image formation and acquisition

Tara Qadr
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3rd Stage
Second Semester
Computer department
College of science
University of sulaimani

Image Formation

in modeling any image formation process, geometric primitives and transformations are crucial to project 3-D geometric features into 2-D features. However, apart from geometric features, image formation also depends on discrete color and intensity values. It needs to know the lighting of the environment, camera optics, sensor properties, etc.

Photometric Image Formation

- The light from a source is reflected on a particular surface. A part of that reflected light goes through an image plane that reaches a sensor plane via optics.

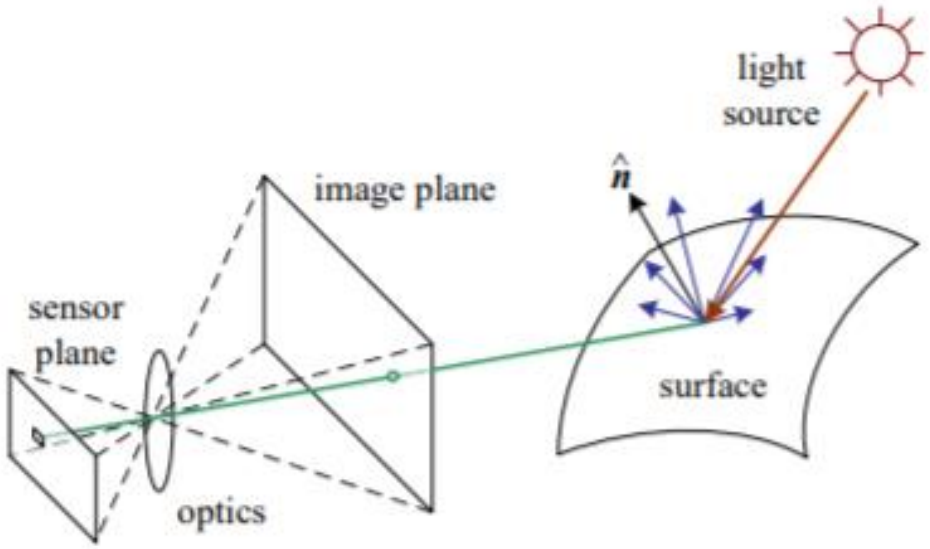


Image Formation

- For natural images we need a light source (λ: *wavelength of the source*)
  - $E(x, y, z, \lambda)$: incident light on a point (*x, y, z world coordinates of the point*)
- Each point in the scene has a reflectivity function.
  - $r(x, y, z, \lambda)$: reflectivity function
- Light reflects from a point and the reflected light is captured by an imaging device.
  - $c(x, y, z, \lambda) = E(x, y, z, \lambda) \times r(x, y, z, \lambda)$: reflected light.

$$\rightarrow \quad E(x, y, z, \lambda)$$

$$\rightarrow \quad c(x, y, z, \lambda) = E(x, y, z, \lambda) \cdot r(x, y, z, \lambda)$$

$$\text{Camera}(c(x, y, z, \lambda)) =$$

factors that affect image formation

1. Reflection and Scattering

- The strength and direction of the light emitted from the source.
- The material and surface geometry along with other nearby surfaces.
- Sensor Capture properties

2. Color :

Not every sensor captures all the three components (RGB) of light

Bayer proposed a grid in which there are 50% green, 25 % red, and 25% blue sensors.

Two factors are noticed when a colored light arrives at a sensor:

