Overview of Digital Image Processing Basics

Image Formation

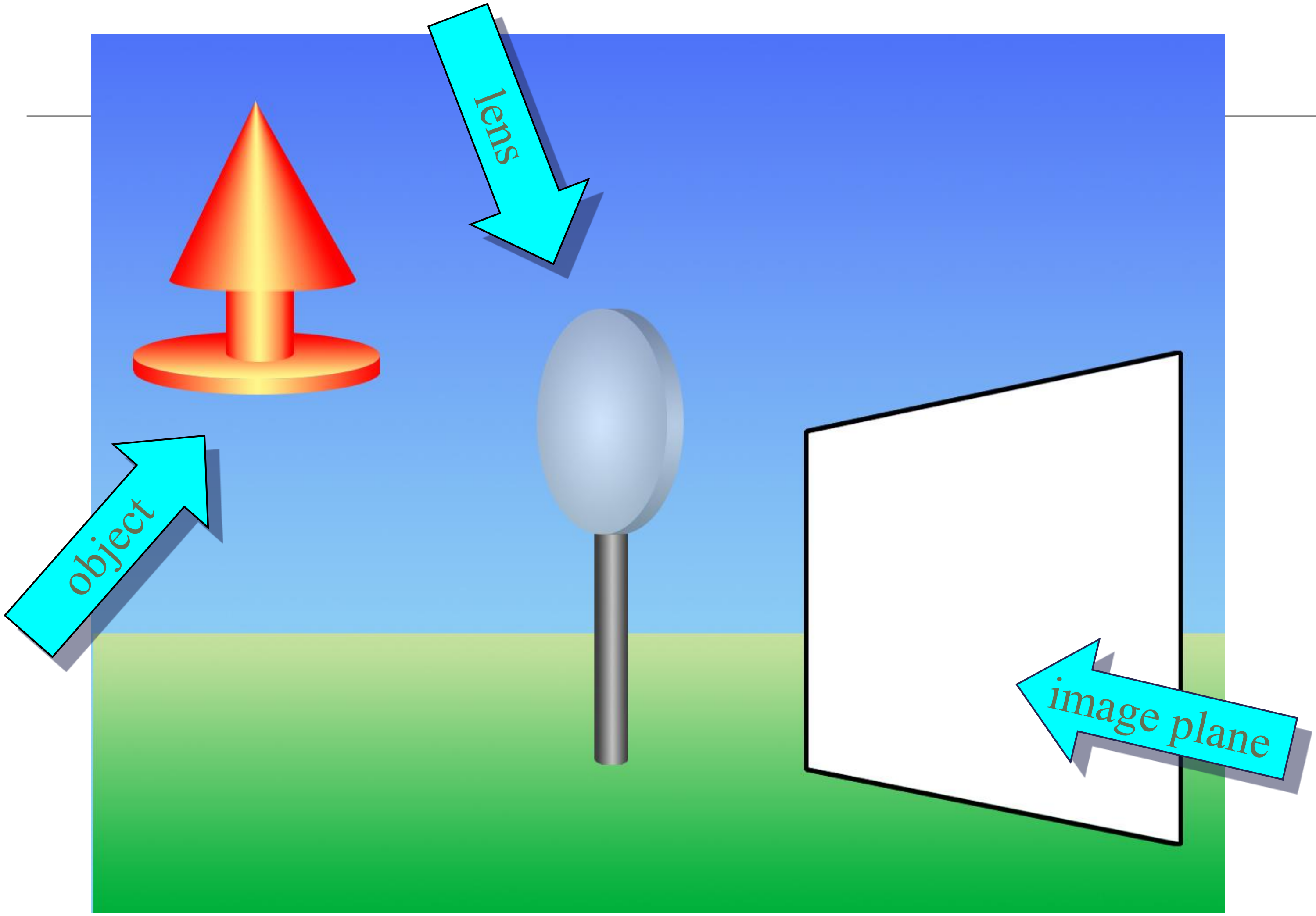


Image Formation

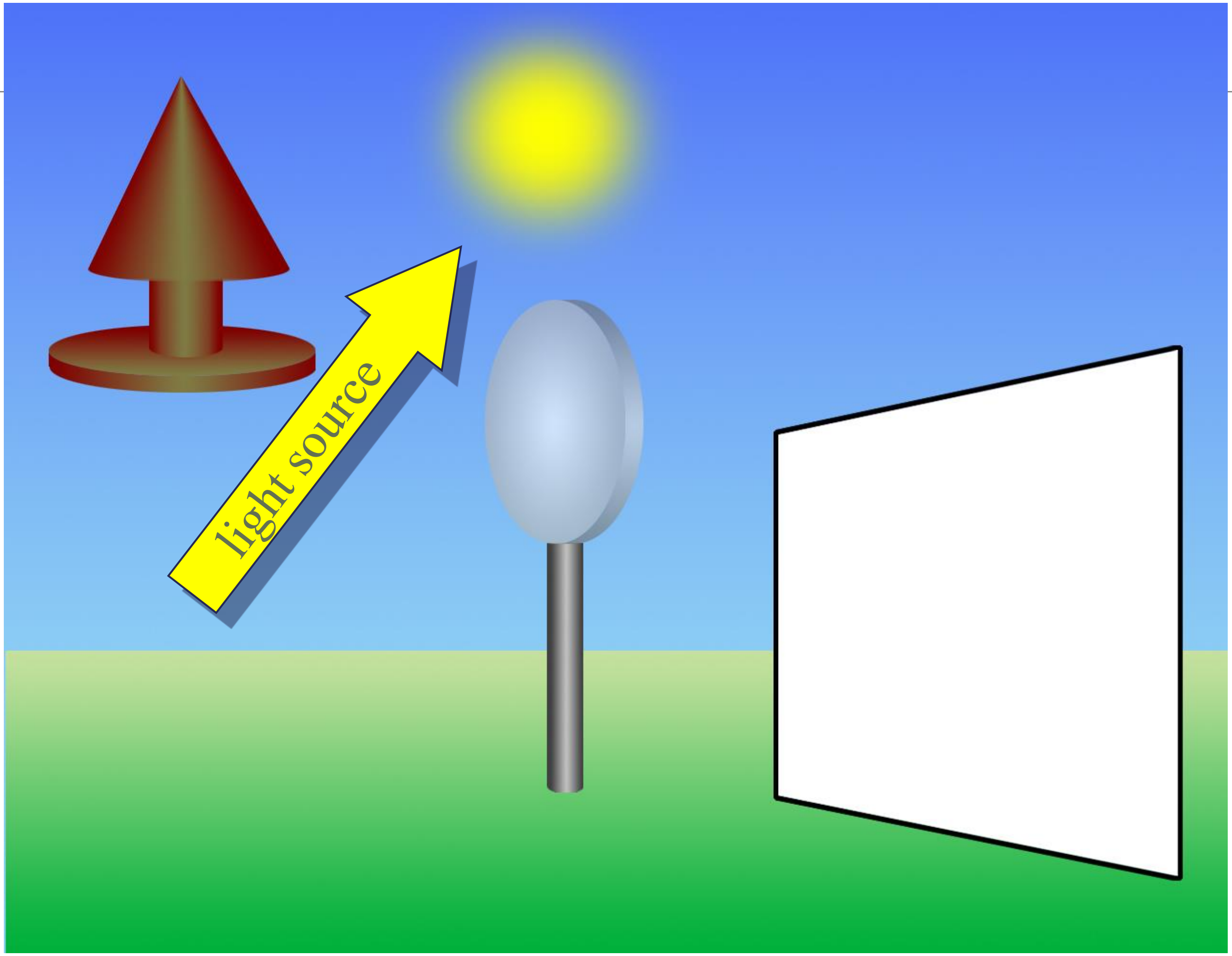


Image Formation

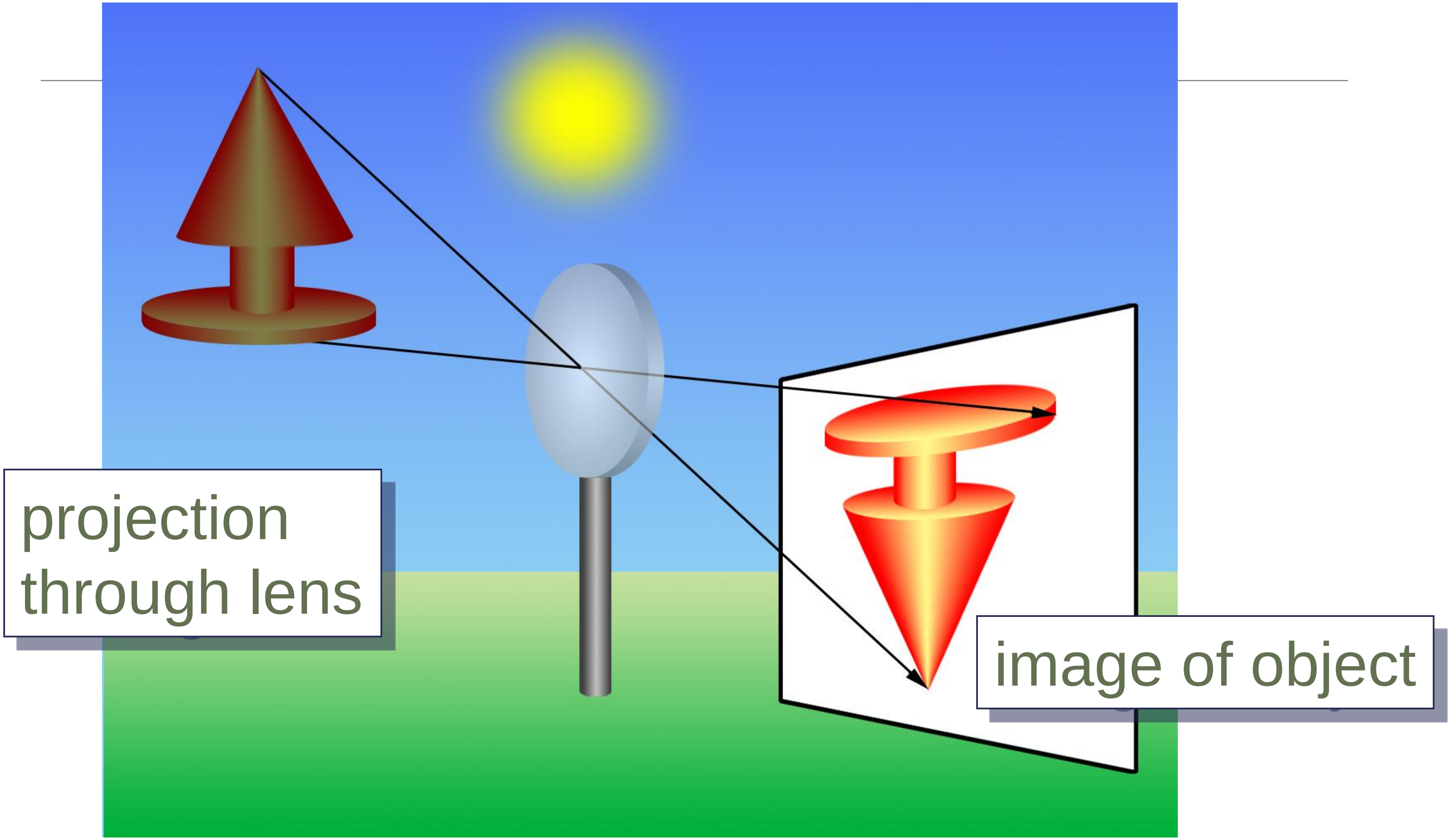


