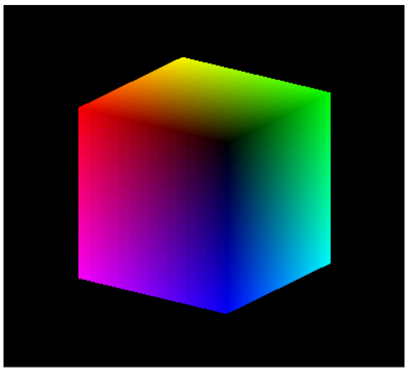
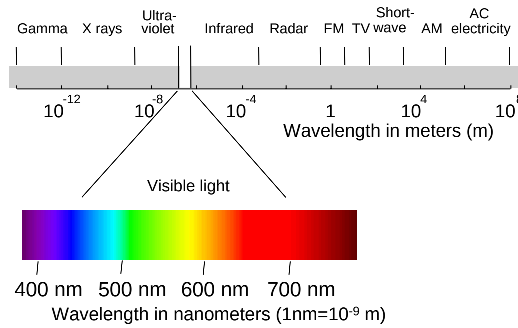
Color Representation

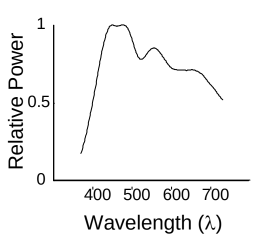


Electromagnetic Radiation - Spectrum

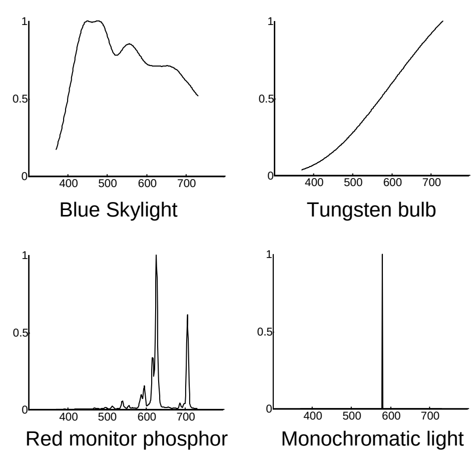


Spectral Power Distribution

The **Spectral Power Distribution** (SPD) of a light is a function f(λ) which defines the energy at each wavelength.

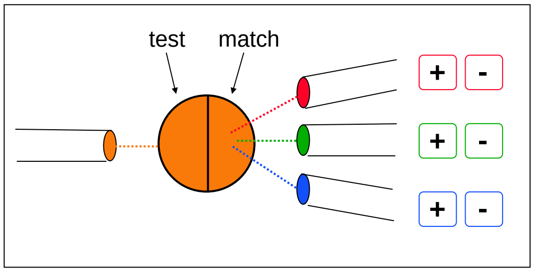


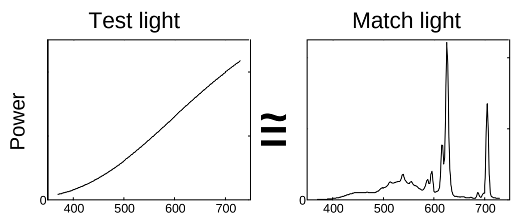
Examples of Spectral power Distributions



Color Matching Experiment

Three primary lights are set to match a test light.





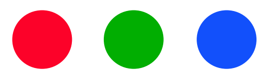
Metamer - two lights that appear the same visually. They might have different SPDs (spectral power distributions).

Trichromatic Color Theory

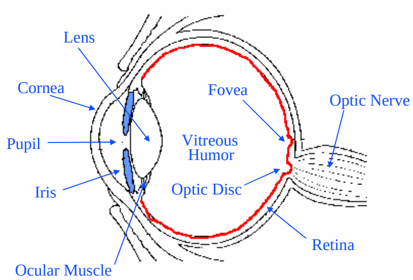
"tri"=three "chroma"=color
color vision is based on three primaries
(i.e., it is 3 dimensional).

