CAP 4453
Robot Vision

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Administrative details

- Assignment Zero:
  - Due tomorrow
- Assignment 1:
  - Deadline: Next Friday

Questions?

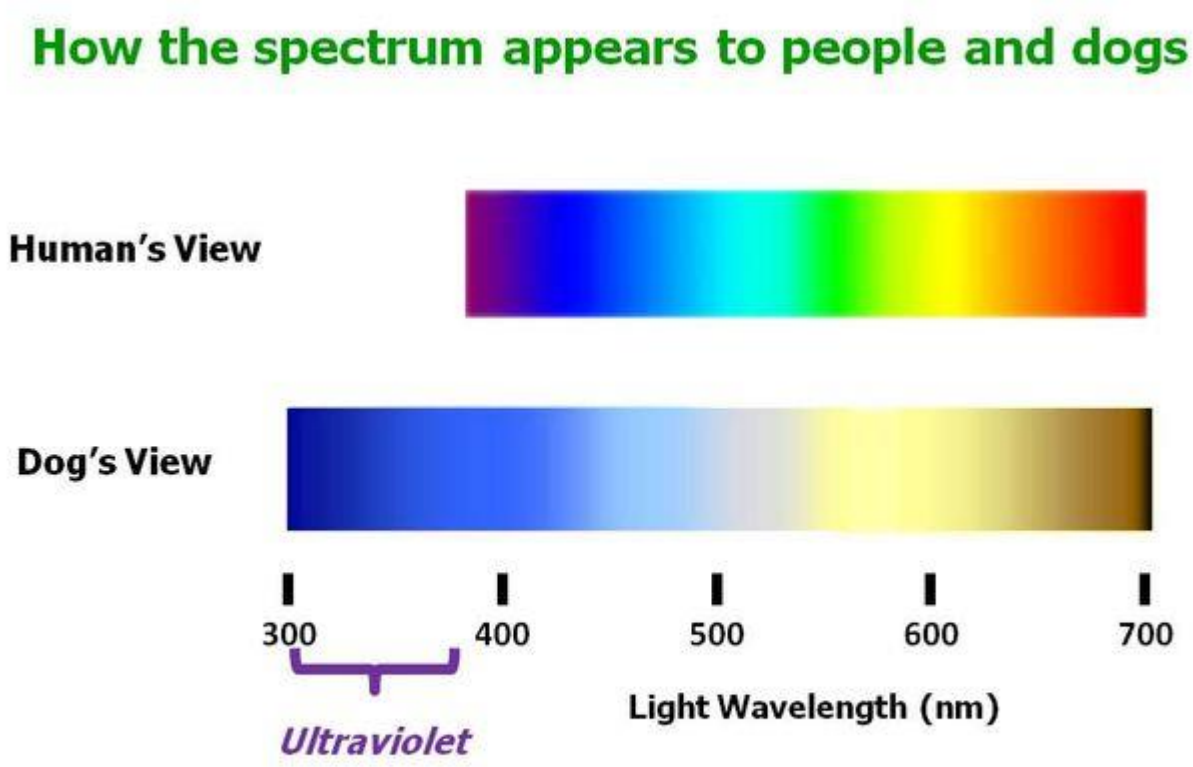
Credits

- Some of this slides comes from:
  - Yogesh S Rawat (UCF)
  - Noah Snavely (Cornell)
  - Ioannis (Yannis) Gkioulekas (CMU)
  - Mubarak Shah (UCF)
  - S. Seitz
  - James Tompkin
  - Ulas Bagci
  - L. Lazebnik

Robot Vision

2. Basics of Images

From last class



[Can Dogs See in Ultraviolet? | Psychology Today]

From last class

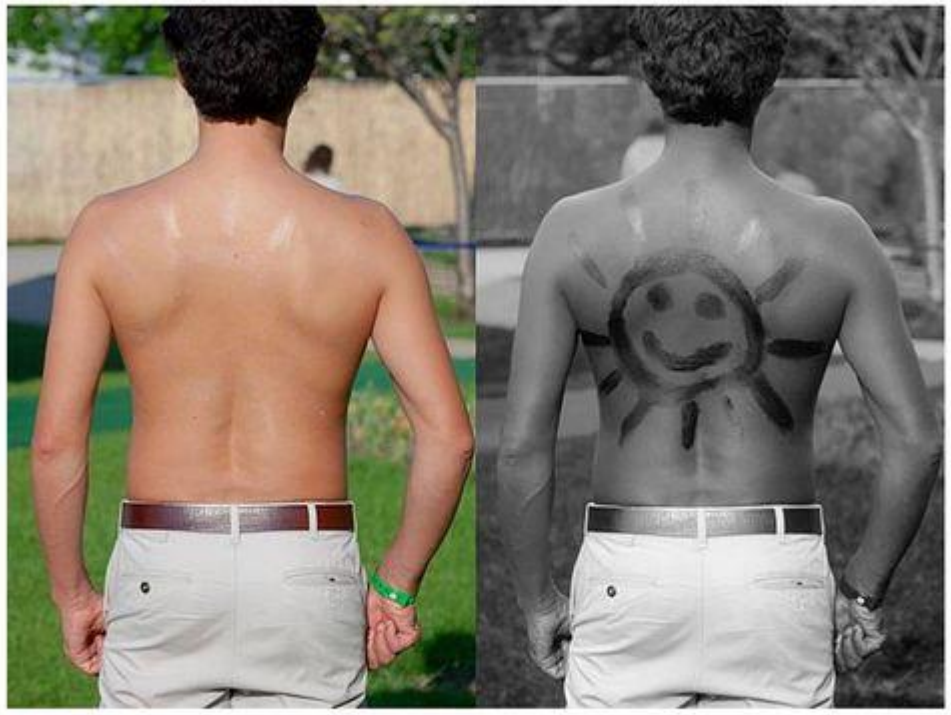
Human View
(No UV Sensitivity)

Dog View
(Some UV Sensitivity)

[Can Dogs See in Ultraviolet? | Psychology Today]

[Dog Vision: What Colors Can Dogs See And Can They See In The Dark? (improveeyesighthq.com)]

From last class



Sensitivity to UV makes targets that block or reflect these short wavelengths visible (like a drawing in sun screen lotion)

[Can Dogs See in Ultraviolet? | Psychology Today]

From last class

The ability to see ultraviolet (UV) helps guide bees to the pollen containing parts of flowers

Human View
(No UV Sensitivity)

Bee View
(UV Sensitivity)

https://www.psychologytoday.com/us/blog/canine-corner/201604/can-dogs-see-in-ultraviolet

Outline

- Image as a function
- Extracting useful information from Images
  - **Histogram**
- Color spaces
  - RGB
  - HUE
  - CIE
- Homework 1

Digitization

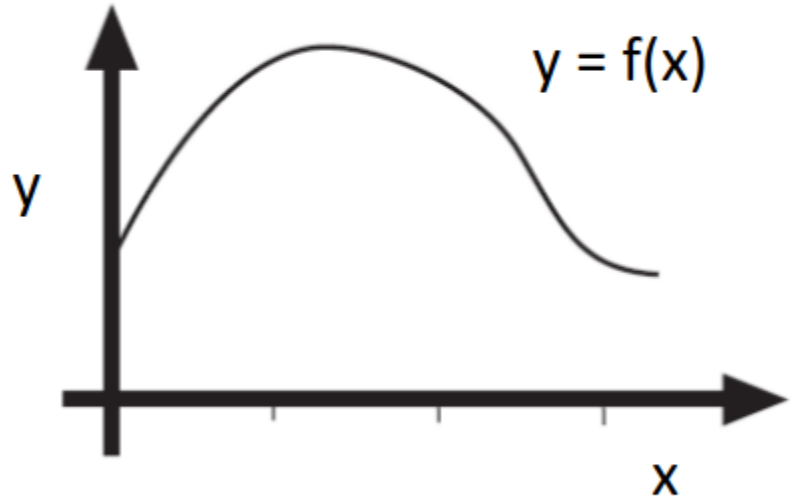
- Computers use discrete form of the images
- The process transforming *continuous space* into *discrete space* is called digitization

