Robotic Mapping & Localization

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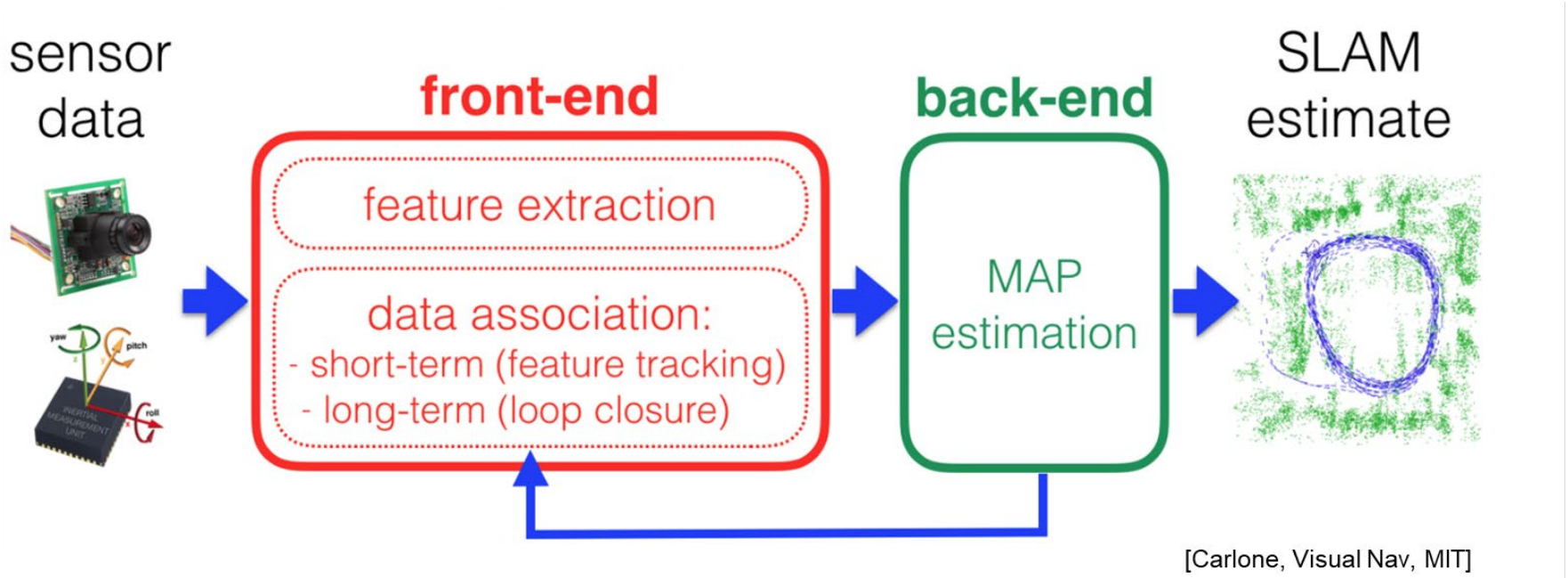
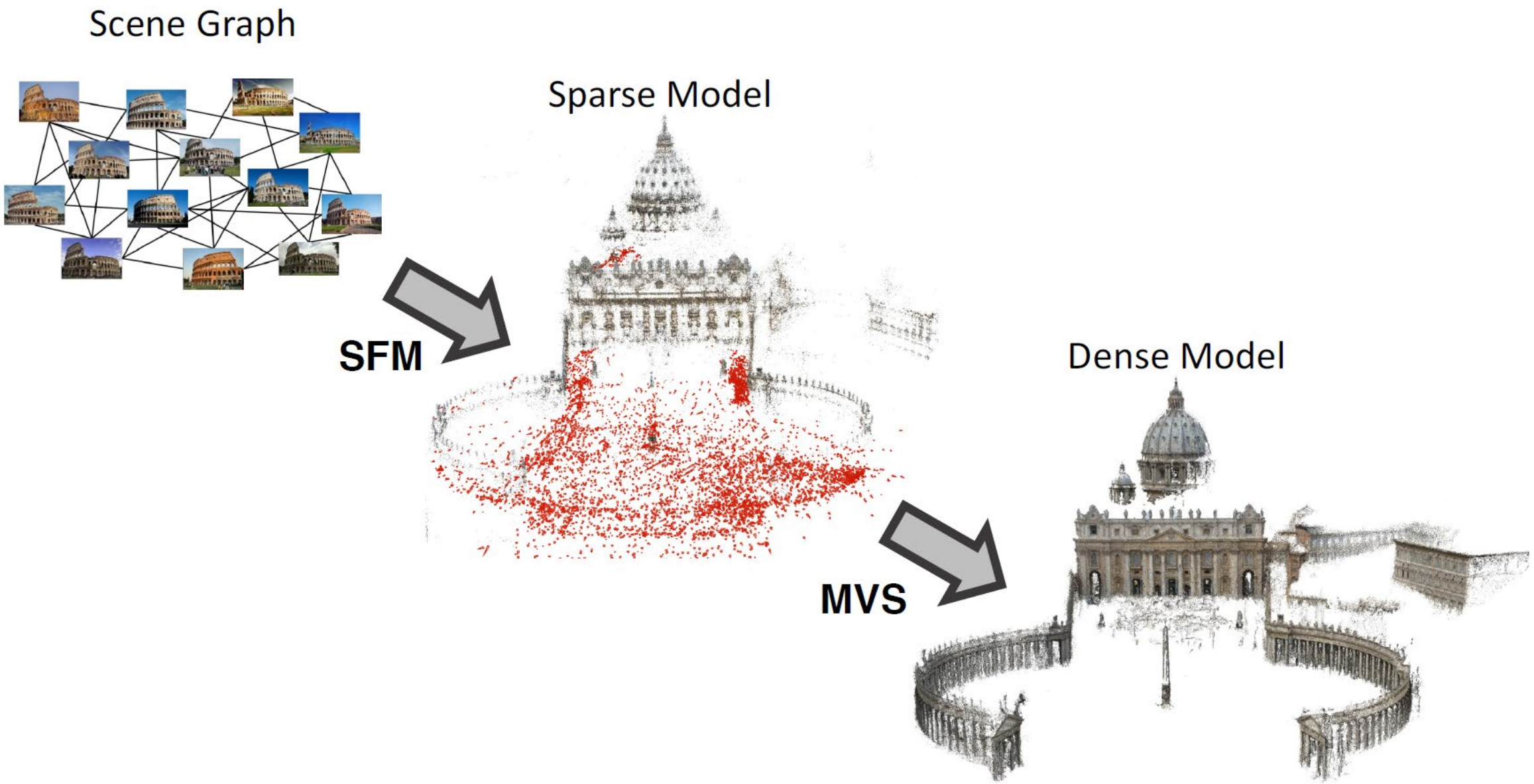
Lec03: Image & Camera

Review

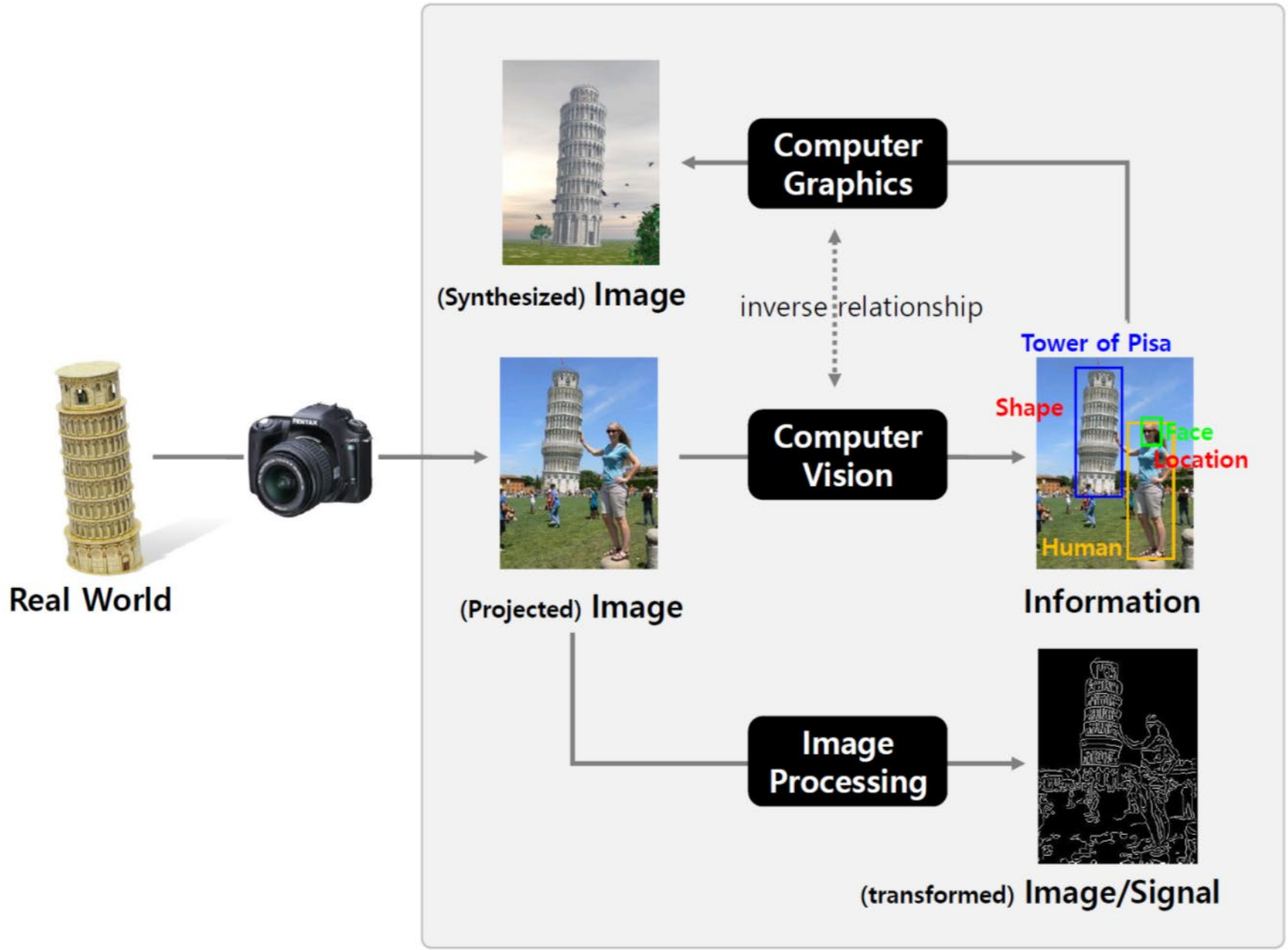


- A SLAM pipeline consists of
  - Sensors
  - Frontend algorithms
  - Backend algorithms

