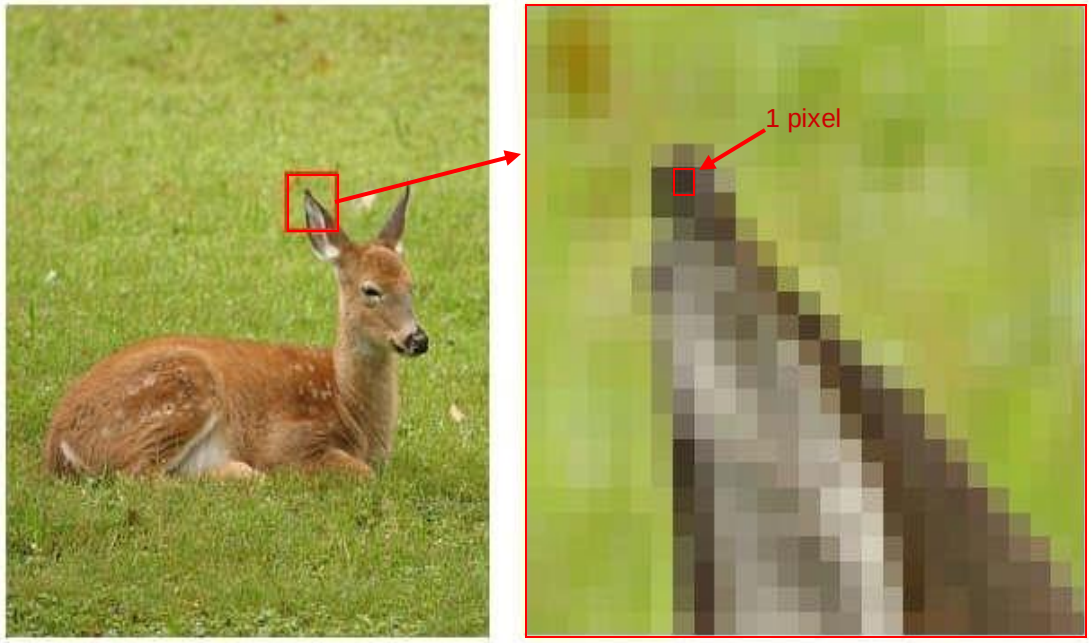
Digital Image Processing

Lecture # 2A: Fundamentals

Digital Image

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

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



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*)