Digitization

- Function

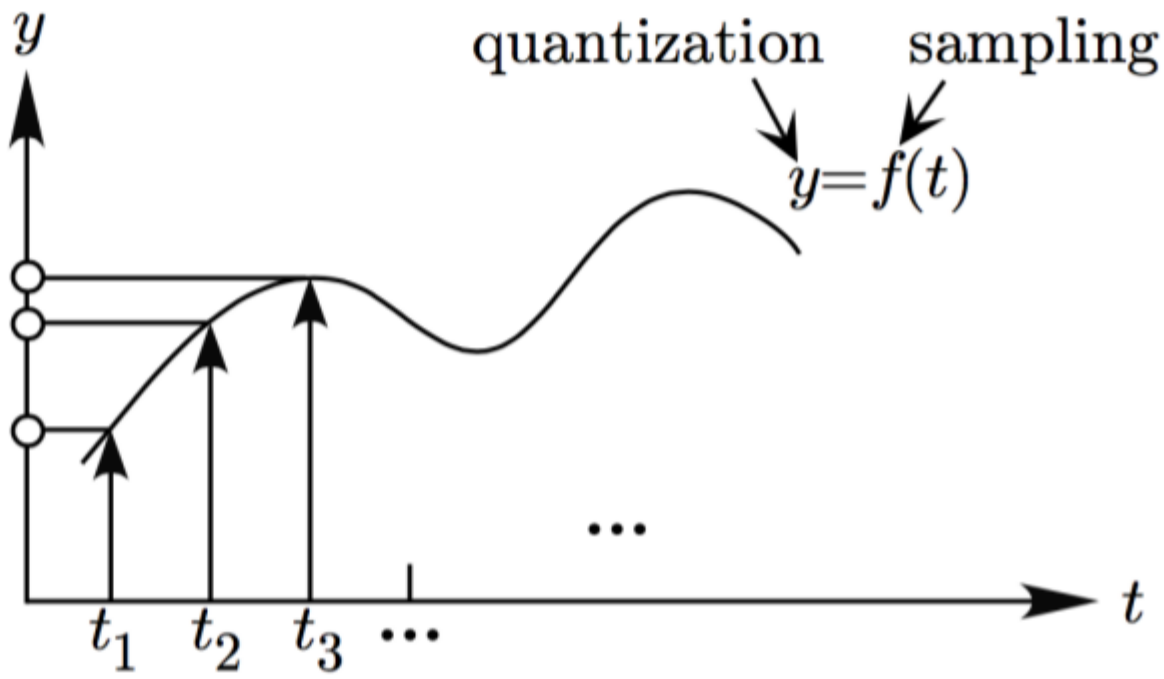
  $$y = f(x)$$

- Domain of a function
- Range of a function
- Sampling
  - Discretization of domain
- Quantization
  - Discretization of range



