



Prof. Pascal Matsakis



Digital Image Processing (DIP): Introduction and Fundamentals

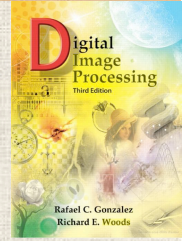


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DIP: Introduction and Fundamentals

I. Origins of DIP

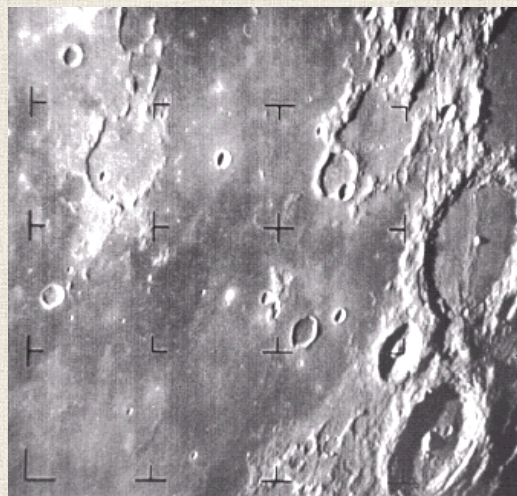
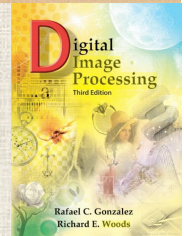
I.1. Newspaper Industry (1920s)



Digital picture produced in 1921

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I.2. Space Program (1960s)



First picture of the moon
by a US spacecraft in 1964

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DIP: Introduction and Fundamentals

II. Interest in DIP



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Interest in DIP

6

II.1. Overview

Applications in many fields:

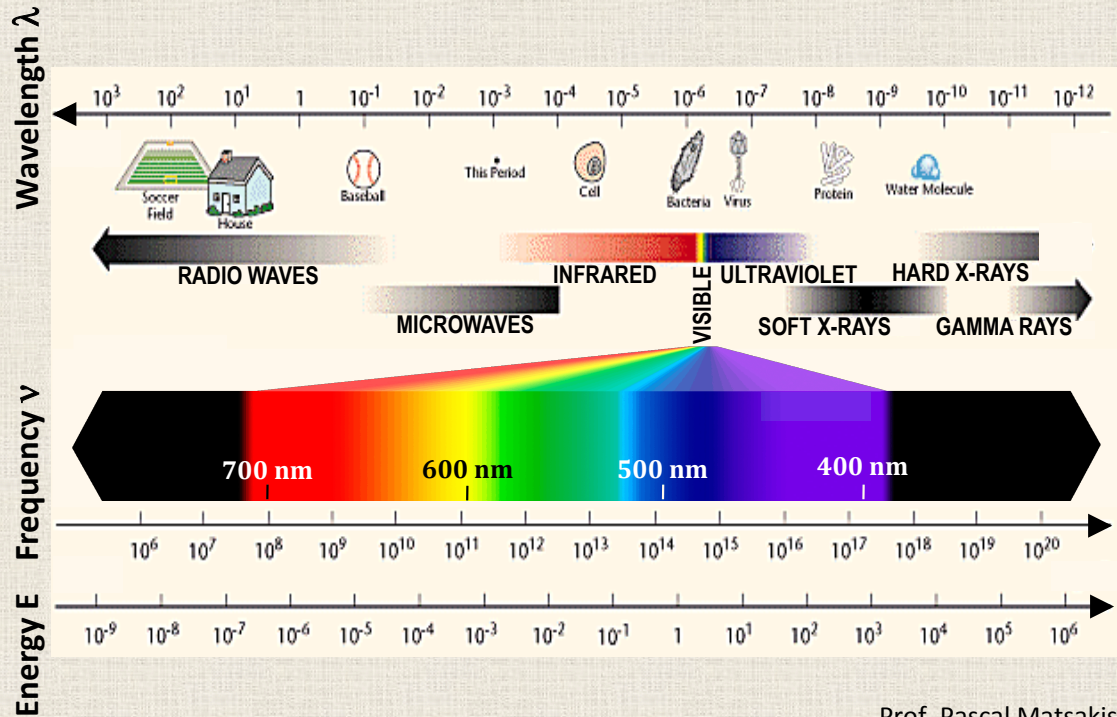
medicine, geography, physics, astronomy, defense...

Examples:

character recognition, fingerprint recognition, target recognition, weather prediction, crop assessment, detection of bone fractures, detection of brain tumors, study of high-energy plasmas...

