

Introduction

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Elaborazione delle immagini (Image processing I)

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Image processing

Computer science concerns the

- ▶ representation,
- ▶ processing and
- ▶ transmission

of information.

Image processing considers in particular the information contained in (digital) images.

What is an image?

Some definitions:

- ▶ a percept that arises from the eyes; an image in the visual system [TheFreeDictionary];
- ▶ an artifact that has a similar appearance to some subject—usually a physical object or a person. [Wikipedia];
- ▶ a reproduction or imitation of the form of a person or thing [Merriam-Webster].

Usually, an image is intended to be a representation of objects or scenes on a bidimensional support

- ▶ painting,
- ▶ picture,
- ▶ graph.

The concept can be extended to a volumetric representation (e.g., a statue).

Definition of digital image

- ▶ In Mathematics, an image is defined as a function,
 $f : \mathbb{R}^m \rightarrow \mathbb{R}^n$.
- ▶ Usually, $m = 2$ and, in the simplest case, $n = 1$.
- ▶ When the spatial coordinates and the function value are finite and discrete, the image is called *digital*.

$$f : \mathbb{Z}^m \rightarrow \mathbb{Z}^n$$

- ▶ The elements composing a digital image are called “pixels” (contraction of *picture element*) or “pels” (or even “image elements”).

What is image processing?

- ▶ Roughly speaking, it can be considered as *image* what is perceived through the sight.
- ▶ However, “seeing” is a complex task, and it results from a very variegated processing chain realized by the brain.
- ▶ In the same way, the image processing is a discipline with a fuzzy contour.
- ▶ Besides, it makes use of and provides techniques to other disciplines.

What is image processing? (2)

- ▶ At least three disciplines are overlapping:
 - ▶ image processing
 - ▶ image understanding
 - ▶ computer vision
- ▶ Generally, three processing categories, which are characterized by their abstraction level, are acknowledged:
 - ▶ low level (image enhancement);
 - ▶ medium level (feature extraction);
 - ▶ high level (object recognition).
- ▶ Example: OCR (*optical character recognition*)
 - ▶ low level: noise suppression, binarization;
 - ▶ medium level: character segmentation;
 - ▶ high level: character and text structure recognition.

Which application for image processing?

- ▶ In several application fields, information is acquired as images.
- ▶ Image processing is used for:
 - ▶ making data interpretation easier;
 - ▶ extracting information.
- ▶ Some application fields:
 - ▶ medicine;
 - ▶ industrial:
 - ▶ quality control;
 - ▶ automation;
 - ▶ security:
 - ▶ biometric application;
 - ▶ license-plate recognition;
 - ▶ topographic survey;
 - ▶ astronomy;
 - ▶ ...and many more!

Which application for image processing? (2)

- ▶ For example, in astronomical observation.

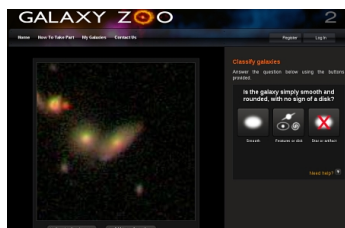


Harvard College Observatory Computers, 1890s.

Stars cataloging were realized with manual methods and were based on photographic plates.

http://www.womanastronomer.com/harvard_computers.htm

- ▶ A lot of tasks are not easily automated:



Galaxy Zoo Project.