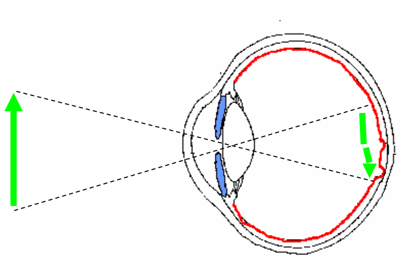
Thomas Young (1773-1829) -
A few different retinal receptors operating with different wavelength sensitivities will allow humans to perceive the number of colors that they do.
Suggested 3 receptors.

Helmholtz & Maxwell (1850) -
Color matching with 3 primaries.

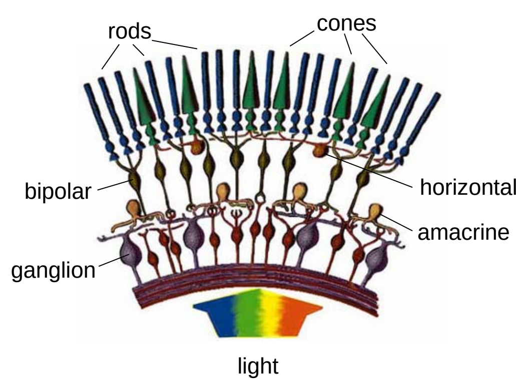


The Human Eye





The Human Retina

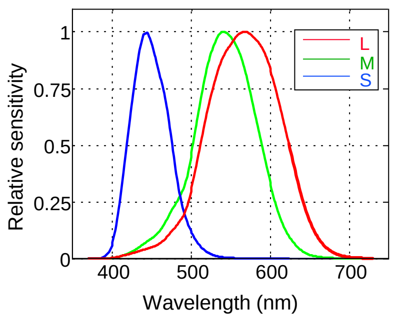


Retinal Photoreceptors

Cones -

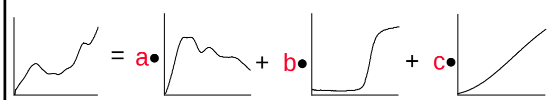
- High illumination levels (Photopic vision)
- Less sensitive than rods.
- 5 million cones in each eye.
- Only cones in fovea (aprox. 50,000).
- Density decreases with distance from fovea.
- 3 cone types differing in their spectral sensitivity: L , M, and S cones.

Cone Spectral Sensitivity

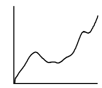


Linear Color Spaces

Colors in 3D color space can be described as linear combinations of 3 basis colors: primaries

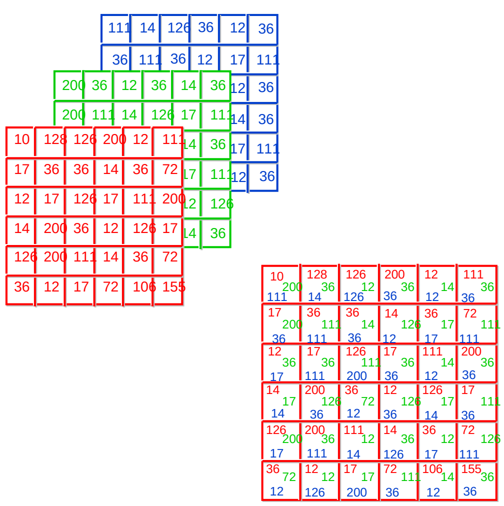


The representation of :

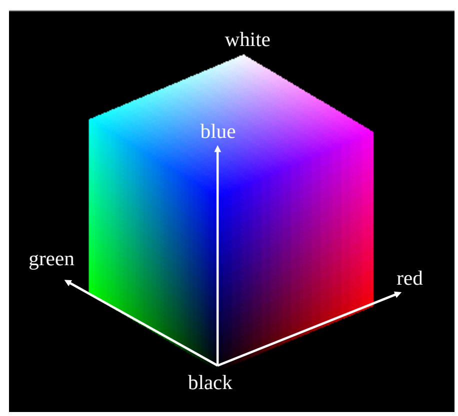


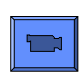
is then given by: (a, b, c)

