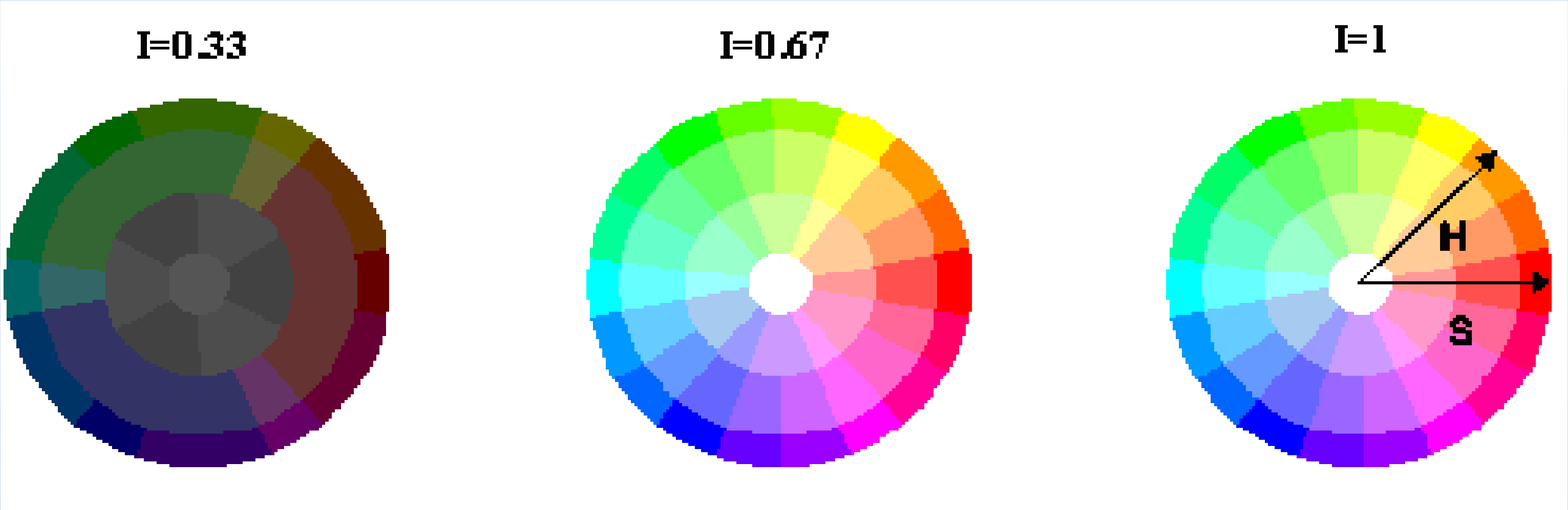


Figure 2.14. HSV Color model and Variations of Hue and Saturation at some Value.