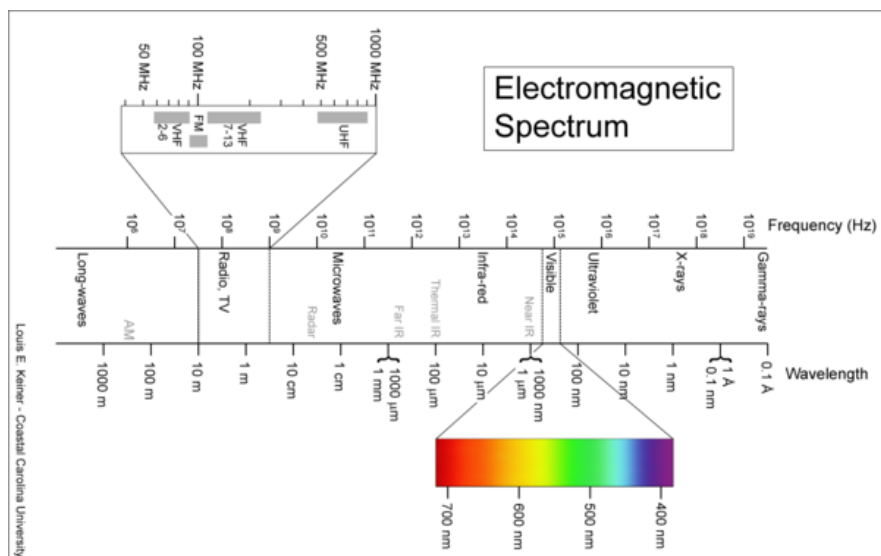
Volunteers (with no special astronomy knowledge) are required for galaxy classification.

<http://www.galaxyzoo.org/>

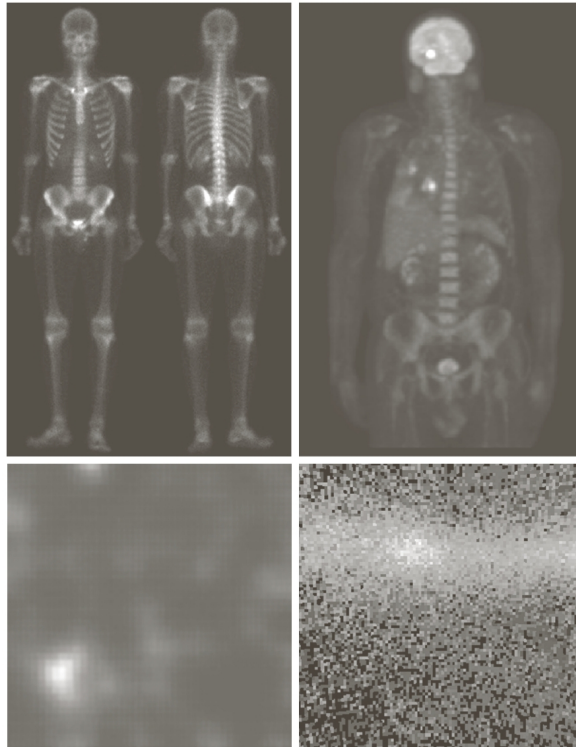
Which images?

- ▶ A possible classification can be based on the radiating source:
 - ▶ electromagnetic waves;
 - ▶ acoustic waves;
 - ▶ ultrasound;
 - ▶ electron beam.

Electromagnetic spectrum



Gamma-ray imaging

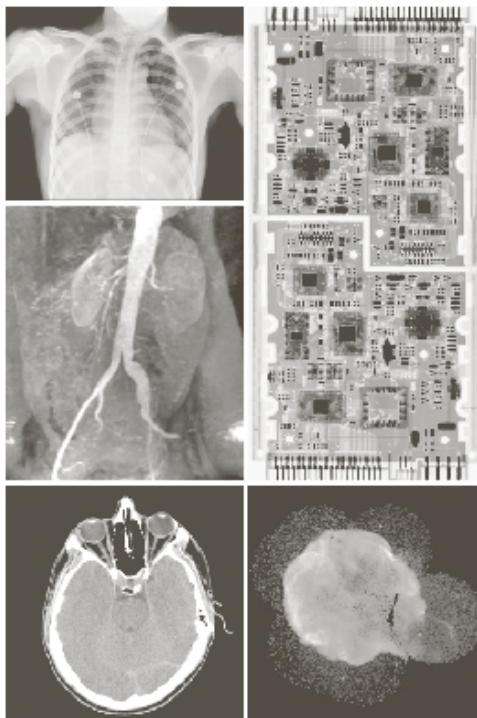


a	b
c	d

- (a) gamma-ray imaging by radioactive isotope injection;
 (b) positron emission tomography (PET);
 (c) Gamma radiation emitted by a nuclear reactor valve;
 (d) Cygnus Loop.

NB: (c) and (d) capture the natural radiation of the observed object.

