

# Introduction to Computer Vision

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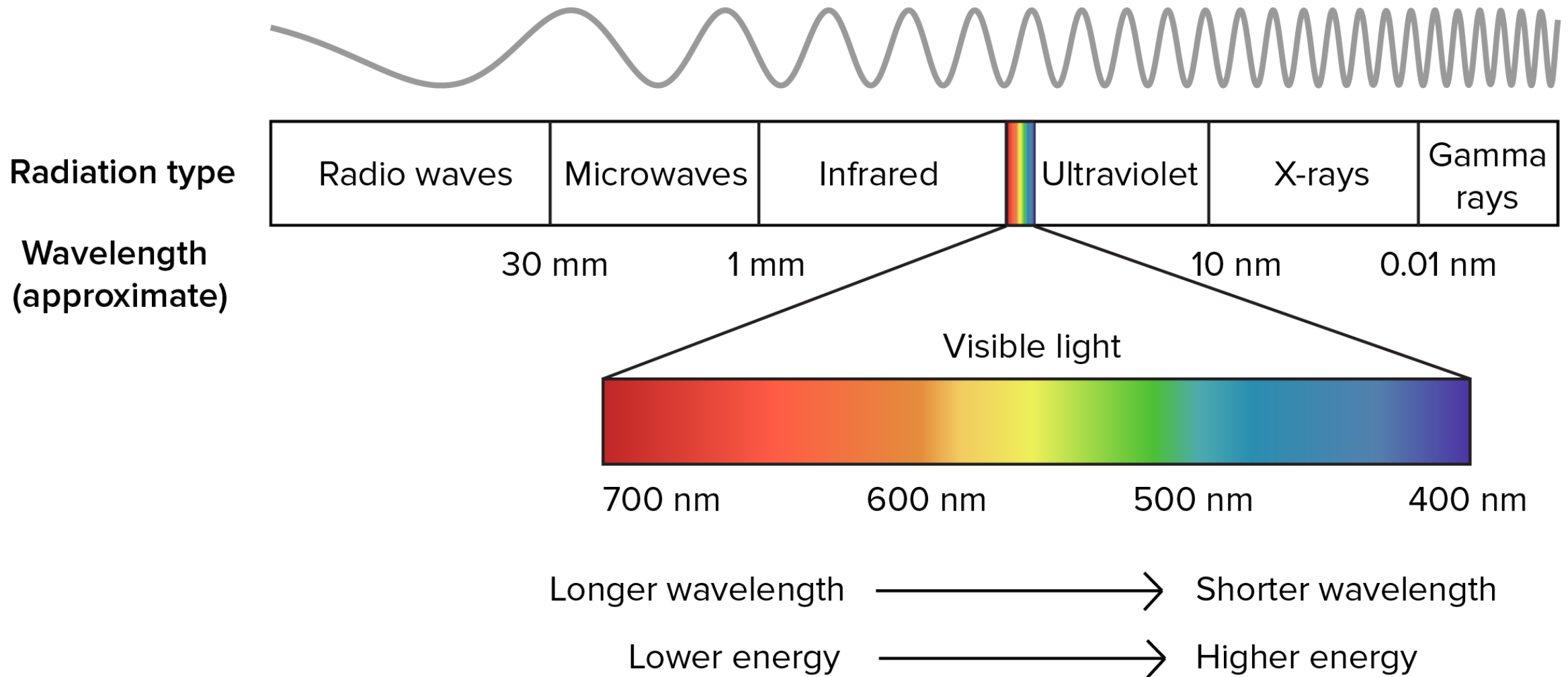
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Internet of Things Group

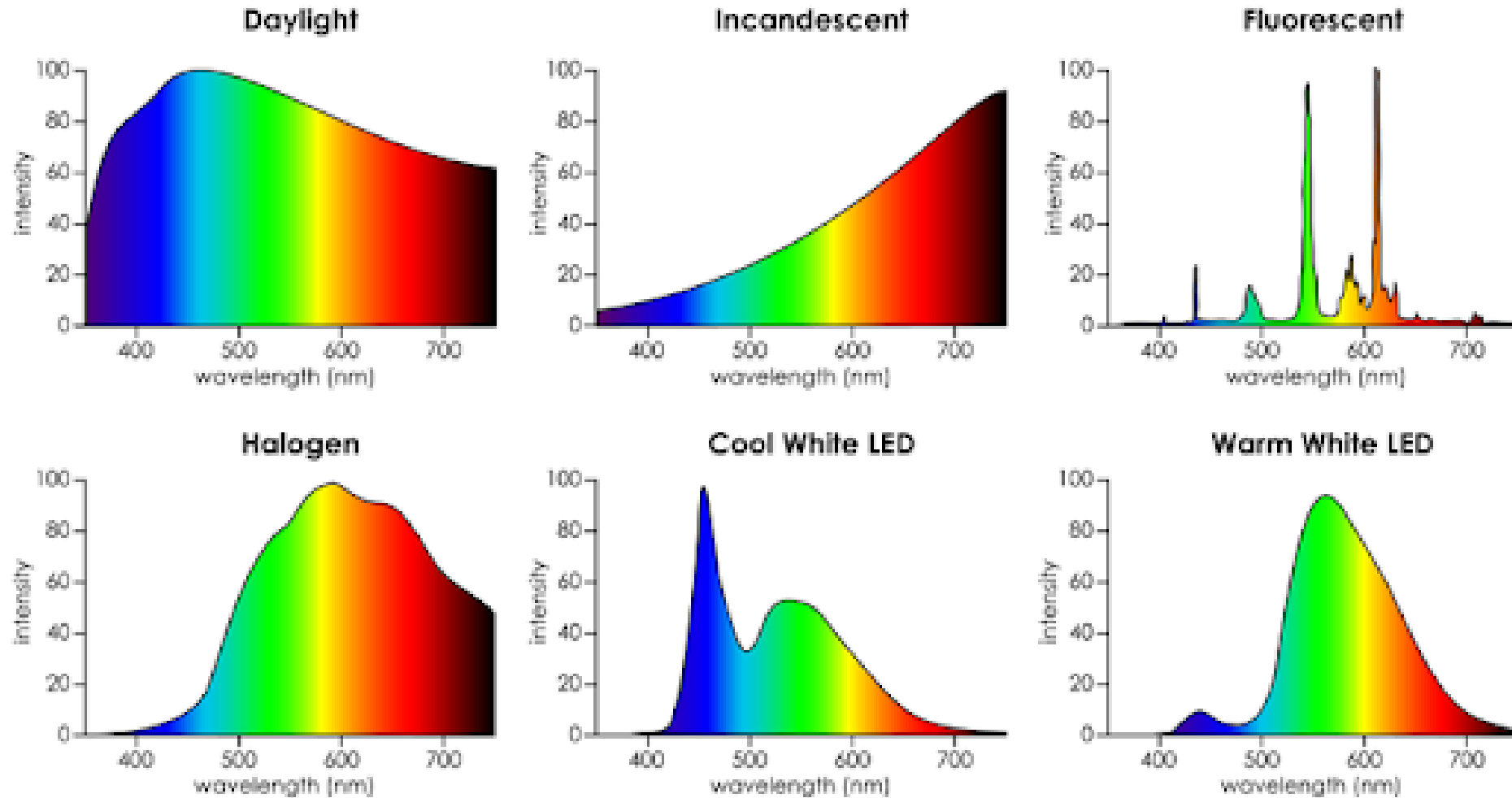
# Plan

- Introduction to natural and digital vision
- Color spaces
- Image manipulations
  - Low level
  - Mid level
  - High level

