

COL7655

Foundations of Visual Computing

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Sampling and Quantization

Thanks to Rahul Narain for help with slides

Image Formation

Directly viewing a scene

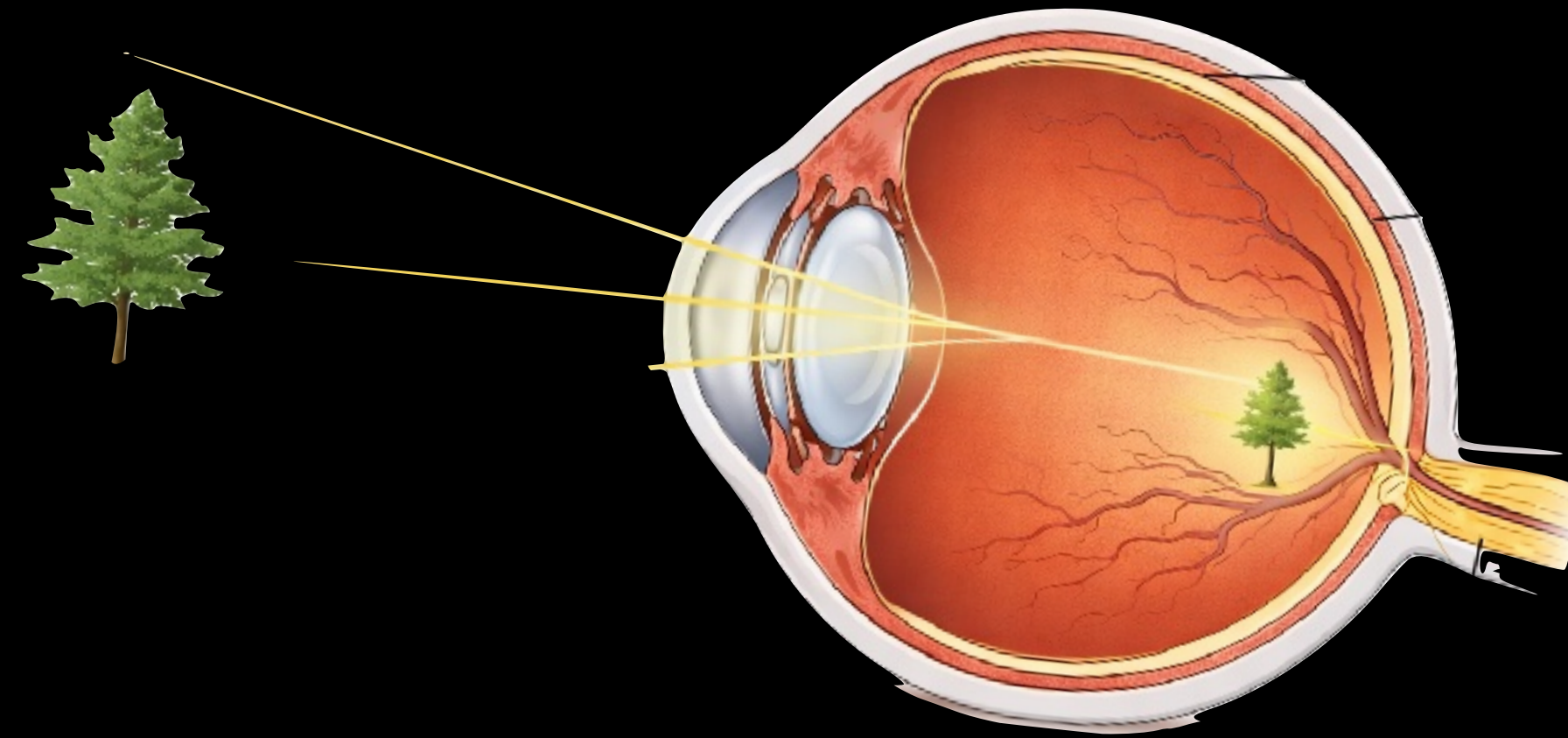
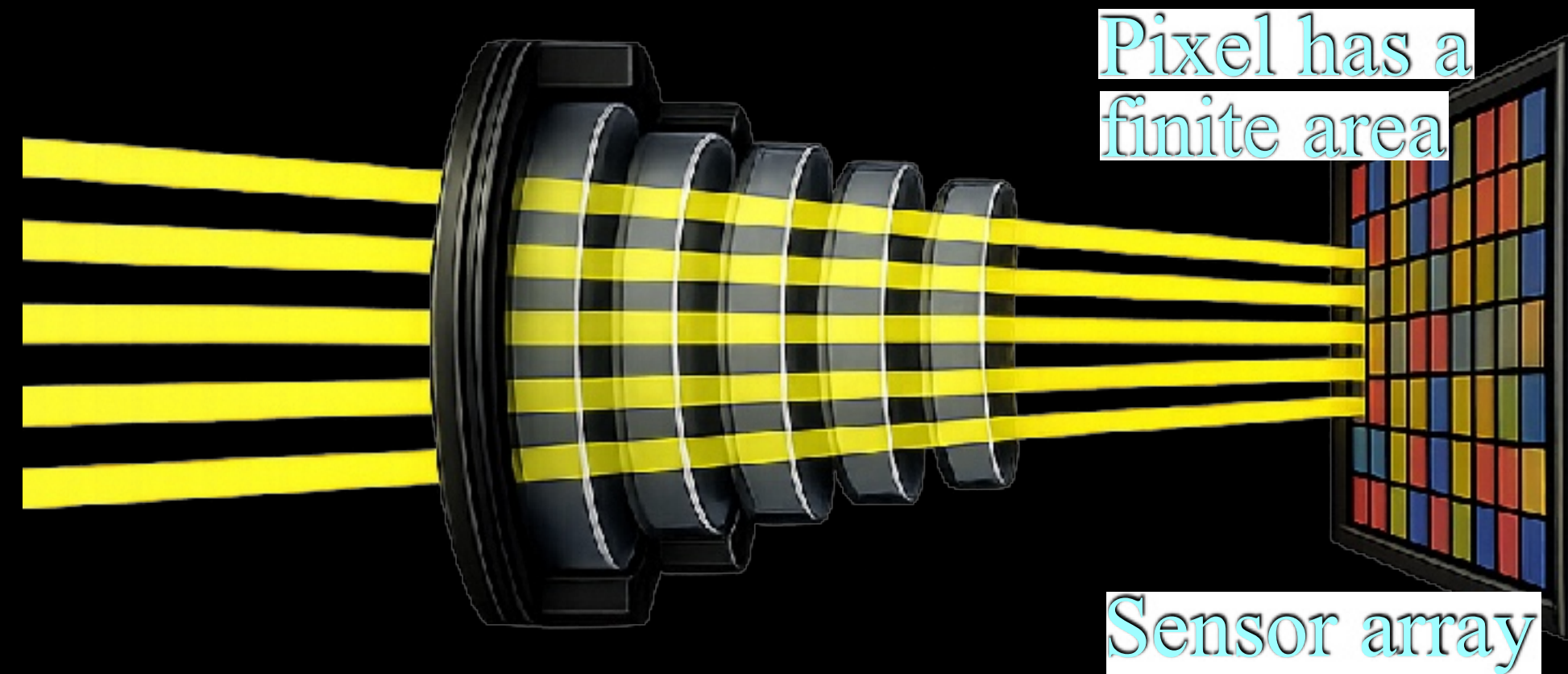
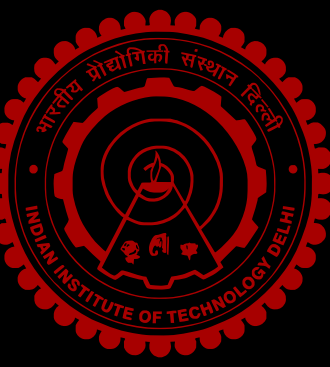
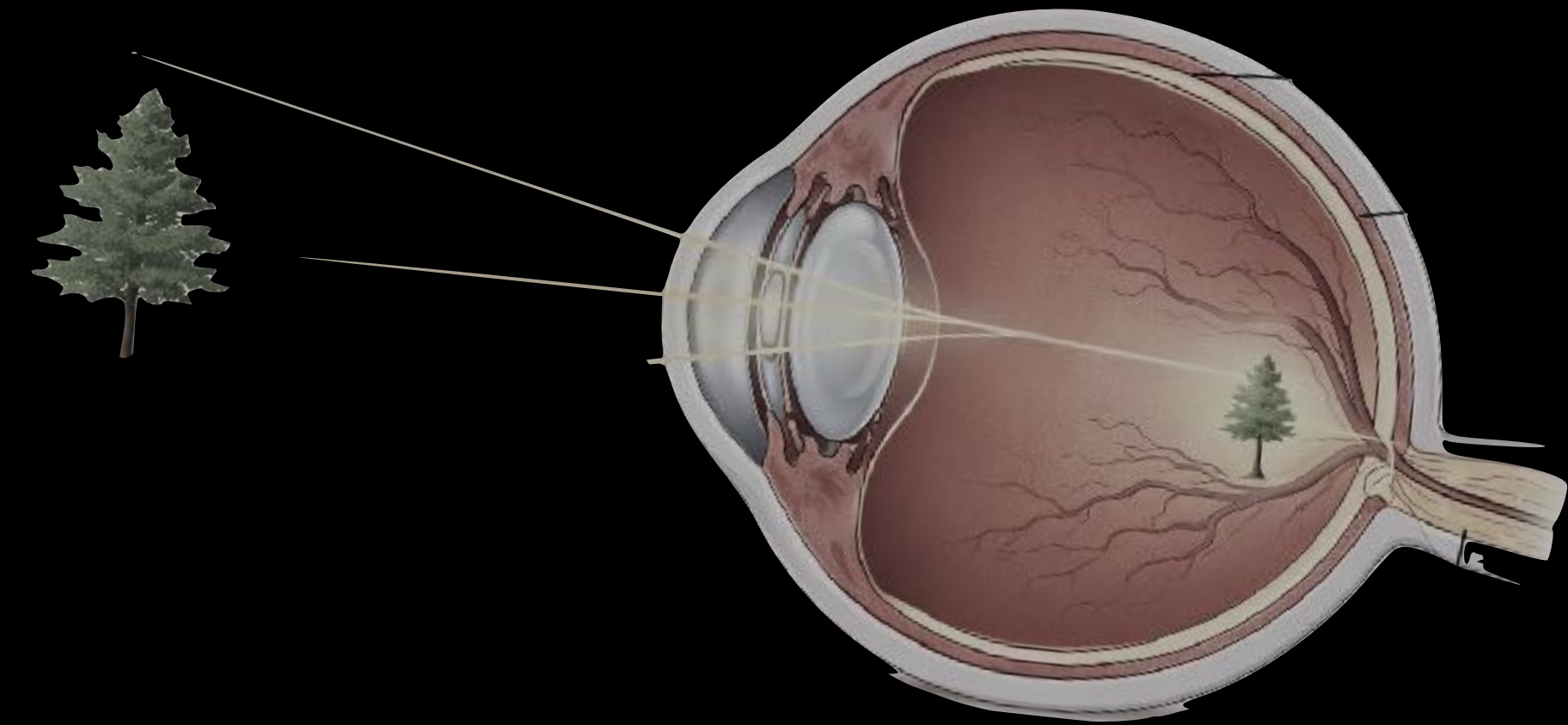


