Bela Borsodi


WÓDKA
VODKA
Cuisinart
SNOW CRYSTALS
MATHEMATICS
MAN AND SPACE
DRUGS
STACK-ON

WHAT IS AN IMAGE?

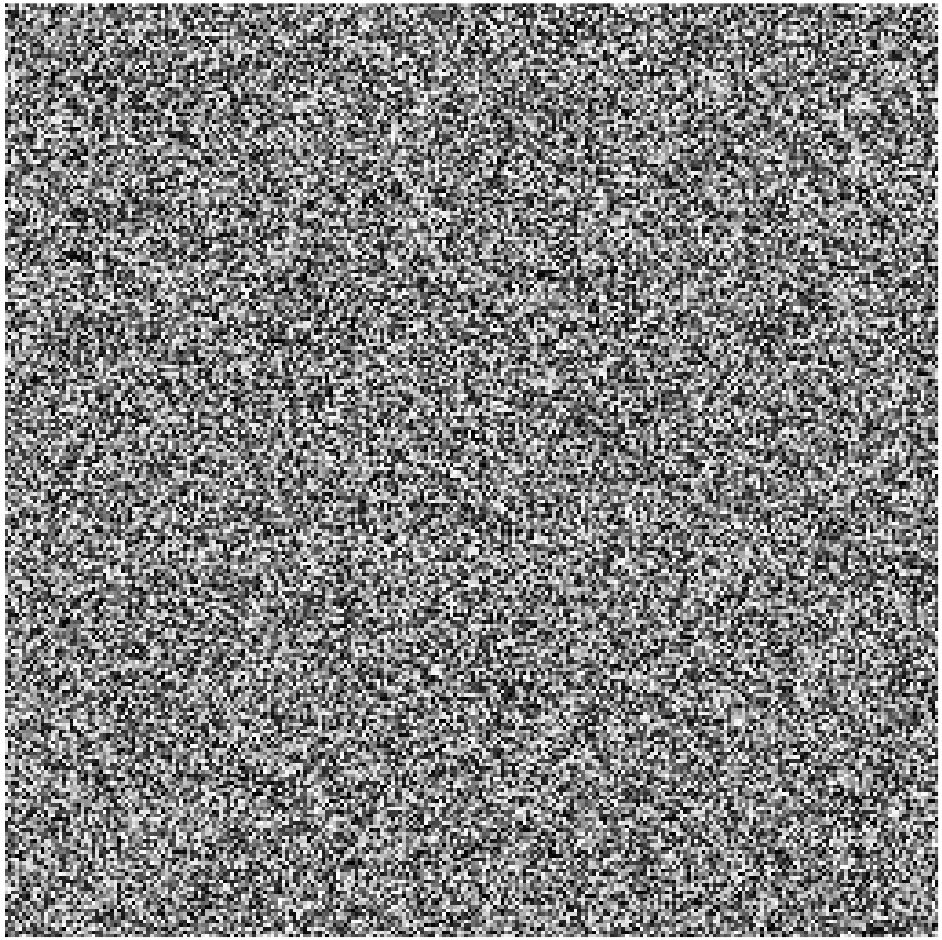
```
>> I = rand(256,256);
```

Think-Pair-Share:

- What is this? What does it look like?
- Which values does it take?
- How many values can it take?

- Is it an image?

```
>> I = rand(256,256);
>> imshow(I);
```



Dimensionality of an Image

- @ 8bit = 256 values ^ 65,536
  - Computer says ‘Inf’ combinations.

- Some depiction of all possible scenes would fit into this memory.

Dimensionality of an Image

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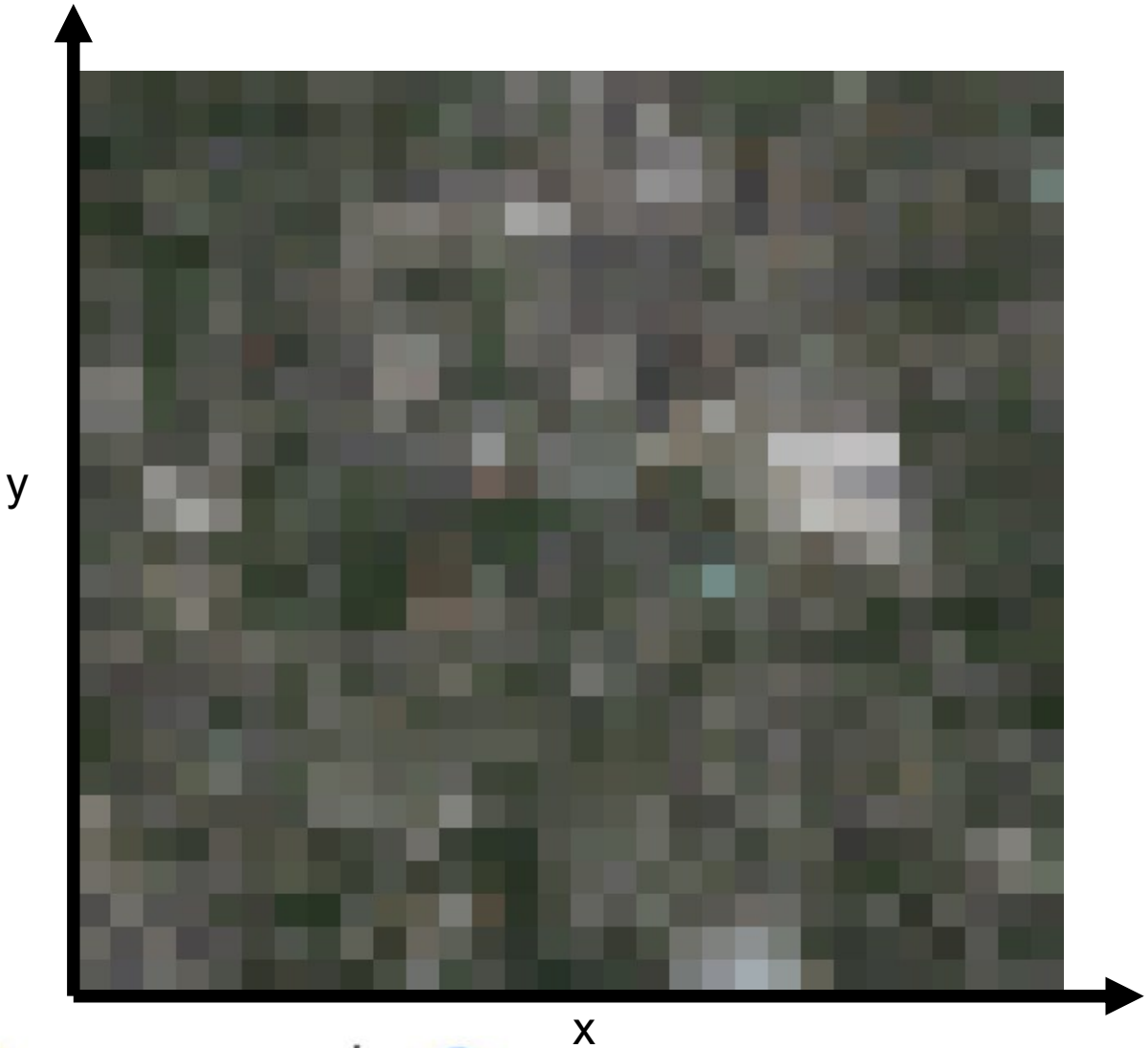
- Some depiction of all possible scenes would fit into this memory.
- Computer vision as making sense of an extremely high-dimensional space.
  - Subspace of ‘natural’ images.
  - Deriving low-dimensional, explainable models.

What is each part of an image?



What is each part of an image?

