Acquisition and representation of images

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Methods for Image Processing

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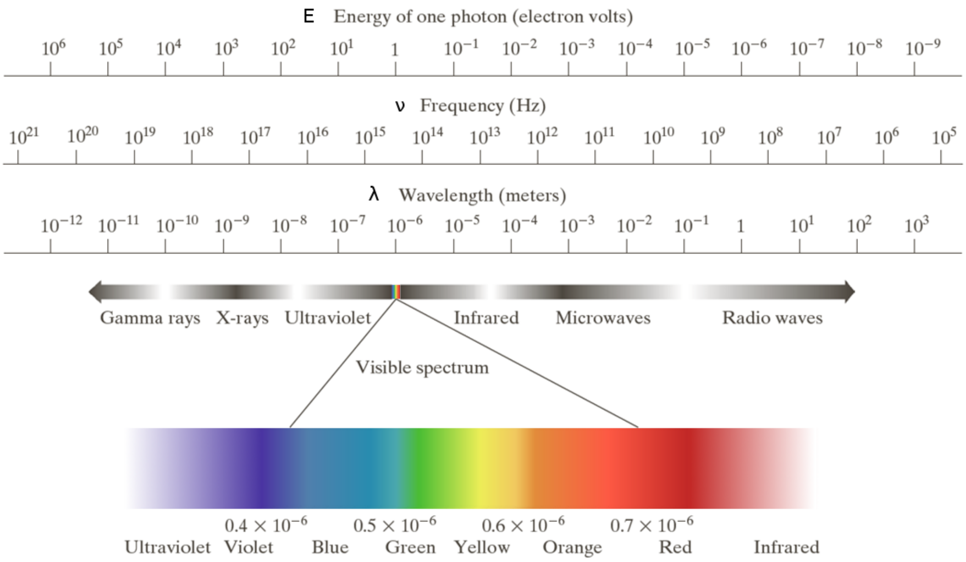
Electromagnetic radiation

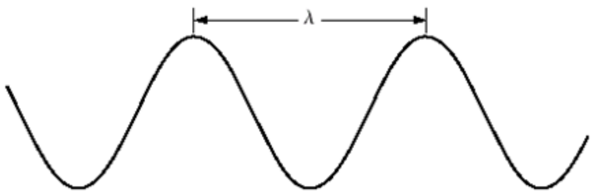


$$\lambda = \frac{c}{\nu} \qquad E = h\nu$$

Electromagnetic radiation (2)

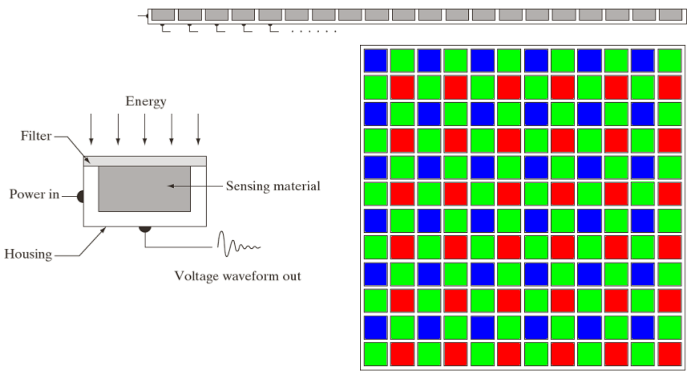
- Visible light is a small fraction of the spectrum.
- As well as the other components of the spectrum, the colors are not well separated, but they shades one in the next one.
- The light composed of waves from a sub-band small enough such that it does not contain more than one color is called *monochromatic* (or *achromatic*).
  - It is characterized only by its *intensity* (or *gray level*).
- Sometimes, the acquisition is performed without taking into consideration the color information (the whole spectrum is considered a single band).

Electromagnetic radiation (3)



- The electromagnetic radiation can be considered as:
  - a wave;
  - a stream of massless particles (*photons*).
- Objects can be seen only by their reflected light: only the reflected frequencies can be detected (the wavelenght have to be smaller than the size of the object).
- Besides its frequency (or color), the light can be caracterized for
  - *radiance*: total energy [W];
  - *luminance*: perceived energy [lm];
  - *brightness*: subjective perception.