II.2a. Imaging in the Electromagnetic Spectrum

$$\lambda \nu = c, E = h\nu$$



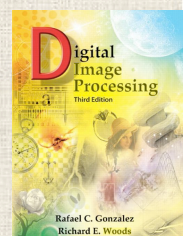
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II.2b. Imaging in the Electromagnetic Spectrum

Gamma-Ray



Bone scan
(to localize infections and tumors)



II.2c. Imaging in the Electromagnetic Spectrum

X-Ray

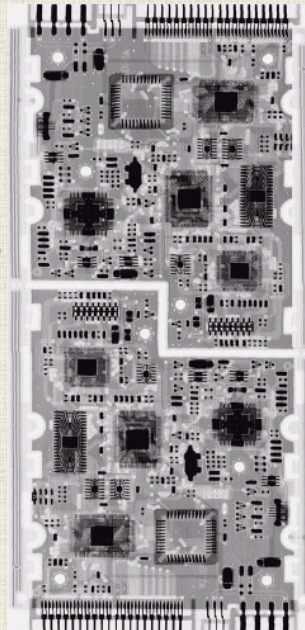
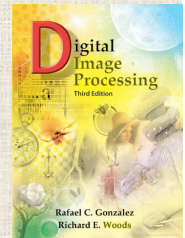


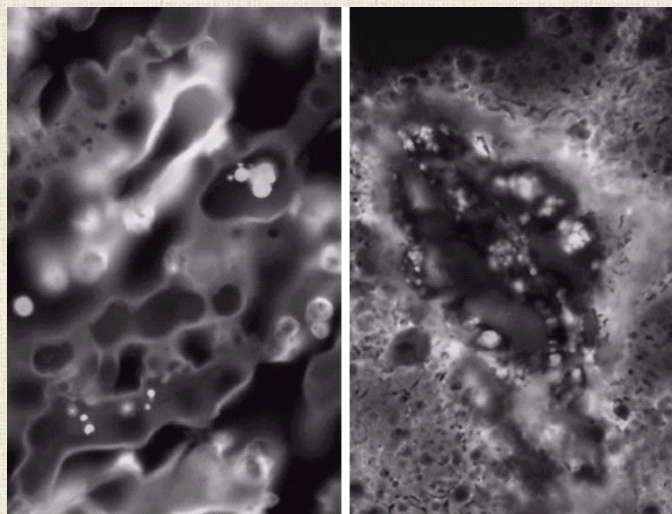
Image of a circuit board
(to detect flaws)



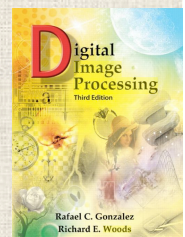
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II.2d. Imaging in the Electromagnetic Spectrum

Ultraviolet



Fluorescence microscope images of corn
(to find if corn is infected by smut)



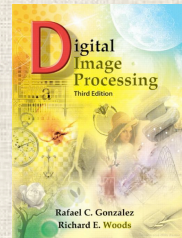
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II.2e. Imaging in the Electromagnetic Spectrum

Visual Spectrum



Image of paper currency
(to track and identify bills)

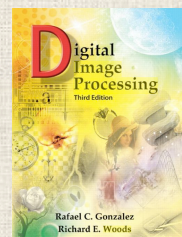


II.2f. Imaging in the Electromagnetic Spectrum

Infrared

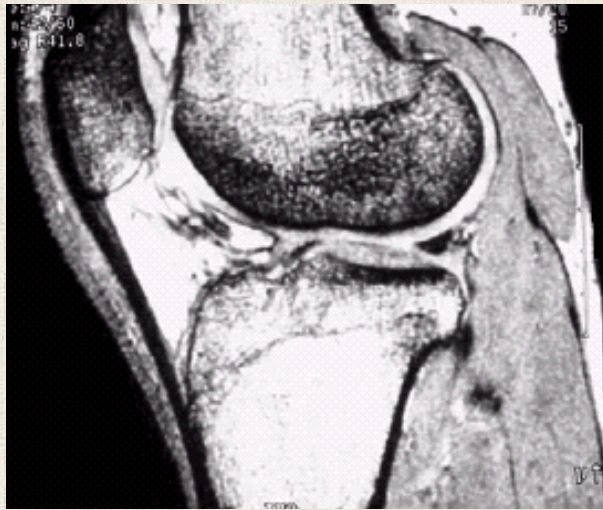


Satellite image of North America
(global inventory of human settlements)

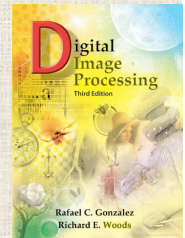


II.2g. Imaging in the Electromagnetic Spectrum

Radio-Band



MRI image of a human knee
(diagnosis of sport-related injuries)