Rgb Image

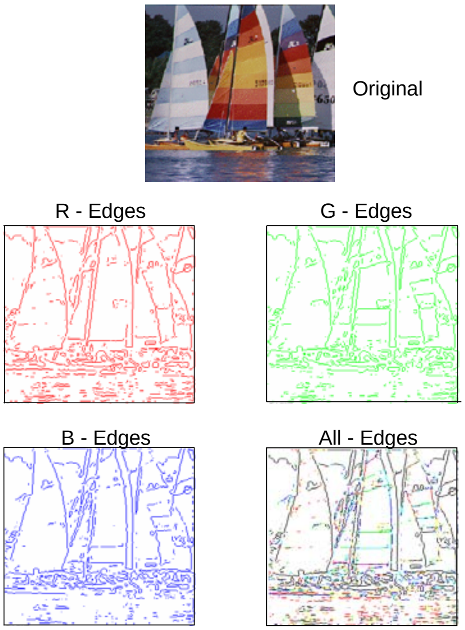


The RGB Cube

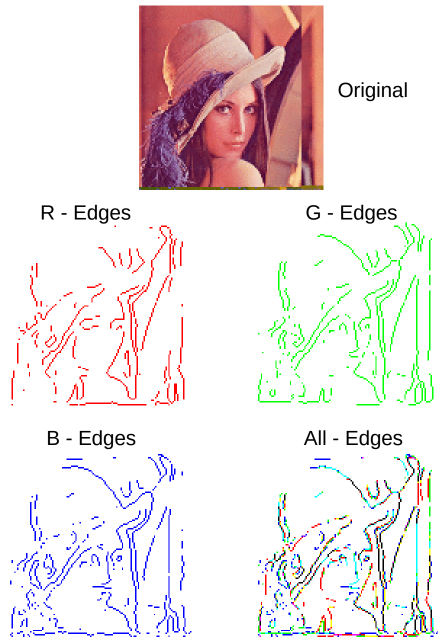




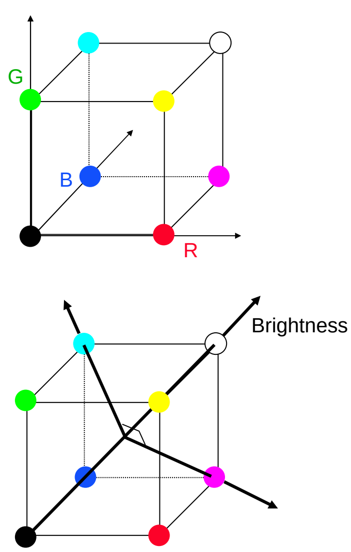
Color Edge Detection



Color Edge Detection



RGB Color Cube

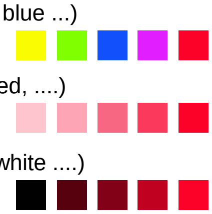


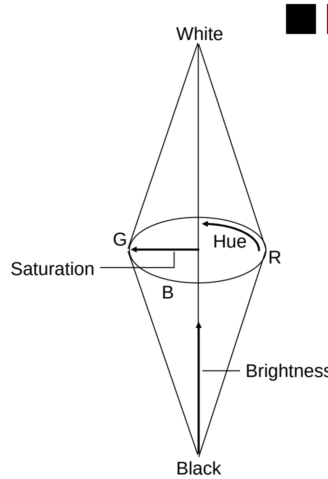
Color Description

Hue (red, green, yelow, blue ...)

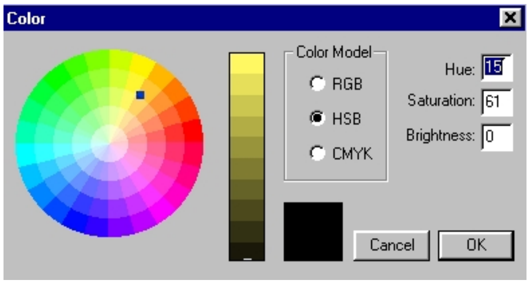
Saturation (pink,bright red, ...)