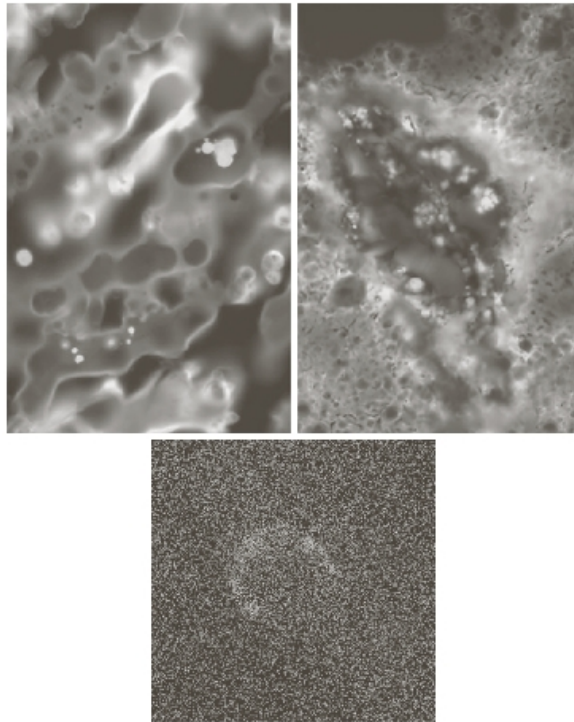
X-ray imaging



a	d
b	
c	e

- (a) radiography;
 (b) angiography;
 (c) computerized axial tomography (CAT);
 (d) X-ray image of a printed circuit board for inspection during production;
 (e) Cygnus Loop.

Ultraviolet imaging

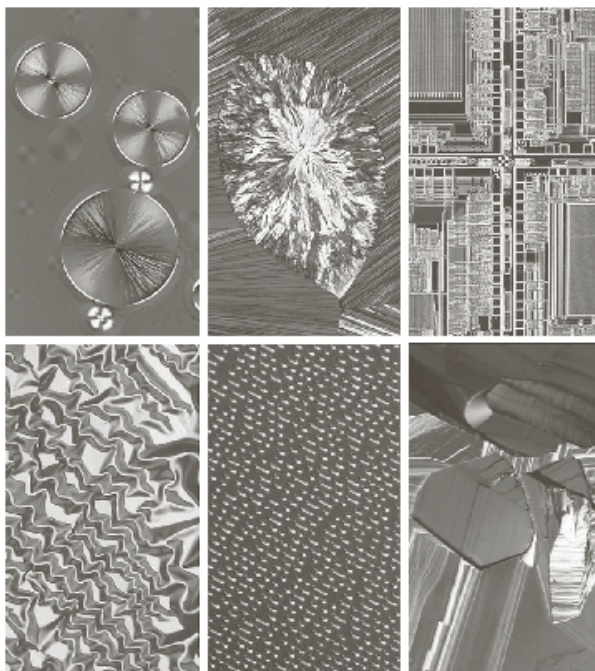


a	b
c	

- (a) normal corn;
(b) smut corn;
(c) Cygnus Loop.

In UV imaging, the fluorescence phenomenon is often exploited.

Visible light imaging

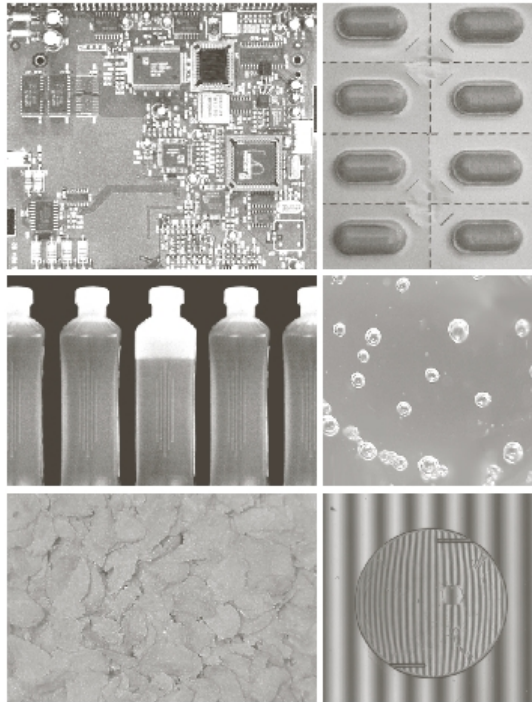


a	b	c
d	e	f

Microscopy

- (a) Taxol (anticancer agent);
(b) cholesterol;
(c) microprocessor;
(d) nickel oxide thin film;
(e) surface of an audio CD;
(f) organic superconductor.