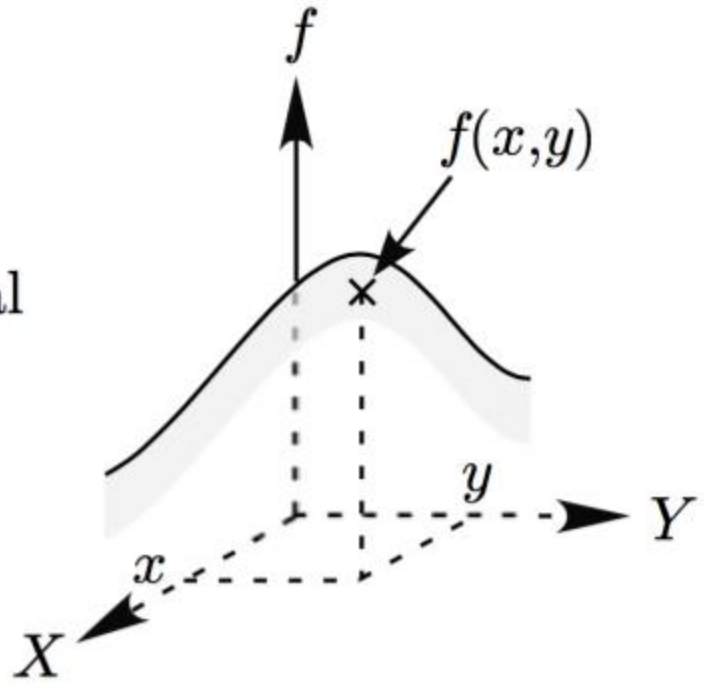
Digitization of 1D function

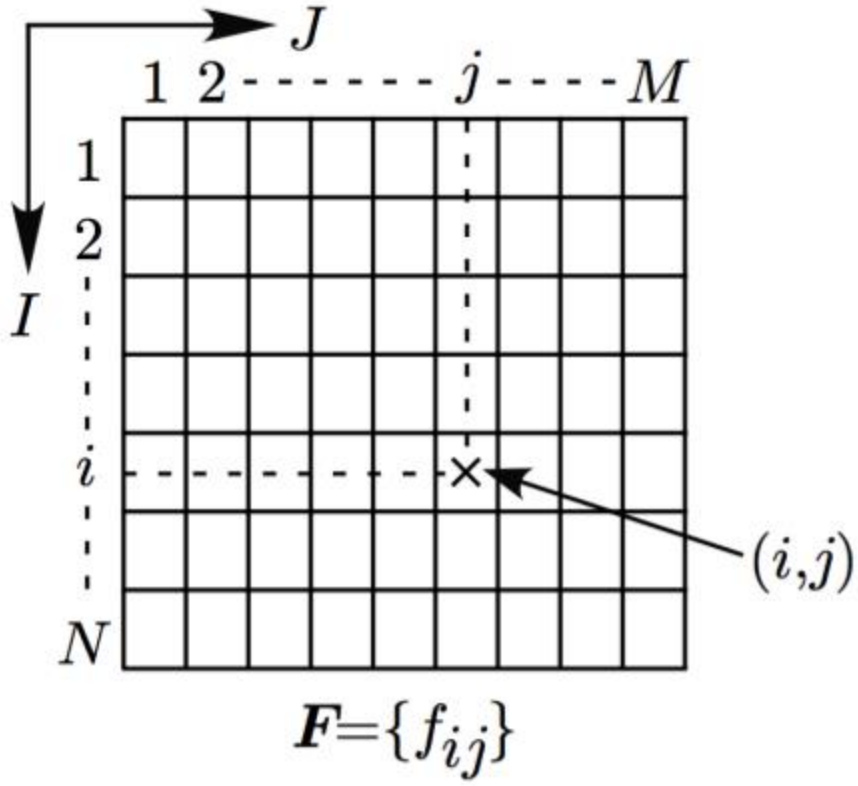
one-dimensional



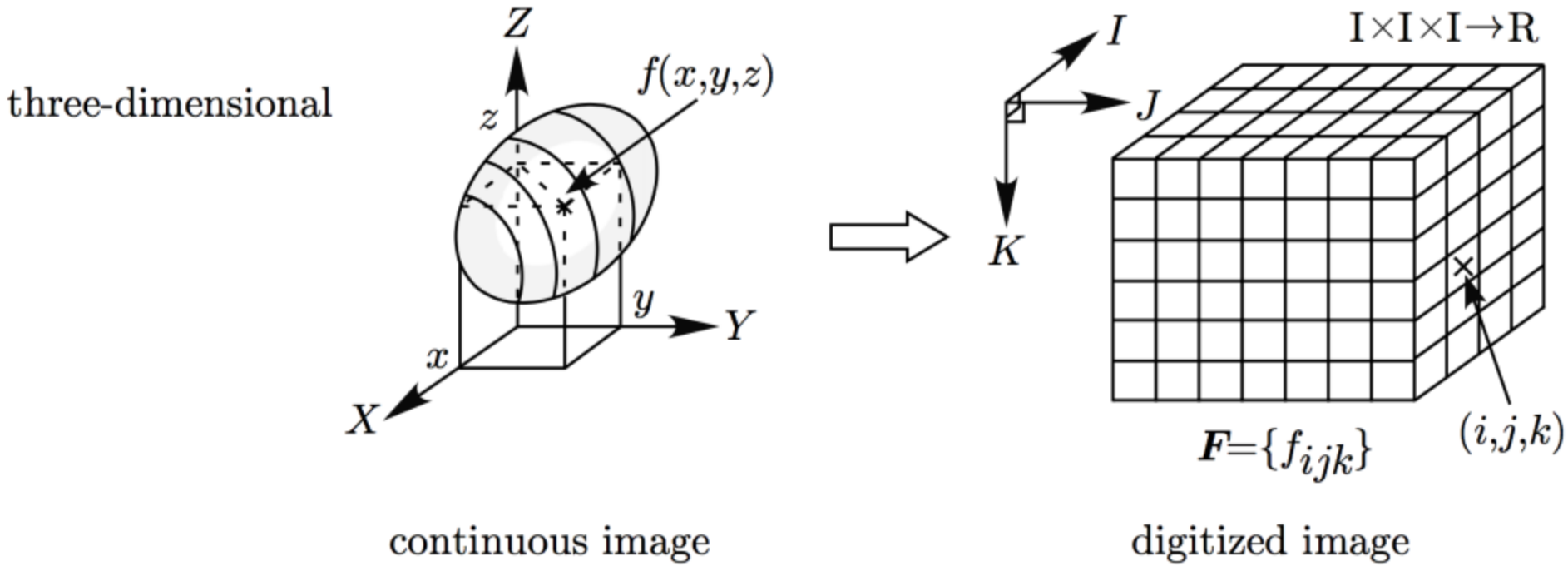
Digitization of 2D function

two-dimensional

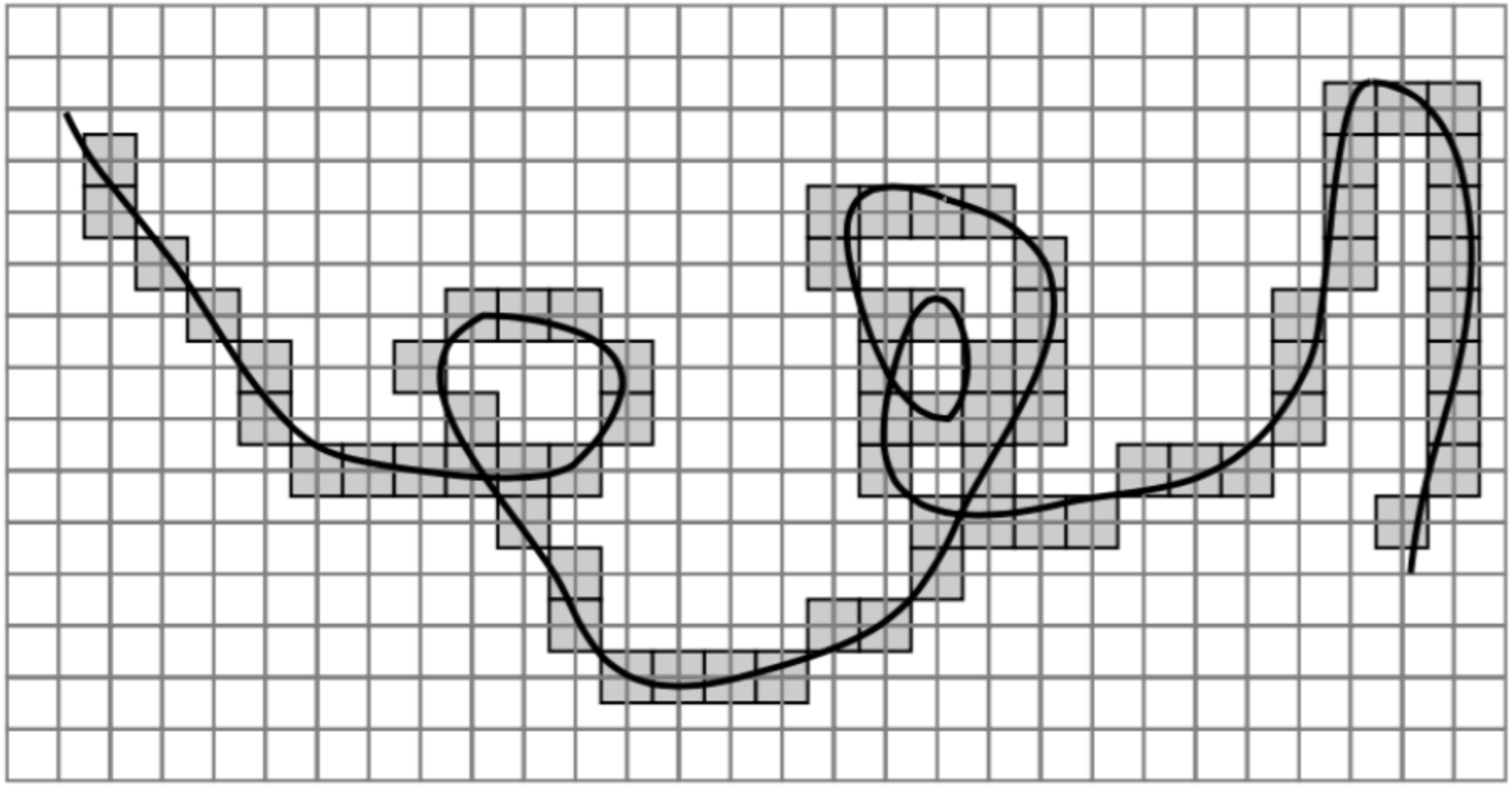




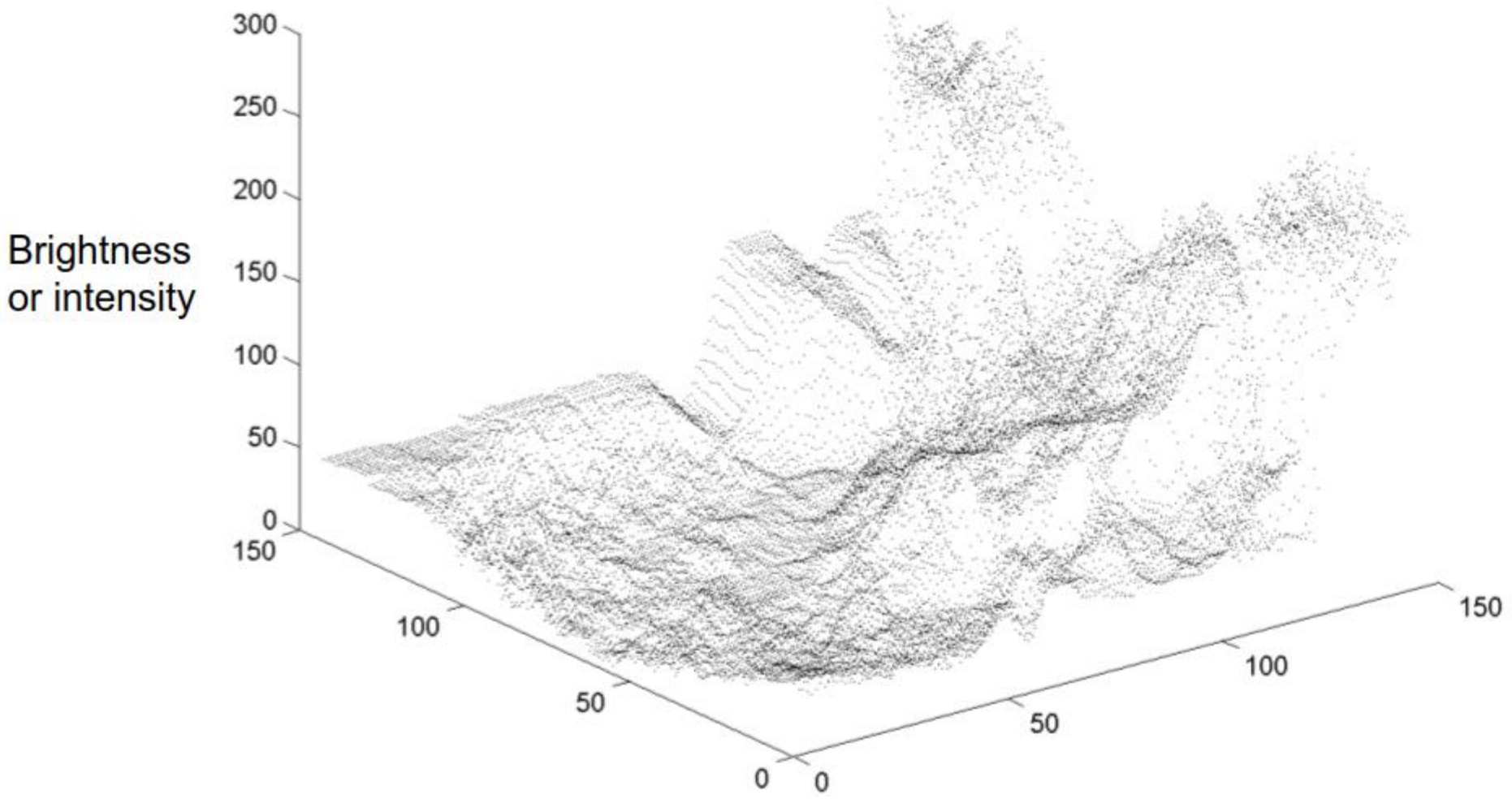
Digitization of 3D function



Digitization of an arc