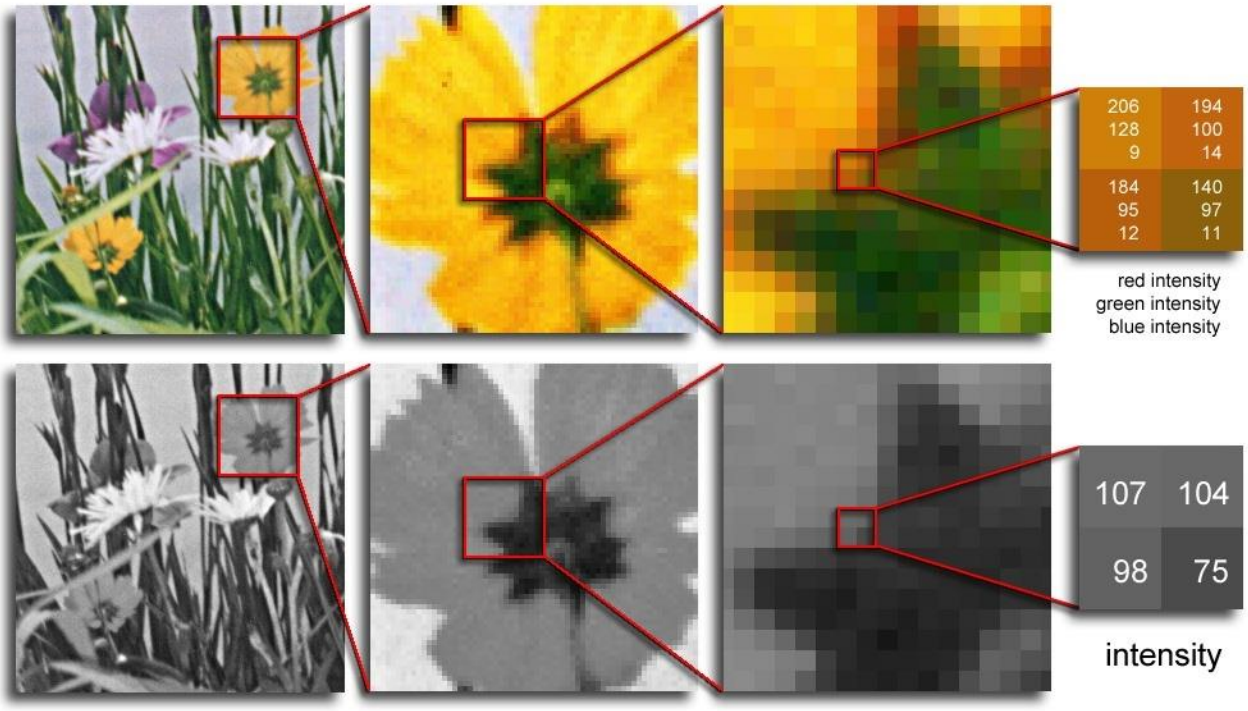


Image Formation

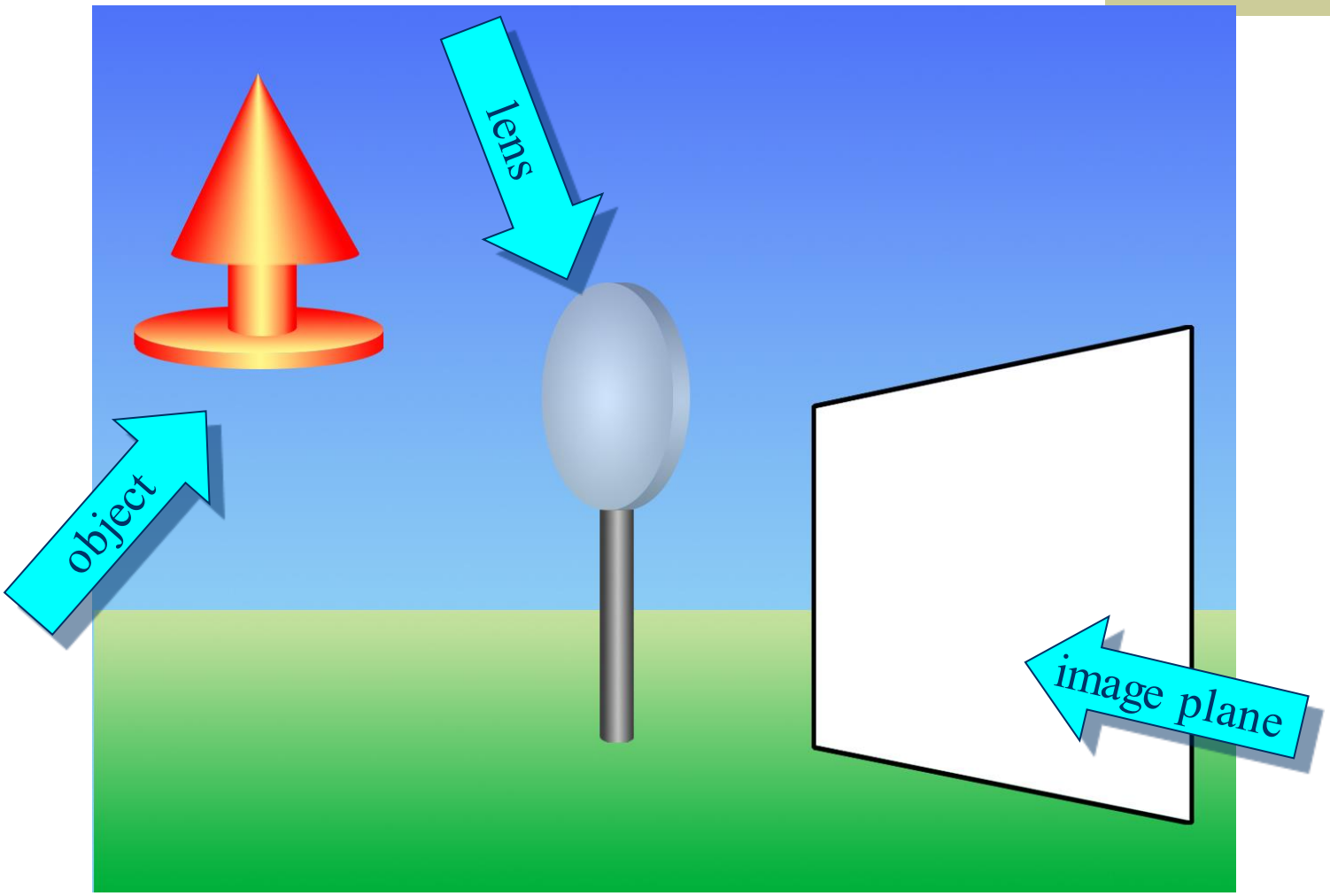


Image Formation

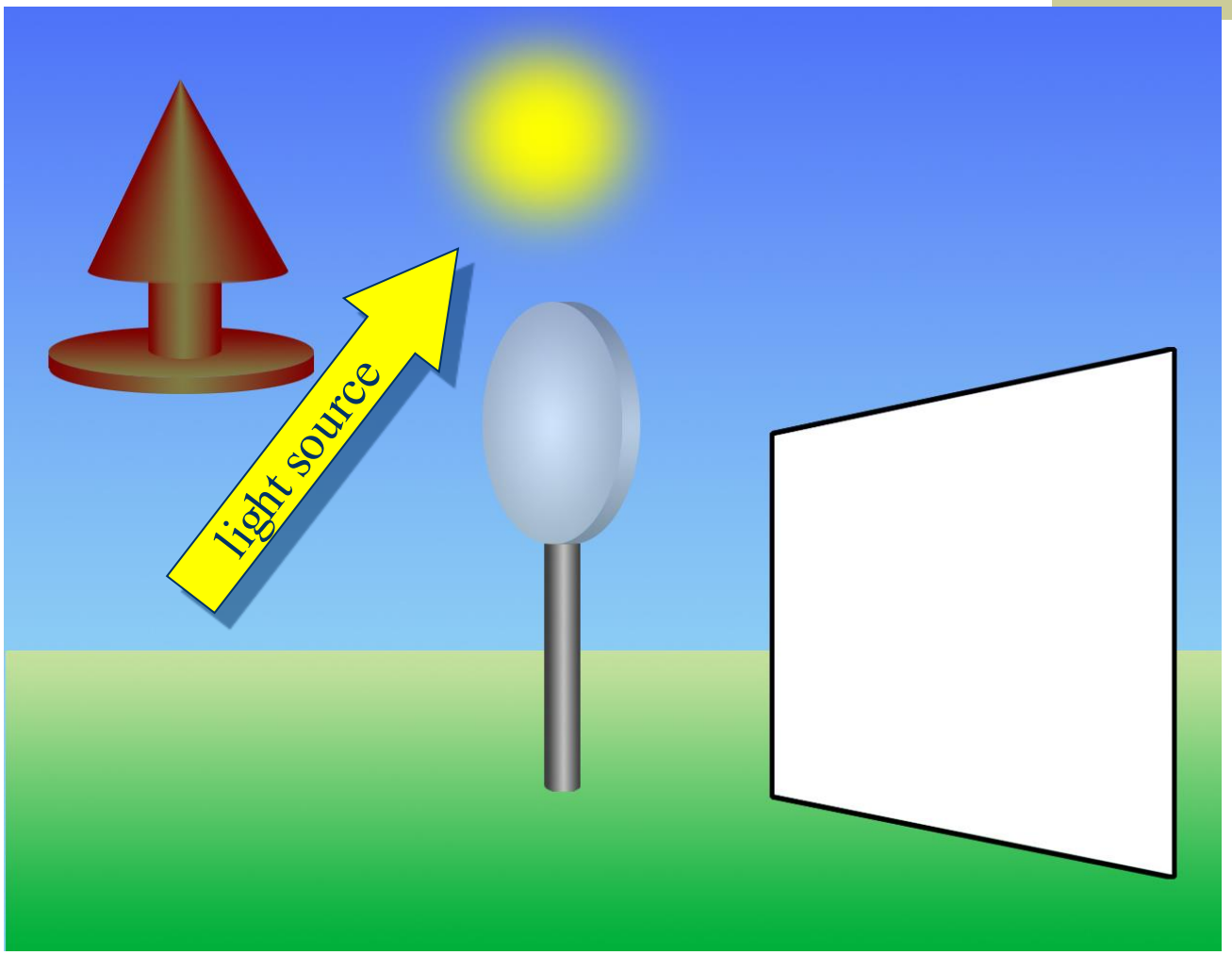


Image Formation

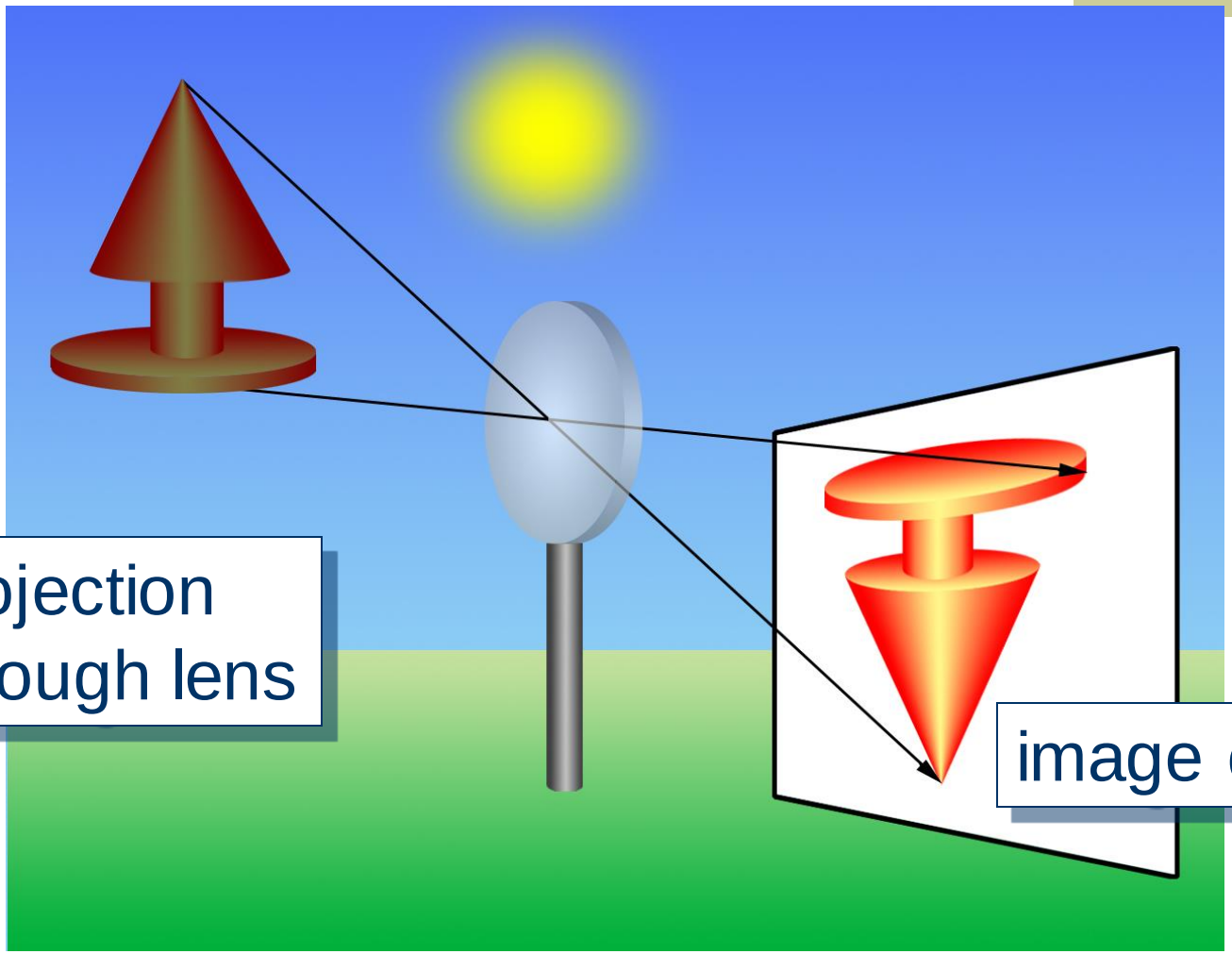


Image Formation

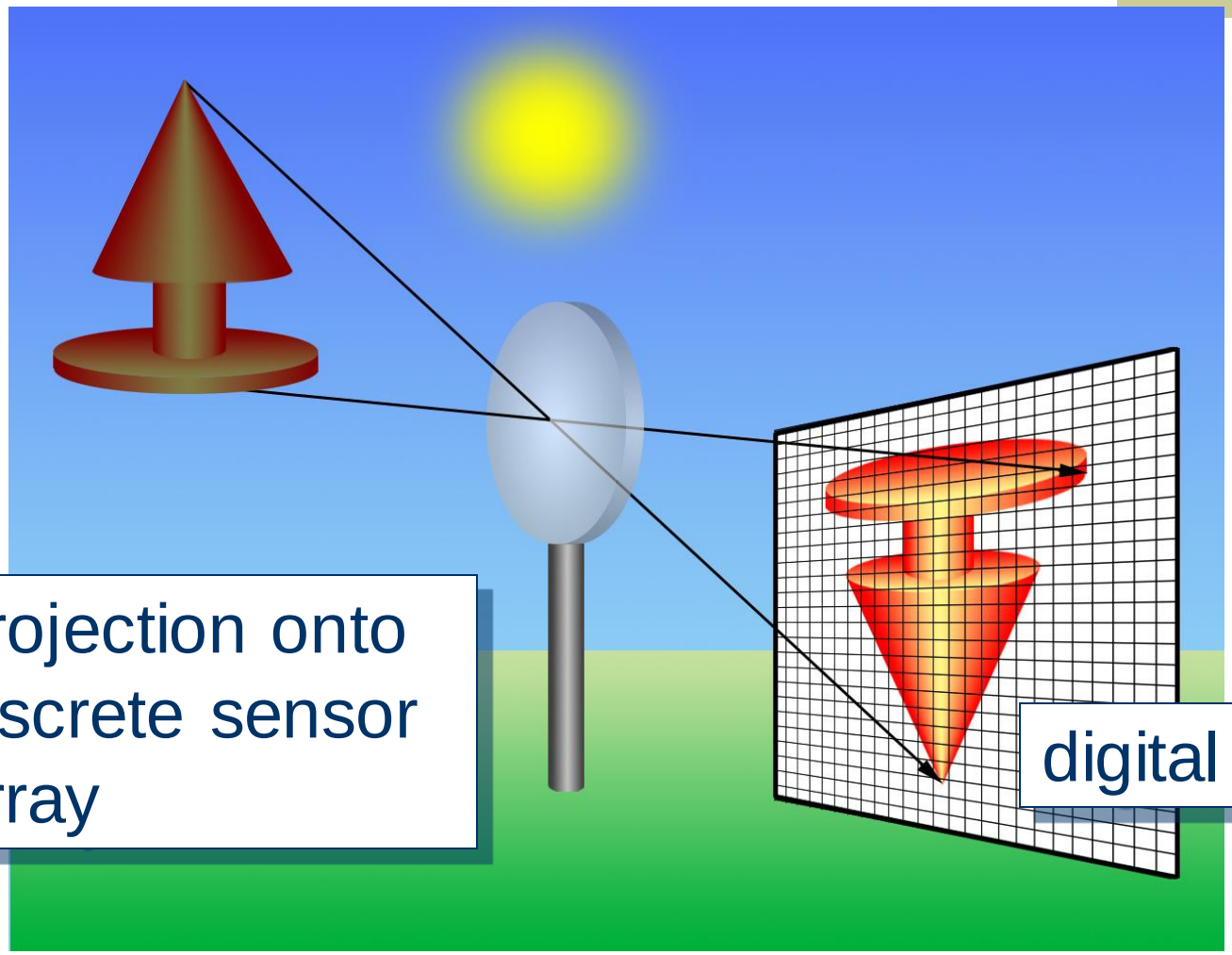


Image Formation

- Digital Image is an approximation of a real world scene