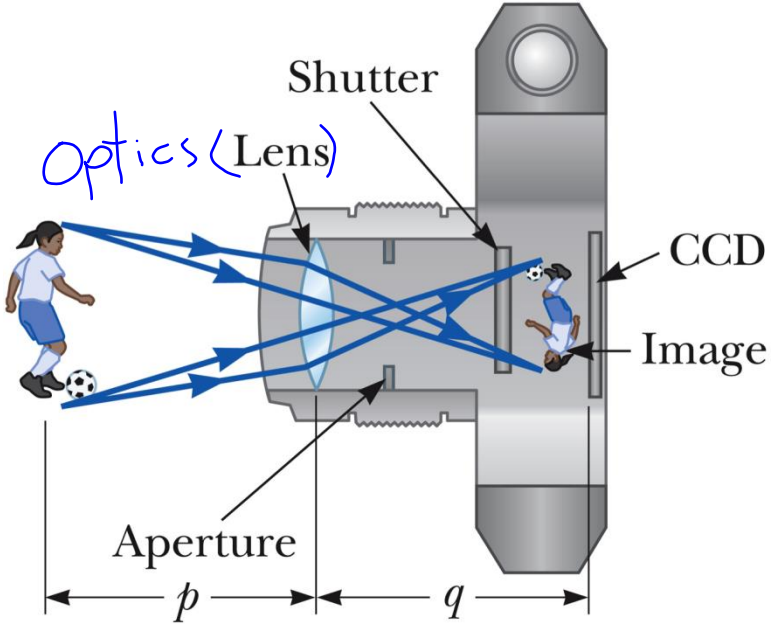
- Color of the light
- Color of the surface

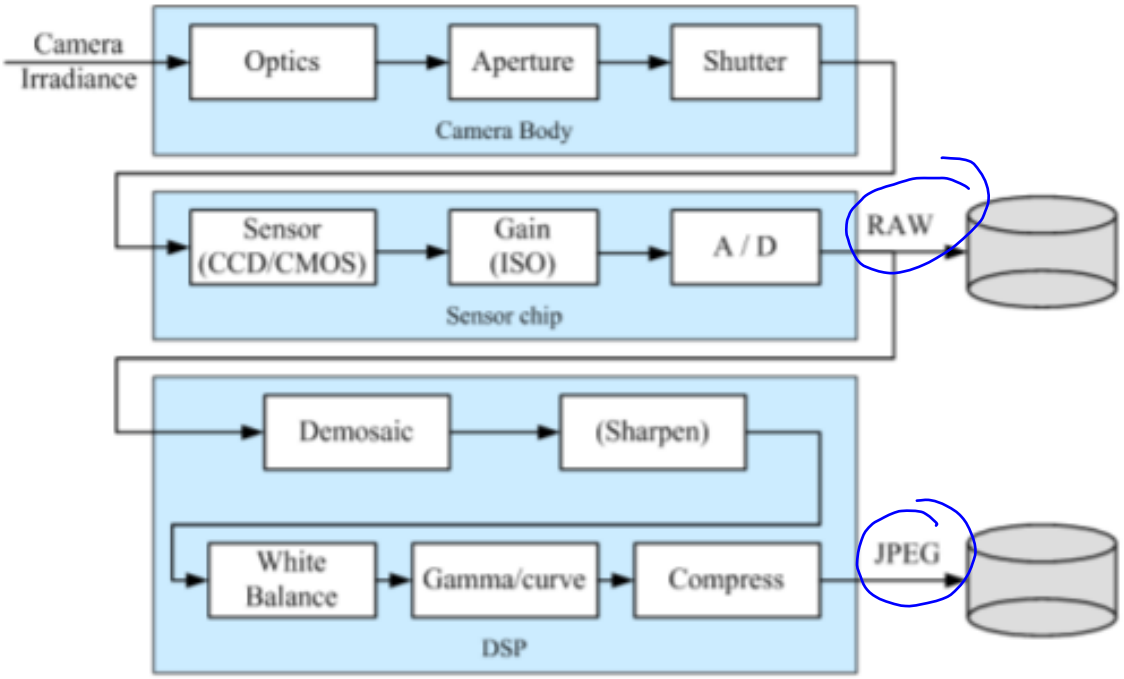
factors that affect image formation (cont.)

3. **Image sensing:**

In a camera, in the **first step** the light first falls on the lens (optics). Following that is the aperture and shutter which can be specified or adjusted. Then the light falls on sensors which can be CCD or CMOS ,then we get the raw image.