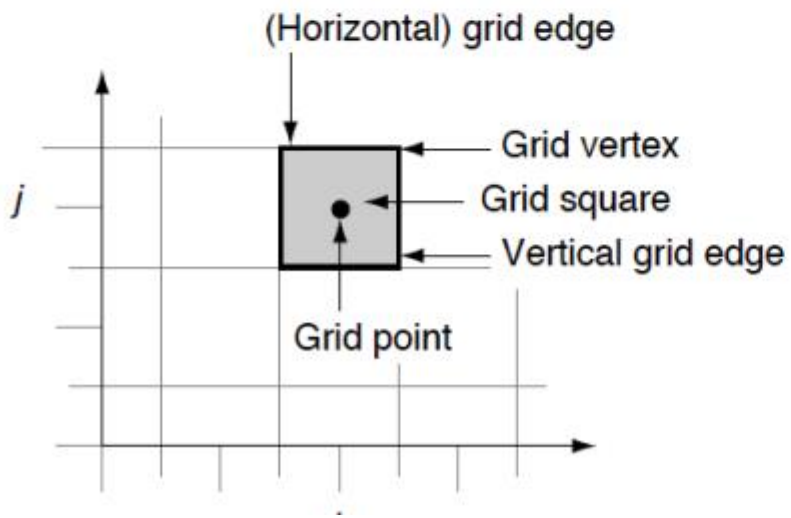


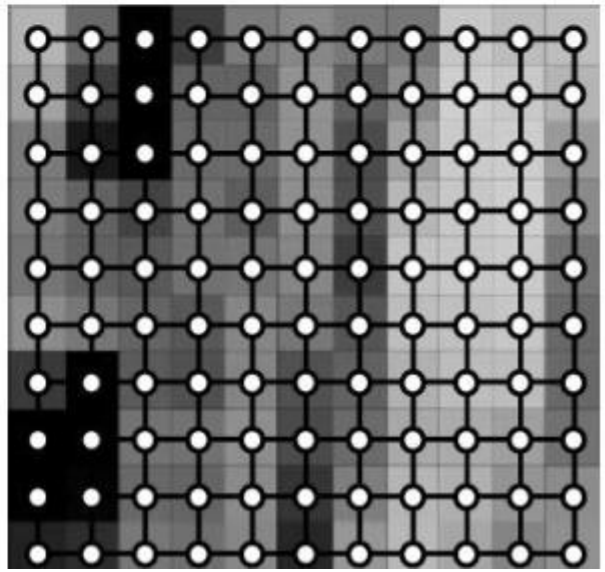
Gray scale digital image



Definition

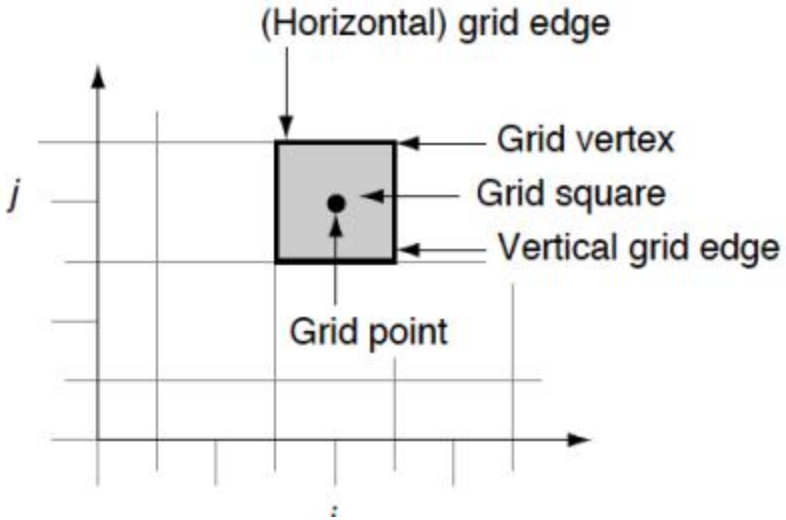
- An image *P* is a function defined on a (finite) rectangular subset *G* of a regular planar orthogonal array.
- *G* is called (2D) grid, and an element of *G* is called a pixel.
- *P* assigns a value of *P(p)* to each $p \in G$

