

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

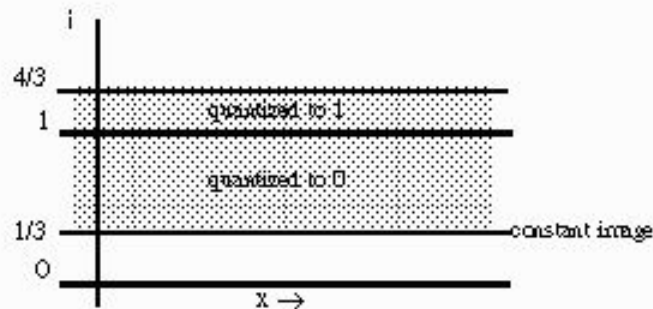
Robert's Algorithm

First add noise

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

Then quantize

$$0 \leq \text{noise} < 1$$



Moves low frequency (average error) to high frequency

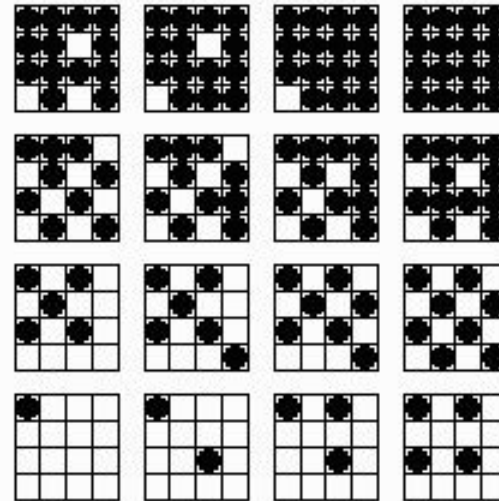
Pink (low), Blue (high), White (all) frequency noise

