.

# Introduction

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**Methods for Image Processing**

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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.

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## 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, but also the inside).

## 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").

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## 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.

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## 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!

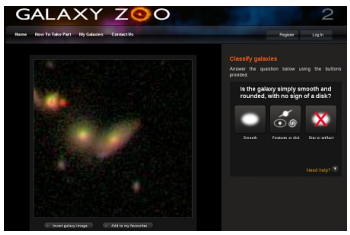
## Which application for image processing? (2)

- 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/`

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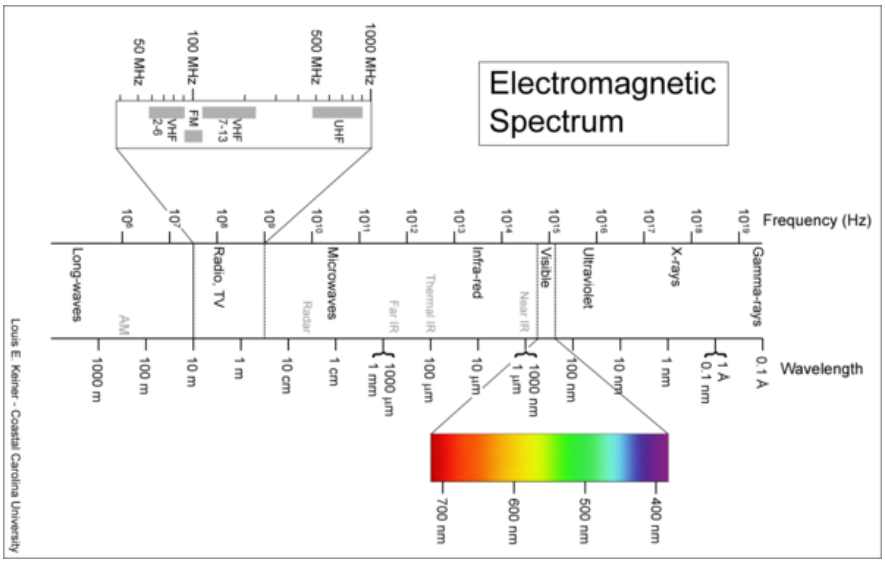
## Which images?

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

## Electromagnetic spectrum



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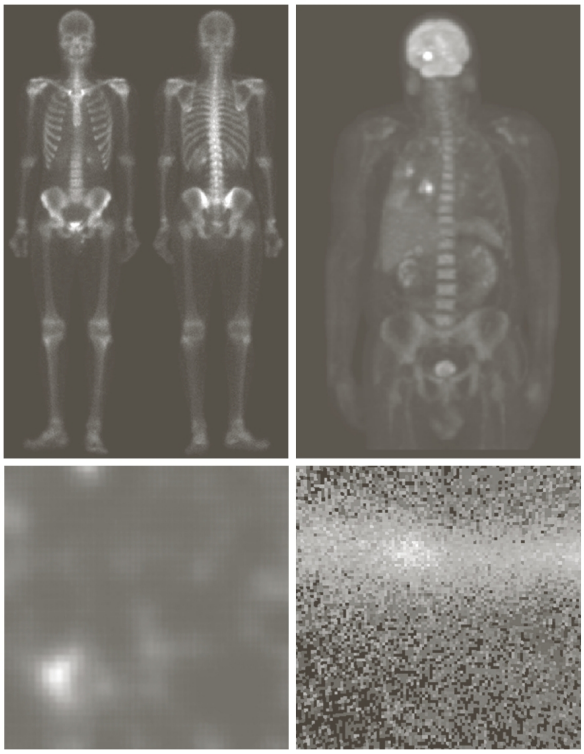
## Gamma-ray imaging