Second step use **demosaic** algorithms and Image is sharpened if required or any other important processing algorithms are applied. **Post this,** white balancing and other digital signal processing tasks are done and the image is finally compressed to a suitable format and stored.


Shutter
optics (Lens)
CCD
Image
Aperture
p
q


Camera Irradiance
Optics
Aperture
Shutter
Camera Body
Sensor (CCD/CMOS)
Gain (ISO)
A / D
RAW
Sensor chip
Demosaic
(Sharpen)
White Balance
Gamma/curve
Compress
JPEG
DSP

CCD vs. CMOS

- In charged coupled device (CCD). A charge is generated at each sensing element and this photo generated charge is moved from pixel to pixel and is converted into a voltage at the output node. Then an analog to digital converter (ADC) converts the value of each pixel to a digital value.
- The complementary metal-oxide-semiconductor (CMOS) sensors work by converting charge to voltage inside **each** element , therefore does not need ADC. CMOS is widely used in cameras in the current times.

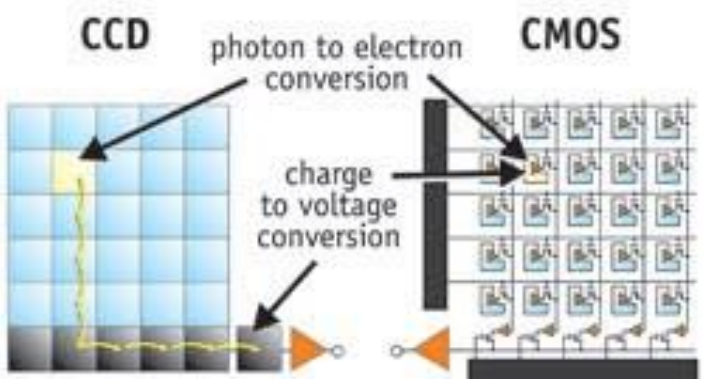
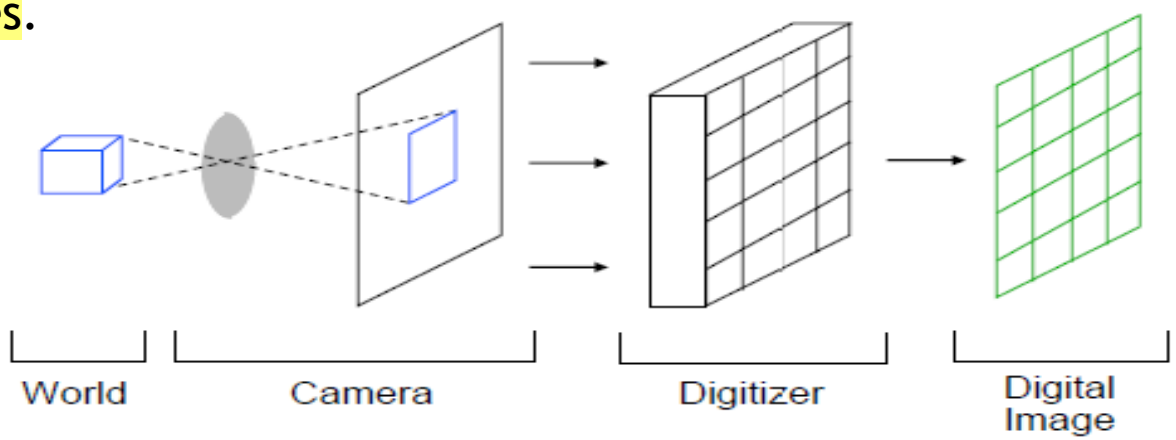


Image Acquisition

Image acquisition is the process of translating the analog world around us into binary data composed of zeros and ones, interpreted as digital images.



