Elaborazione di immagini
Image Processing

AA 2016-2017

Dipartimento di Informatica

Università degli Studi di Verona

General information

- Teacher: Gloria Menegaz
- Teaching assistant: Silvia Obertino
- Scheduling
  - Theory (4 CFU)
    - Thu. 9.30 to 11.30, room B
    - Fri. 9.30 to 11.30, room B
    - Laboratory (2 CFU)
    - Wed. 8.30 to 11.30, lab. Delta
  - Tutoring (*ricevimento*)
    - by appointment (email)
  - Start and end dates
    - March 9nd, 2017 – beginning May , 2017

- Exam
  - Theory: oral/written
  - Lab: mini-project
- Support
  - Slides of the course
- Books:
  - Digital image processing, Gonzalez-Woods
  - Digital image processing, Pratt

Q&A

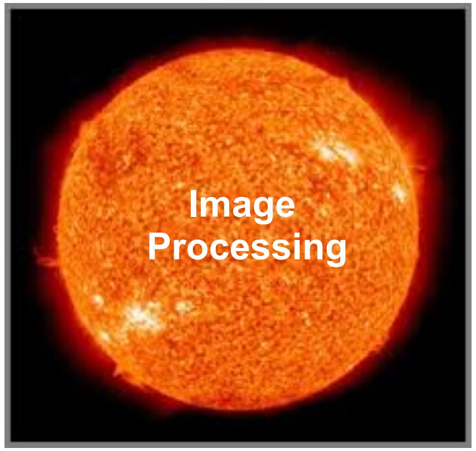
- What is image processing?
  - Image proc … s an image as input and r … utpu

What what what???

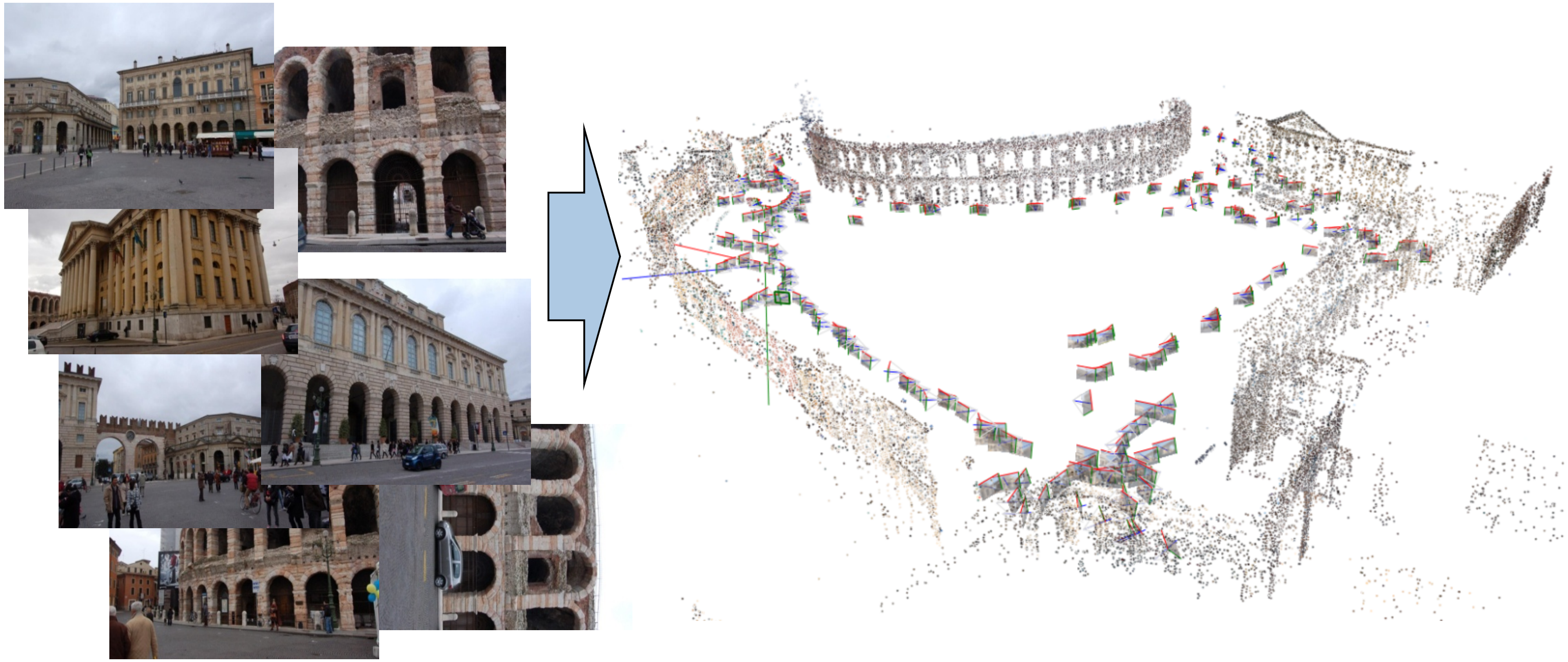
- What is an im
  - An image i … s generated by some acquisition process
  - It is a partic … appening in 2D
- How do we manipulate images?
  - By making mathematical operations on matrices of numbers

Good news: you just need to get familiar with tools and concepts, and have fun!