# Introduction: Visible light

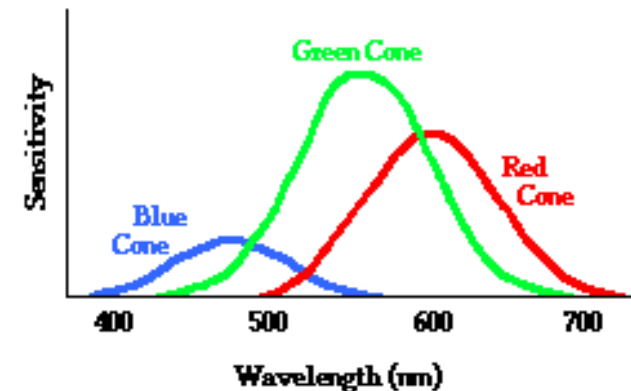
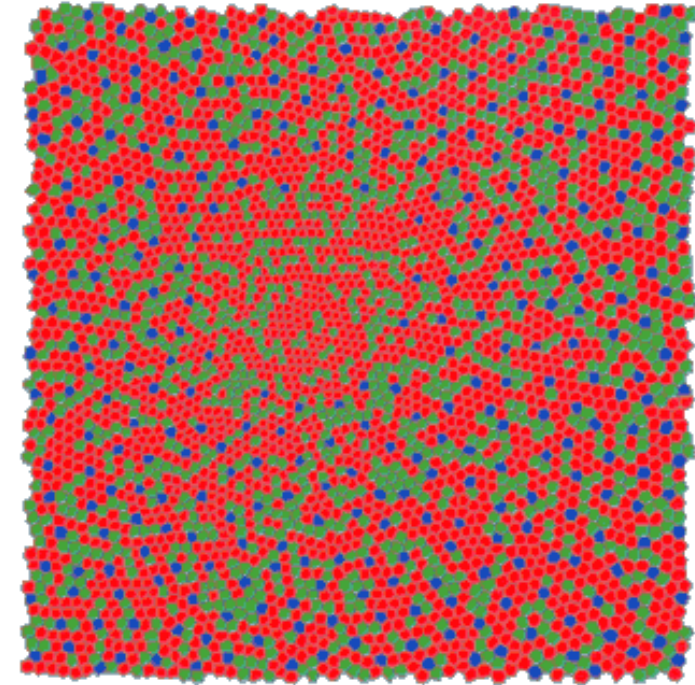


# Introduction: Visible light



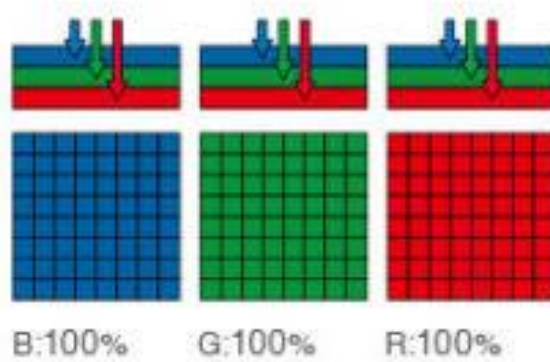
# Introduction: Human eye

- Cone and rod cells are a base photoreceptor
- Receptor has responsiveness curve
- Rod cell peak  $\sim 490\text{nm}$
- 3 types of cone cells:
  - Short: peak  $\sim 440\text{ nm}$
  - Medium: peak  $\sim 540\text{ nm}$
  - Long: peak  $\sim 570\text{ nm}$

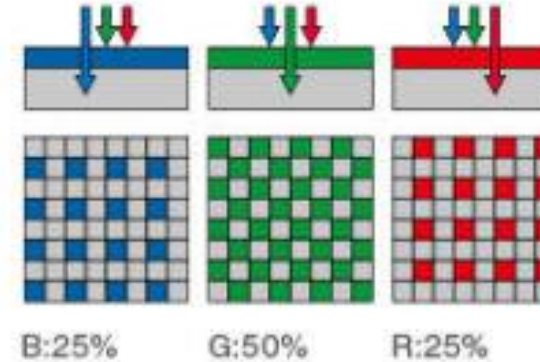
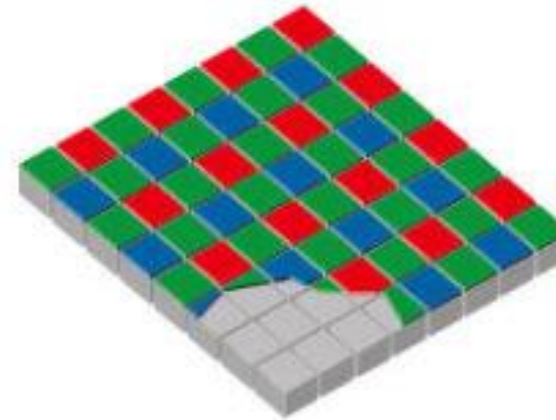


# Introduction: Digital vision

Foveon X3  
direct image sensor



Color filter array sensor  
(Bayer filter sensor)



# Introduction: CV tasks

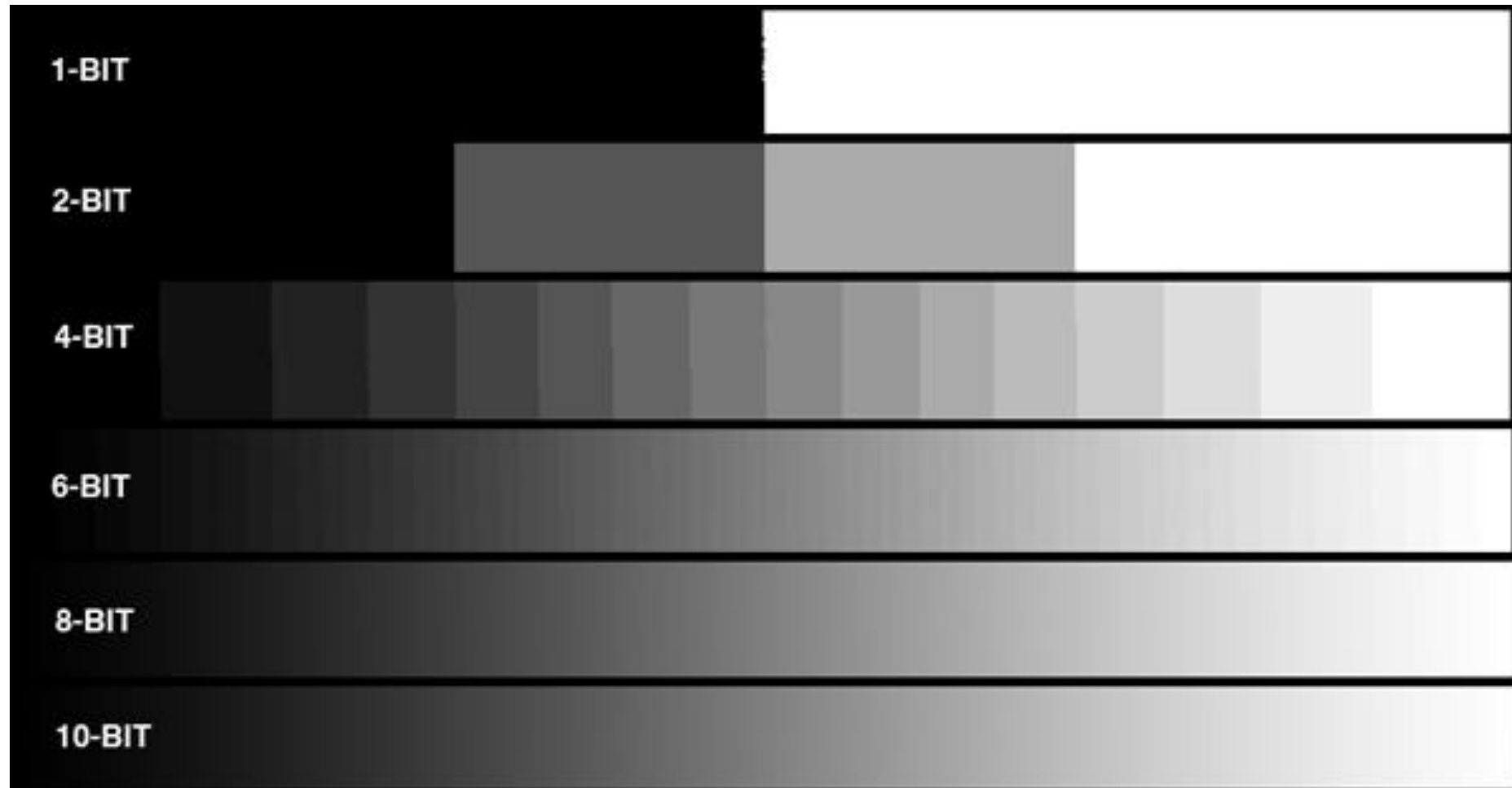
- Receive image
- Process image
- Visualize image

# Color space

- Grayscale
- RGB, RGBA, BGR
- LUV, LAB, HSV
- YUV, YUV 420, YUV422, YUYV
- CMY, CMYK
- etc.