Visible light imaging (2)



a	b
c	d
e	f

Industrial automation

- (a) missing components;
- (b) missing pills;
- (c) right quantity;
- (d) defects detection (too many bubbles);
- (e) defects detection (some burnt flake?);
- (f) defects detection (lens with distortion).

Visible light imaging (3)

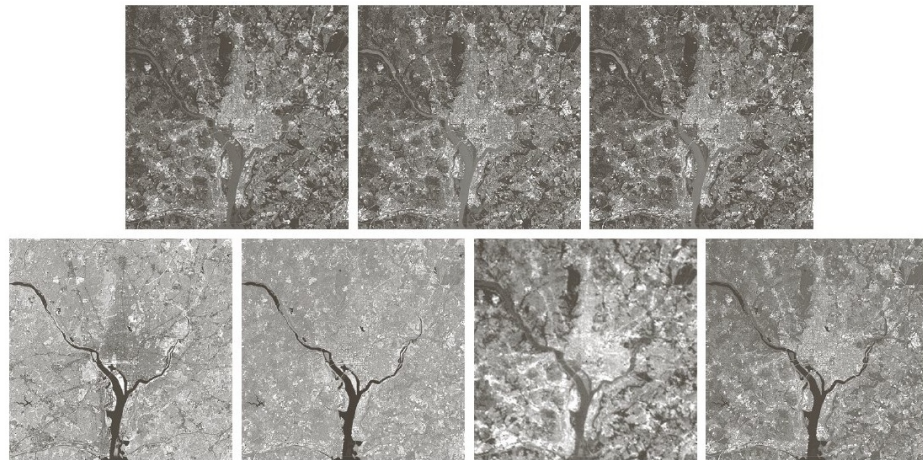


a	b
c	d

Security and traceability

- (a) fingerprint;
- (b) banknote counting and serial number tracking;
- (c) Automatic license plate recognition;
- (d) Automatic license plate recognition (with perspective correction).

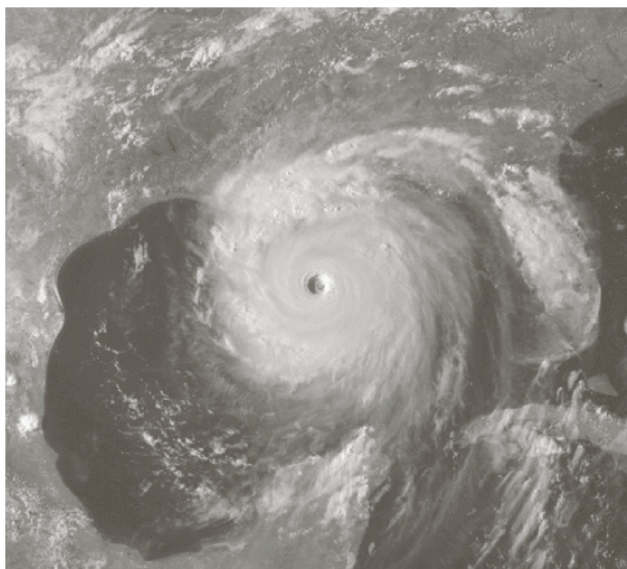
Visible light and infrared imaging



a	b	c	
d	e	f	g

(a) blue; (b) green; (c) red;
 (d) near IR; (e) short-wave IR;
 (f) thermal IR; (g) mid-wave IR.