Sensor



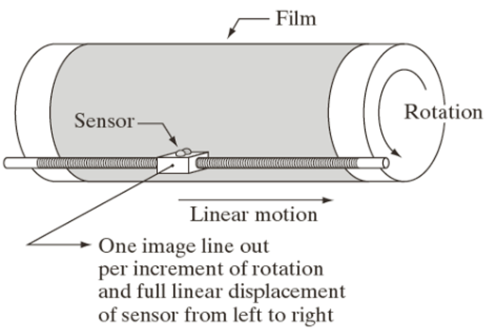
b

a | c

- The sensor transduces the radiant energy in electricity, (a).
- Sensors can be arranged in line or bidimensional array, (b) e (c).
- Bayer mask is often used for obtaining a color sensor.

Acquisition devices

In order to be used for scanning a scene, the sensors can be utilized in different set-ups:



- single-sensor devices make use of mechanical devices for moving the sensor with respect to the scene;
- in-line arranged sensors can be used both for desktop and airborne scanners;
- 2-D array of sensors are used both in digital cameras and in tomographic scanners;
  - in the latter case, further processing is required for obtaining the section of the scanned object from the acquired data.

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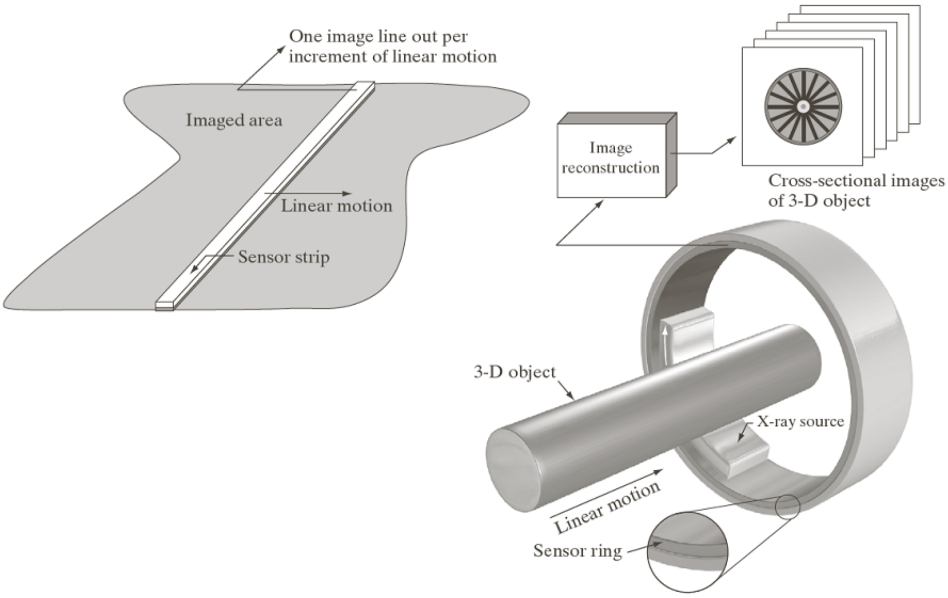
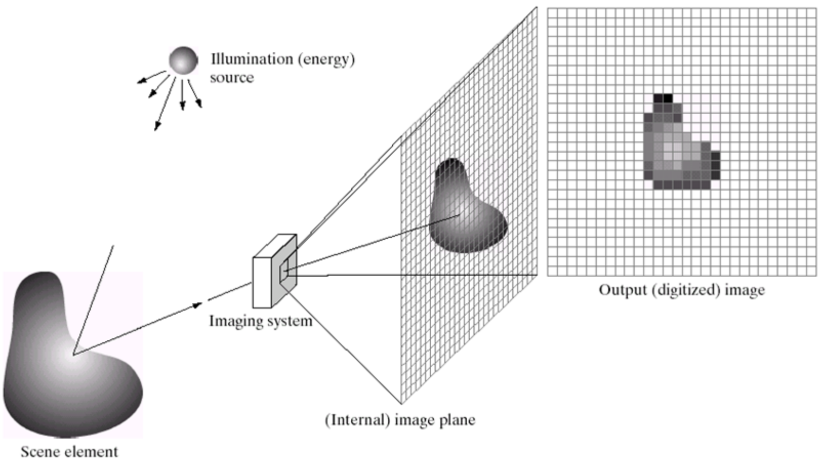
Acquisition devices (2)