2.3. Spatial Relationships between image pixels

2.3.1. Neighbourhood of image pixels

2.3.2. Distance between image pixels

2.3. Spatial Relationships between image pixels

2.3.1. Neighbourhood of image pixels

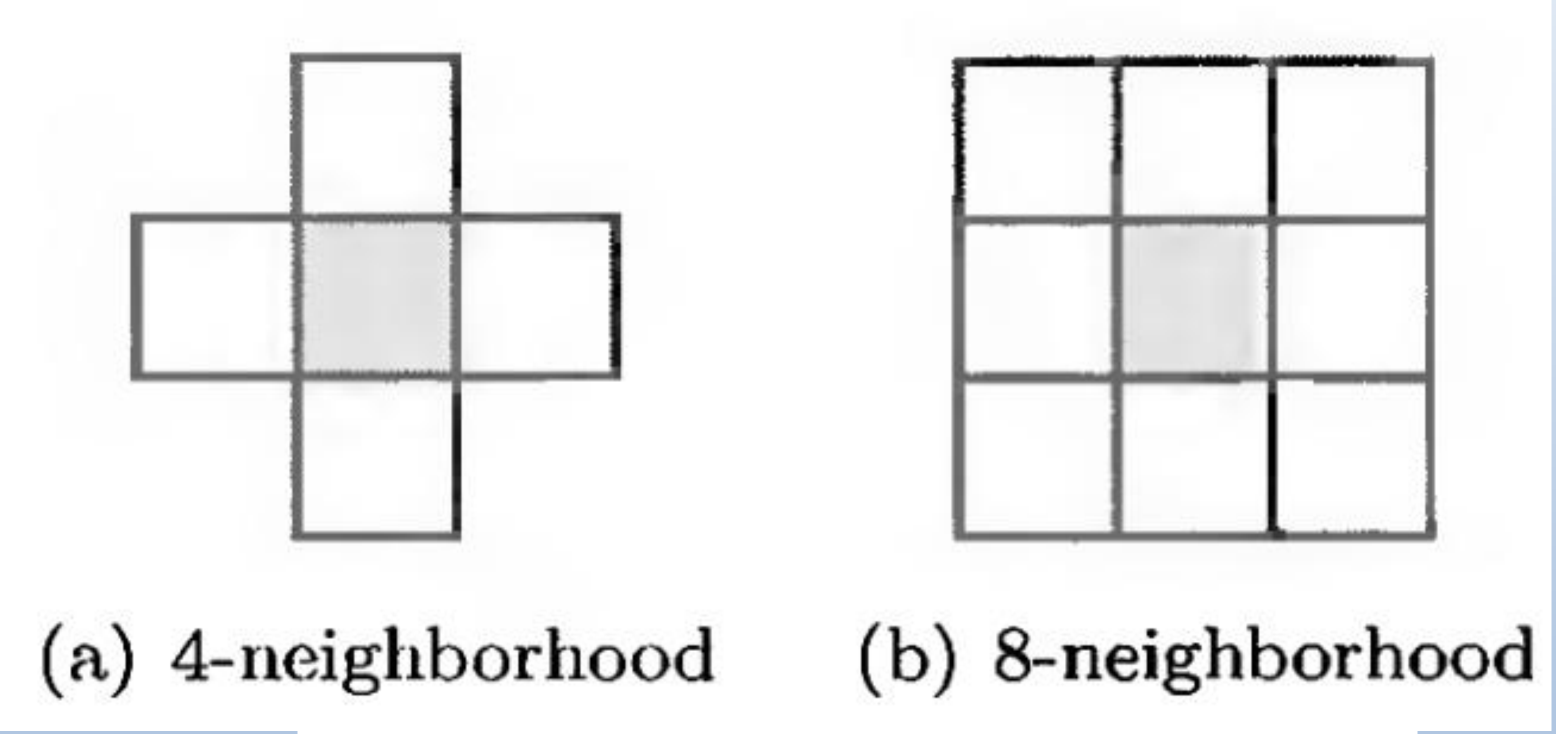


Figure 2.15. Neighbourhood of image pixels.