- Pixel -> picture element

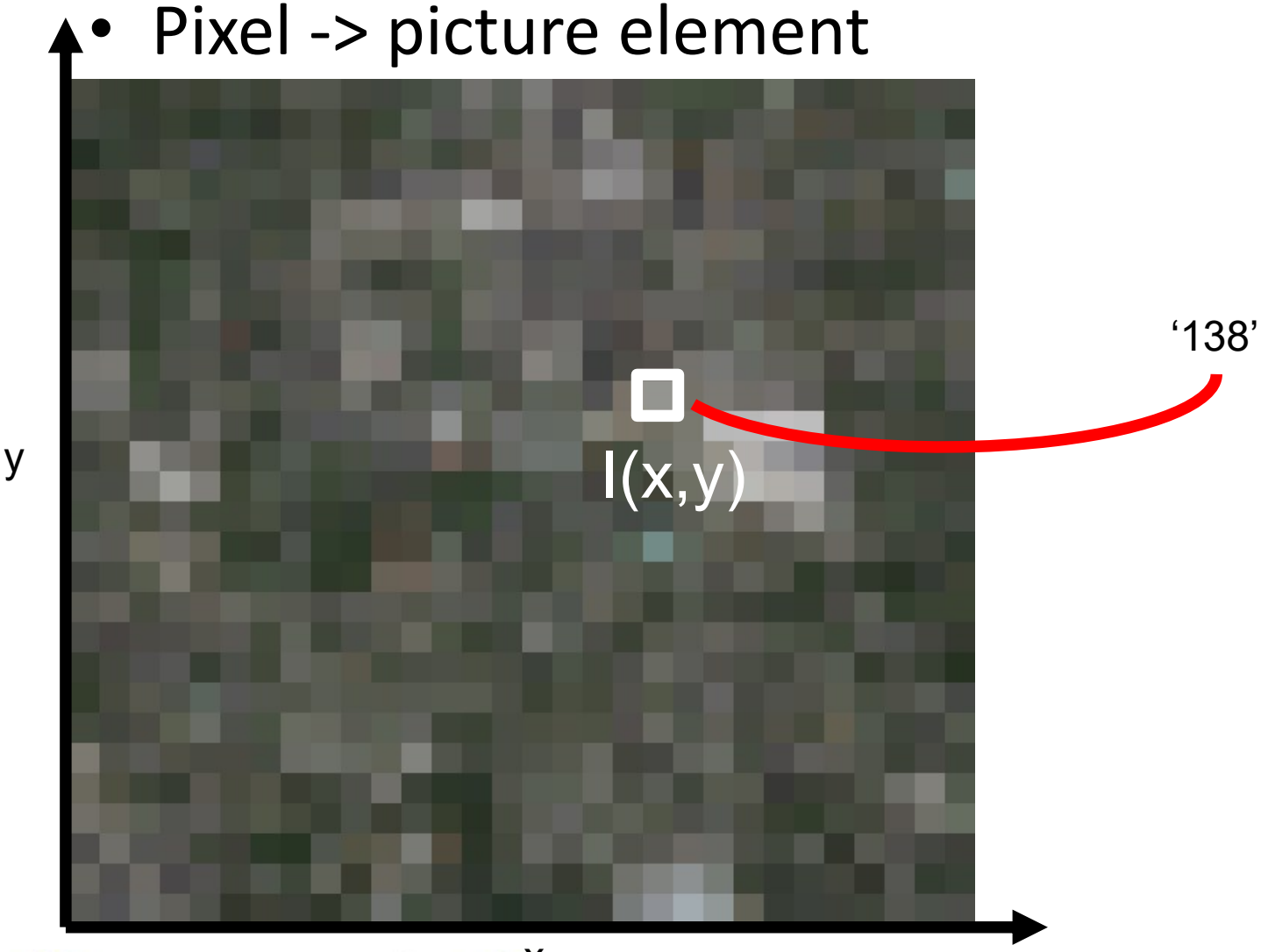


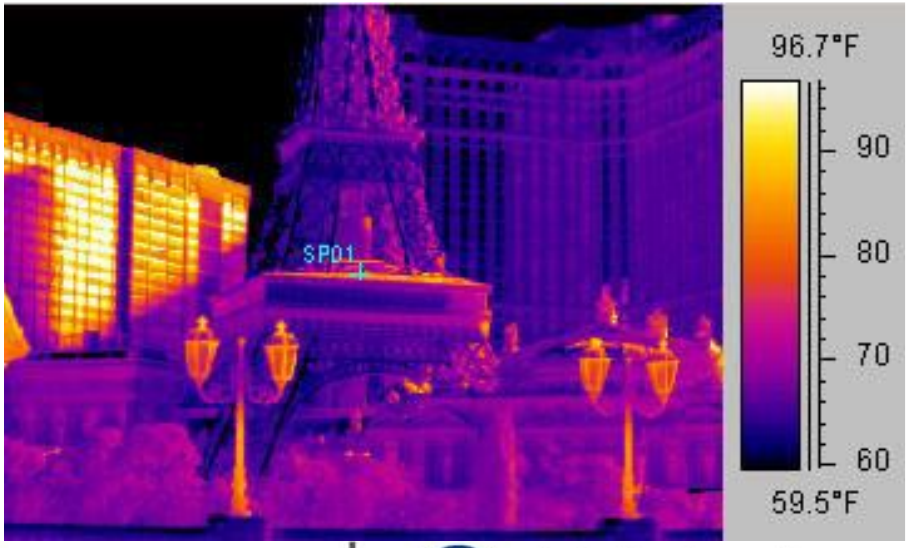
Image as a 2D sampling of signal

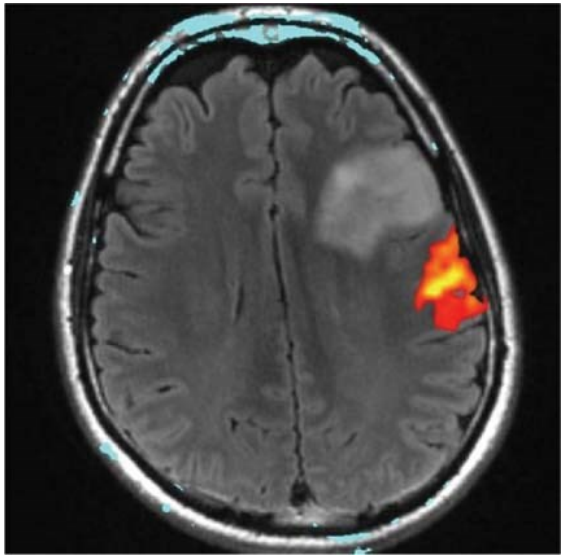
- Signal: function depending on some variable with physical meaning.

- Image: sampling of that function.
  - 2 variables: xy coordinates
  - 3 variables: xy + time (video)
  - ‘Brightness’ is the value of the function for visible light

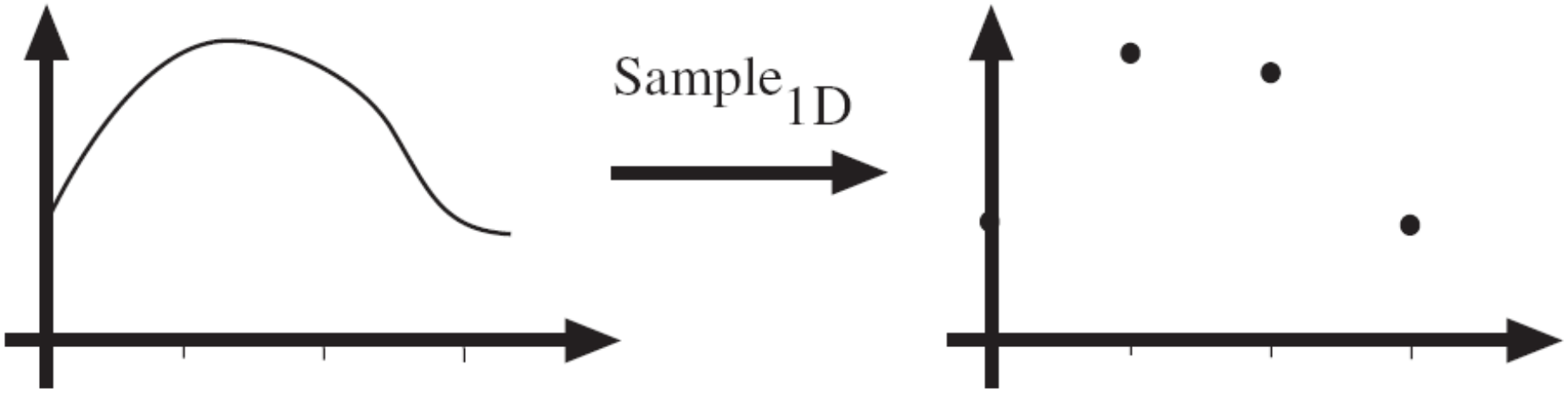
- Can be other physical values too: temperature, pressure, depth …

