Dithering and Halftoning

Trade spatial for intensity resolution

- Random dither; Robert's algorithm
- Ordered dither
- Clustered dither or halftones
- Error diffusion

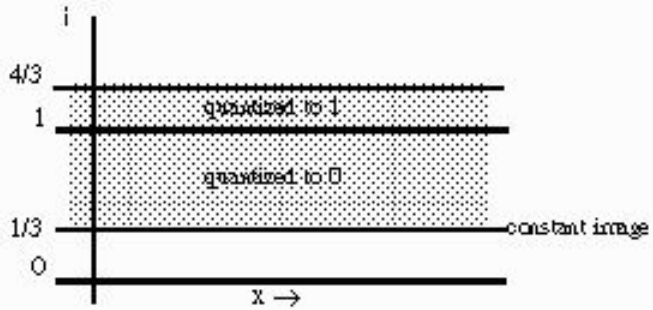
Your eye will average over an area

Copyright © Pat Hanrahan

Robert's Algorithm

First add noise $\hat{v}(x,y) = trunc(K \times v(x,y) + noise(x,y))$

Then quantize $0 \le noise < 1$



Moves low frequency (average error) to high frequency

Pink(low), *Blue (high)*, White(all) frequency noise

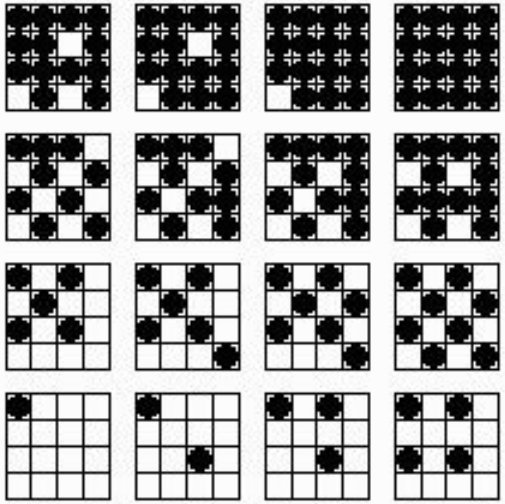
Copyright © Pat Hanrahan

Bayer Ordered Dither Patterns

$$D_2 = \begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

$$D_n = \begin{bmatrix} 4D_{n/2} + 0 & 4D_{n/2} + 2 \\ 4D_{n/2} + 3 & 4D_{n/2} + 1 \end{bmatrix}$$