0	10	10	15	50	70	80
0	0	100	120	125	130	130
0	35	100	150	150	80	50
0	15	70	100	10	20	20
0	15	70	0	0	0	15
5	15	50	120	110	130	110
5	10	20	50	50	20	250

PIXEL
(picture element)

Typically:
0 = black
255 = white

Image Representation

1. **Image as a matrix**:

that values between 0 to 255 represent the intensity for each pixel in the image where 0 is black and 255 is white

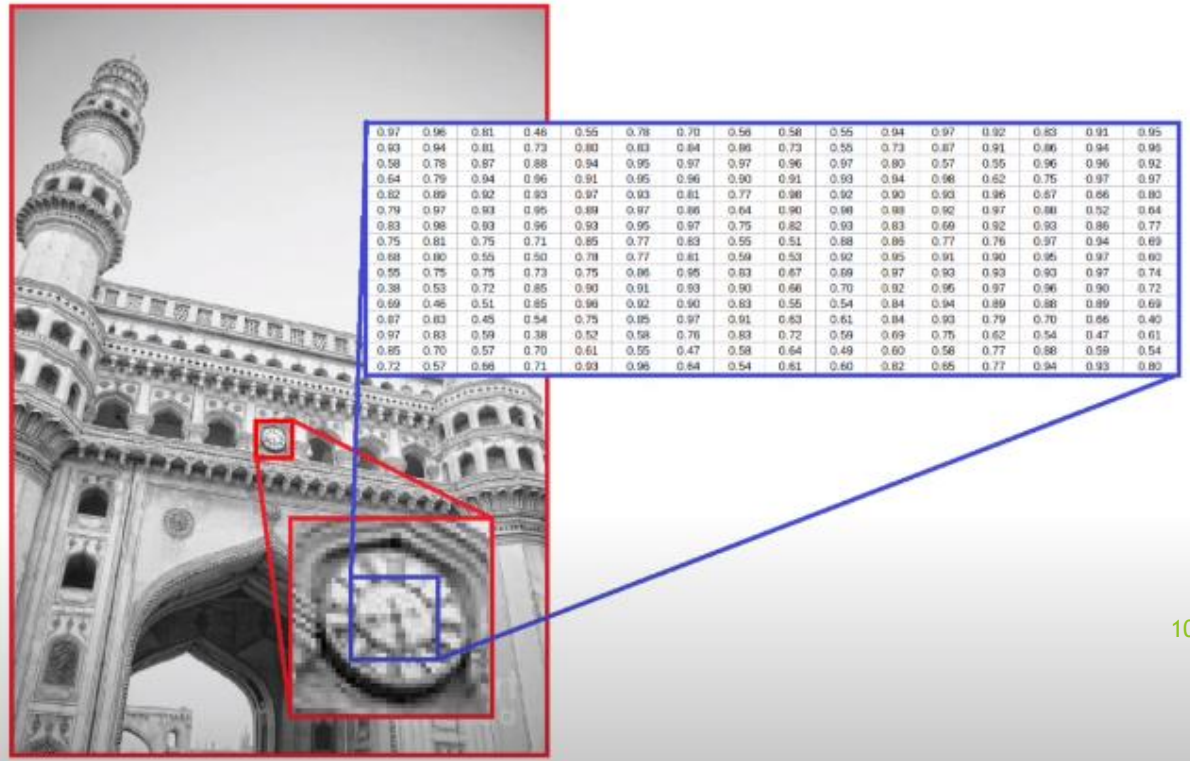


Image Representation (cont.)

2. **Image as a function**

An image (gray scale) can be thought of as a function that takes in a pixel coordinate and gives the intensity at that pixel.

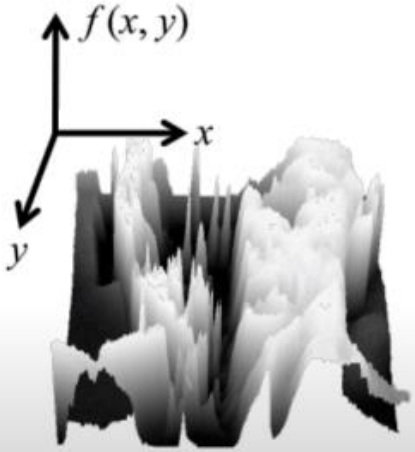


Image Representation (cont.)