2.3. Spatial Relationships between image pixels

2.3.2. Distance between image pixels

$$d(p,q) = \left(\sum_{i=1}^{n} \left| p_i - q_i \right|^r \right)^{1/r},$$

p_i, q_i là tọa độ thứ i của điểm p, q

$0 < r < \infty$

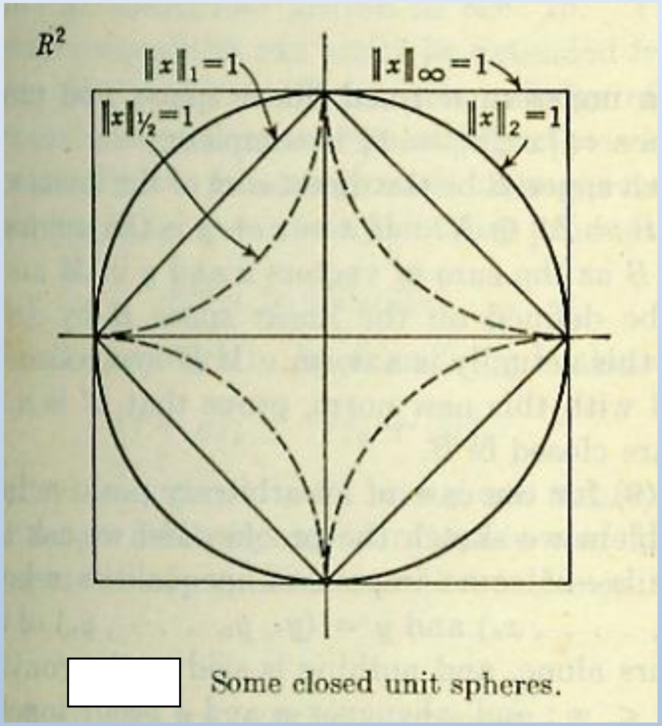


Figure 2.16. Minkowski distance and visualization on unit sphere

2.4. Basic features of digital images

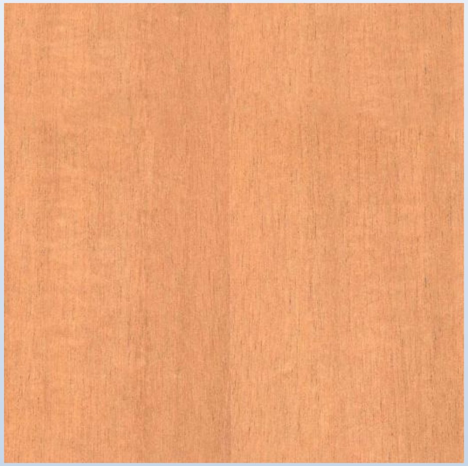
2.4.1. Color features

2.4.2. Texture features

2.4.3. Shape features

2.4. Basic features of digital images

Color cues



Texture cue

Shape cue

Figure 2.17. Basic features of digital images: Color, Texture and shape

2.4.1. Color feature

Color histogram

Color space HSV is quantified as follows :

$\mathrm{H} = 12, \mathrm{S} = 3, \mathrm{V} = 3$

The number of color is 108.

$$h(i) = \frac{N(i)}{N}, i = 0..107$$

$h(i) : i^{th}$ *component of color histogram*

$N(i) :$ *number of pixels in color i*

$N :$ *total number of pixels of* image

2.4.1. Color feature

Color Histogram

The color histogram $\boldsymbol{h}^{\text{color}}$ of an image $\boldsymbol{I}^{\boldsymbol{C}}$ is a vector defined as follows:

$$\boldsymbol{h}^{\text{color}} = (h^{\text{color}}[0], \ldots, h^{\text{color}}[M-1]),$$

where each component is computed as

$$h^{\text{color}}[m] = \frac{1}{I_x I_y} \sum_{x=0}^{I_x-1} \sum_{y=0}^{I_y-1} \begin{cases} 1 & \text{if } Q^{color}(\boldsymbol{I}^{\boldsymbol{C}}(x,y)) = m \\ 0 & \text{otherwise,} \end{cases}$$

where m is the index of each one of the M possible colors in the quantized color palette. Each component $h^{\text{color}}[m]$, known as *bin*, represents the number of pixels in the quantized image valued to that color. Analogously, we denote the color histogram of a frame $\boldsymbol{I}_t^{\boldsymbol{C}}$ as $\boldsymbol{h}_t^{\text{color}}$.