$$D_4 = \begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$



Copyright © Pat Hanrahan

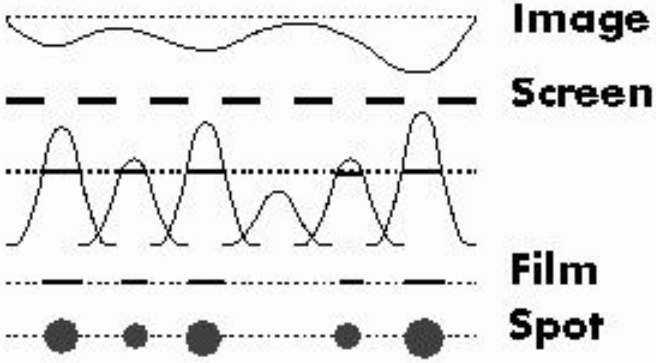
Classic Halftoning

Printers: *Binary Blobs* of ink

- Clustered pattern
- Enlarging spot

Classical printer screens

- Spot function
- Line frequency
- Tilt angle



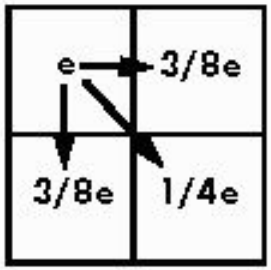
CS248 W98 Lecture 3

Copyright © Pat Hanrahan

Error Diffusion

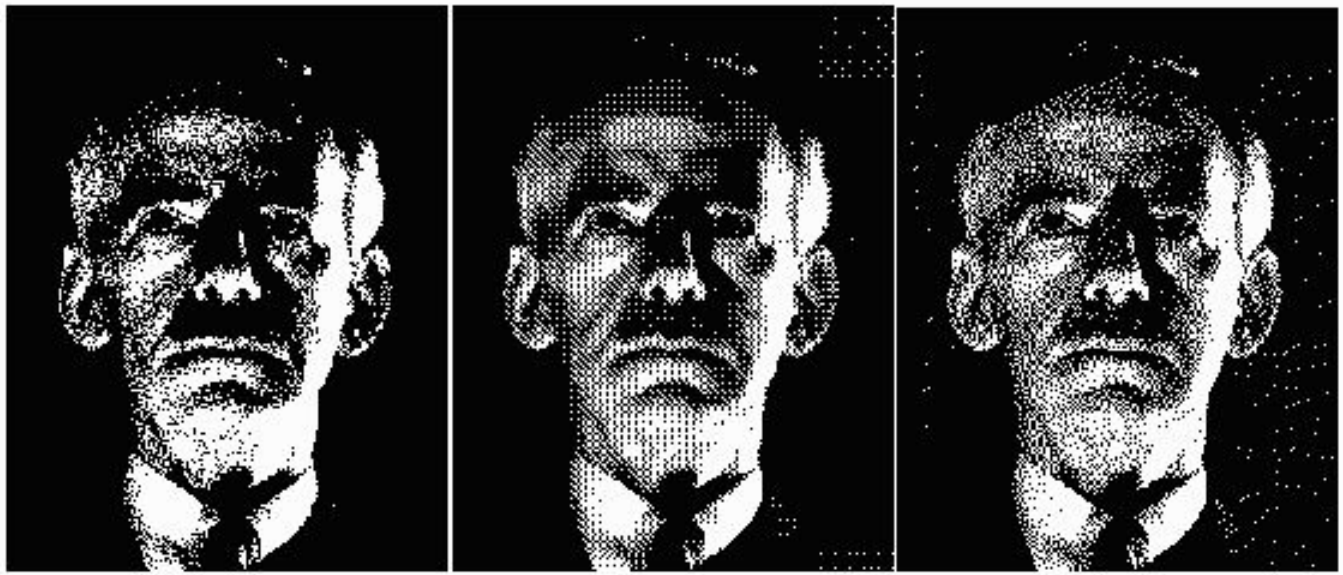
Idea: Quantize, then distribute error to neighbors

```
for(y=0; y<ny; y++)
  for(x=0; x<nx; x++){
    vq[x][y] = quantize(v[x][y]);

    e = v[x][y] - vq[x][y];

    i[x+1][y] += 3/8*e;
    i[x][y+1] += 3/8*e;
    i[x+1][y+1] += 1/4*e;
}
```