Image Formation

A visual pipeline

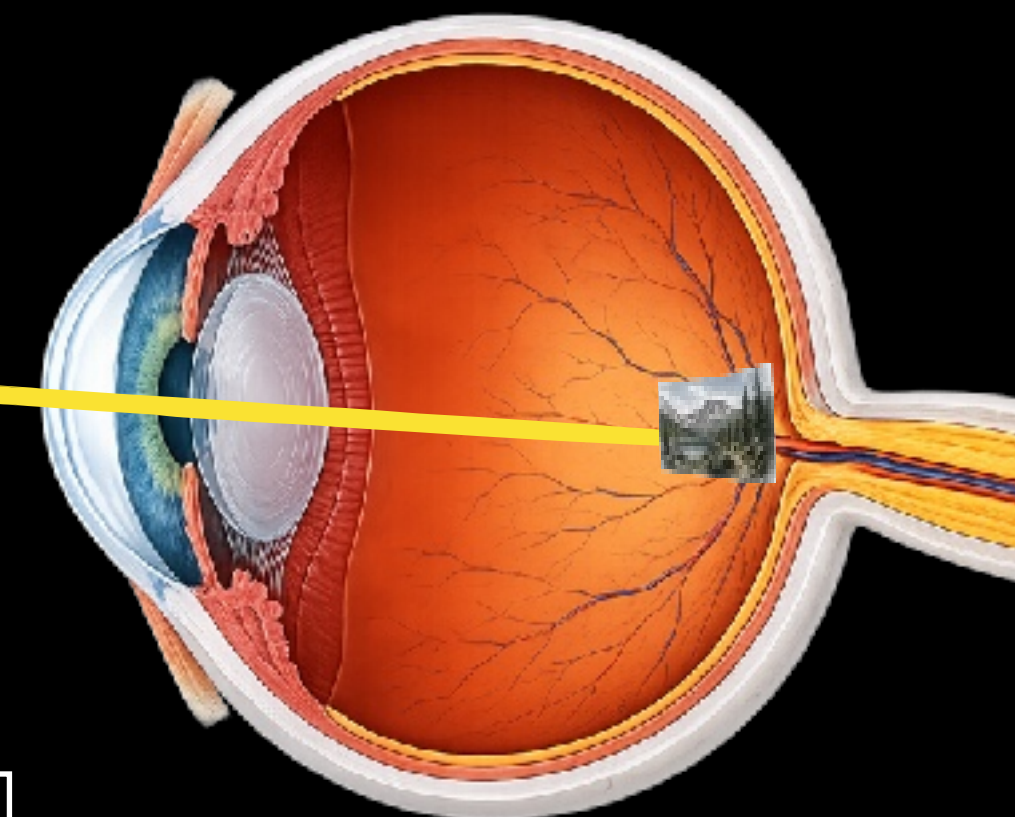


File rendered on screen
with samples rendered
as finite area pixels



Real scene is sampled on
CCD/CMOS photosensor array

May be saved in a file,
one color per sample



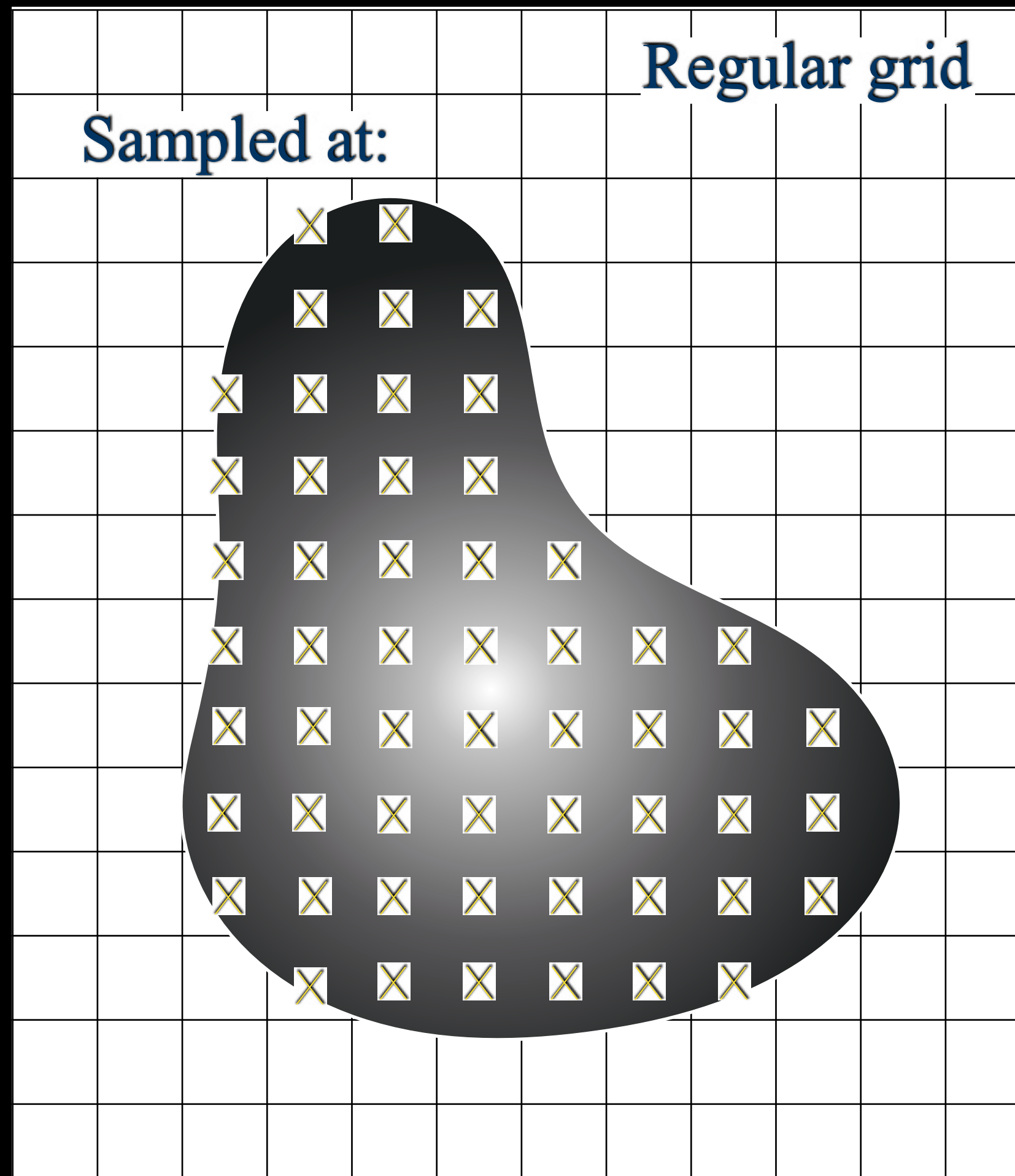
Light sampled on eye's
(discrete) photosensors
with a "smooth" image
finally perceived.