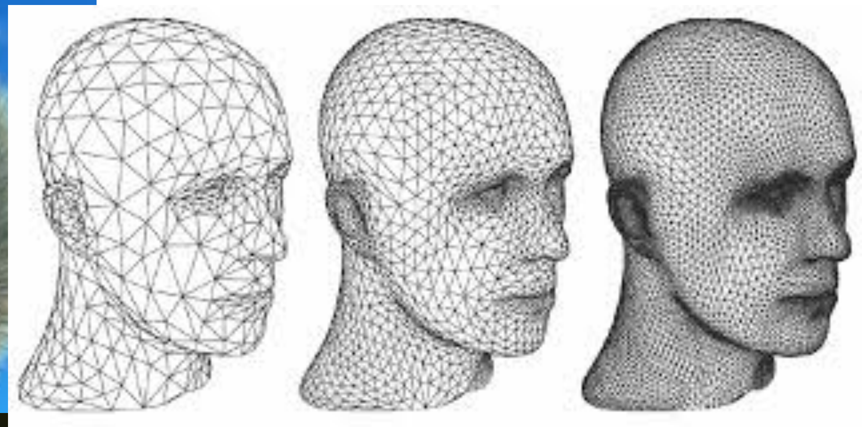
In perspective



Computer vision

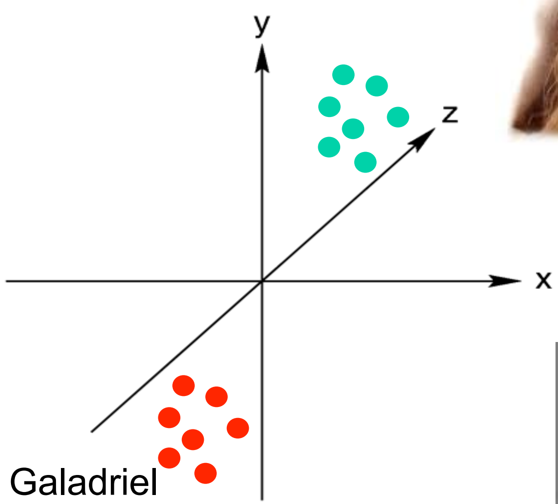


Computer graphics

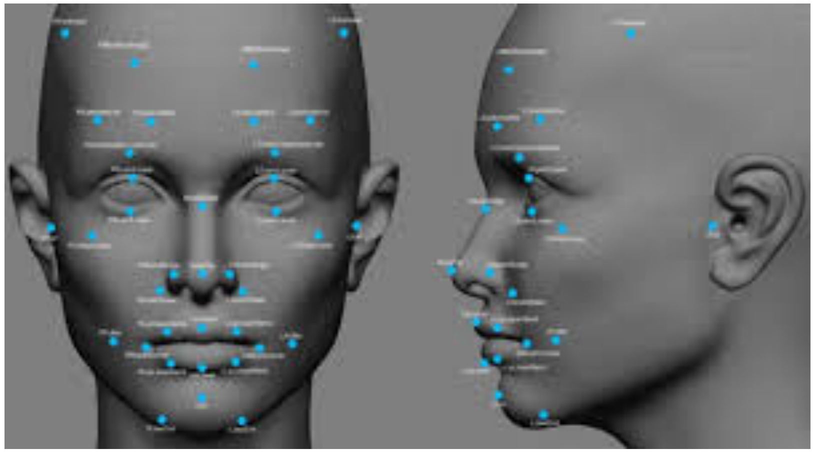


Machine learning

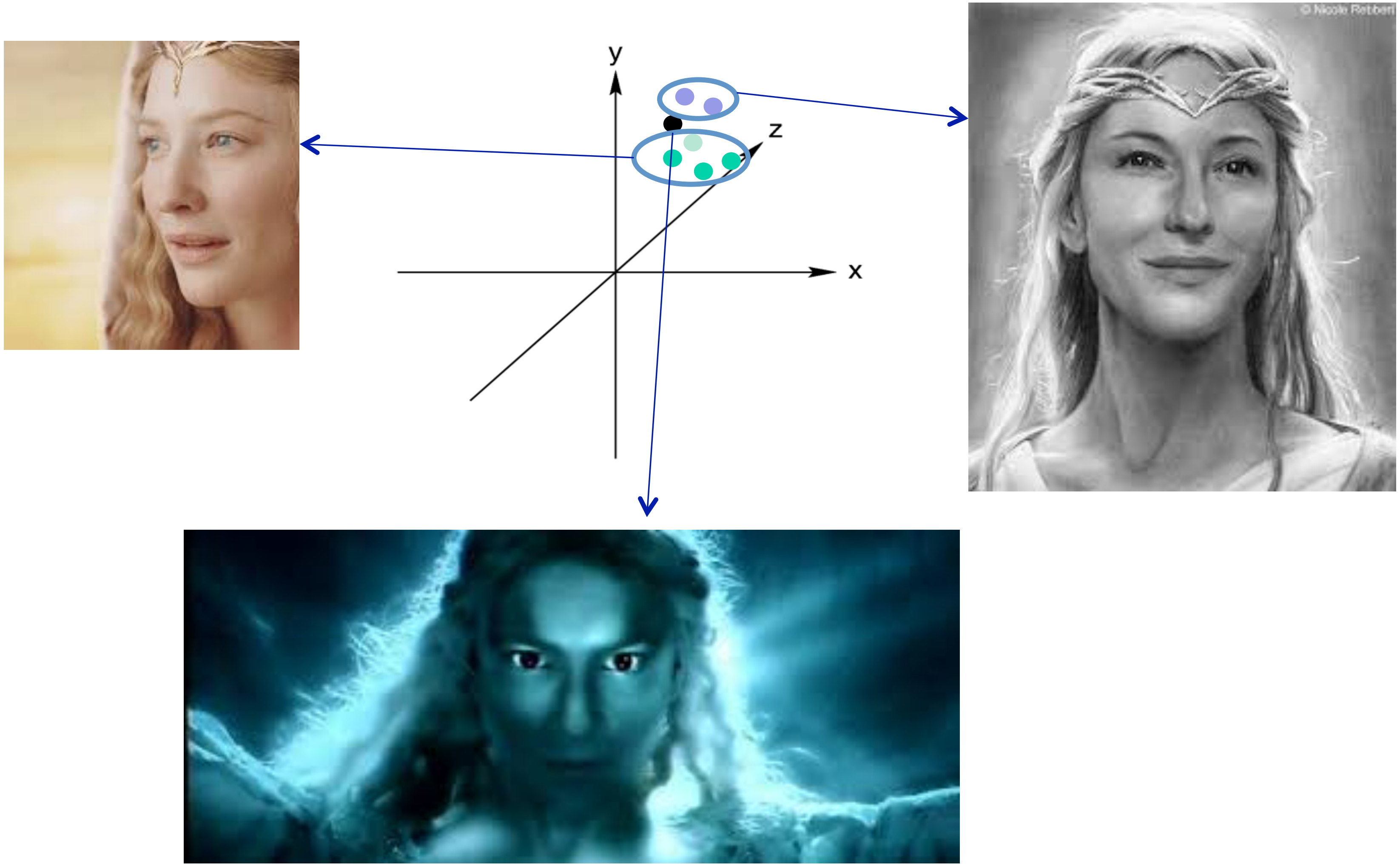
Galadriel



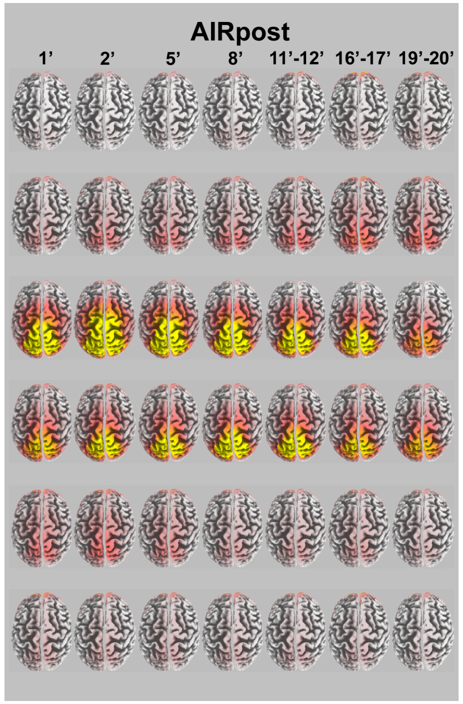
Not Galadriel

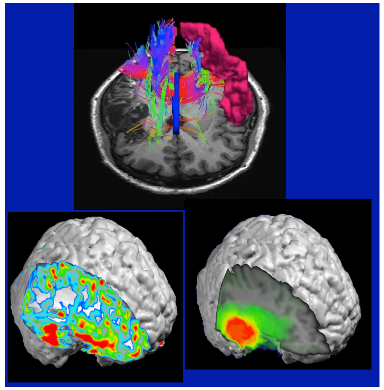


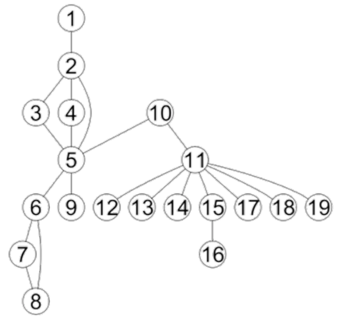
Traveling the feature-space

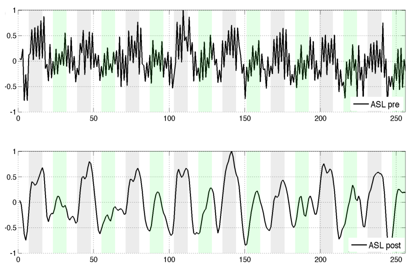


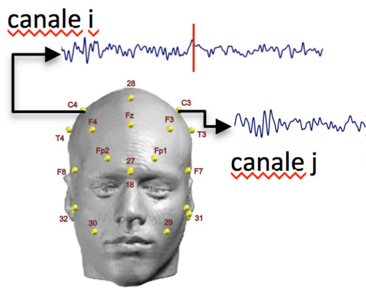
Bioimaging

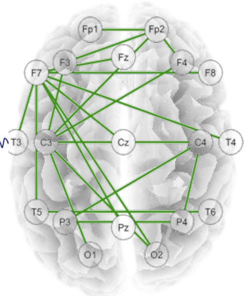

AIRpost
1’ 2’ 5’ 8’ 11’-12’ 16’-17’ 19’-20’

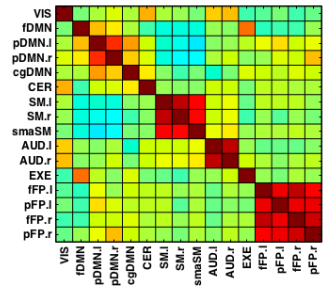



1
2
3 4 10
5 11
6 9 12 13 14 15 17 18 19
7 16
8


ASL pre
ASL post


canale i
canale j


Fp1 Fp2
F7 F3 Fz F4 F8
T3 C3 Cz C4 T4
T5 P3 Pz P4 T6
O1 O2


VIS
fDMN
pDMN.l
pDMN.r
cgDMN
CER
SM.l
SM.r
smaSM
AUD.l
AUD.r
EXE
fFP.l
pFP.l
fFP.r
pFP.r

Link alle lauree magistrali

- Laurea Magistrale in Ingegneria e scienze informatiche (LM-ISI)
  - Computer vision ←→Visione computazionale, AIDV
  - Machine learning, Big data←→Teoria e tecnica del riconoscimento, sistemi avanzati di riconoscimento
  - Bioimaging, machine learning ←→Elaborazione di Immagini 2
  - Virtual reality, Bioimaging←→Interazione uomo-macchina
- Laurea Magistrale in Medical Bioinformatics (LM-MB)
  - Bioimaging ←→Bioimaging
  - Connections with all the other exams of the Computational Vision curriculum in the LM in ISI
- Master in Computer Game Development (MSc-CGD)
  - Virtual reality, Computer vision

Take-home message

- All the keywords map to one ore more courses
- All the courses correspond to research activities
- *A unified and unique framework, different perspectives*
- People involved






Gloria Menegaz EI2, IUM LM-ISI Bioimaging LM-MB	Marco Cristani TTR, SAR, IUM LM-ISI	Andrea Giachetti AIDV, IUM LM-ISI	Umberto Castellani VC, LM-ISI **MSc-CGD**	Manuele Bicego Computational analysis of biological structures and networks LM-MB	Alessandro Daducci Bioimaging LM-MB

Computer vision

- Methods for estimating the *geometrical* and *dynamical* properties of the imaged scene based on the acquired images
  - Scene description based on image features
- Complementary to computer graphics
  - Get information about the 3D real world based on its 2D projections in order to automatically perform predefined tasks

Pattern Recognition

- Image interpretation
- Identification of basic and/or complex structures
  - implies pre-processing to reduce the intrinsic redundancy in the input data
  - knowledge-based
    - use of a-priori knowledge on the real world
    - stochastic inference to compensate for partial data
- Key to clustering and classification
- Applications
  - medical image analysis
  - microarray analysis
  - multimedia applications

Pattern Recognition

- Clustering
  - data analysis aiming at constructing and characterizing clusters (sets without prior knowledge)
- Feature extraction and selection
  - reduction of data dimensionality
- Classification
  - Structural (based on a predefined “syntax”):
    - each pattern is considered as a set of primitives
    - clustering in the form of parsing
  - Stochastic
    - Based on statistics (region-based descriptors)

Contents

- Introduction (GW, Chapter 1)

Contents

- Introduction (GW, Chapter 1)
- Fourier Transform
- Sampling in 2D
- Quantization
- Filtering (linear filters)
- Edge detection
- Segmentation techniques
- Basics of pattern recognition
  - Clustering, classification
- Color imaging
- Hints for Wavelets and multiresolution
- The JPEG coding standard

Why do we process images?

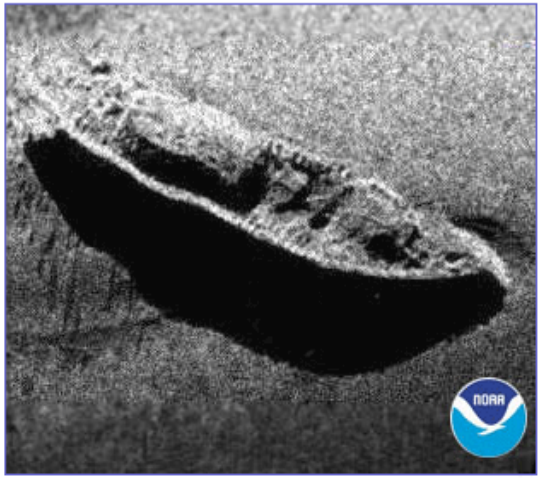
- To facilitate their storage and transmission
- To prepare them for display or printing
- To enhance or restore them
- To extract information from them
- To hide information in them

Image types

Optical (CCD)

radar (SAR)

underwater



infrared

medical (MRI)