Visible light and infrared imaging (2)



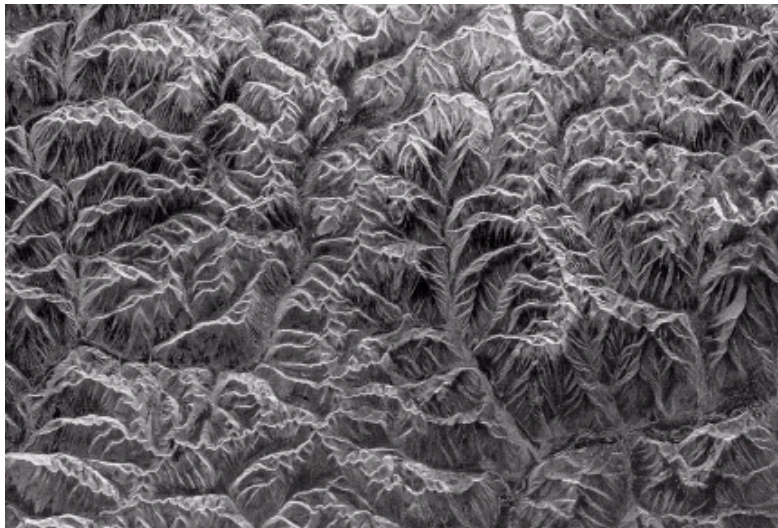
The weather satellite images are taken from several bands. This LANDSAT image pictures the Katrina hurricane (2005) in the visible and infrared bands.

IR satellite imaging



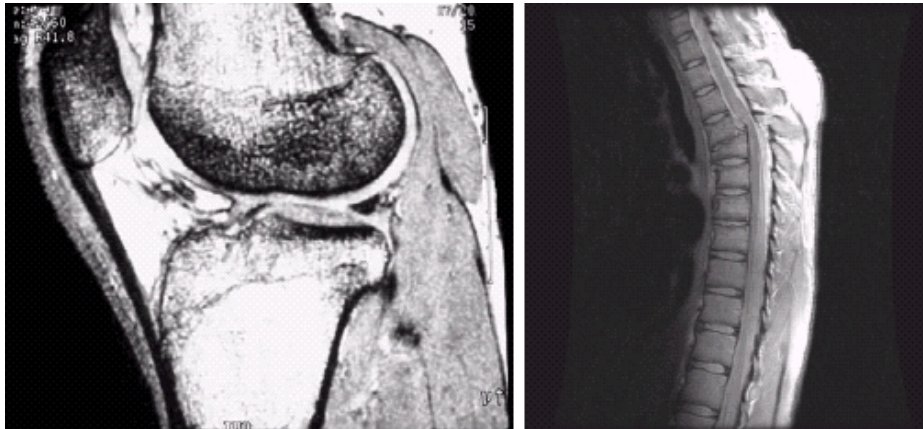
The infrared band emission provides clues of human activities.

Radar satellite imaging



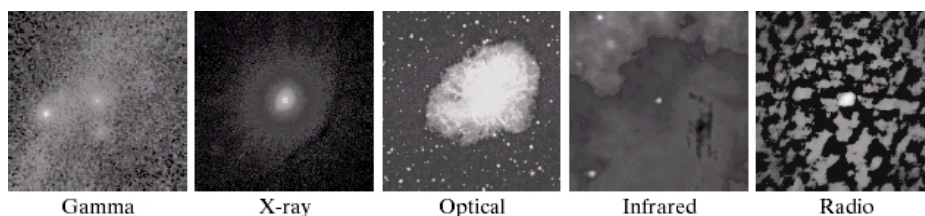
The microwaves can pass through the clouds and some layers of plants, ice, and sand. A space-borne radar emits a pulse and, through an antenna, detects the reflected wave.