Several Continuous $\leftrightarrow$ Discrete conversions

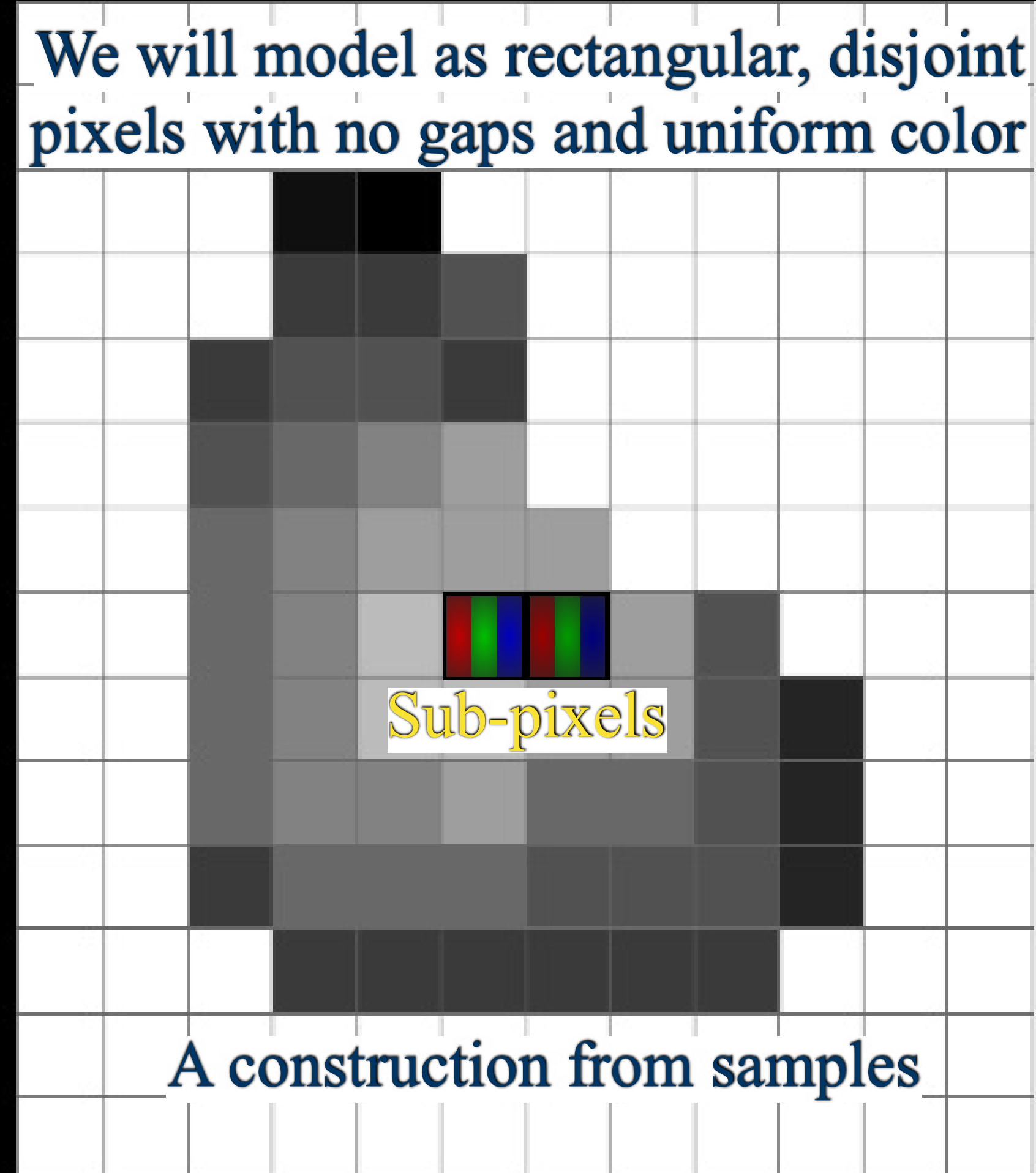
Spatial Resolution

- Images are a set of pixel values sampled on a uniform grid
- Resolution = minimum separable distance (Typical human resolution: $\sim .3' - .5'$)
 - Minimum distance between two “points” that appear distinct
- Image resolution measures resolvable detail in image
 - Relates to sampling rate: pixels per inch, e.g.
- “Well” sampled image means two neighboring pixels cannot be told apart
 - Or, barely told apart

Continuous vs. Discrete images

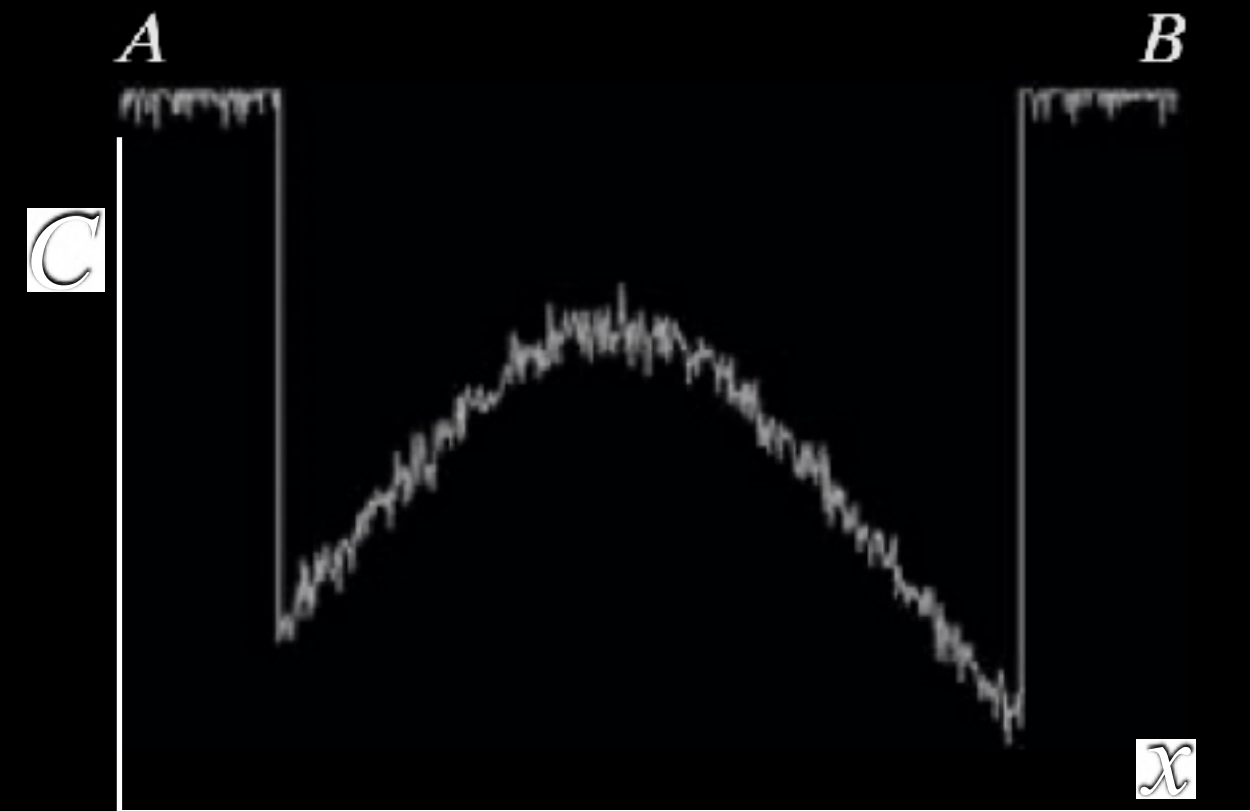
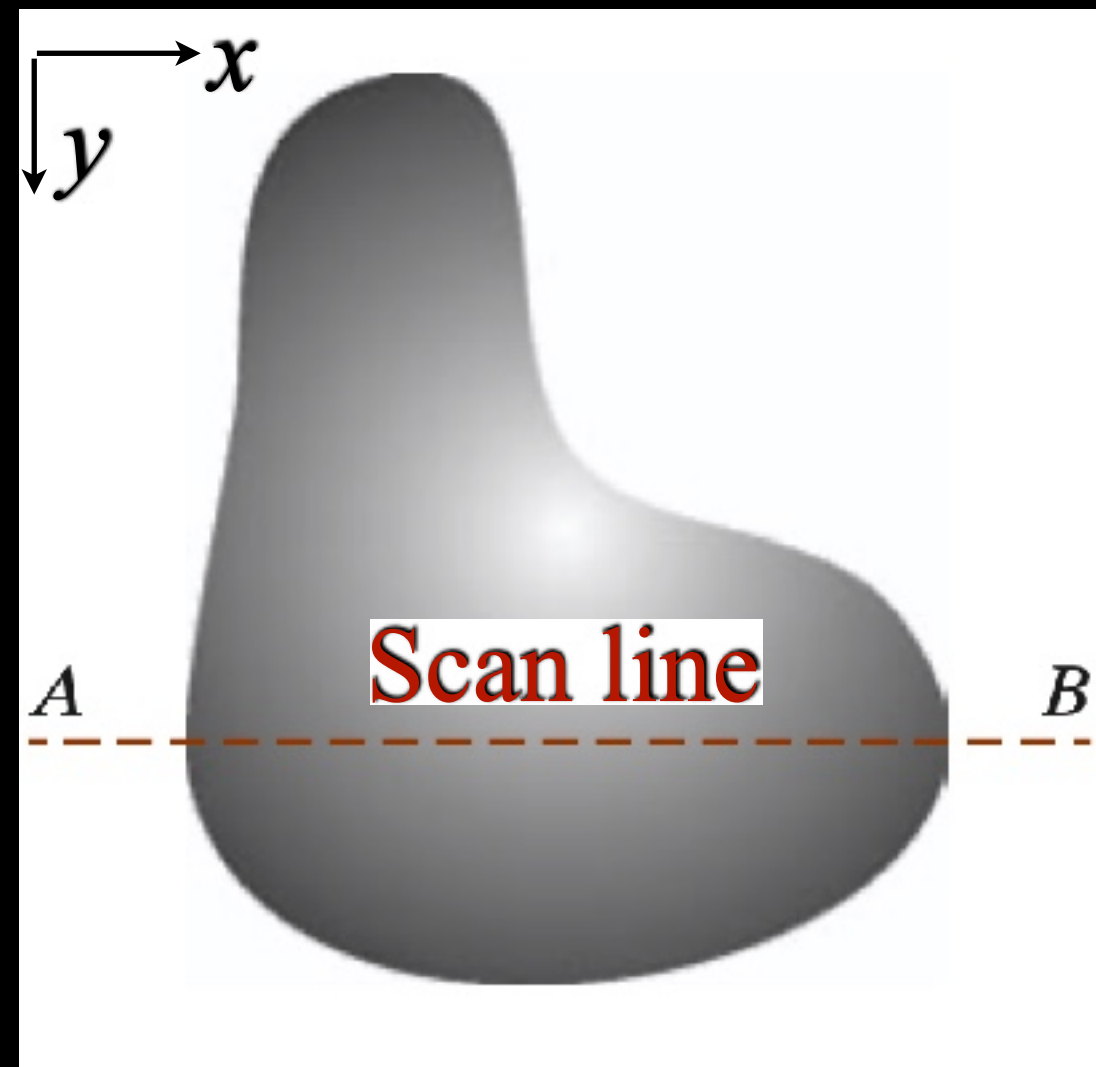