Image Digitalization

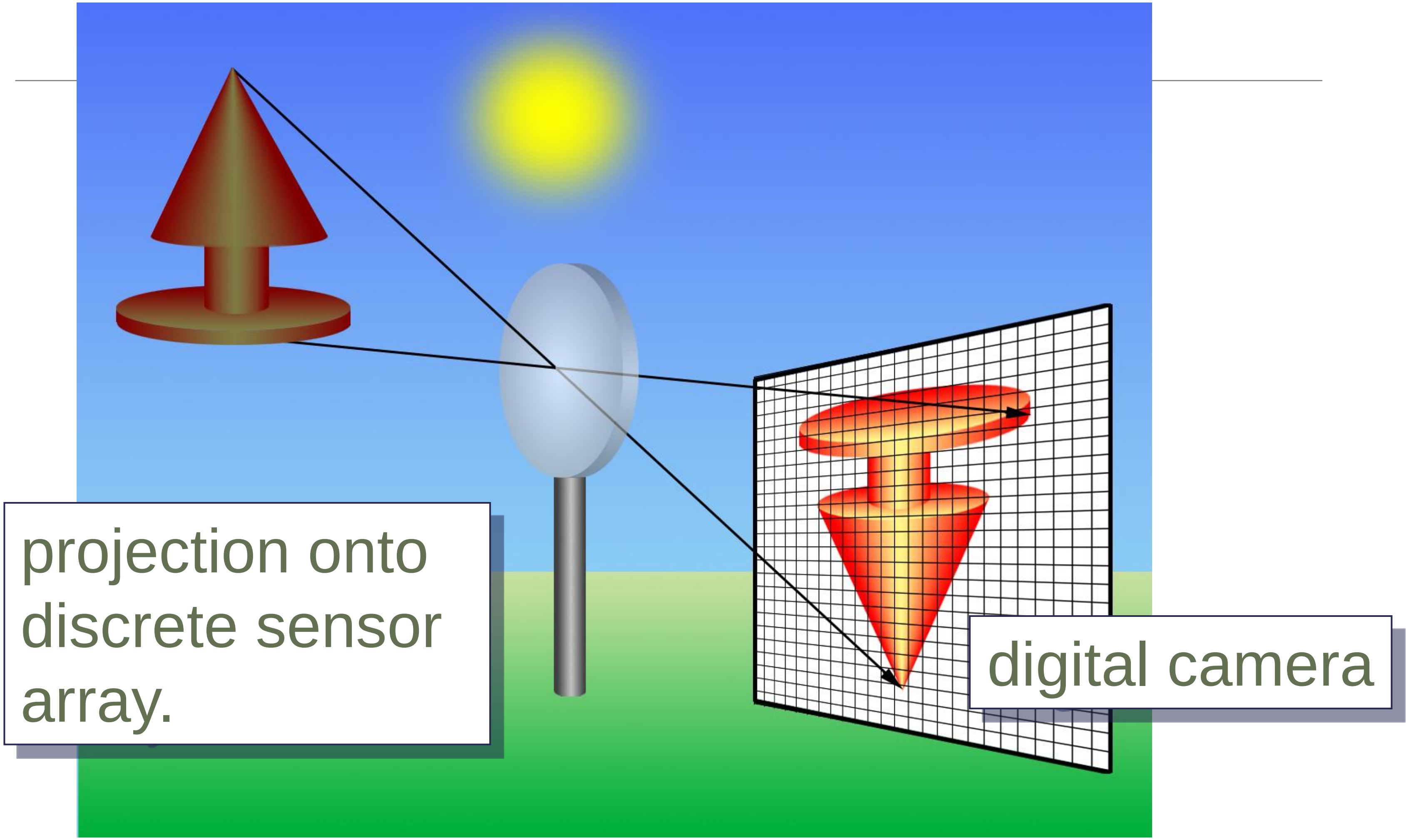


Image Digitalization

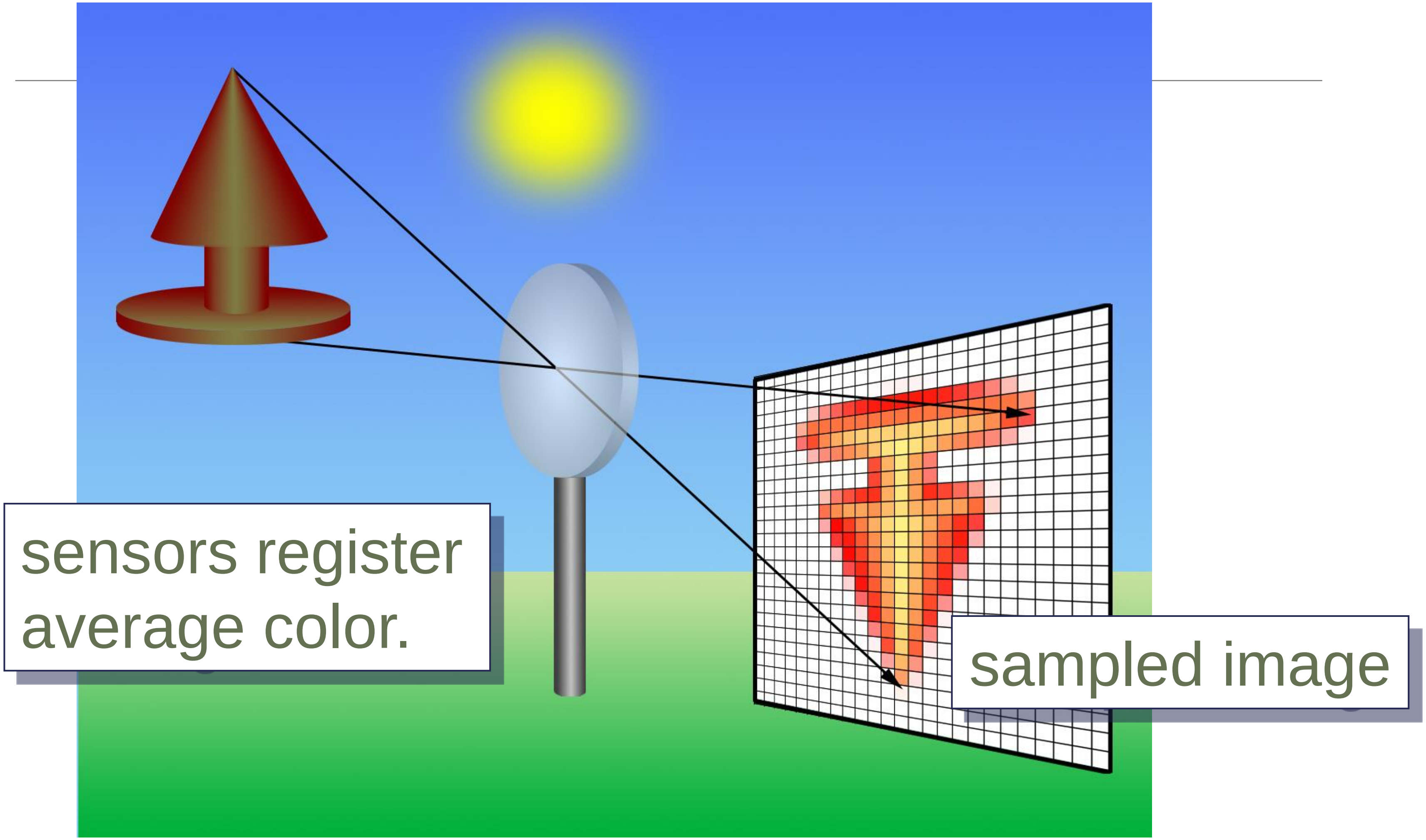
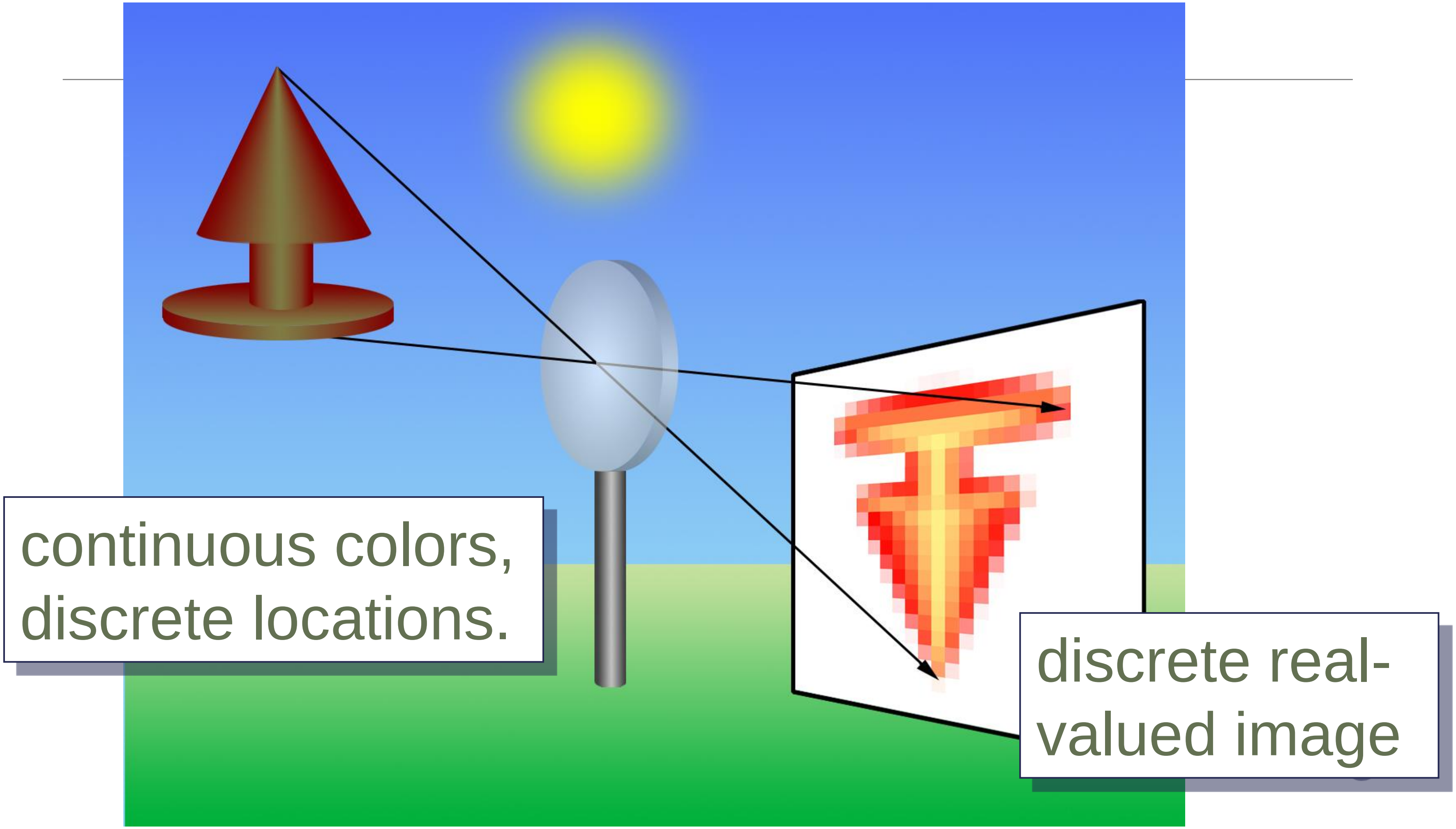
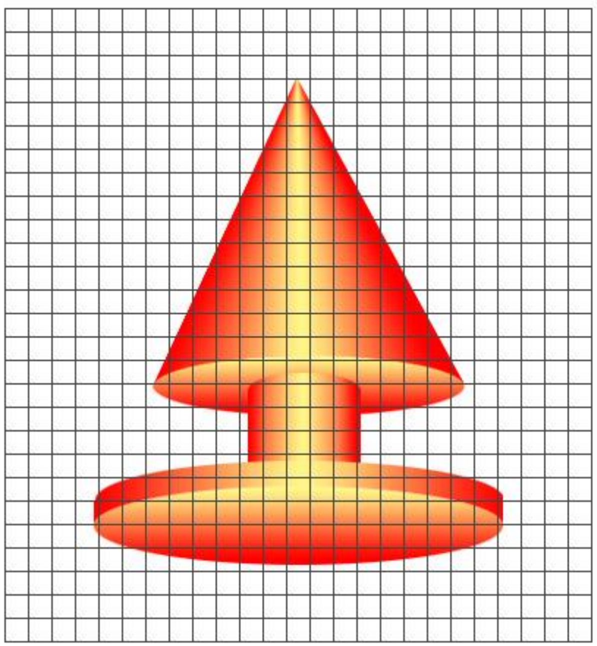