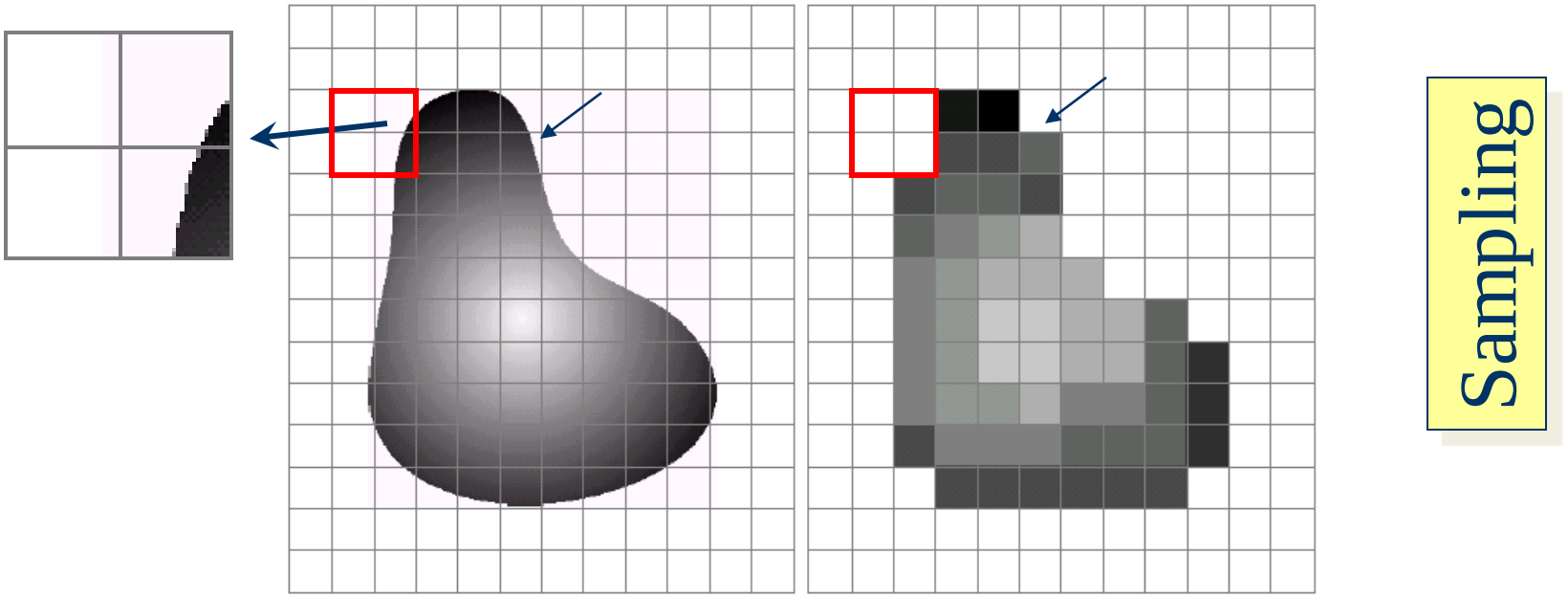


Image Formation

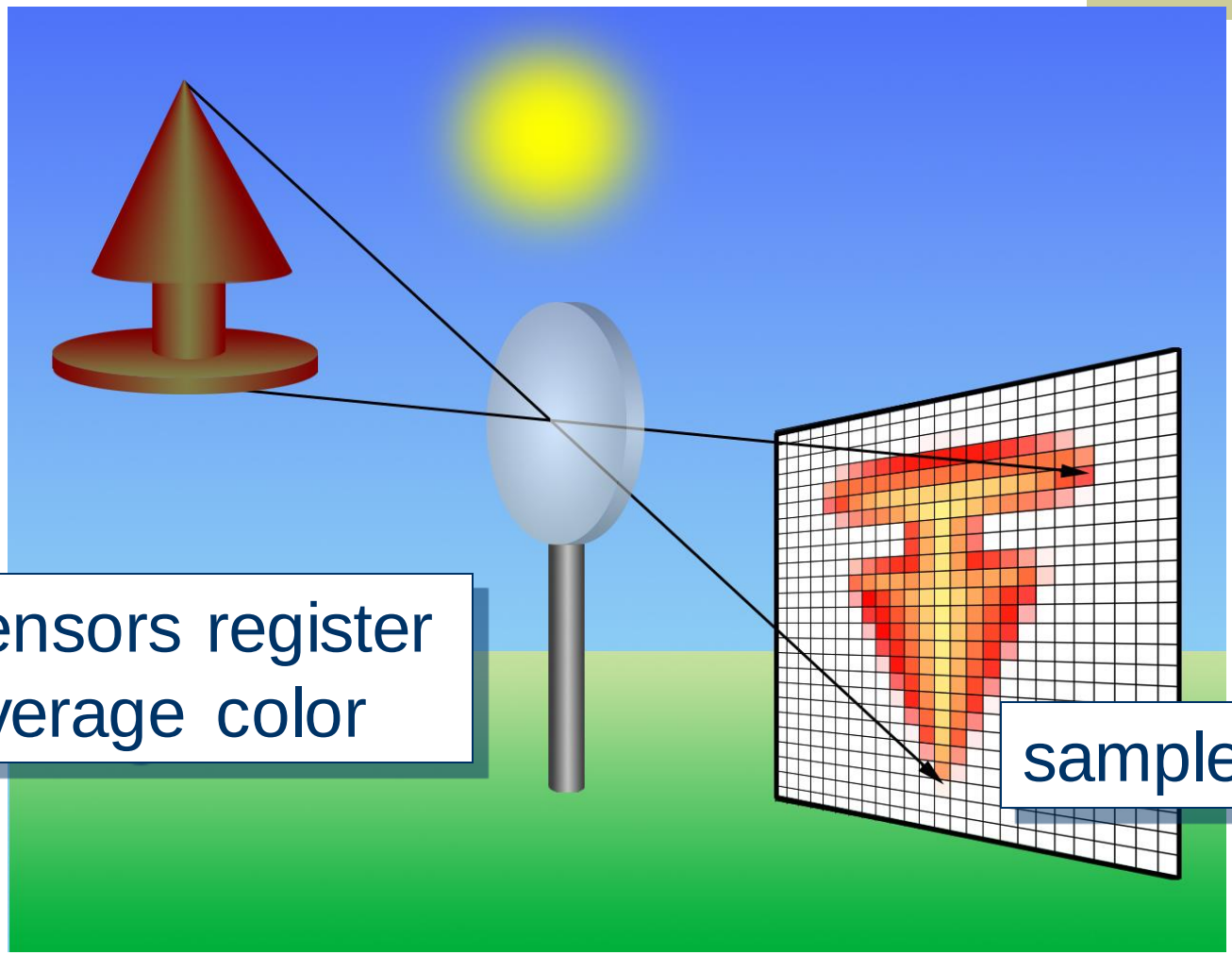


Image Formation

- Digital Image is an approximation of a real world scene

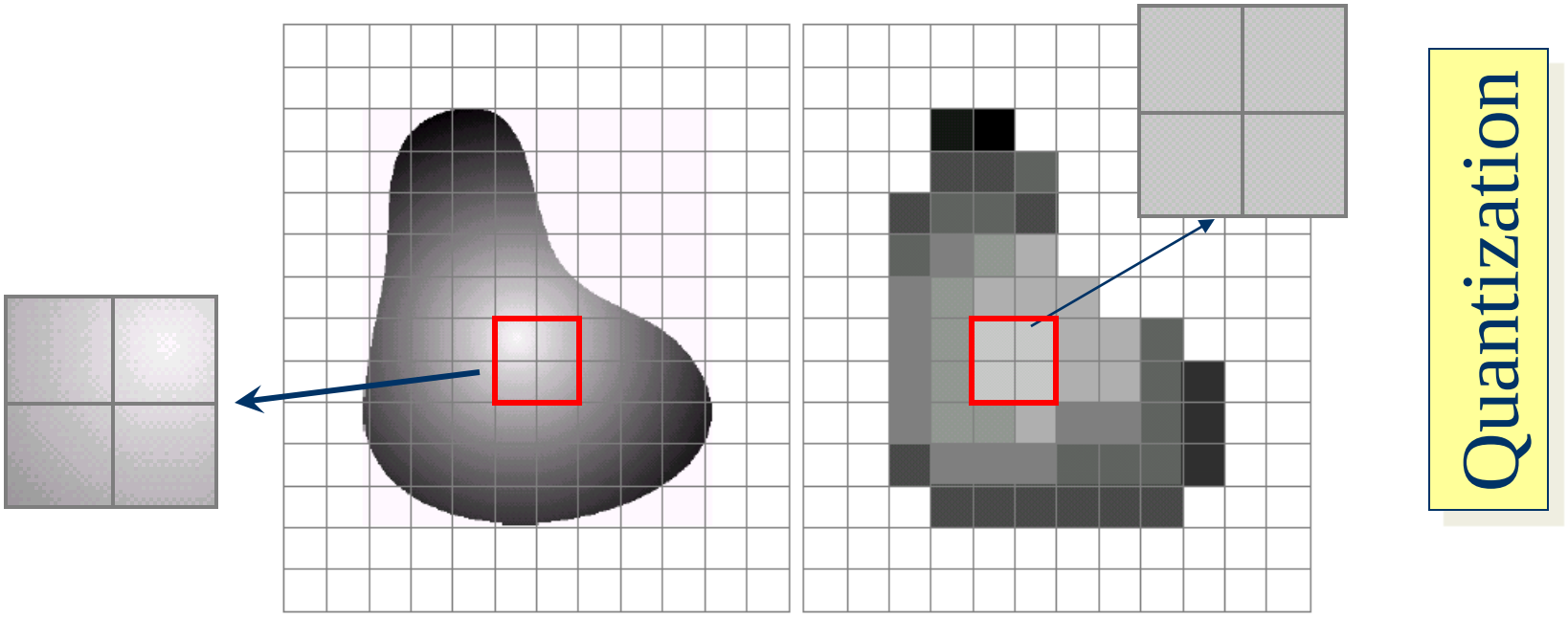
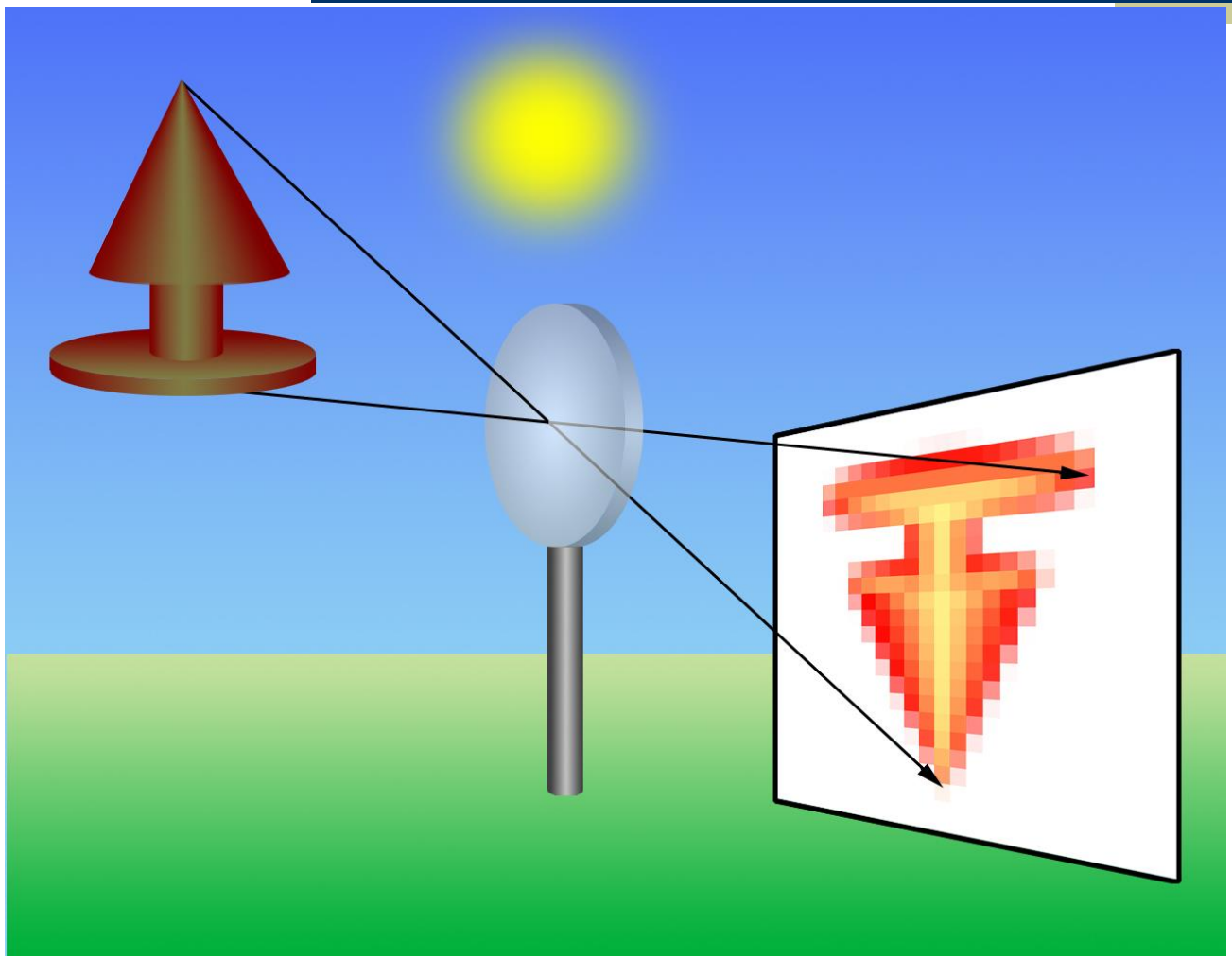
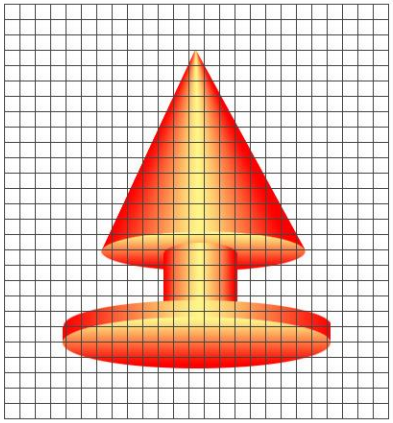


Image Formation

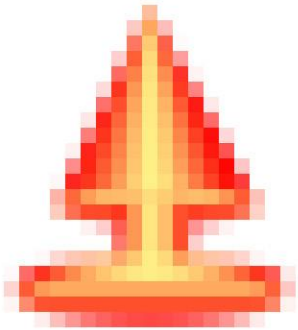


Sampling and Quantization

pixel grid



real image



sampled

quantized

sampled & quantized

Quantization: Example

Return change using only these notes

Quantization: Example

For Rs. 2	Return 5
For Rs. 7	Return 5
For Rs. 9	Return 10
For Rs. 12	Return 10
For Rs. 23	Return 25
….	….