II.2h. Imaging in the Electromagnetic Spectrum

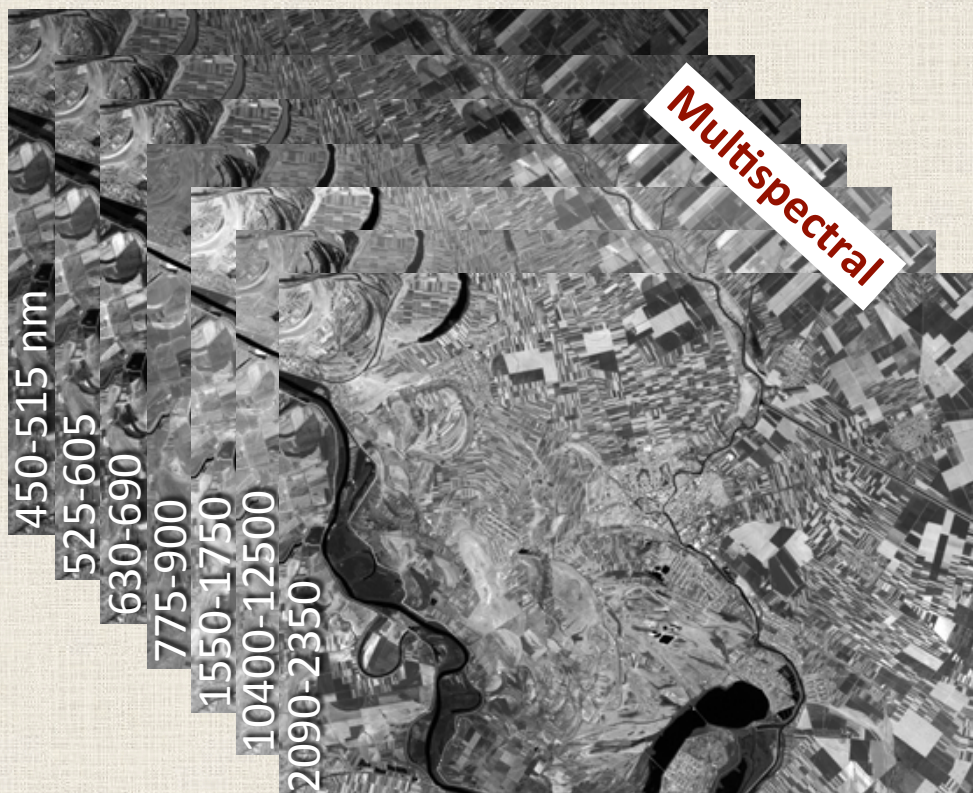


II.2i. Imaging in the Electromagnetic Spectrum



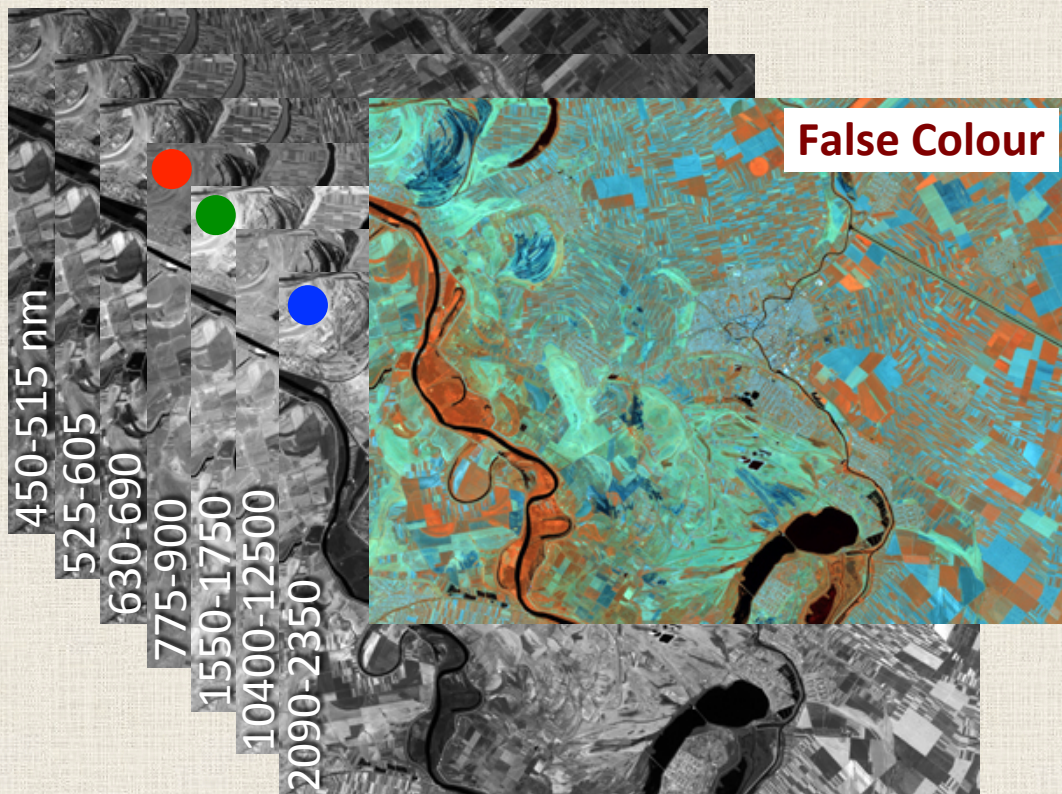
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II.2j. Imaging in the Electromagnetic Spectrum