2.4.1. Color feature

Color Histogram

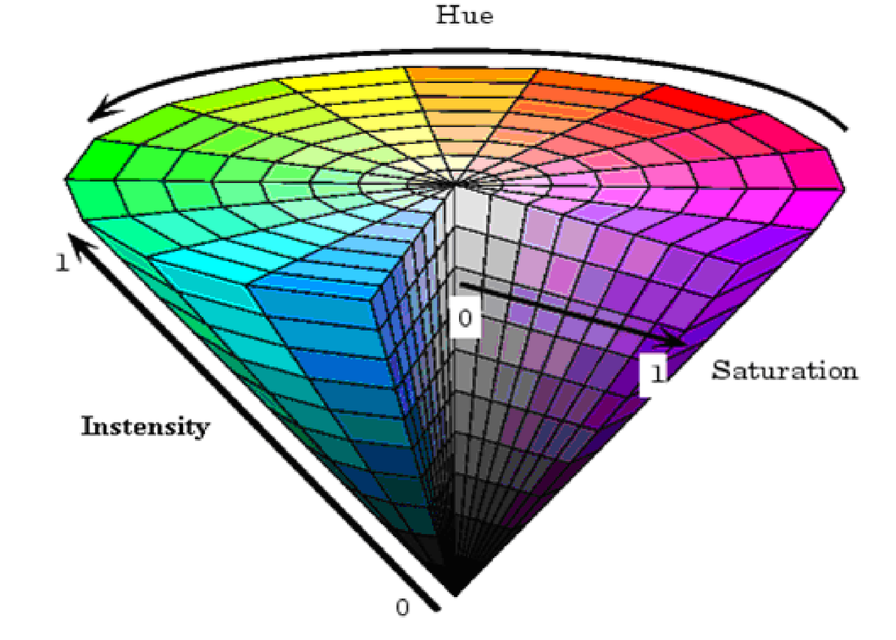


Figure 2.18. Color quantization based on HSV Color Model

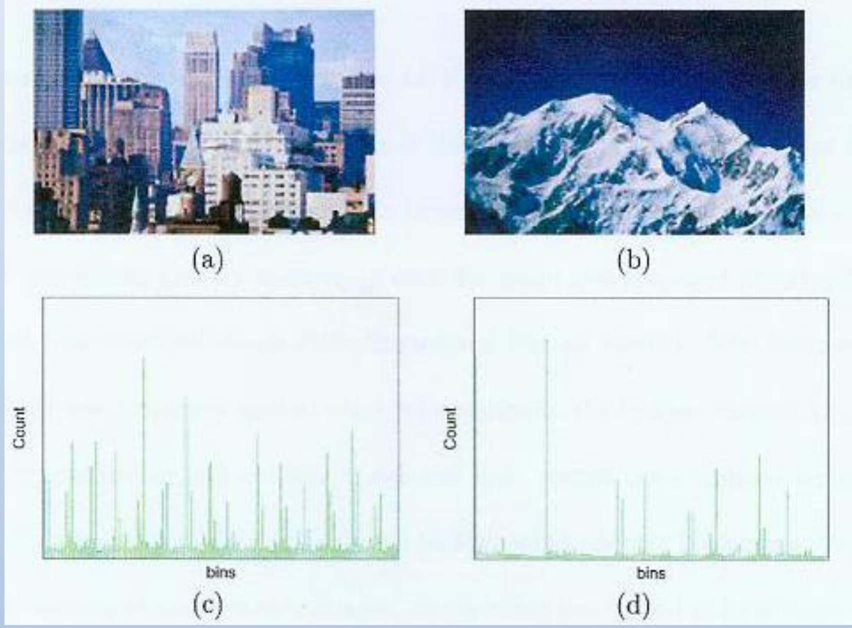


Figure 2.19. Color-based features for (a) city and (b) landscape image; (c) and (d) show the color histogram features for (a) and (b)

2.4.1. Color feature

Color Histogram

Fig.2.20. Image before color quantization

(in RGB color model)

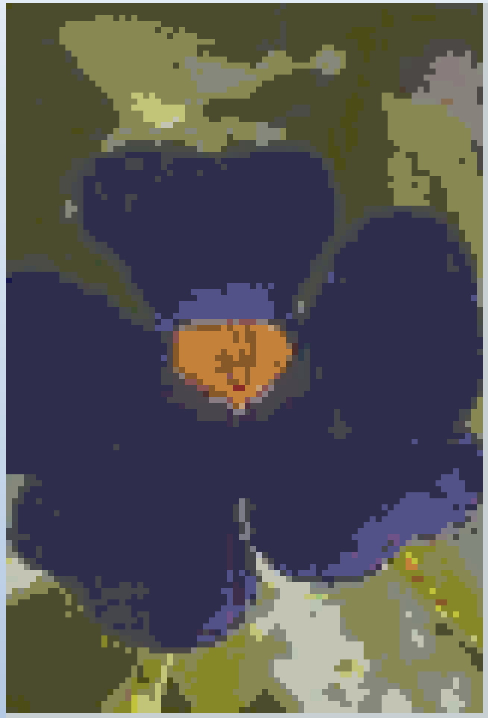


Fig.2.21. Image after color quantization

(in HSV color model)