Microarray images

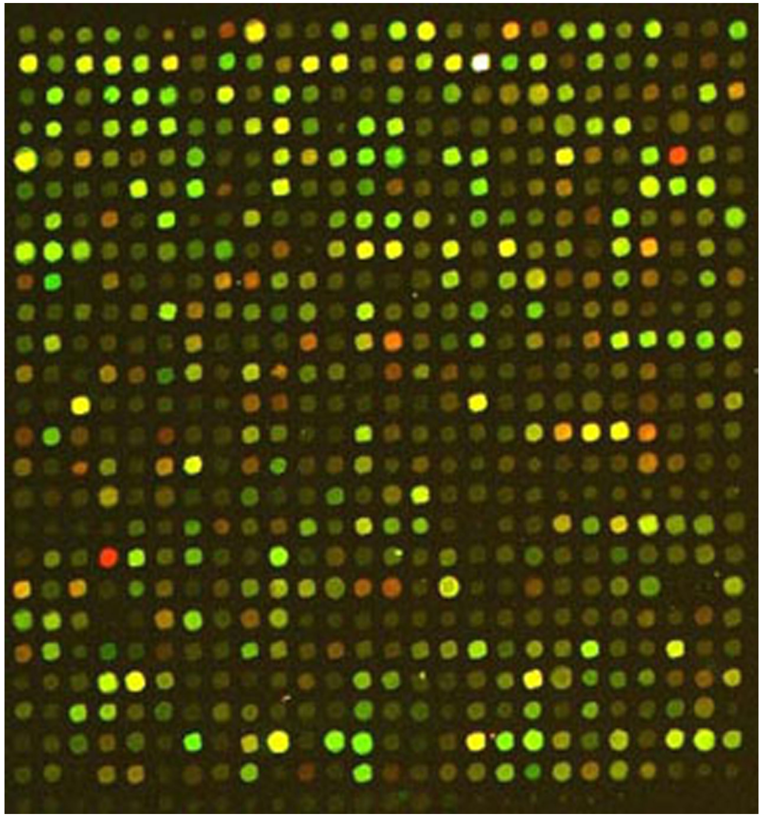


Image Processing Example

- Image Restoration

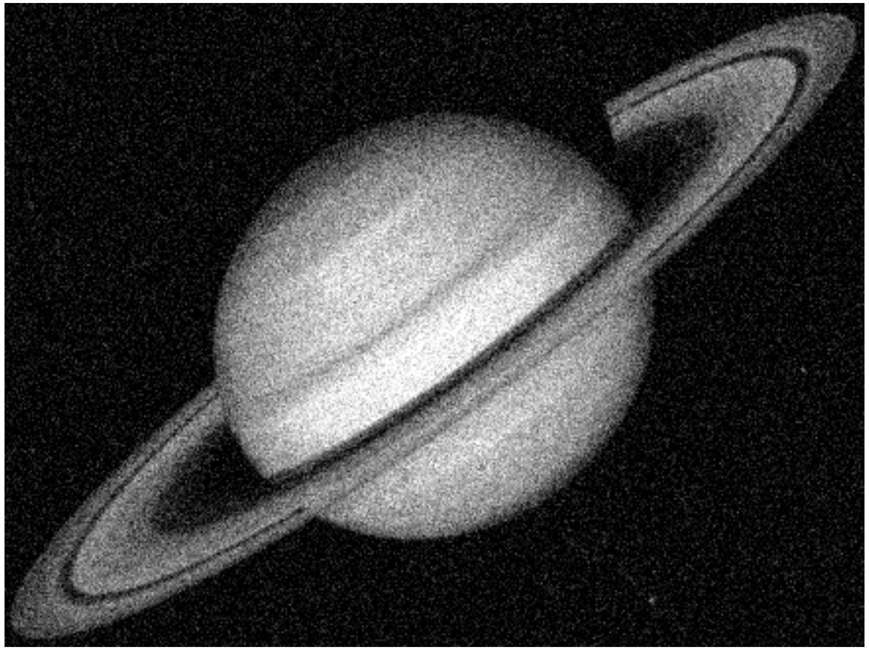
Original image

Blurred

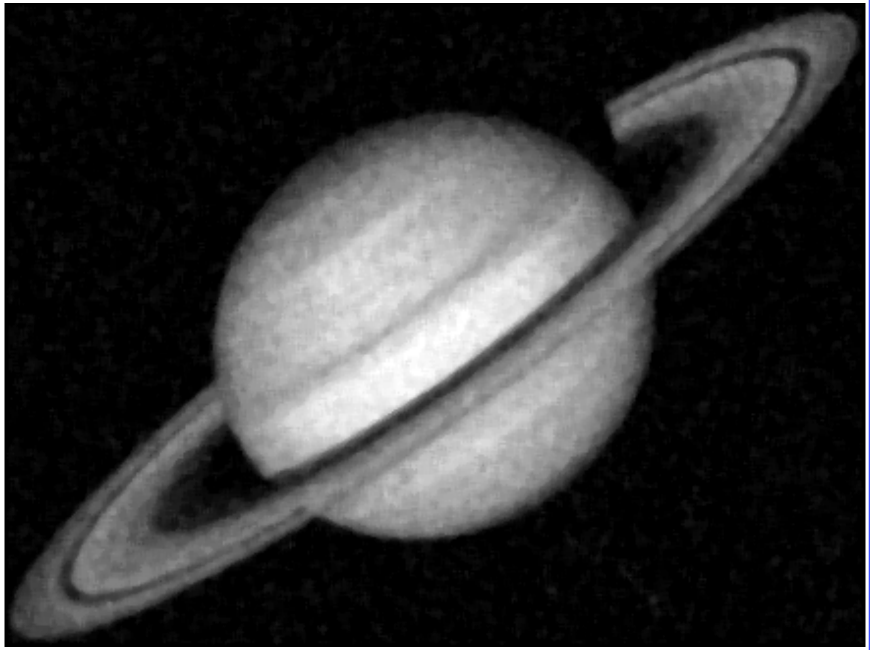
Restored by Wiener filter

Image Processing Example

- Noise Removal



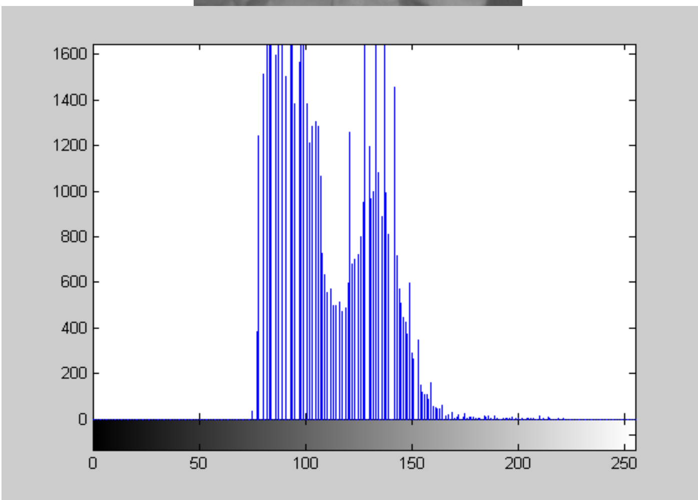
Noisy image



Denoised by Median filter

Image Processing Example

- Image Enhancement



Histogram equalization

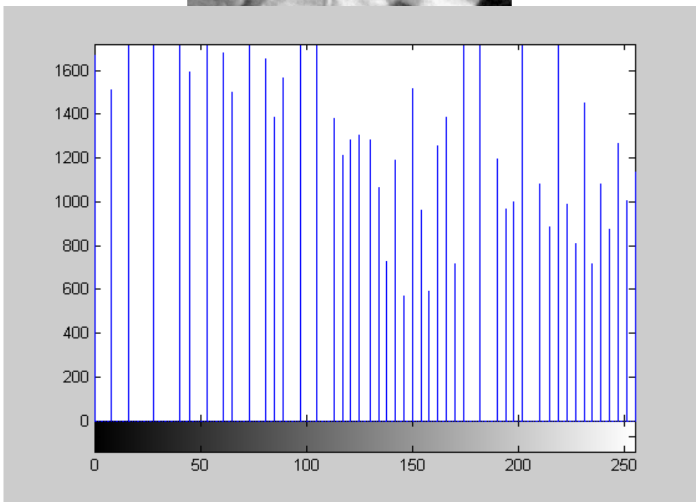


Image Processing Example

- Artifact Reduction in Digital Cameras

Original scene

Captured by a digital camera

Processed to reduce artifacts

Image Processing Example

- Image Compression

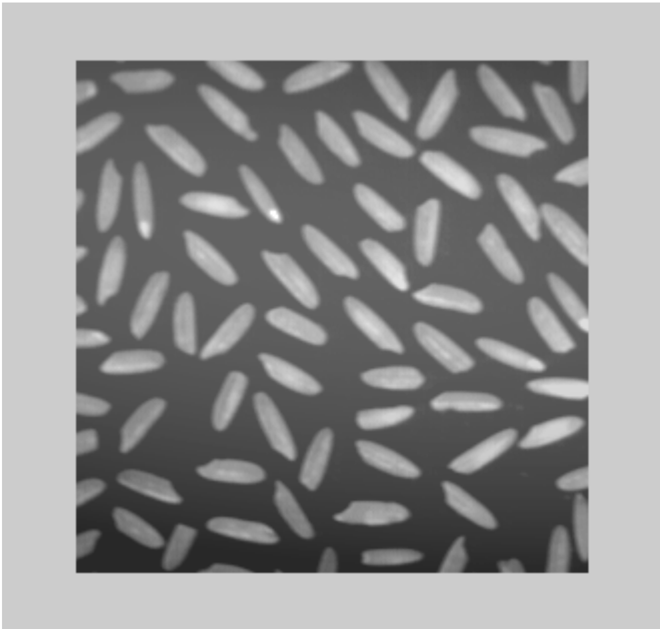
Original image 64 KB

JPEG compressed 15 KB

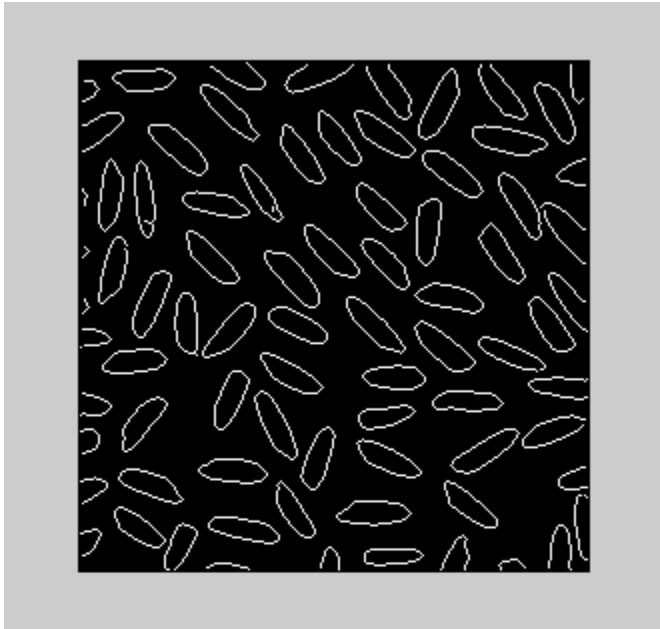
JPEG compressed 9 KB

Image Processing Example

- Object Segmentation



“Rice” image



Edges detected using Canny filter

Image Processing Example

- Resolution Enhancement

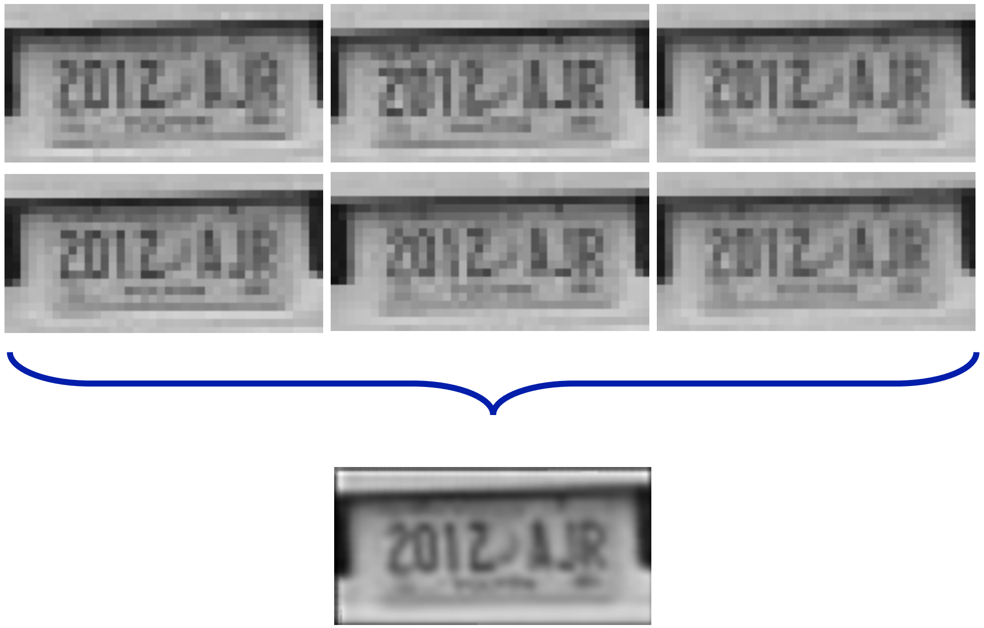


Image Processing Example

- Security and encryption
  - Watermarking

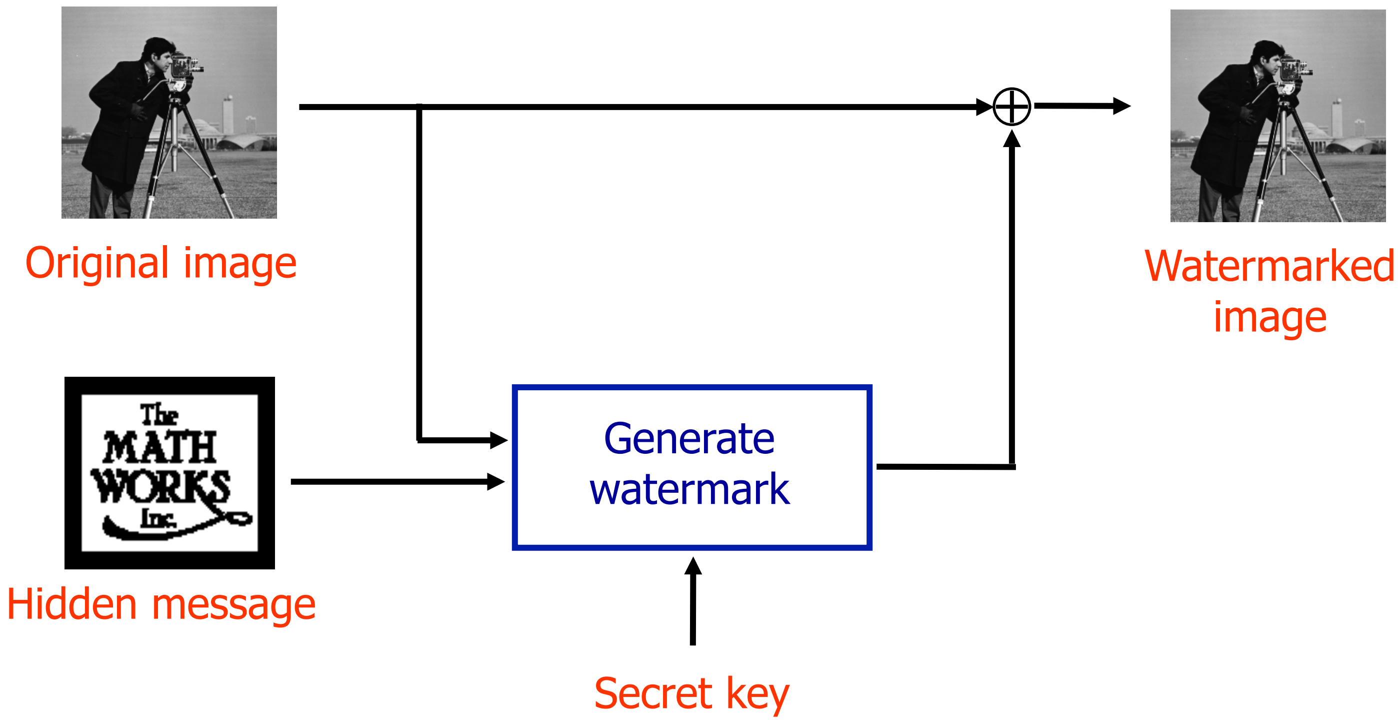


Image Processing Example

- Face Recognition

Image Processing Example

- Fingerprint Matching

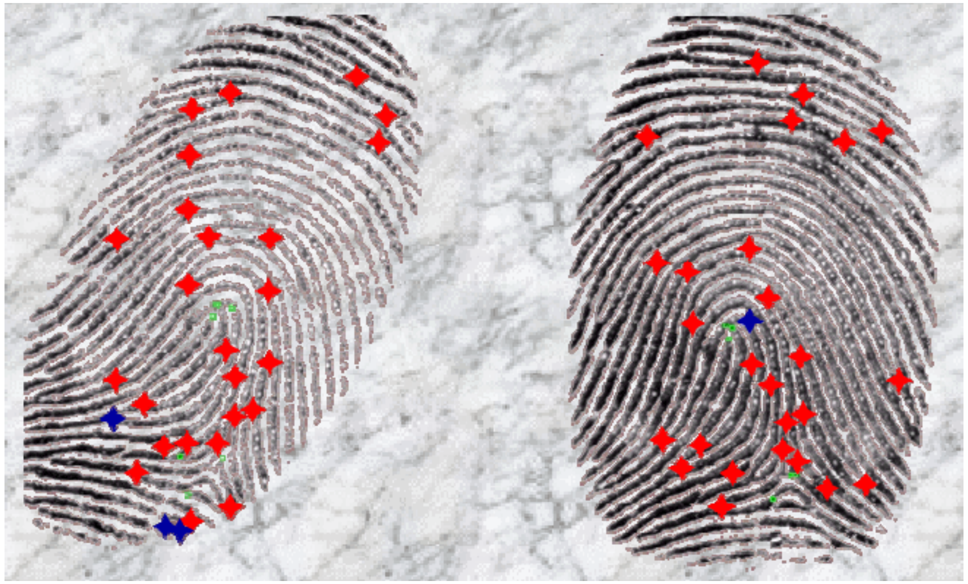


Image Processing Example

- Segmentation

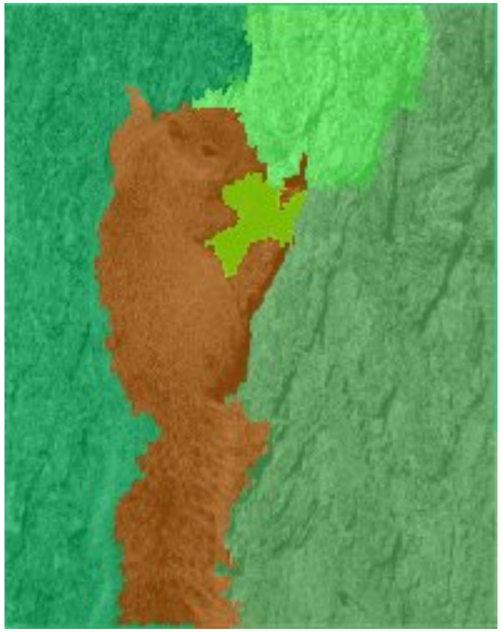
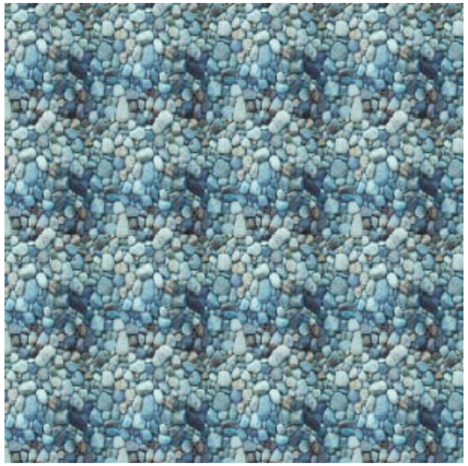