From the scene to the image



a/b	c	d	e

The radiation (a) is reflected by the object (b) and captured from the imaging system (c). The scene is then projected onto the digitization plane constituted of sensors (d) and it is digitalized (e).

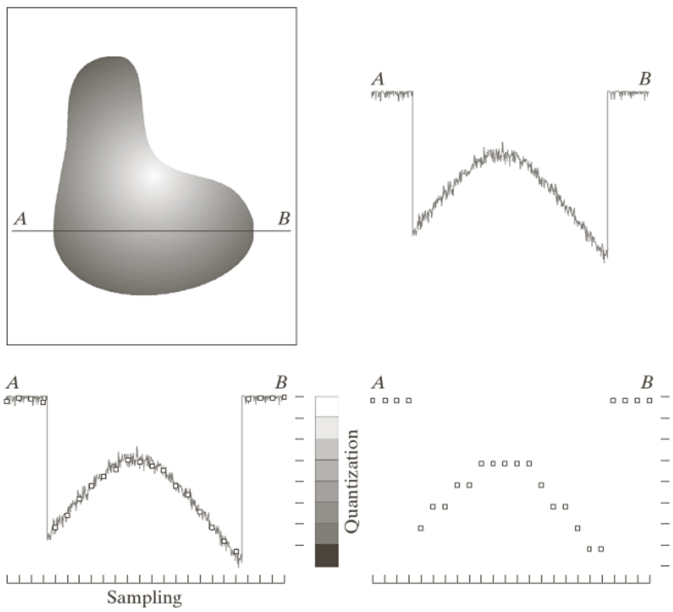
Image formation model

- image: $f(x, y)$, $\quad 0 < f(x, y) < \infty$
- illumination: $i(x, y)$, $\quad 0 < i(x, y) < \infty$
- reflectance: $r(x, y)$, $\quad 0 < r(x, y) < 1$
  - reflectance + absorbance + transmittance = 1
- $f(x, y) = i(x, y)\, r(x, y)$

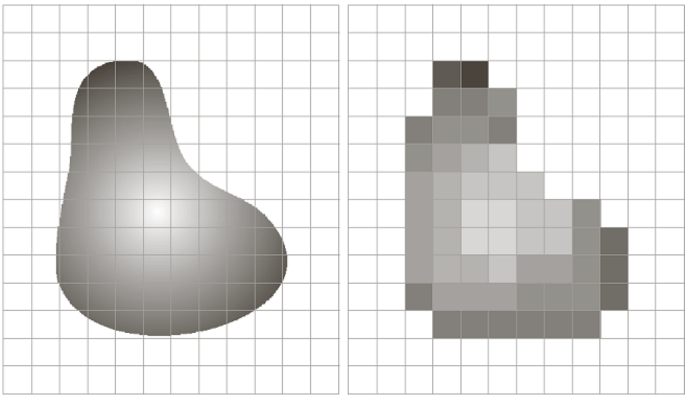
In practice:

- $L_{\text{min}} < f(x, y) < L_{\text{max}}$
  - where: $L_{\text{min}} = i_{\text{min}}\, r_{\text{min}}$ e $L_{\text{max}} = i_{\text{max}}\, r_{\text{max}}$
- $[L_{\text{min}}, L_{\text{max}}]$ is called *gray scale* of the image.
- Conventionally, $[L_{\text{min}}, L_{\text{max}}]$ is scaled in $[0, L-1]$ ([black, white]).
  - althoght, $[0, 1]$ can be preferred for the calculation.