3. **Image Transformation:**

mages can be transformed when they are looked upon as functions. A change in the function can result in changes in the pixel values of the image.

Image Data Types

- Black & white images
  - 1-bit images
  - 8-bit gray-level images
- Color images
  - 8 -bit color images
  - 24 -bit color images
  - 32 -bit color images

8-bit gray-level images

Color images (24-bits)

- Popular File Formats
  - GIF
  - JPEG
  - BMP
  - PNG
  - TIFF
  - Others

Binary images (1-bit)

Image Size and Resolution

- **Refers to the number of pixels in a digital image: width x height y (higher resolution always yields better quality).**
- **is the number of pixels in a linear inch—pixels per inch (or PPI), but it is most commonly referred to as dots per inch (DPI). The more pixels, or "dots," per inch, the higher your image resolution will be.**

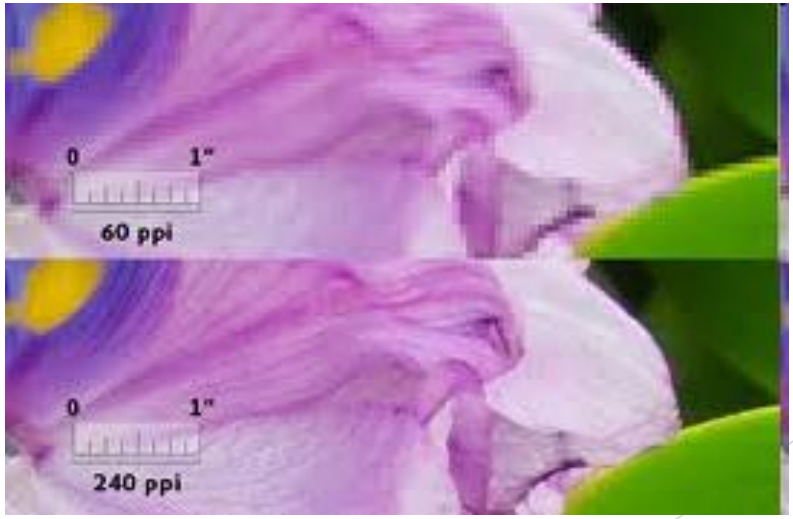


Image Size Calculation I

- **Ex1:** Find the binary image size for a 6x4 inch image at 150 ppi if the header file equal to 10 bytes?

Total image size = header size + data size

Data size = width * height * No. of bit/pixel

Data size= (6*150) * (4*150) * 1

Data size= 540000 bit=67500 bytes → **1byte=8 bit**

Total image size = 10 + 67500 = 67510 bytes = 65.92 kbyte → 1kbyte=1024 bytes

Image Size Calculation II

- **Ex2:** Find the gray scale image size for a 200x200 pixels if the header file equal to 80 bytes?

  8-bit يعني

  Total image size = header size + data size

  Data size = width * height * No. of bit/pixel

  Data size= 200 * 200 * 8

  Data size= 320000 bit=40000 bytes → **1byte=8 bit**

- **Total image size = 80 + 40000 = 40080 bytes = 39.14 Kbyte**
  1kbyte=1024 bytes

Image Size Calculation III

- **Ex3:** Find the color image size for a 400x400 pixels if the header file equal to 100 bytes?