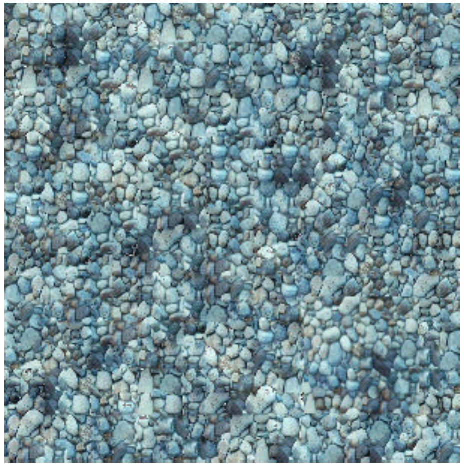
Image Processing Example

- Texture Analysis and Synthesis

Photo



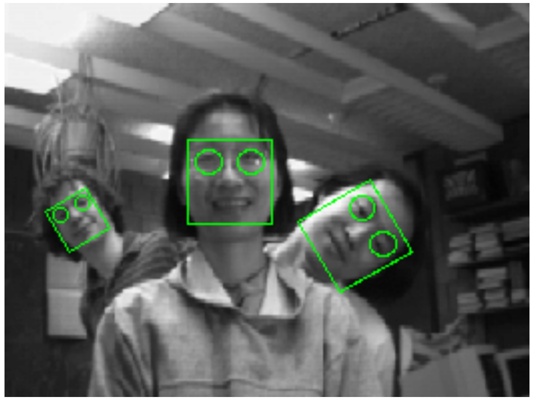
Pattern repeated



Computer generated

Image Processing Example

- Face detection and tracking



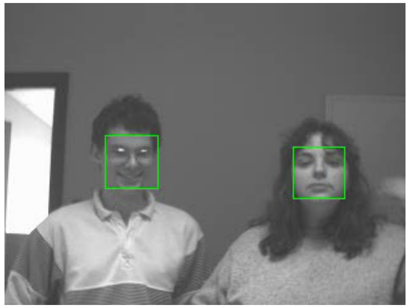


Image Processing Example

- Face Tracking

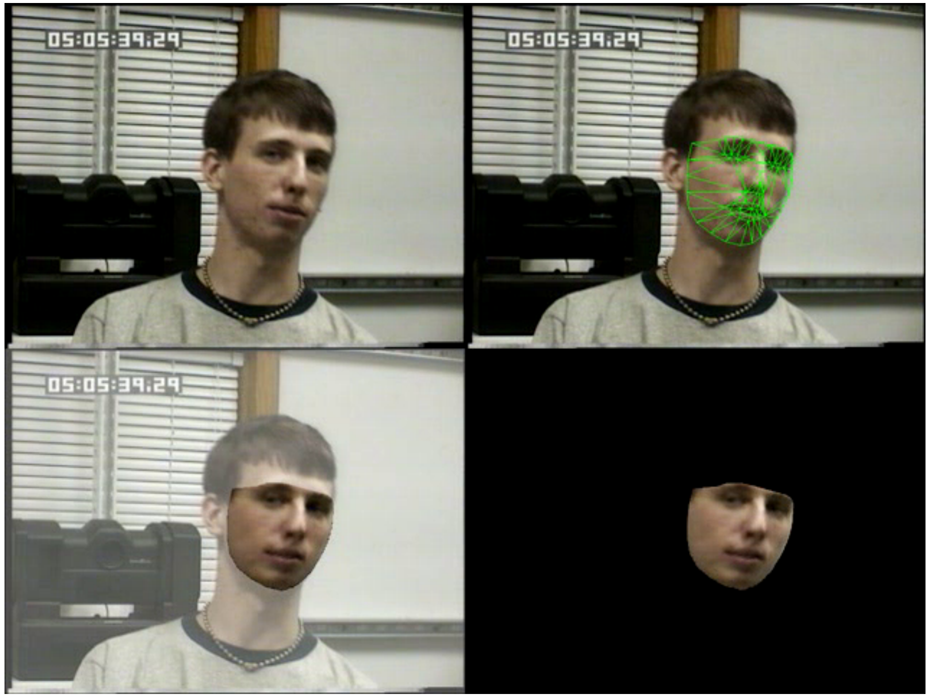
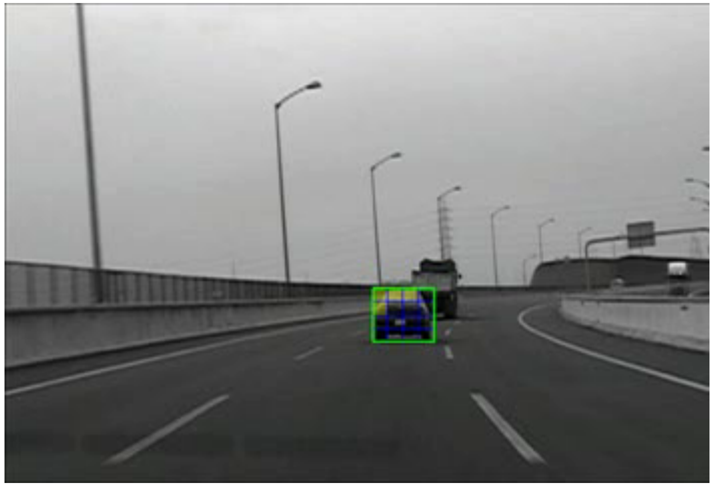
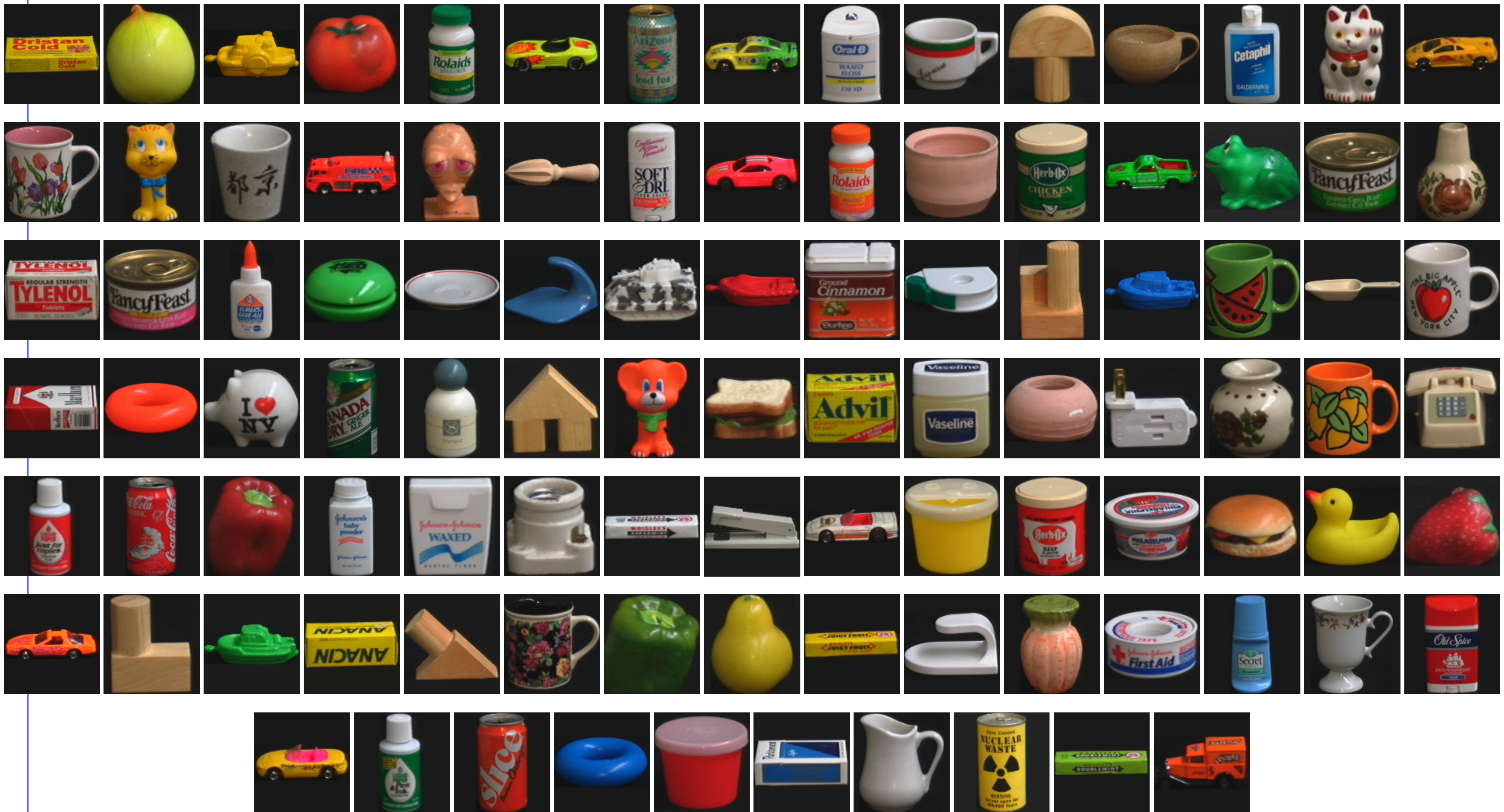