Continuous Image



Sampled and Quantized

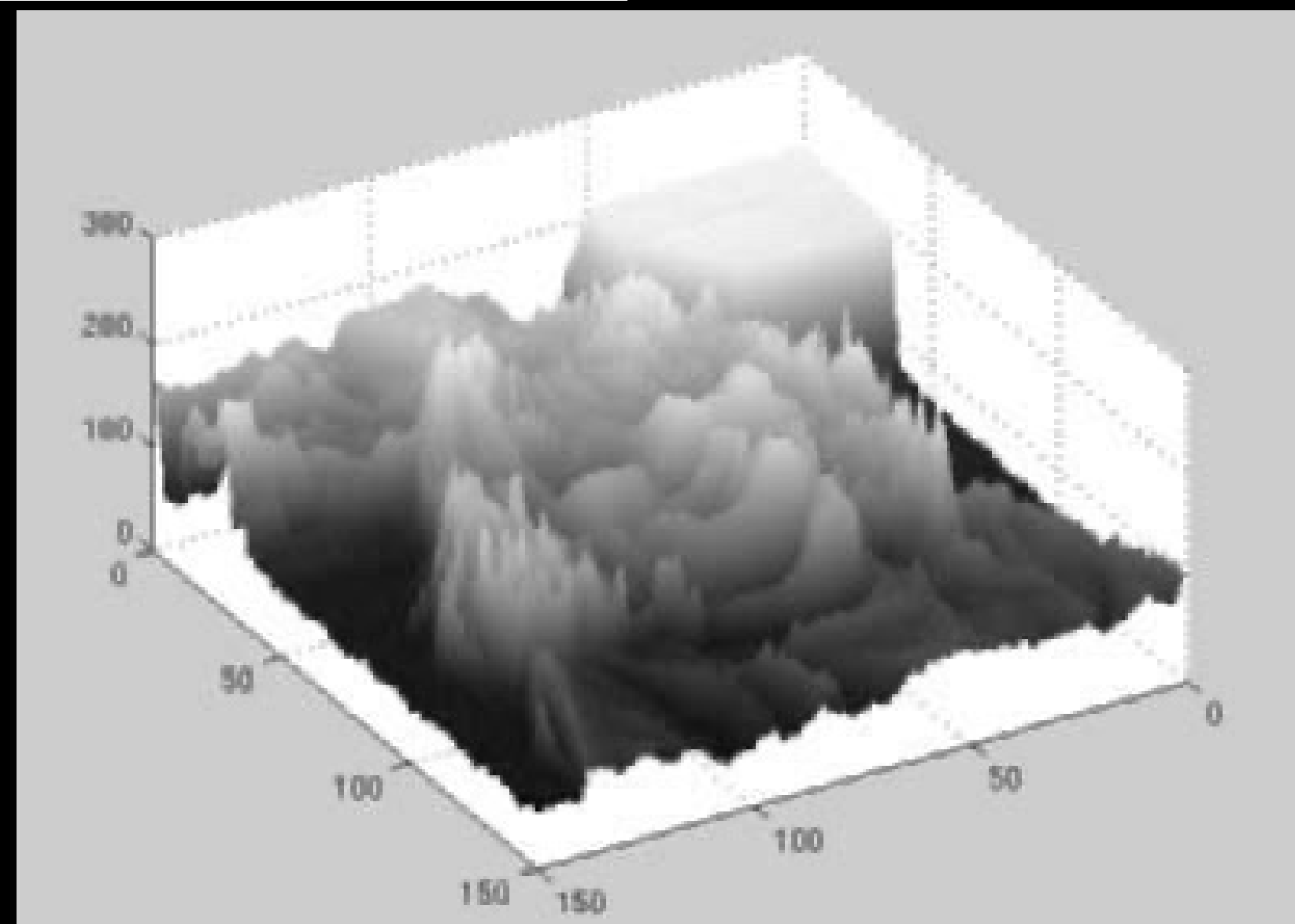
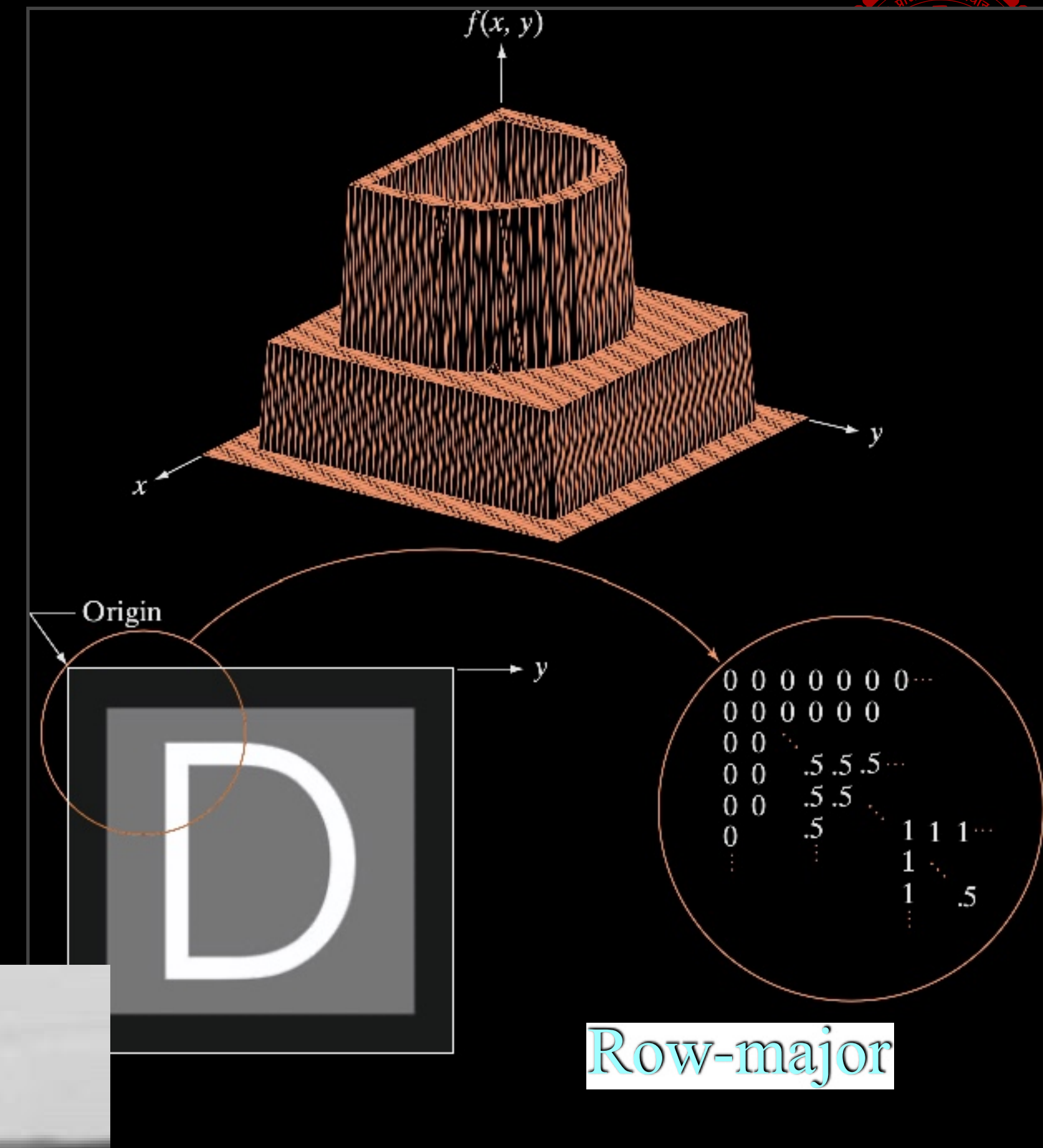
Sampling and Quantization



Continuous image

function:

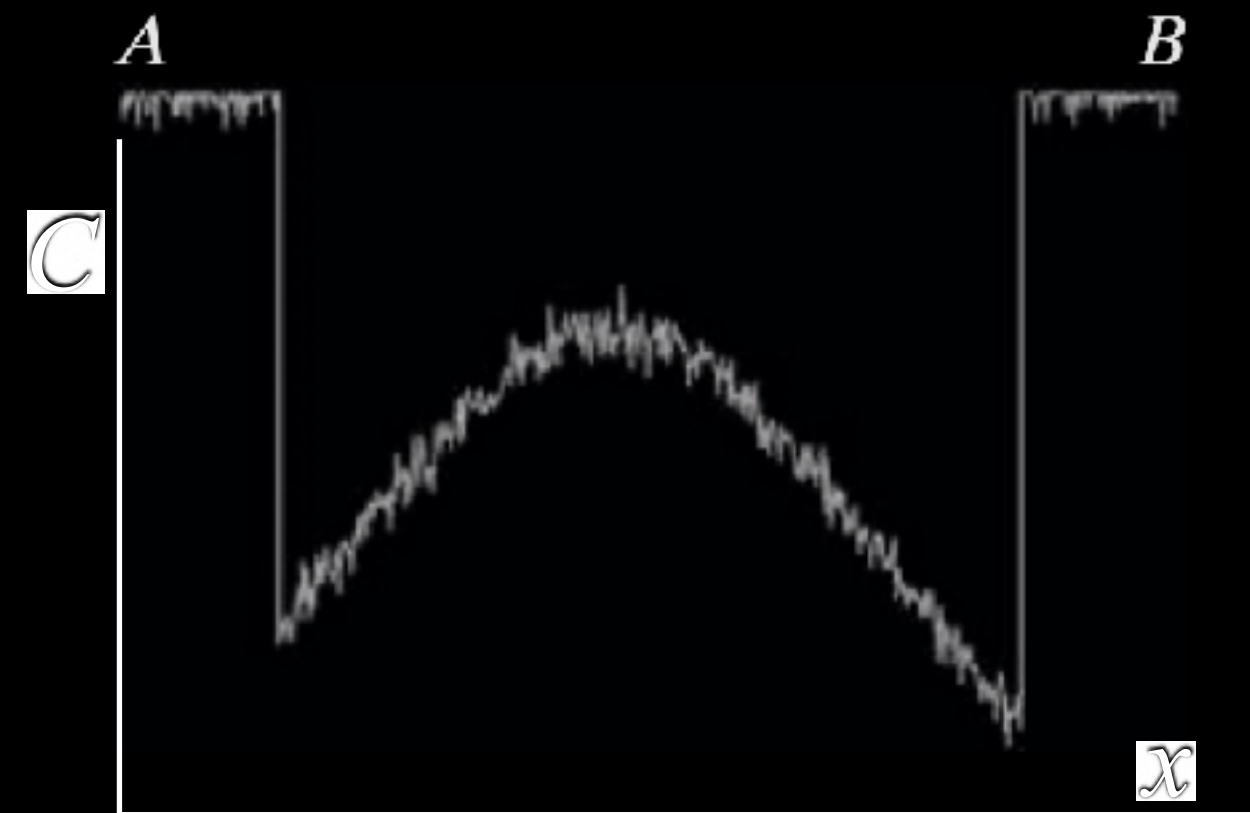
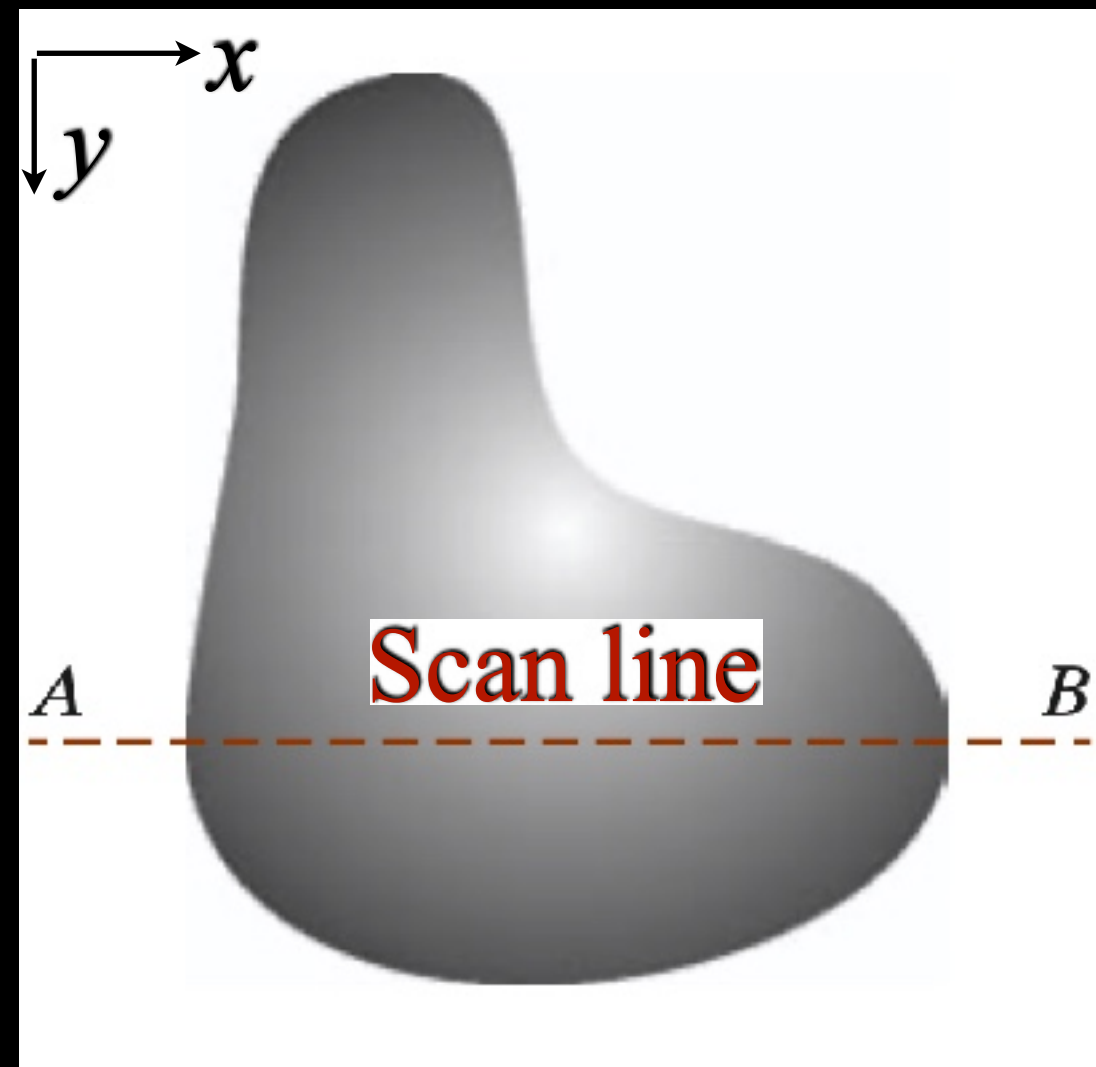
$f(x, y)$ (x, y in some range)