Radio wave imaging



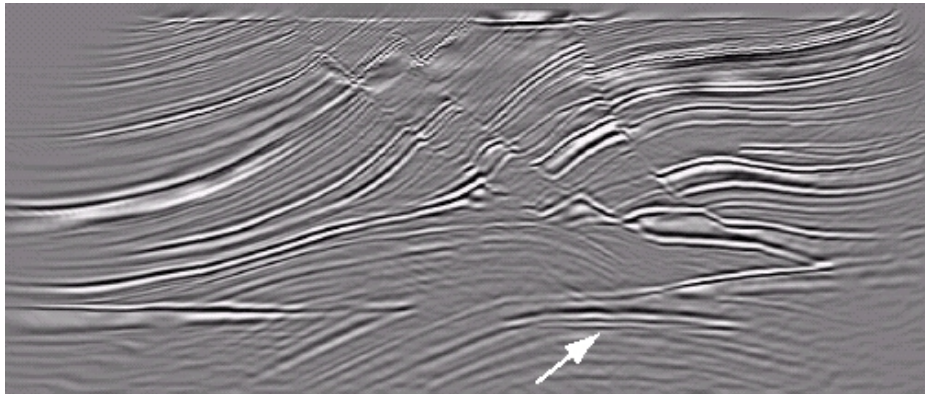
Radio waves are used in medicine, for instance, for magnetic resonance imaging (MRI).

Multi-spectral imaging



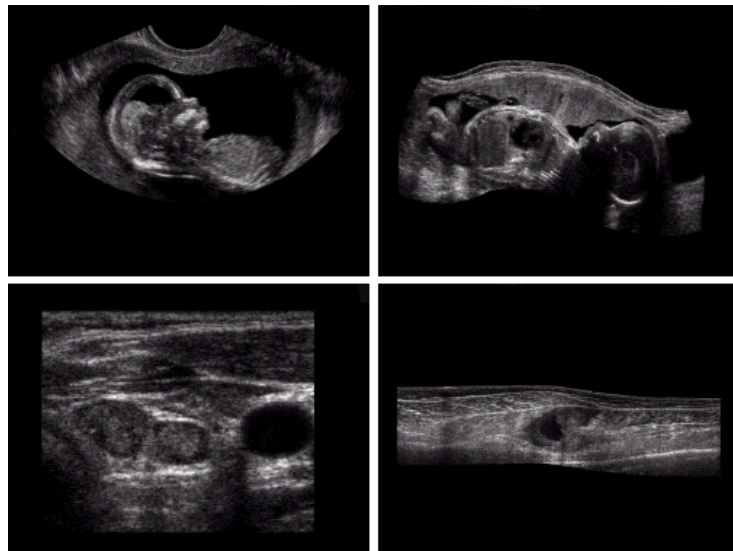
The Crab pulsar in several sub-bands of the spectrum. The same object can appear very different, since its emitted electromagnetic radiation is not uniform in the spectrum.

Acoustic wave imaging



Detecting the echo from acoustic waves, the reflective properties of the ground (or seabed) can be traced. This allows to identify the stratified materials in the ground.

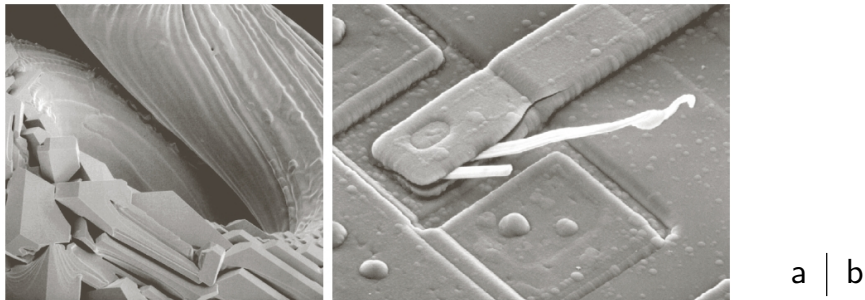
Ultrasound imaging



a	b
c	d

Ultrasound waves are used in medicine for echography.
(a) e (b) fetus; (c) thyroids; (d) muscle layers showing lesion.