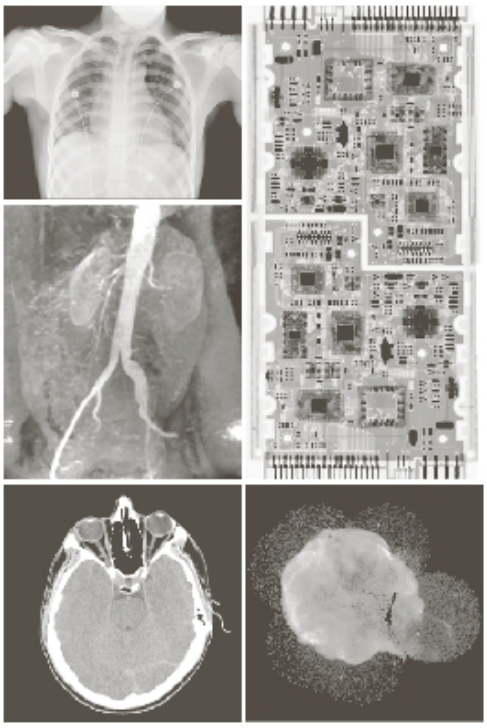


| a | b |
|---|---|
| c | d |

(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 | |
|---|---|
| b | d |
| c | e |

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

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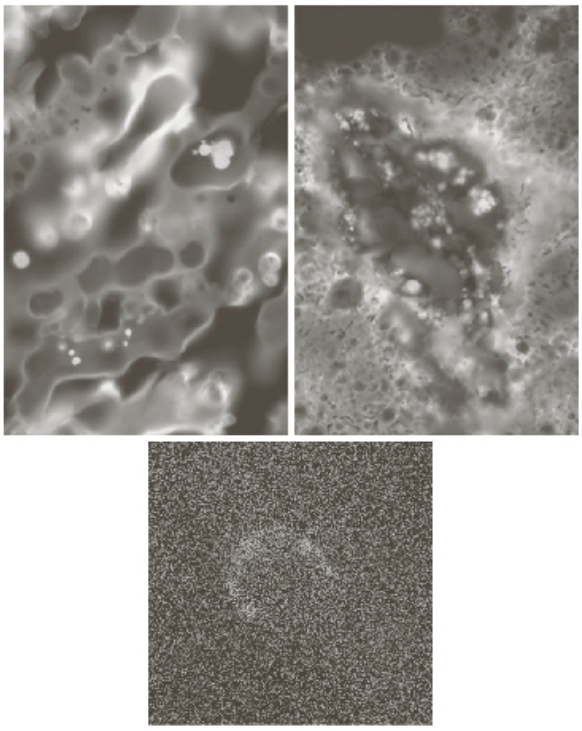
## Ultraviolet imaging

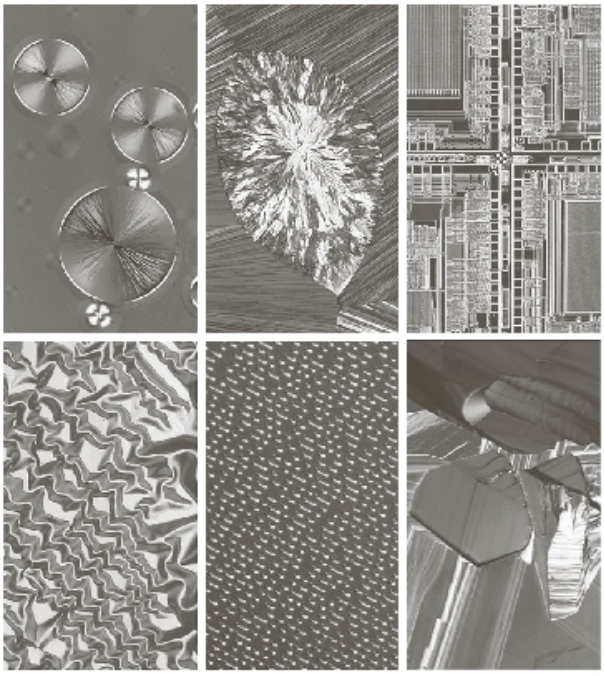


| a | b |
|---|---|
| c | |

(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.