Copyright © Pat Hanrahan

Comparison



Blue Noise | Bayer Dither | Floyd-Steinberg

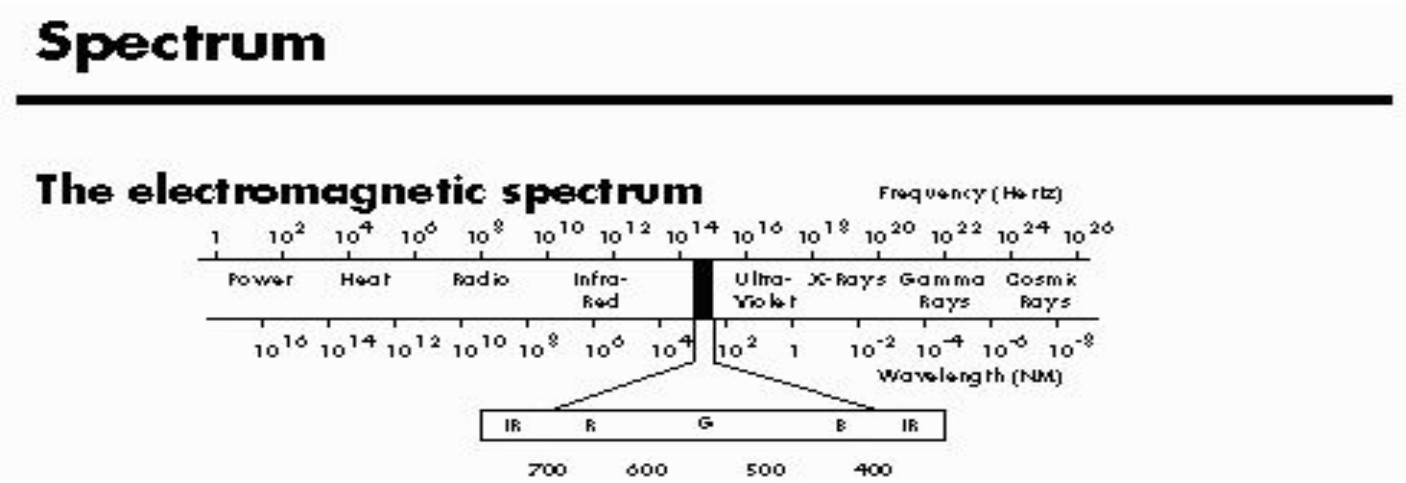
CS248 W98 Lecture 3

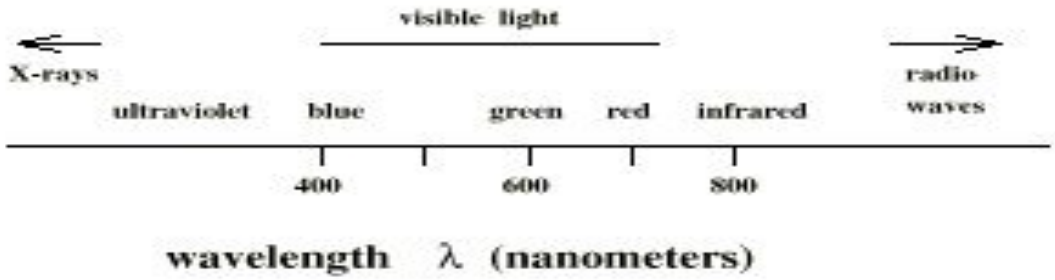
Copyright © Pat Hanrahan

СВЕТ и ЦВЕТ

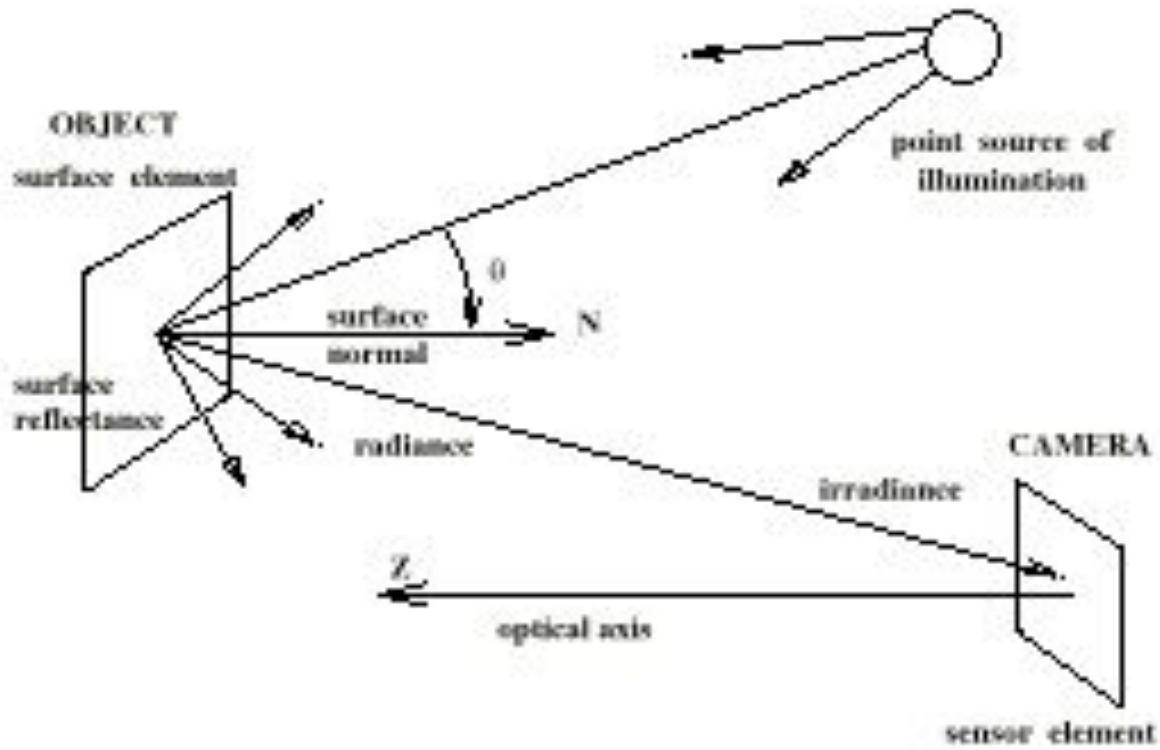
- Физика цвета
- Восприятие цвета
- Цветовые системы
  RGB
  CMY
  HSI
  YIQ (YUV)