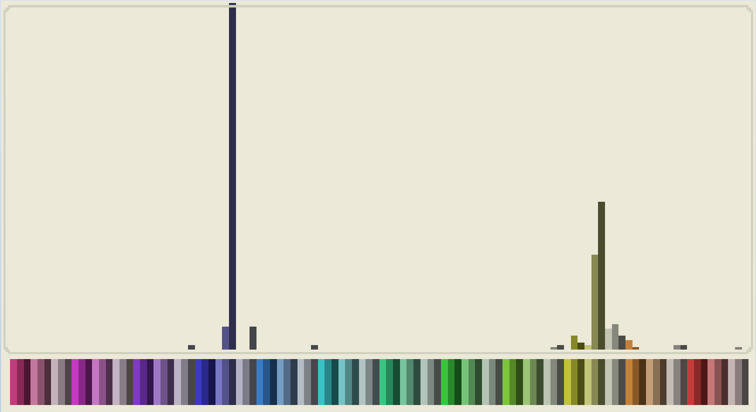


Fig. 2.22. Color histogram after color quantization

2.4.3. Shape feature

Edge Direction Histogram

$\text{EDH consisted of } 73 \text{ elements:}$

$72\ \textit{elements}\ \text{are denoted by}\ EDH(I,i)\ (i = 0,1,\ldots 71)$

The last element includes the number of pixels are not on edge.

$$EDH(i) = \frac{m(i)}{n_E(I)}, i = 0,1,\ldots 71;\ EDH(72) \stackrel{\Delta}{=} \frac{EDH(72)}{n(I)}$$