Bayer Ordered Dither Patterns

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

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

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



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Classic Halftoning

Printers: *Binary Blobs* of ink

Clustered pattern

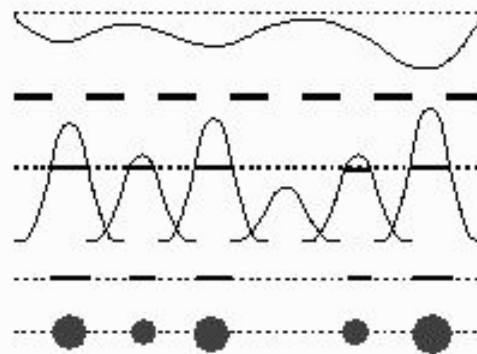
Enlarging spot

Classical printer screens

Spot function

Line frequency

Tilt angle



Image

Screen

Film

Spot

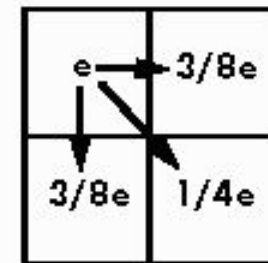
Error Diffusion

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;
  }
```



Comparison



Blue Noise

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Bayer Dither

Floyd-Steinberg

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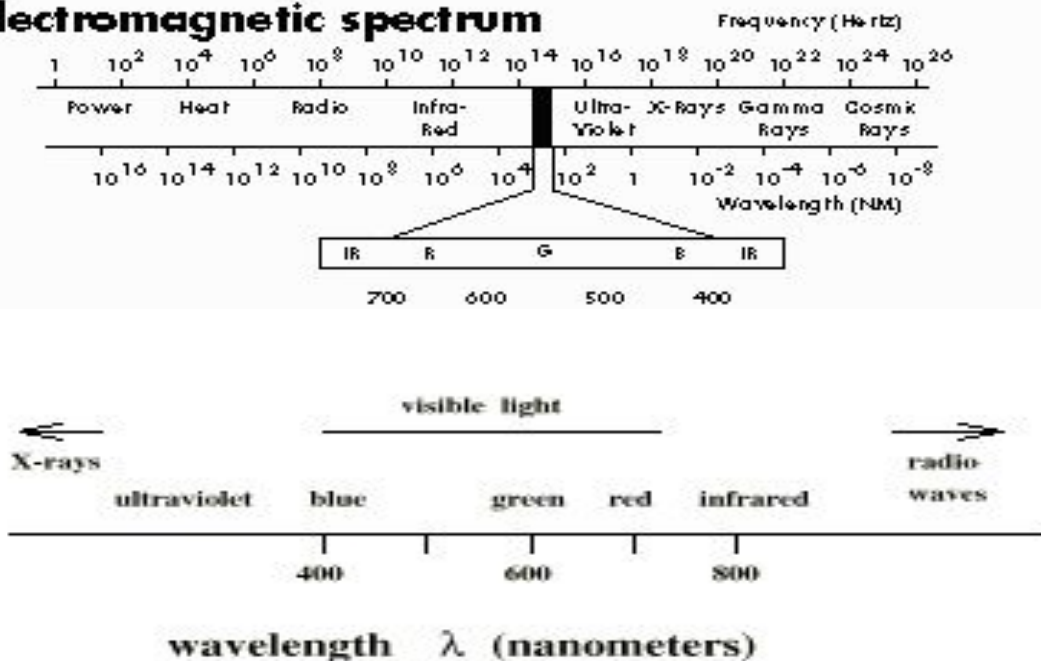
СВЕТ и ЦВЕТ

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

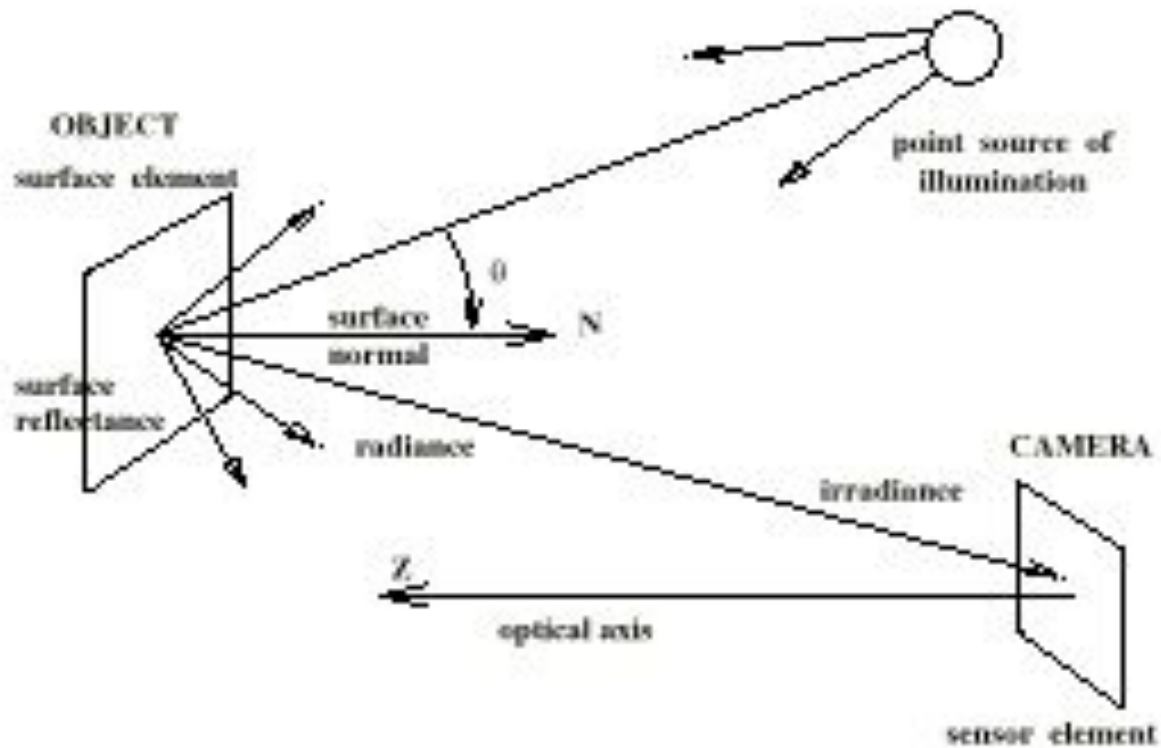
Видимая часть электромагнитного спектра

Spectrum

The electromagnetic spectrum



Распространение света



Восприятие цвета