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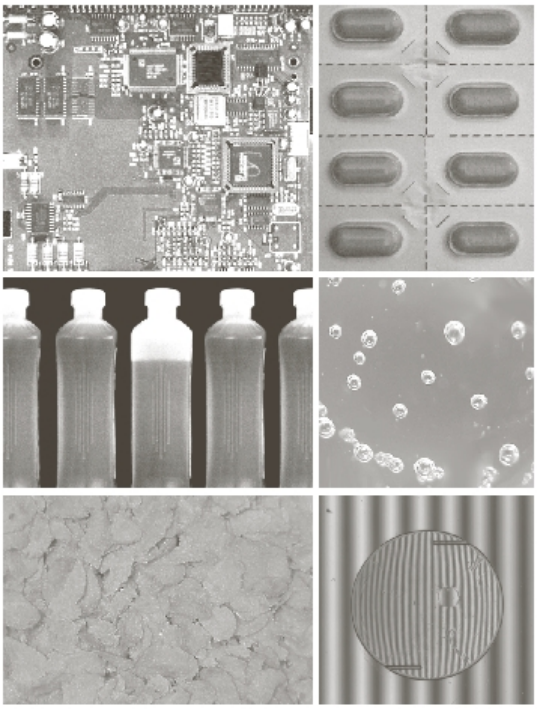
## Visible light imaging (2)



| 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).

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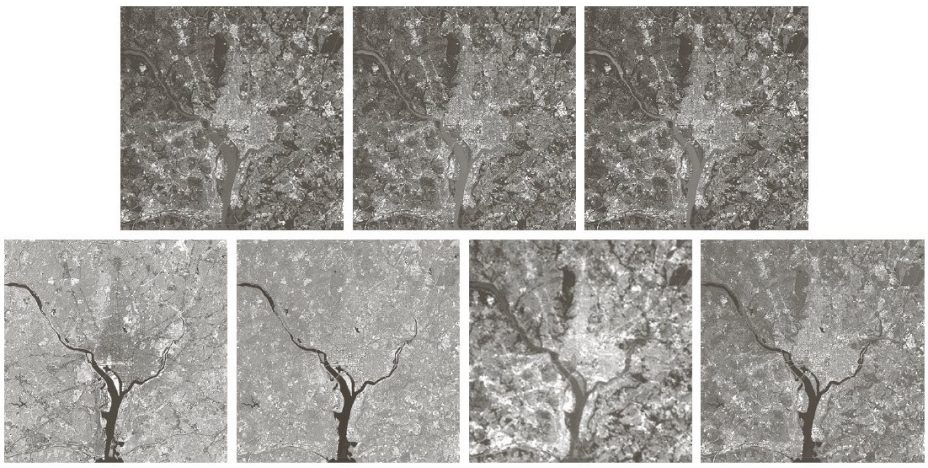
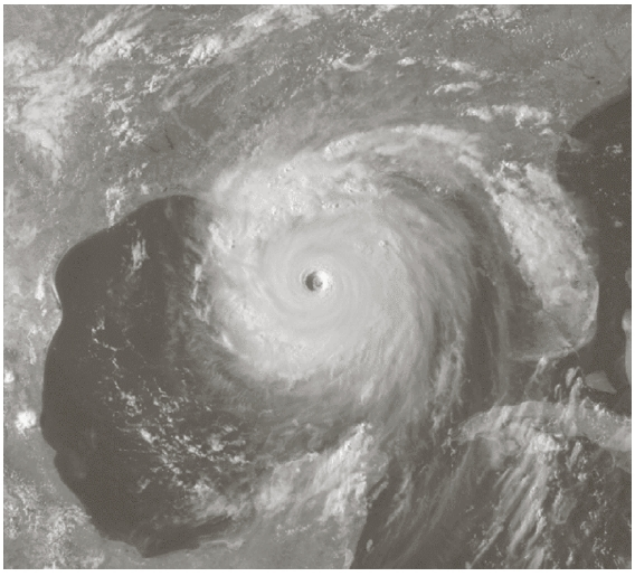
## Visible light and infrared imaging



| 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.