Видимая часть электромагнитного спектра





Распространение света

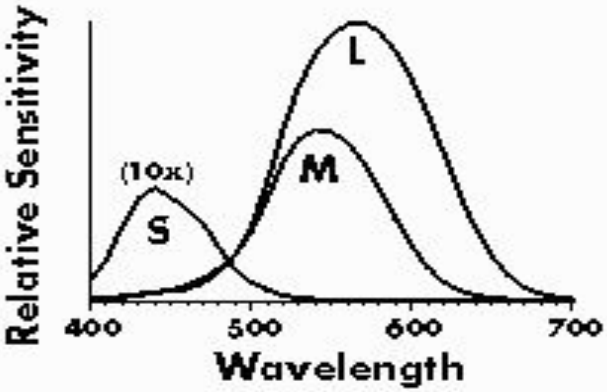


Восприятие цвета

Human Color Vision

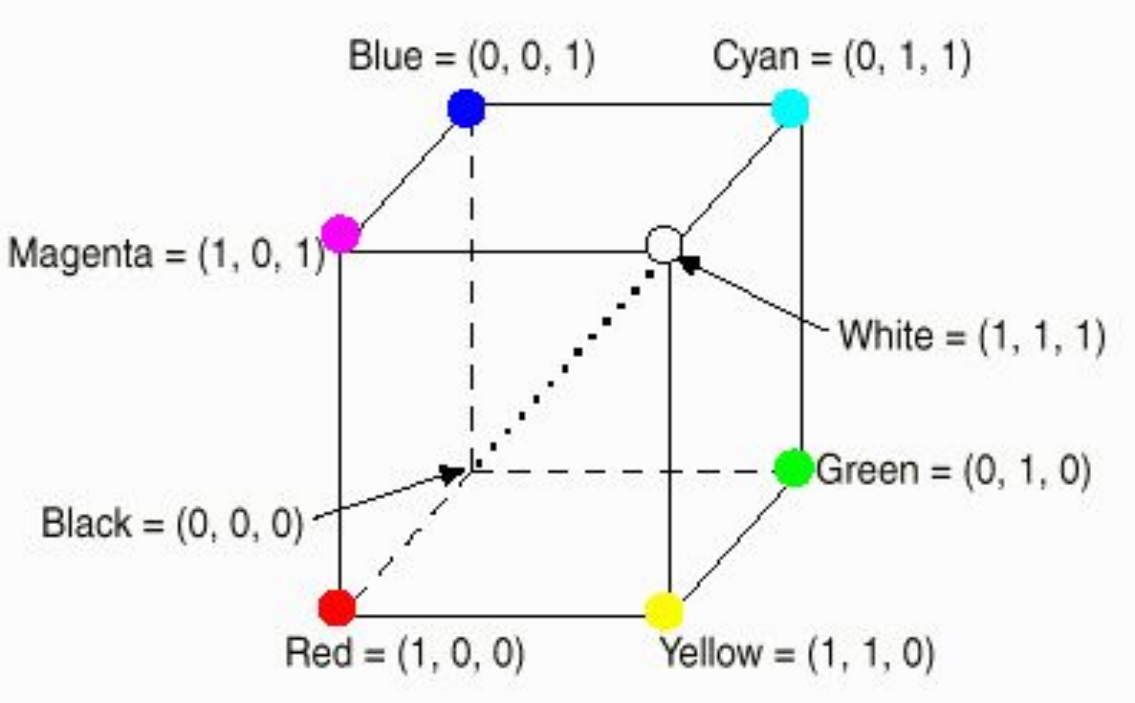
- **There are 3 light sensitive pigments in your cones (L,M,S), each with a different *spectral response curve***

$$L = \int L(\lambda)E(\lambda)d\lambda$$
$$M = \int M(\lambda)E(\lambda)d\lambda$$
$$S = \int S(\lambda)E(\lambda)d\lambda$$