32-bit

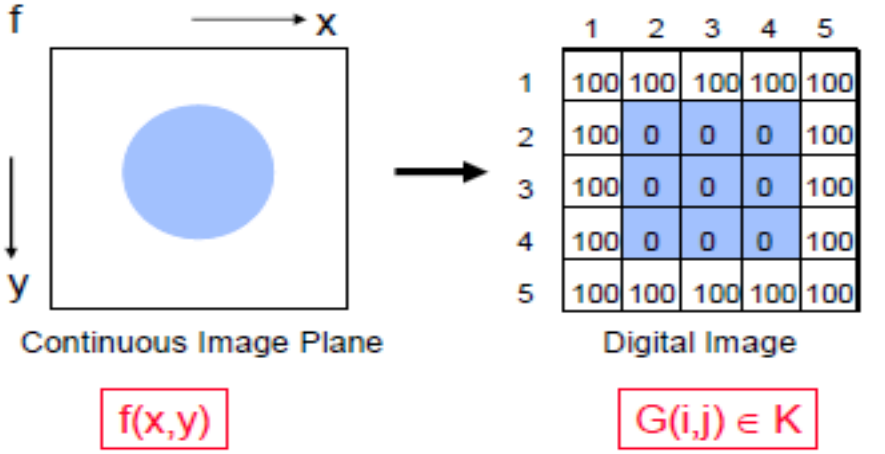
Total image size = header size + data size
Data size = width * height * No. of bit/pixel
Data size= 400 * 400 * 24
Data size= 3840000 bit=480000 bytes → **1byte=8 bit**
Total image size = 100 + 480000 = 480100 bytes = 46884 Kbyte

If the color image is coded with 32 bits per pixel,
Data size= 400 * 400 * 32

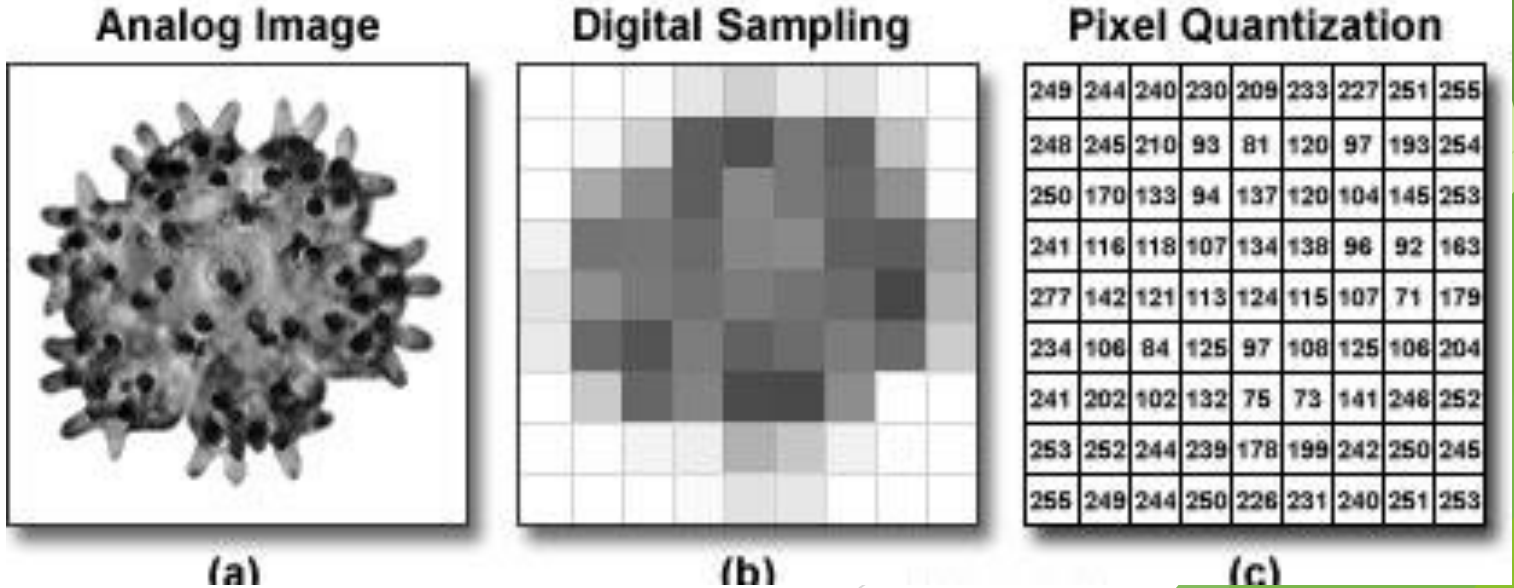
Image Digitization

Stages in the Digitization Process:

1. **SAMPLING - spatial**
2. **QUANTIZATION - gray level**



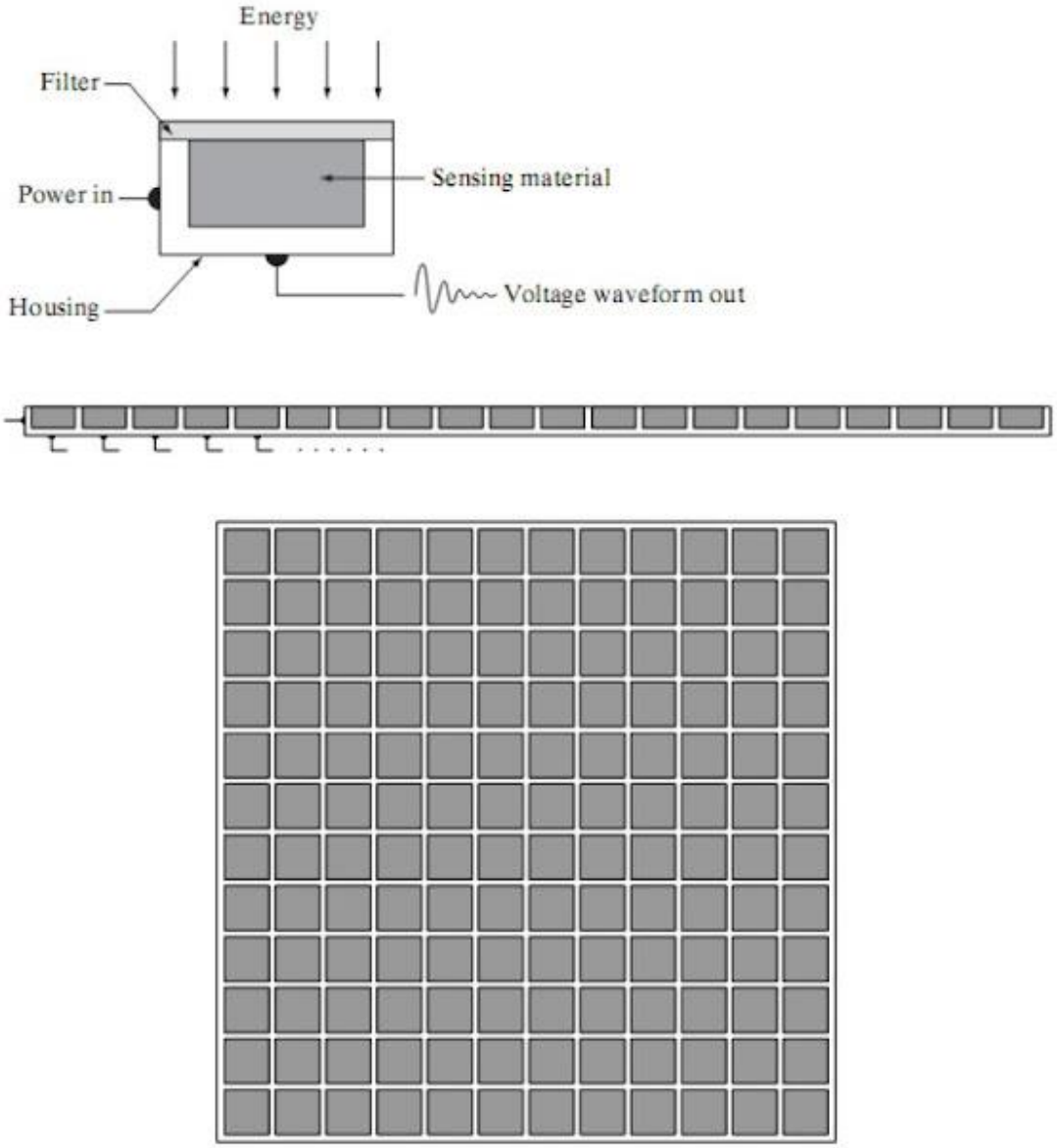
Creation of a Digital Image



Sampling

- Digitizing the coordinate values is called sampling
- Method of sampling determined by Sensor arrangement witch are :