Example 2D Images



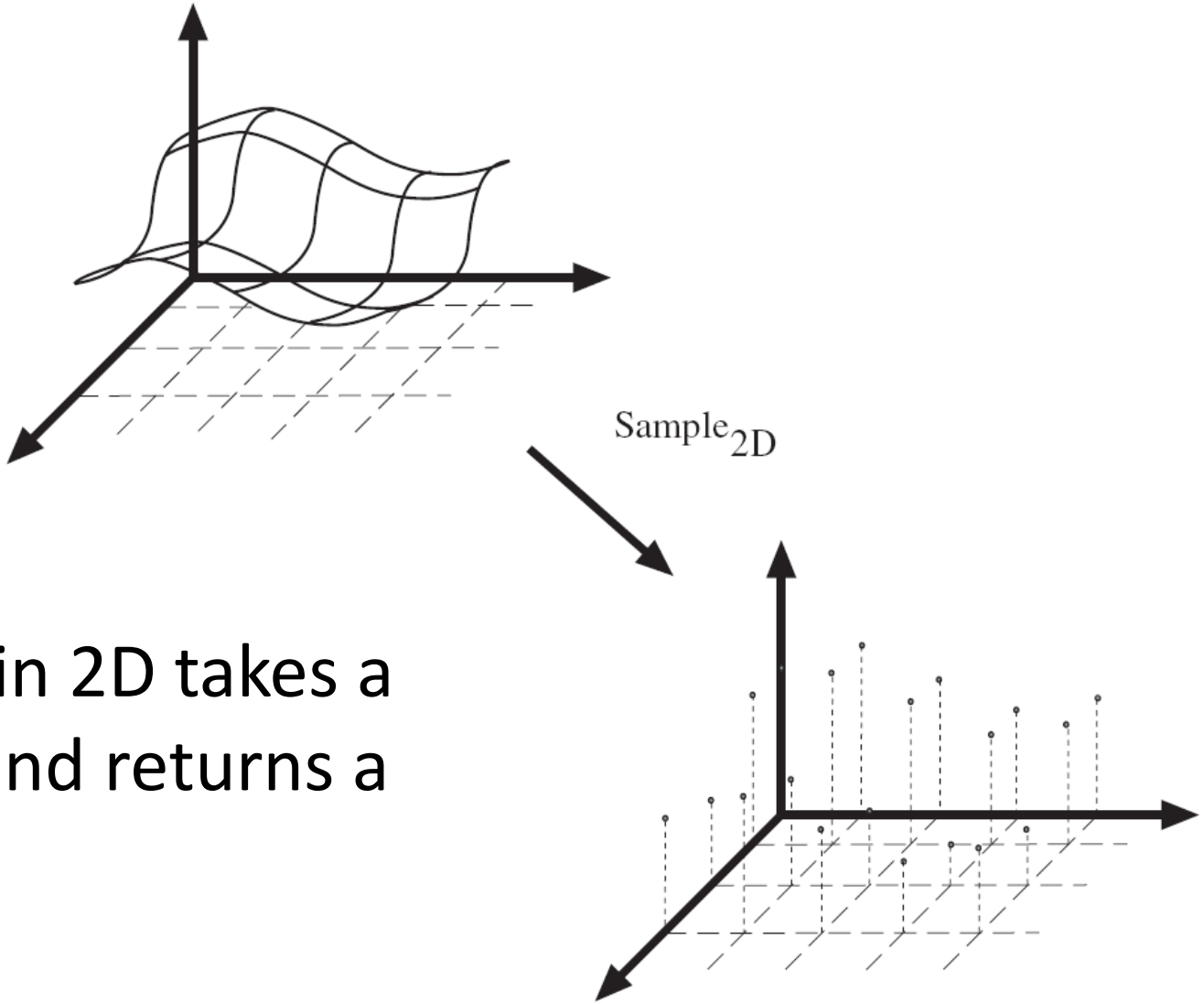


Sampling in 1D



- Sampling in 1D takes a function, and returns a vector whose elements are values of that function at the sample points.

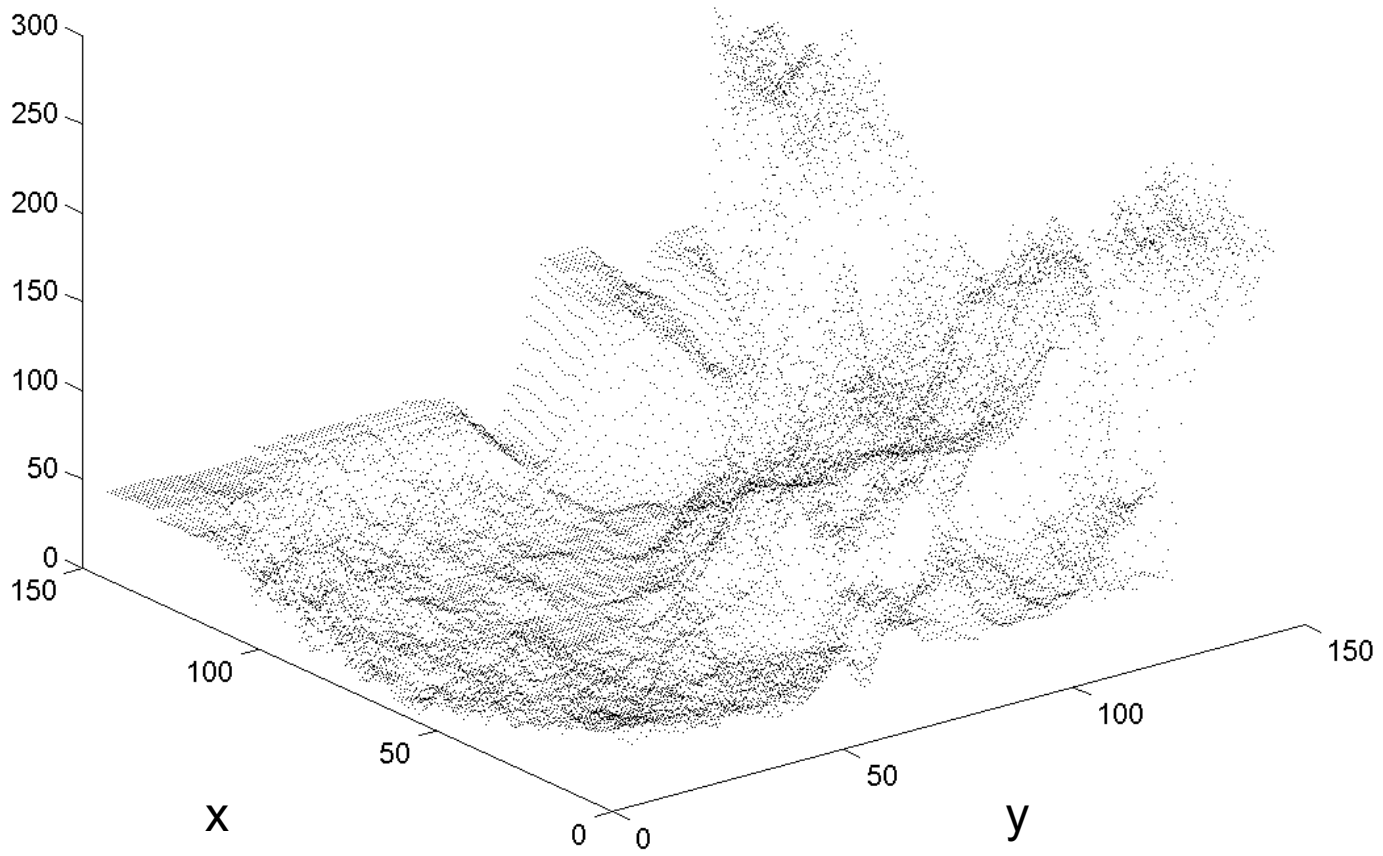
Sampling in 2D



- Sampling in 2D takes a function and returns a matrix.