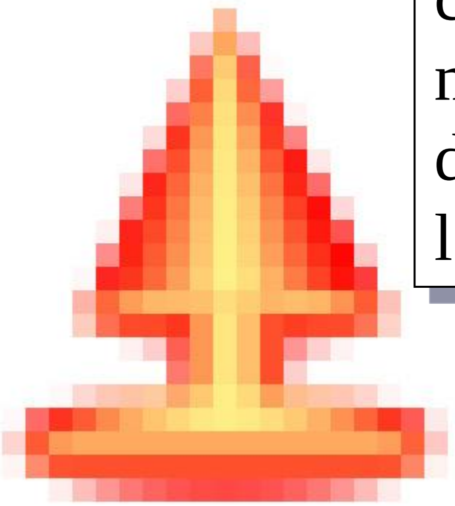
Image Digitalization



Sampling



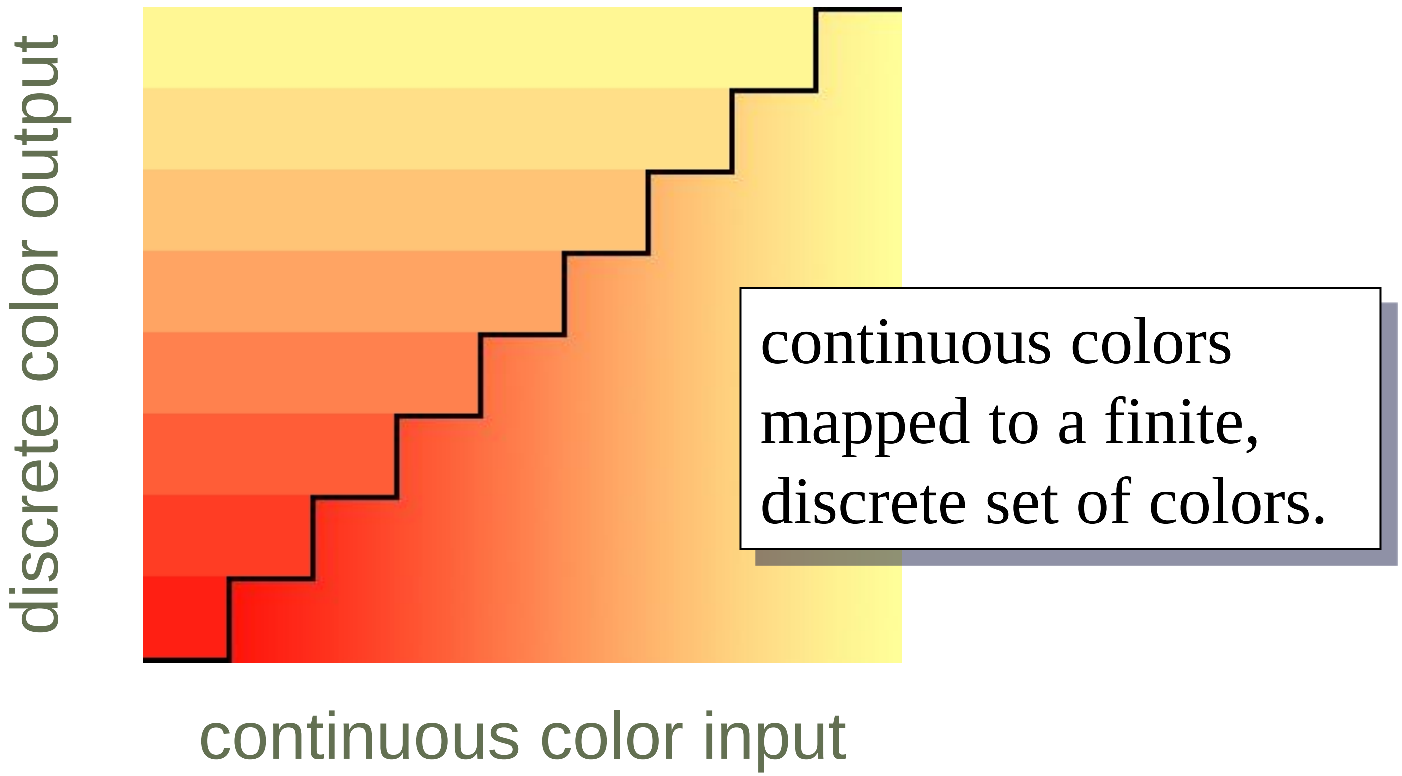
Continuous locations



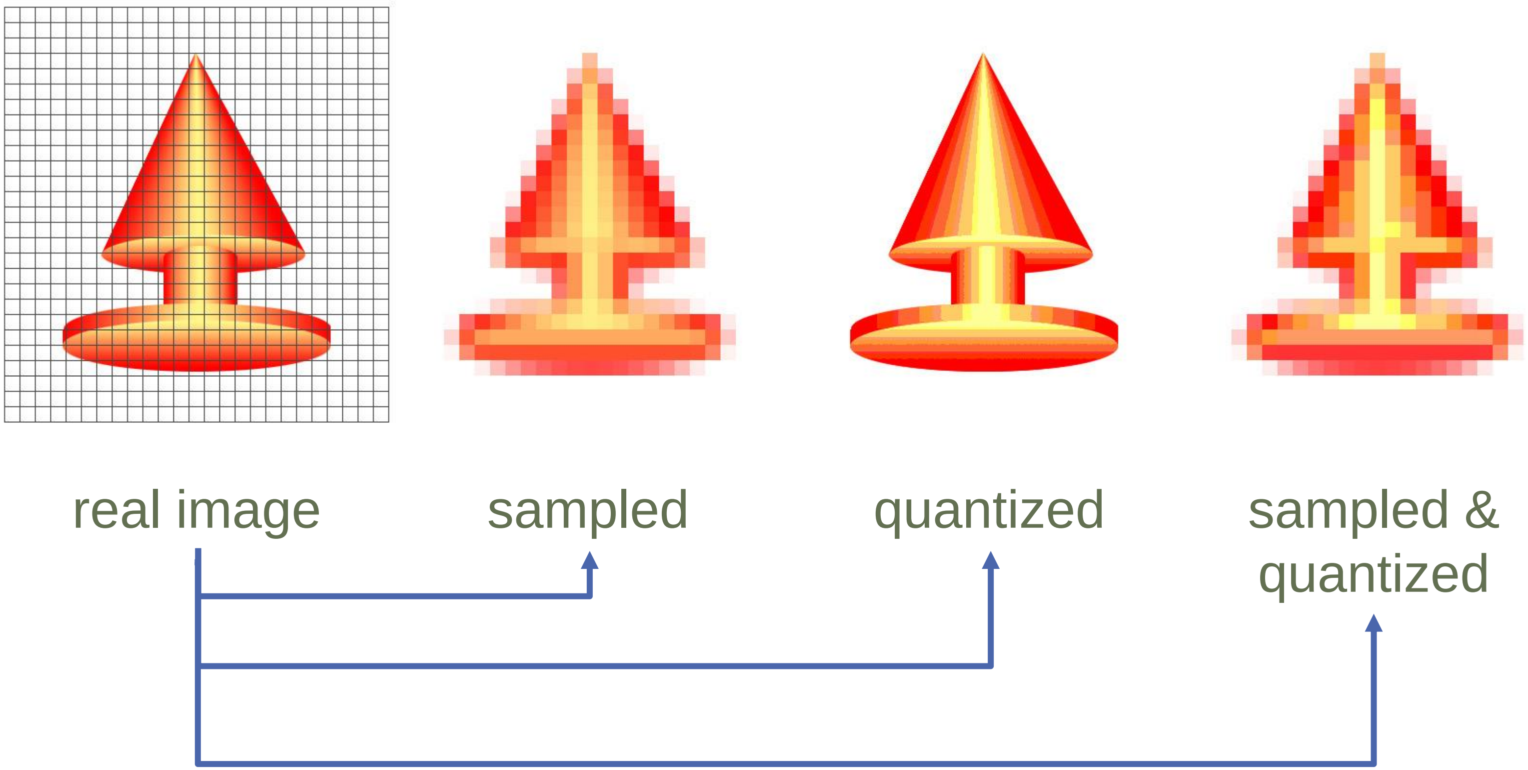
Discrete locations

continuous locations mapped to a finite, discrete set of locations.

Quantization

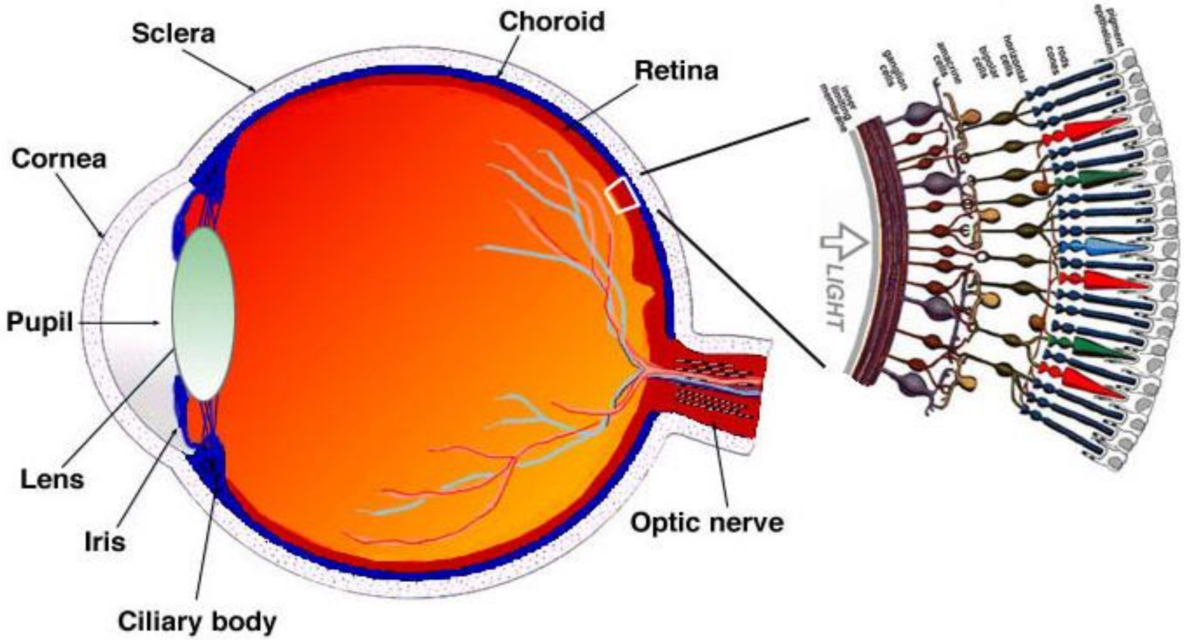


Sampling and Quantization



Color Processing

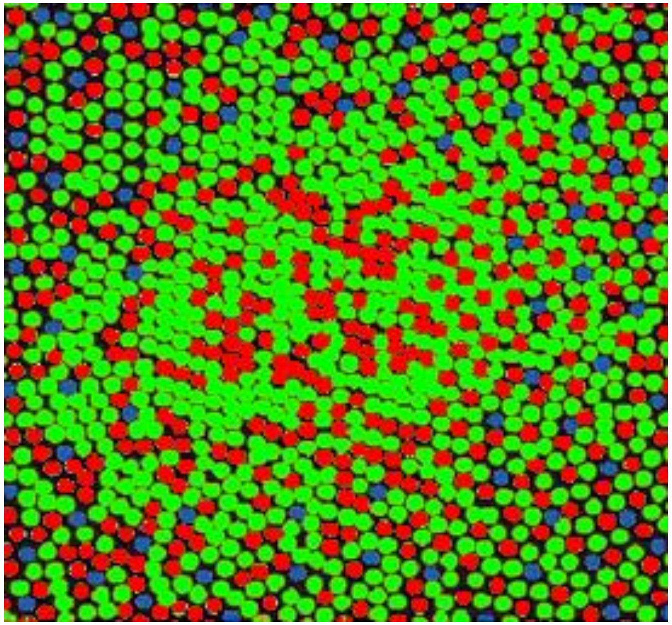
requires some knowledge of how we see colors



A drawing of a section through the human eye with a schematic enlargement of the retina.

Eye's Light Sensors

cone density near fovea



#(blue) << #(red) < #(green)

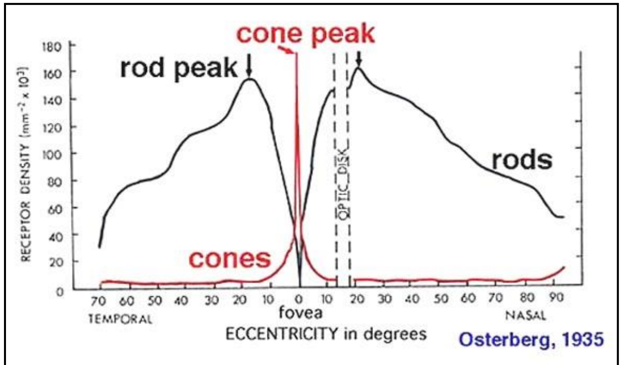


Fig. 20. Graph to show rod and cone densities along the horizontal meridian.