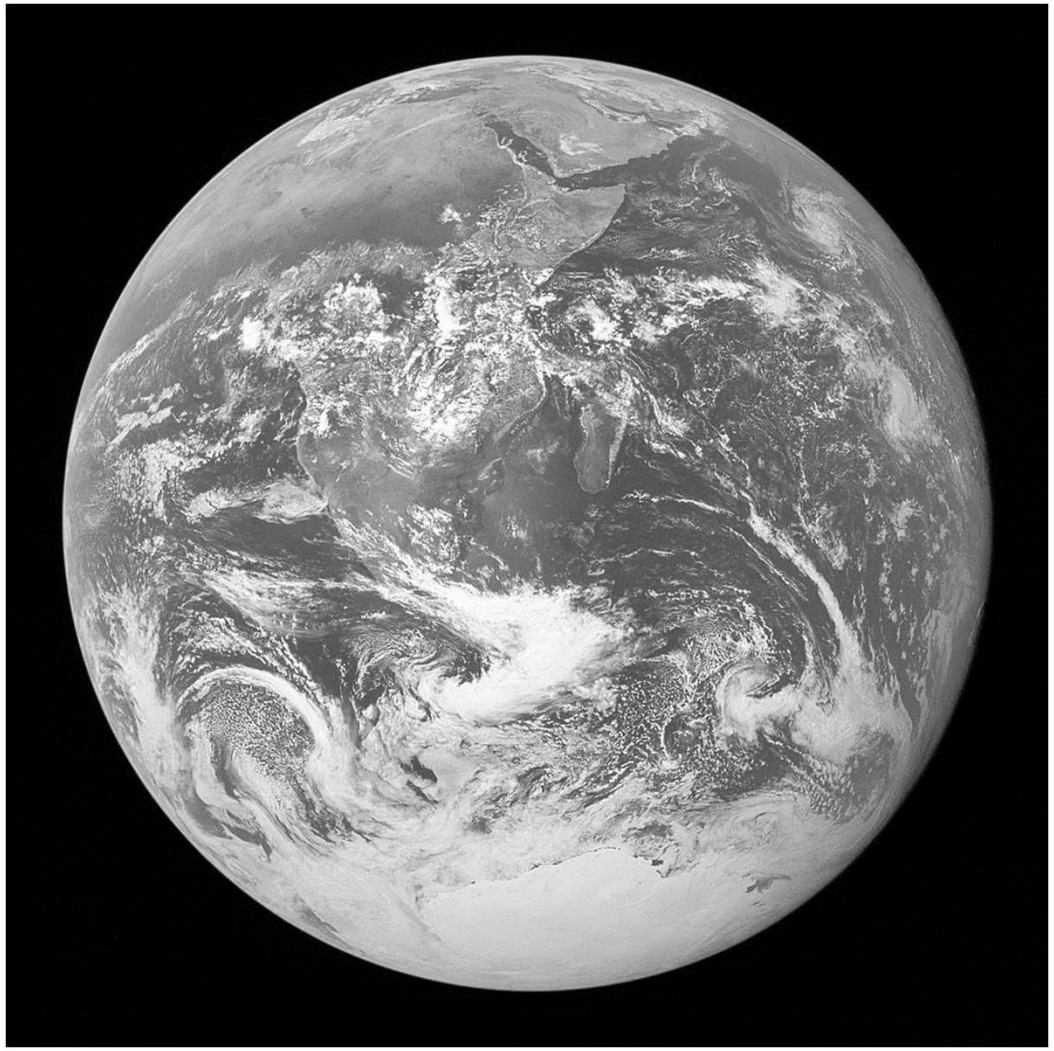
Structure from Motion (SfM)



Computer Vision and Nearby Fields

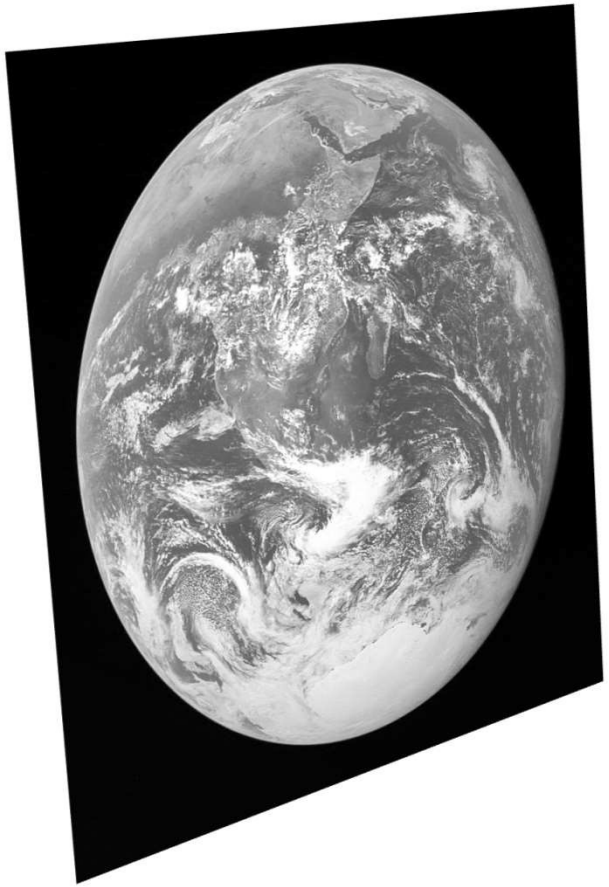


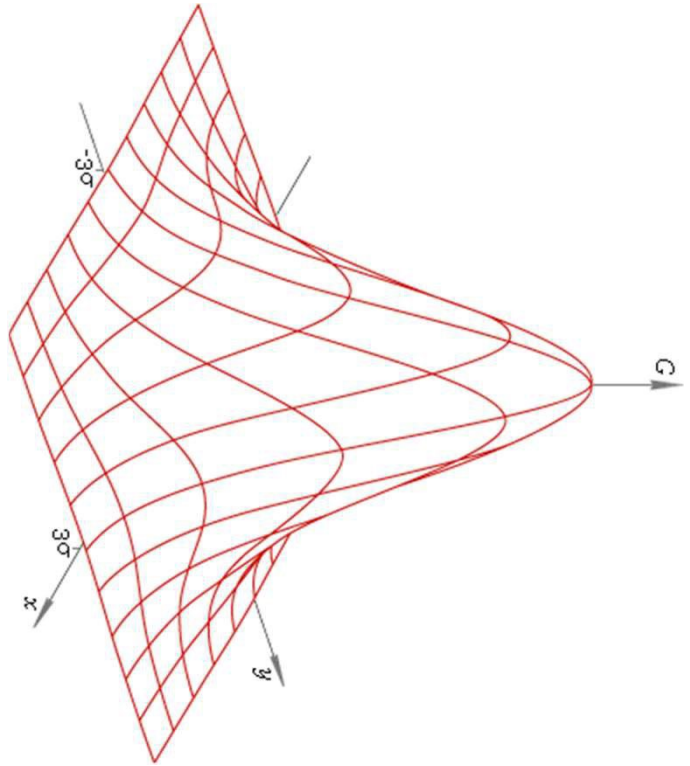
Image



Blue Marble. NASA | Apollo 17

Image



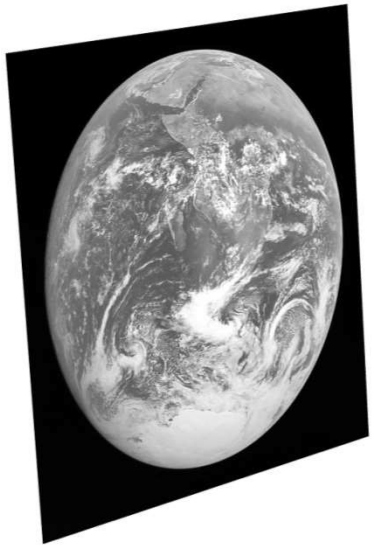


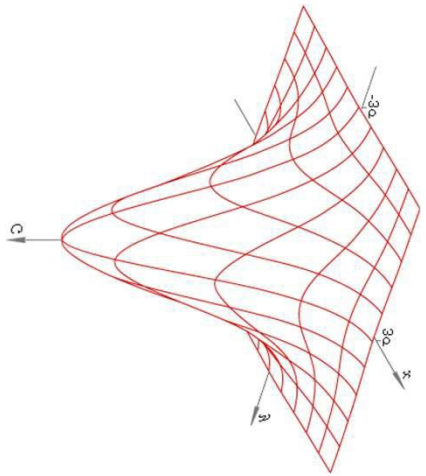
Blue Marble. NASA | Apollo 17

Signal

Definition

Signal: A (multi-dimensional) function that contains information about a phenomenon.