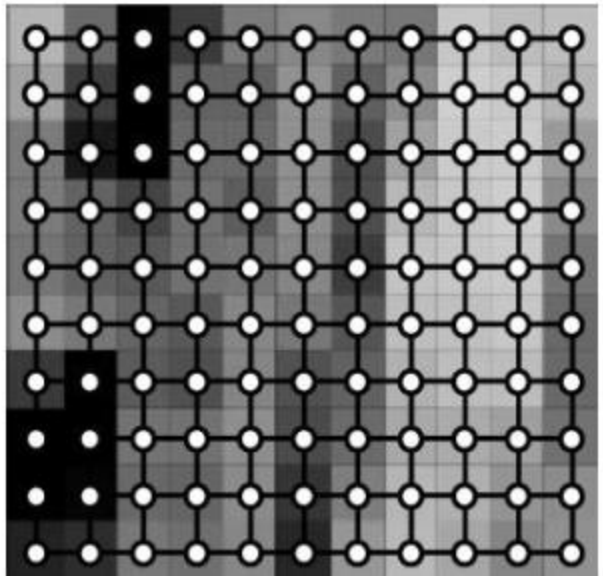




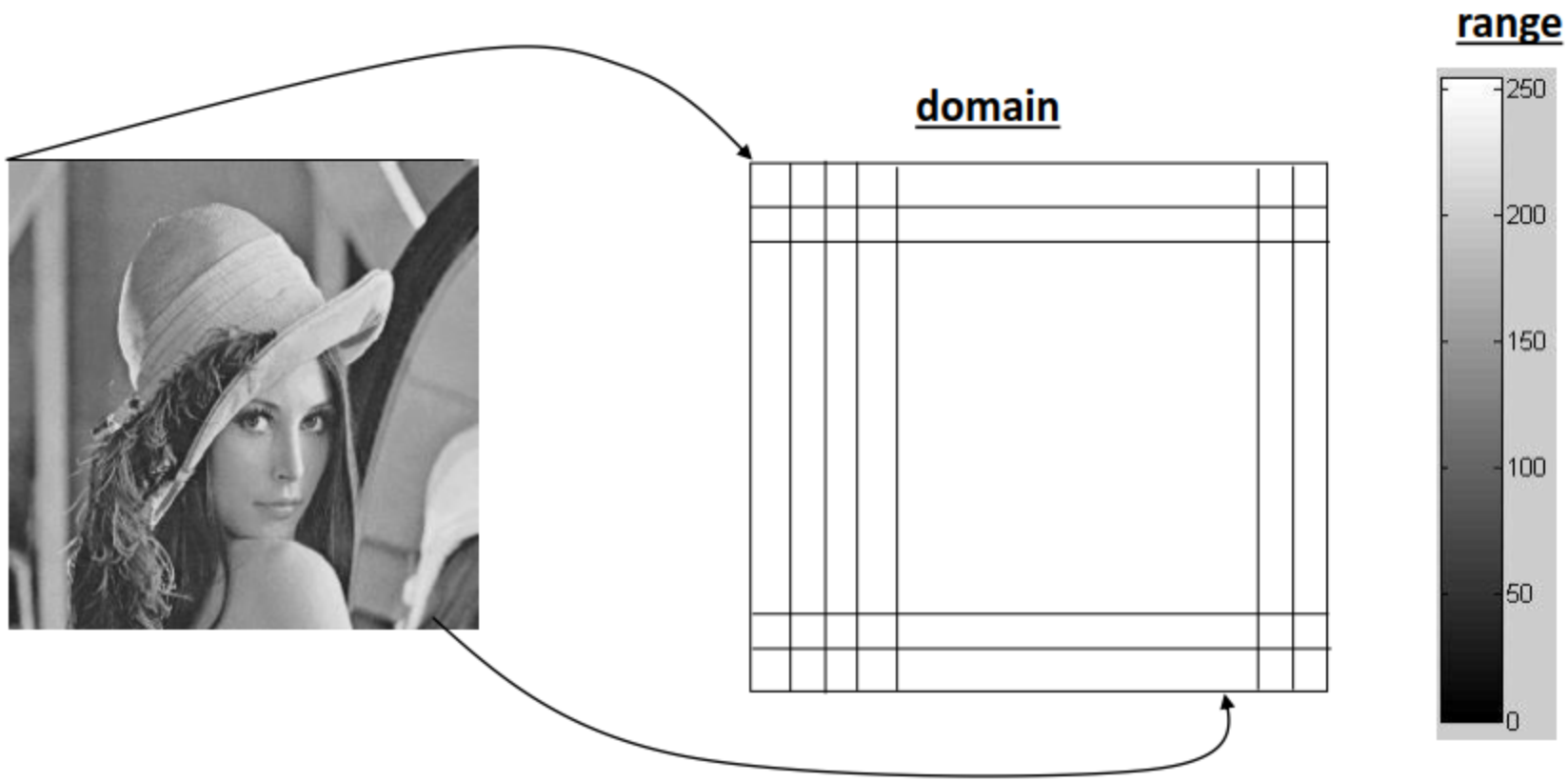
Definition

- Pictures are not only sampled
- They are also quantized
  - they may have only a finite number of possible values
  - i.e., 0 to 255, 0-1, …





Digitization



Sampling

Quantization

Original
(256 colors)

8 colors

4 colors

About the picture

[Lena Forsen - playmate, who became the "mother" of JPEGs (fotoblogia.pl)]

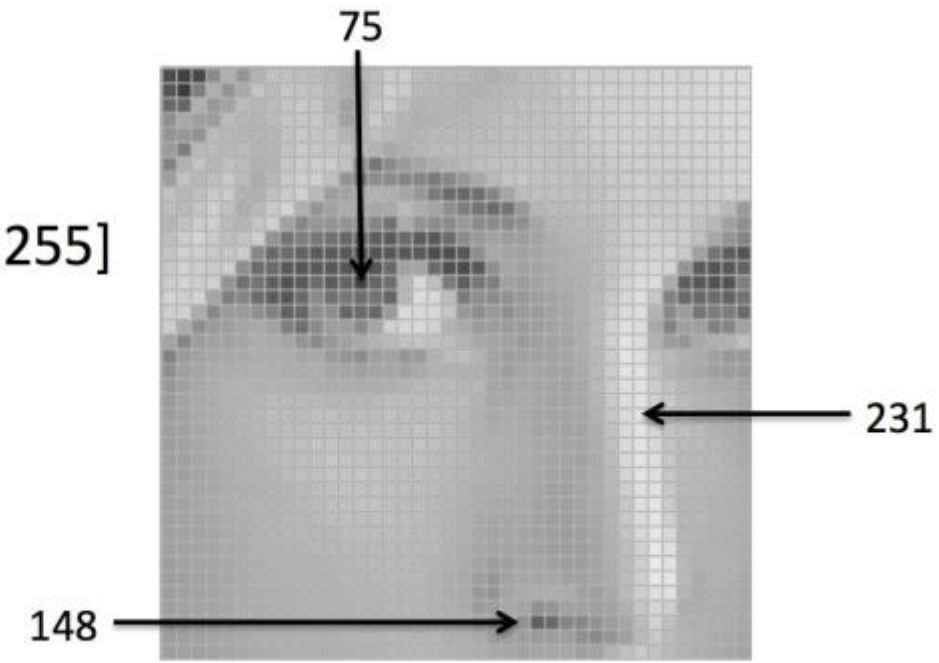
Resolution

- Also a display parameter
  - defined in dots per inch (DPI) or
  - measure of spatial pixel density
  - standard value for recent screen technologies is 72 dpi.
  - Recent printer resolutions are in 300 dpi and/or 600 dpi.

Gray scale image

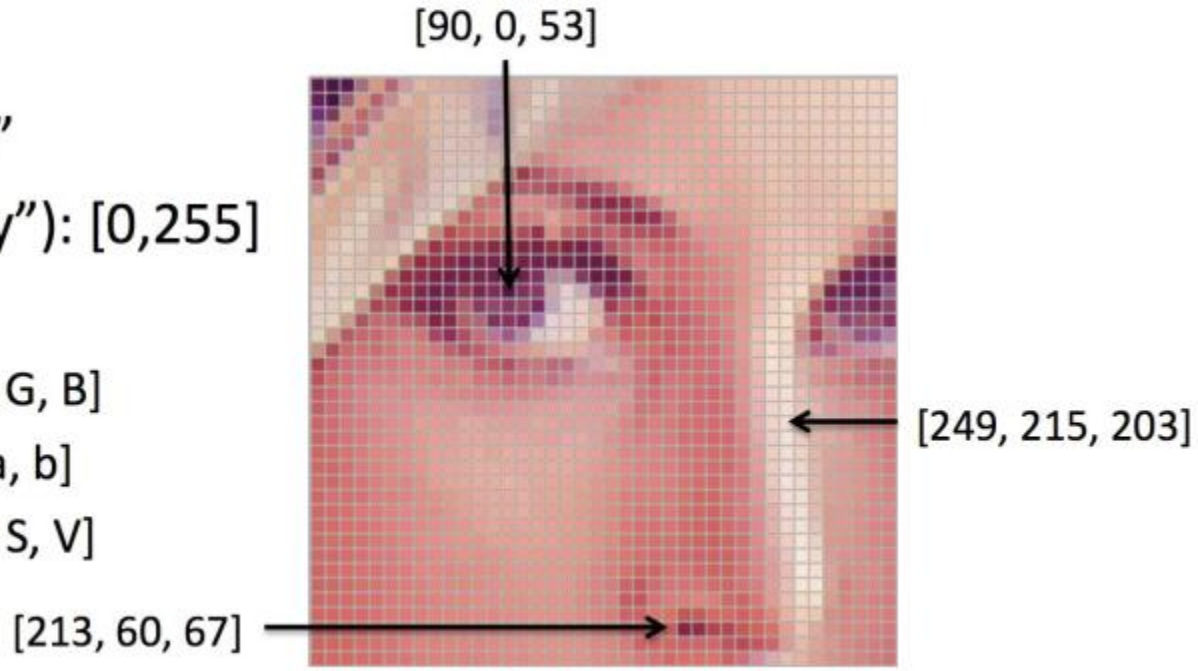
- An image contains discrete number of pixels
  - A simple example
  - Pixel value:
    - "grayscale"

    (or "intensity"): [0,255]