Quantization



Sampling

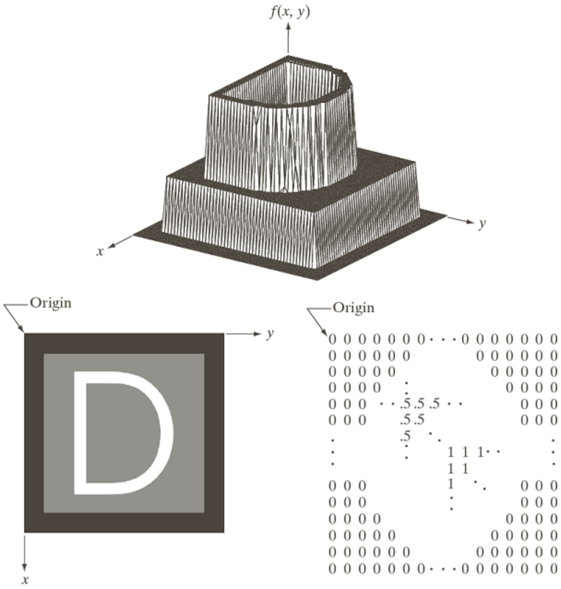


a | b

The image observed by the acquisition device is projected onto the sensor array (a) where it is sampled and quantized (b).

The color of every pixel of the image (b) is obtained as the average color of the corresponding region in (a) (sampling), approximated at the closer gray level among those available (quantization).

Representation of images



- The image $f(x, y)$ is represented as a $M \times N$ matrix at L discrete values.
- x is conventionally associated to the discrete coordinates $\{0, \ldots, M-1\}$, y to $\{0, \ldots, N-1\}$ and $f(x, y)$ to $\{0, \ldots, L-1\}$

- For practical reasons, L is generally a power of 2: $L = 2^k$.
- In this way, every pixel is represented using k bits.

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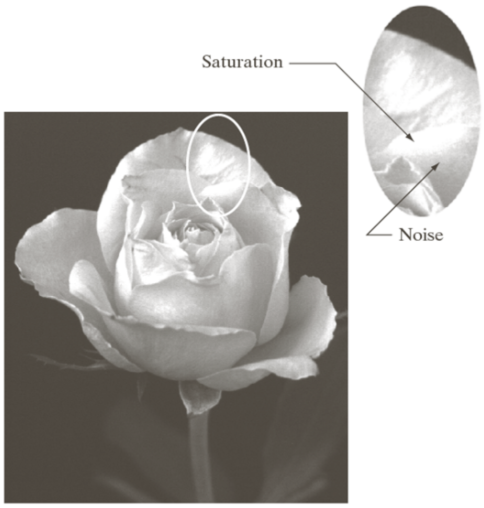
Sampling limitations



- The sensor performs a measurement of the light intensity.
- Since it is a measurement instrumentation, the sensor is prone to error.
- The *saturation* is the phenomenon for which all the intensities over a given threshold are represented as white
- The *noise* is the measurement error of the sensor. It can be detected in the darker regions, where, instead of being black, some pixels are dark gray.
- The *dynamic range* of the image is the ratio between the higher and the lower intensity level in the image.

Number of bits

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

- The number of bits, b, required for representing a $M \times N$ image at L gray levels is: $b = MN \log_2 L$.
- For $L = 2^k$, $b = MNk$.

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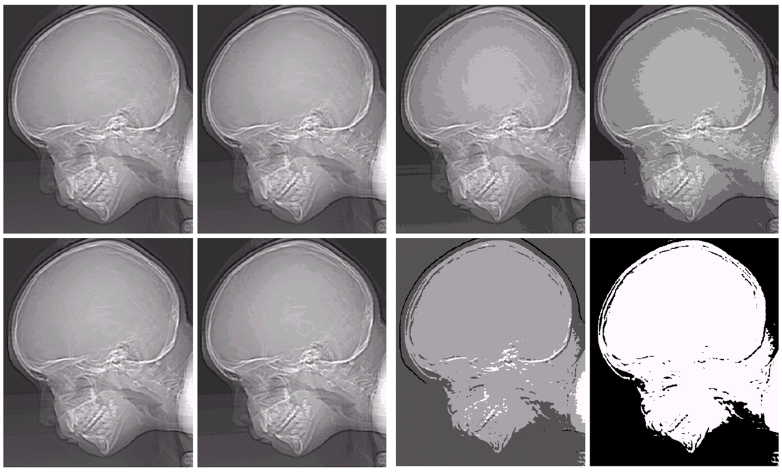
Resolution

- The spatial resolution of an image is the size of the smallest detail that can be recognized in the image.
- Often, the resolution is measured in *dpi* (*dots per inch*).

