ECE 178: Introduction (contd.)

Lecture Notes #2: more basics

- Section 2.4 –sampling and quantization
- Section 2.5 –relationship between pixels, connectivity analysis

Light and the EM Spectrum

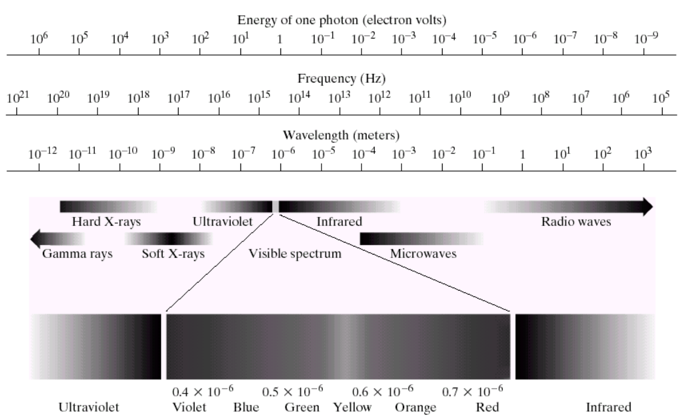
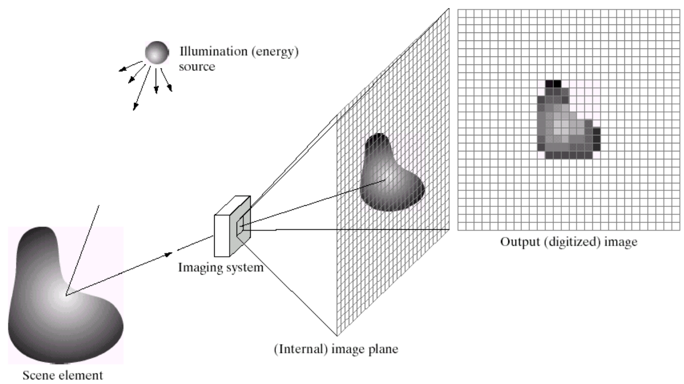


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

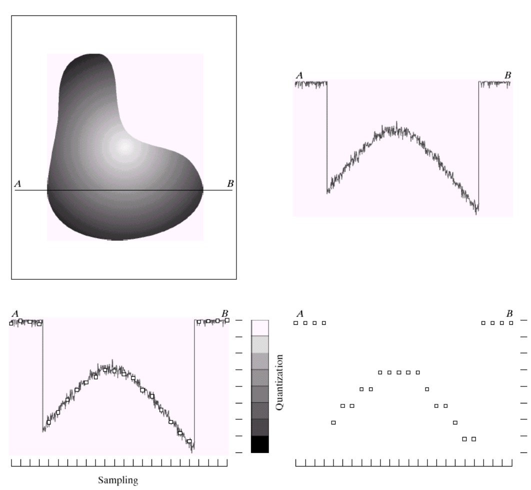
Digial Image Acquisition



a b c d e

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Sampling and Quantization



a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Sampling & Quantization (contd.)

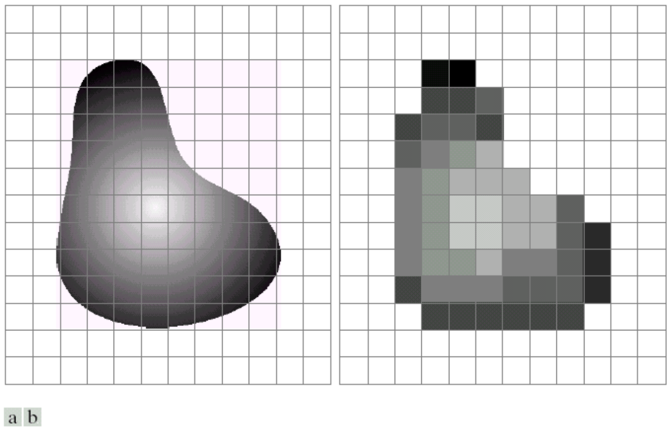


FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Digital Image: Representation

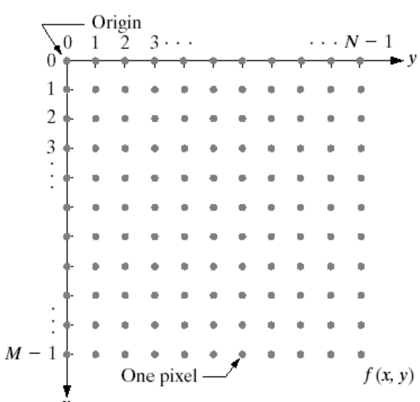


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

Storage Requirement

Image Dimension: NxN; k bits per pixel.