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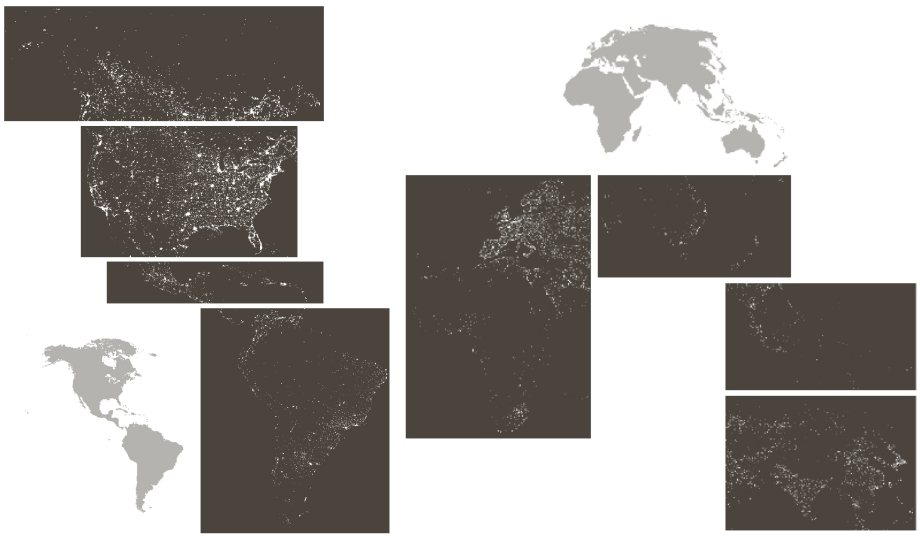
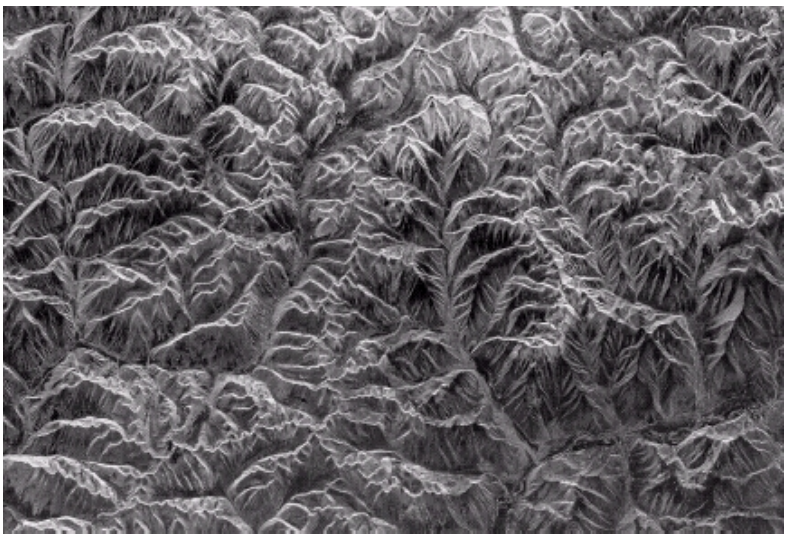
## IR satellite imaging



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.

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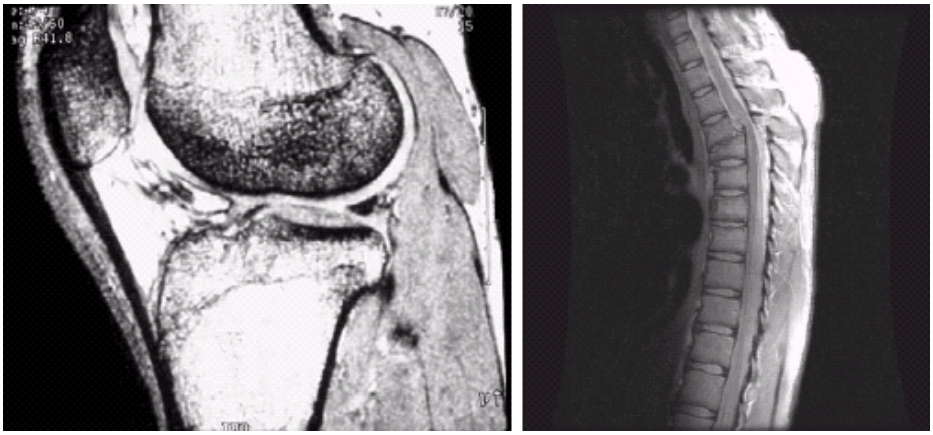
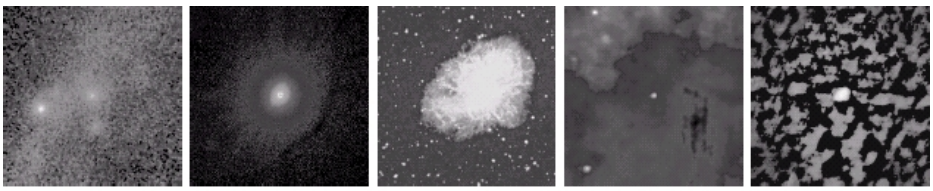
## Radio wave imaging



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.