Lightness (black, grey, white ....)

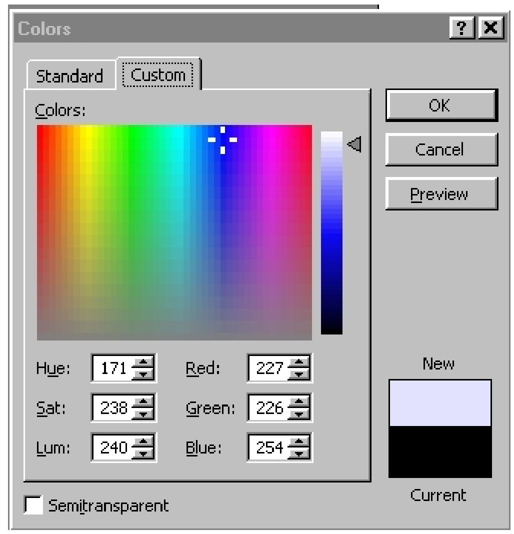




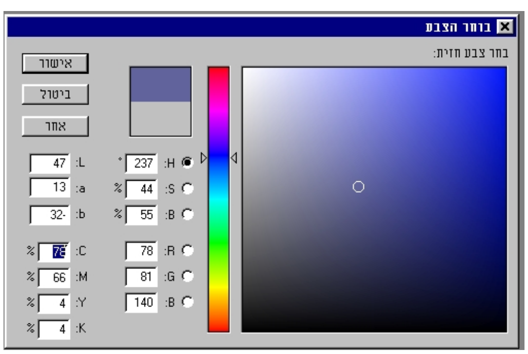
MayuraDraw



PowerPoint



PhotoShop



YIQ - Color Space

NTSC = National Television Systems Committee

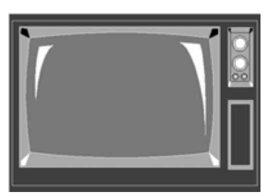
Y = luminance

I = red-green

Q = blue-yellow

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.177 & 0.813 & 0.011 \\ 0.540 & -0.263 & -0.174 \\ 0.246 & -0.675 & 0.404 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

R G B are the CIE-RGB

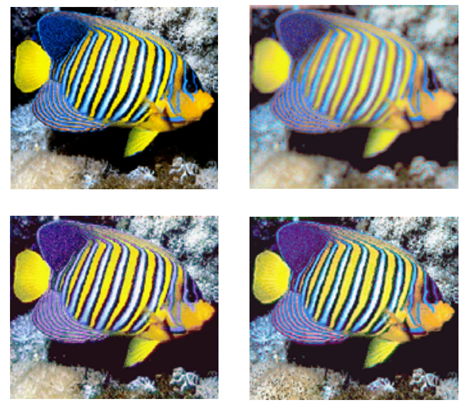


RGB To Monochrome

RGB

Y

Original Y - Blur



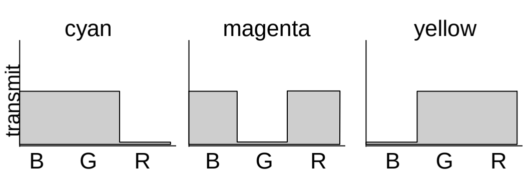
I - Blur Q - Blur

Subtractive Color System - CMYK

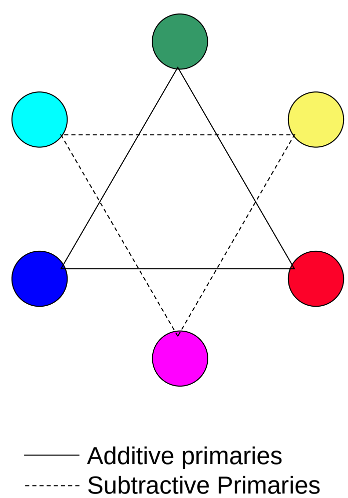
Printer Dyes:

- Cyan = removes red
- Magenta = removes green
- Yellow = removes blue
- blacK = removes all