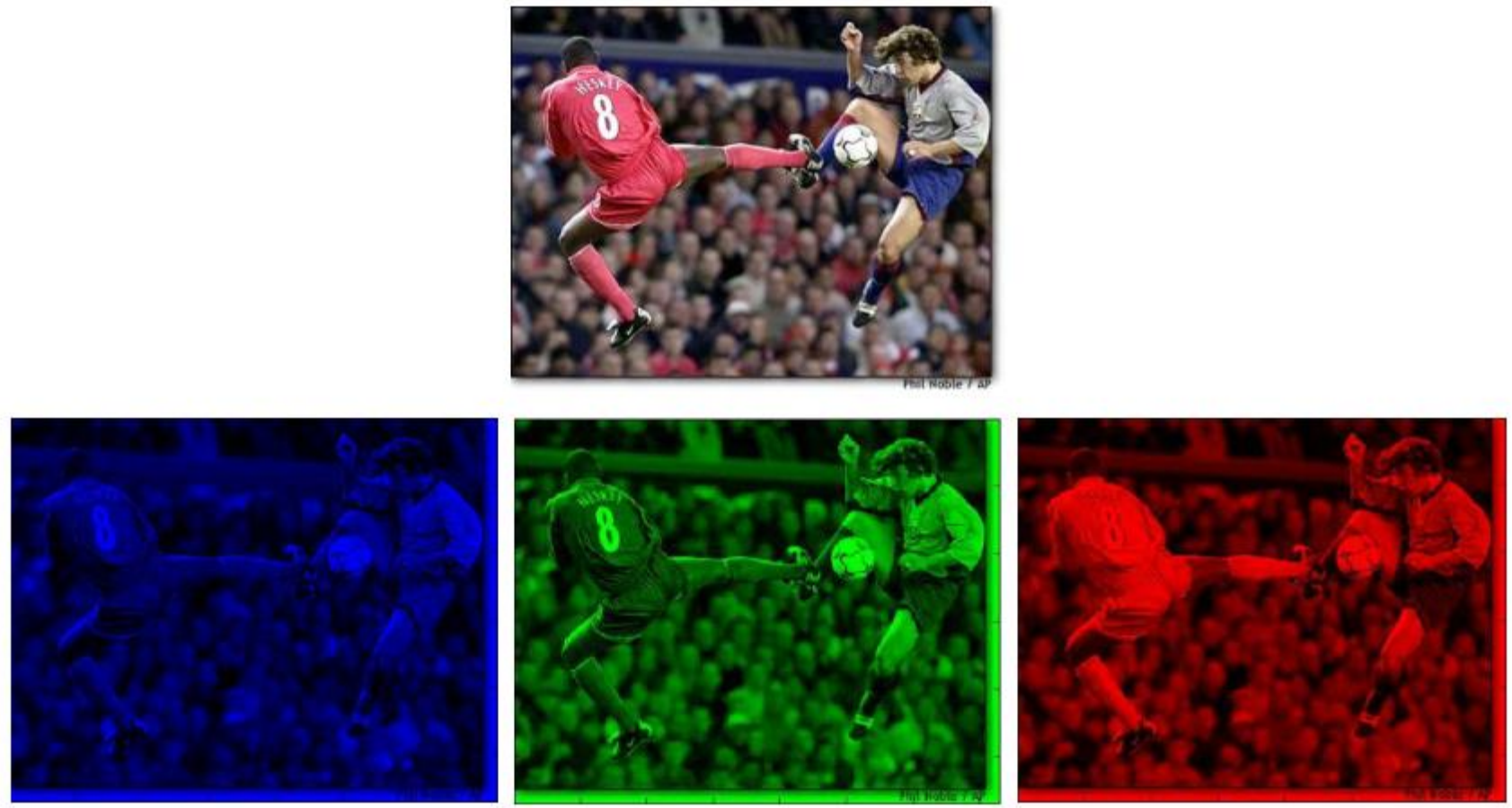
Color image

- An image contains discrete number of pixels
  - A simple example
  - Pixel value:
    - "grayscale" (or "intensity"): [0,255]
    - "color"
      - RGB: [R, G, B]
      - Lab: [L, a, b]
      - HSV: [H, S, V]



Source: F.F. Li

RGB Channels



RGB Channels

640

480

How many pixels do you need to represent this image?

RGB Channels

640

480

How many bytes do you need to represent this image?

RGB Color Space

Compression technique

$$R = \int_{300}^{830} S(\lambda)\, R(\lambda)\, d\lambda$$

$$G = \int_{300}^{830} S(\lambda)\, G(\lambda)\, d\lambda$$

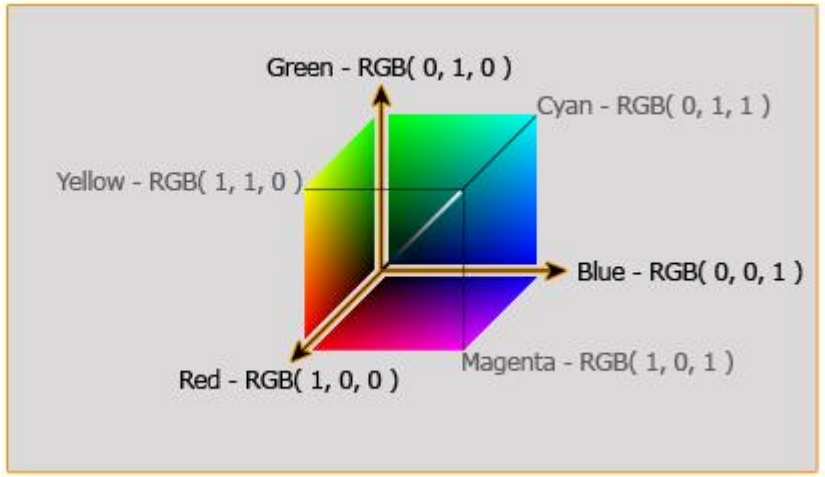
$$B = \int_{300}^{830} S(\lambda)\, B(\lambda)\, d\lambda$$

$S(\lambda)$ is the light spectrum,

$R(\lambda)$, $G(\lambda)$ and $B(\lambda)$ are the sensitivity functions

Color Cube

RGB Color Format



www.equasys.de

- These are colours with different spectra but with same perceptual values
- RGB colour space is the basic colour space
- Device-dependant colour space

RGB Color Space

Compression technique

$$R = \int_{300}^{830} S(\lambda)\, R(\lambda)\, d\lambda$$

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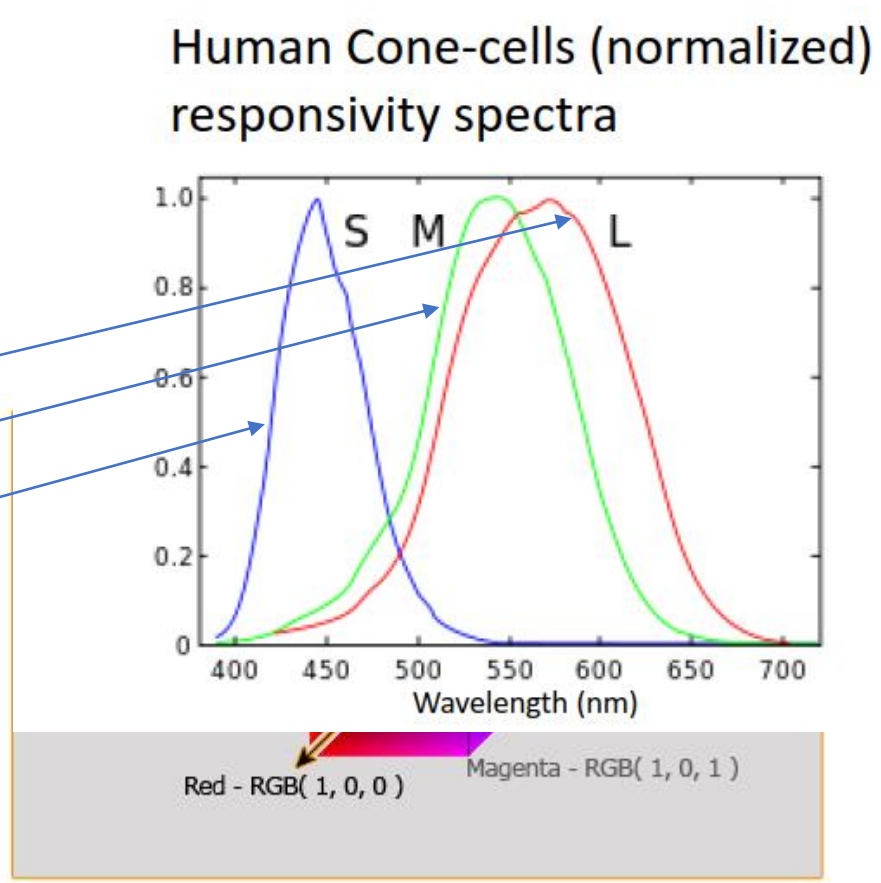

www.equasys.de

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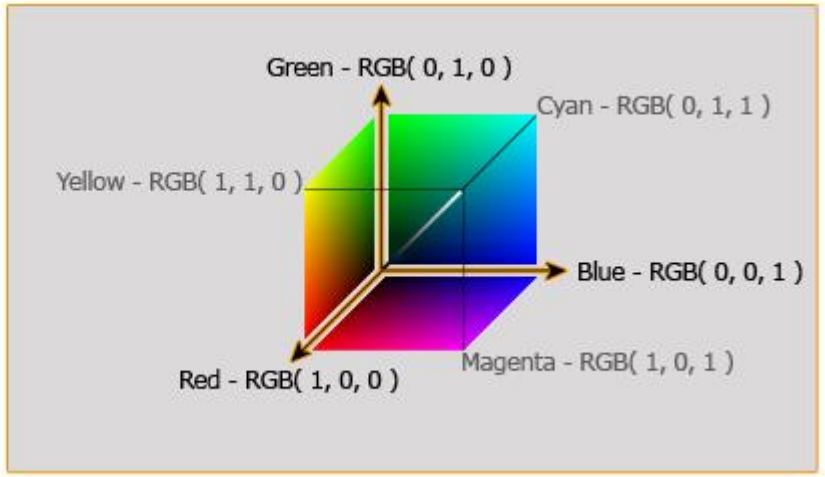