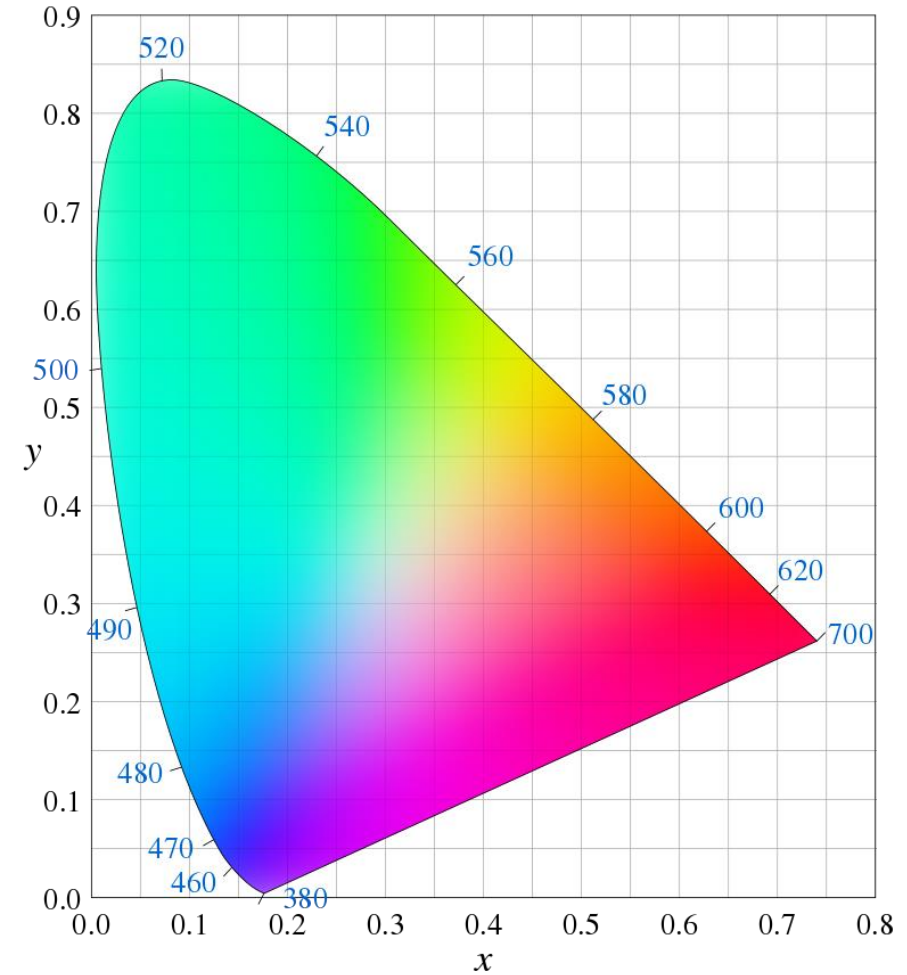
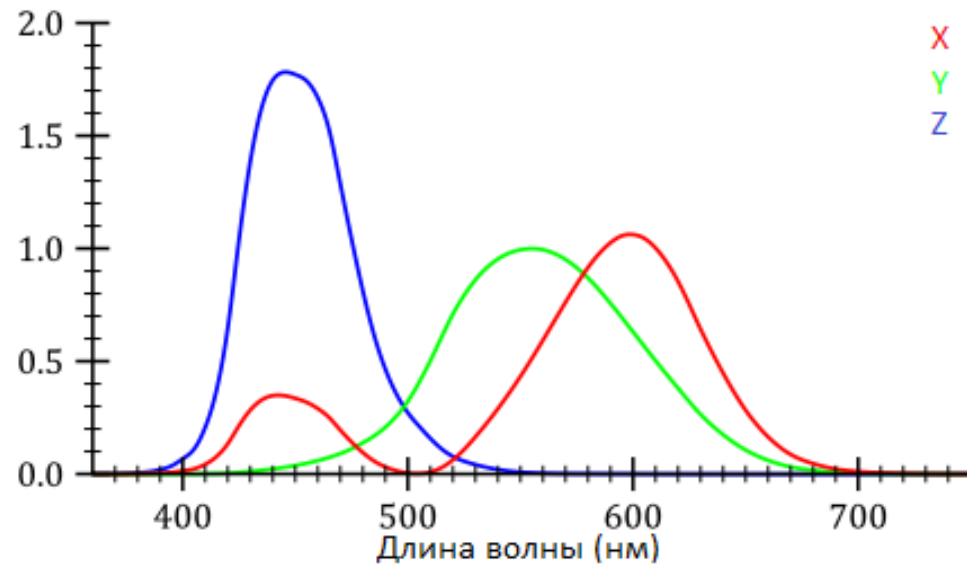