Number of colors



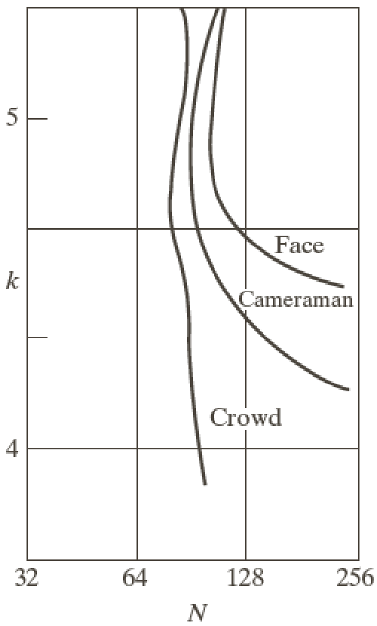
- The number of the gray levels determines the intensity resolution.
- A low number of gray levels in an almost uniform region may cause the so called *false contouring* effect.

Image content

a | b | c

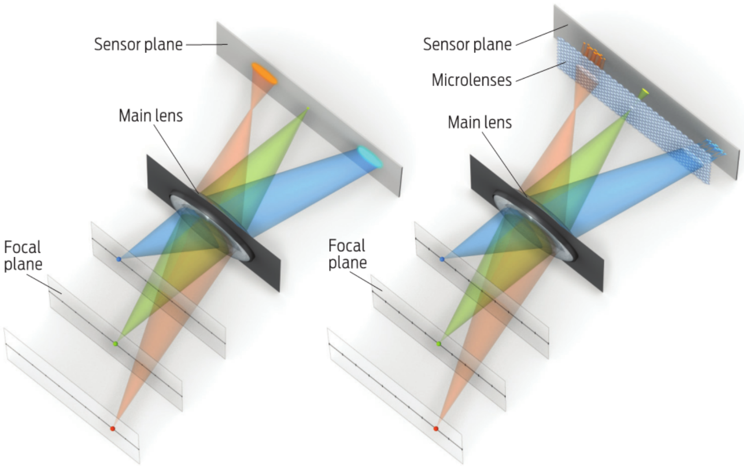
- Images can be classified on the base of their details density.
- (a) low details content: most of the regions are almost uniform.
- (b) medium details content: almost uniform regions and few details.
- (c) high details content: every object of the scene is described by few pixels.

Isopreference curve



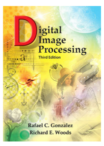
- The *isopreference curve* of an image is generated asking to several people to group copies of the same image, but at different spatial and intensity resolution, such that images from the same group share the same subjective quality.
- Low detailed images are mainly affected by the number of intensity levels, while those with many details are sensitive to the spatial resolution.

Light-field camera



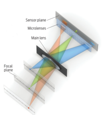
- Light-field cameras can capture not only the color and the intensity of incoming rays, but also their direction.
- The image has to be computed a-posteriori.
- Camera settings (e.g., focus, aperture) can be decided when processing the image.

Homeworks and suggested readings



DIP, Sections 2.2, 2.3, 2.4

- pp. 43–65



Light-field cameras

- `http://spectrum.ieee.org/consumer-electronics/gadgets/lightfield-photography-revolutionizes-imaging/0`
- `http://dx.doi.org/10.1109/MSPEC.2012.6189575`

Pixel size matters

- `http://spectrum.ieee.org/geek-life/tools-toys/pixels-size-matters`
- `http://dx.doi.org/10.1109/MSPEC.2012.6189568`