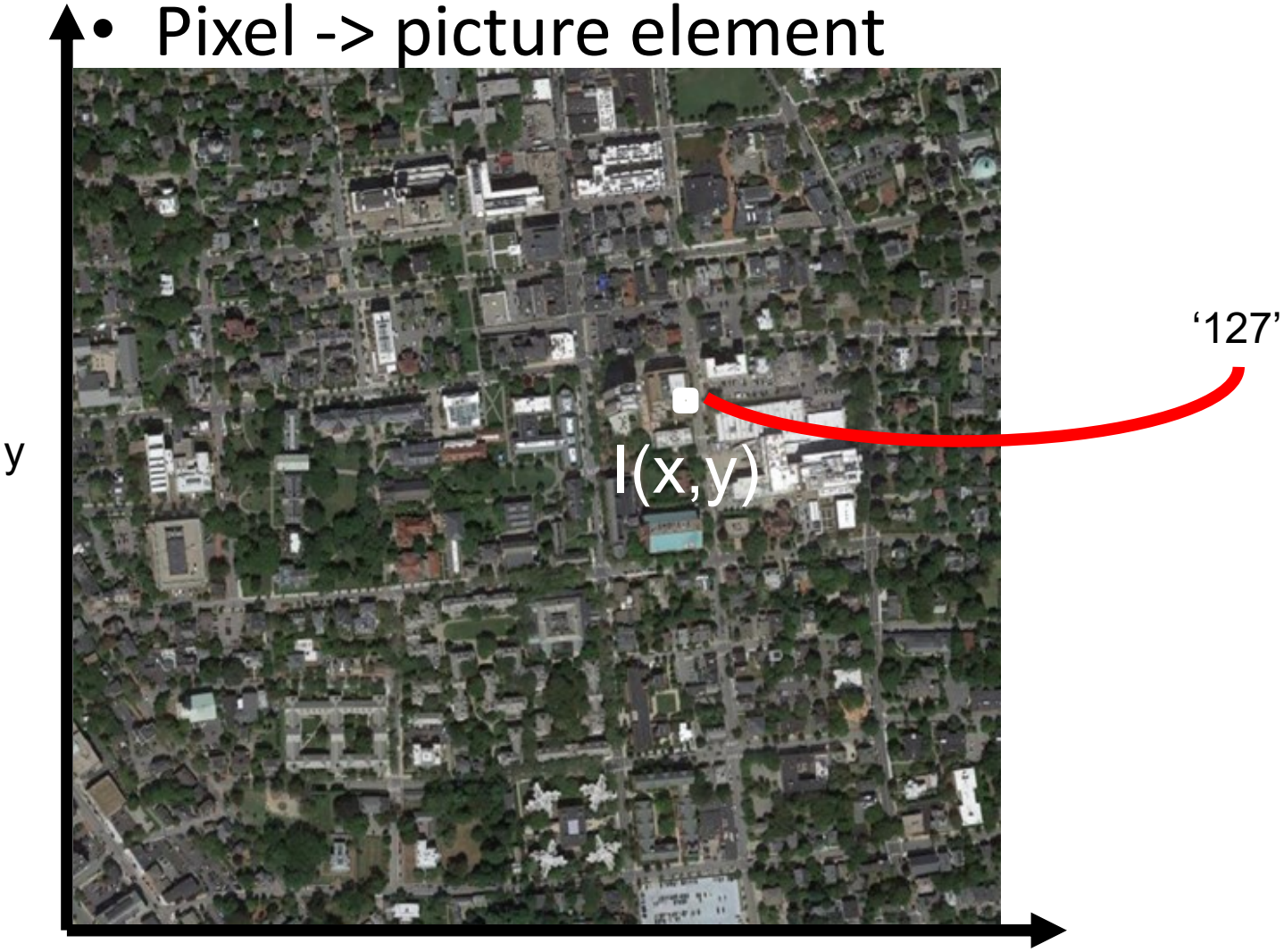
Grayscale Digital Image

Brightness or intensity

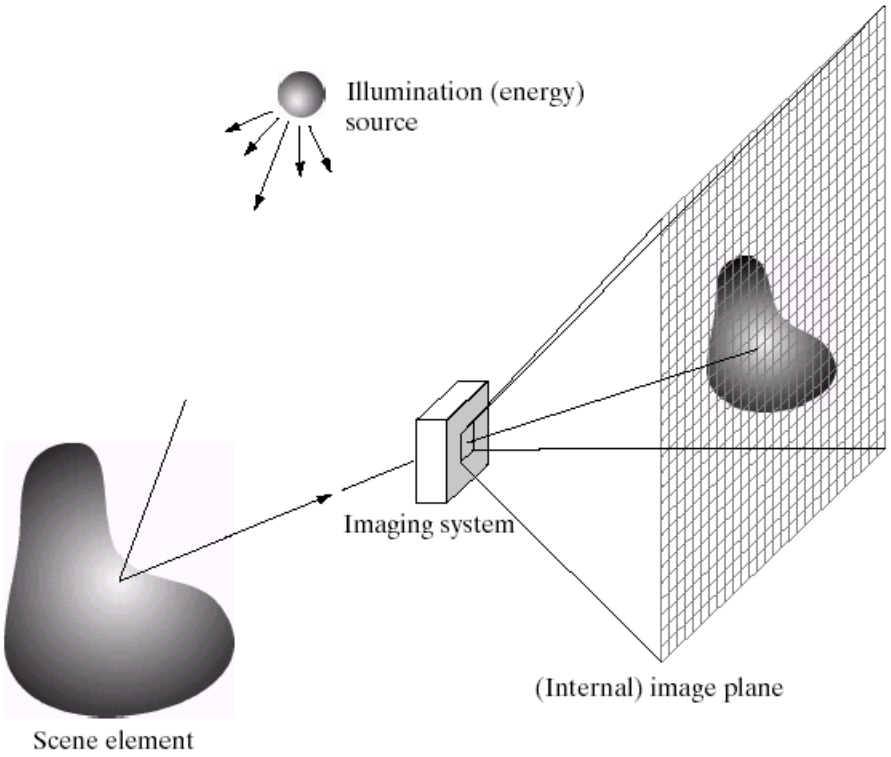


What is each part of a photograph?

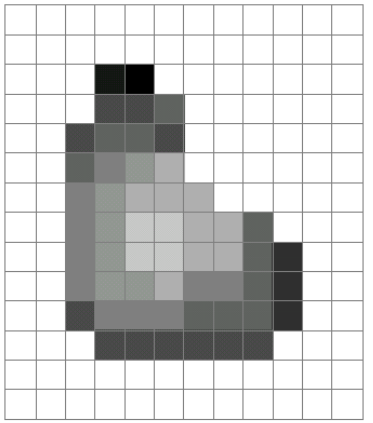
- Pixel -> picture element



Integrating light over a range of angles.



Camera Sensor

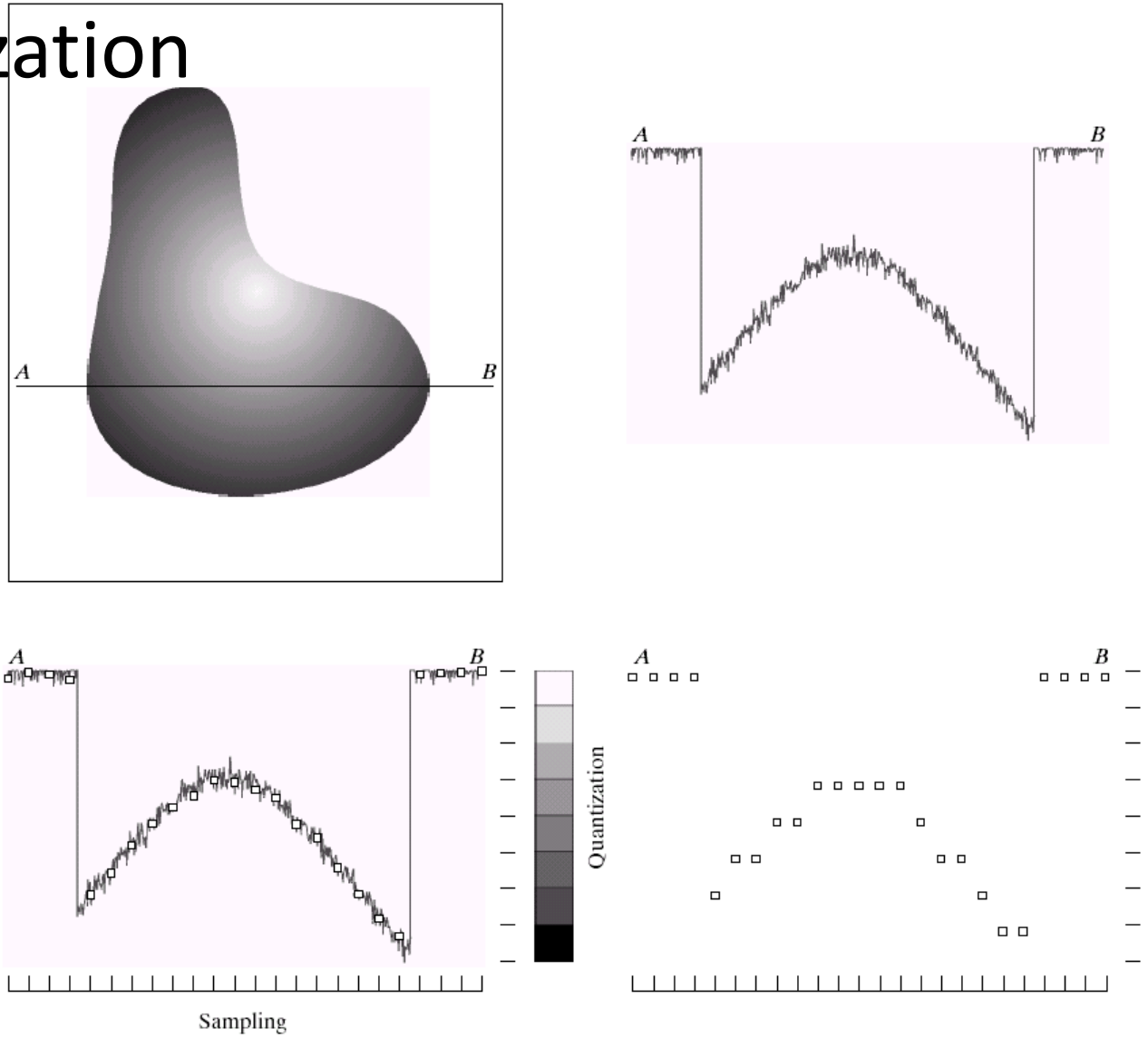


Output Image

Resolution – geometric vs. spatial resolution

Both images are ~500x500 pixels

Quantization



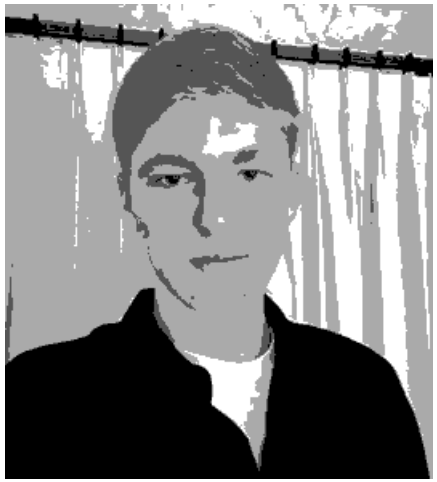
a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Quantization Effects – Radiometric Resolution