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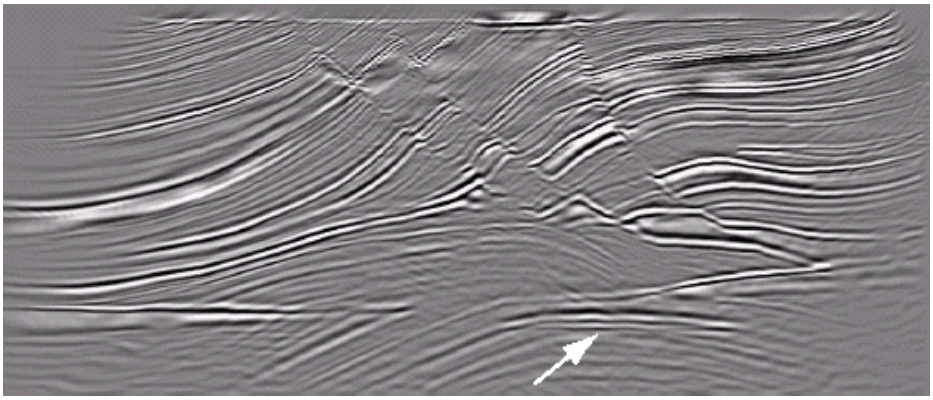
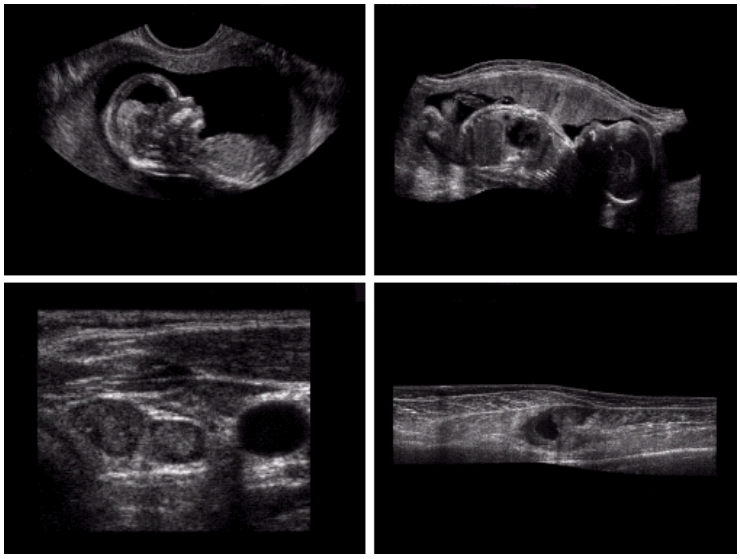
## Acoustic wave imaging



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.

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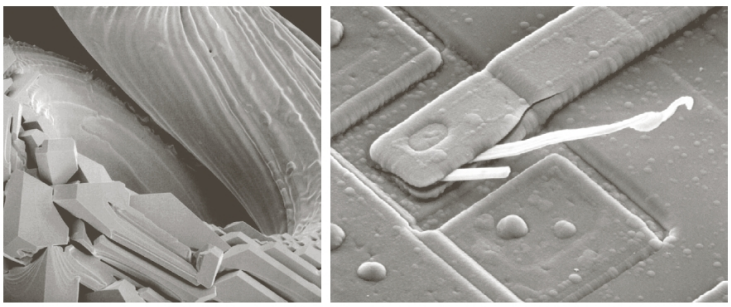
## Electrons beam imaging