# Color space: Grayscale



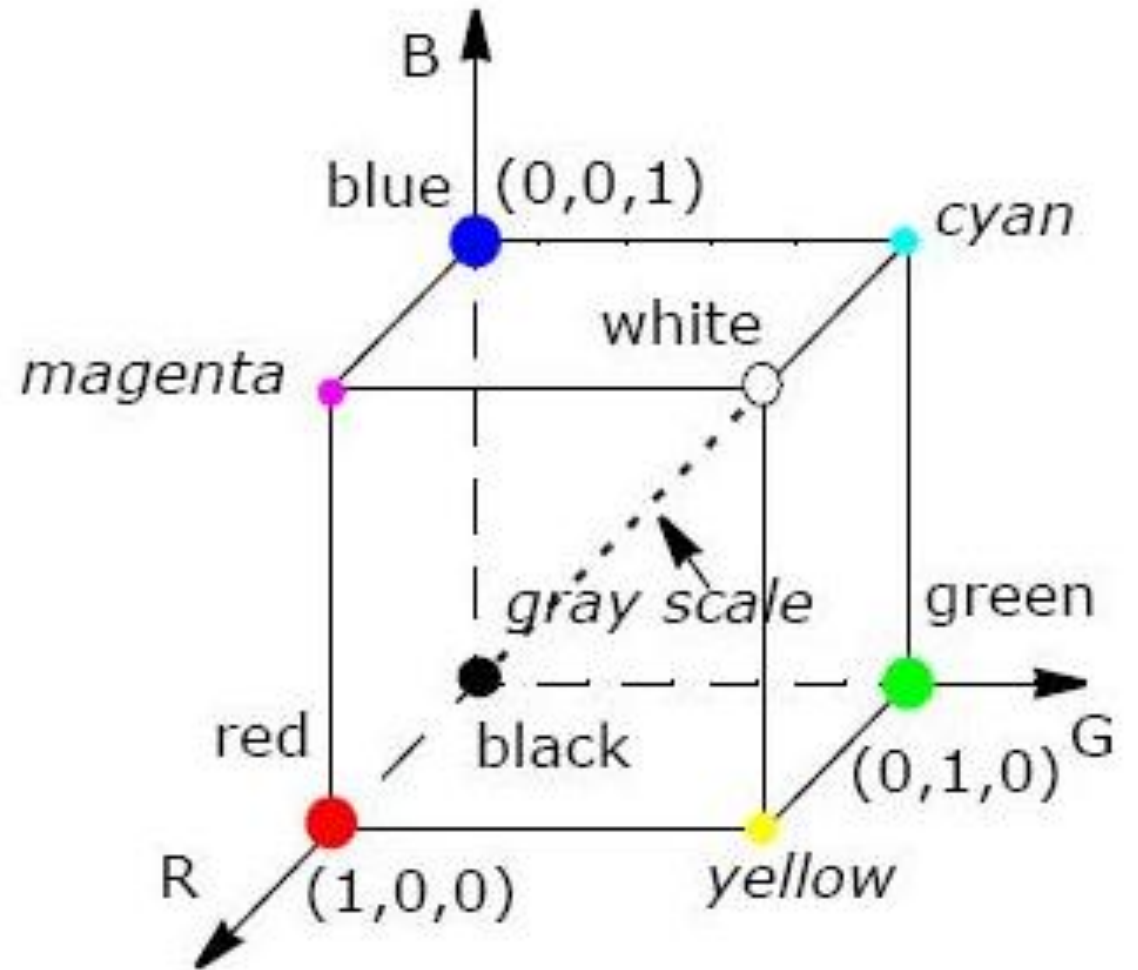
# Color space: XYZ

- Nonlinear color model
- Based on cone cells responsiveness curve



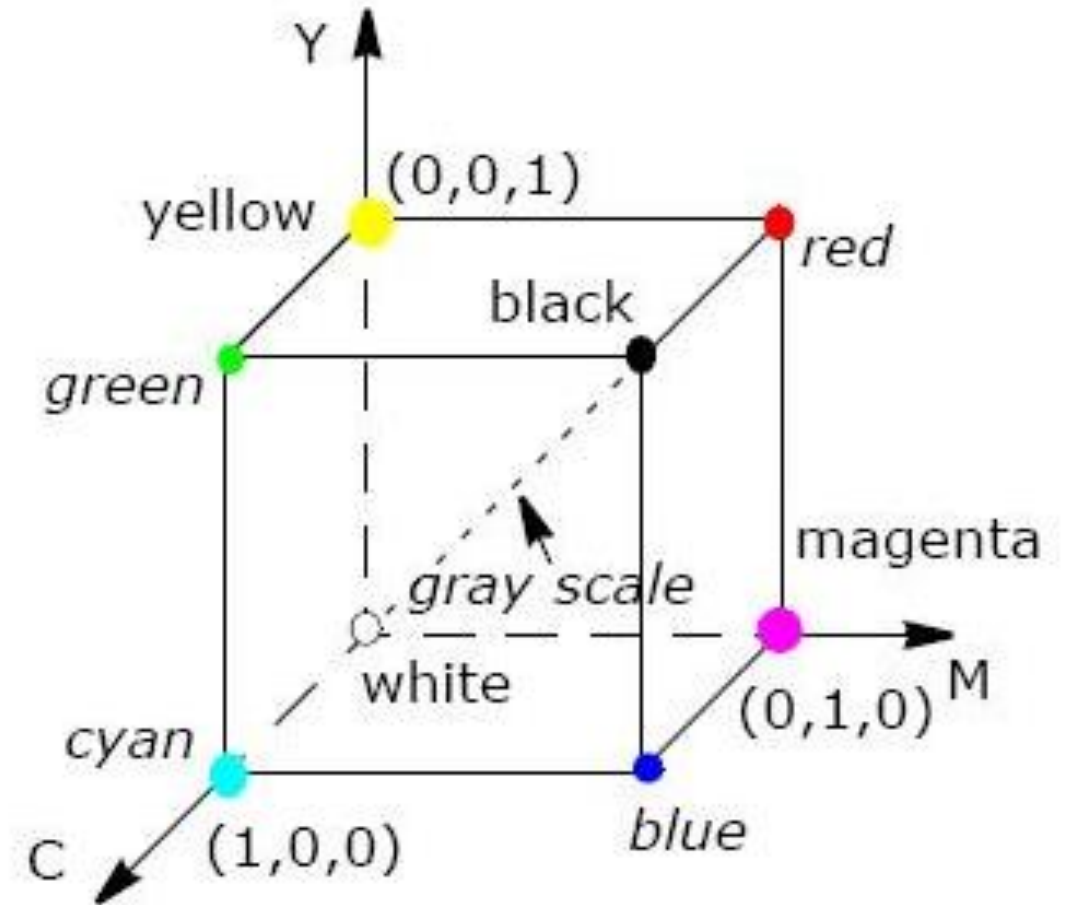
# Color space: RGB

- Additive color model
- 3 channels: red, green and blue



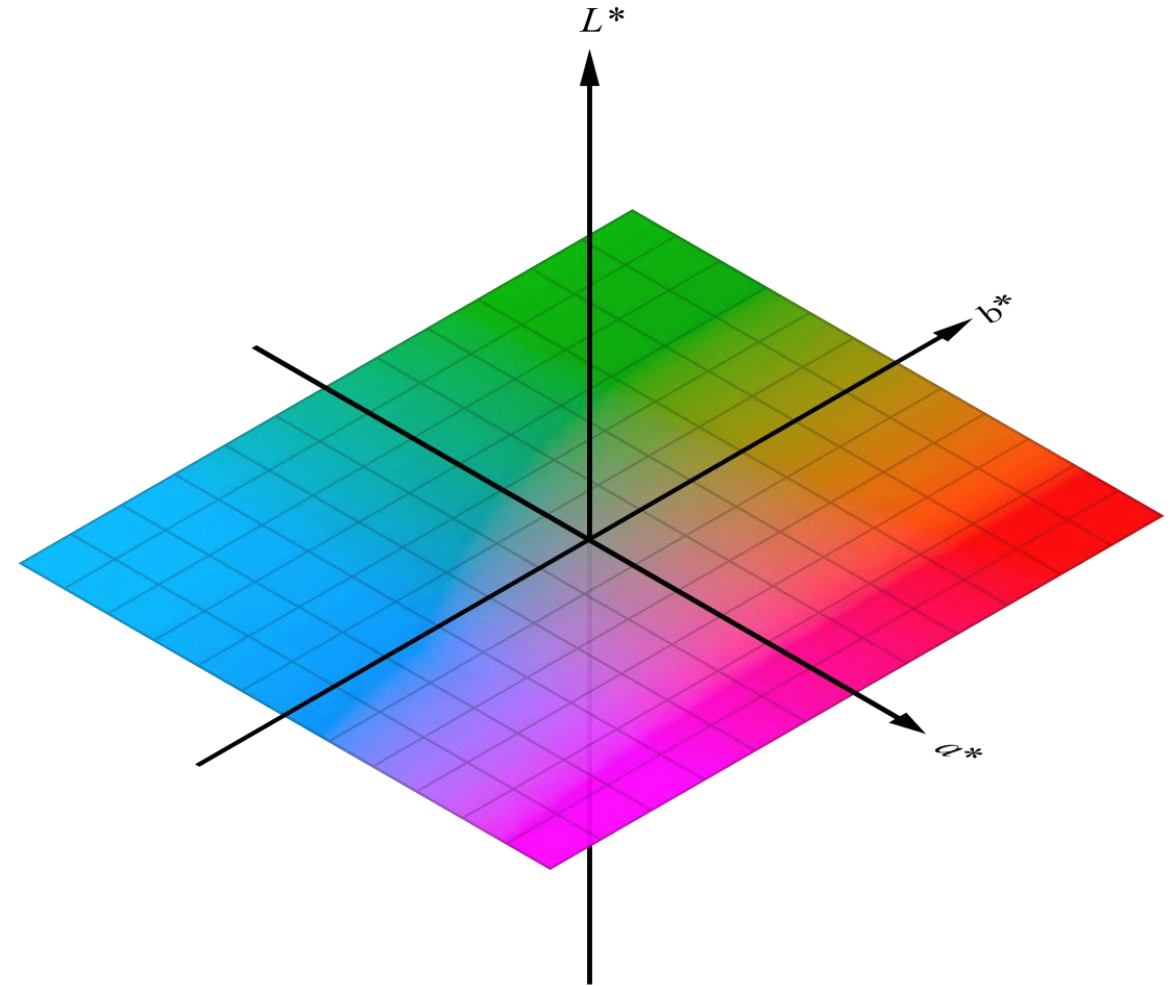
# Color space: CMY and CMYK

- Subtractive color model
- Channels: cyan, magenta, yellow and black (for CMYK)
- Black stands for key color
- Typographical color space