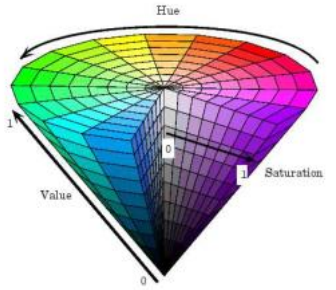
www.equasys.de

Disadvantages

- a high correlation between its components
  - about 0.78 for rBR (cross correlation between the Band R channel)
  - 0.98 for rRG
  - 0.94 for rGB
- It is psychologically non-intuitive
- Perceptual non-uniformity (add a value have different effect for every color)

Phenomenal color spaces

- Most natural way for humans of describing colors
- Described by 3 attributes
  - Hue: the colour is red, green, yellow, blue, purple ...
  - Saturation: the level of non-whiteness
  - Brightness is a measure of the intensity of light.
- HSL color space. Hue, Saturation, Luminance
  - linear transformations from the RGB space.
  - inherit all the short-comings of RGB space.
  - There is usually a hue discontinuity around 360 degrees.
  - This makes difficult to make arithmetic operations in such a color space.



$$I = \frac{R+G+B}{3}$$

$$S = 1 - \left(\frac{3}{R+G+B}\right) \min(R,G,B)$$

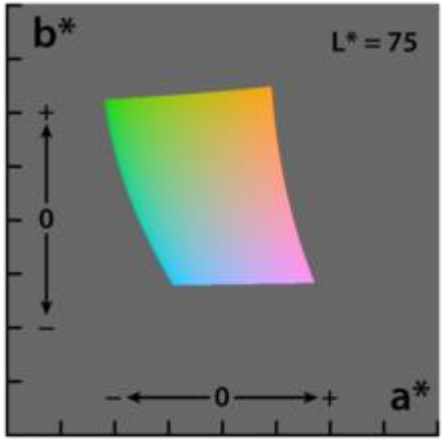
$$H = \cos^{-1}\left(\frac{0.5\,(R-G)+(R-B)}{\sqrt{(R-G)^2+(R-B)\,(G-B)}}\right)$$

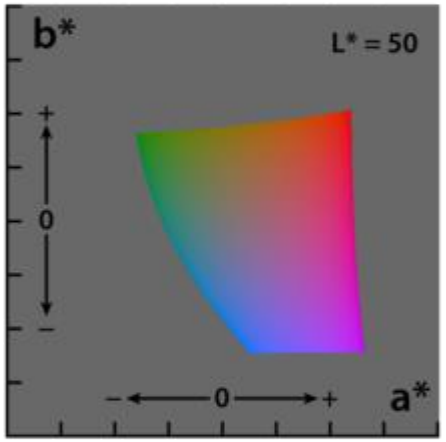
where I (intensity) is used instead of V (value).

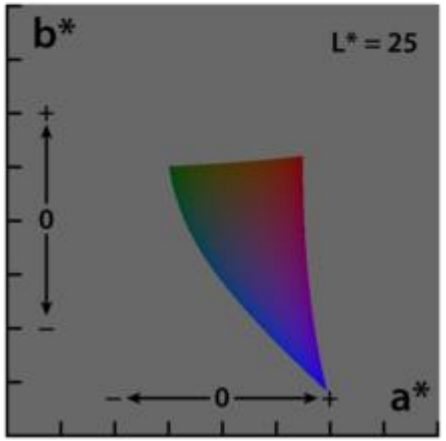
CIE Colour Spaces

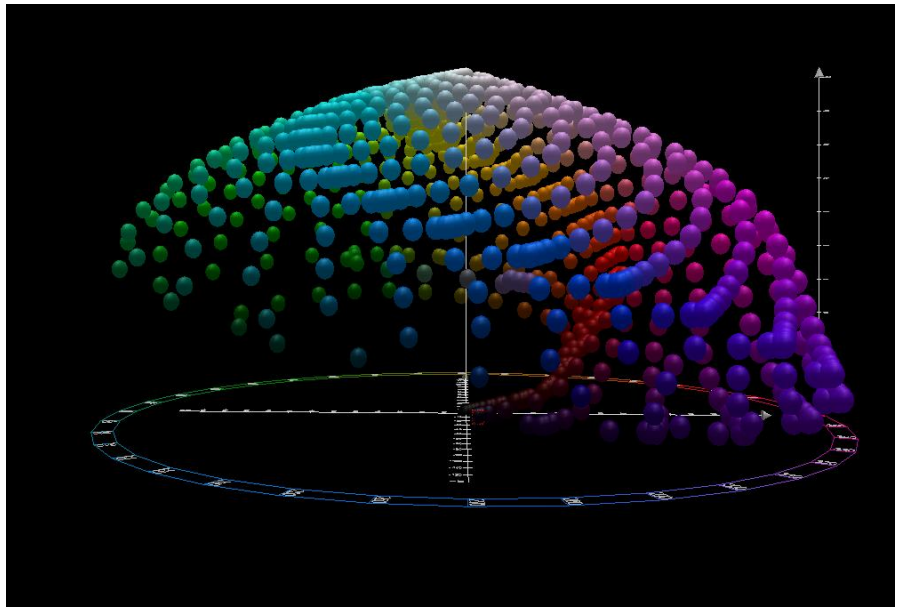
- CIE (Commission Internationale de l'Eclairage (illumination))
  - In 1931 laid down the CIE 1931 standard colorimetric observer.
  - CIE XYZ: CIE standardized the XYZ values as tristimulus values that can describe any color that can be perceived by an average human observer
    - XYZ are positives
    - It is device dependent
  - CIELuv and CIELab: proposed in 1976
  - Goal: provide a perceptually equal space
  - CIElab
    - *L** closely matches human perception of lightness (black at 0 and white at 100)
    - *a** : green–red opponent colors, with negative values toward green and positive values toward red. Unbounded, usually bounded from -128 to 127
    - *b** : blue–yellow opponents, with negative numbers toward blue and positive toward yellow. Unbounded