Ideal block dyes:

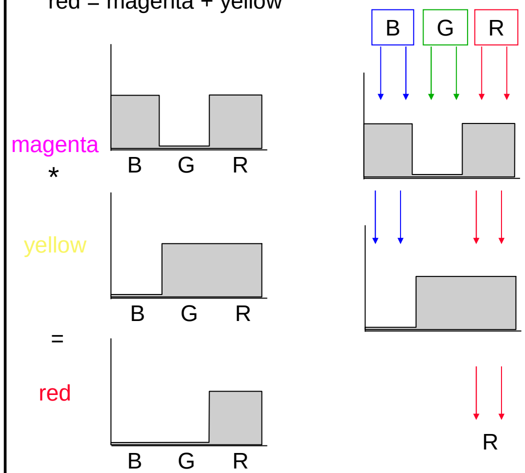


Opponent Color Wheel



Multiplicative (Subtractive) Color System

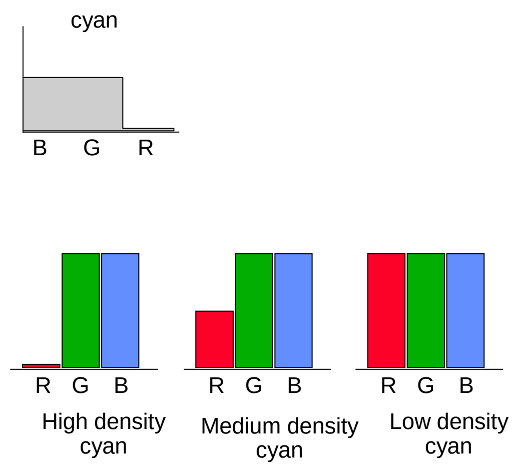
red = magenta + yellow

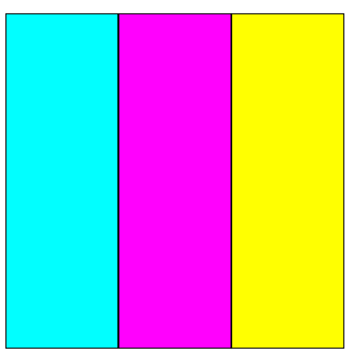


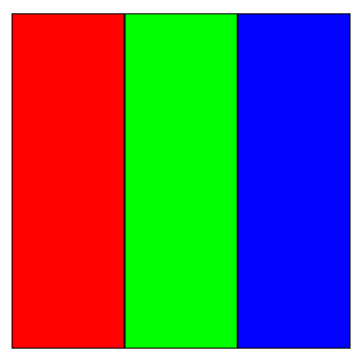
red = magenta + yellow
green = cyan + yellow
blue = magenta + cyan

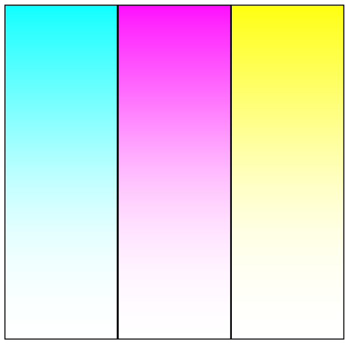
Cyan - controls amount of red in print:

low C = high R (also high G and B)
high C = low R (high G and B)







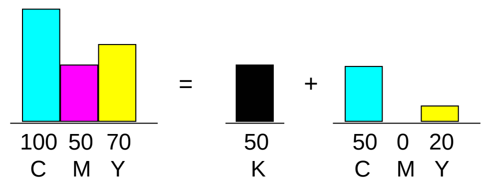


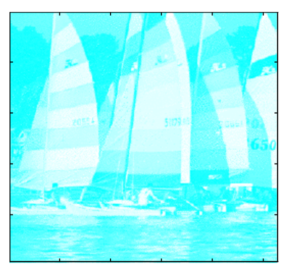
CMY + Black

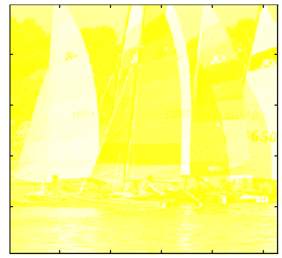
C + M + Y = K (black)

- Using three inks for black is expensive
- C+M+Y = dark brown not black
- Black instead of C+M+Y is crisper with more contrast.