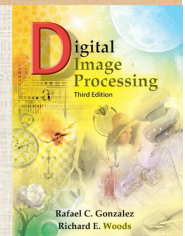
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II.2k. Imaging in the Electromagnetic Spectrum



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II.3a. Other Imaging Modalities



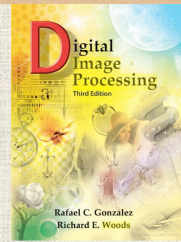
Ultrasound



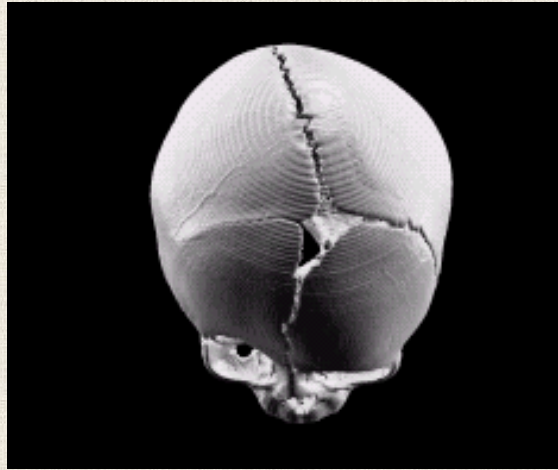
Image of an unborn baby
(to determine the health of his development)

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II.3b. Other Imaging Modalities



Synthetic



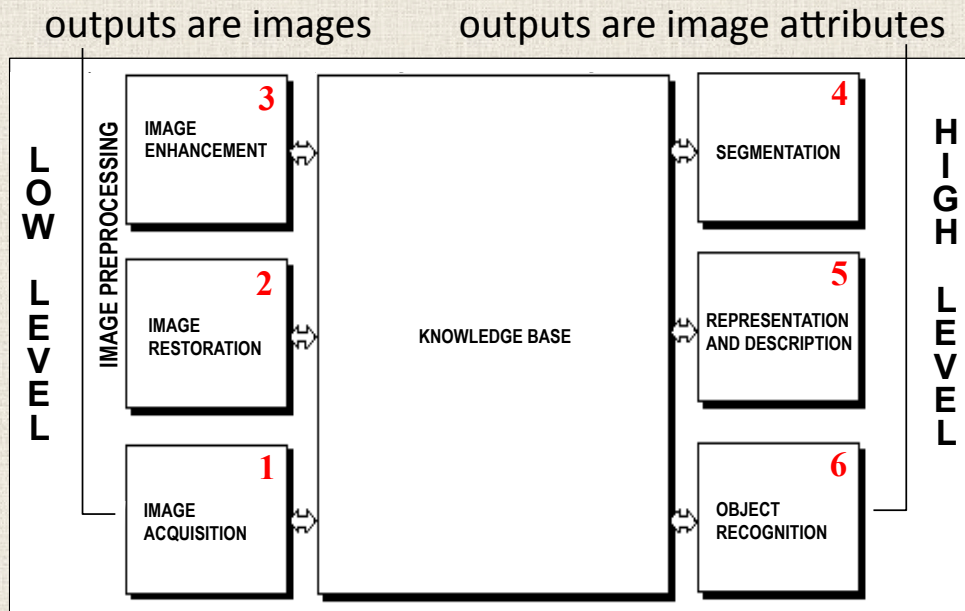
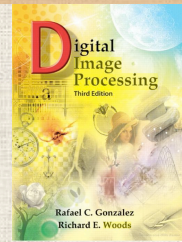
Computer-generated image of a human skull
(for criminal forensics)

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III. Main Steps in DIP

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III.1a. Overview



III.1b. Overview

LOW LEVEL:

acquisition and improvement of pictorial information for human interpretation and analysis

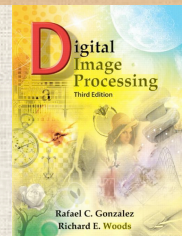
HIGH LEVEL:

autonomous machine perception

III.1c. Overview

- DIP characterized by specific solutions.
- Techniques that work well in one area can be totally inadequate in another.
- Actual solution of a specific problem generally still requires significant research and development.