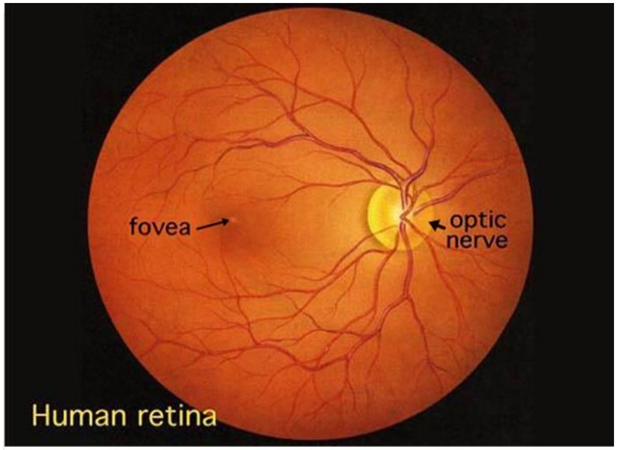
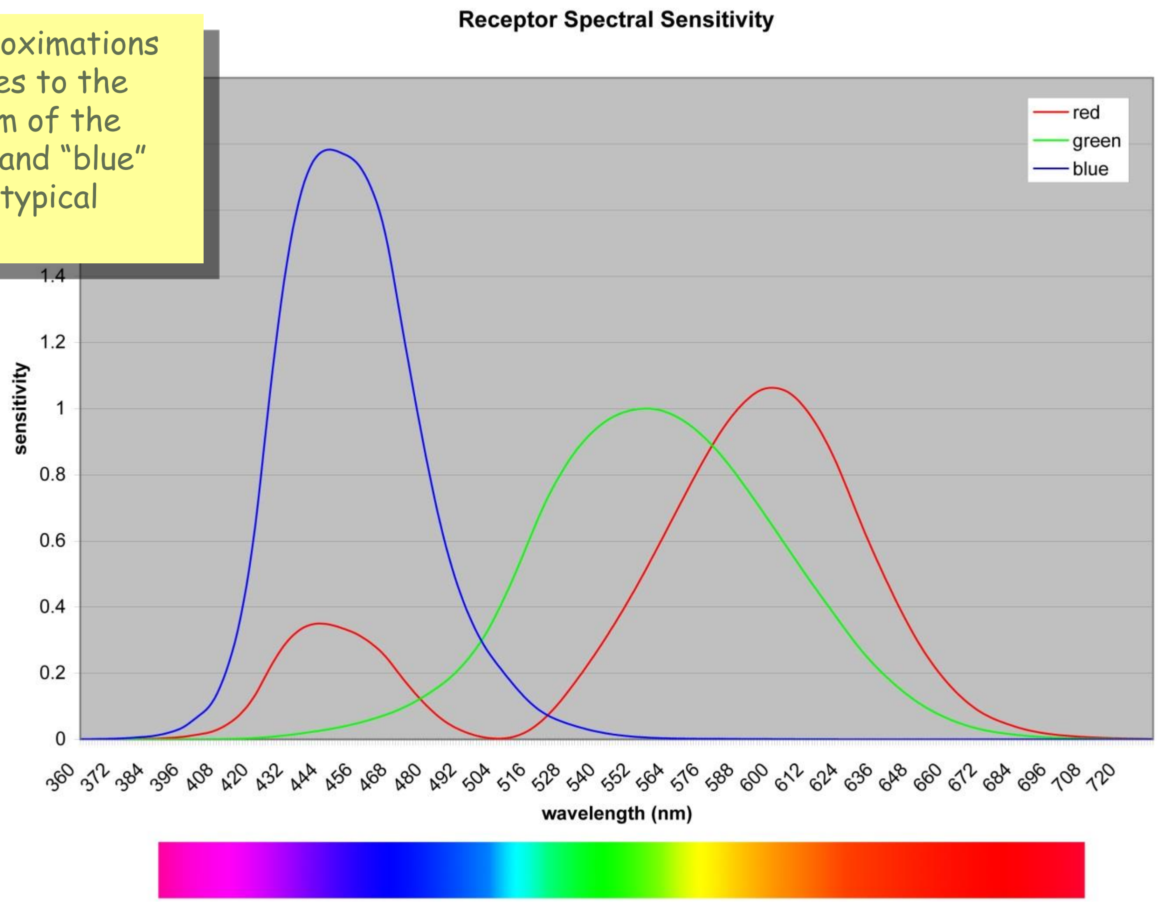


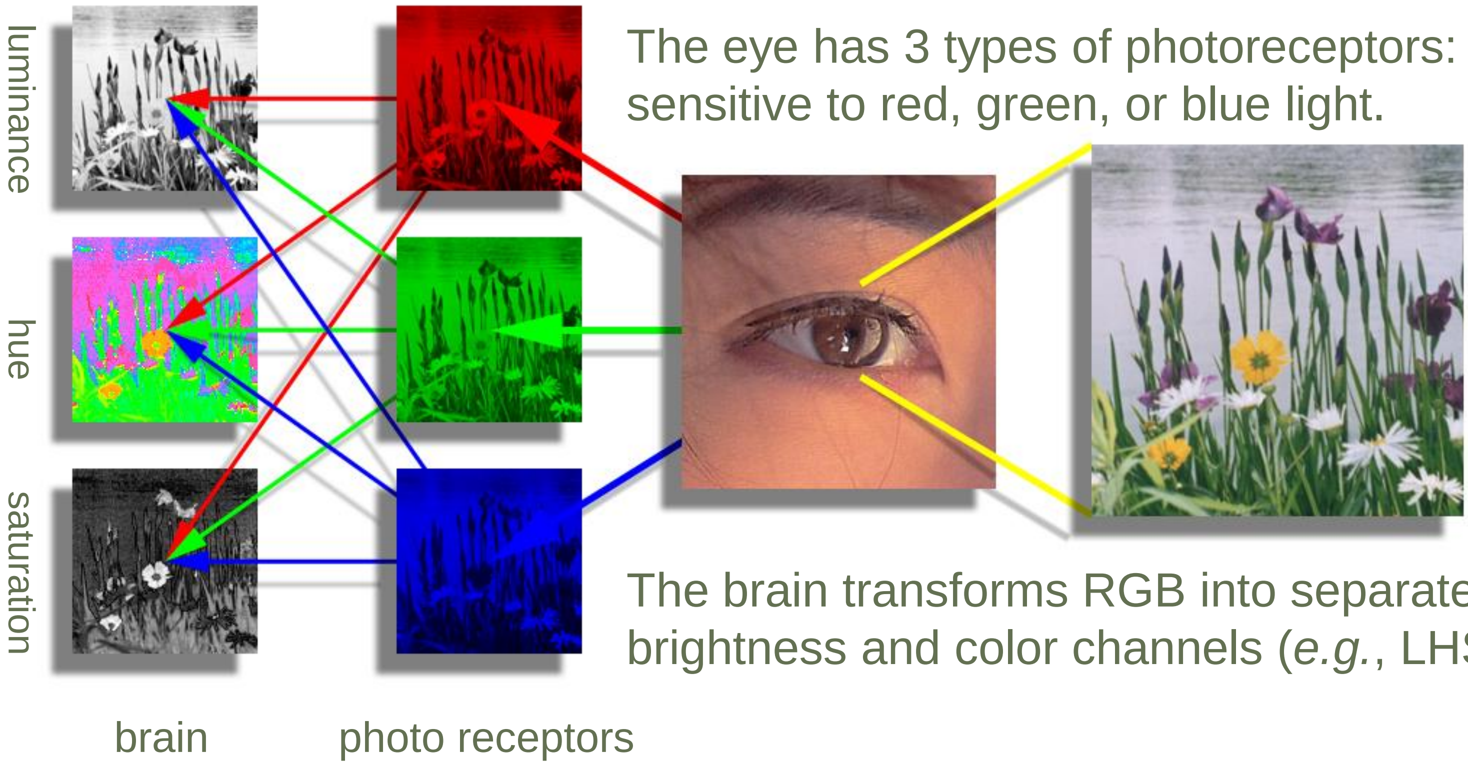
Fig. 1. Human retina as seen through an opthalmoscope.

Color Sensing / Color Perception

These are approximations of the responses to the visible spectrum of the “red”, “green”, and “blue” receptors of a typical human eye.



Color Perception



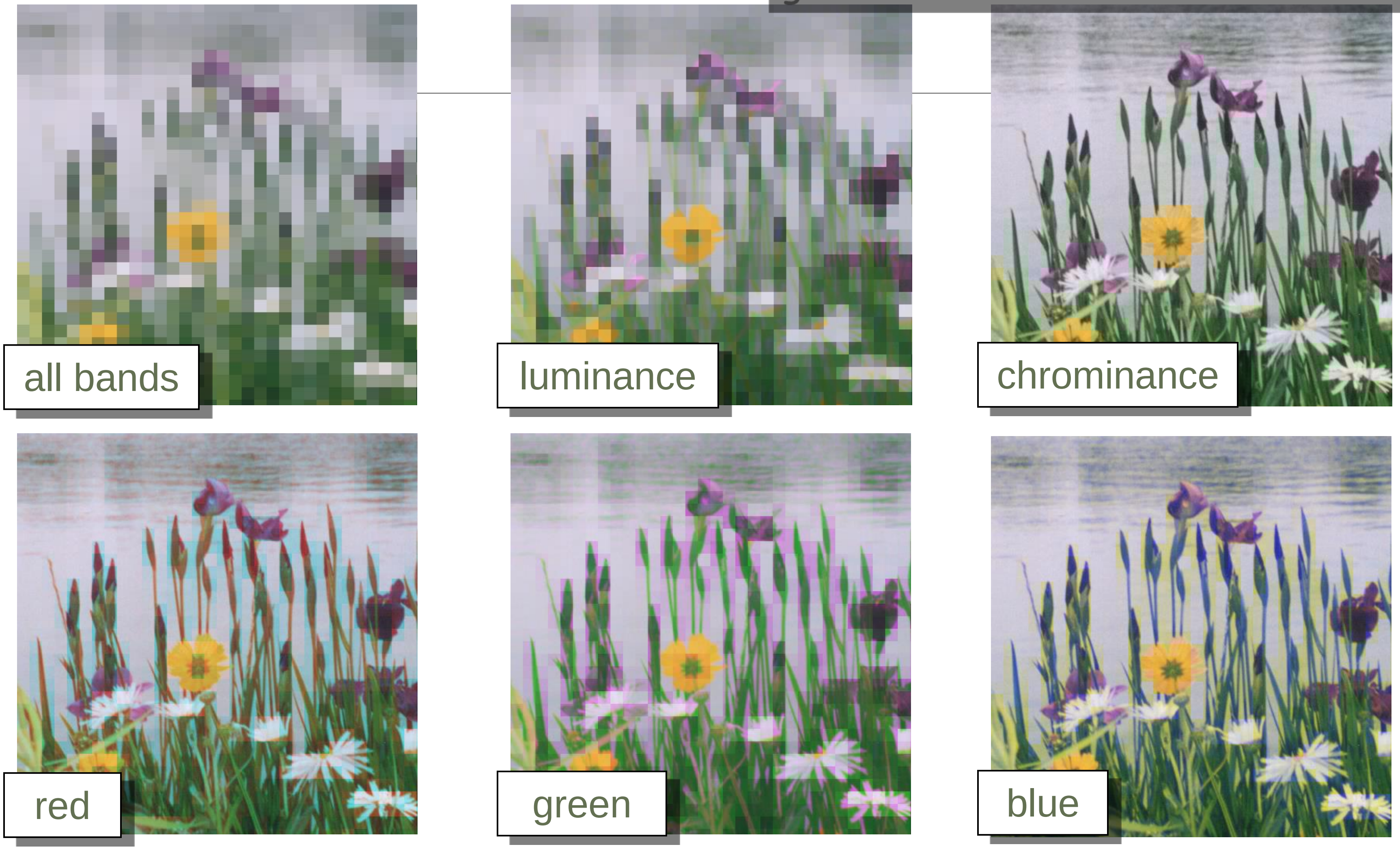
The eye has 3 types of photoreceptors: sensitive to red, green, or blue light.