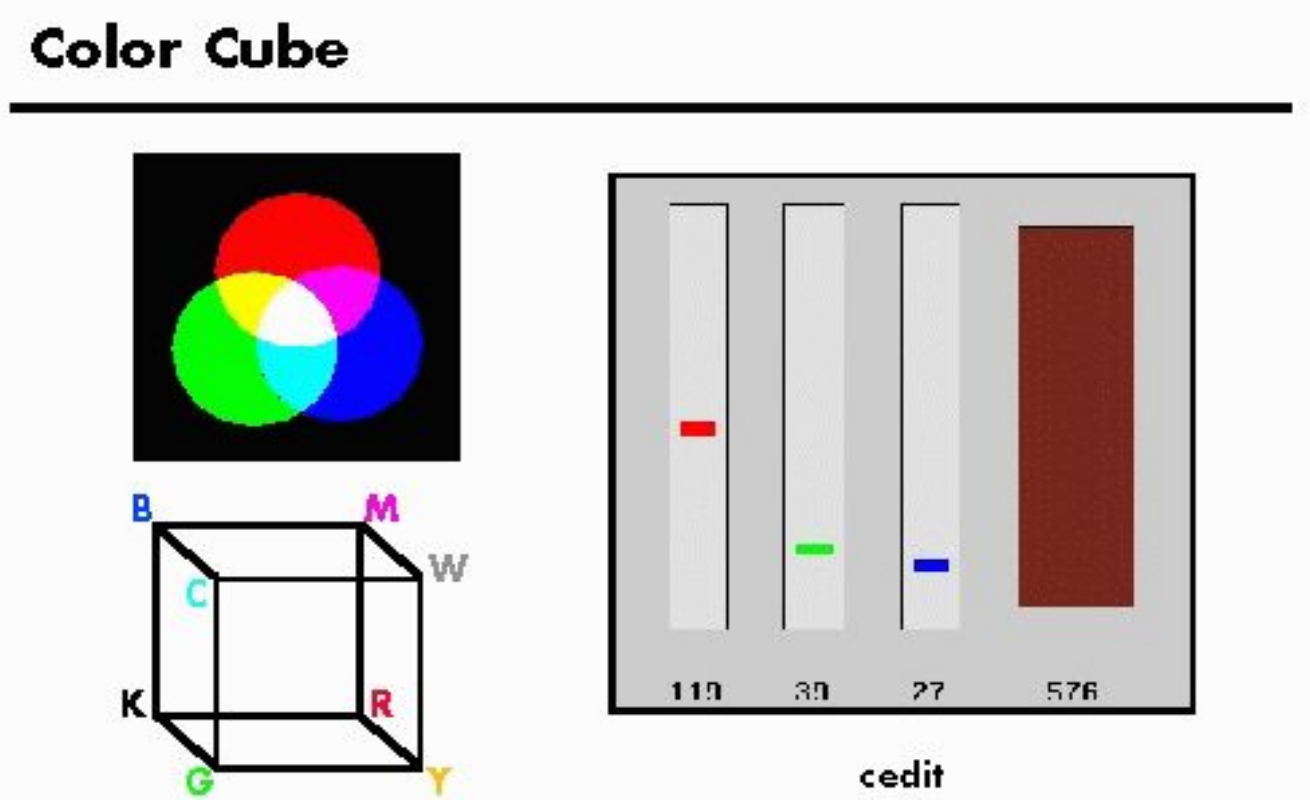


- **Metamerism**
- **Biological basis of color