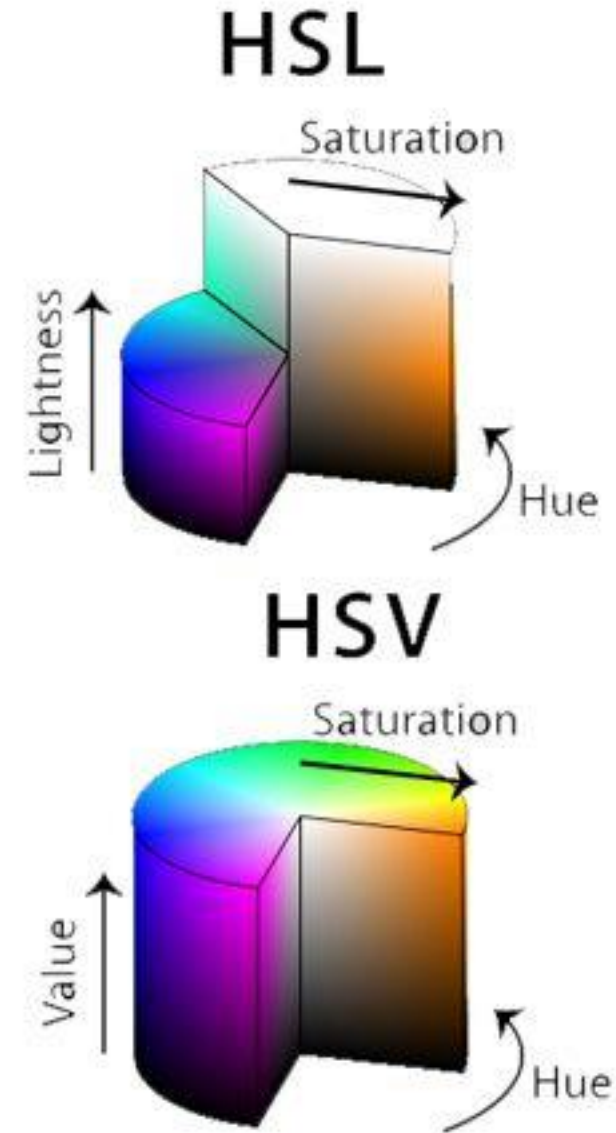
# Color space: LAB

- L – lightness (from black to white)
- A – from green(-) to red(+)
- B – from blue(-) to yellow(+)



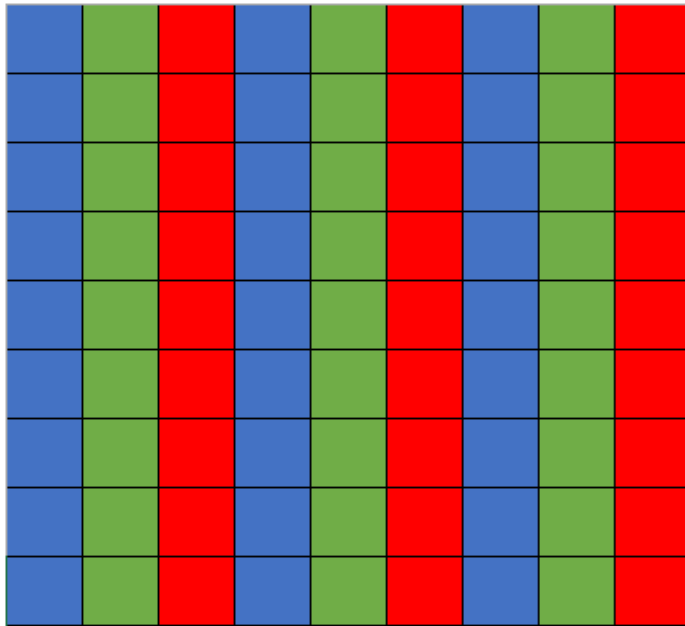
# Color space: HSL and HSV

- Cylindrical-coordinate color model
- Channels: hue, saturation and lightness (HSL) or value (HSV)
- Hue changes from  $0^\circ$  to  $360^\circ$
- Red –  $0^\circ$ , yellow –  $60^\circ$ , green –  $120^\circ$ , cyan –  $180^\circ$ , blue –  $220^\circ$ , magenta –  $300^\circ$

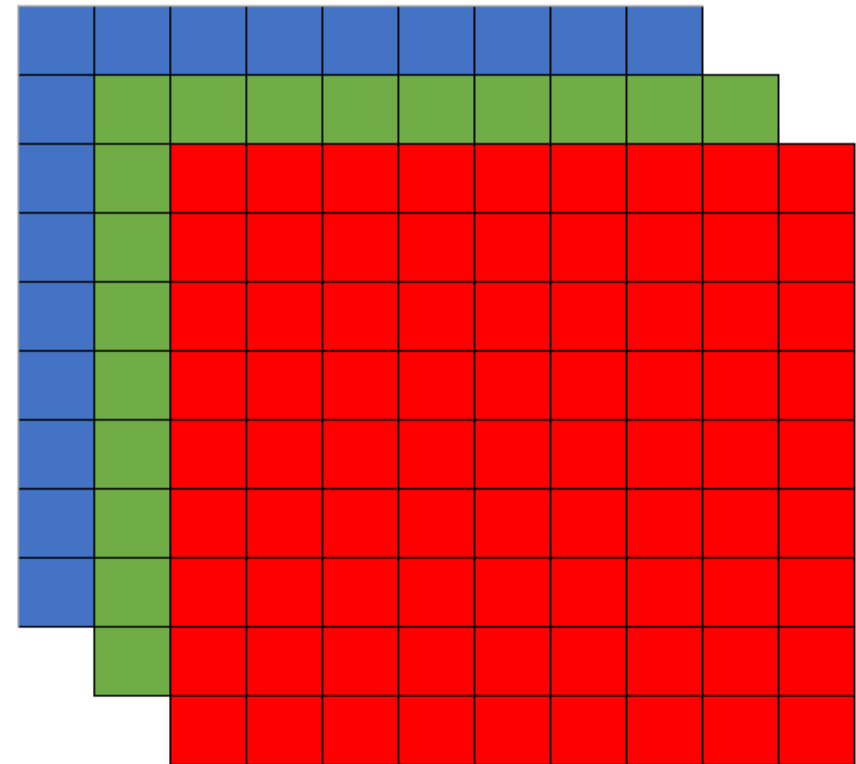


# Color space: Channel order

Packed storage



Planar storage



# Image processing

- Low-level
  - Operations over pixels
- Mid-level
  - Operations over image or several images
- High-level
  - Operations over image content