The brain transforms RGB into separate brightness and color channels (*e.g.*, LHS).

Color Perception

16× pixelization of:

luminance and chrominance (hue+saturation) are perceived with different resolutions, as are red, green and blue.

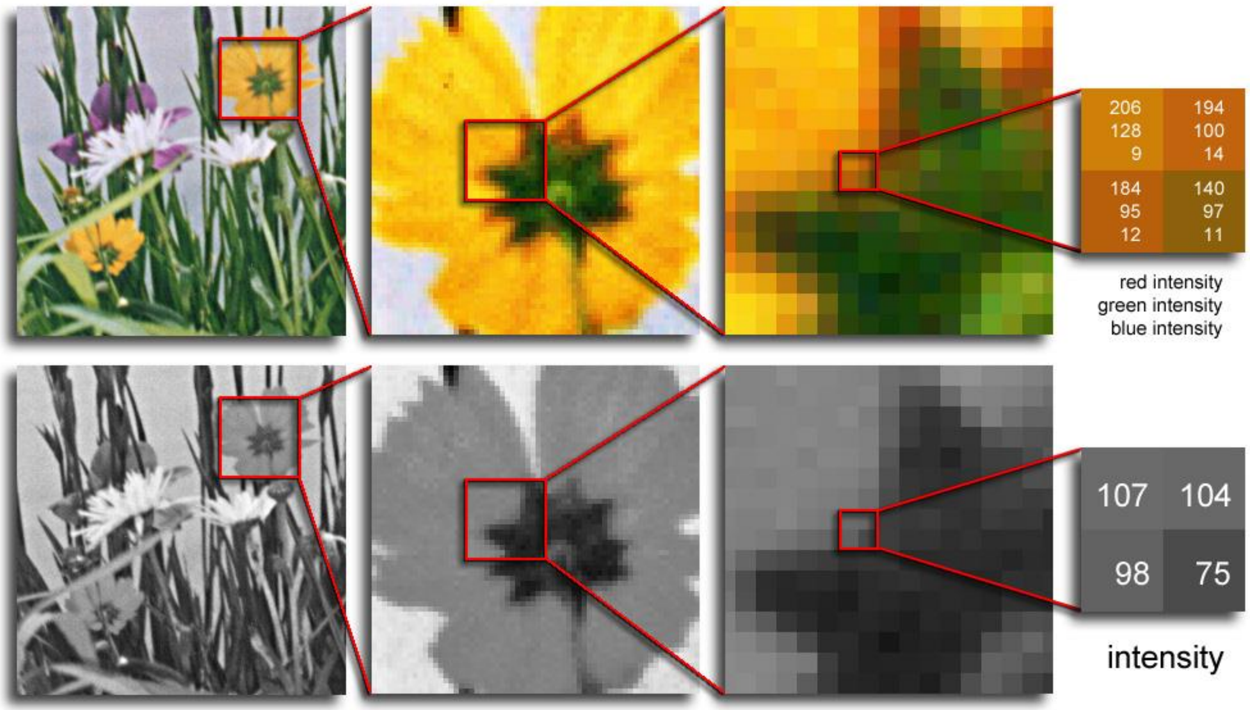


Digital Image

Color images have 3 values per pixel; monochrome images have 1 value per pixel.

a grid of squares, each of which contains a single color

each square is called a pixel (for *picture element*)



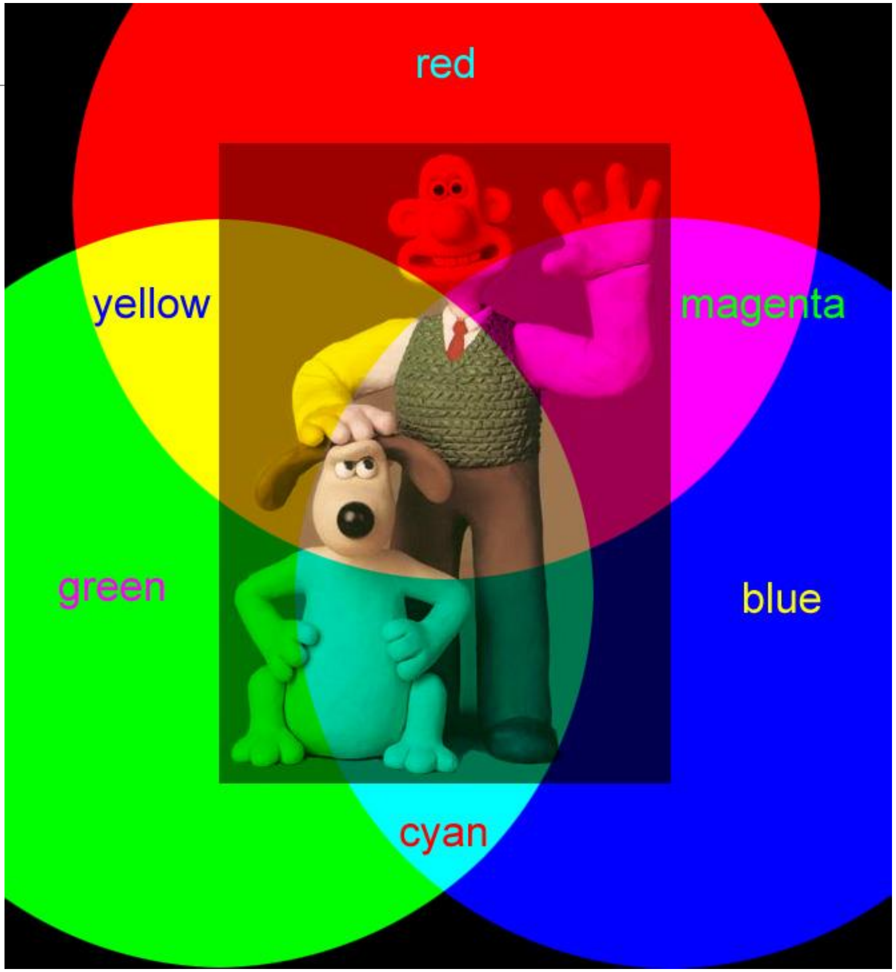
Color Images…

Are constructed from three intensity maps.

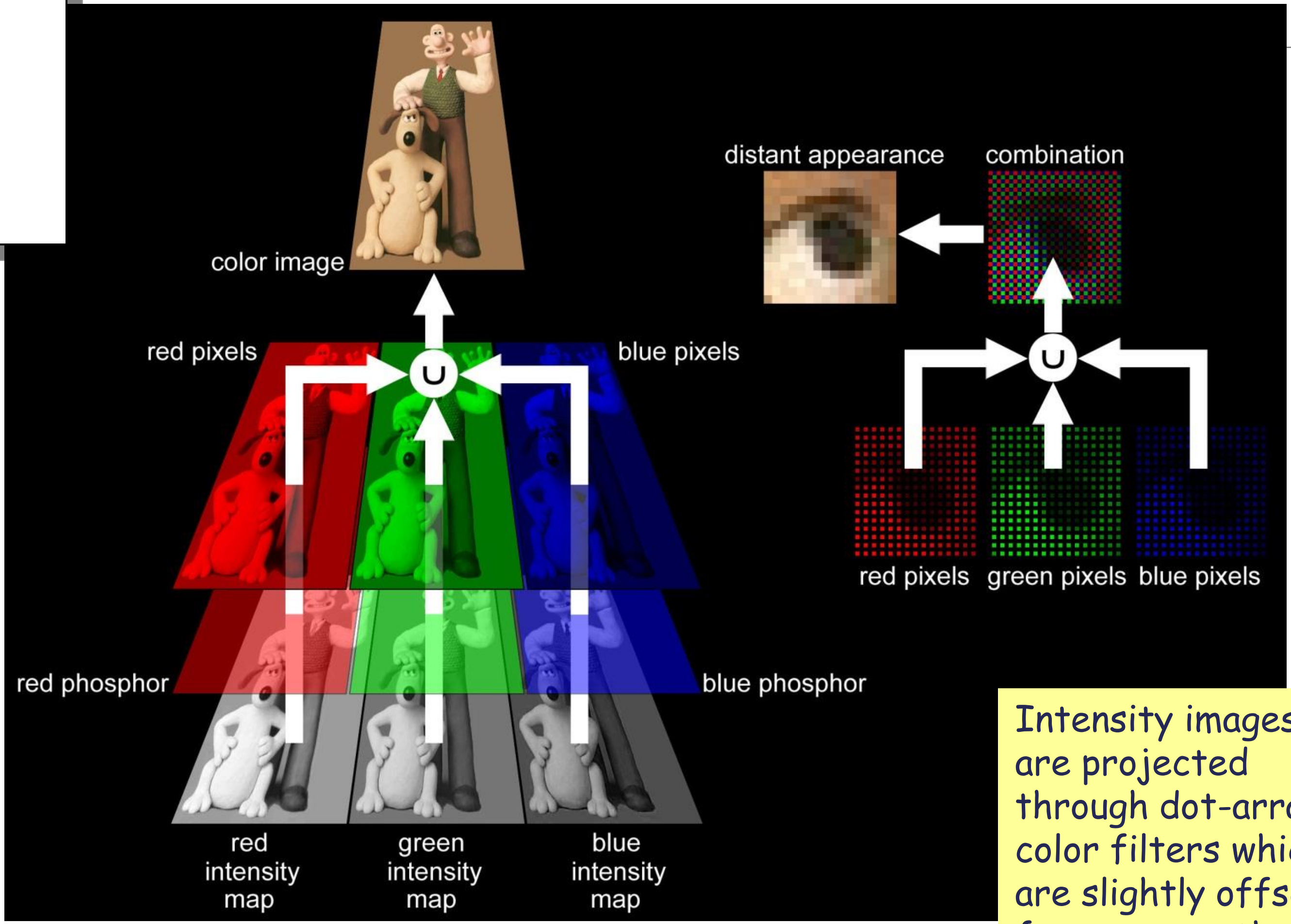
Each intensity map is projected through a color filter (*e.g.,* red, green, or blue, or cyan, magenta, or yellow) to create a monochrome image.

The intensity maps are overlaid to create a color image.

Each pixel in a color image is a three element vector.



Color Images On a CRT



Intensity images are projected through dot-array color filters which are slightly offset from one another.

Image processing techniques

Histogram

Castle Rock, Sedona, Arizona. There is one histogram for each of red, green, and blue. The red rock's color is in the midrange of intensities while the greenery is darker. Blue peaks correspond to the haze on the mountainside (dark) and the sky (bright).