Image Processing Example

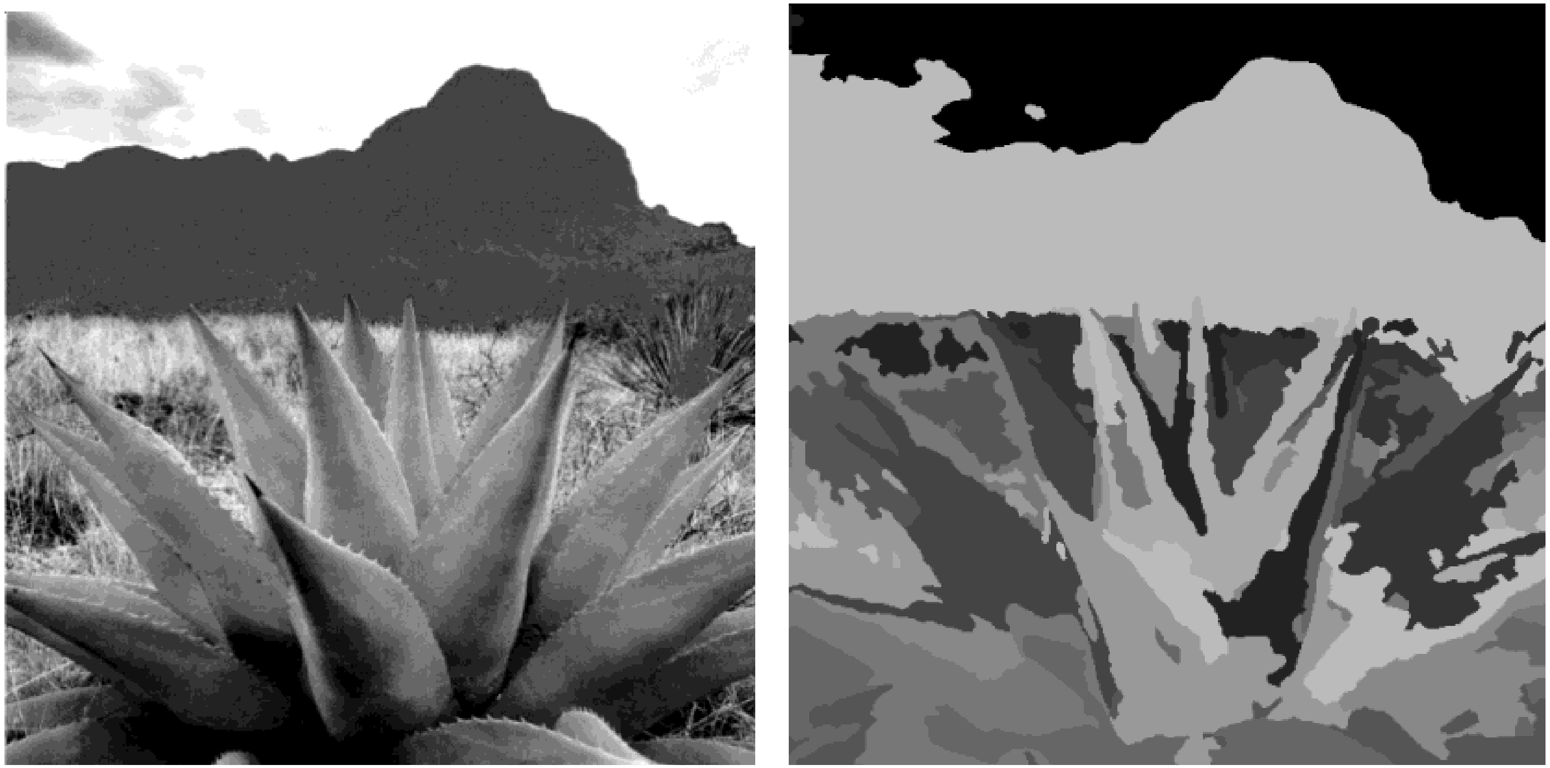
- Object Tracking



Query by example



Segmentation

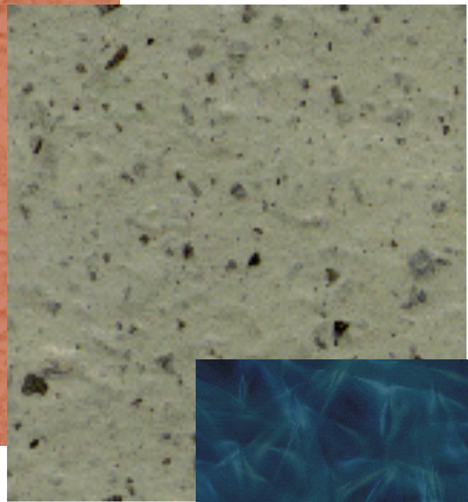
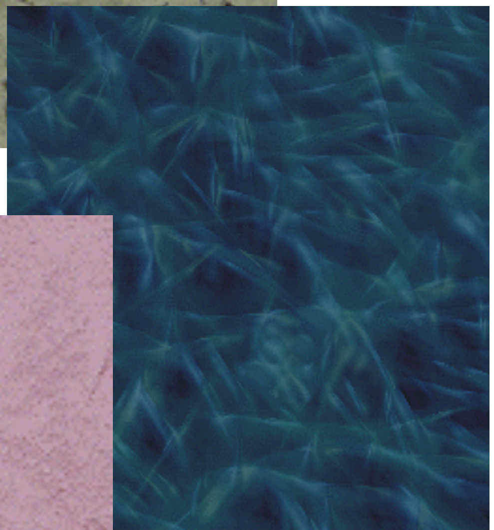