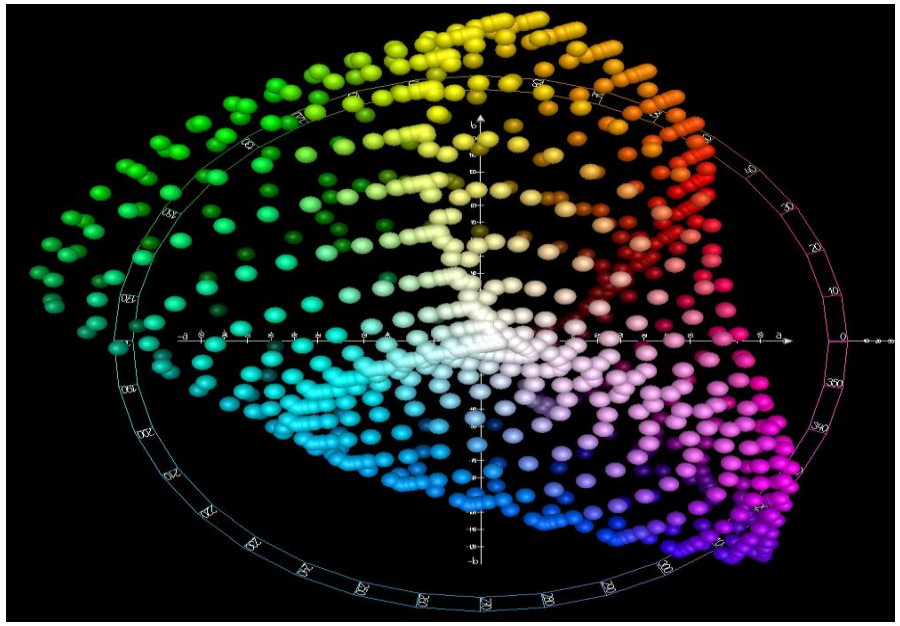
CIELab









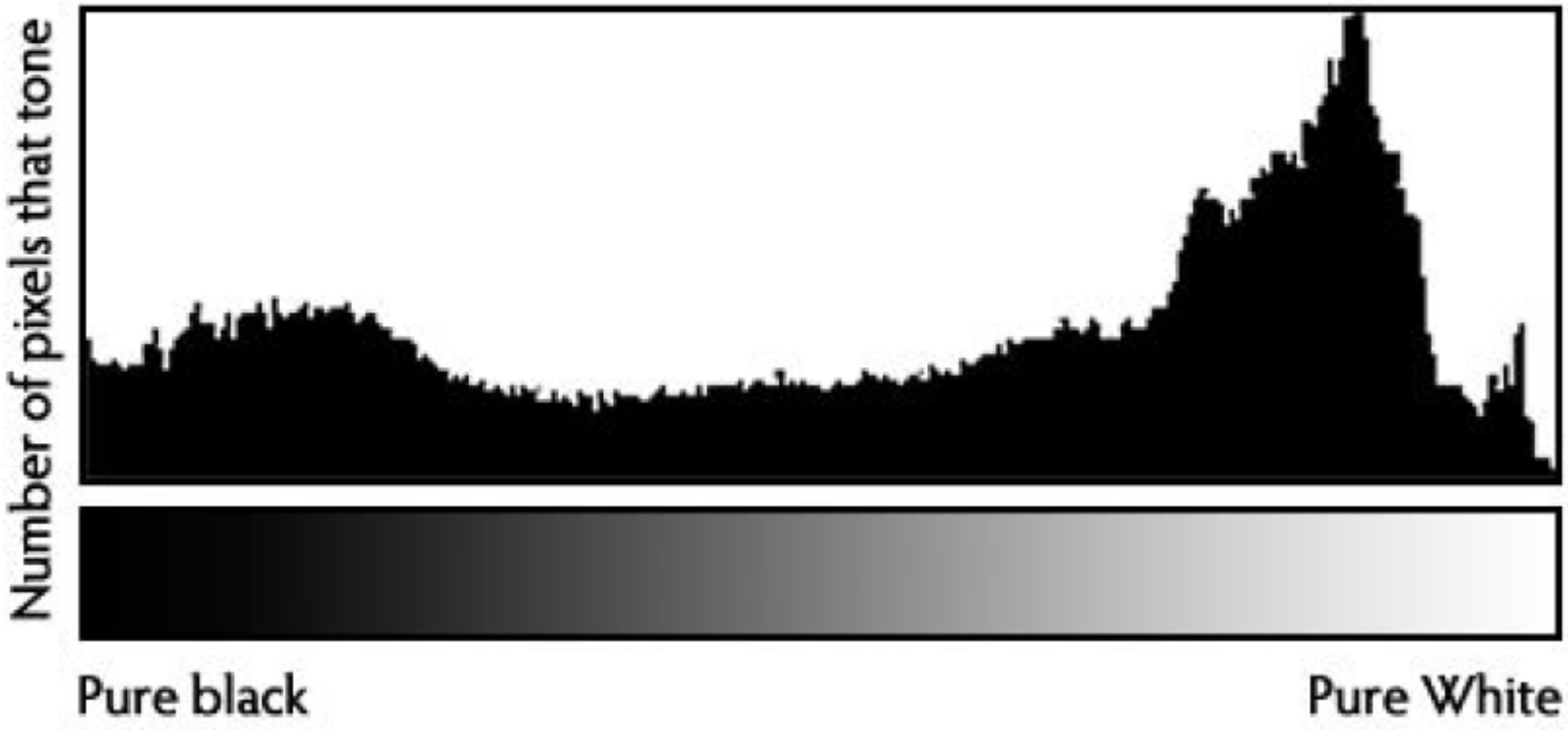


Cielab

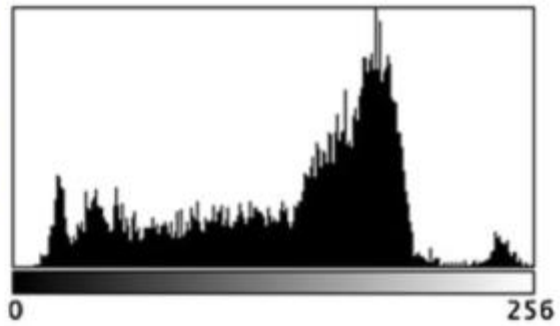
LAB color enhancement in Photoshop.

Normal Image

Image Histogram



Histogram Example



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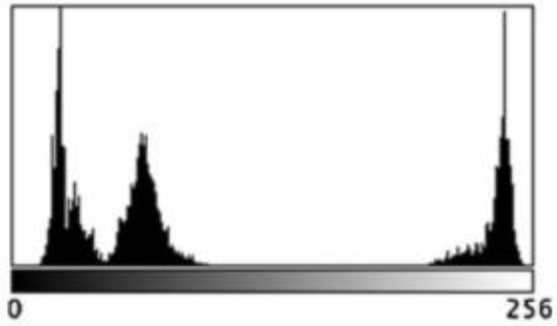
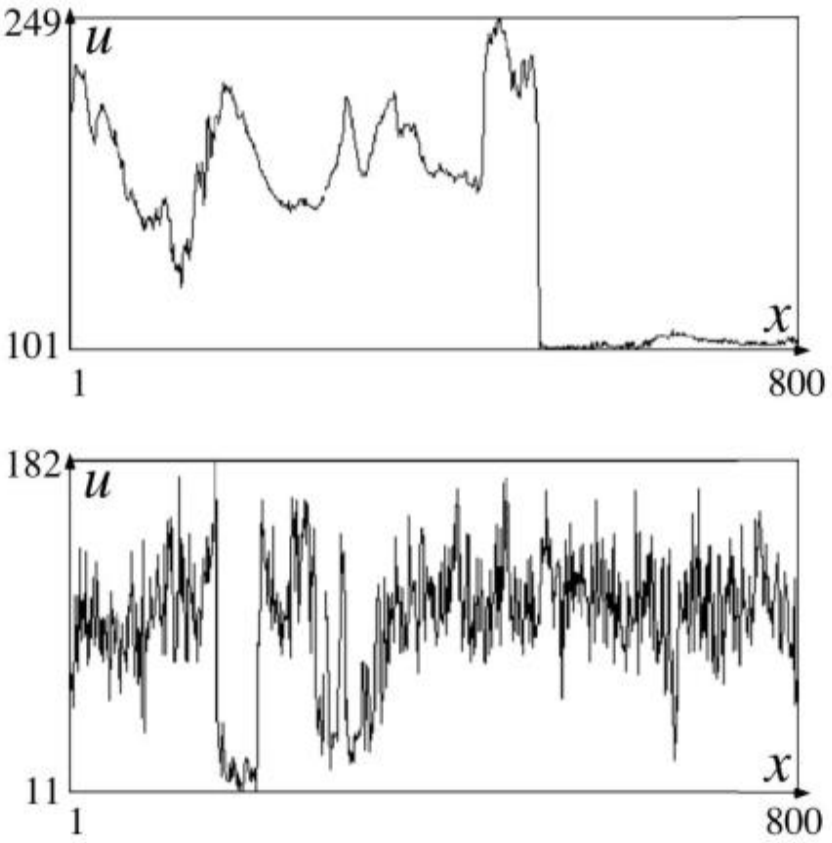
Mean: 133.711
StdDev: 55.391
Min: 9
Max: 255
Mode: 178 (180)



Count: 10192
Mean: 104.637
StdDev: 89.862
Min: 11
Max: 254
Mode: 23 (440)

Intensity profiles for selected (two) rows



Questions?

Coding homeworks

- Presented as a notebook using colab
  - https://colab.research.google.com/
- Homeworks are posted at webcouses as a link to:
  - gonzo1978/CAP4453: Colab notes for CAP 4453 (github.com)