# Low level: Resize



# Low level: Resize



No interpolation



Bilinear interpolation

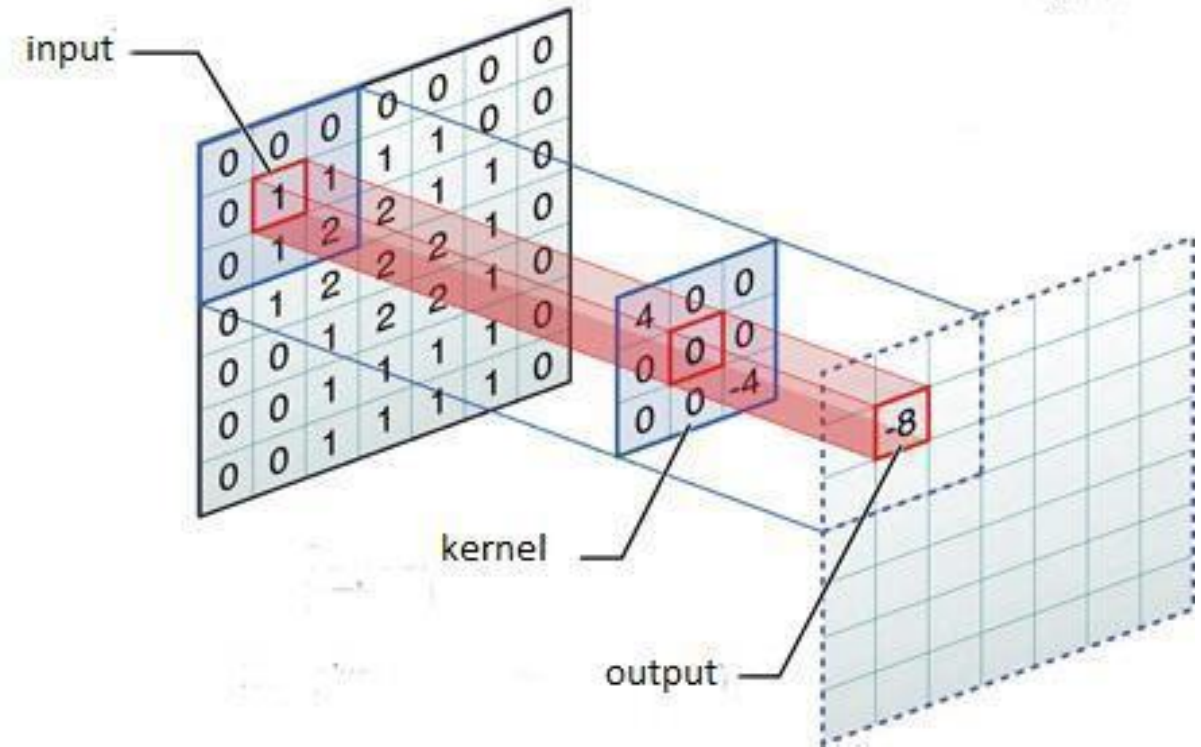


Bicubic interpolation

# Low level: Convolution

$$(f \otimes g)(t) = \int_{-\infty}^{+\infty} f(\tau)g(t - \tau)d\tau$$

$$(f \otimes g)[n] = \sum_{m=-\infty}^{+\infty} f[m]g[n - m]$$





# Low level: Convolution – blur



$$\frac{1}{9} \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$



$$\frac{1}{25} \begin{pmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

# Low level: Convolution – contrast



$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$



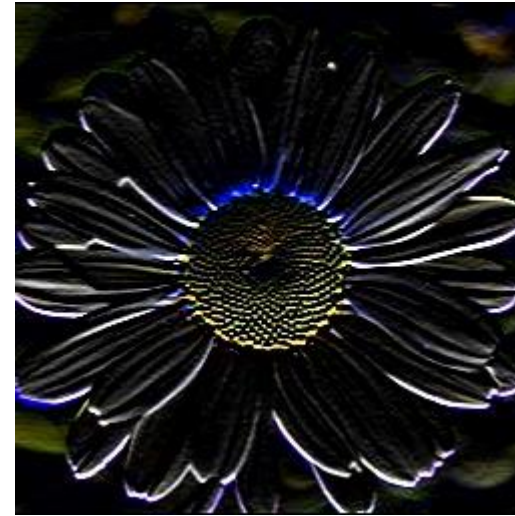
$$\begin{pmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{pmatrix}$$



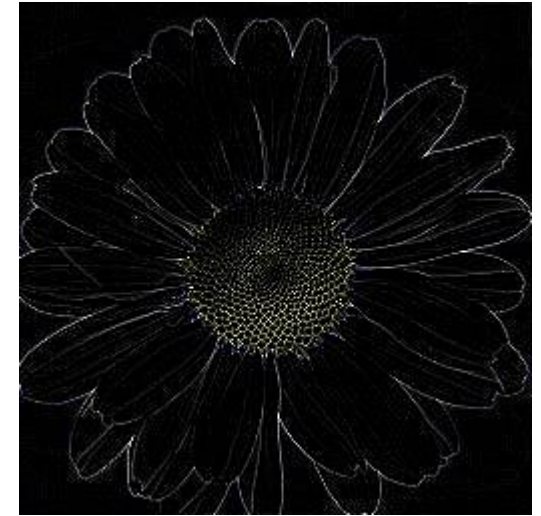
# Low level: Convolution – edges



$$\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$$



$$\begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}$$



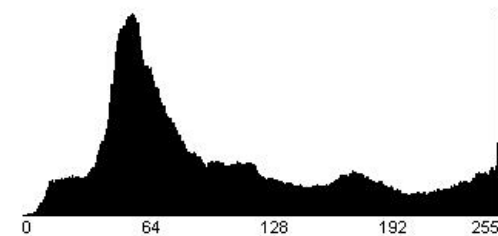
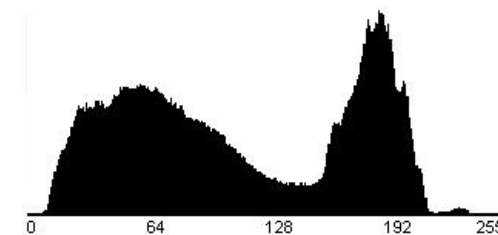
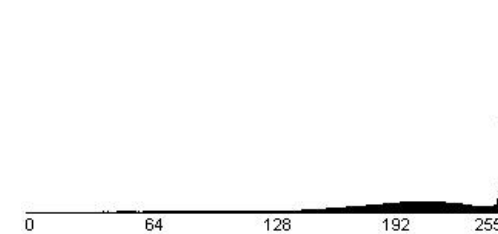
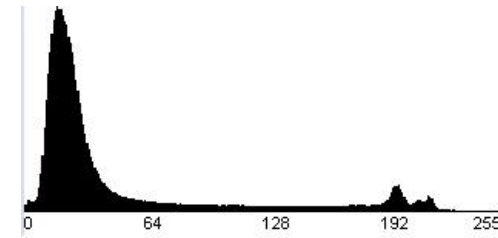
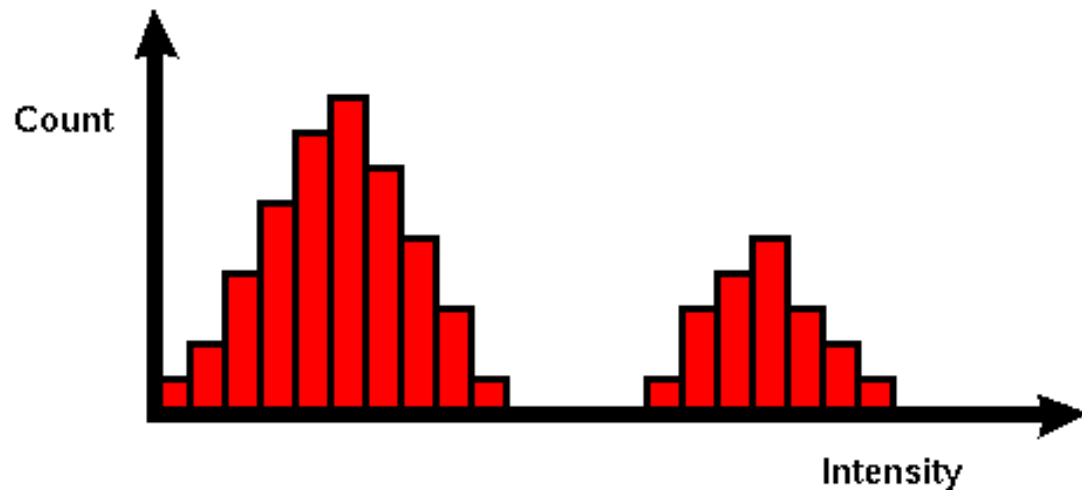
$$\begin{pmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