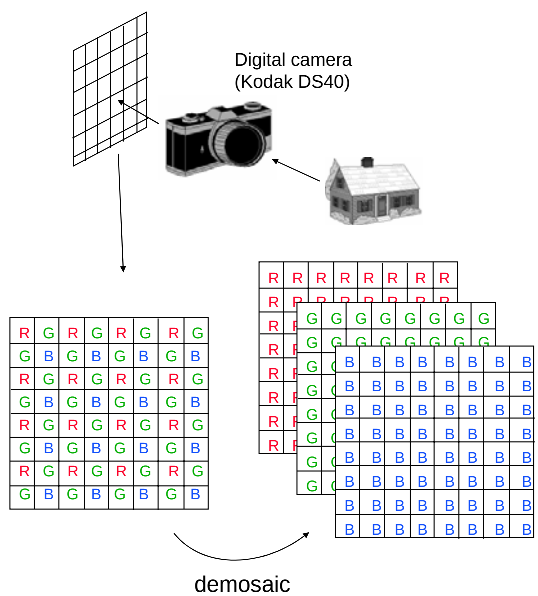
Undercolor removal -
(gray component replacement)



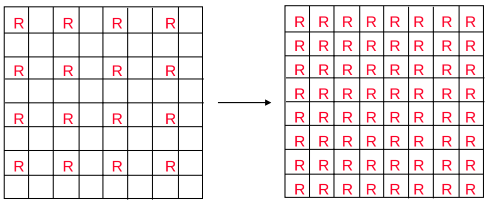




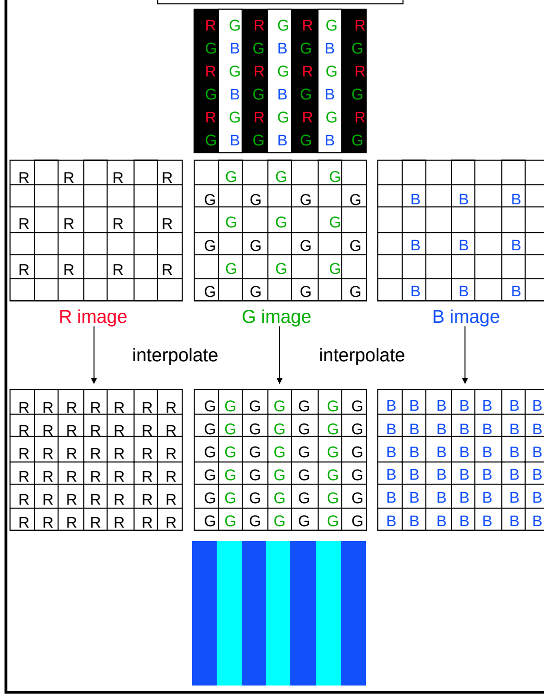
Demosaicing



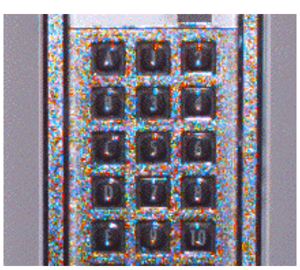
Demosaicing - Linear interpolation



Demosaic Aliasing



Demosaicing - Example (Kodak)



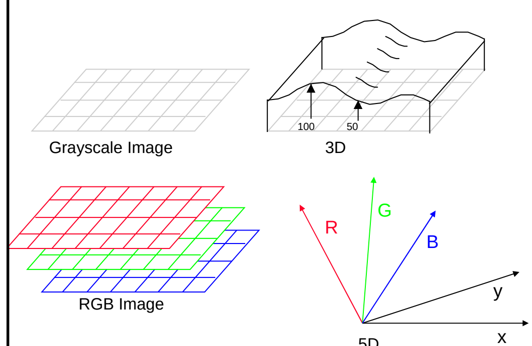
Demosaicing - Various Approaches

Regularization

Minimize over a functional with a data fit term and an inter-channel color correlation term. (Gamer & Keren)

Minimal Surface

Minimize over a functional with a data fit term and a 5D surface area term. (Beltrami Flow) (Kimmel)

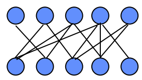


Demosaicing - Various Approaches

Learning Schemes

Learn linear and non linear optimal filters
for classes of images (ANN).