blindness - genetic disease**

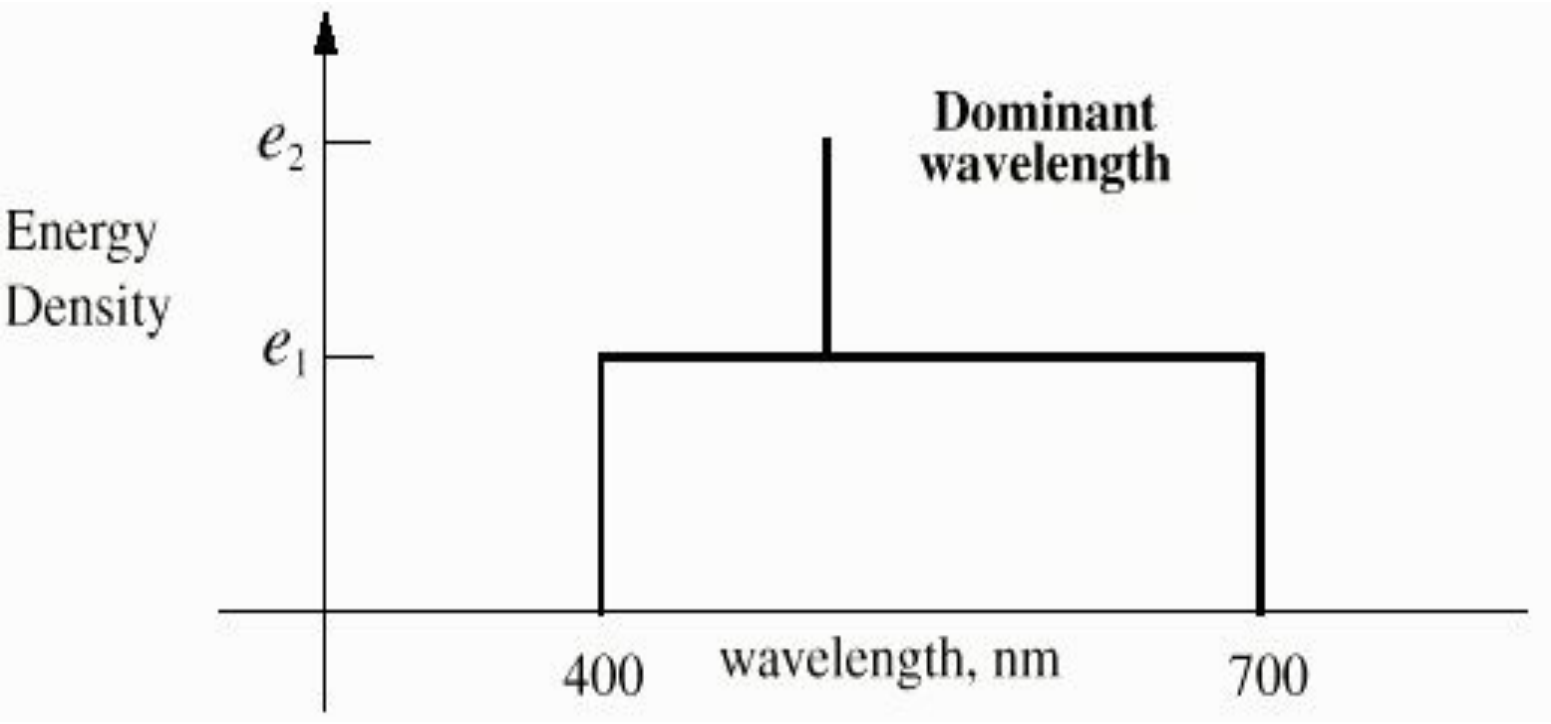
RGB (Color Cube)