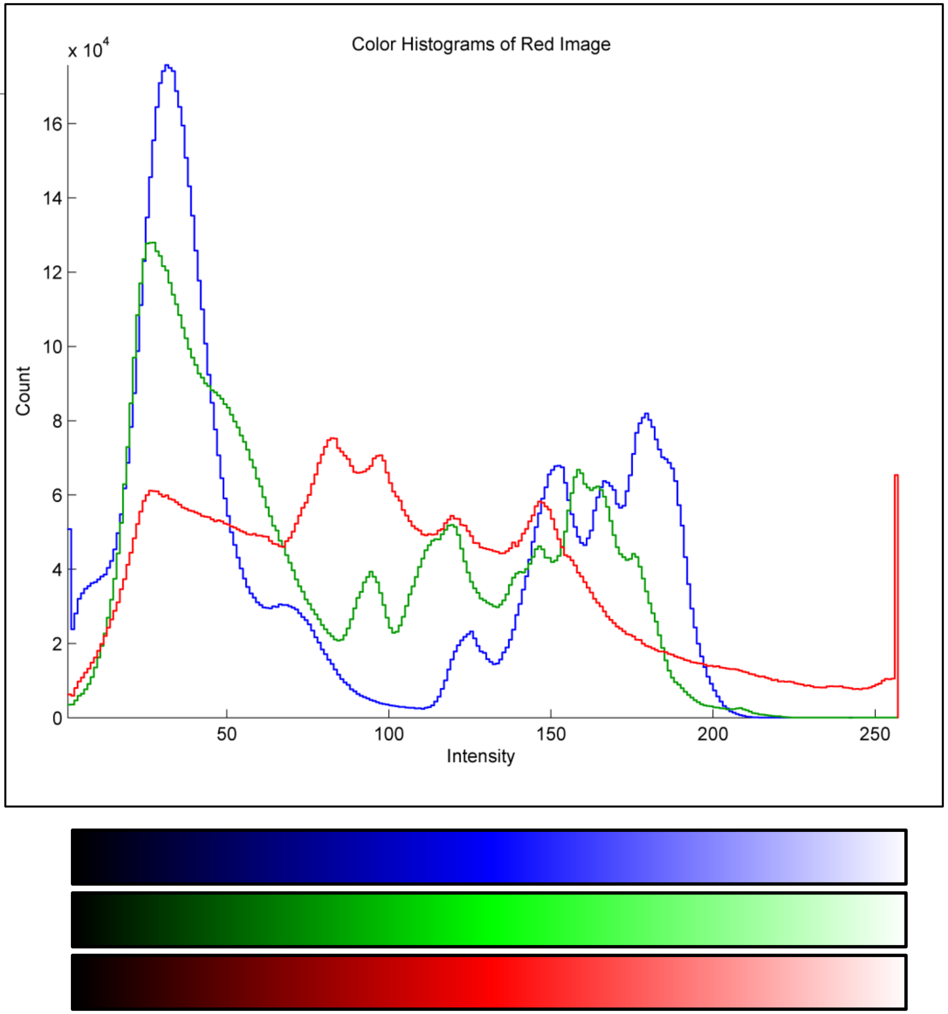
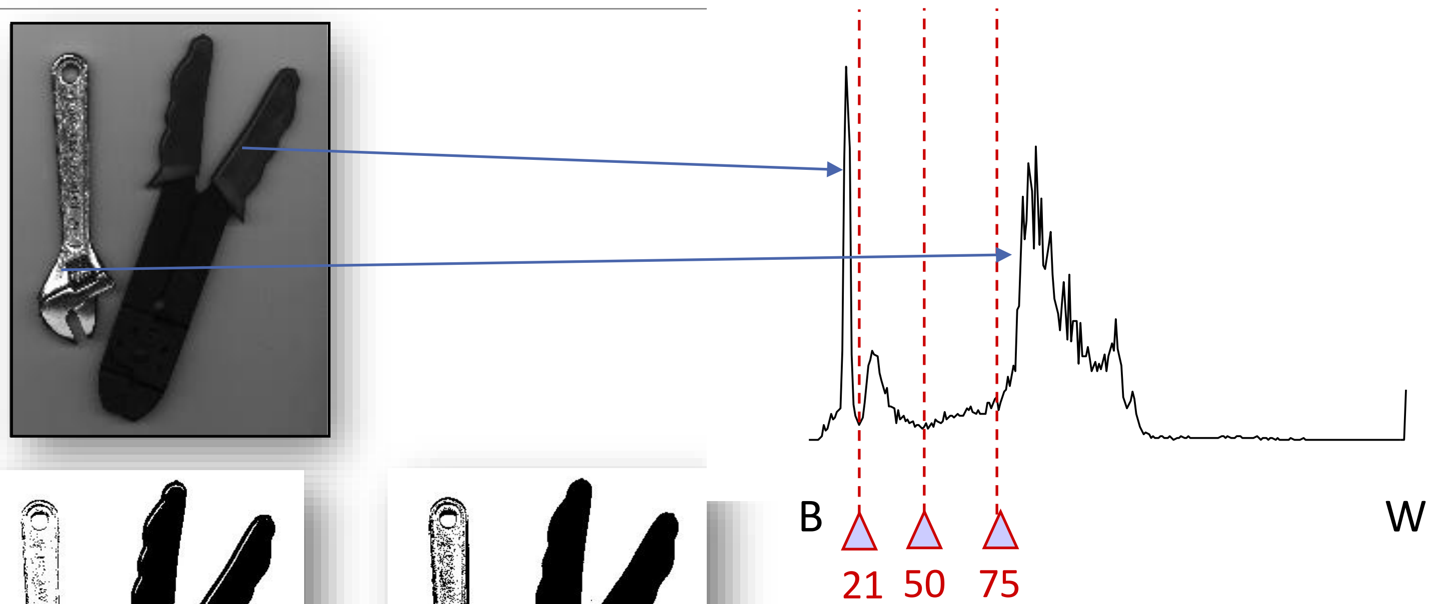


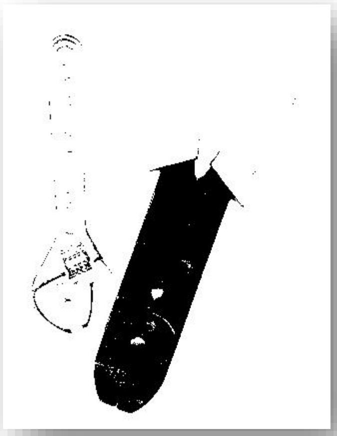
Photo by Edward Chavez, http://www.zensoulstyle.com

Segmentation using Thresholding

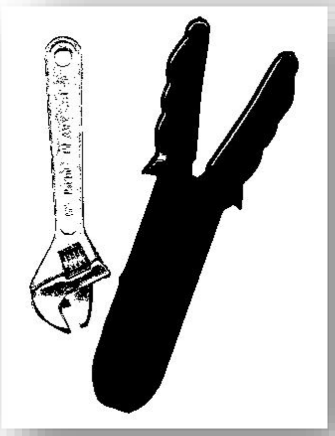
Original

Histogram

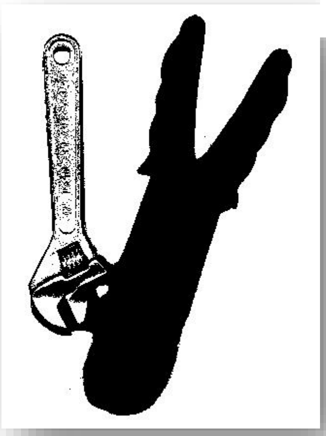




Threshold = 21



Threshold = 50



Threshold = 75

$$\begin{cases} g_{new} = 255, \text{if } g \geq Threshold \\ g_{new} = 0, \text{if } g < Threshold \end{cases}$$

Point Operations

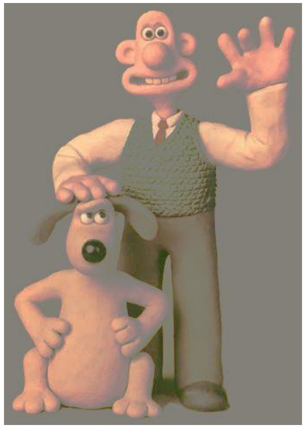
- gamma

- brightness

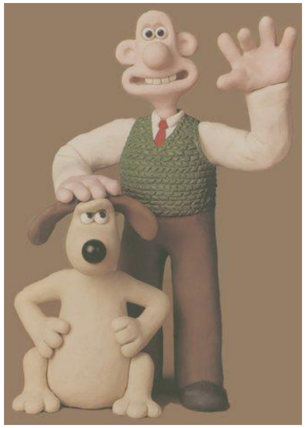
original

+ brightness

+ gamma



histogram mod



- contrast

original

+ contrast

histogram EQ

Spatial Filtering

blurred original sharpened

Smoothing Sharpening

Spatial Filtering

bandpass filter

original

unsharp masking

Noise Reduction

periodic noise

original

frequency tuned filter

Shot Noise or Salt & Pepper Noise

+ shot noise

s&p noise

- shot noise

Nonlinear Filters: the Median

original

s&p noise

median filter

Nonlinear Filters: Min and Maxmin

salt noise

min filter

maxmin filter

Nonlinear Filters: Max and Minmax

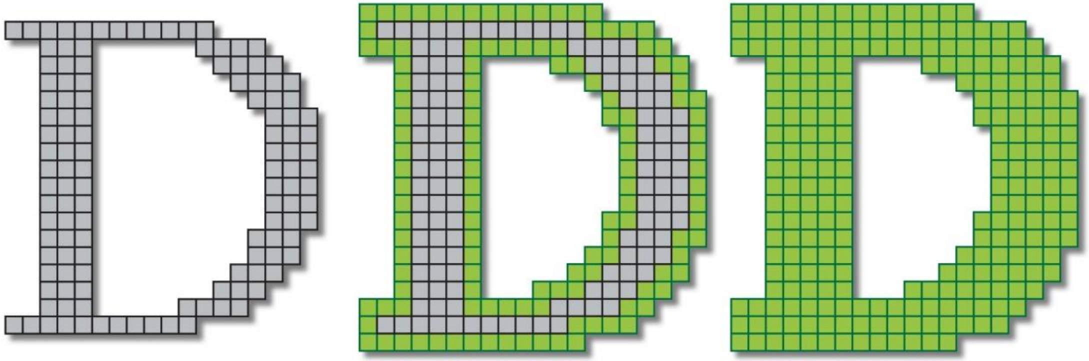
Pepper noise

max filter

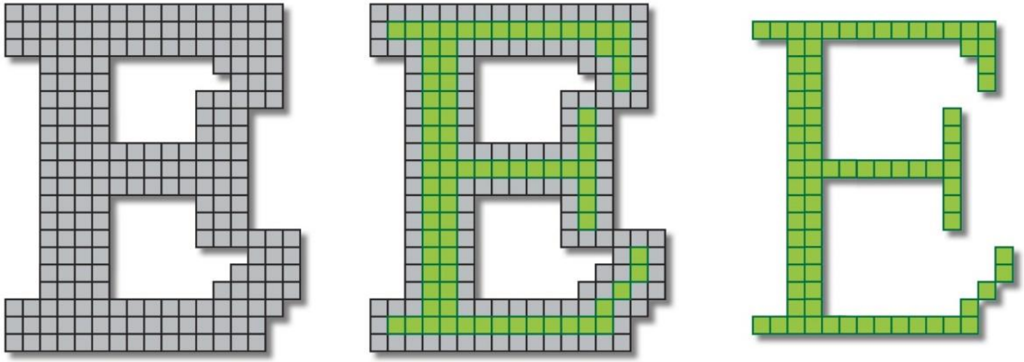
minmax filter

Binary Morphology

Dilation

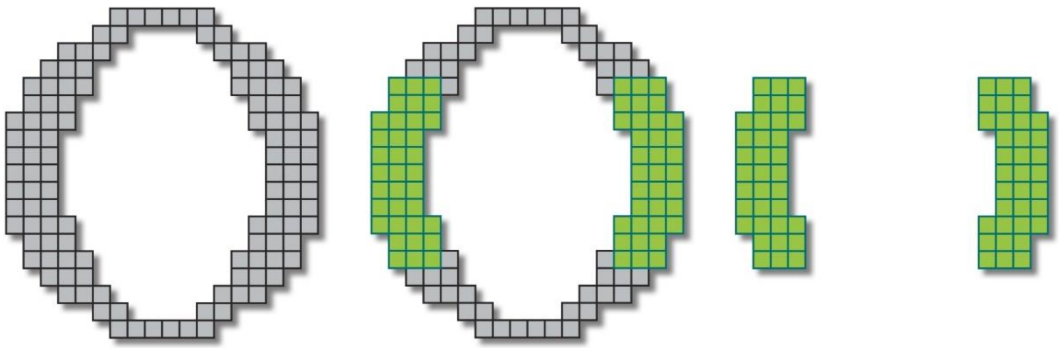


Erosion

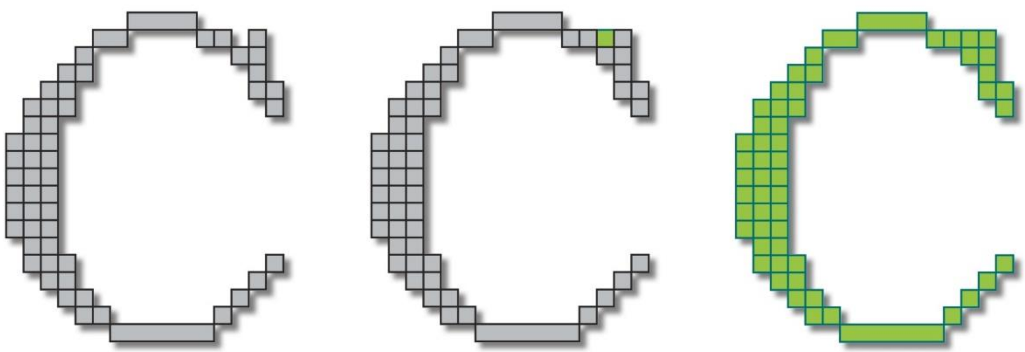


Binary Morphology

Opening



Closing



Transformations and compression

2D Fourier Transform

The Fourier Transform decompose an image into its sine and cosine components.
Let $I(r,c)$ be a single-band (intensity) digital image with R rows and C columns. Then, $I(r,c)$ has Fourier representation