Single imaging Sensor ,sensor strips and sensor array

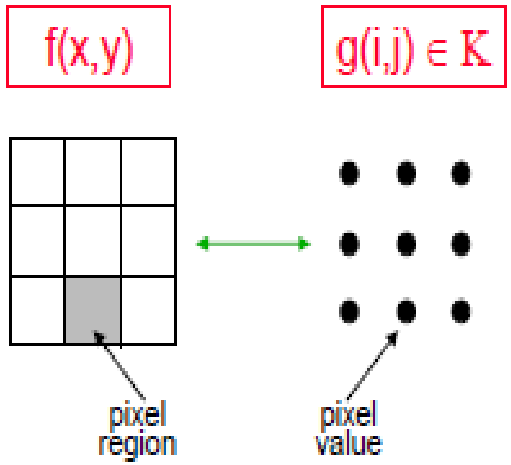


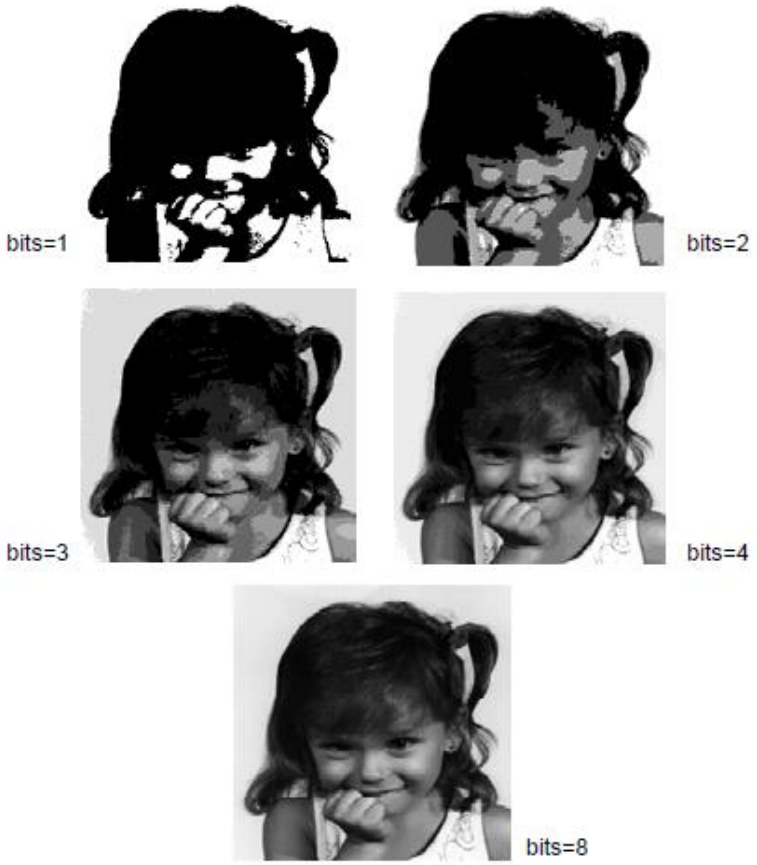
(a) Single imaging Sensor (b) Line sensor (c) Array sensor

Quantization

Digitizing the amplitude value is called quantization

- Choose number of gray levels (according to number of assigned bits).
- Divide continuous range of intensity values.





Continuous Intensity Range → Discrete Gray Levels

References

- Book :

Richard Szeliski,Computer Vision: Algorithms and Applications, 2nd ed

- Link:

https://towardsdatascience.com/computer-vision-image-formation-and-representation-a63e348e16b4

- http://legendtechz.blogspot.com/2013/03/5-explain-process-of-image-acquisition.html