8 bit – 256 levels

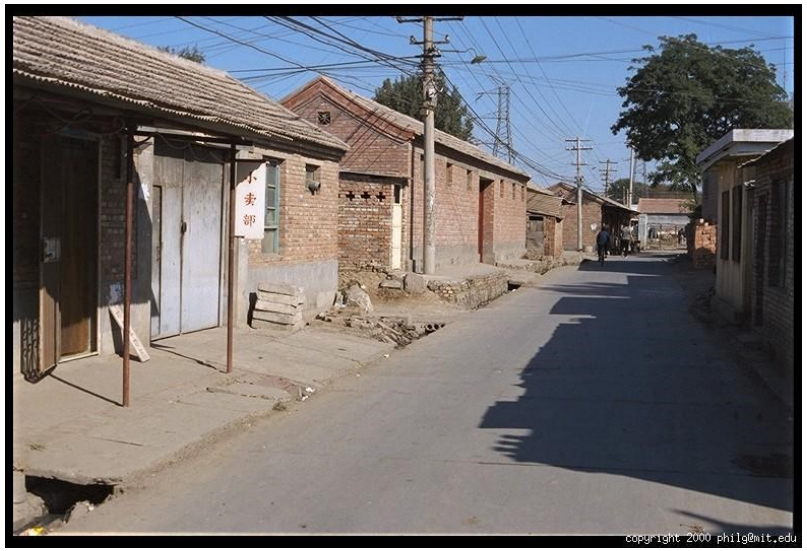
4 bit – 16 levels

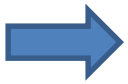


2 bit – 4 levels

1 bit – 2 levels

Color


copyright 2000 philg@mit.edu

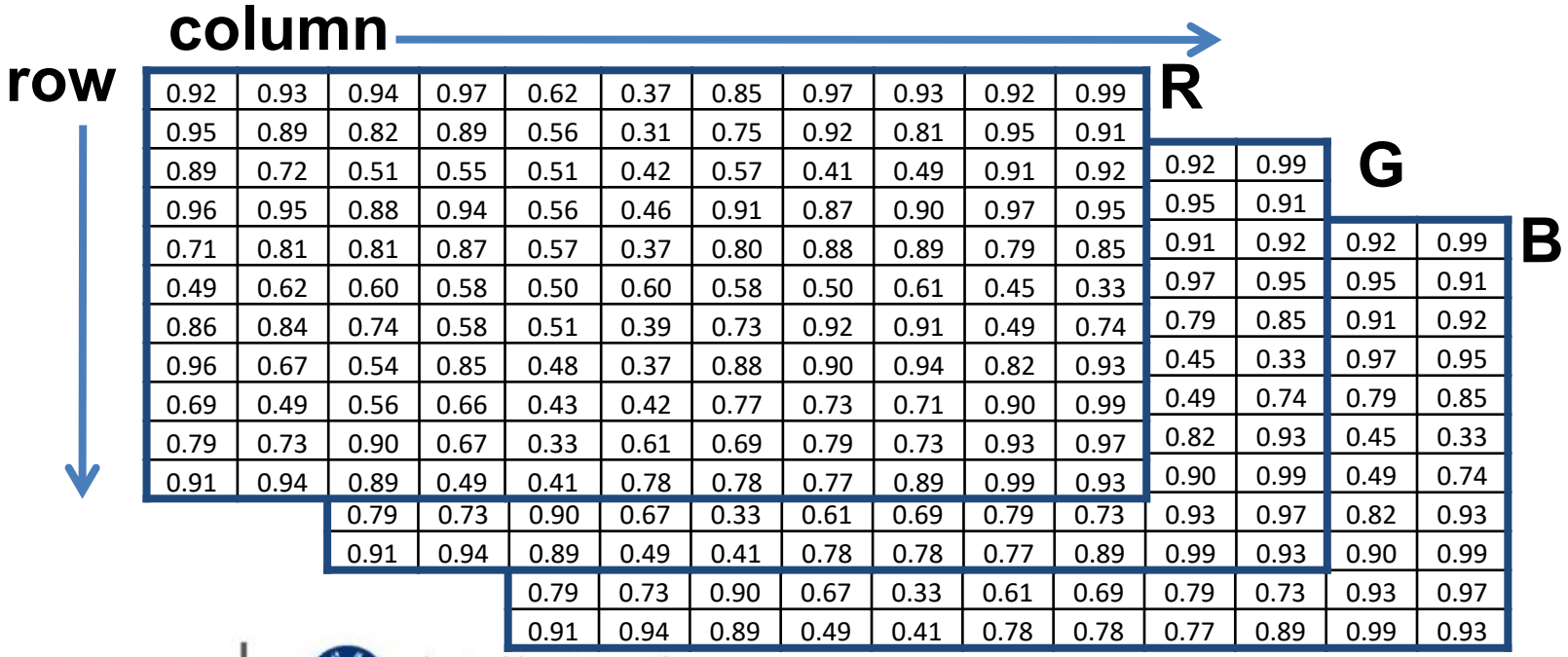



R
G
B
copyright 2000 philg@mit.edu

Images in Matlab

- NxM RGB “im”
  - im(1,1,1) = top-left pixel value in R-channel
  - im(y, x, b) = y pixels down, x pixels to right in the b^{th} channel
  - im(N, M, 3) = bottom-right pixel in B-channel

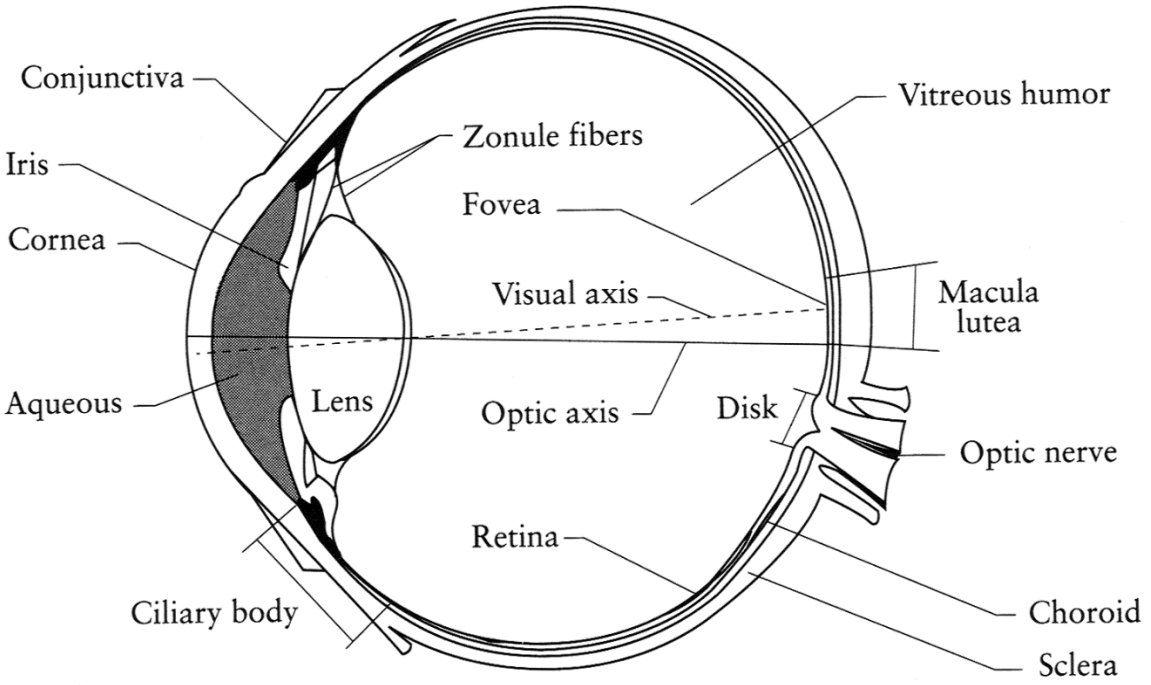
- imread(filename) returns a uint8 image (values 0 to 255)
  - Convert to double format (values 0 to 1) with im2double



But what is color?