$m(i): \textit{number of pixels of bin i,}$

$\textit{bin i consisted of edge directions}\ \alpha_i\ \textit{in range:}$

$i*5 \le \alpha_i < (i+1)*5)$

$n_E(I): \textit{number edges' pixels}; n(I): \textit{number of image pixels}$

2.4.3. Shape feature

Edge Direction Histogram

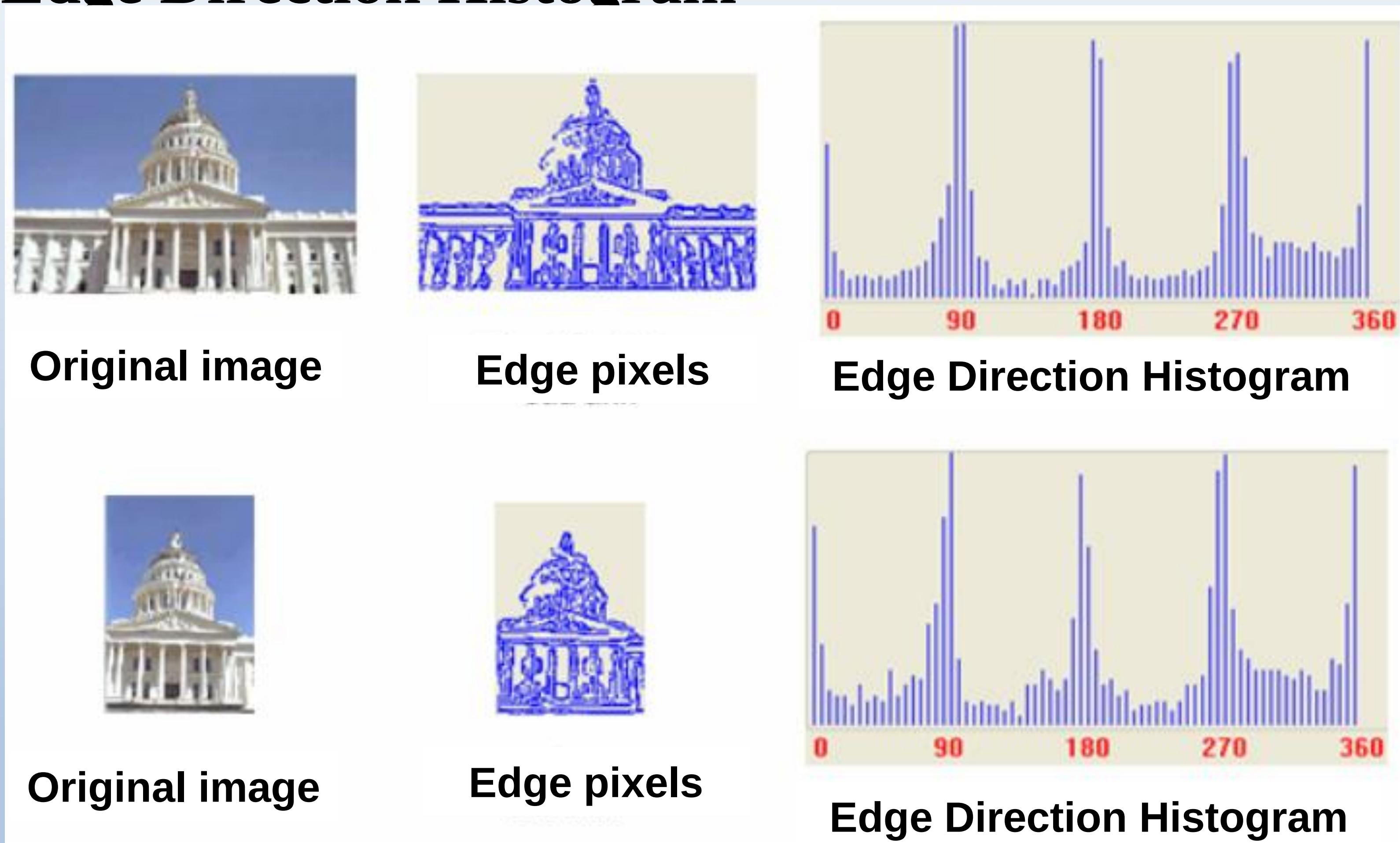


Fig. 2.23. Edge Direction Histogram

2.4.3. Shape feature

Edge Direction Histogram

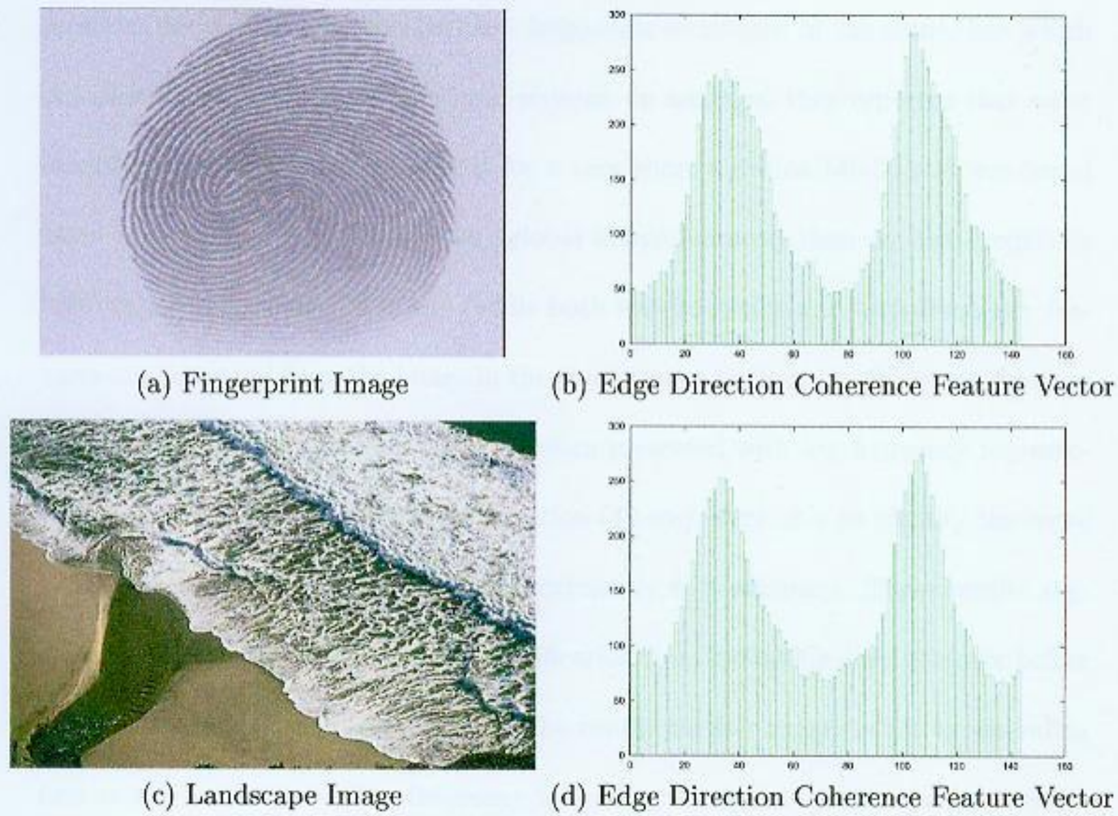


Fig. 2.24. Edge direction coherence vector features for (a) fingerprint and (c) landscape image; The distance, $d(b, d)$, between these two histograms is 0.0147.