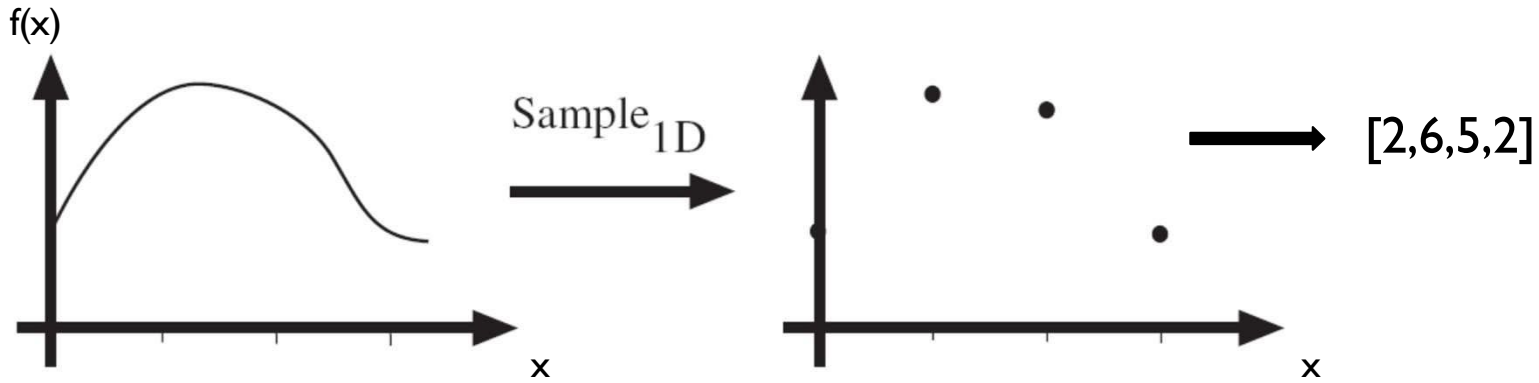




- Signals can be
  - Continuous: light
  - Discrete: measurement of a light
  - Sampling: reduction of continuous signal to a discrete signal
- Any phenomenon
  - Light
  - Heat
  - Gravity

Sampling

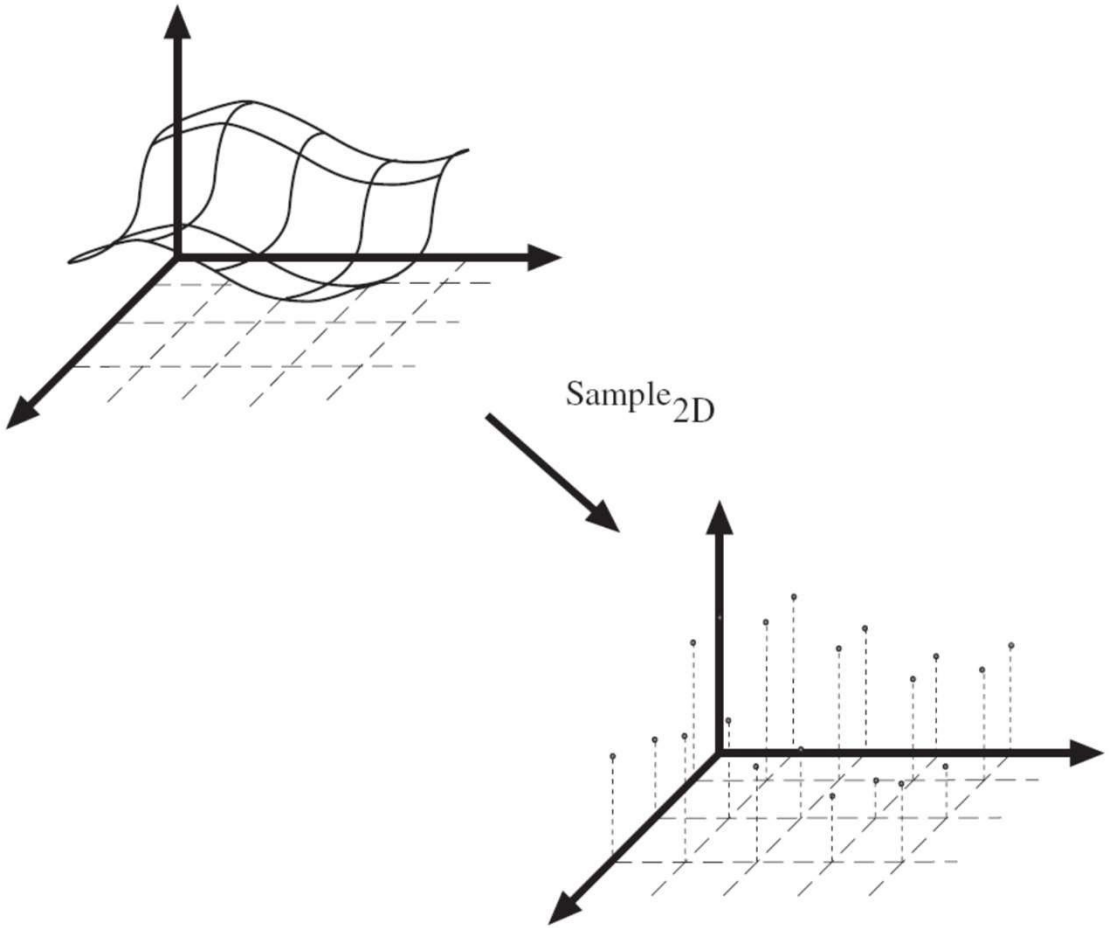
- Sampling in 1D takes a function and returns a vector whose elements are values of that function at the sample points.



Danny Alexander

Sampling

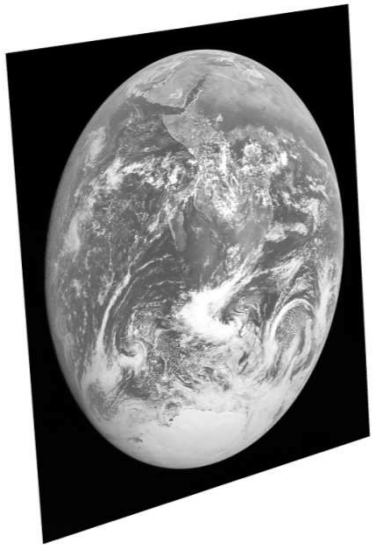
- Sampling in 2D takes a function and returns a matrix

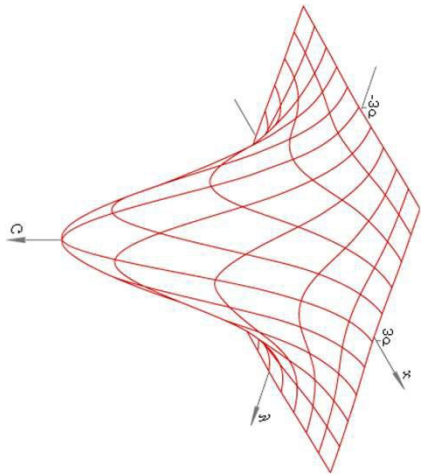


2D Image

Definition

Image: A sampling of a function that contains information about a 2D* signal.

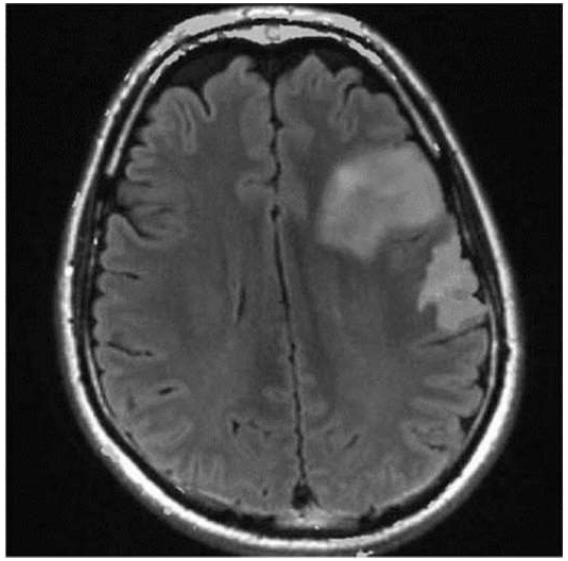




* or a 2D projection of a multi-dimensional signal

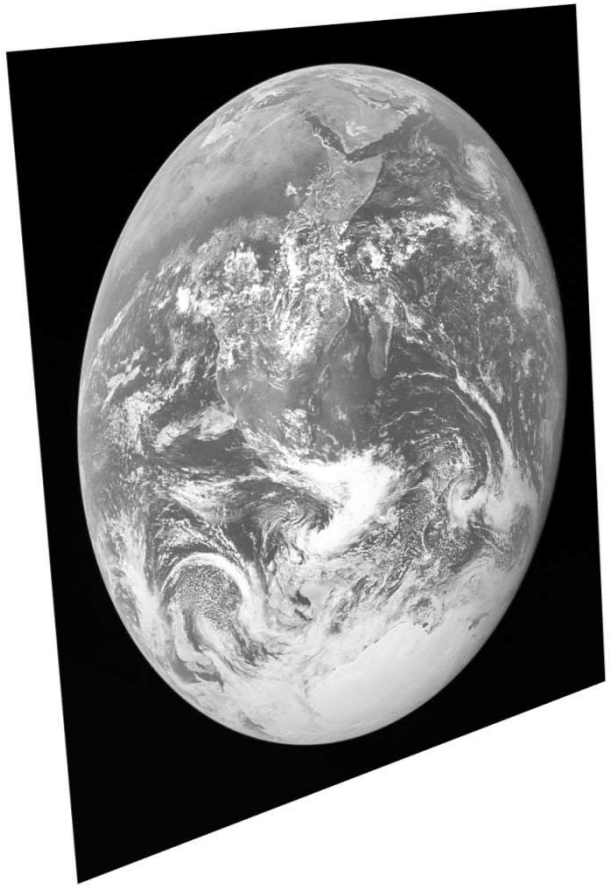
- Function stores 'brightness'
- 2D signals are special for us
  - Brightness along x and y dimensions
- Video: xy-coordinates + time
  - Time-varying 2D signal