Face recognition

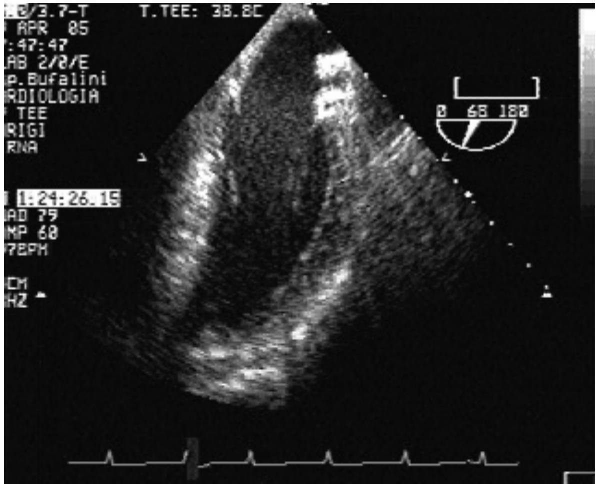




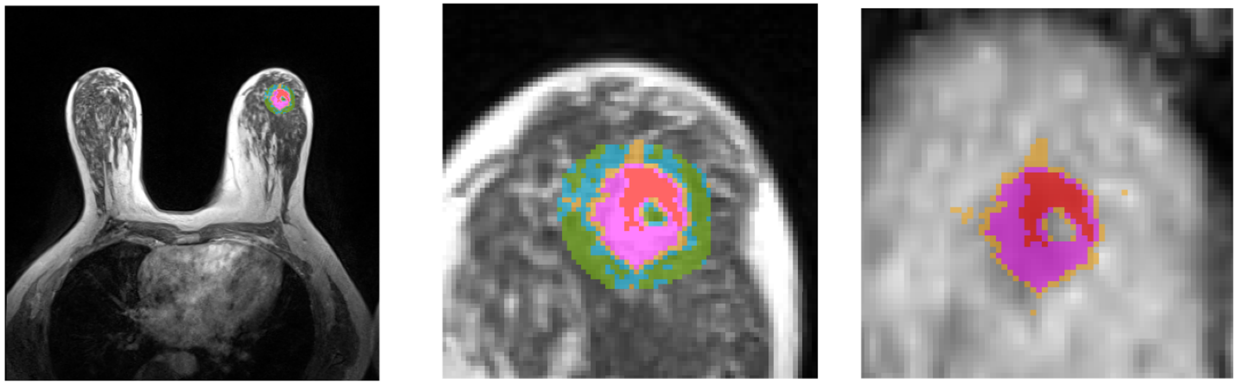
Texture analysis


Medical textures

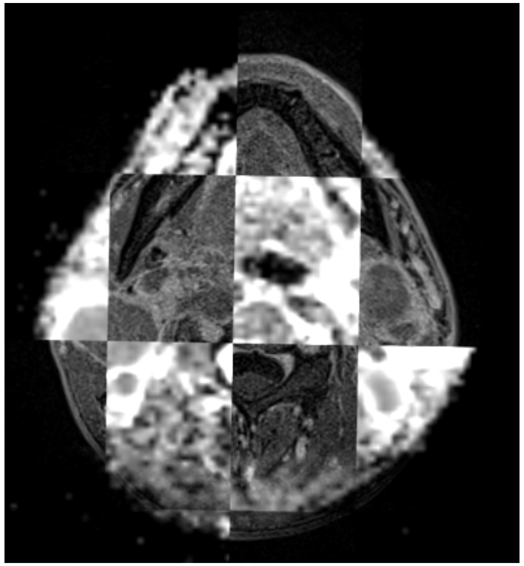


Medical Image Analysis



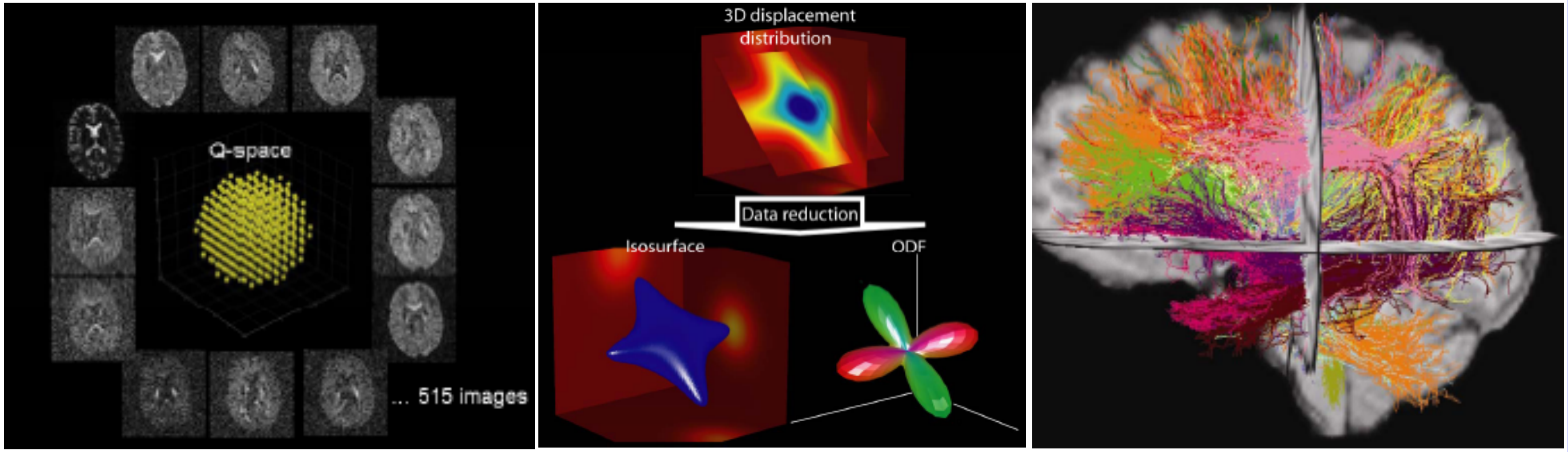
MI applications

- Tumor identitication and staging

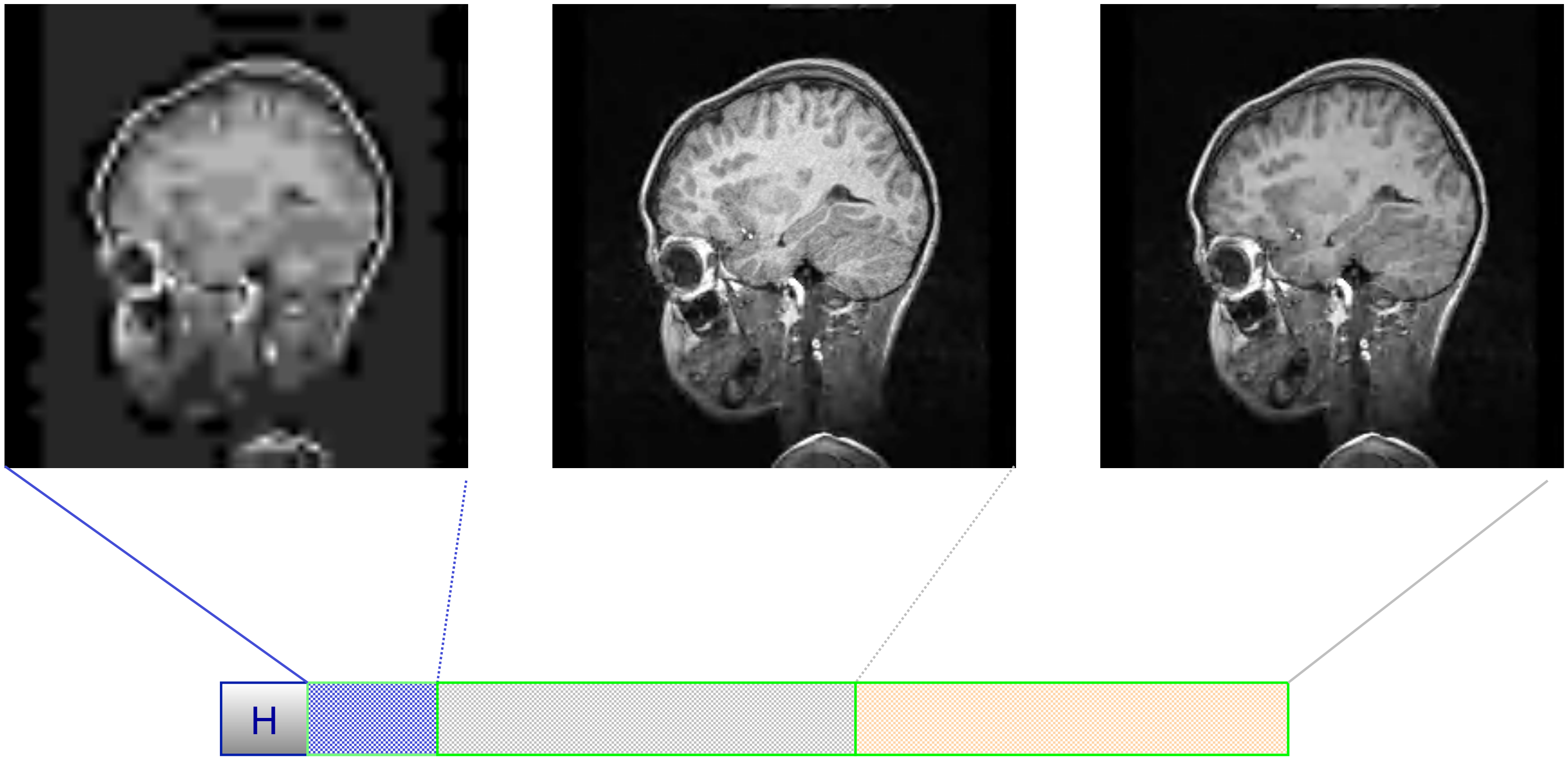


MI applications

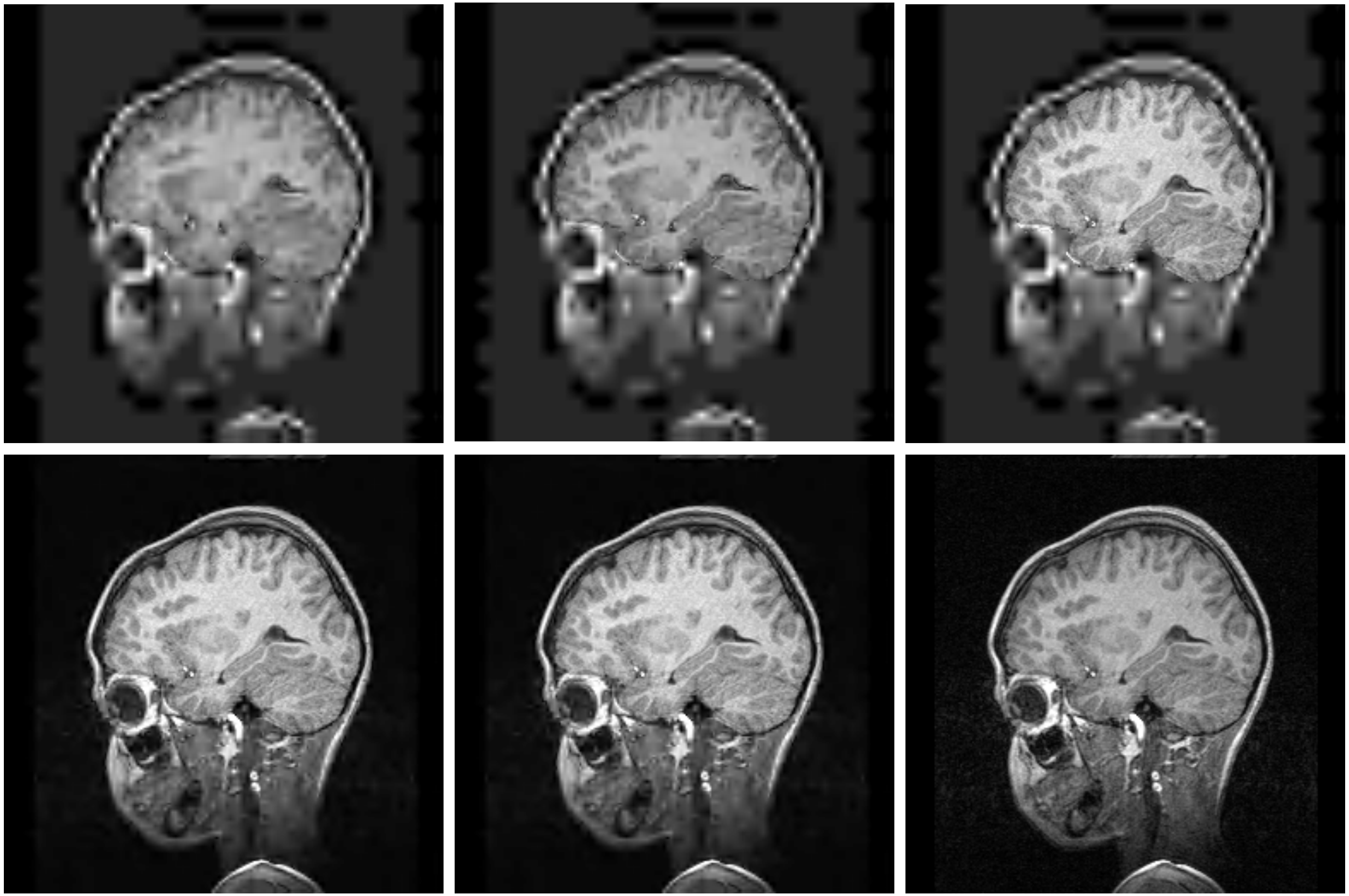
- Exploring brain anatomy by diffusion weighted MRI



Compression and coding

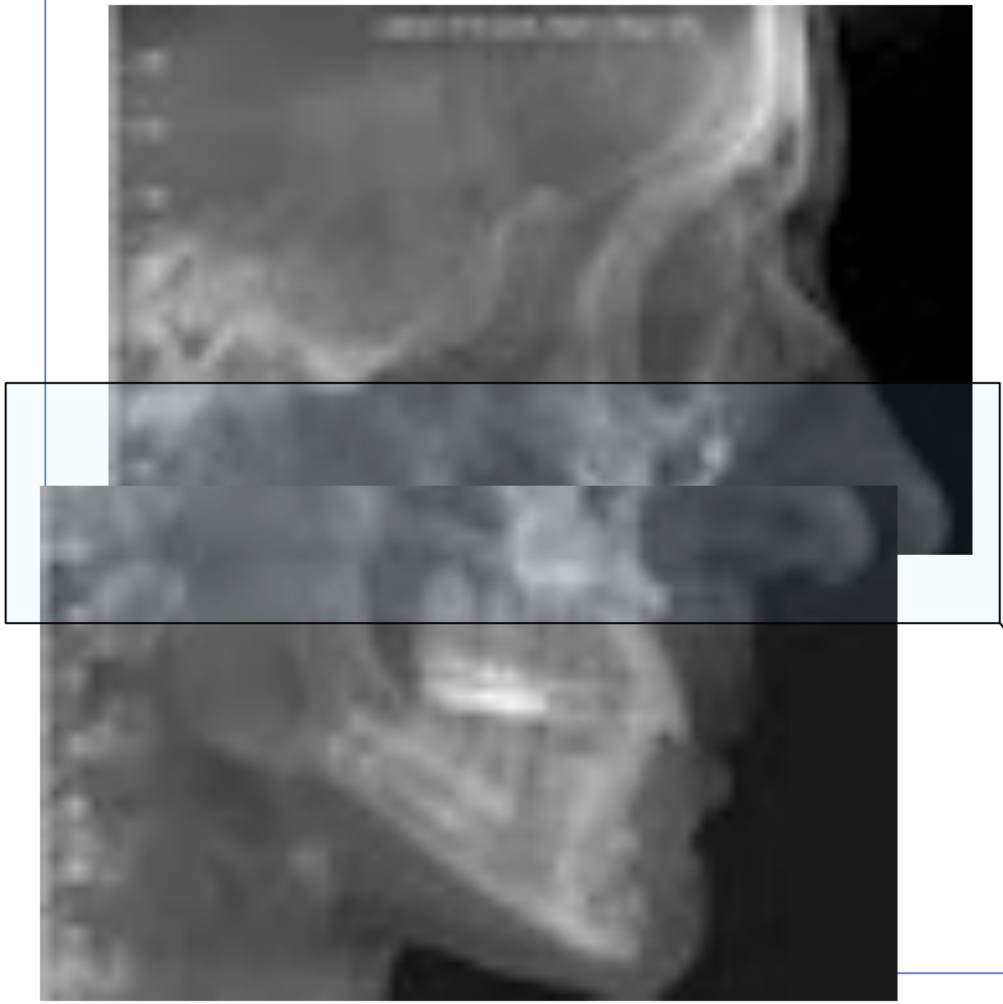


Object-based processing



Mosaicing

Volumetric stitching



Align the two images acquired at different times and blend them in the area of overlap obtaining a new high-resolution image

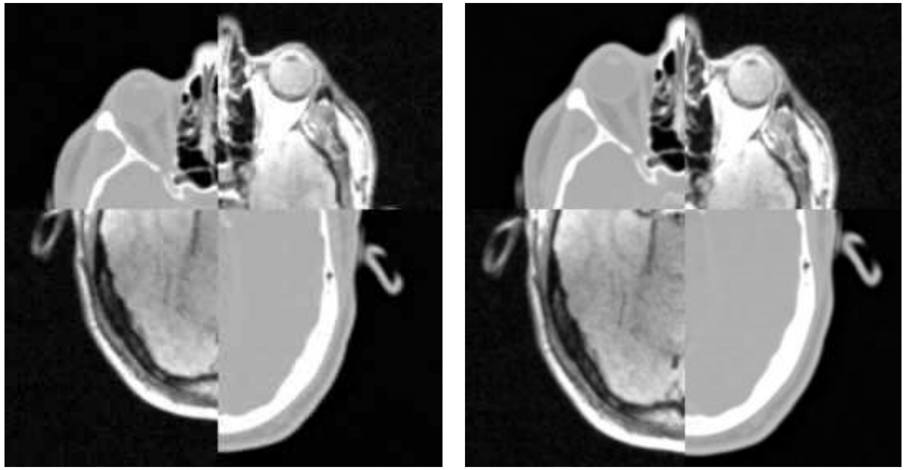
Overlap Area

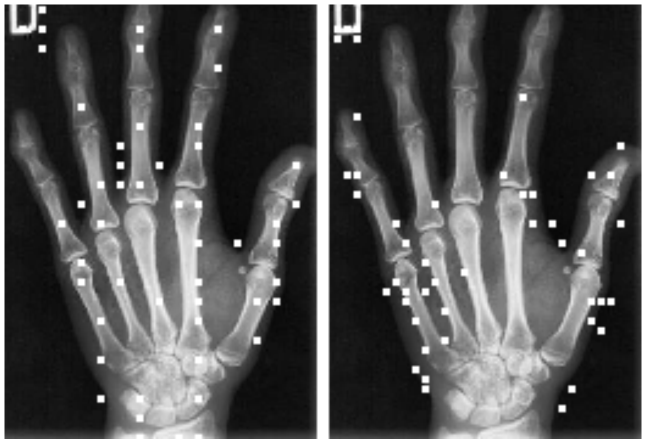
Volume stitching

Applications:

- maxillofacial
- chest x-ray
- where is required a large area of observation.

Image registration





One image is the reference (fixed image) and the other is the one to be matched (moving image). The registration process can be performed either on the entire set of voxels (pixels) or by choosing some target points according to some predefined criteria (feature points). These are usually pixels where there is high contrast like edges, junctions or user-defined landmarks (manually defined through a user interface).

Applications

- Efficiently manage different types of images
  - Satellite, radar, optical..
  - Medical (MRI, CT, US)
  - Image representation and modelling
- Quality enhancement
  - Image restoration
    - deblurring, denoising, hole filling
- Image analysis
  - Feature extraction and exploitation
- Image reconstruction from projections
  - scene reconstruction, CT, MRI
- Compression and coding

Typical issues

Context-independent

- Image resampling and interpolation
  - Sampling, quantization, filtering
- Visualization and rendering
- Multispectral imaging
  - Satellite, color
- Motion detection, tracking
- Automatic quality assessment
- Data mining
  - query by example

Medical imaging

- Image analysis
  - optical devices, MRI, CT, PET, US (2D to 4D)
- Image modeling
  - Analysis of hearth motion, models of tumor growth, computer assisted surgery
- Telemedicine
  - remote diagnosis, distributed systems, medical databases

Other applications

- Quality control
- Reverse engineering
- Surveillance (monitoring and detection of potentially dangerous situations)
- Social computing (face and gesture recognition for biometrics and behavioural analysis)
- Robotics (machine vision)
- Virtual reality
- Telepresence