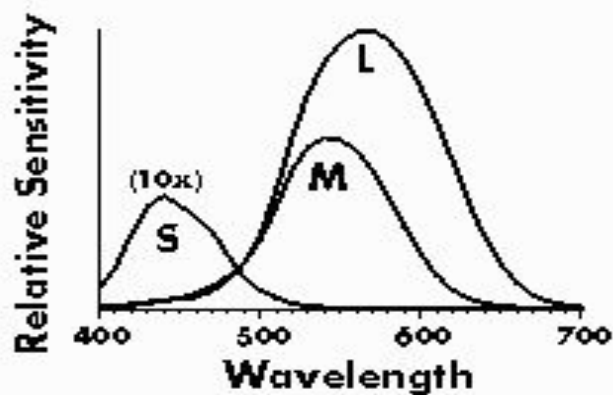
Human Color Vision

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

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

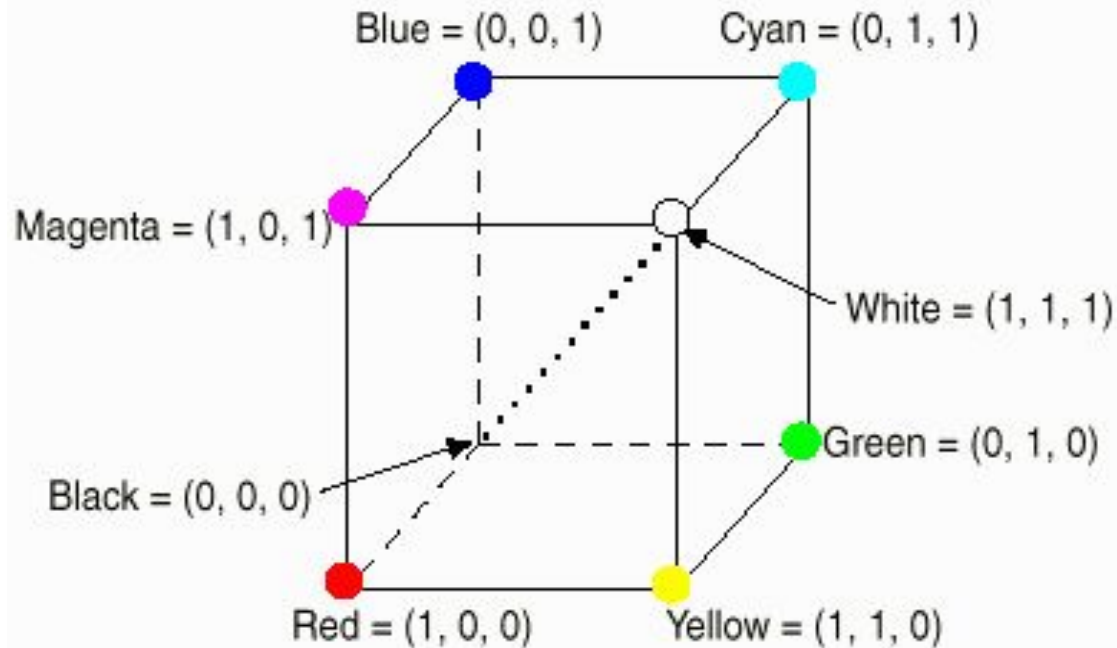
$$M = \int M(\lambda)E(\lambda)d\lambda$$

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



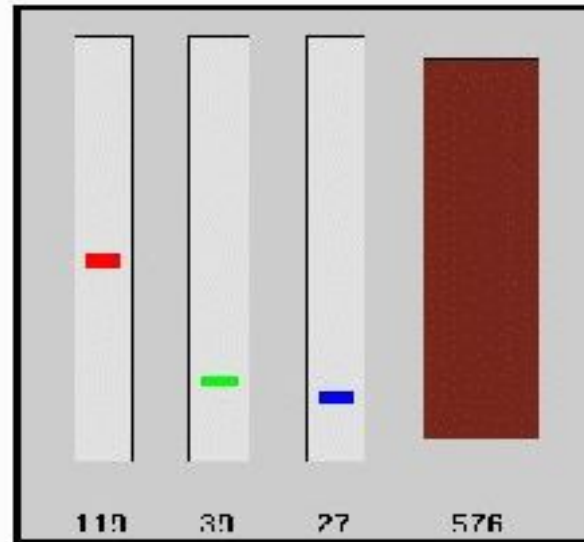
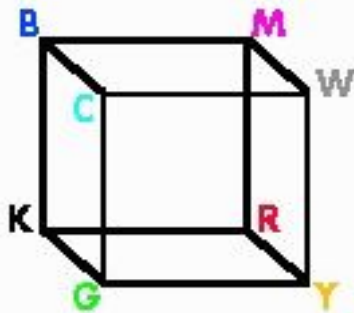
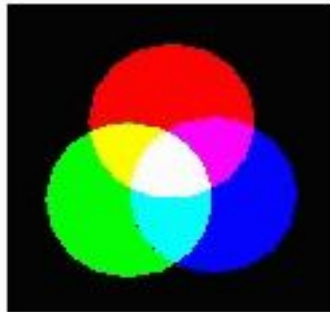
- Metamerism
- Biological basis of color blindness - genetic disease

RGB (Color Cube)