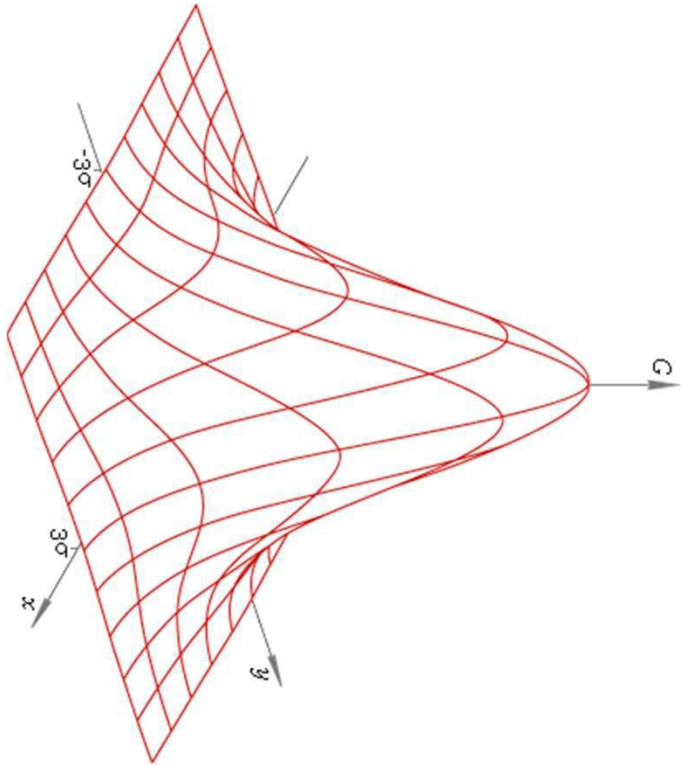
Example of 2D Images



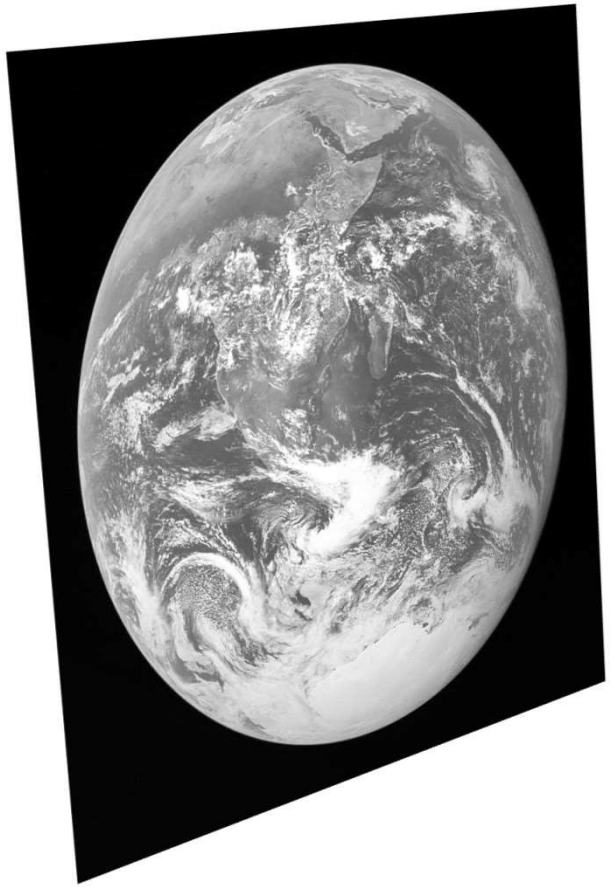
http://radiologykey.com/wp-content/uploads/2016/01/9781604063325_c014_f004.jpg