TABLE 2.1
Number of storage bits for various values of N and k.

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

Spatial Resolution

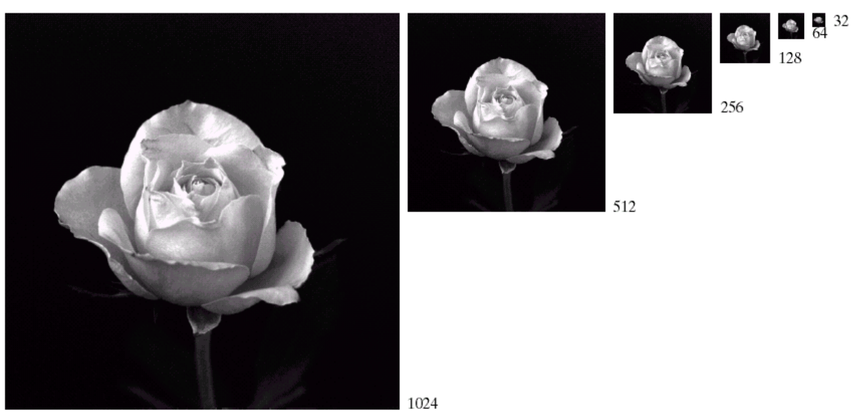
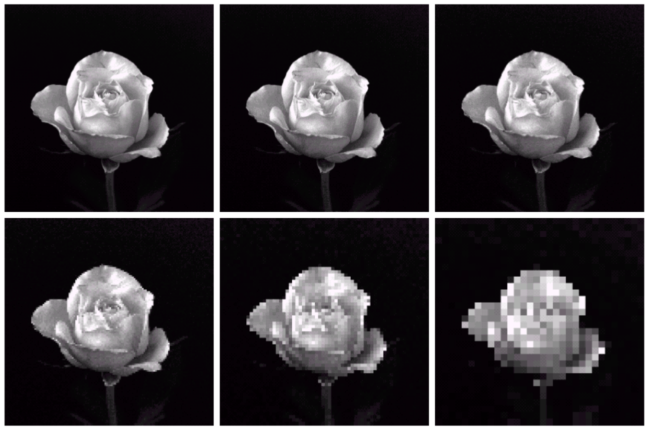


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

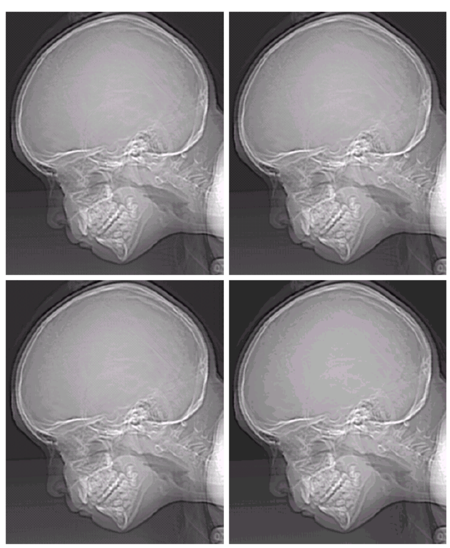
Re-sampling…



a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

Quantization: Gray-scale resolution



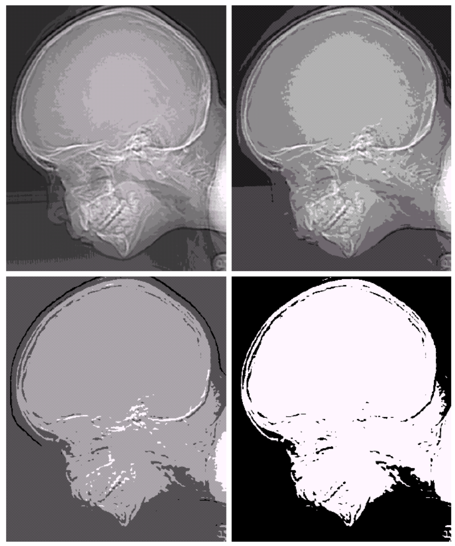
a b
c d

FIGURE 2.21 (a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.