ANATOMY

The Eye

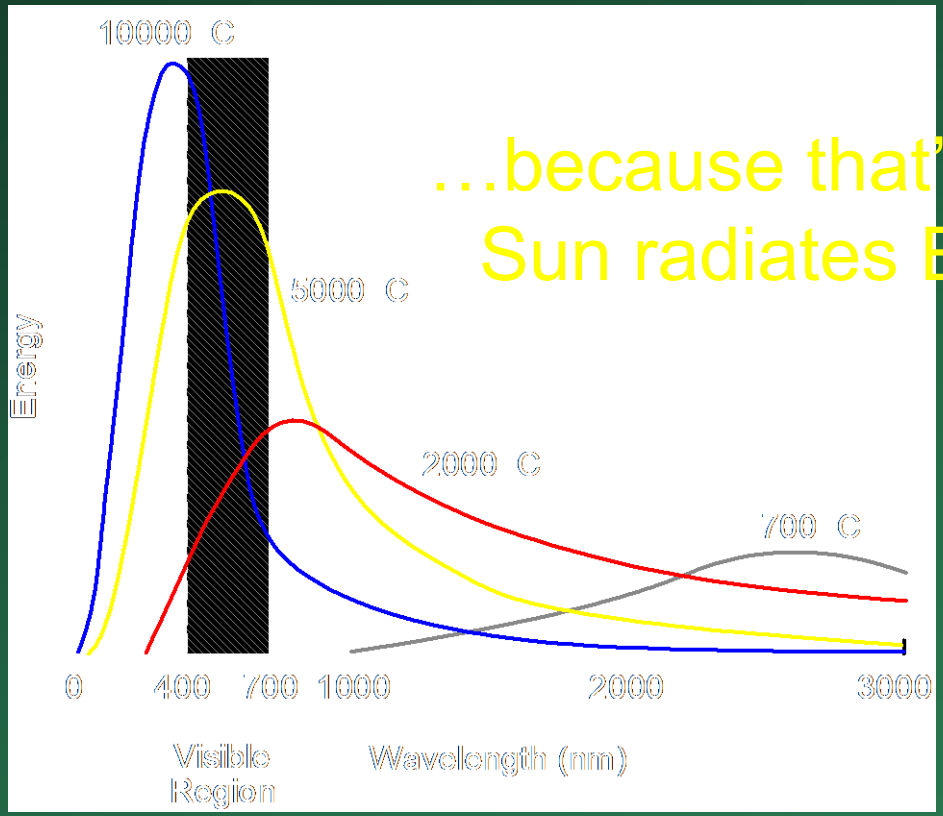


- The human eye is a camera
  - **Iris （虹膜）** - colored annulus with radial muscles
  - **Pupil （瞳孔）** - the hole (aperture) whose size is controlled by the iris
  - **What's the sensor?**
    - photoreceptor cells (rods and cones) in the **retina （视网膜）**

Slide by Steve Seitz

Visible Light

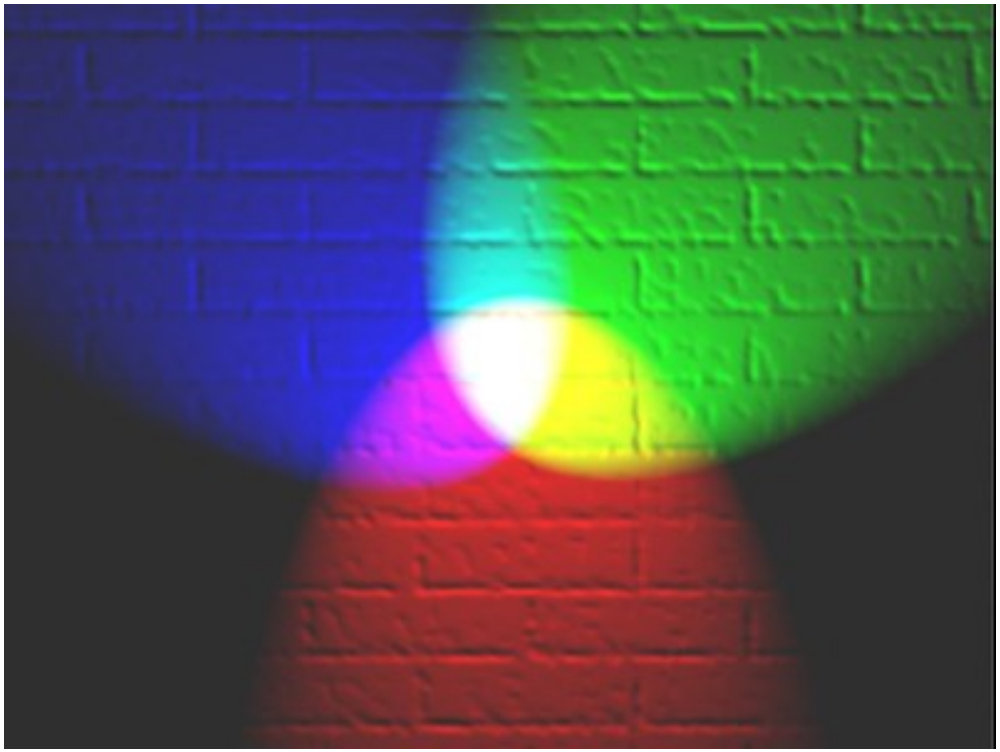
Why do we see light of these wavelengths?



…because that's where the Sun radiates EM energy

Color spaces

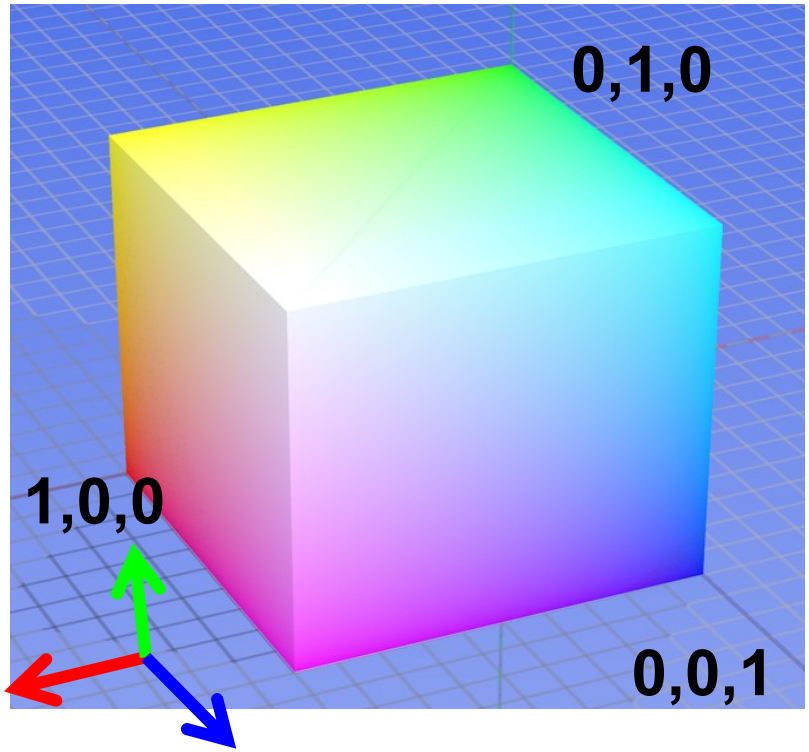
- How can we represent color?



http://en.wikipedia.org/wiki/File:RGB_illumination.jpg

Color spaces: RGB

Default color space



R = 1
(G=0,B=0)

G = 1
(R=0,B=0)

B = 1
(R=0,G=0)