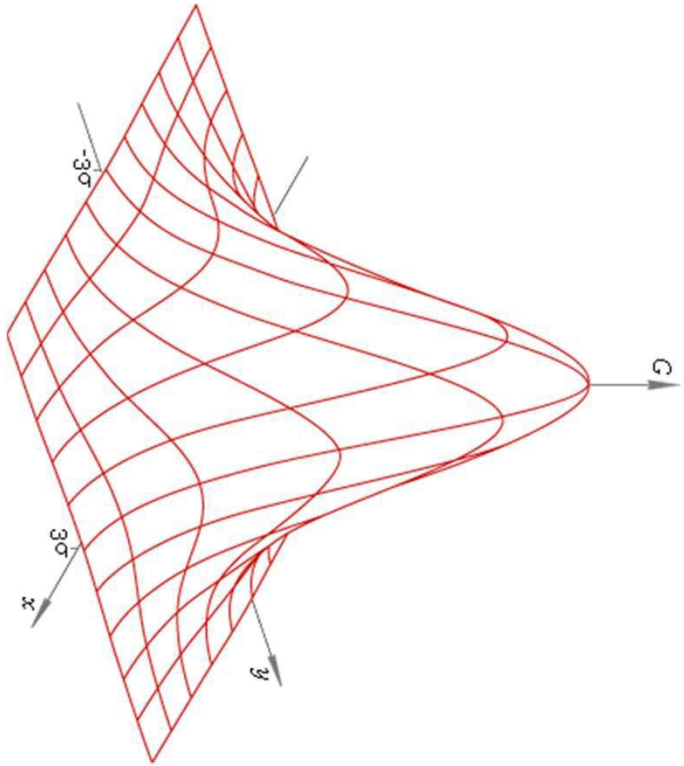
Sampling in Practice

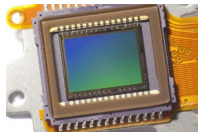




Sampling in Practice: Digital Image

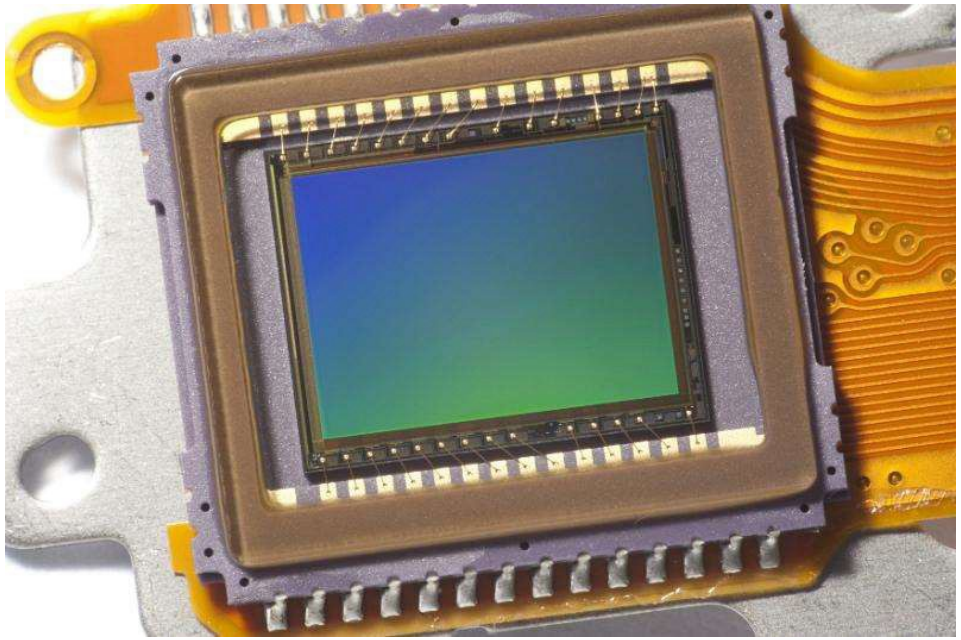




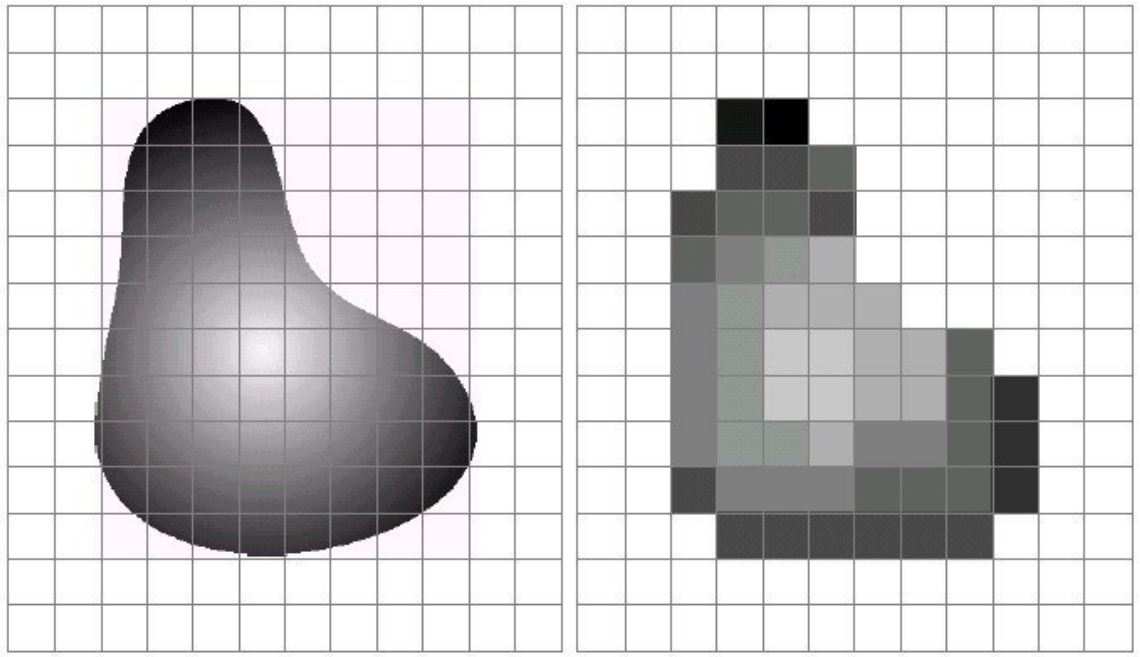


CMOS / CCD

Sensor Array



CMOS sensor



a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

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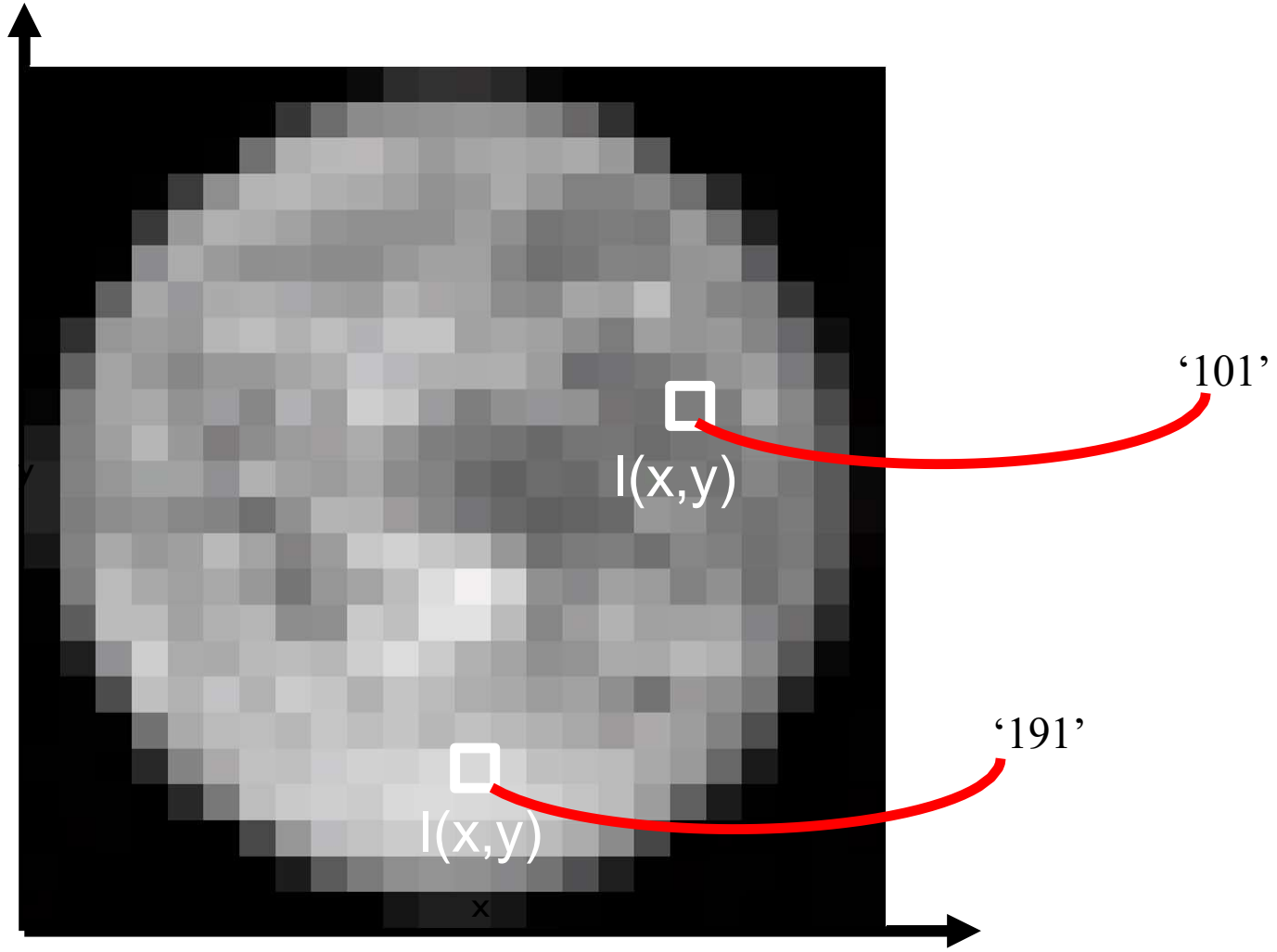
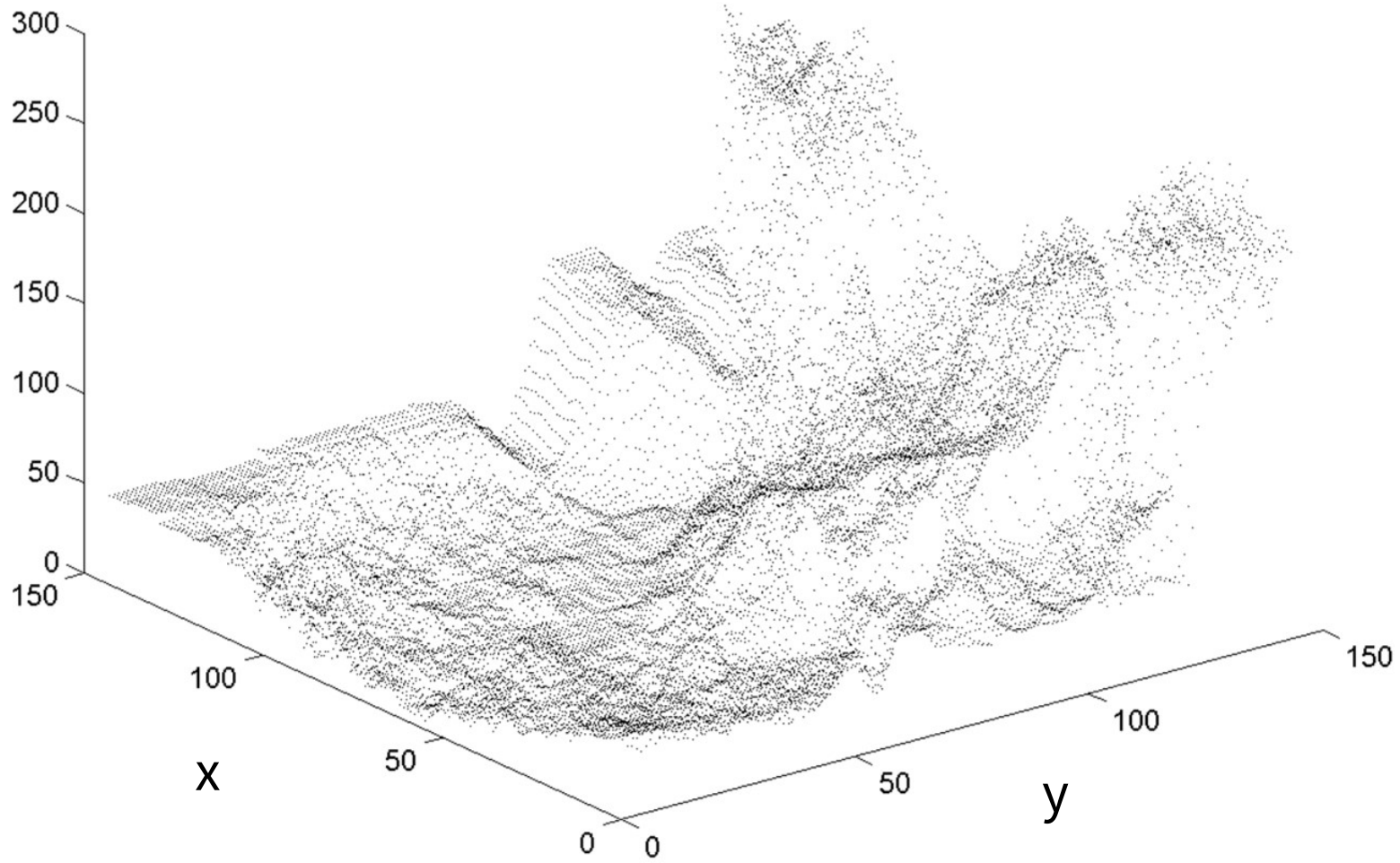
Elements of a Digital Image