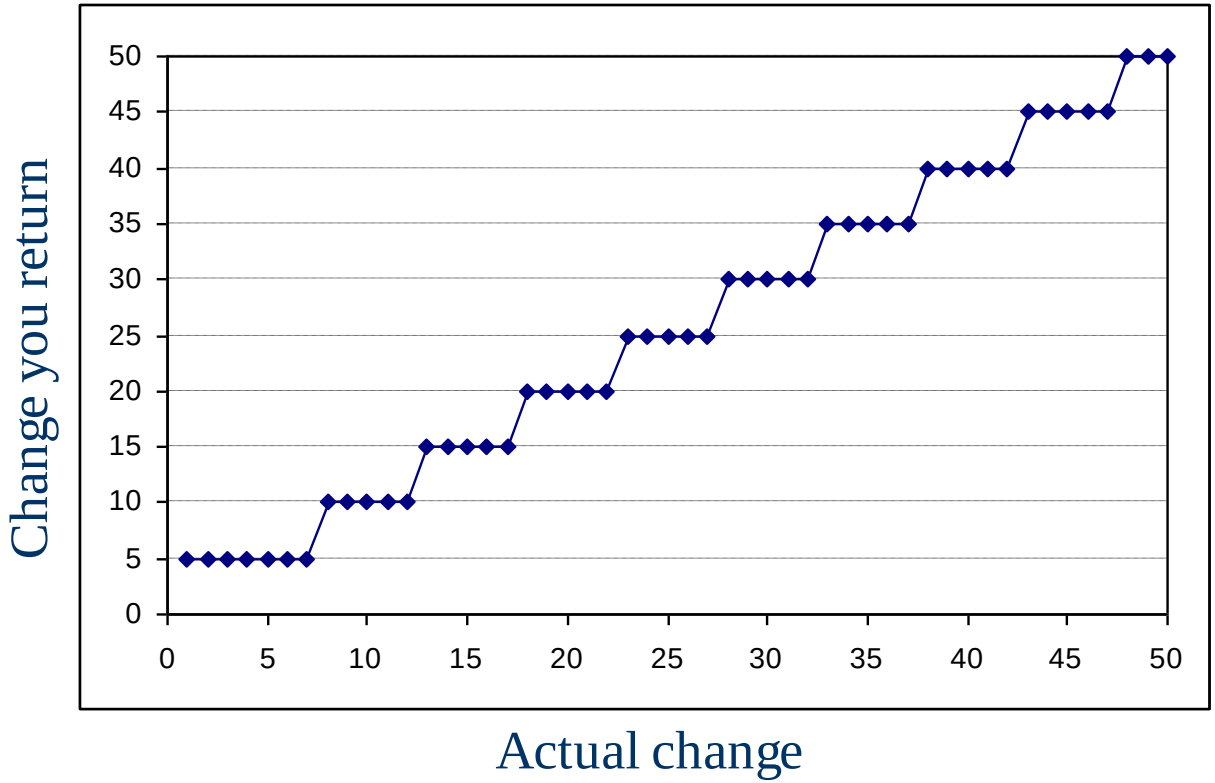
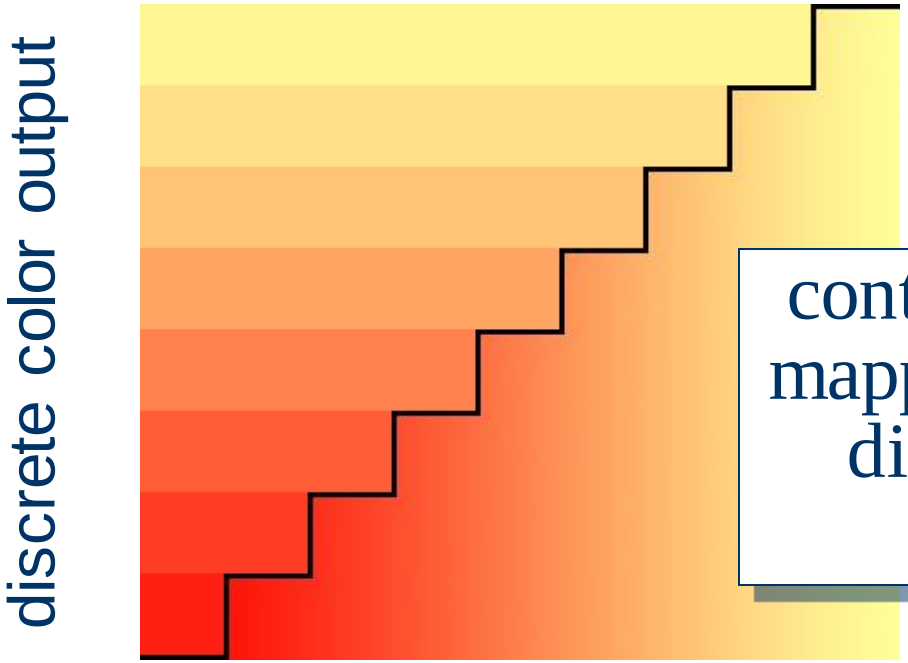
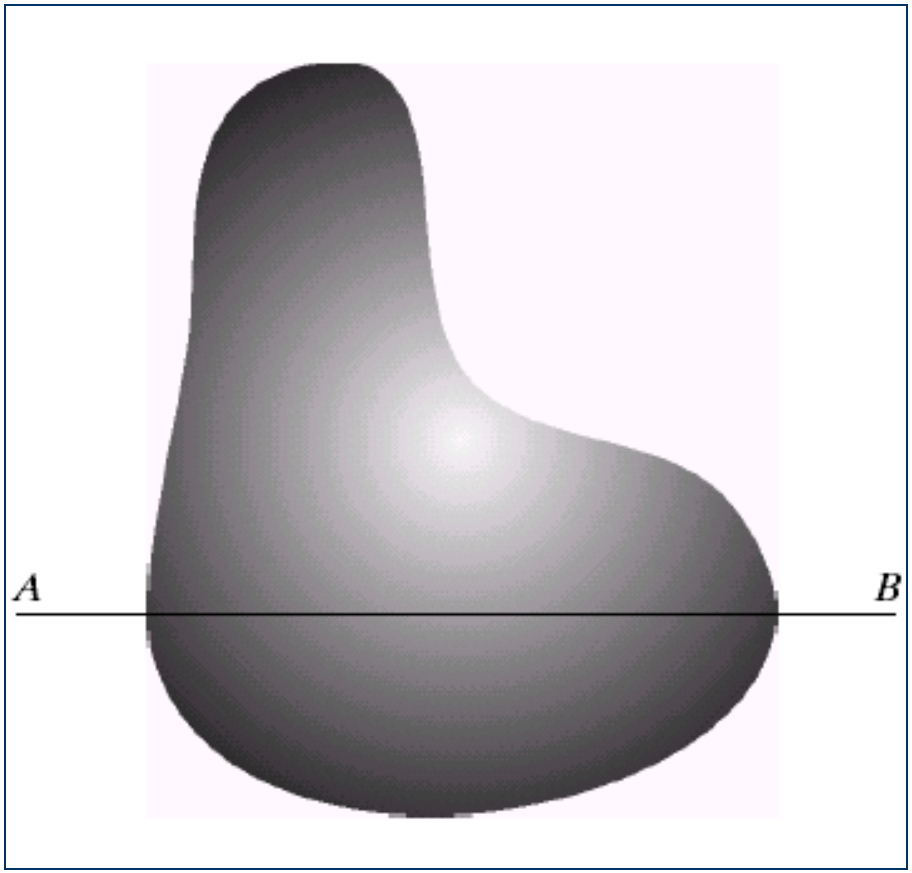


Image Formation - Quantization

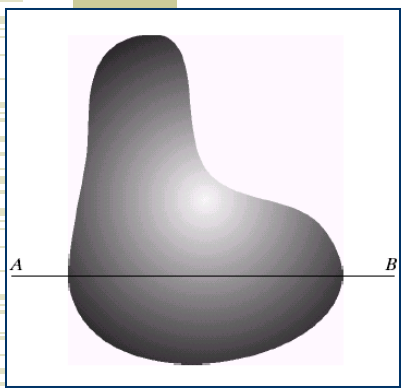


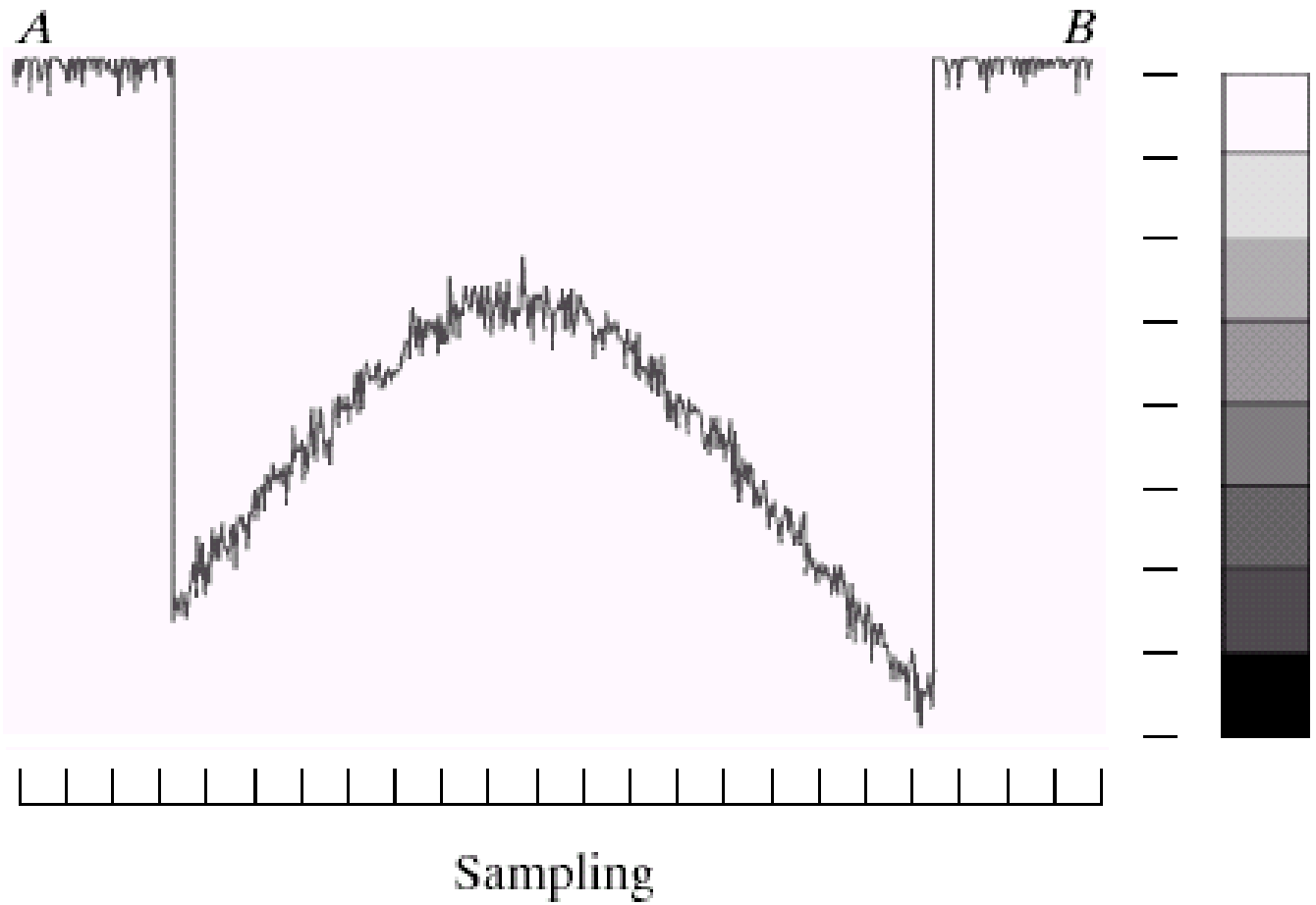
continuous colors mapped to a finite, discrete set of colors.