Hierarchical Image Pyramid

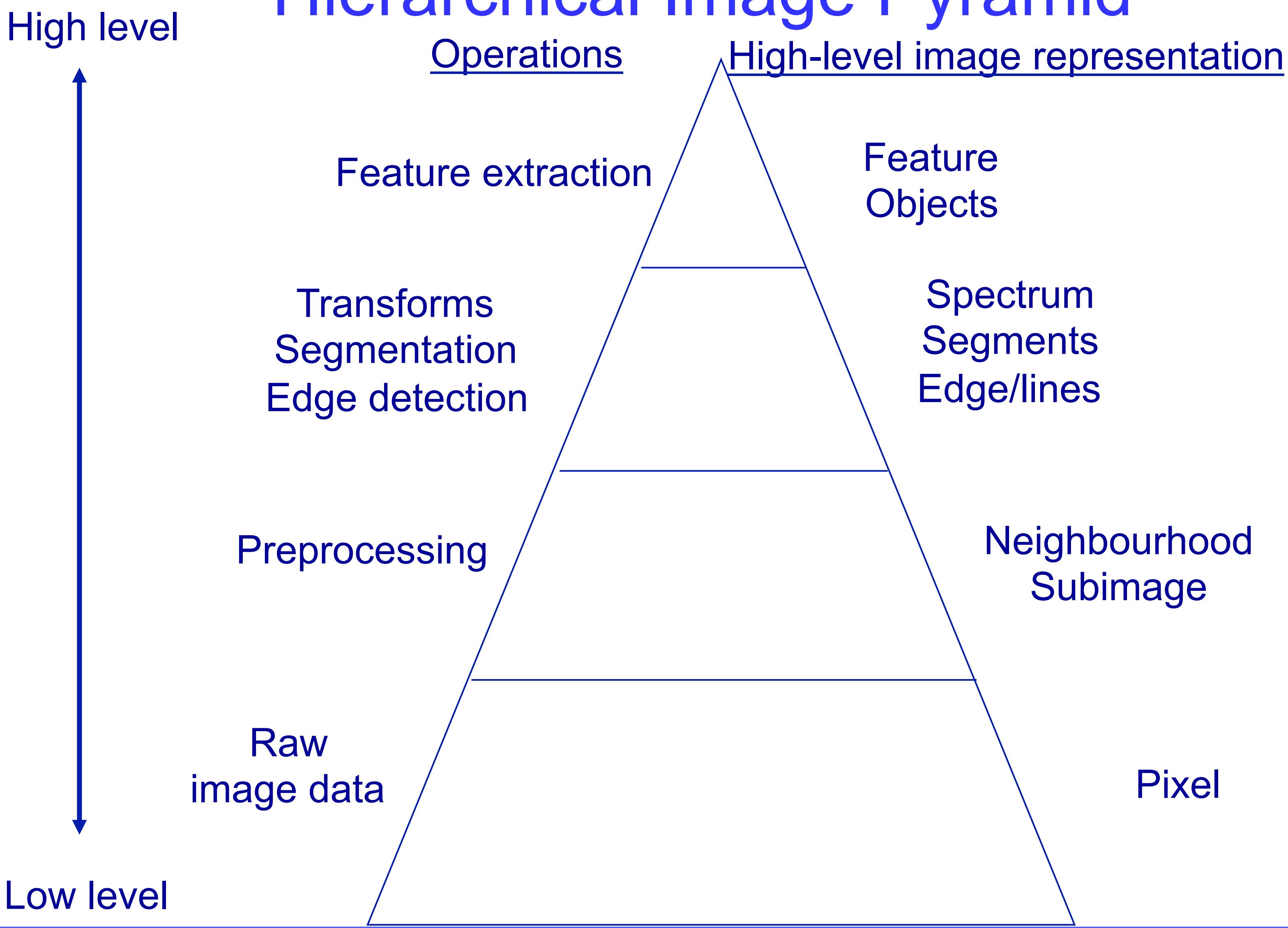
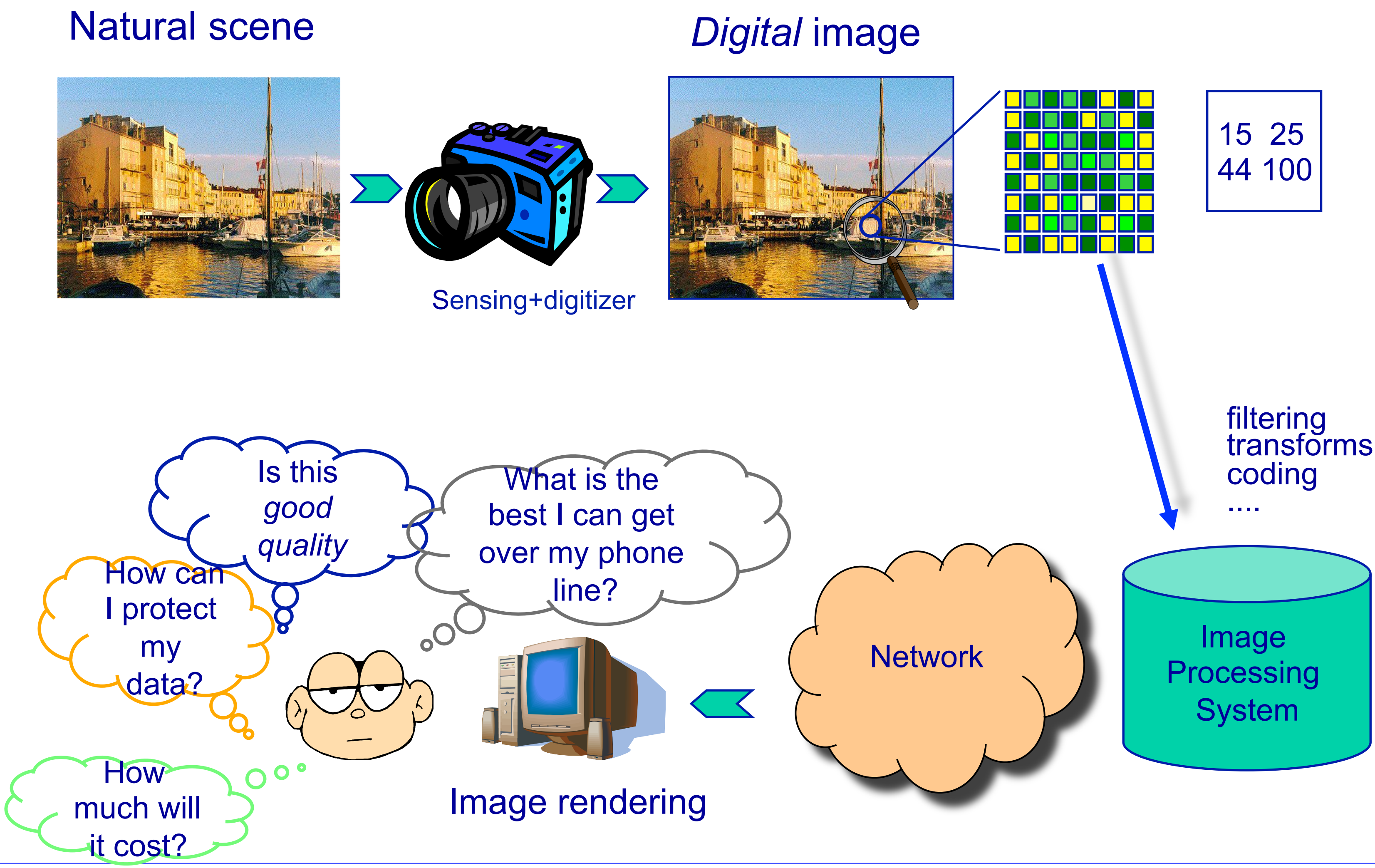


Image formation and fundamentals

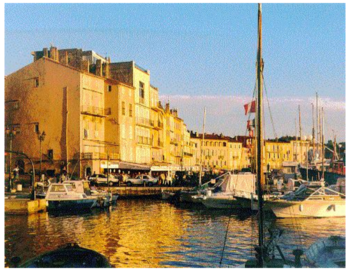
Gonzalez-Woods Chapter 1

Digital image acquisition



Sensing and digitization

Analogic image



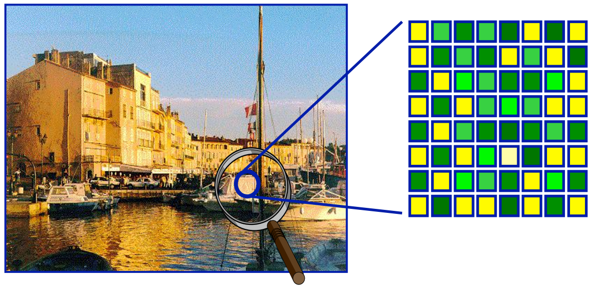
(capturing device)

A/D conversion

Sampling (2D)

Quantization

Digital image



{15,1,2}
{25,44,1}
….

Sensing and digitization

- Sensing device: device that is sensitive to the light emitted by the object we intend to image
- Digitizer: is a device for converting the output of the physical sensing device into digital form
  - For instance, in a digital video camera, the sensors produce an electrical output proportional to light intensity.The digitizer converts these outputs to digital data
- *Specialized image processing hardware* usually consists of the digitizer just mentioned, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), which performs arithmetic and logical operations in parallel on entire images.

Components of an image processing (IP) system

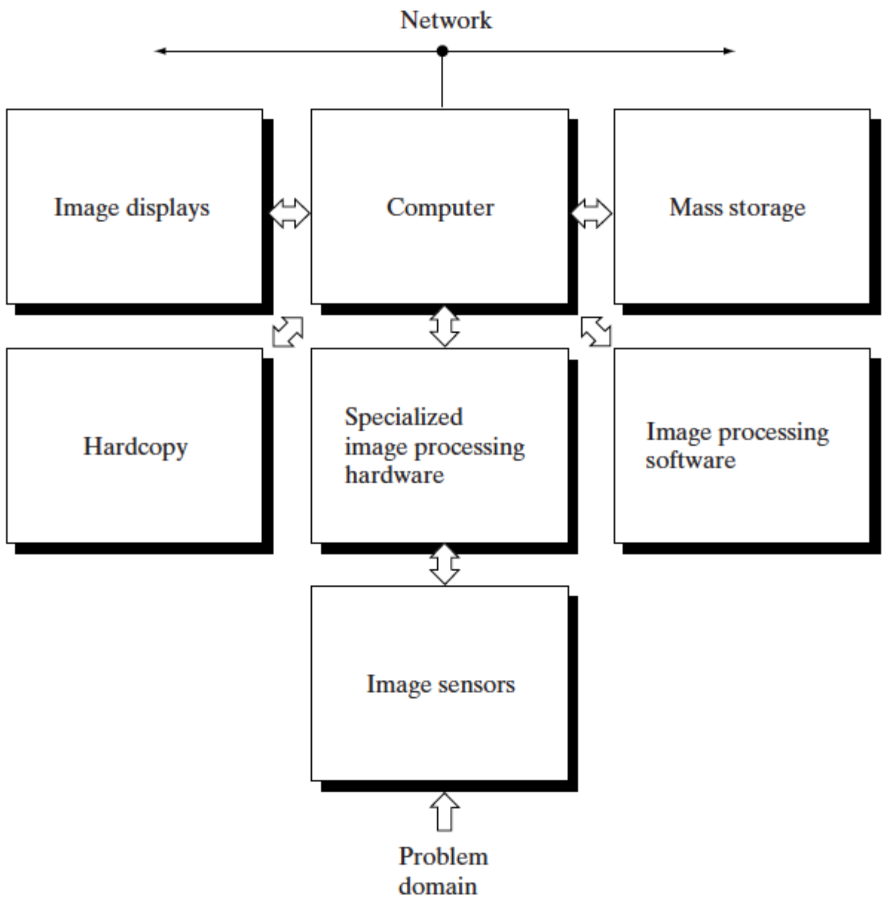


FIGURE 1.24 Components of a general-purpose image processing system.

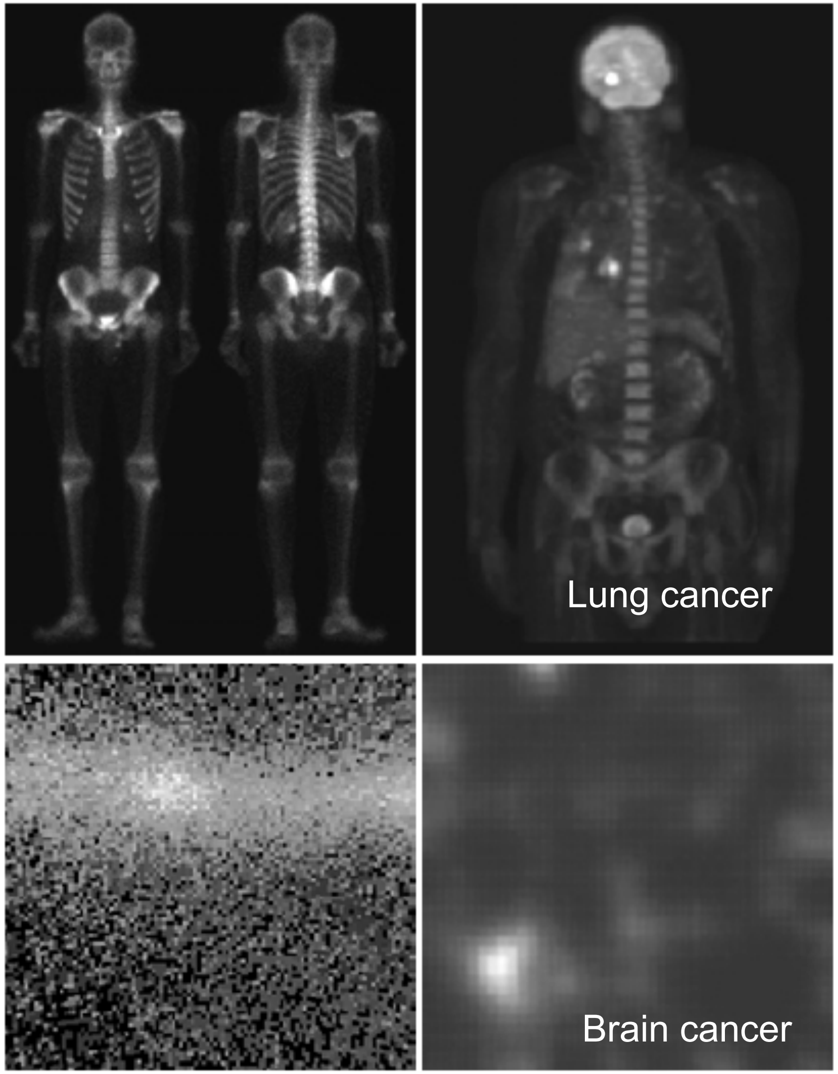
Mass storage

- Mass storage capabilities is a must in image processing applications.
  - An image of size 1024*1024 pixels, in which the intensity of each pixel is an 8-bit quantity, requires one megabyte of storage space if the image is not compressed.
- When dealing with thousands, or even millions, of images, providing adequate storage in an image processing system can be a challenge (Big data)
- **Units**
  - 1 byte = 8 bits = 2^3 bit
  - 1 KB (kilobyte) = 1024 bytes = 2^{10} byte = 2^{13} bit
  - 1 MB (mega byte) = 1024*1024 bytes = 2^{20} byte = 2^{23} bit

Gamma-ray imaging

a b
c d

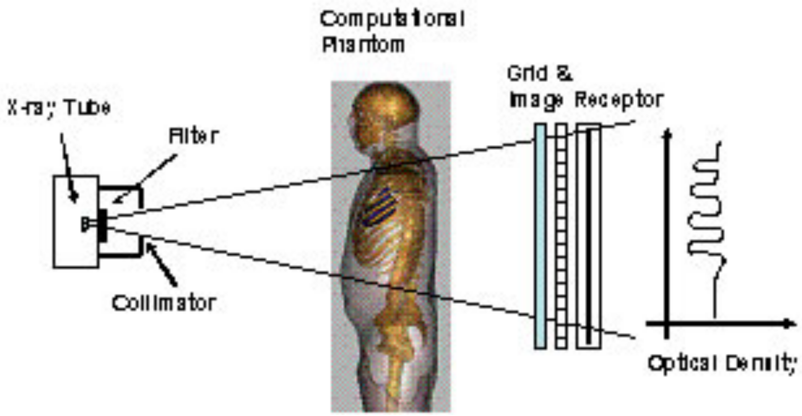
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)



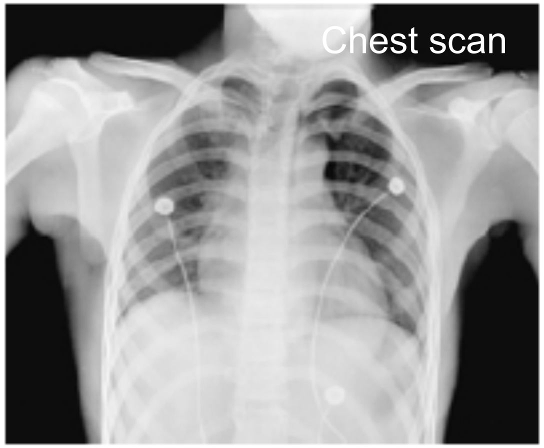
Bone scan and Positron emission tomography (PET). The patient is given a radioactive isotope that emits positrons as it decays. When a positron meets an electron, both are annihilated and two gamma rays are given off. These are detected and a tomographic image is created using the basic principles of tomography. The detector captures the gamma rays that are emitted.