# Low level: Color segmentation



# Mid level: Histogram

$$Hist[i] = \sum_{x,y} \begin{cases} 1, & Pixel(x,y) = i \\ 0, & Pixel(x,y) \neq i \end{cases}$$

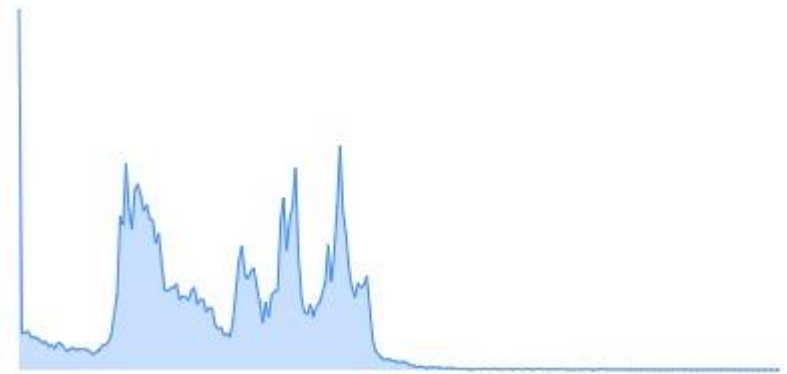
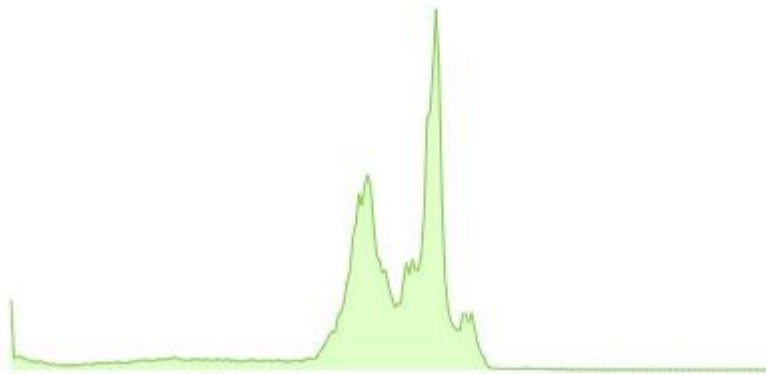
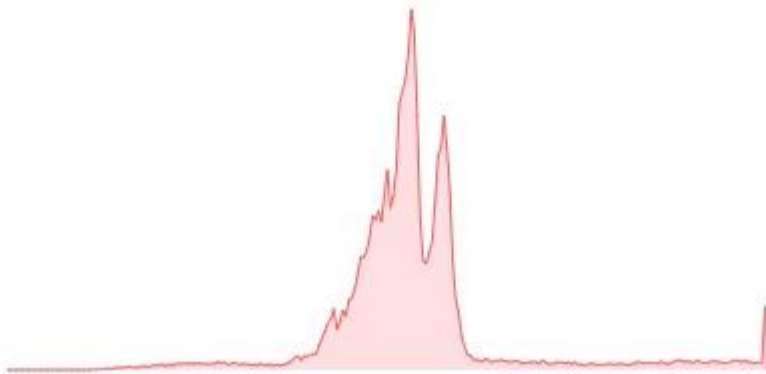
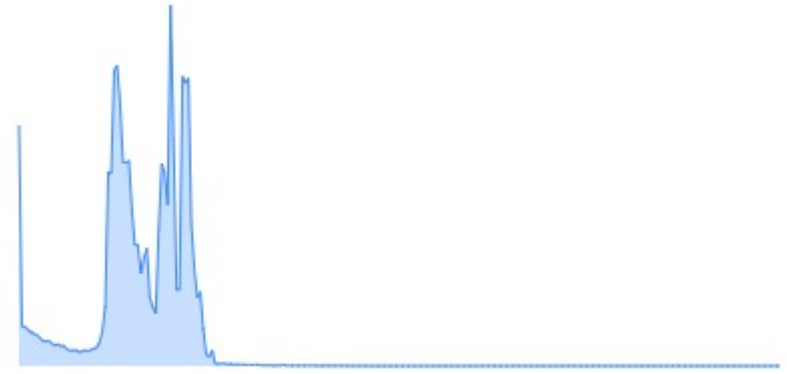
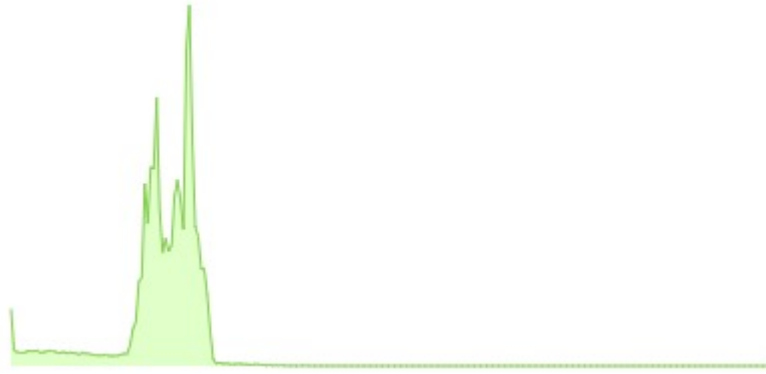
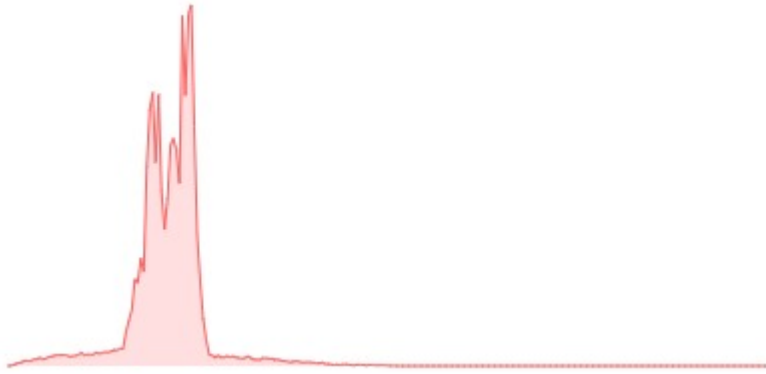