Sampling and Quantization

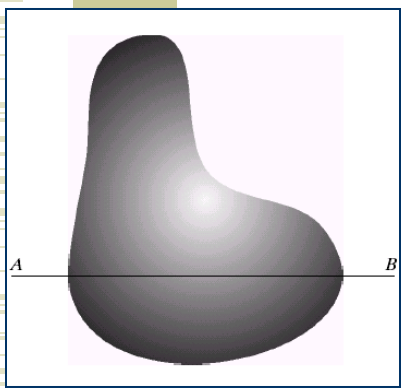


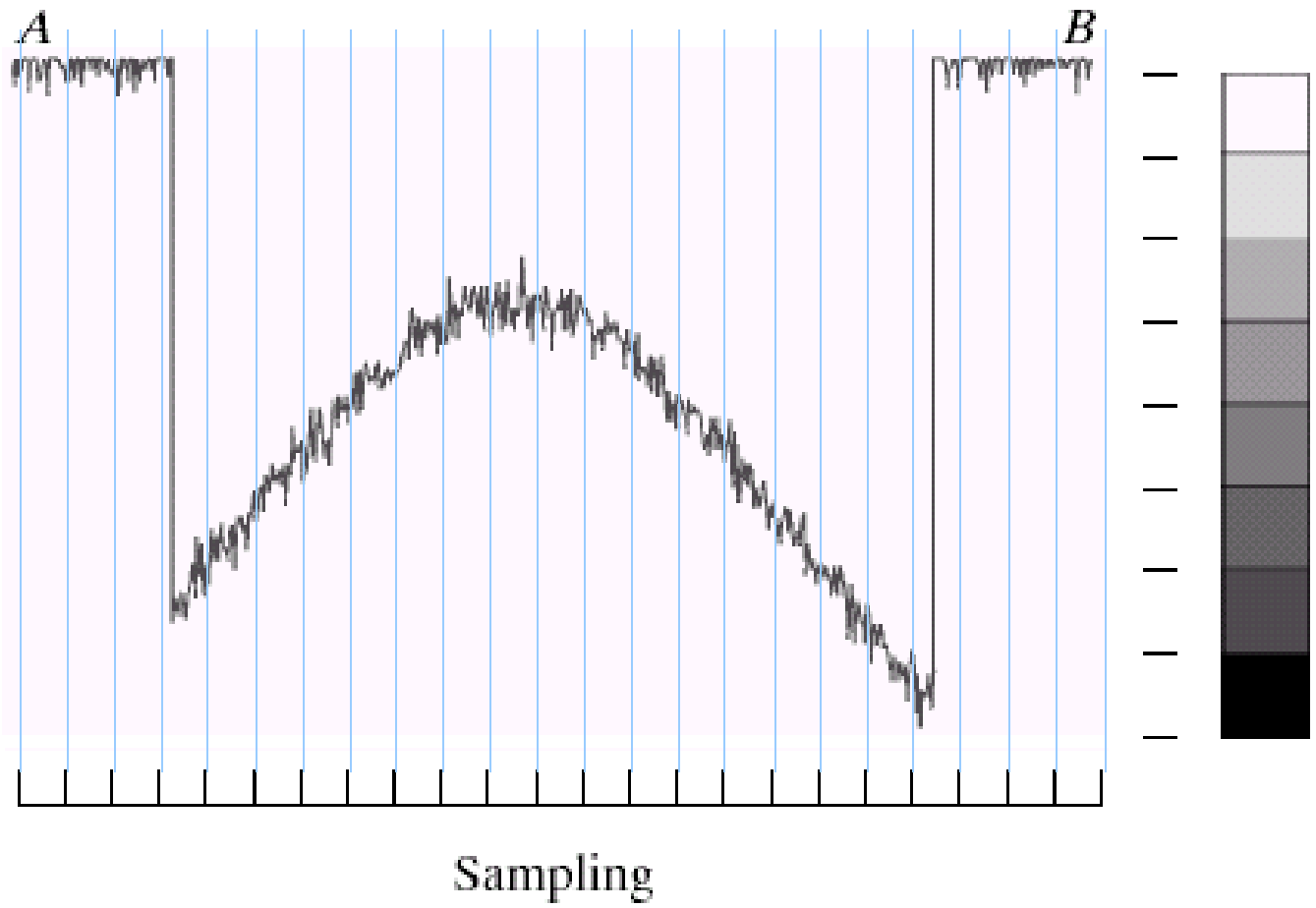
Sampling and Quantization





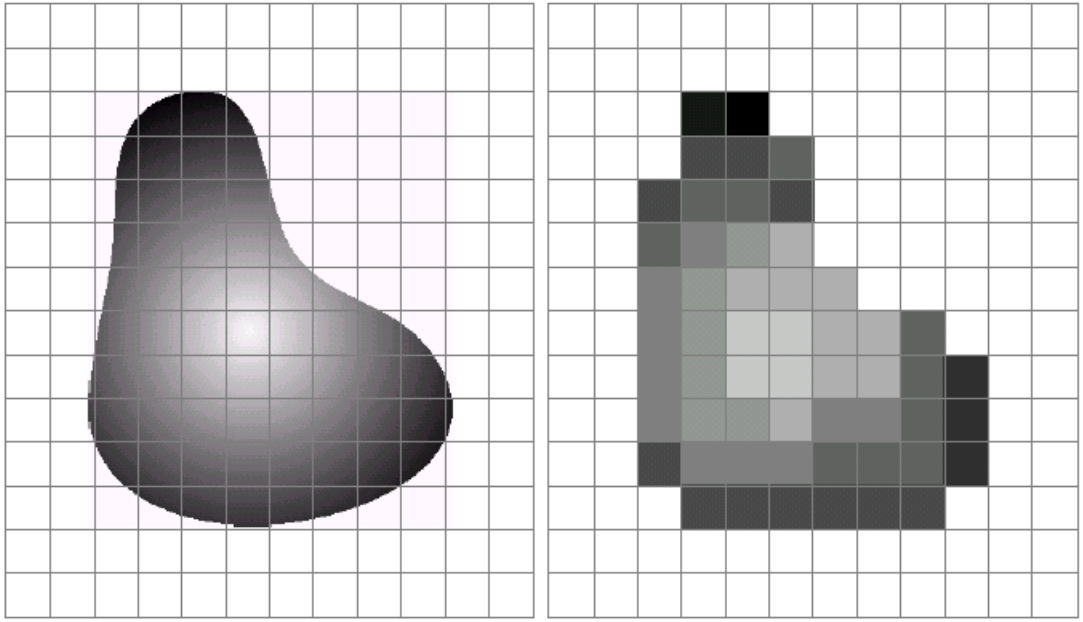
Sampling and Quantization





Sampling and Quantization

- Digital Image is an approximation of a real world scene



Sampling and Quantization

- Sampling:
  - Digitization of the spatial coordinates (x,y)
- Quantization:
  - Digitization in amplitude (also known as gray level quantization)

Sampling and Quantization

- Quantization
  - 8 bit quantization: 2^8 =256 gray levels (0: black, 255: white)
  - 1 bit quantization: 2 gray levels (0: black, 1: white) – binary
- Sampling
  - Commonly used number of samples (resolution)
    - Digital still cameras: 640x480, 1024x1024, up to 4064 x 2704
    - Digital video cameras: 640x480 at 30 frames/second (fps)

Digital Image Representation

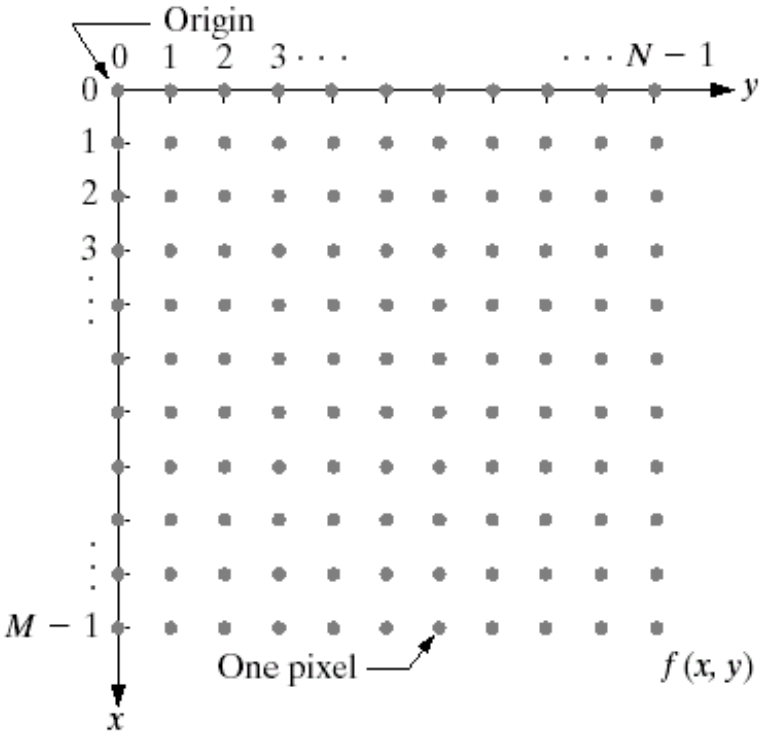
Columns

Rows

$$\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \cdots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