Pixel: picture element

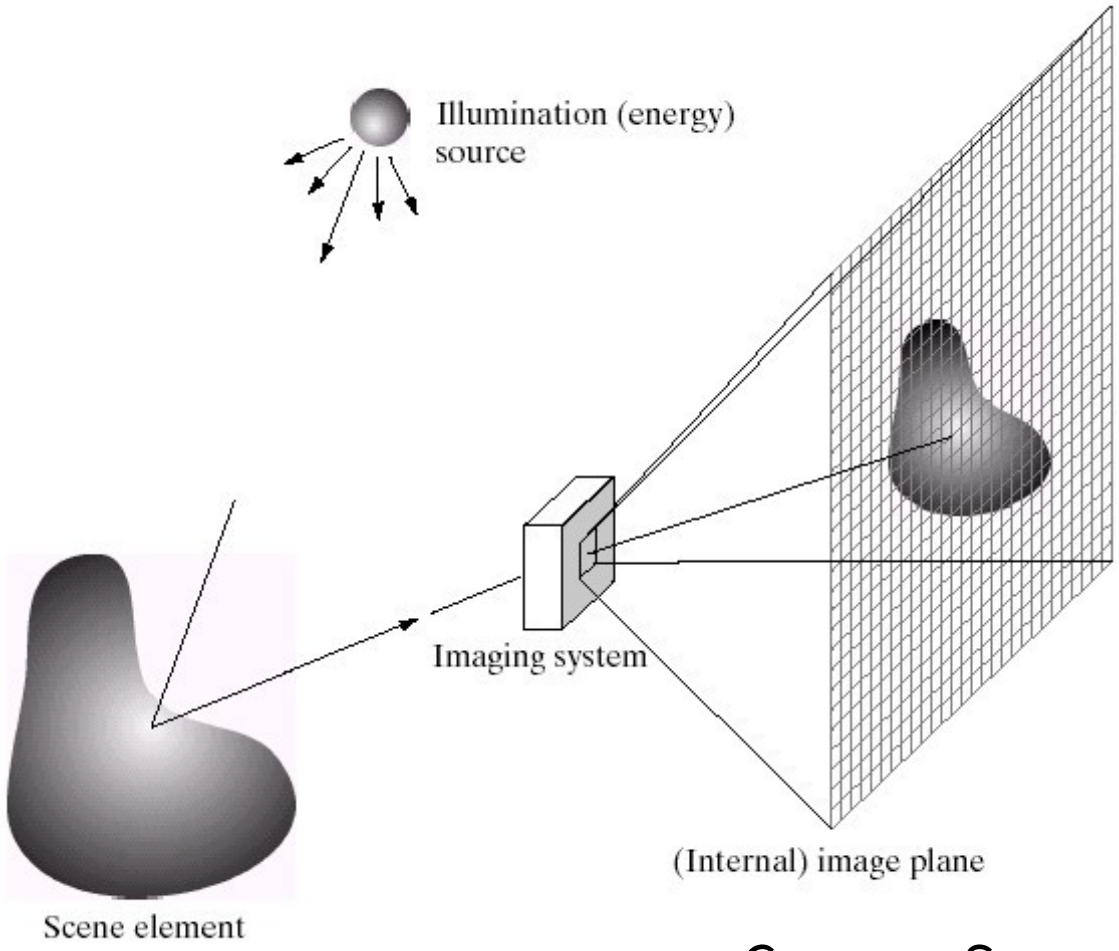


Digital Image is a 2D Signal

Brightness or intensity



Light Integration Over the “Frustum”



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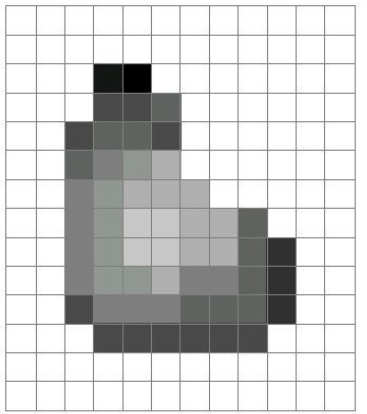
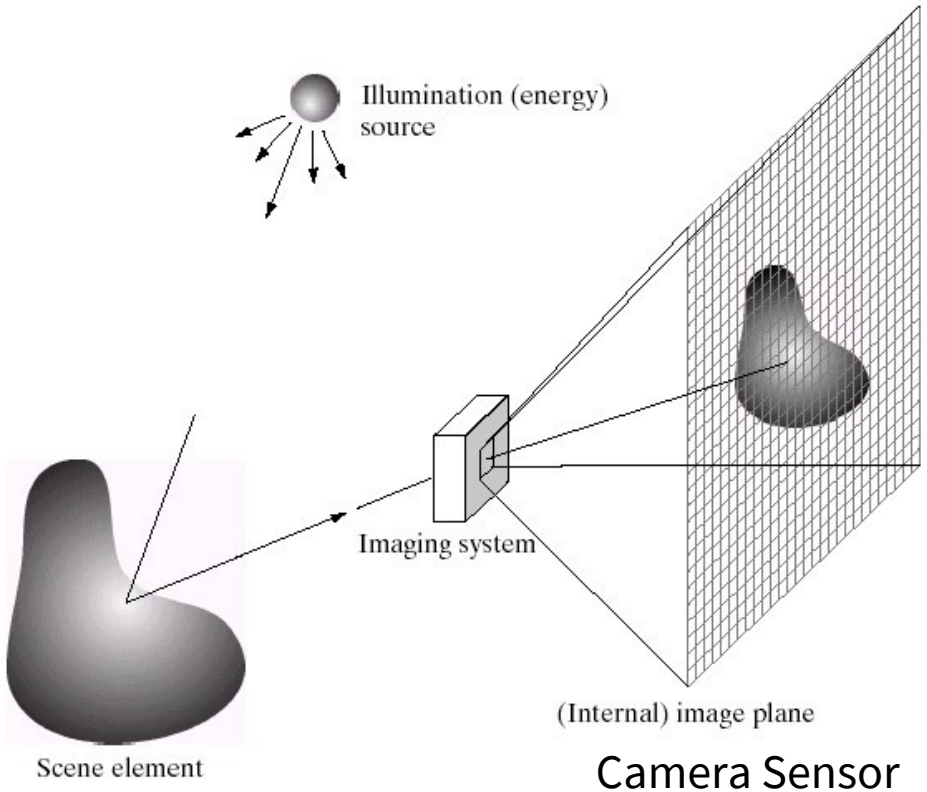
Camera Sensor



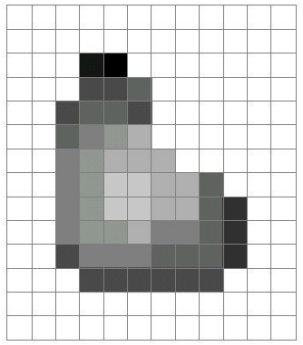
Output Image

Light Integration Over the “Frustum”