2.4.3. Shape feature

Edge Direction Histogram

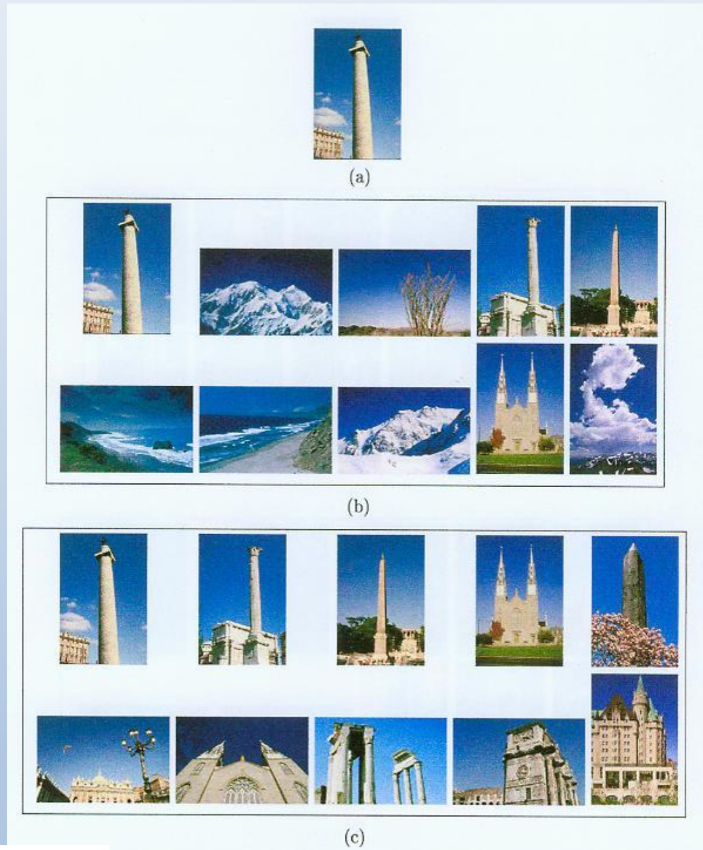


Fig. 2.25. Color-based retrieval results; (a) query image; (b) top-10 retrieved images from 2, 145 city and landscape images; (c) top-10 retrieved images from 760 city images; filtering out landscape images prior to querying improves the retrieval results.

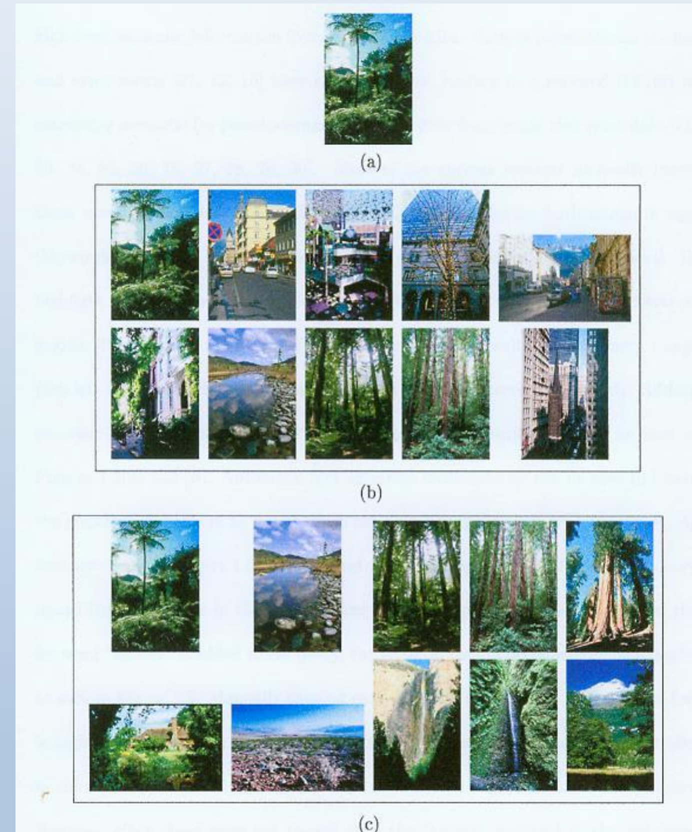


Fig. 2.26 Color-based retrieval results; (a) query image; (b) top-10 retrieved images from 2, 145 city and landscape images; (c) top-10 retrieved images from 1, 386 landscape images; filtering out city images prior to querying improves the retrieval results.