N : No of Columns

M : No of Rows

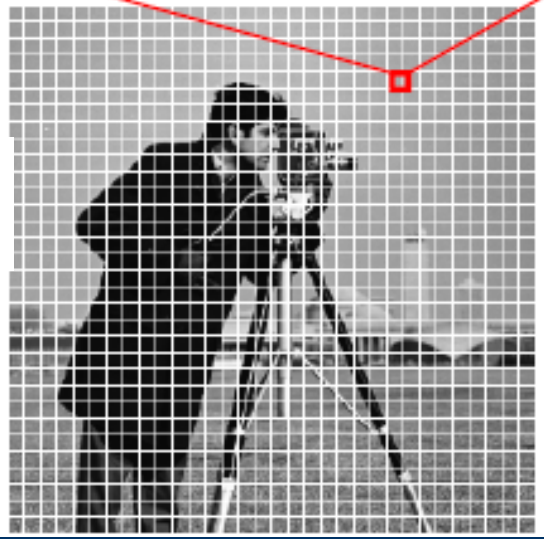


Digital Image Representation

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$$

183	160	94	153	194	163	132	165
183	153	116	176	187	166	130	169
179	168	171	182	179	170	131	167
177	177	179	177	179	165	131	167
178	178	179	176	182	164	130	171
179	180	180	179	183	169	132	169
179	179	180	182	183	170	129	173
180	179	181	179	181	170	130	169

Divided into 8x8 blocks



Digital Image Representation

- Number of intensity levels – An integer power of 2

$$L = 2^k$$

- Intensity levels

$$[0, L-1]$$

- Dynamic range – Range of values spanned by the gray scale

Digital Image Representation

- Image Size
  - Number of bits required to store an image

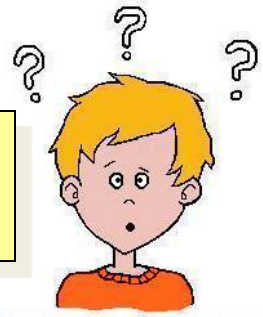
$$b = M \times N \times k$$

  - Image having 2^k intensity levels
    - k – bit image
    - 256 intensity levels – 8 bit image

Spatial Resolution

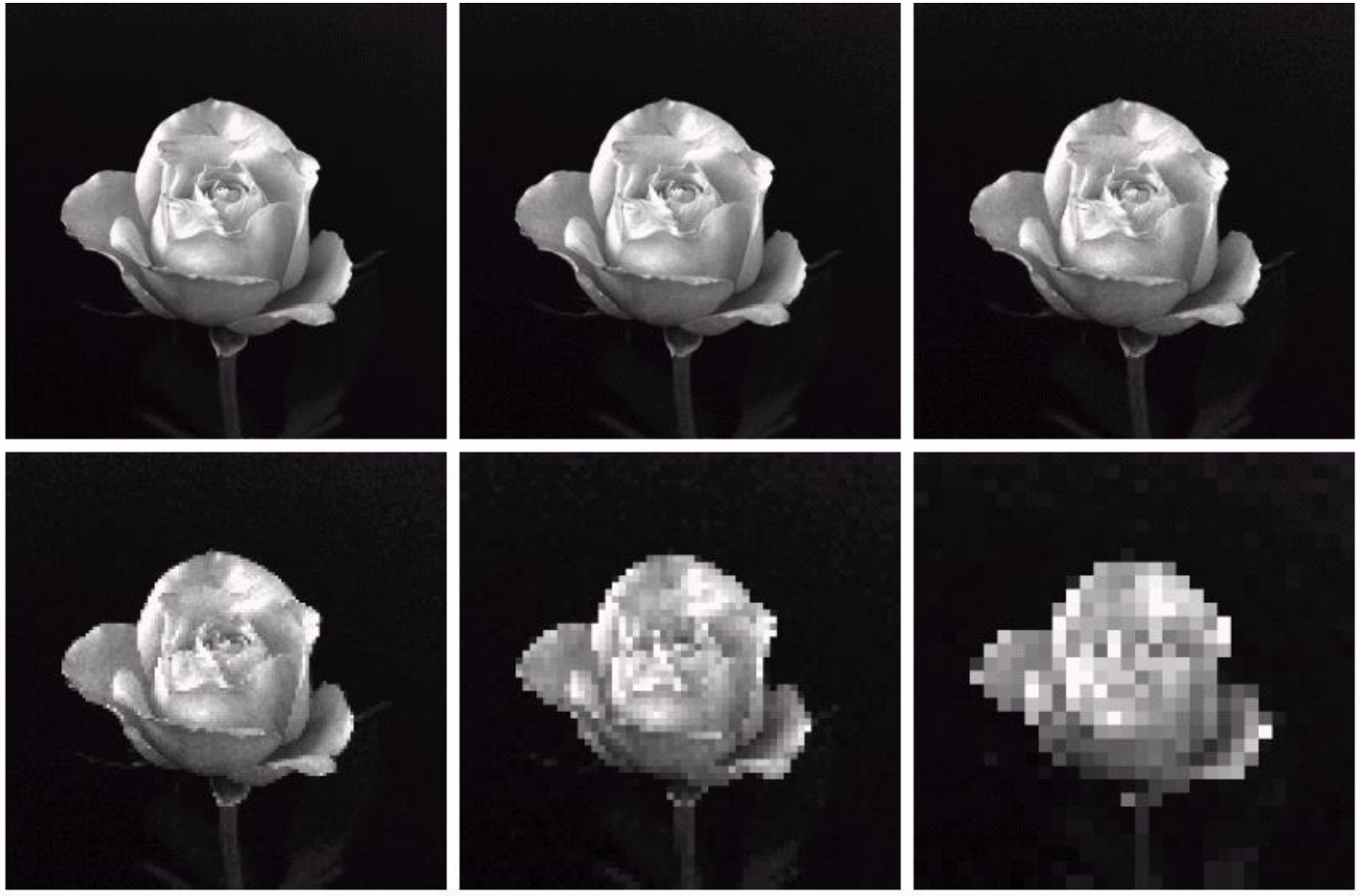
- The *spatial resolution* of an image is determined by how sampling was carried out
- Three measures we come across when talking about Image Size/Resolution
  - Pixel count - e.g 3000x2000 pixels
  - Physical size - e.g. 8" x 10"
  - Resolution - e.g. 240 pixels per inch (PPI)

Difference/Relation between these three?



Spatial Resolution

Spatial Resolution



Intensity Level Resolution

- *Intensity level resolution* refers to the number of intensity levels used to represent the image
  - The more intensity levels used, the finer the level of detail discernable in an image
  - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