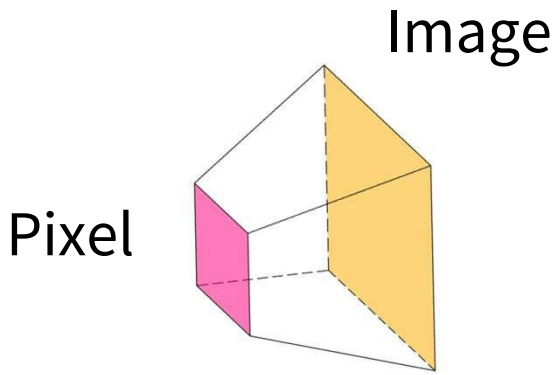


Camera Sensor

James Hays



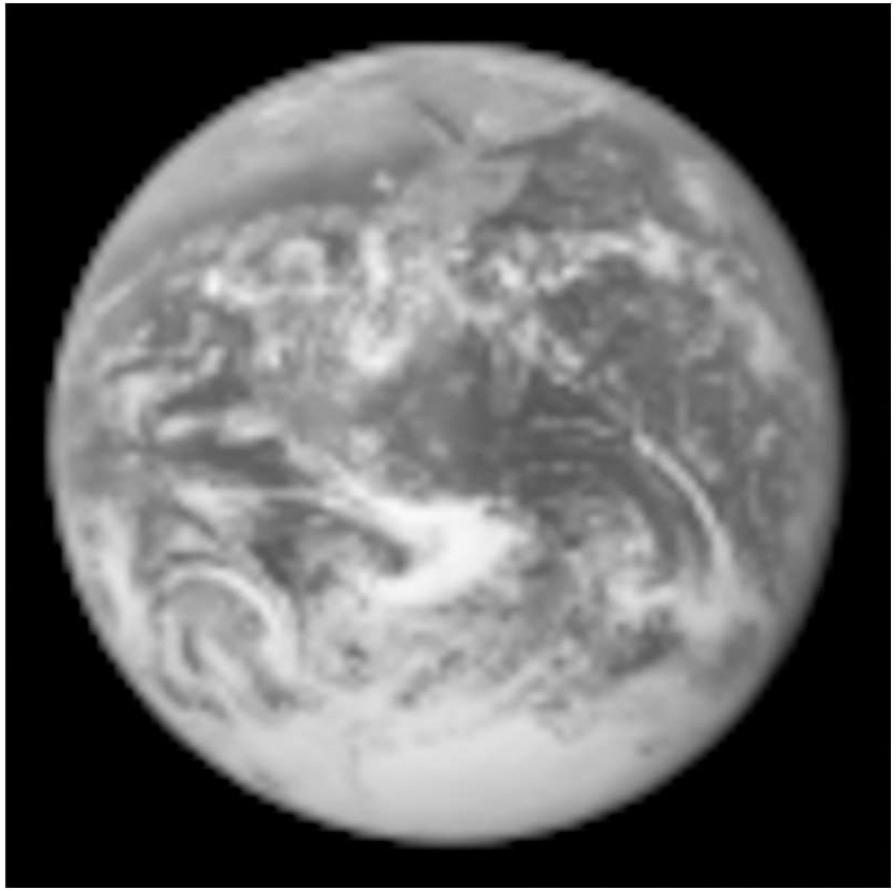
Output Image

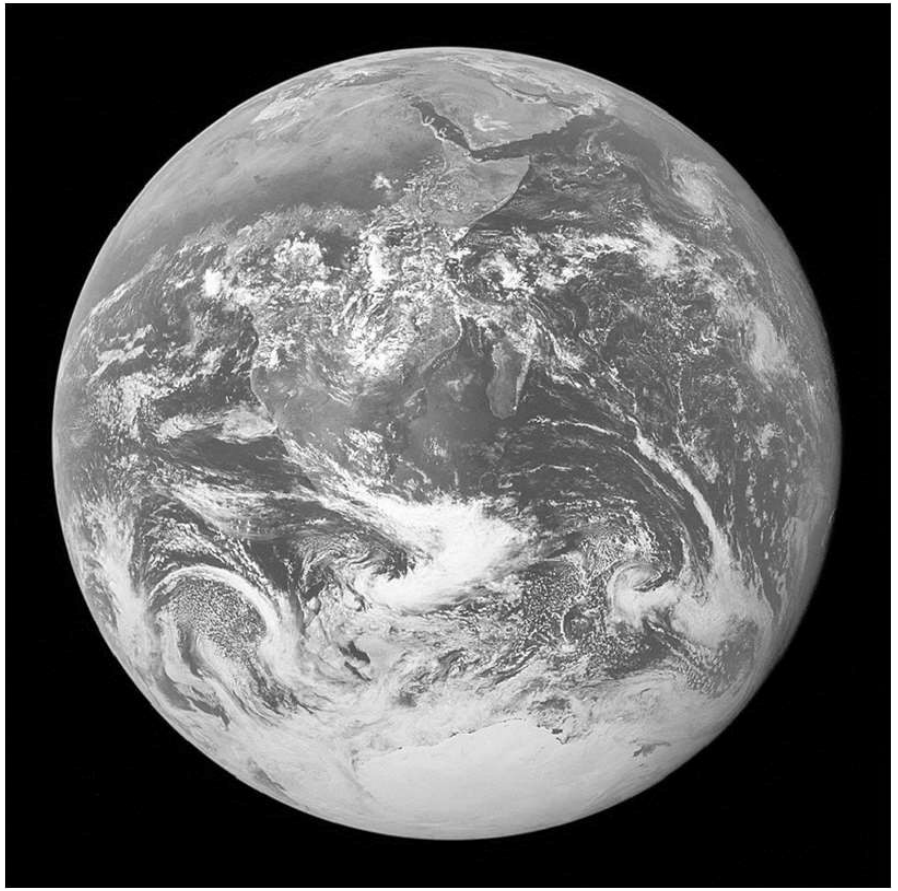


A frustum approximates the ray space that a pixel samples

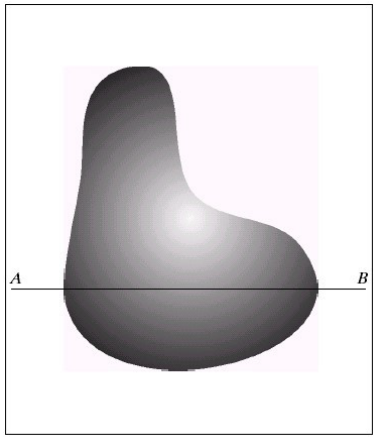
Resolution: geometric vs. spatial

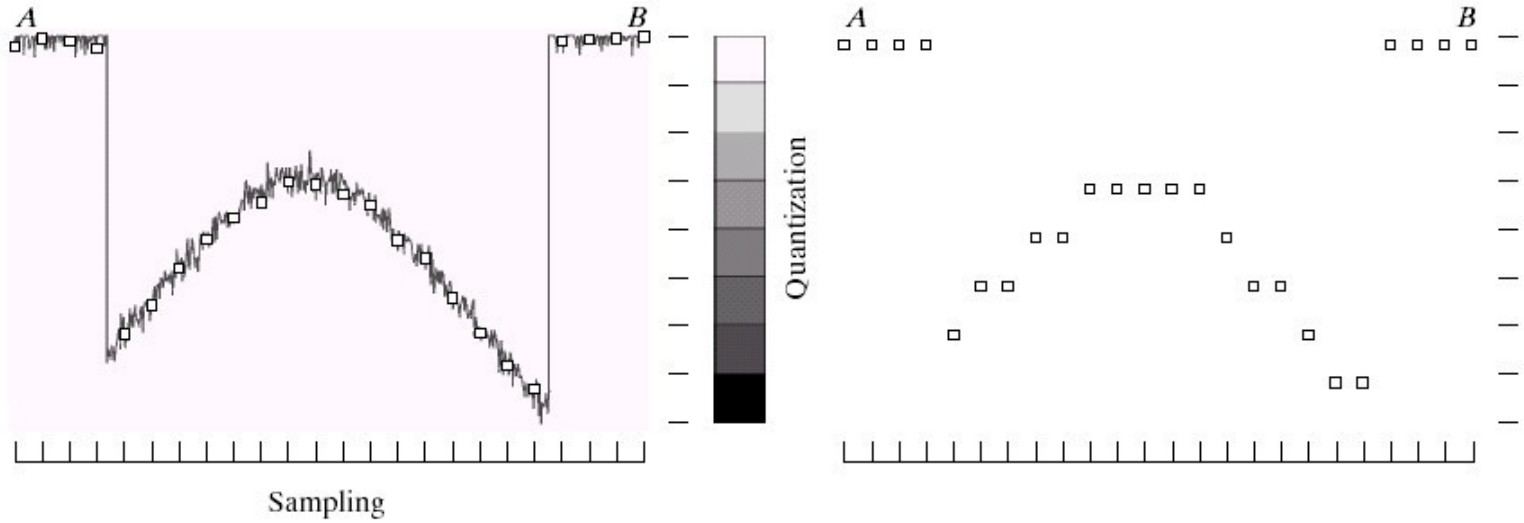
Both images are 1000x1000 pixels:





Quantization

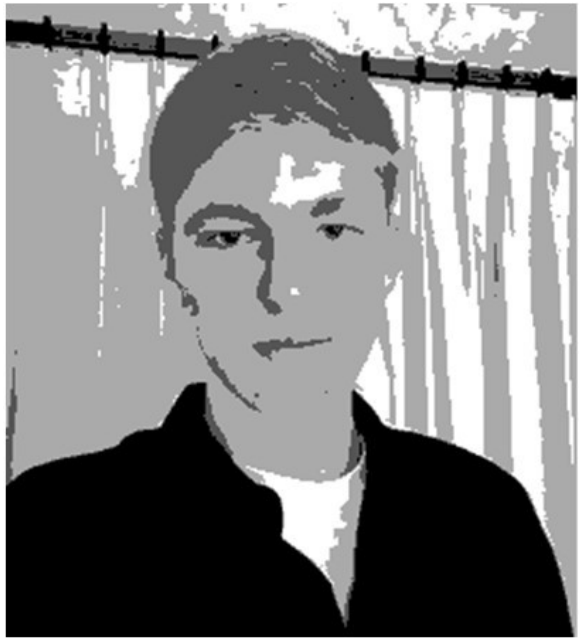




Quantization Effects – Radiometric Resolution

8 bit – 256 levels

4 bit – 16 levels



2 bit – 4 levels

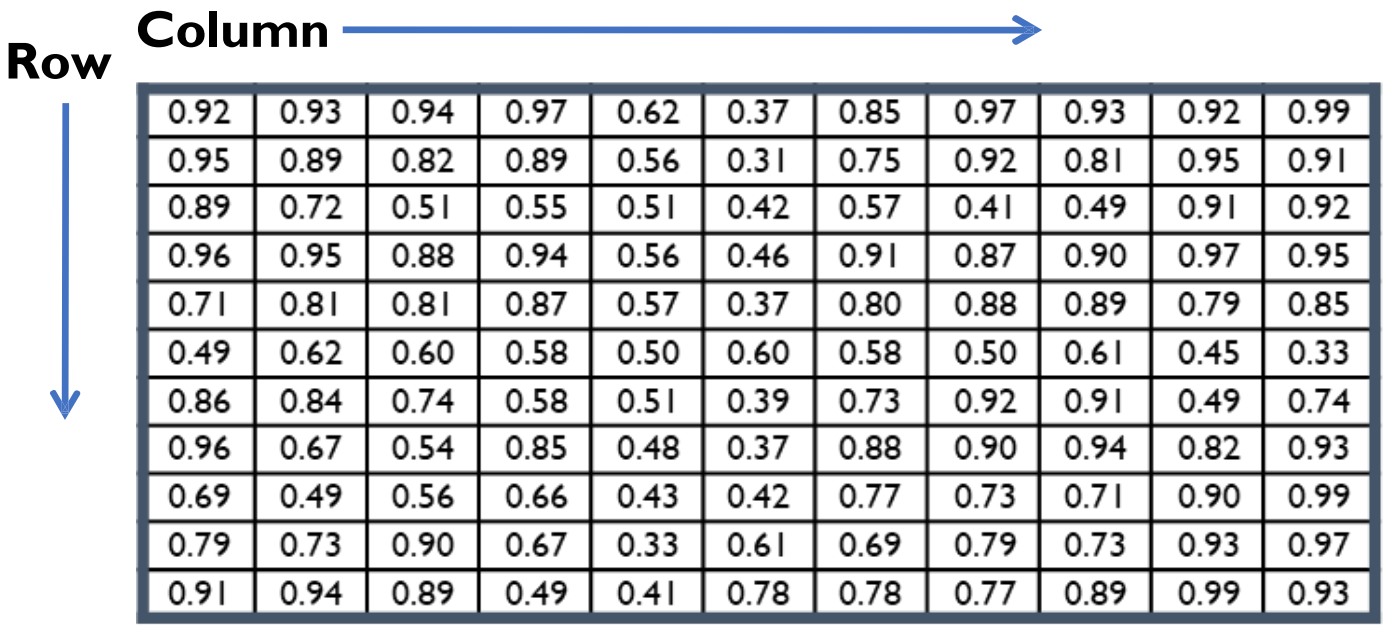
1 bit – 2 levels

We often call this ***bit depth***.
For photography, this is also related to ***dynamic range***.