(Kapah & Hel-Or)



Demosaicing - Learning Schemes

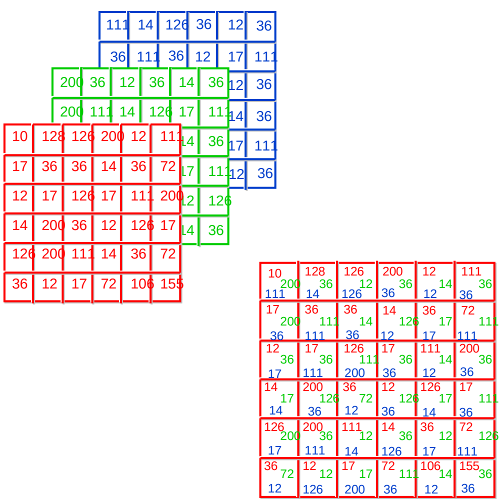
Channel independent

Perceptron (Linear)

Quadratic - Learned on Image

Quadratic - Learned on Class

Color Quantization



Indexed Image

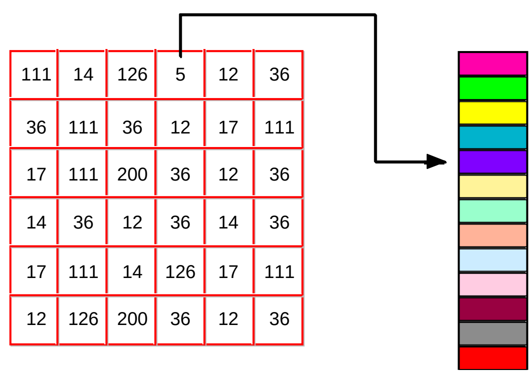


Image Independent Quantization

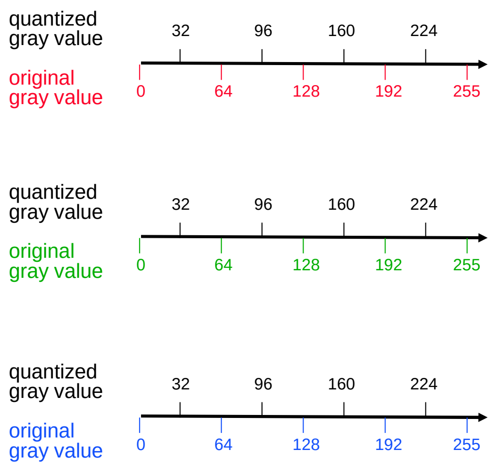


Image Independent Quantization

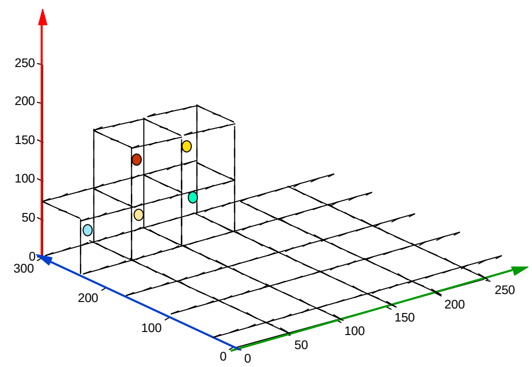
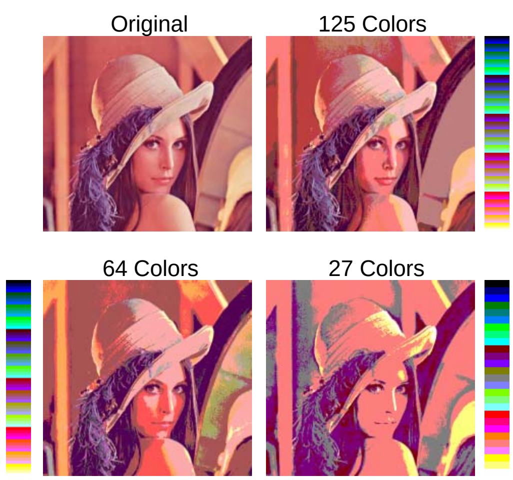
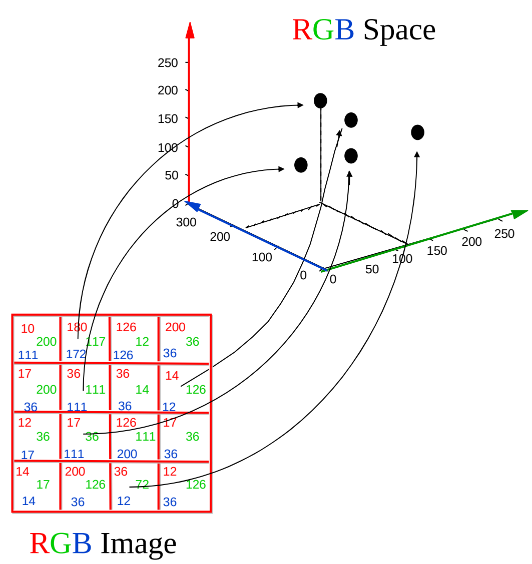


Image Independent Quantization