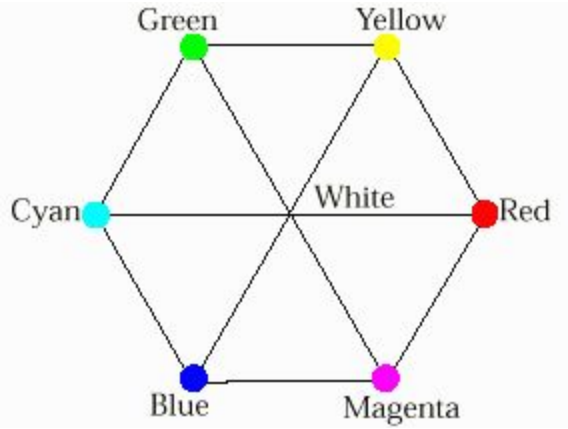
RGB

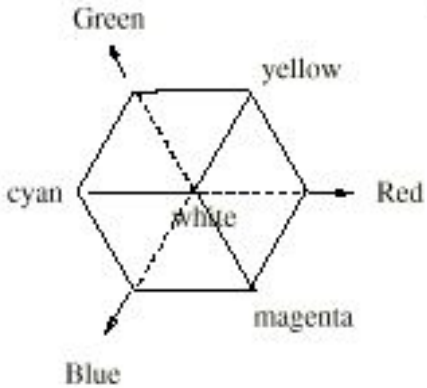


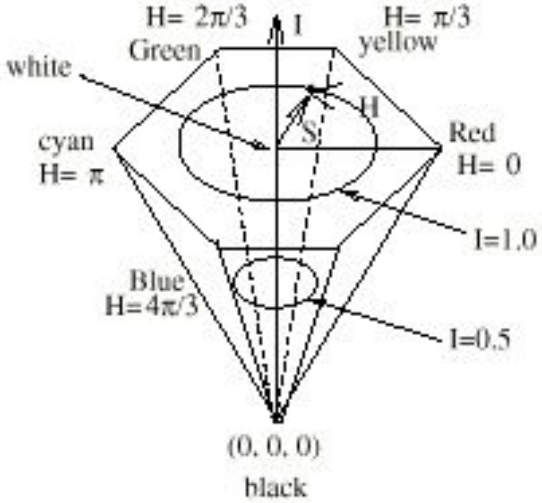
Интуитивные цветовые системы



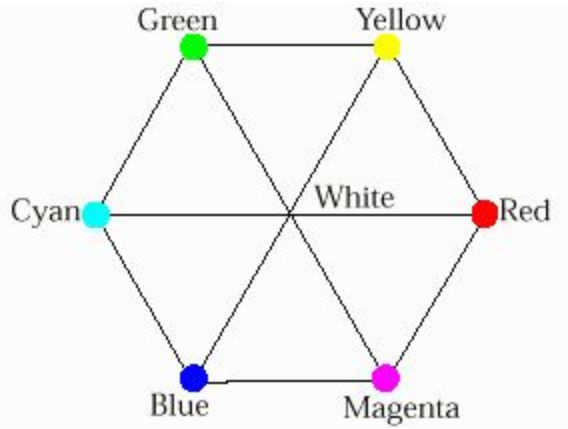