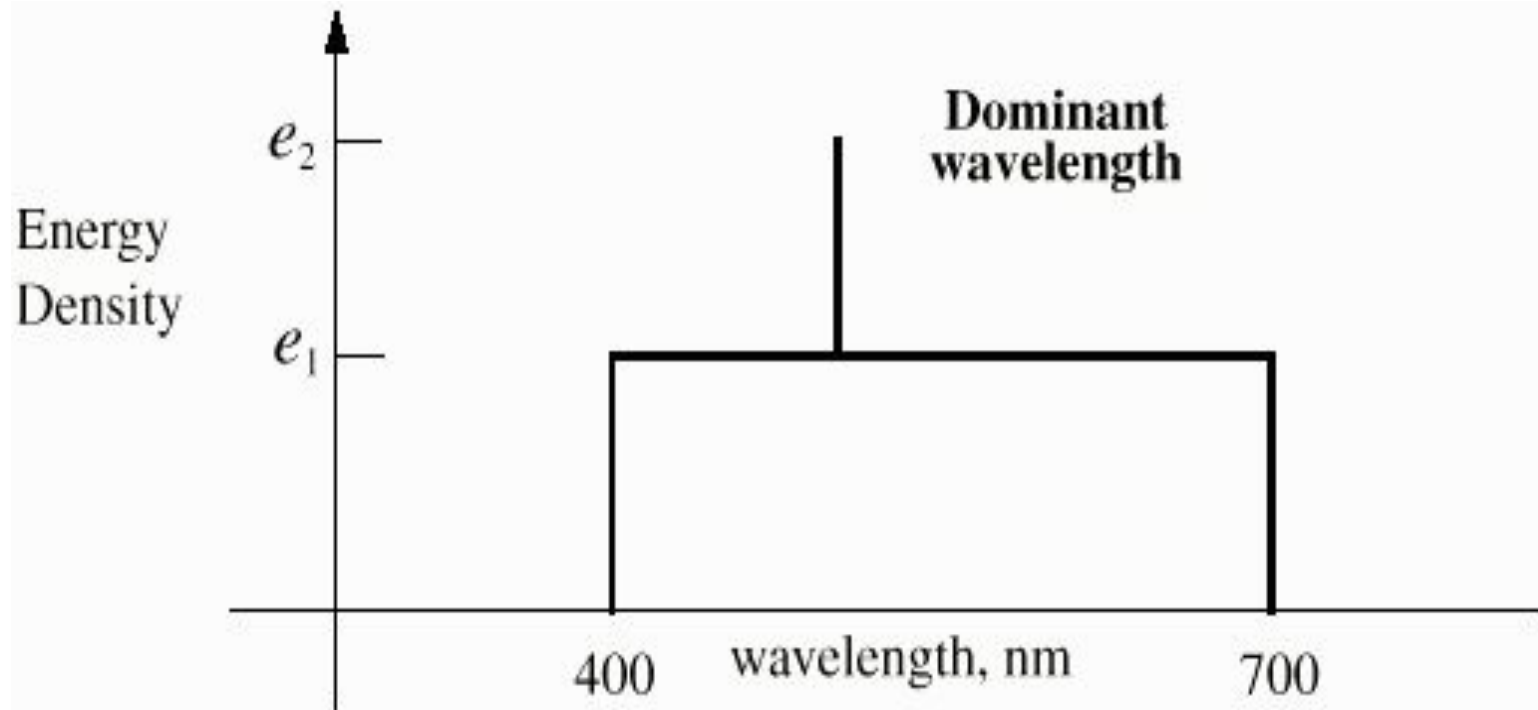
RGB

Color Cube

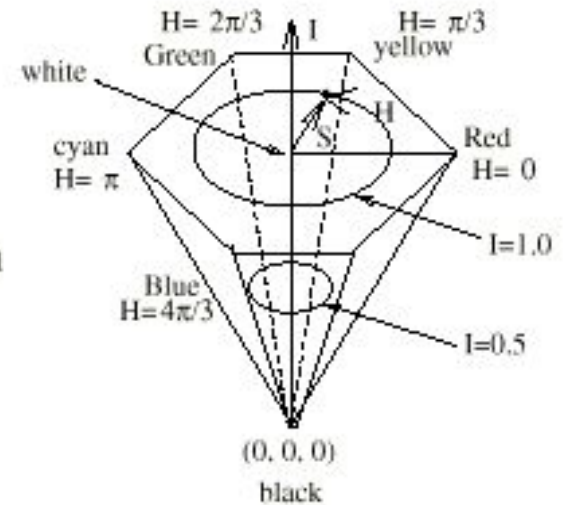
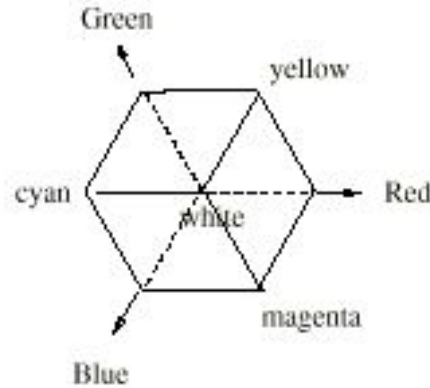
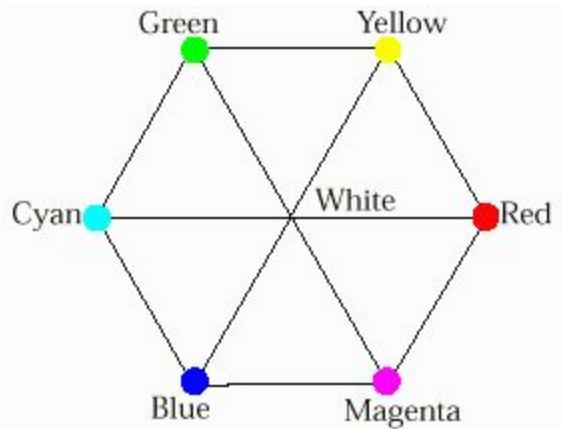


cedit

Интуитивные цветовые системы

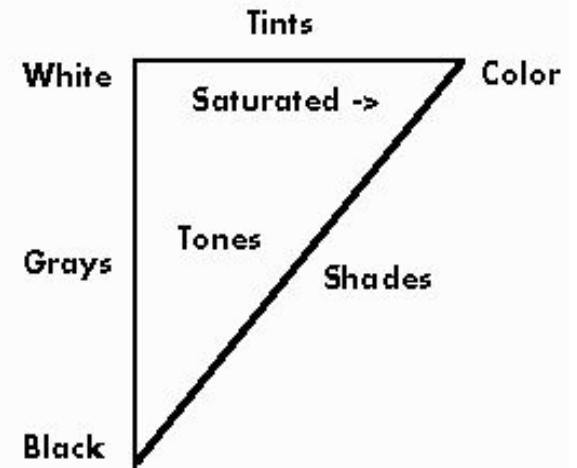
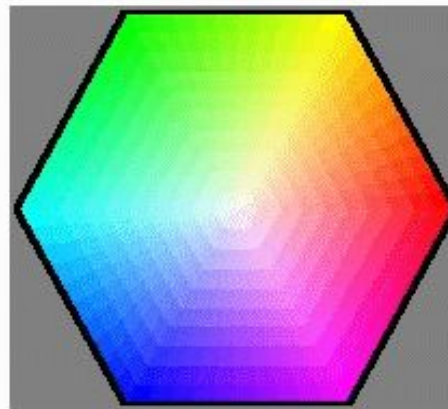
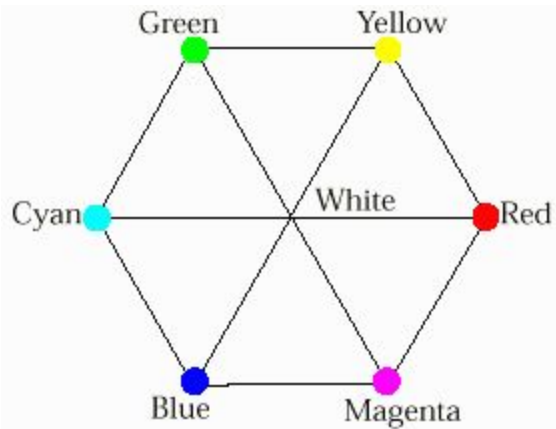


HSI: Hue--Saturation--Intensity



HSI: Hue--Saturation--Intensity

Intuitive Color Spaces



Hexagon is a diagonal Cross-Section of the Color Cube

HSI: Hue--Saturation--Intensity