Any color = r*R + g*G + b*B

- Strongly correlated channels
- Non-perceptual

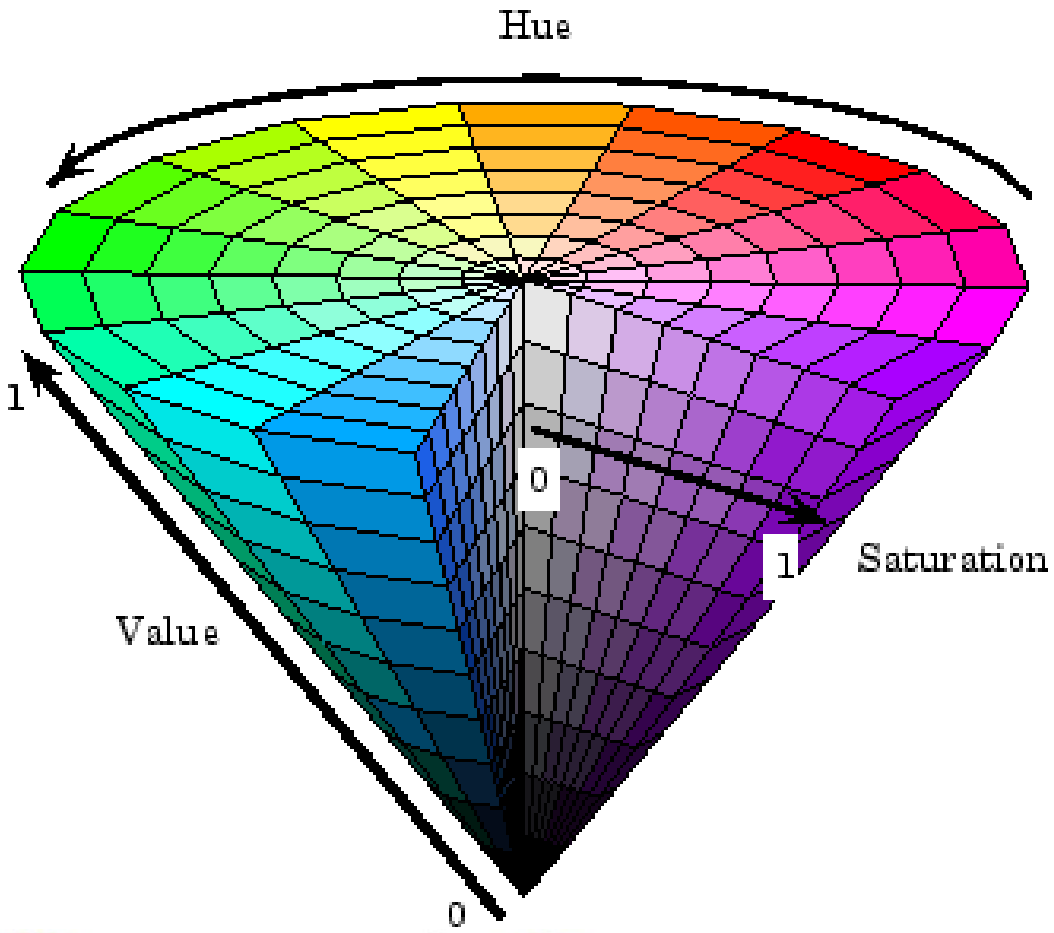
Image from: http://en.wikipedia.org/wiki/File:RGB_color_solid_cube.png

Got it. C = r*R + g*G + b*B

IS COLOR A VECTOR SPACE? THINK-PAIR-SHARE

Color spaces: HSV

Intuitive color space



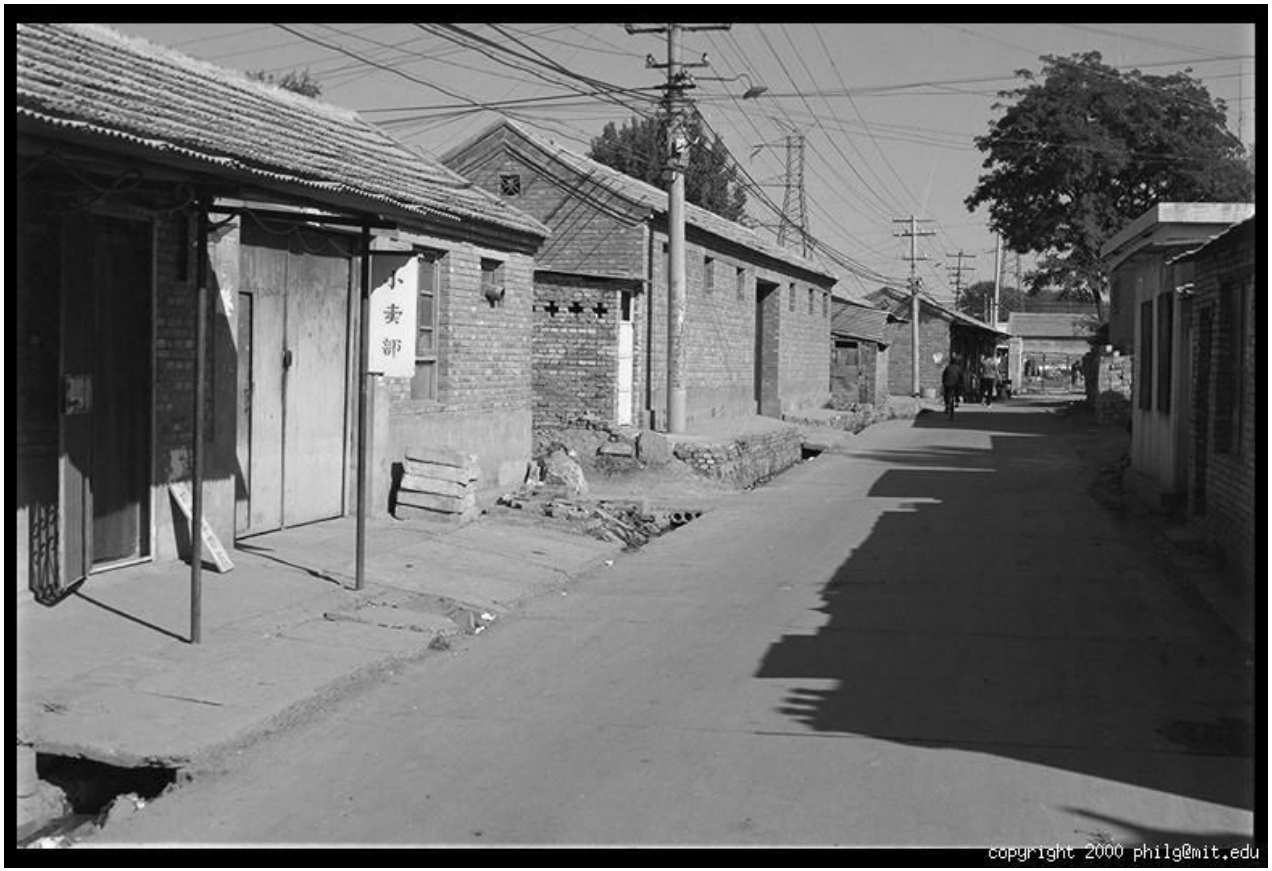
If you had to choose, would you rather go without:
- intensity (‘value’), or
- hue + saturation (‘chroma’)?