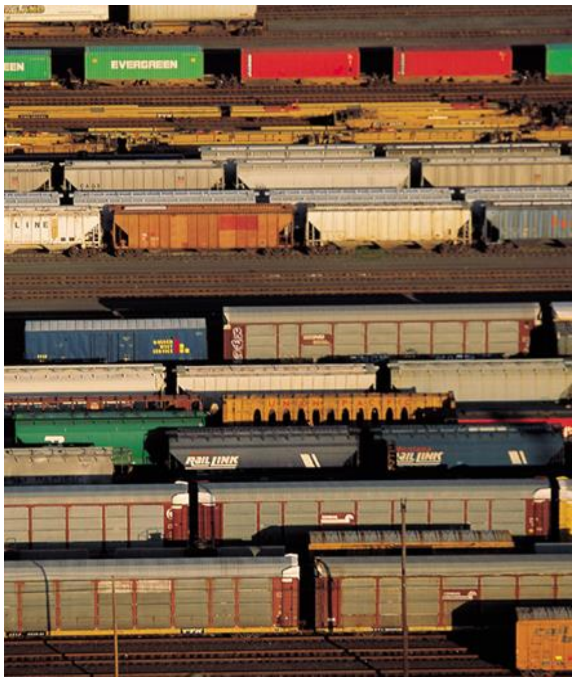
$$I(r,c) = \sum_{u=0}^{R-1} \sum_{v=0}^{C-1} F(u,v)\, e^{+i2\pi\left(\frac{ur}{R}+\frac{vc}{C}\right)},$$

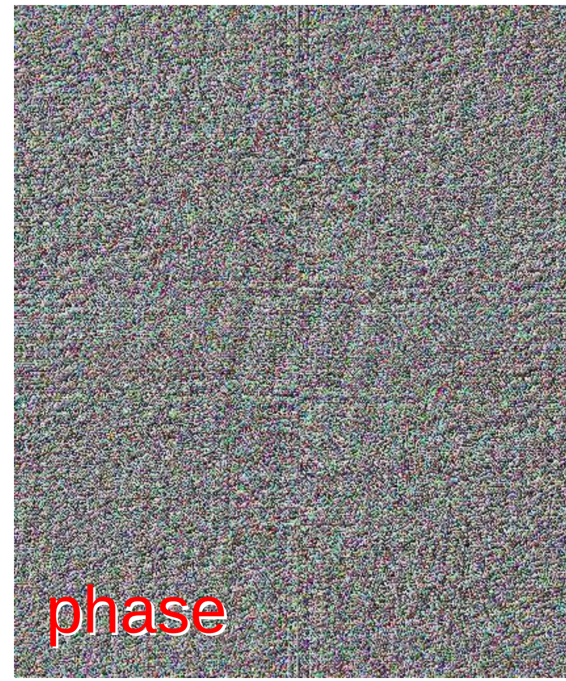
where

$$F(u,v) = \frac{1}{RC} \sum_{r=0}^{R-1} \sum_{c=0}^{C-1} I(r,c)\, e^{-i2\pi\left(\frac{ur}{R}+\frac{vc}{C}\right)}$$

are the R x C Fourier coefficients.

2D Fourier Transform





I

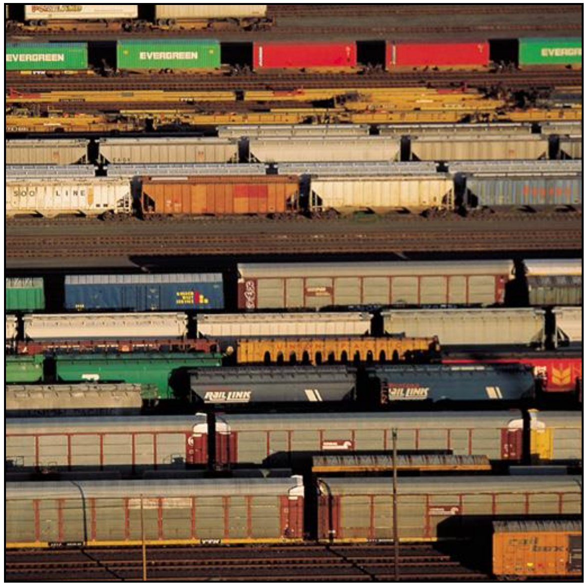
$|\mathscr{F}\{I\}|$

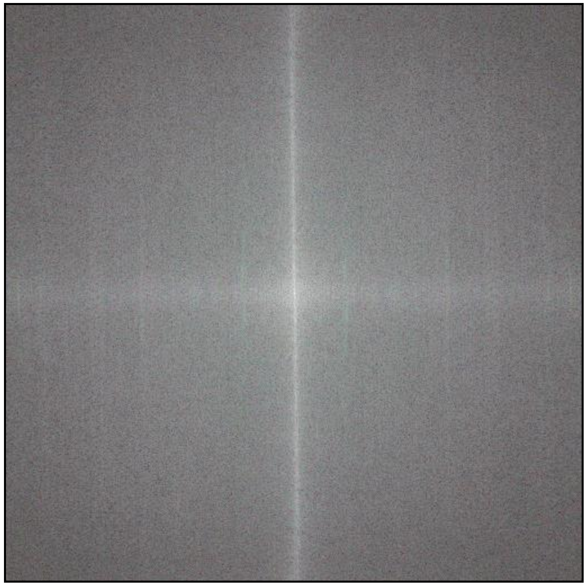
contains most geometric info !