Images in Python (`import numpy`)

`N x M` grayscale image "`im`"

- `im[0,0]` = top-left pixel value
- `im[y,x]` = y pixels down, x pixels to right
- `im[N-1,M-1]` = bottom-right pixel



0.92	0.93	0.94	0.97	0.62	0.37	0.85	0.97	0.93	0.92	0.99
0.95	0.89	0.82	0.89	0.56	0.31	0.75	0.92	0.81	0.95	0.91
0.89	0.72	0.51	0.55	0.51	0.42	0.57	0.41	0.49	0.91	0.92
0.96	0.95	0.88	0.94	0.56	0.46	0.91	0.87	0.90	0.97	0.95
0.71	0.81	0.81	0.87	0.57	0.37	0.80	0.88	0.89	0.79	0.85
0.49	0.62	0.60	0.58	0.50	0.60	0.58	0.50	0.61	0.45	0.33
0.86	0.84	0.74	0.58	0.51	0.39	0.73	0.92	0.91	0.49	0.74
0.96	0.67	0.54	0.85	0.48	0.37	0.88	0.90	0.94	0.82	0.93
0.69	0.49	0.56	0.66	0.43	0.42	0.77	0.73	0.71	0.90	0.99
0.79	0.73	0.90	0.67	0.33	0.61	0.69	0.79	0.73	0.93	0.97
0.91	0.94	0.89	0.49	0.41	0.78	0.78	0.77	0.89	0.99	0.93

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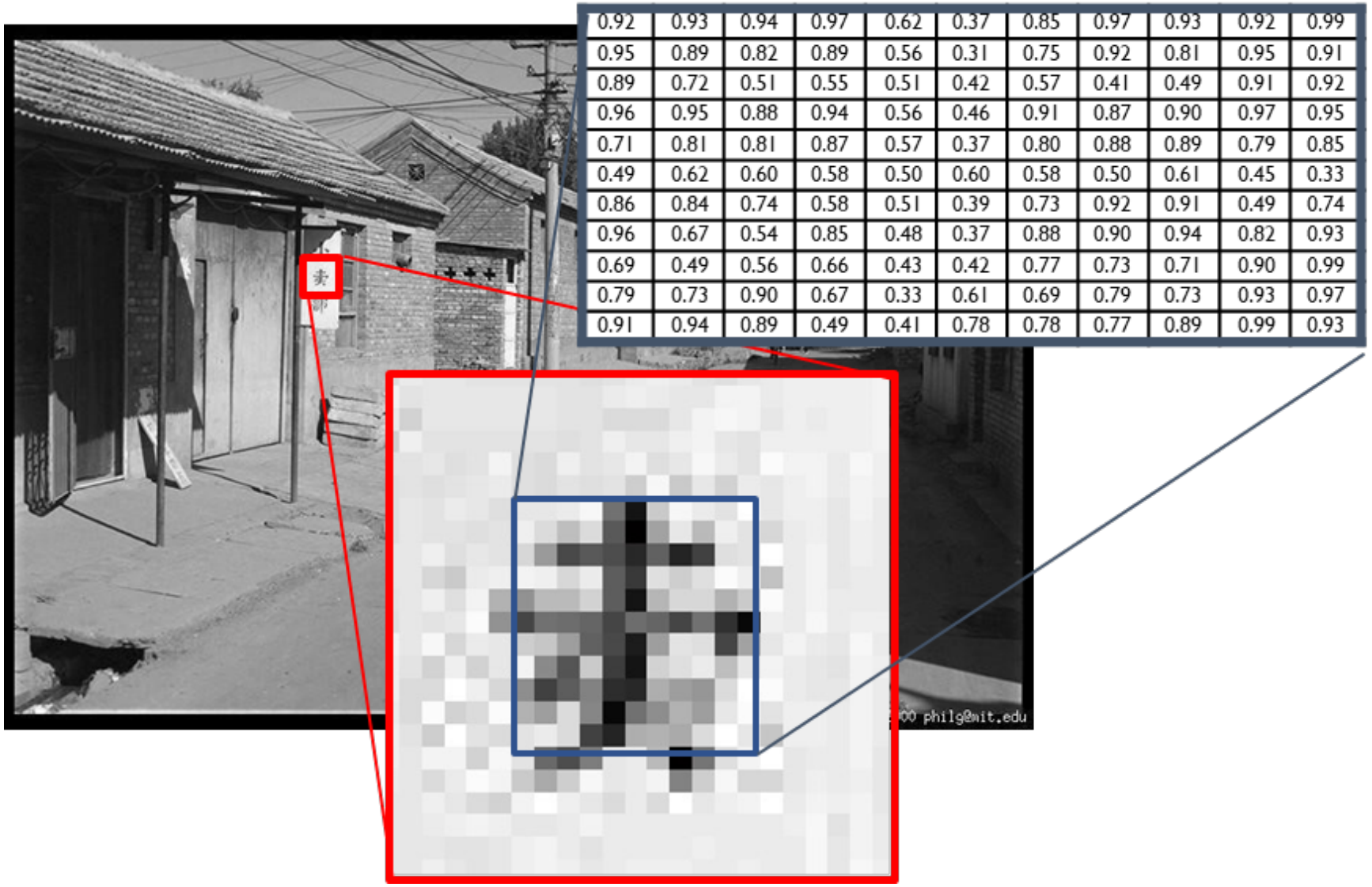
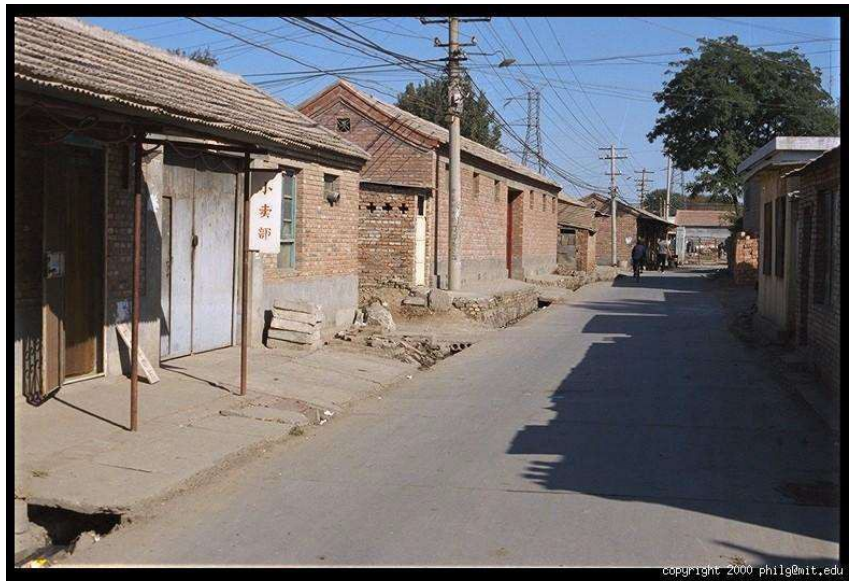
Grayscale Intensity



Color



Red intensity

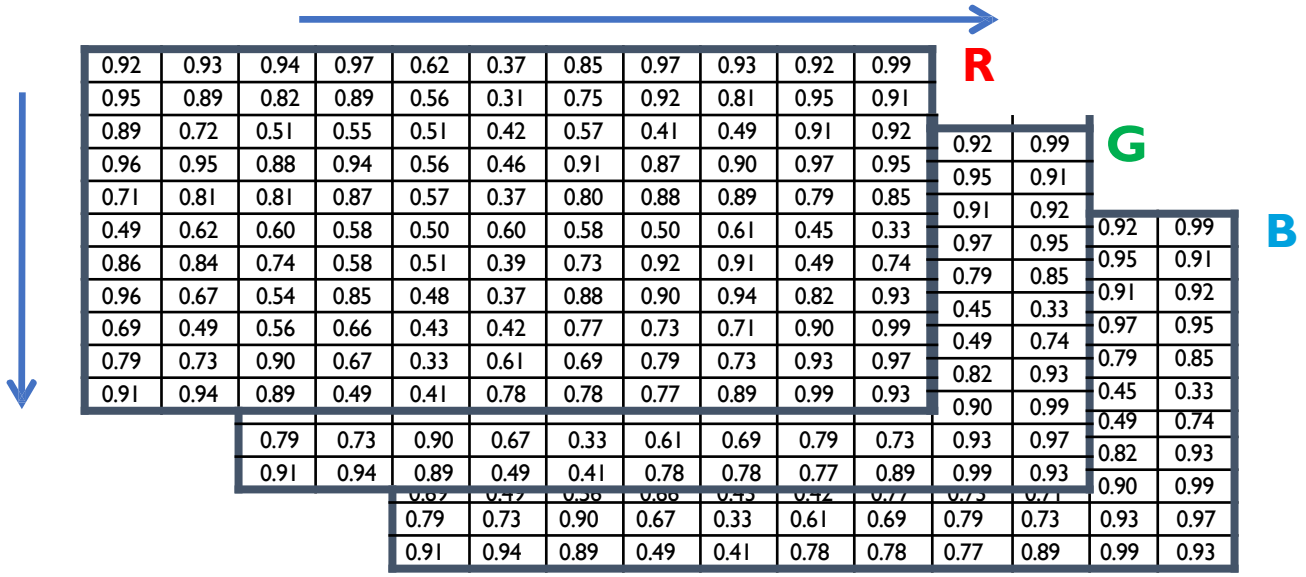
Green

Blue

Images in Python (import numpy)

N x M grayscale image "im"

- im[0,0,0] = top-left pixel value, red channel
- im[y,x,1] = y pixels down, x pixels to right, green channel
- im[N-1,M-1,2] = bottom-right pixel, blue channel



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