III.2a. Examples



Which step?

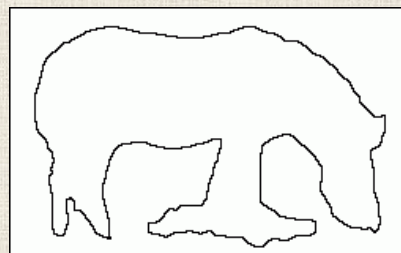
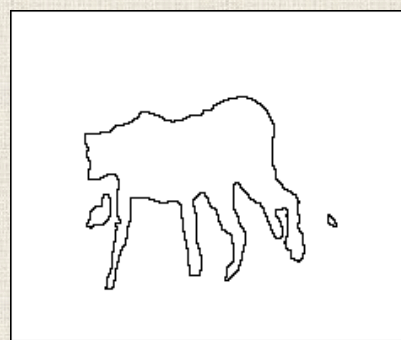
III.2b. Examples



Which step?

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III.2c. Examples



Which step?

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III.2d. Examples



Which step?

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IV. Image Definition and Representation

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IV.1a. Analog Image

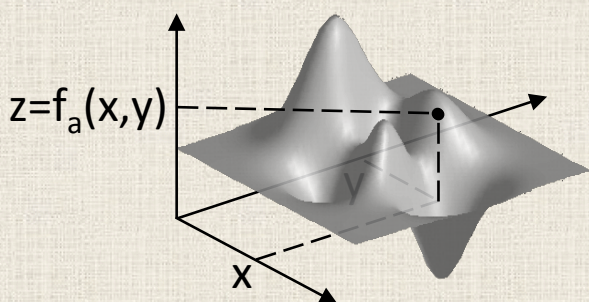
image {

- function $f_a | \mathbb{R}^2 \rightarrow [0; +\infty[$
- function $f_a | \mathbb{R}^3 \rightarrow \mathbb{R}$
- function $f_a | \mathbb{R}^2 \rightarrow \mathbb{R}^3$
- function $f_a | \mathbb{R}^2 \rightarrow \mathbb{C}$

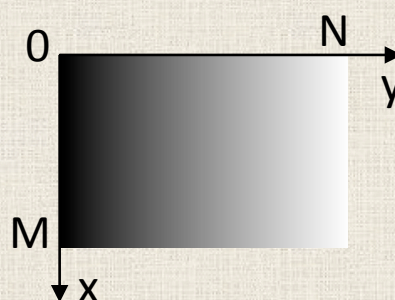
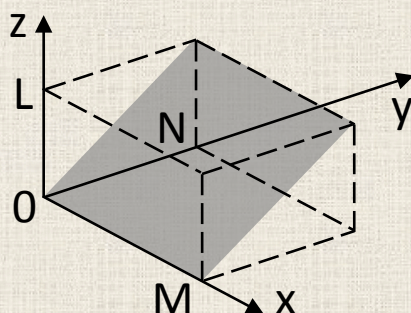
$f_a | \mathbb{R}^2 \rightarrow [0; +\infty[$ is a typical case;
 $f_a(x,y)$ is the **intensity** of f_a at (x,y) .

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IV.1b. Analog Image



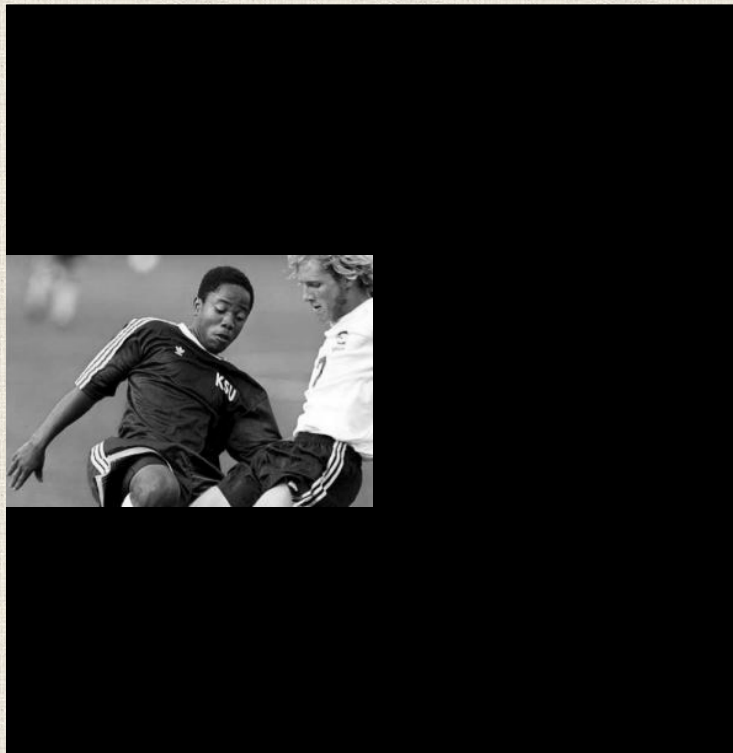
Consider $f_a | \mathbb{R}^2 \rightarrow [0; +\infty[$