Sonka et al., Image Processing, Analysis, and Machine Vision



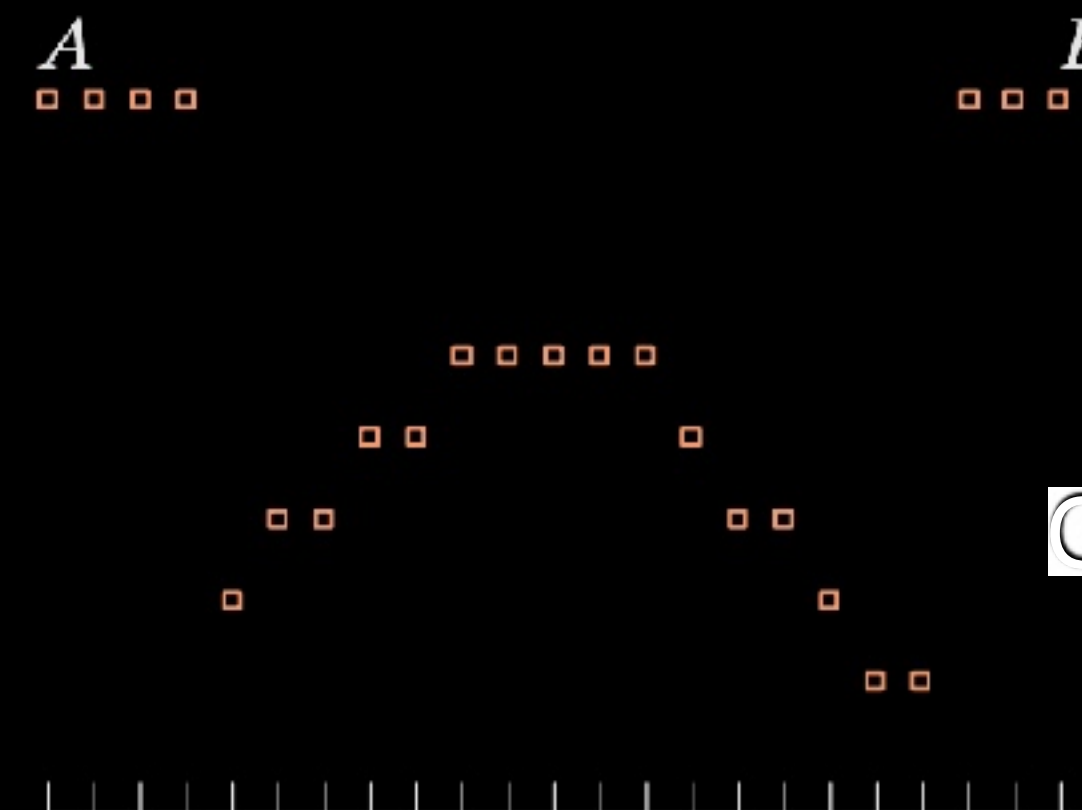
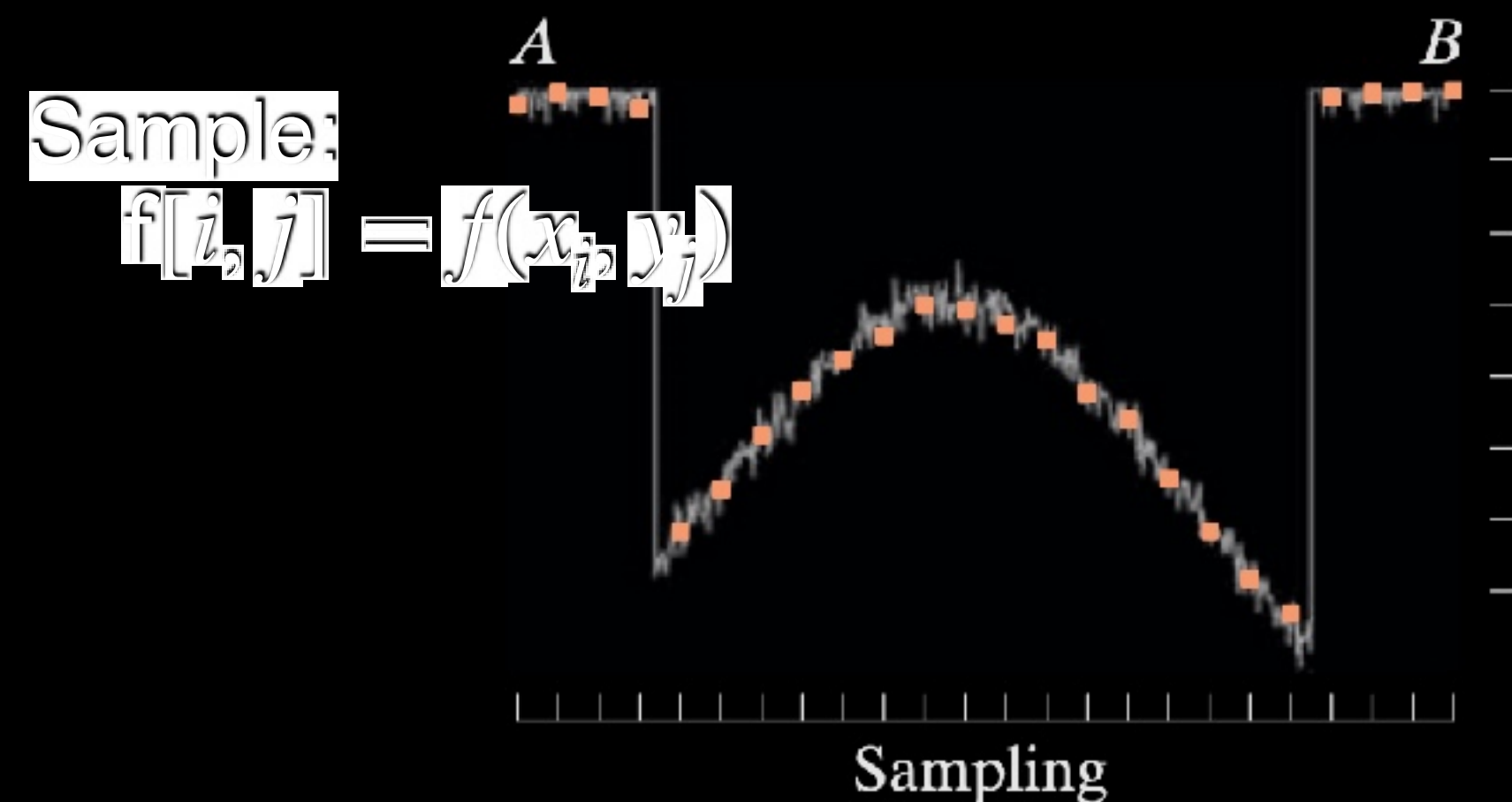
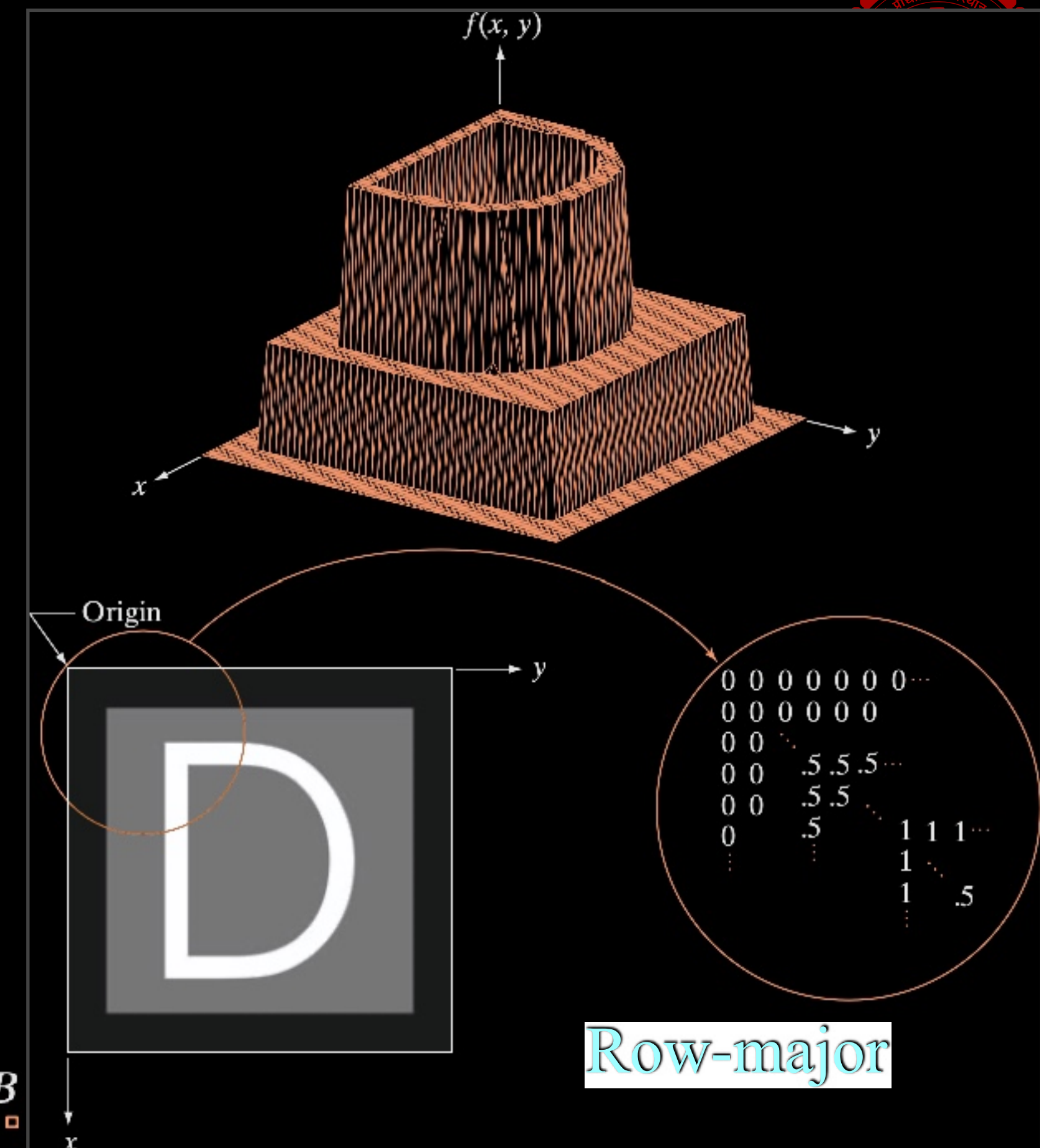
Sampling and Quantization



Continuous image

function:

$f(x, y)$ (x, y in some range)



Quantize:

$$I[i, j] = \text{round}(f[i, j] + n)$$

noise

Sampling Controls Spatial Resolution

- Recall, image resolution is about perceivable detail
 - Image resolution $\neq$ Image size (number of pixels)
 - Image can be scaled to display



High-res scan of stamp:

300 pixels / inch

514 $\times$ 370 pixels

Low-res image of A4 sheet:

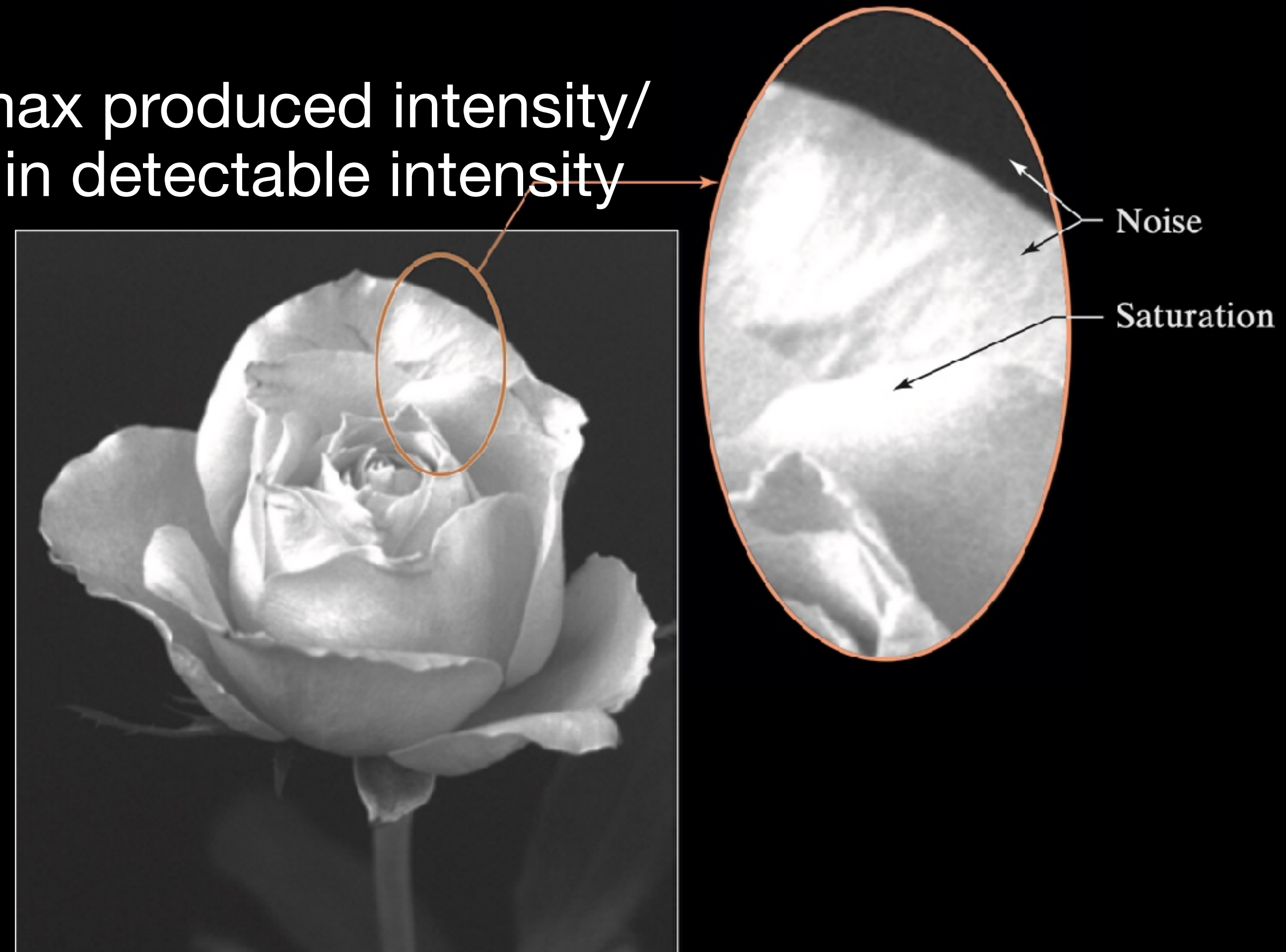
72 pixels / inch

842 $\times$ 595 pixels



Quantization Controls Color Resolution

- *Dynamic range* of imaging system = max produced intensity / min detectable intensity
- Total *contrast* of image = max - min intensity
- Recall 2^b levels are used for some b
 - e.g., equally spaced
 - Issues: saturation, noise, quantization