Think-Pair-Share

Most information in intensity

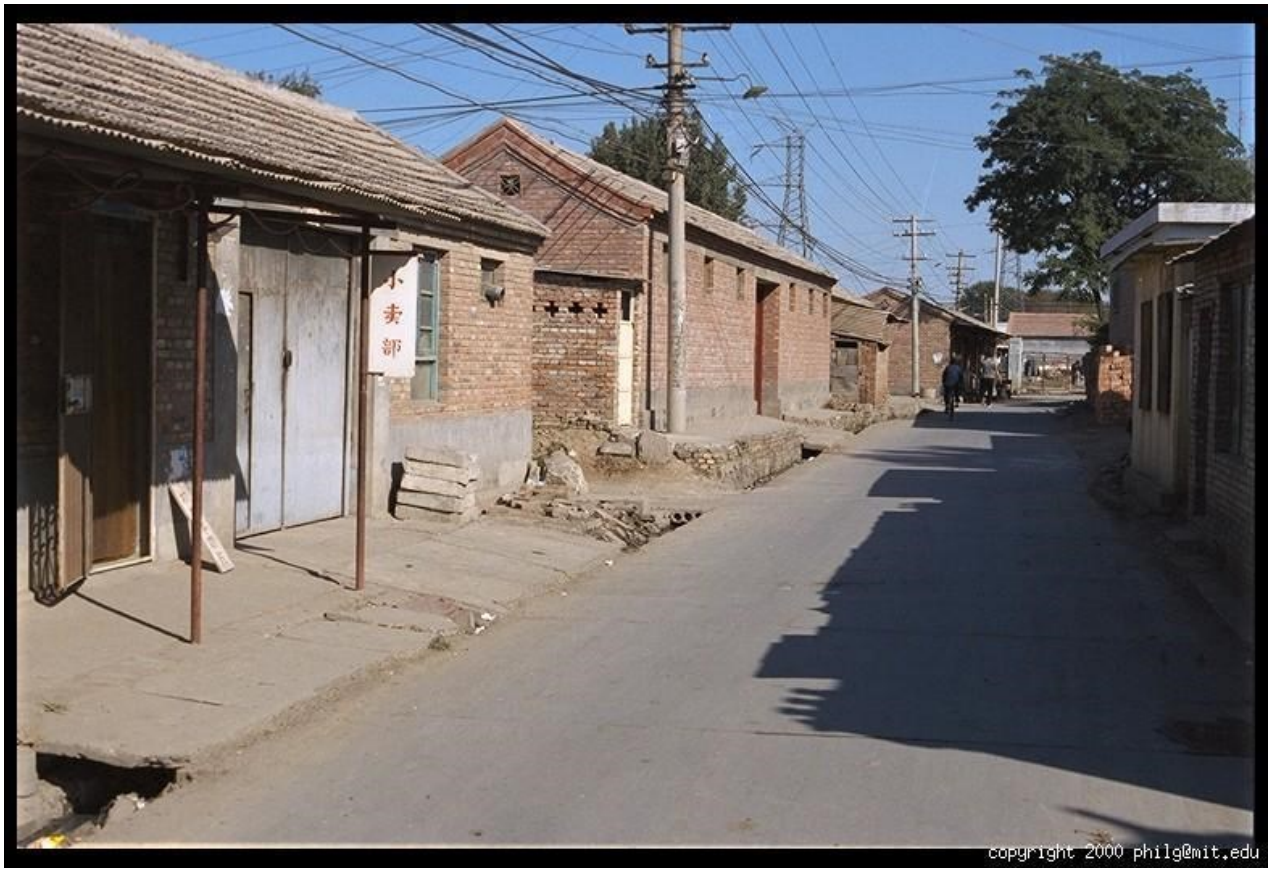
Only color shown – constant intensity

Most information in intensity



Only intensity shown – constant color

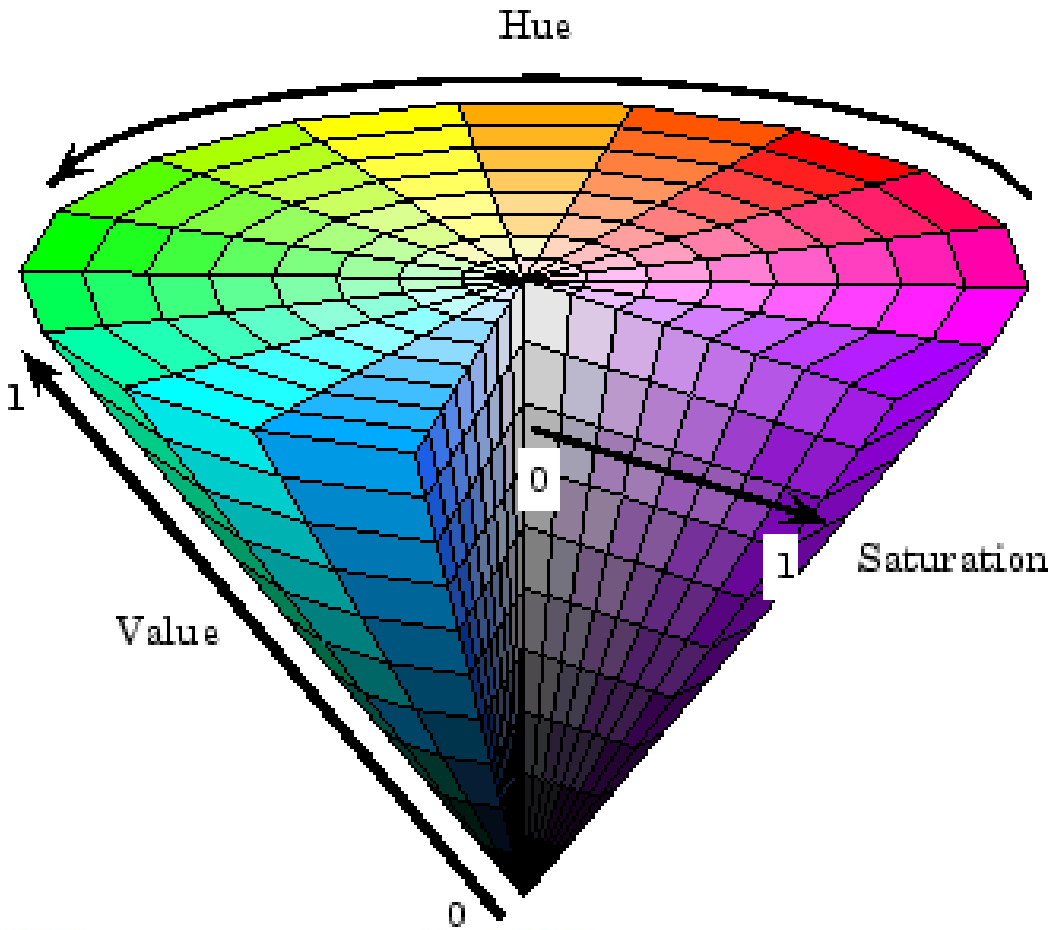
Most information in intensity

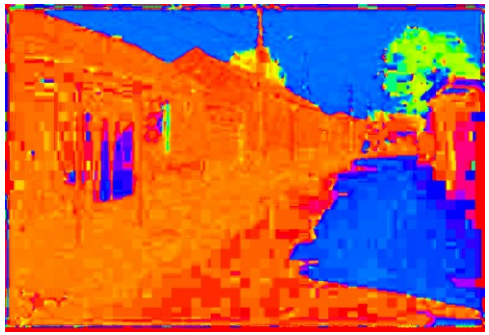


Original image

Color spaces: HSV

Intuitive color space





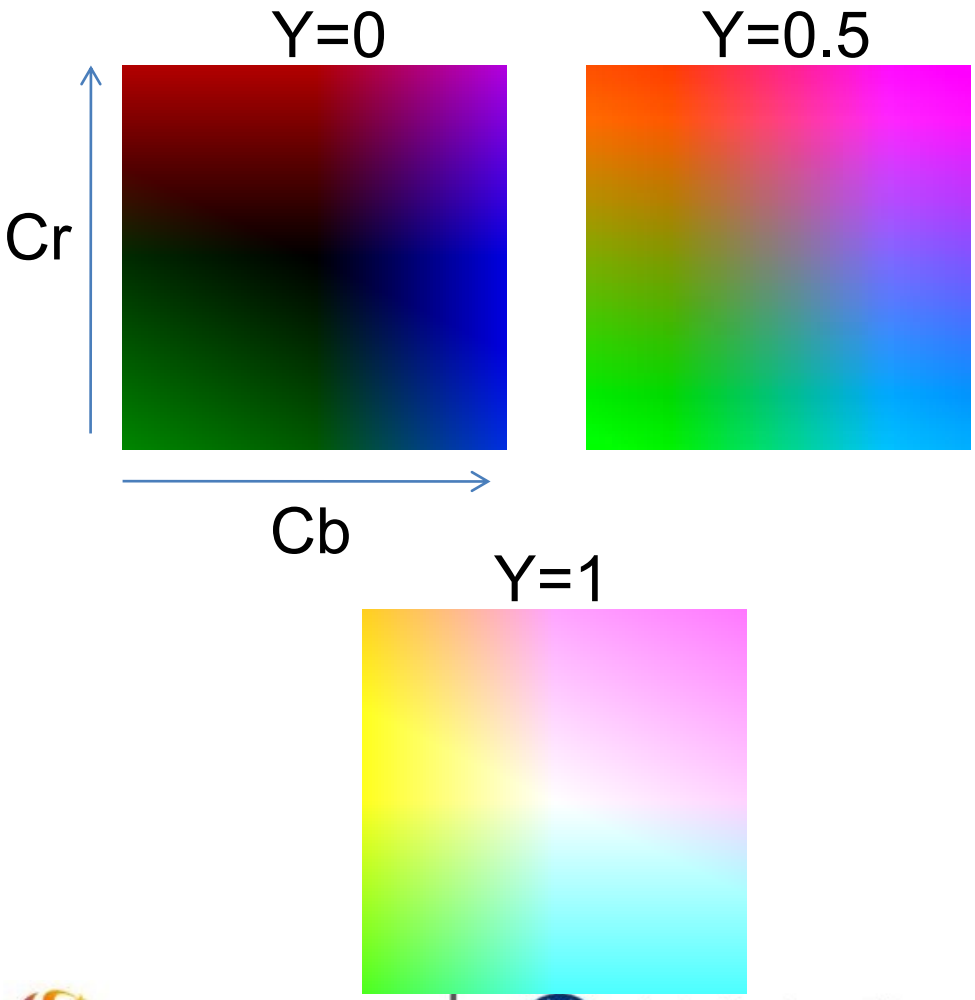
H
(S=1,V=1)

S
(H=1,V=1)

V
(H=1,S=0)

Color spaces: YCbCr

Fast to compute, good for compression, used by TV



Y
(Cb=0.5,Cr=0.5)

Cb
(Y=0.5,Cr=0.5)

Cr
(Y=0.5,Cb=05)

More references

- https://www.colorsystem.com/

- A description of many different color systems developed through history.
- Navigate from the right-hand links.

- Thanks to Alex Nibley!