RGB Space

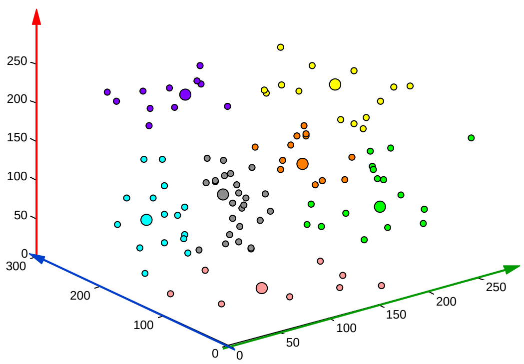
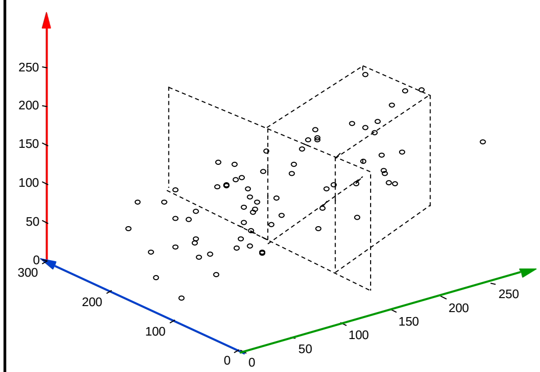


Image Dependent Quantization



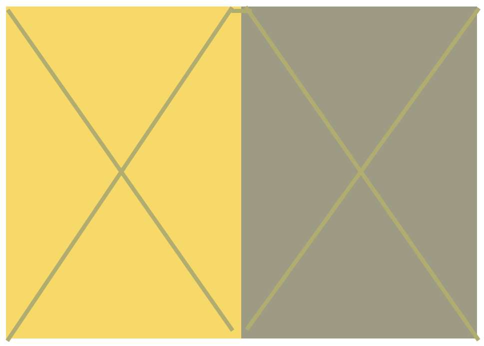
Clustering using Iso Data

Input: C={c_i}, i=1..n - color points.

Output: S={s_j}, j=1..k - color indices.

- Distribute s_j, j=1..k, uniformly in color space.
- Divide C into k classes based of distances to S.
- For each class j, calculate the mean M_j.
- Set S_j=M_j.
- Iterate until convergence.

Image Dependent Quantization



Albers (1975)