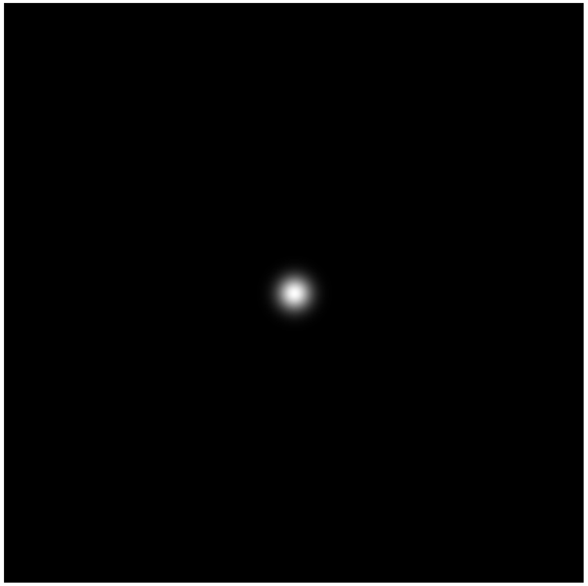
$\angle[\mathscr{F}\{I\}]$

Frequency Domain (FD) Filtering

Image size: 512x512
SD filter sigma = 8







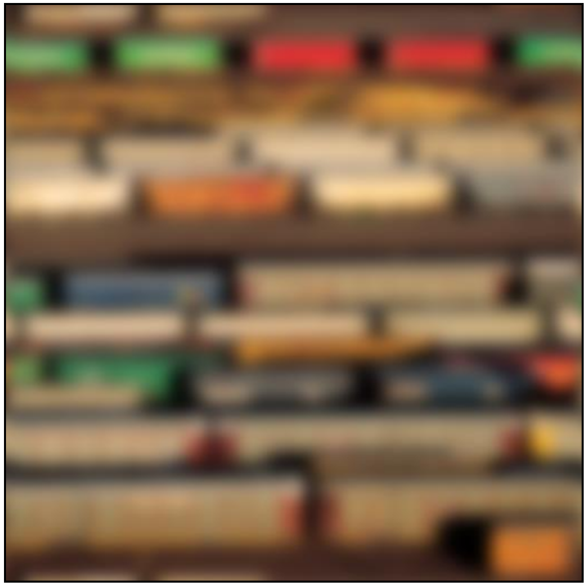
Original Image

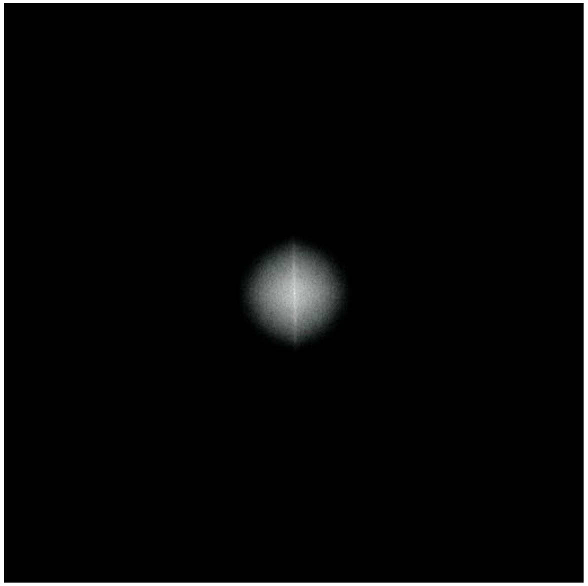
Power Spectrum

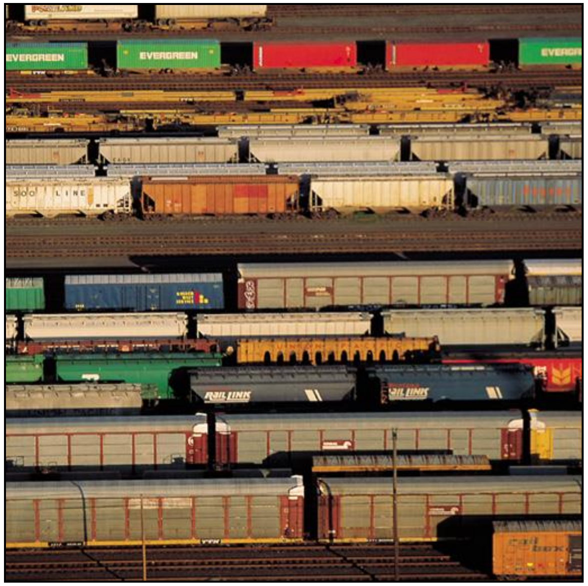
Gaussian LPF in FD

Frequency Domain (FD) Filtering

Image size: 512x512
SD filter sigma = 8







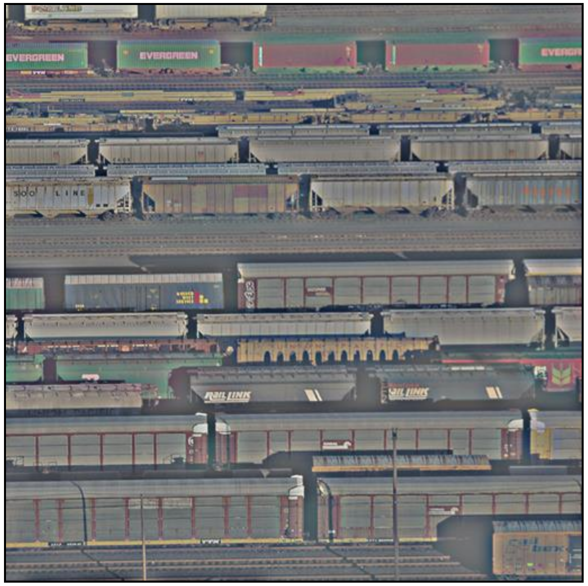
Filtered Image

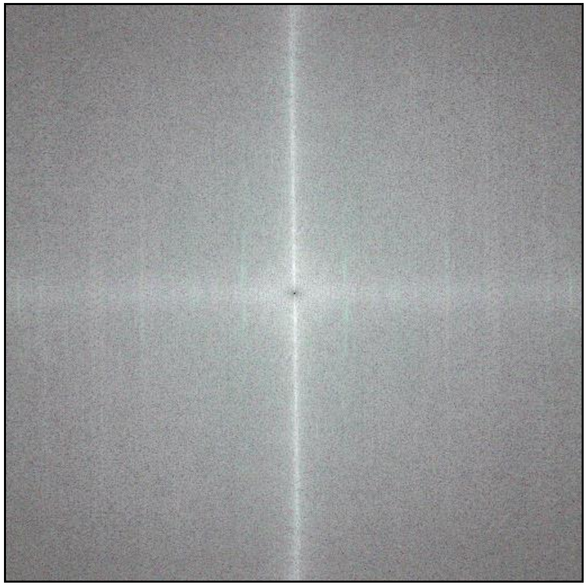
Filtered Power Spectrum

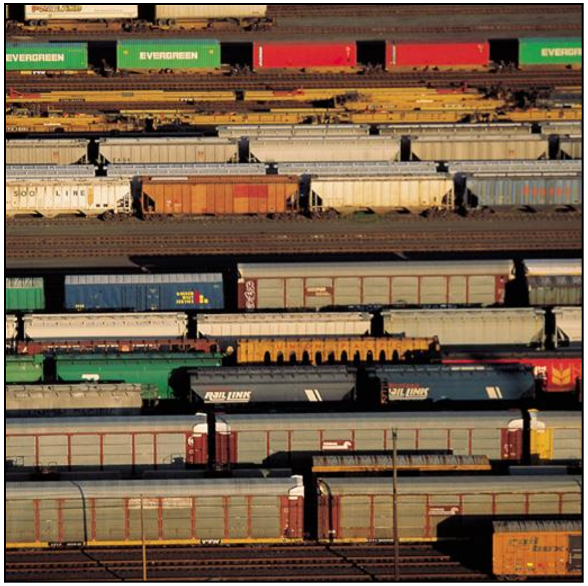
Original Image

Frequency Domain (FD) Filtering

Image size: 512x512
FD notch sigma = 8





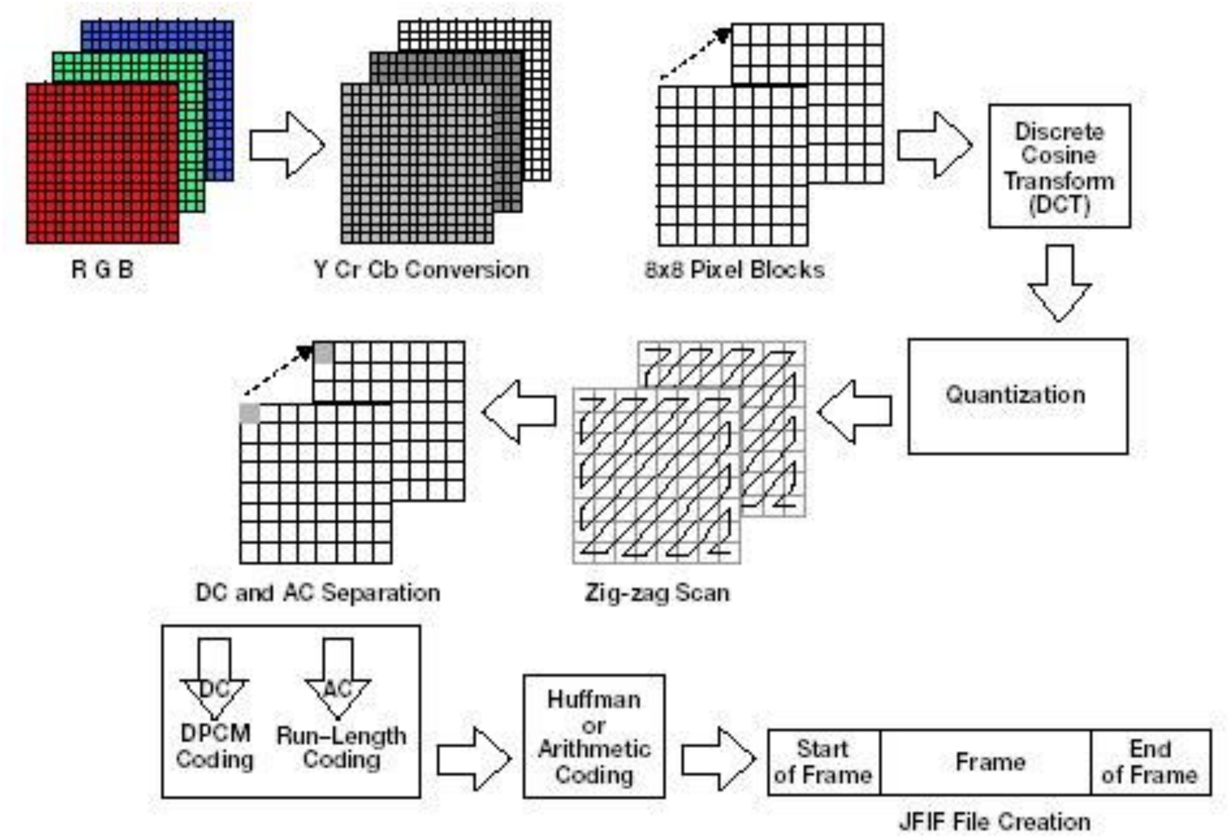


Filtered Image

Filtered Power Spectrum

Original Image

Image Compression



Baseline JPEG encode data flow

Image Compression

Original image is 5244w x 4716h @ 1200 ppi: 127MBytes

Yoyogi Park, Tokyo, October 1999. Photo by Alan Peters.

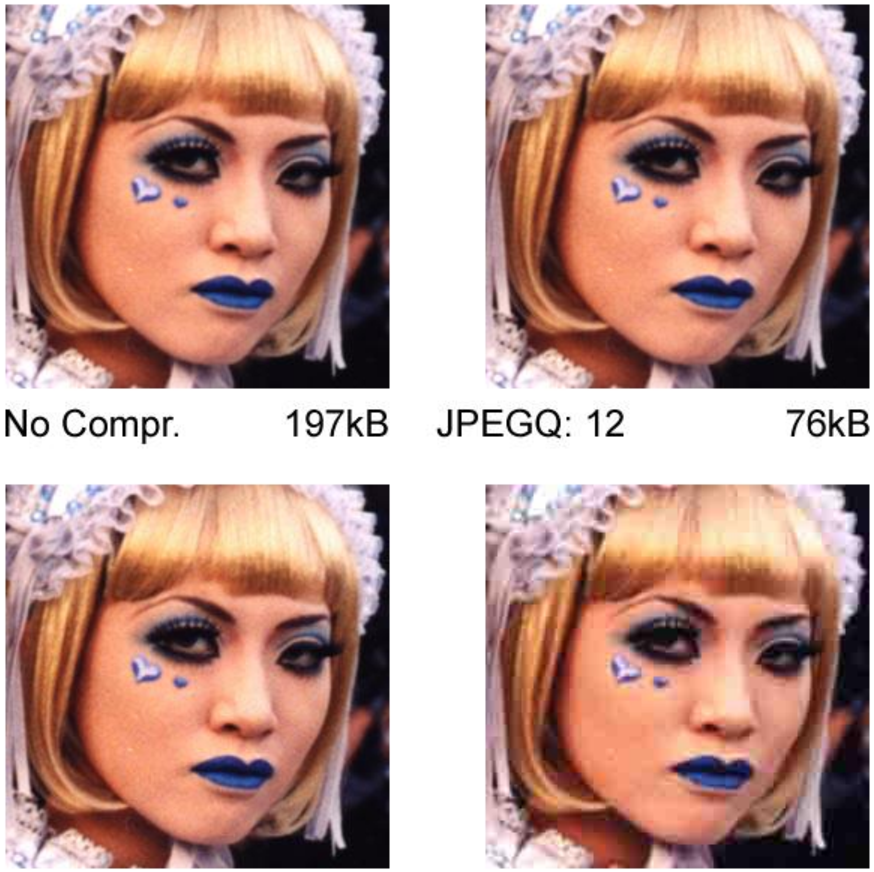
Image Compression

JPEG quality level

File size in bytes

Image Compression

JPEG quality level



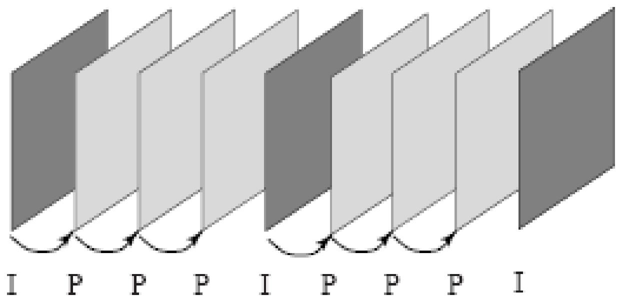
No Compr. 197kB | JPEGQ: 12 76kB

JPEGQ: 6 21kB | JPGEQ: 0 12kB

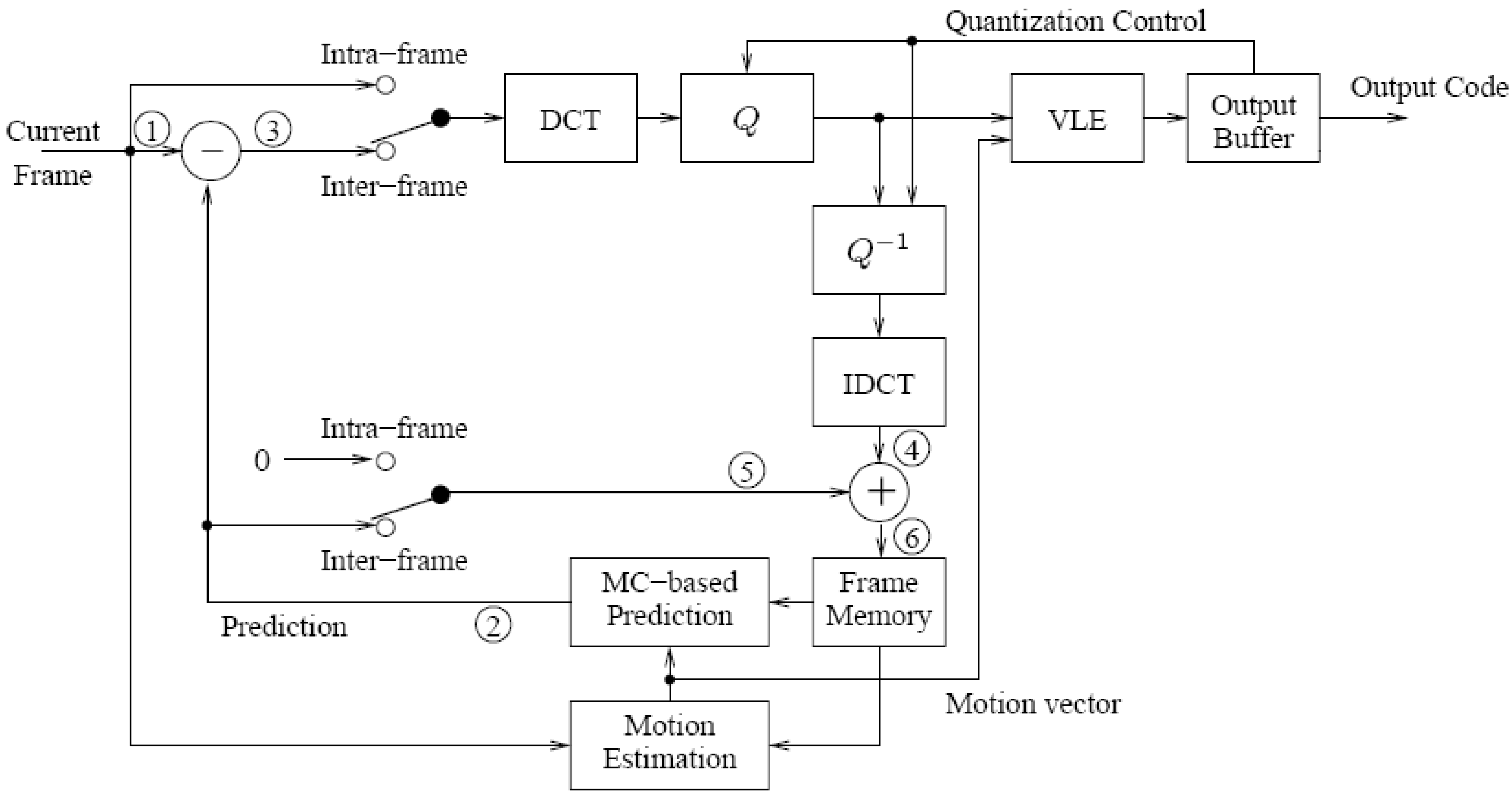
File size in bytes

Video processing techniques

Video Compression



- Video is composed of a sequence of frames.
- Two types of frame in a video: Intra-frames (I-frames) and Inter-frames (P-frames):
  - I-frames are treated as independent images. Transform coding method similar to JPEG is applied within each I-frame, hence "Intra".
  - P-frames are not independent: coded by a forward predictive coding method



H.261 encoder block diagram

Q&A