# Mid level: Histogram equalization



# Mid level: Histogram equalization



# Mid level: Panorama

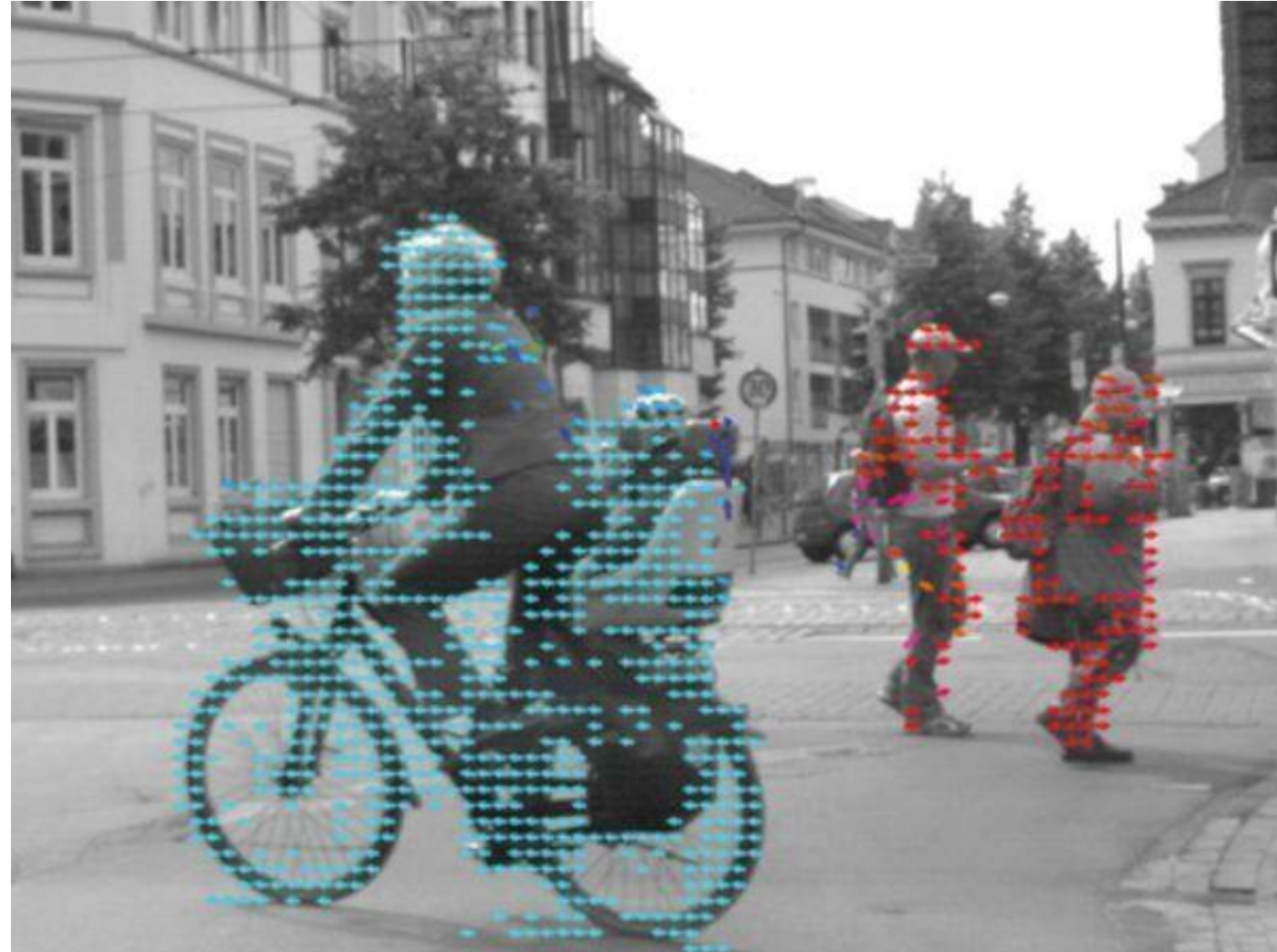
- Several images
- Stitching by keypoints





# Mid level: Optical flow

- Temporal image sequence
- Tracking pixels changes

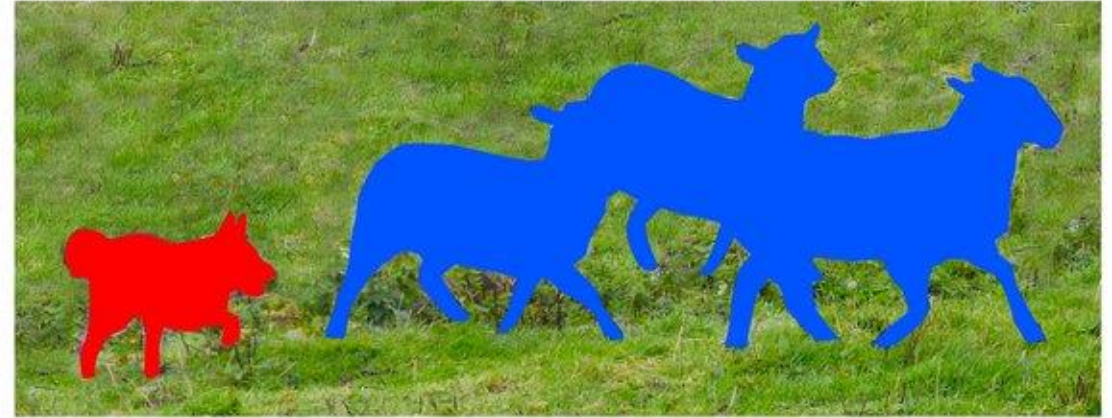




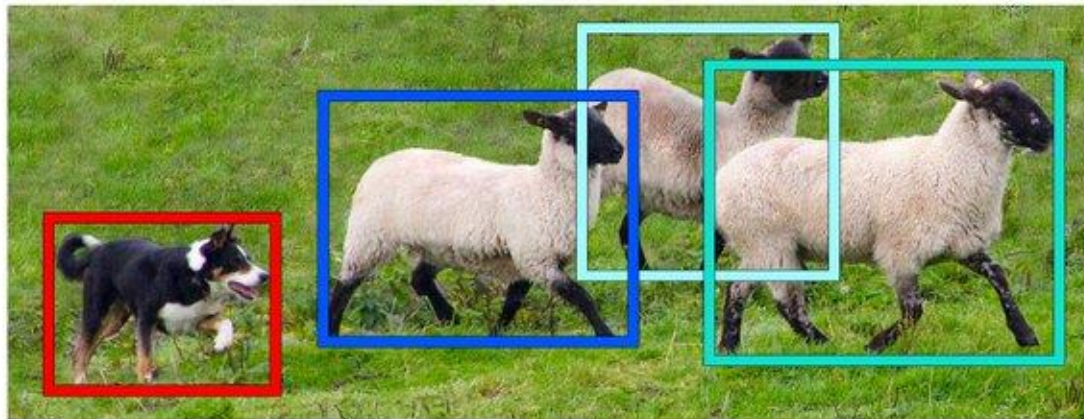
# High level



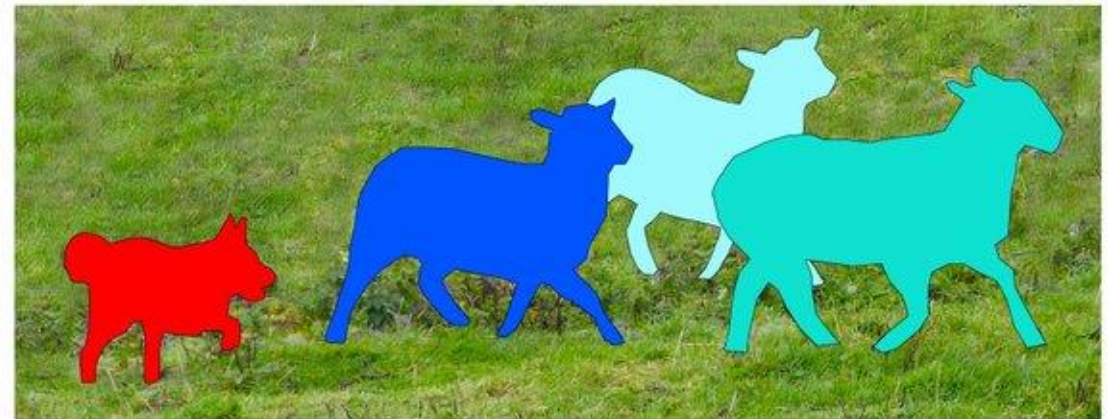
**Image Recognition**



**Semantic Segmentation**



**Object Detection**



**Instance Segmentation**

# High level

- Classification
- Detection
- Segmentation
- Super-resolution
- Image generation
- etc.