Domain of definition $[0,M] \times [0,N]$ and range $[0,L]$

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IV.1c. Analog Image

 f_a **Zero Padding**

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IV.1d. Analog Image

 f_a **Circular Indexing**

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IV.1e. Analog Image



Reflected Indexing

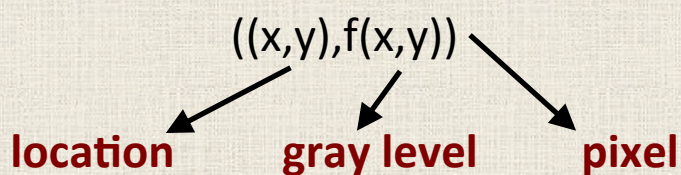
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IV.2a. Digital Image

image {

- function
 $f \mid \mathbb{Z}^2 \rightarrow 0..+\infty$
- function
 $f \mid \mathbb{Z}^3 \rightarrow \mathbb{Z}$
- function
 $f \mid \mathbb{Z}^2 \rightarrow \mathbb{Z}^3$

$f \mid \mathbb{Z}^2 \rightarrow 0..+\infty$ is a typical case: **grayscale image**



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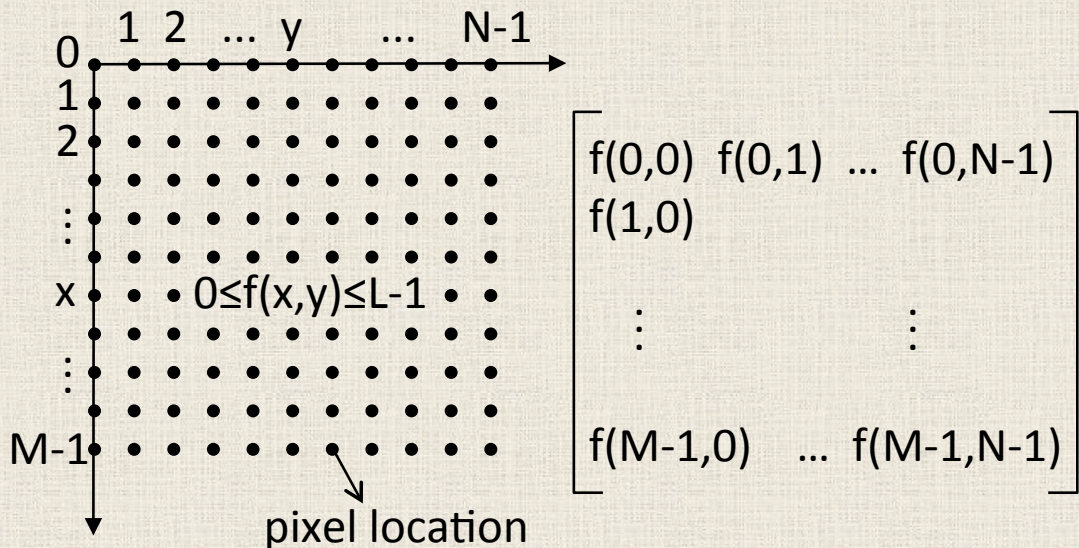
IV.2b. Digital Image

Consider $f | \mathbb{Z}^2 \rightarrow 0..+\infty$

Assume range included in $0..L-1$:

typically, $L=2^\ell$, i.e., **ℓ -bit grayscale image**

Assume domain of definition is $0..M-1 \times 0..N-1$:



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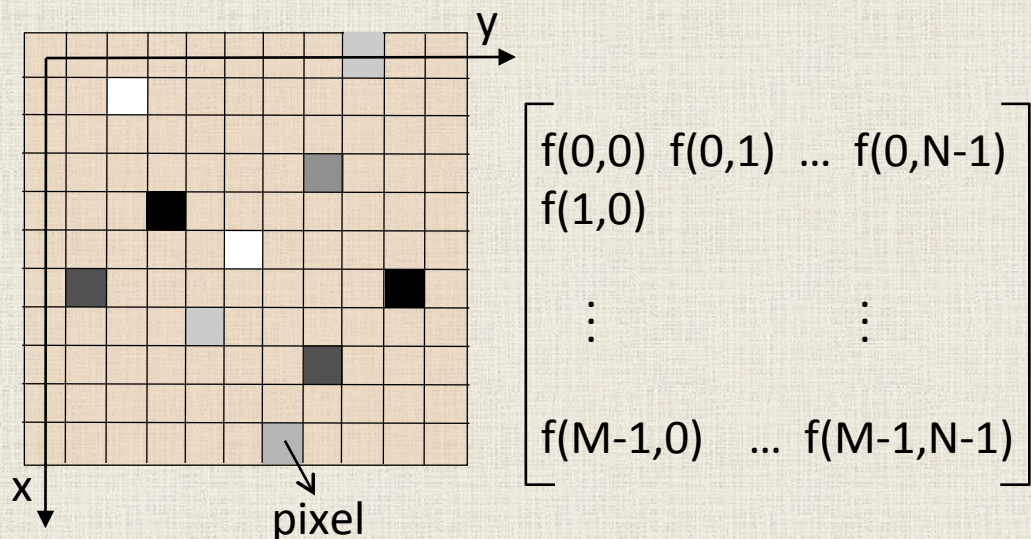
IV.2c. Digital Image

Consider $f | \mathbb{Z}^2 \rightarrow 0..+\infty$

Assume range included in $0..L-1$:

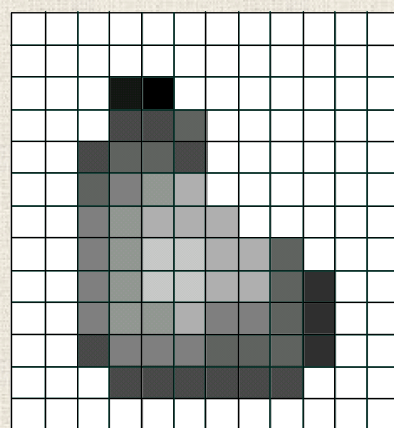
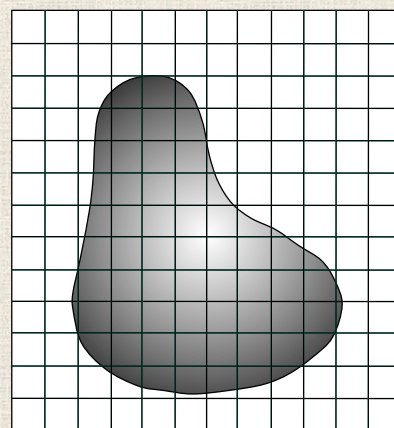
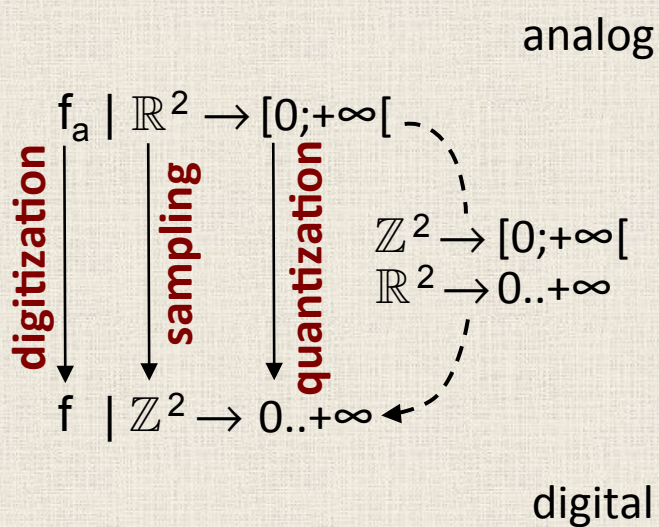
typically, $L=2^\ell$, i.e., **ℓ -bit grayscale image**

Assume domain of definition is $0..M-1 \times 0..N-1$:



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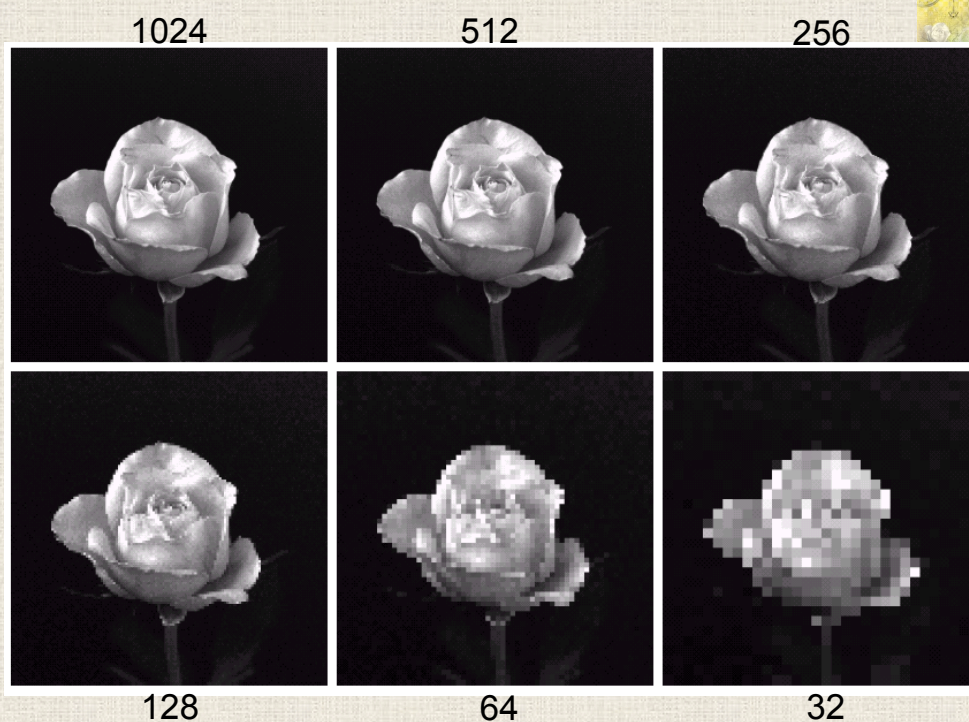
IV.3a. Digitization



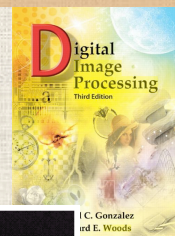
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IV.3b. Digitization

Checkerboard effect:

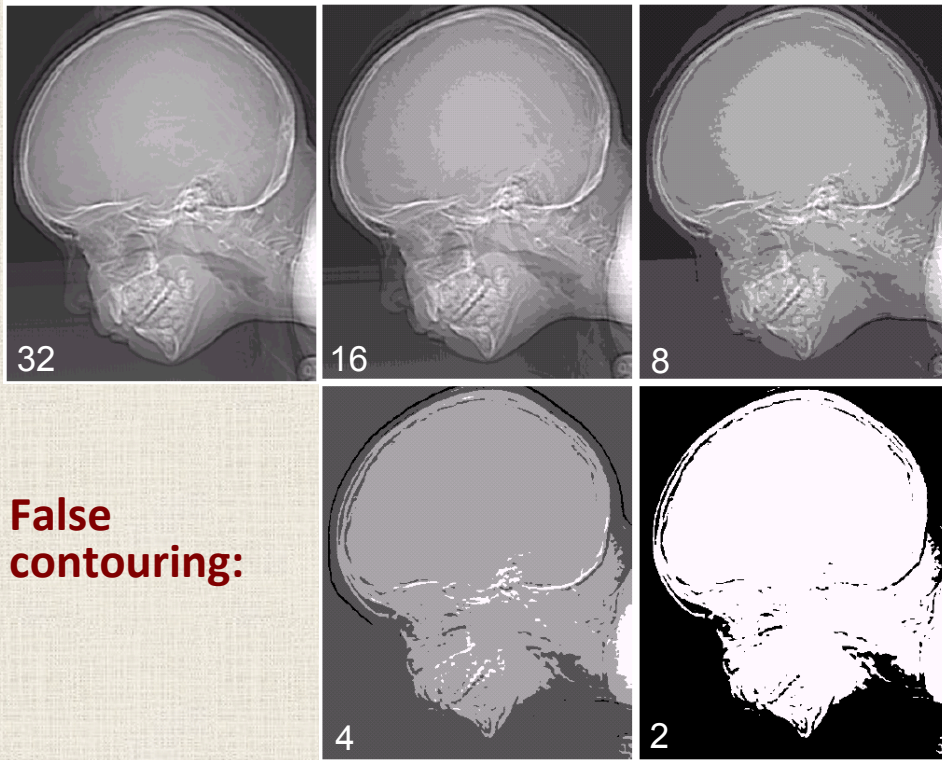
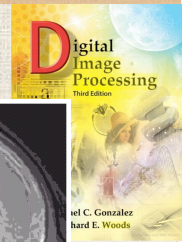


sampling



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IV.3c. Digitization



**False
contouring:**

quantization