a | b

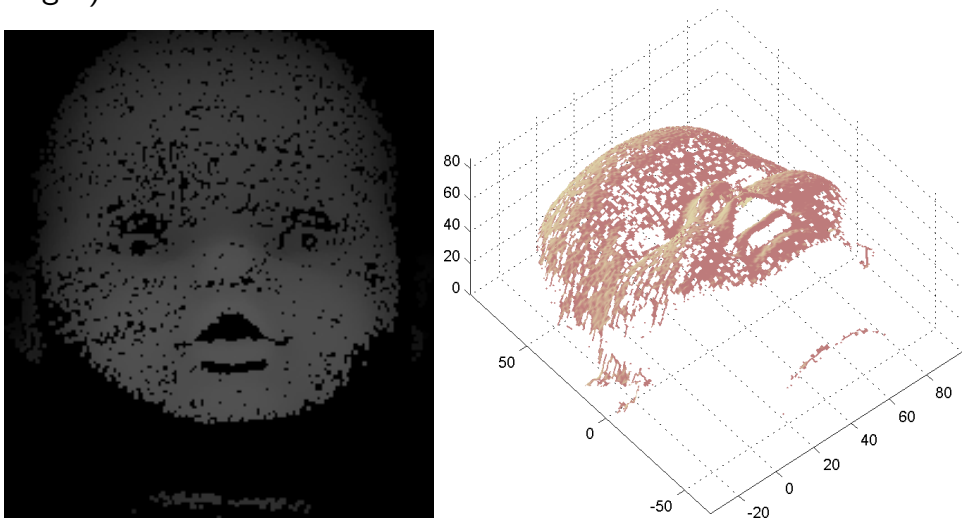
Electrons beams are used in two microscope techniques:

- 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).



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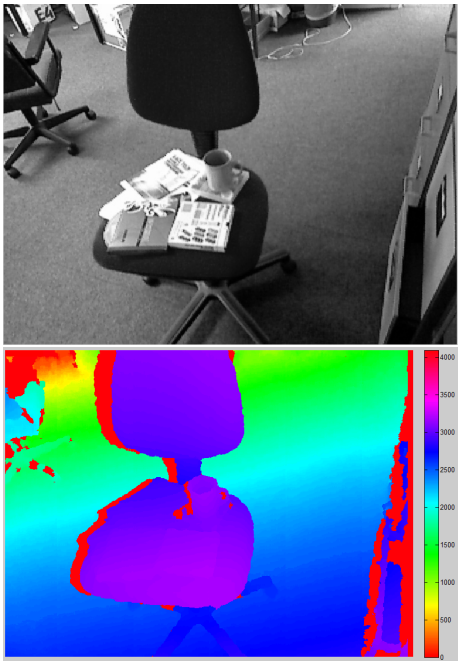
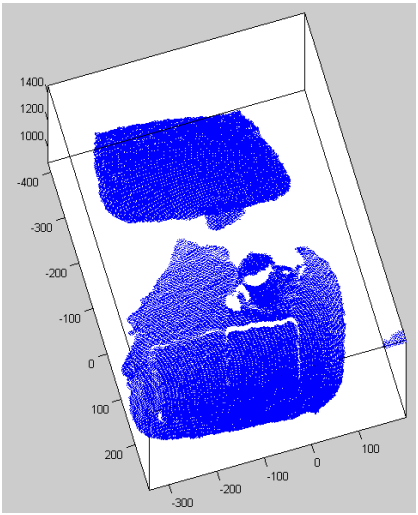
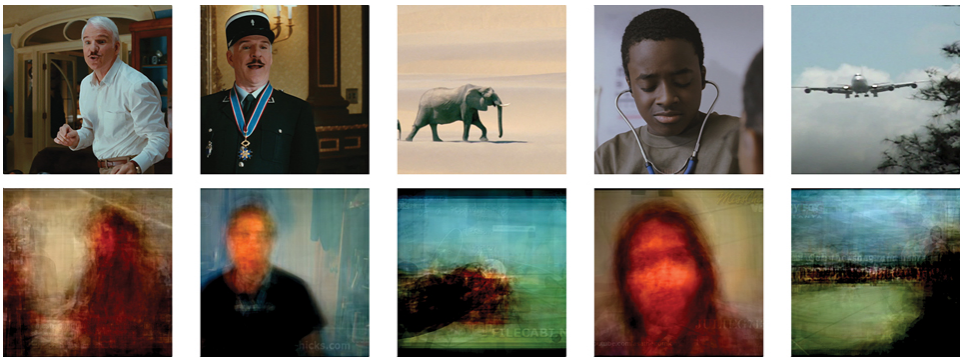
## Example: Kinect™




## 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

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## 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`