Electrons beam imaging



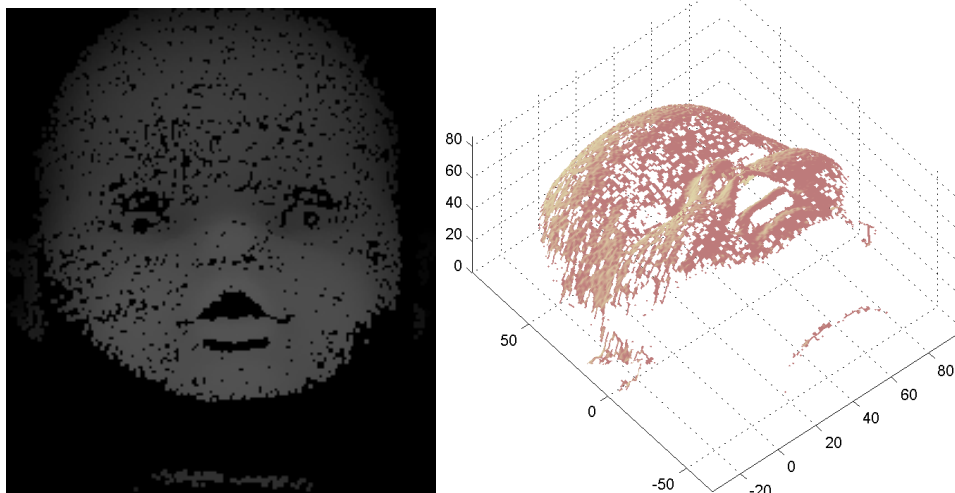
Electrons beams are used in two microscope techniques:

- ▶ transmission electron microscopy (TEM), where the fraction of the beam that pass through the object is acquired;
- ▶ scanning electron microscope (SEM), where the interaction between the object and the electrons beam is detected.

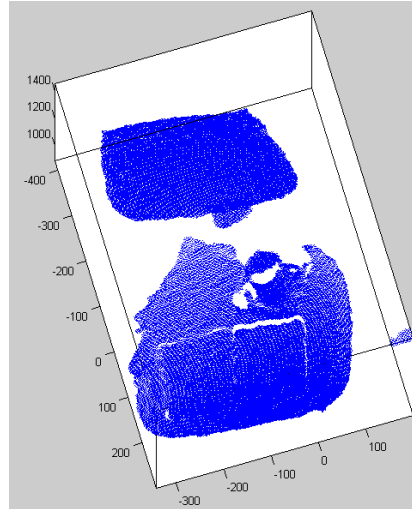
(a) tungsten filament burnt; (b) heat damaged integrated circuit (the white fibers results from the thermal destruction).

Other imaging techniques

Through image processing techniques, new kind of images can be obtained. For example, the depth images (aka range images, $2\frac{1}{2}$ D images).

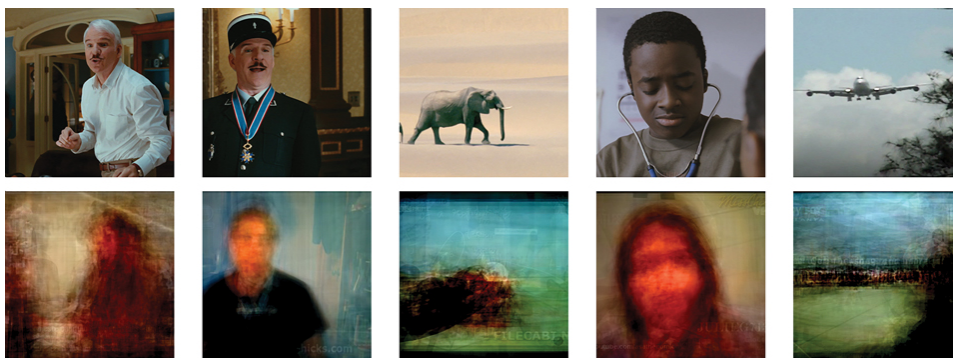


Example: Kinect™



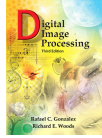
Futuristic (?)

Mind reading? Processing fMRI images.



- ▶ fMRI recording of subject while watching movie clips
- ▶ model of the brain fed with the recording
- ▶ model output as images

Homeworks and suggested readings



DIP, Sections 1.1, 1.2, 1.3

- ▶ pp. 1–24



This is your brain on fMRI

- ▶ <http://spectrum.ieee.org/geek-life/tools-toys/this-is-your-brain-on-fmri>
- ▶ <http://dx.doi.org/10.1109/MSPEC.2012.6189569>