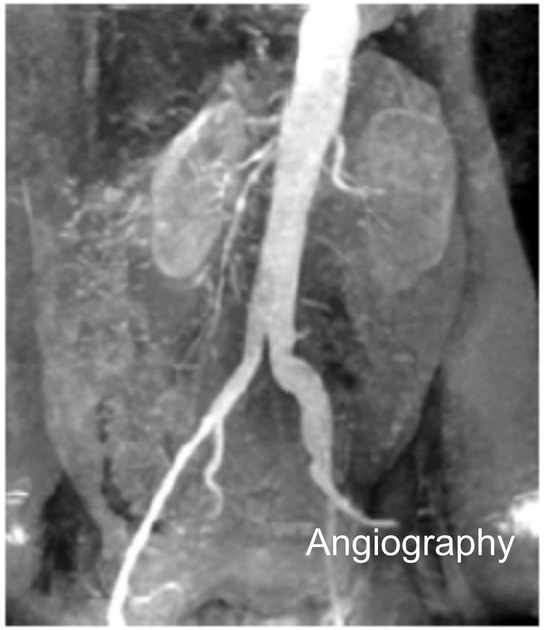
X-ray imaging

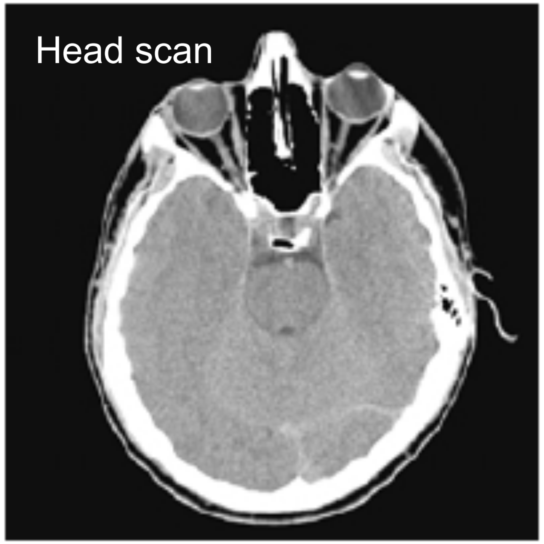
- An X-ray source is used. Electrons fly from the catode to the anode. When they hit a nucleus in the patient, energy is released in the form of X-ray radiation.
- In digital radiography, digital images are obtained by one of two methods:
  - (1) by digitizing X-ray films;
  - or (2) by having the X-rays that pass through the patient fall directly onto devices (such as a phosphor screen) that convert X-rays to light.
  - The light signal in turn is captured by a light-sensitive digitizing system.

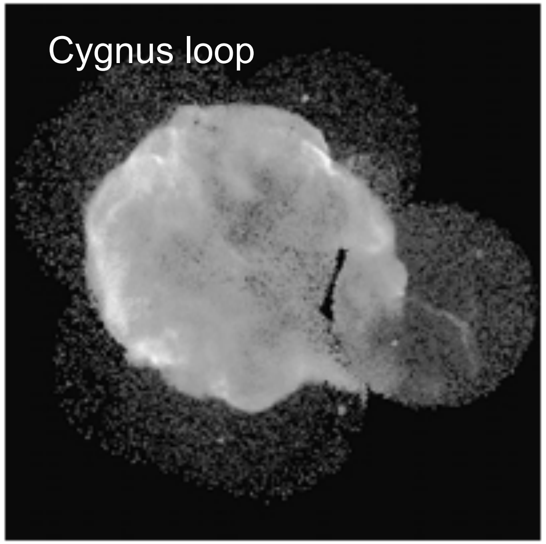


X-ray imaging









large supernova remnant (SNR) in the constellation Cygnus

Multispectral imaging

- It was originally developed for space-based imaging.
- Acquired by remote sensing radiometers (RS)
- A multispectral image is one that captures image data at specific frequencies across the electromagnetic spectrum.
- The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, such as infrared.
- Spectral imaging can allow extraction of additional information the human eye fails to capture with its receptors for red, green and blue.

Multispectral imaging

Includes several bands in the visual and infrared regions of the spectrum.

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Multispectral imaging

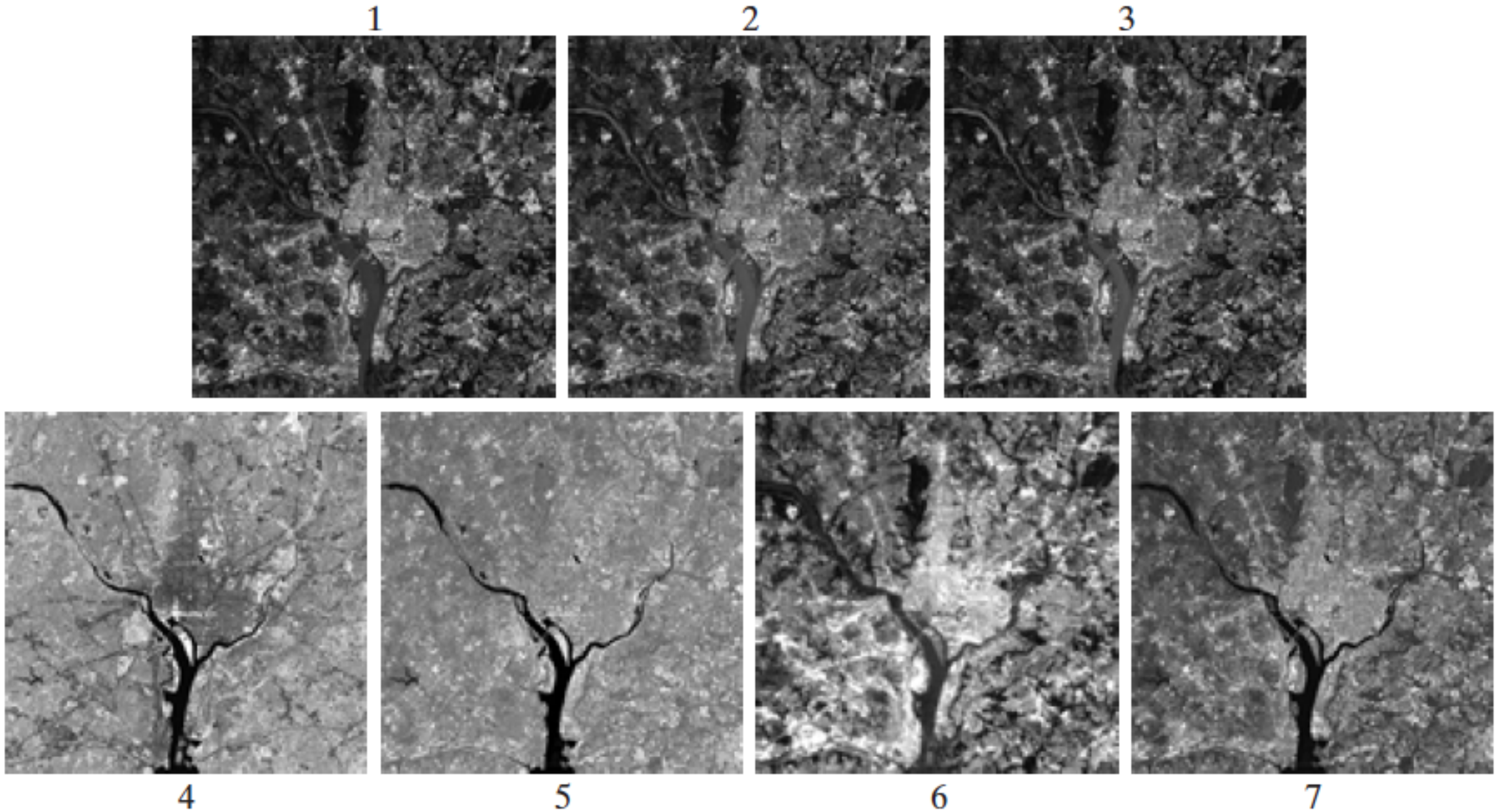


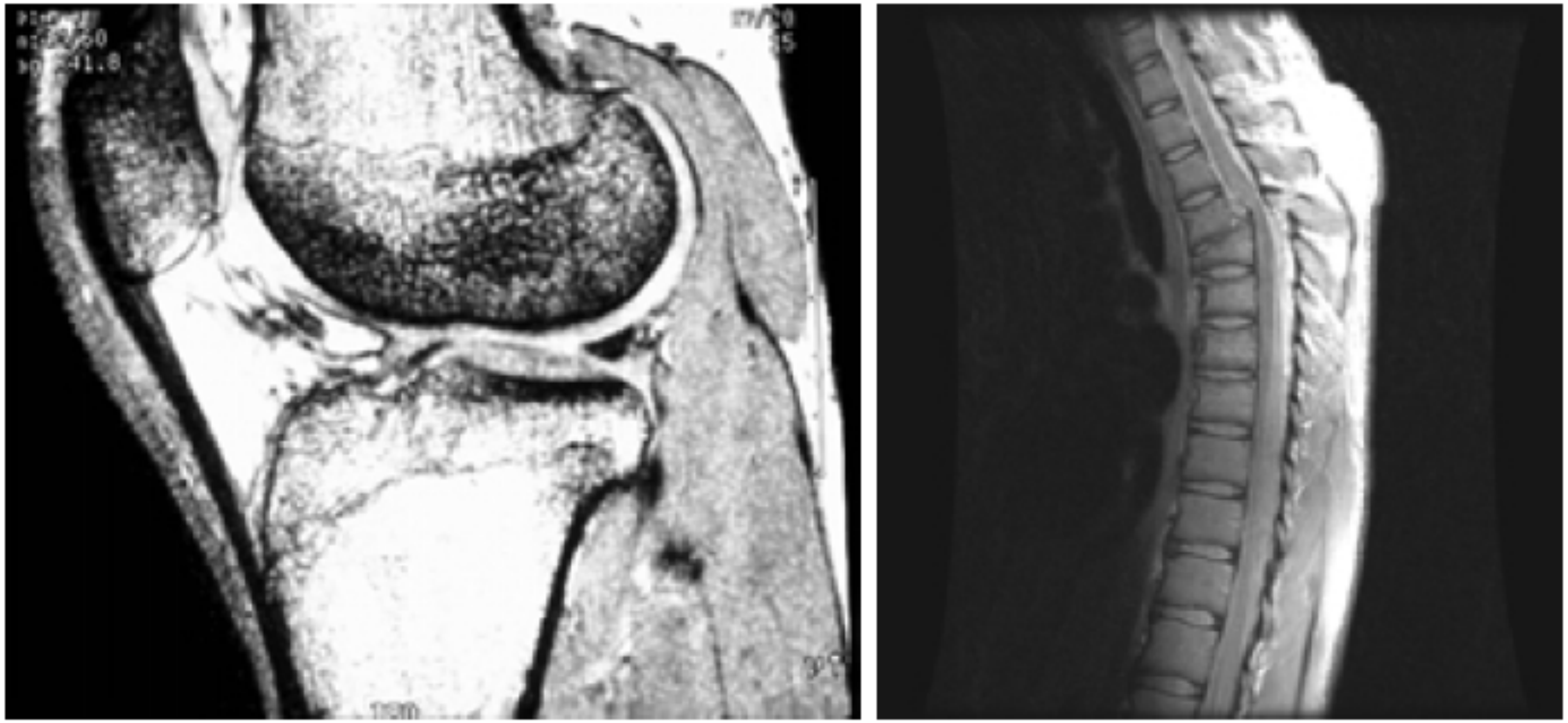
FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Imaging in the radio band

- In medicine radio waves are used in magnetic resonance imaging (MRI). This technique places a patient in a powerful magnet and passes radio waves through his or her body in short pulses. Each pulse causes a responding pulse of radio waves to be emitted by the patient' s tissues.
- The location from which these signals originate and their strength are determined by a computer, which produces a two-dimensional picture of a section of the patient.
- MRI can produce pictures in any plane.

Imaging in the radio band: MRI in humans

Imaging in the radio band: MRI in humans



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)