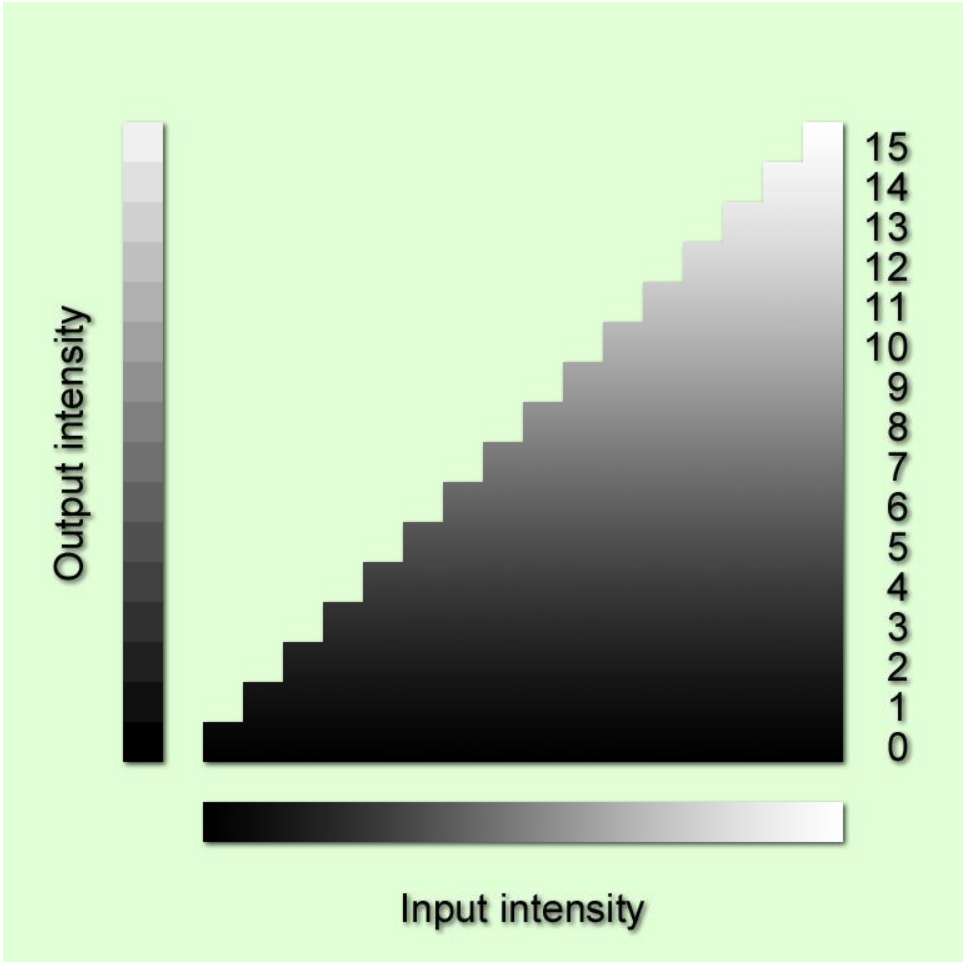
Intensity Level Resolution

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

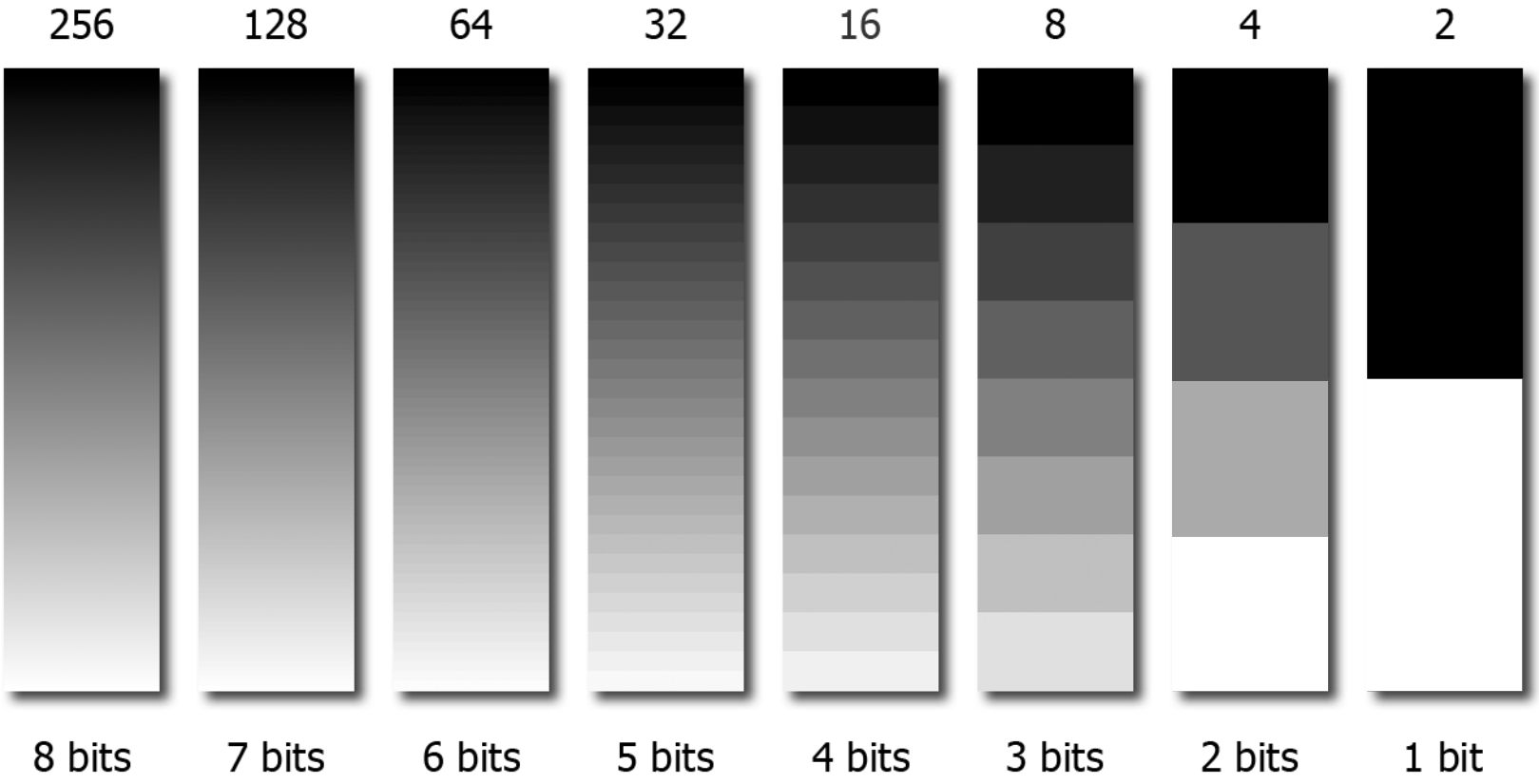
Intensity Level Resolution

16 million colors

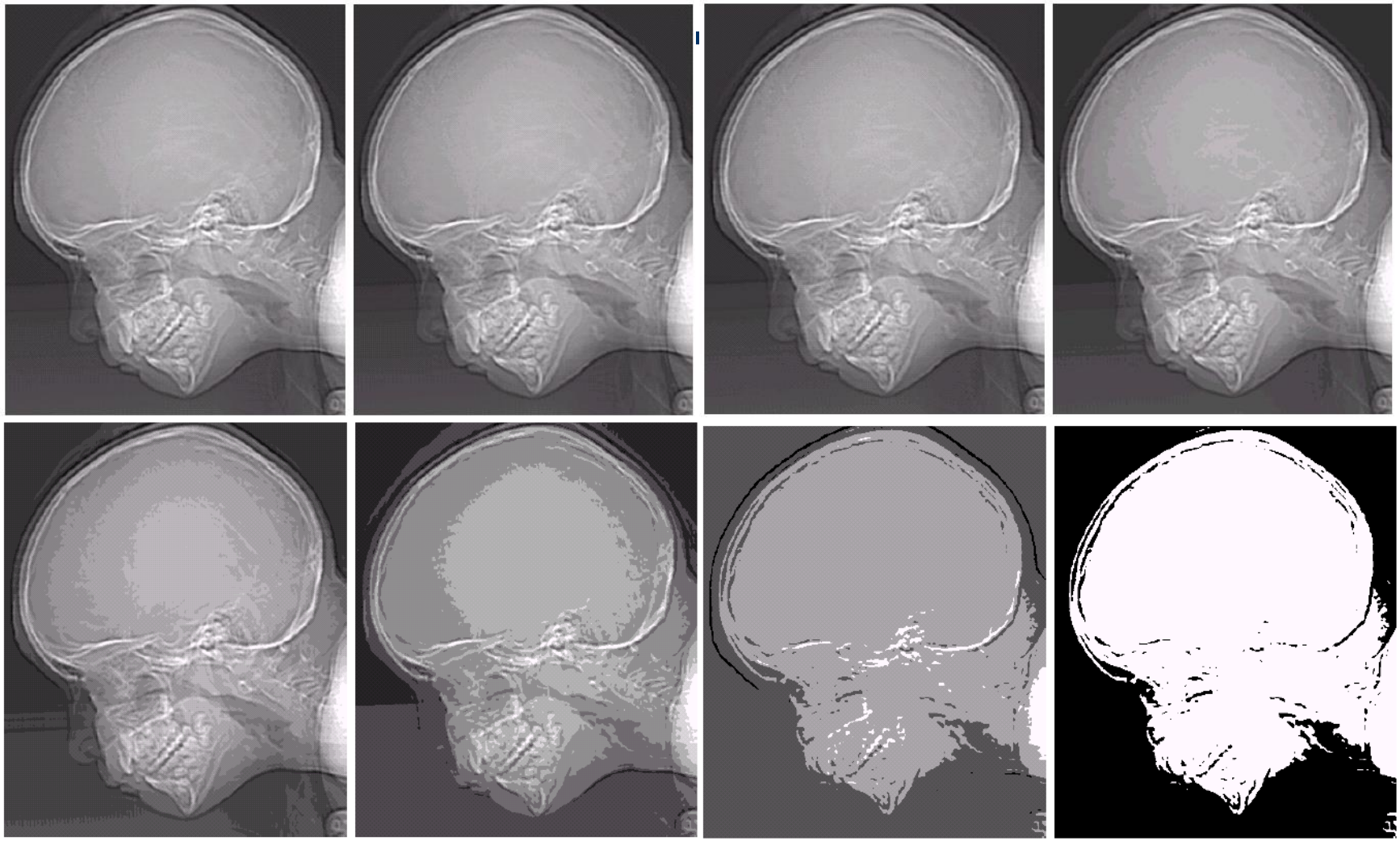
16 colors



Intensity Level Resolution



Intensity Level Resolution



Intensity Level Resolution

8 bits 256 levels

7 bits 128 levels

6 bits 64 levels

5 bits 32 levels

4 bits 16 levels

3 bits 8 levels

2 bits 4 levels

1 bit 2 levels

Resolution: How much is enough?

- How many samples and gray levels are required for a good approximation?
  - Quality of an image depends on number of pixels and gray-level number
  - The more these parameters are increased, the closer the digitized array approximates the original image
  - But: Storage & processing requirements increase rapidly as a function of N, M, and k

Resolution: How much is enough?

- Depends on what is in the image and what you would like to do with it

The picture on the right is fine for counting the number of cars, but not for reading the number plate

Acknowledgements

- Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2002
- Peters, Richard Alan, II, Lectures on Image Processing, Vanderbilt University, Nashville, TN, April 2008
- Brian Mac Namee, Digitial Image Processing, School of Computing, Dublin Institute of Technology
- Computer Vision for Computer Graphics, Mark Borg

Material in these slides has been taken from, the following resources