…false contouring

e f
g h

FIGURE 2.21 *(Continued)* (e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



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Sampling and Aliasing

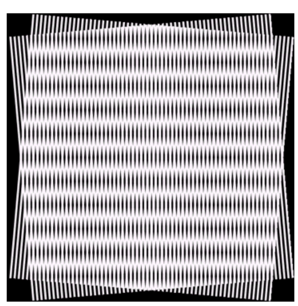

FIGURE 2.24 Illustration of the Moiré pattern effect.

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Additional Reading

- Chapter 1, Introduction
- Chapter 2, Sections 2.1-2.4
  - We will discuss sampling and quantization in detail later
- Next:
  - some basic relationships between pixels (Section 2.5)

Relationship between pixels

- Neighbors of a pixel
  - 4-neighbors (N,S,W,E pixels) == $N_4(p)$. A pixel *p* at coordinates (x,y) has four horizontal and four vertical neighbors:
    - (x+1,y), (x-1, y), (x,y+1), (x, y-1)
  - You can add the four diagonal neighbors to give the 8-neighbor set. Diagonal neighbors == $N_D(p)$.
  - 8-neighbors: include diagonal pixels == $N_8(p)$.

Pixel Connectivity

Connectivity -> to trace contours, define object boundaries, segmentation.

In order for two pixels to be connected, they must be "neighbors" sharing a common property—satisfy some similarity criterion. For example, in a binary image with pixel values "0" and "1", two neighboring pixels are said to be connected if they have the same value.

Let V: Set of gray level values used to define connectivity; e.g., V={1}.

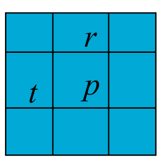
Connectivity-contd.

- 4-adjacency: Two pixels p and q with values in V are 4-adjacent if q is in the set $N_4(p)$.
- 8-adjacency: q is in the set $N_8(p)$.
- m-adjacency: Modification of 8-A to eliminate multiple connections.
  - q is in $N_4(p)$ or
  - q in $N_D(p)$ and $N_4(p) \cap N_4(q)$ is empty.

Connected components

- Let S represent a subset of pixels in an image.
- If p and q are in S, p is connected to q in S if there is a path from p to q entirely in S.
- Connected component: Set of pixels in S that are connected; There can be more than one such set within a given S.

4-connected components



p=0: no action;

p=1: check r and t.

- both r and t = 0; assign new label to p;
- only one of r and t is a 1. assign that label to p;
- both r and t are 1.
  - same label => assign it to p;
  - different label=> assign one of them to p and establish equivalence between labels (they are the same.)

Second pass over the image to merge equivalent labels.

Exercise

Develop a similar algorithm for 8-connectivity.

Problems with 4- and 8-connectivity

- Neither method is satisfactory.
  - Why? A simple closed curve divides a plane into two simply connected regions.
  - However, neither 4-connectivity nor 8-connectivity can achieve this for discrete labelled components.
  - Give some examples..

Related questions

- Can you “tile” a plane with a pentagon?

Distance Measures

- What is a Distance Metric?

  For pixels *p,q,* and *z,* with coordinates (*x,y*), (*s,t*), and (*u,v*), respectively:

$$D(p,q) \geq 0 \quad (D(p,q) = 0 \text{ iff } p = q)$$

$$D(p,q) = D(q,p)$$

$$D(p,z) \leq D(p,q) + D(q,z)$$

Distance Measures

- Euclidean

$$D_e(p,q) = \sqrt{(x-s)^2 + (y-t)^2}$$

- City Block

$$D_4(p,q) = |x-s| + |y-t|$$

- Chessboard

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2