256 levels



128 levels



64 levels



32 levels



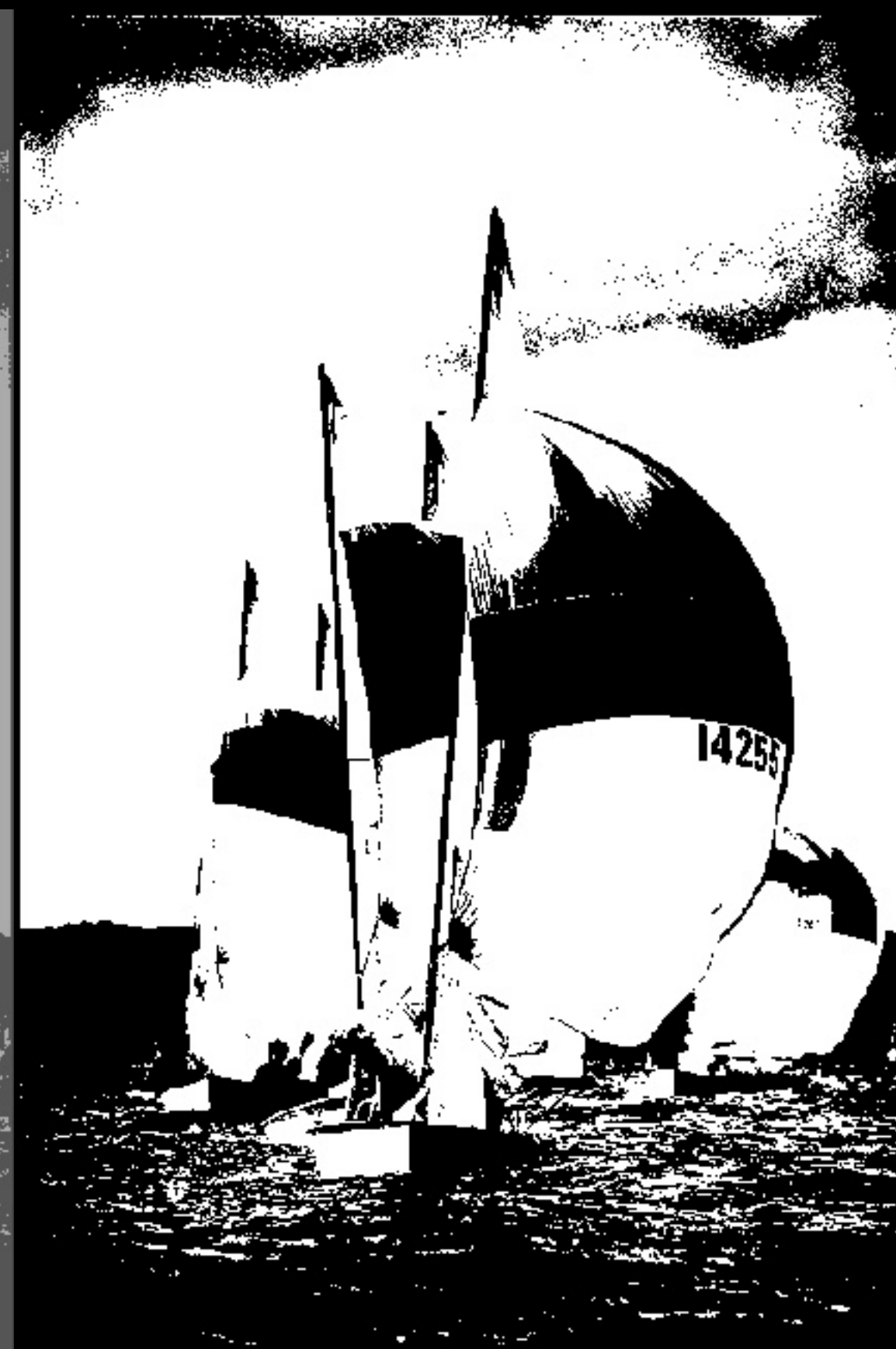
16 levels



8 levels



4 levels

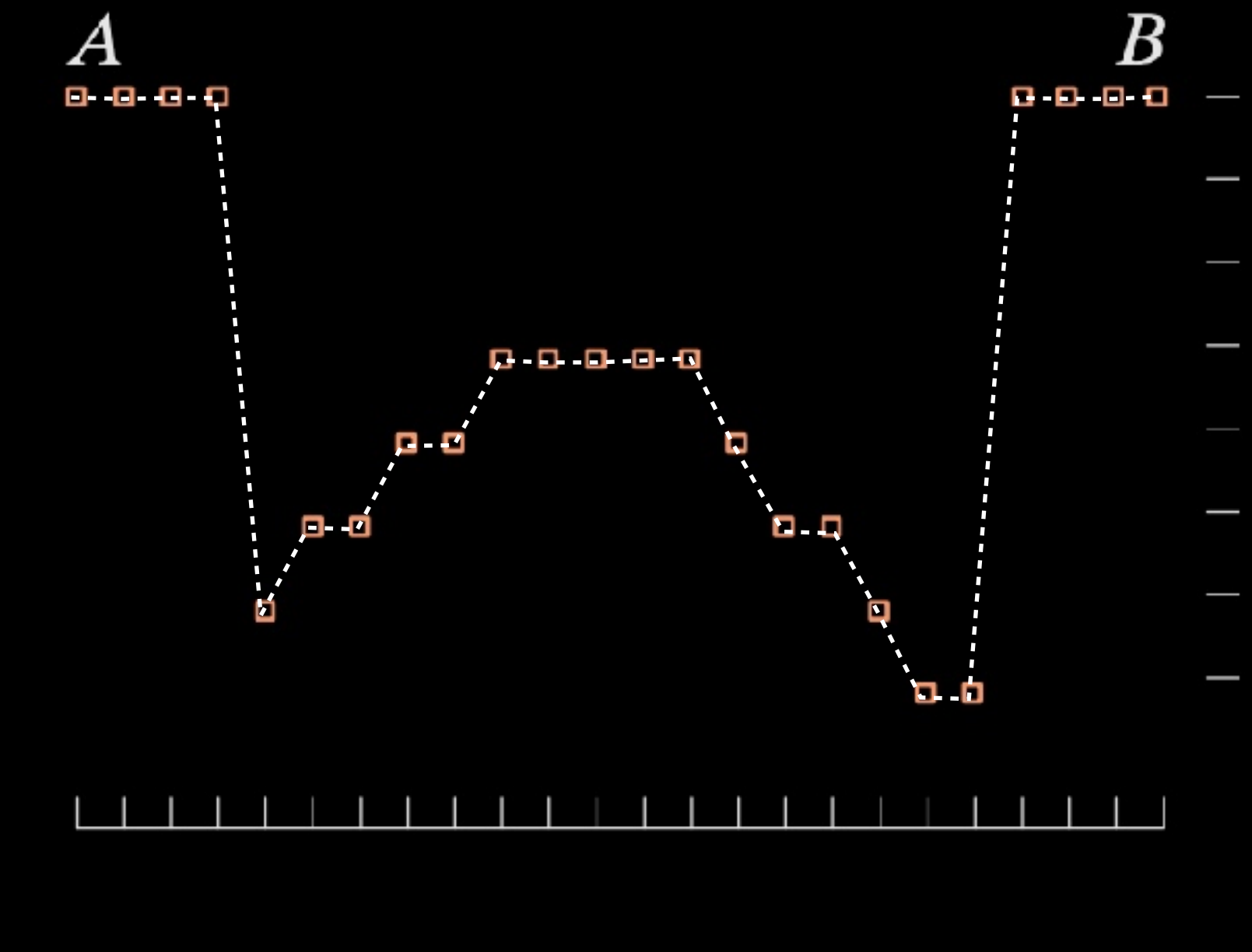
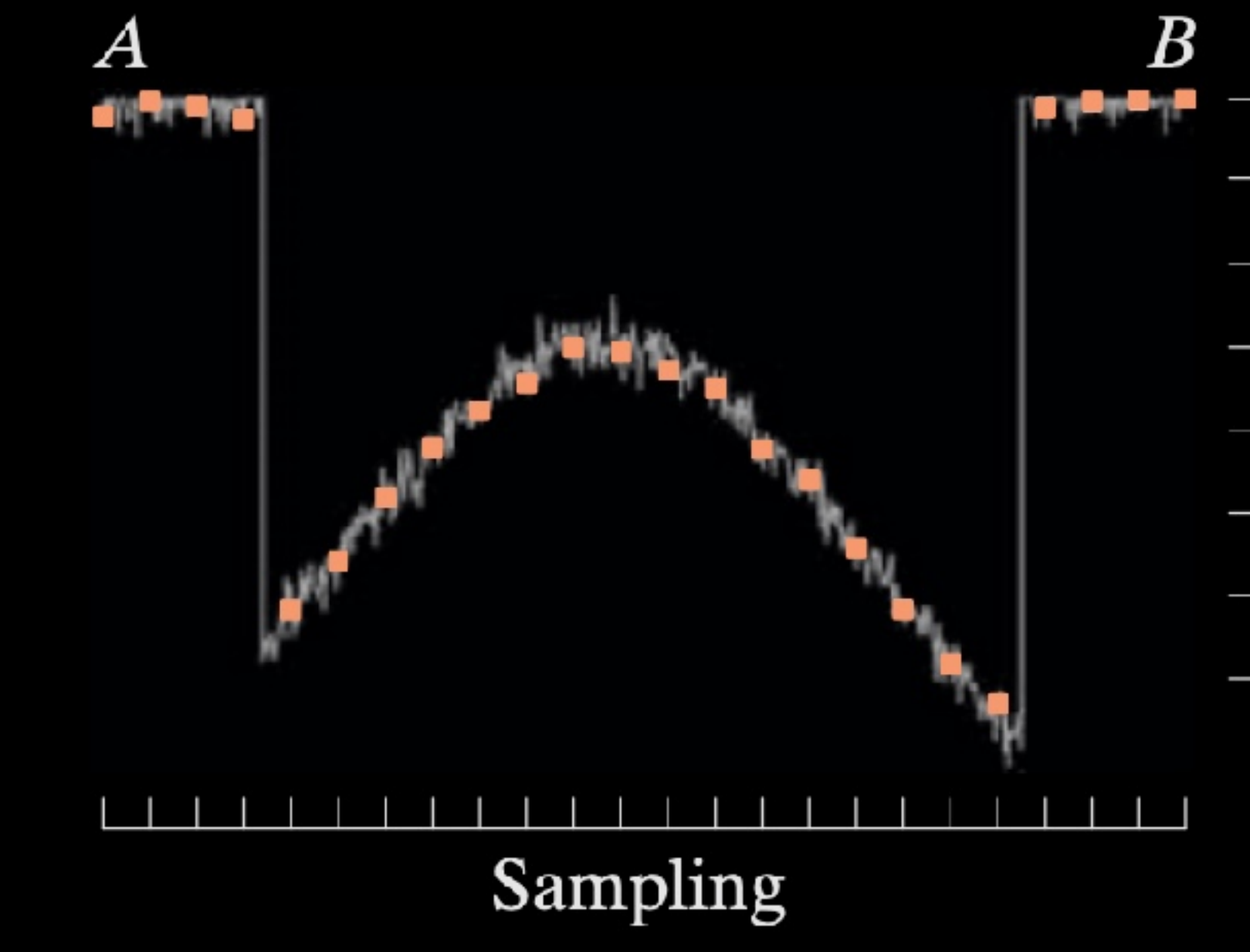


2 levels

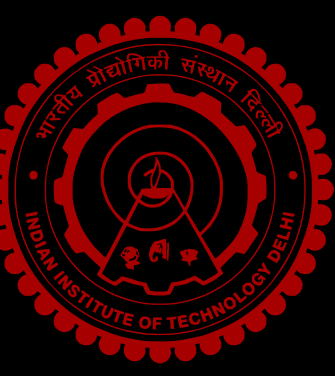
Interpolation

Resample: Find values in between samples

- How to rescale an image to a different size (zooming / shrinking)?

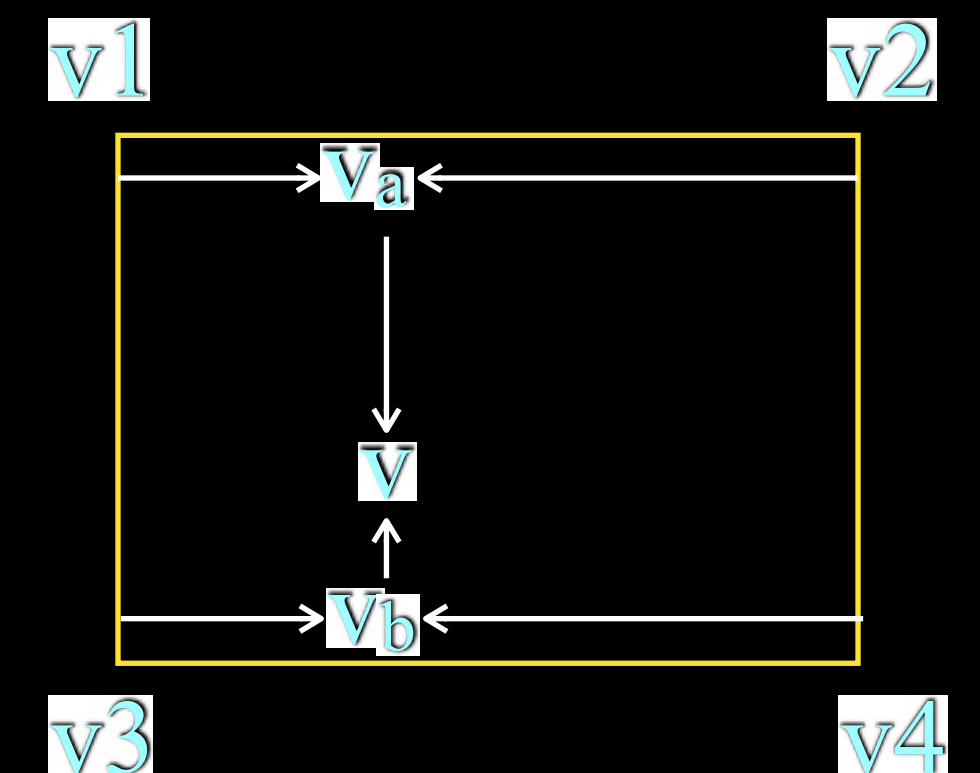


- In effect, estimate $f[x, y]$ at non-integer x, y



Types of Interpolation

- **Nearest neighbour:** Copy from nearest sample $f[i, j]$ where $i = \text{round}(x)$, $j = \text{round}(y)$
- Linear interpolation in one dimension (using two nearest samples)
 - Take values at 2 nearest samples $i_0 = \lfloor x \rfloor$, $i_1 = i_0 + 1$
 - Fit linear polynomial $f(x) = ax + b$ to sample values $f(i_0)$ and $f(i_1)$
- **Bilinear interpolation:** (in 2D, using four nearest samples)
 - interpolate separately in x and y
 - i.e., fit polynomial $f(x, y) = axy + bx + cy + d$ to 4 nearest samples
- **Bicubic interpolation:** Use cubic polynomial instead (in x and y)



((Combines more than
4 nearest samples))