HSI: Hue--Saturation--Intensity

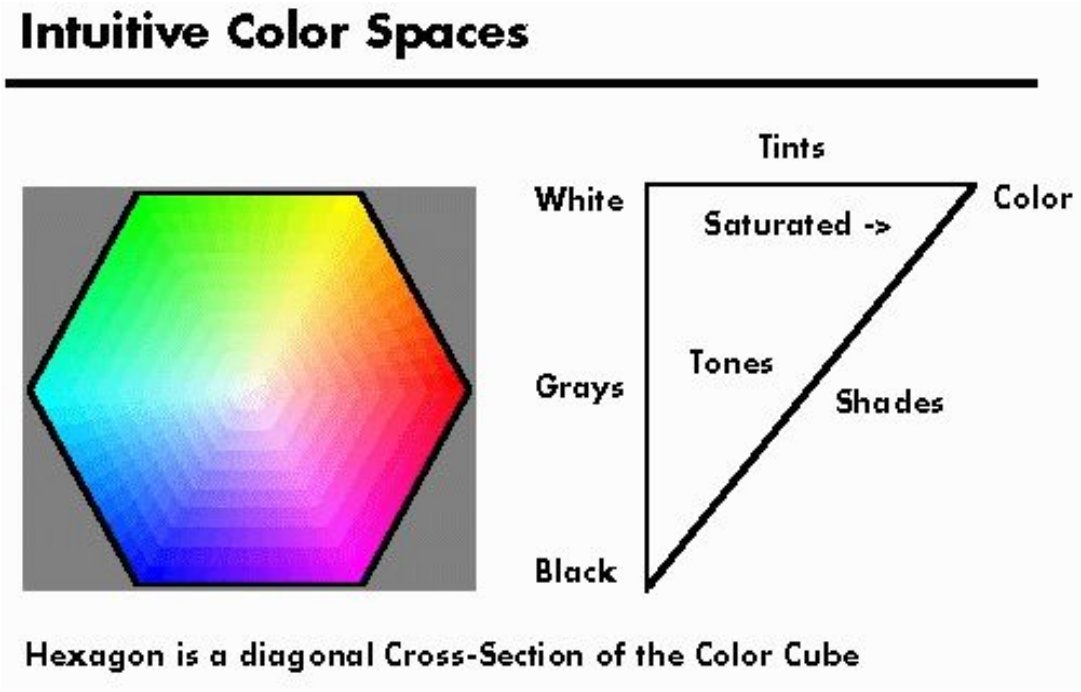
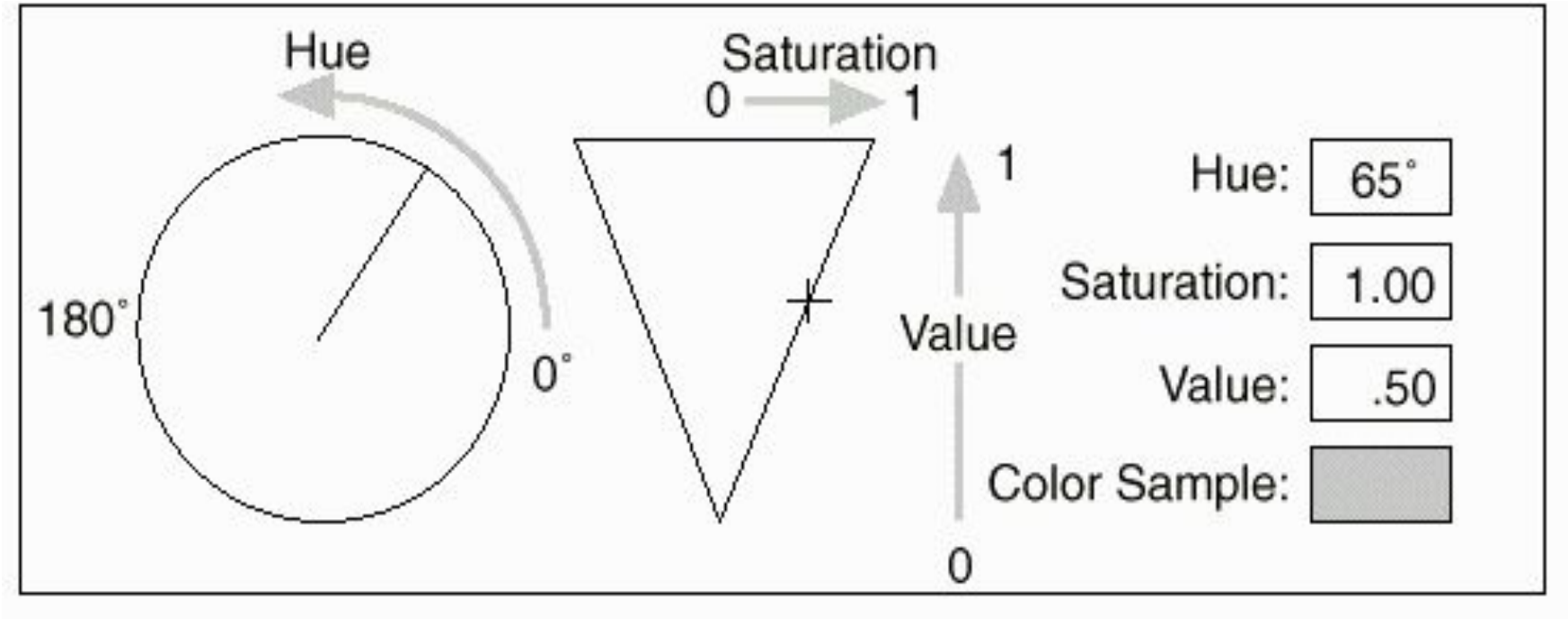






HSI: Hue--Saturation--Intensity





HSI: Hue--Saturation--Intensity