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Institute of Electronics

Medical Imaging

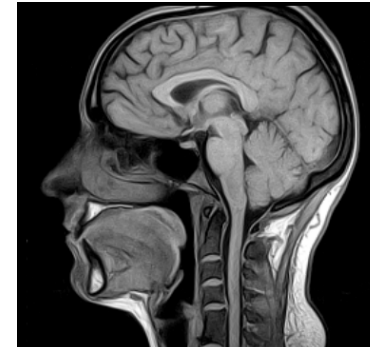## Introduction to Medical Imaging

Medical Imaging

- Introduction
- Image quality
- Imaging technology:
  - Radiography
  - Computed Tomography
  - Magnetic Resonance Imaging
  - Ultrsonography
  - Nuclear Medicine
  - Endoscopy
  - Thermography
- Processing & analysis of medical images
- The future of Medical Imaging

Learning outcomes

- Presentation
- Written test

By the end of this subject student should be able to:

1. explain the basic principles of the major medical imaging techniques;

2. explain the mode of operation and medical applications of the major medical imaging techniques;

3. understand the advantages and disadvantages of the major imaging techniques, including potential hazards for patiens;

4. make use of sample software (or implement simple algorithm) for displaying and basic processing of biomedical images or.

- Lab report

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References

- Lecture notes (.pdf files)
- W. R. Hendee, E.R. Ritenour, Medical Imaging Physics, Wiley-Liss, 2002
- C. Guy, D. ffytche, An Introduction to The Principles of Medical Imaging, Imperial College Press, 2008
- R. Tadeusiewicz, J. Smietański, Pozyskiwanie obrazów medycznych oraz ich przetwarzanie, analiza, automatyczne rozpoznawanie i diagnostyczna interpretacja, Wydawnictwo Studenckiego Towarzystwa Naukowego, Kraków 2011 (PL)
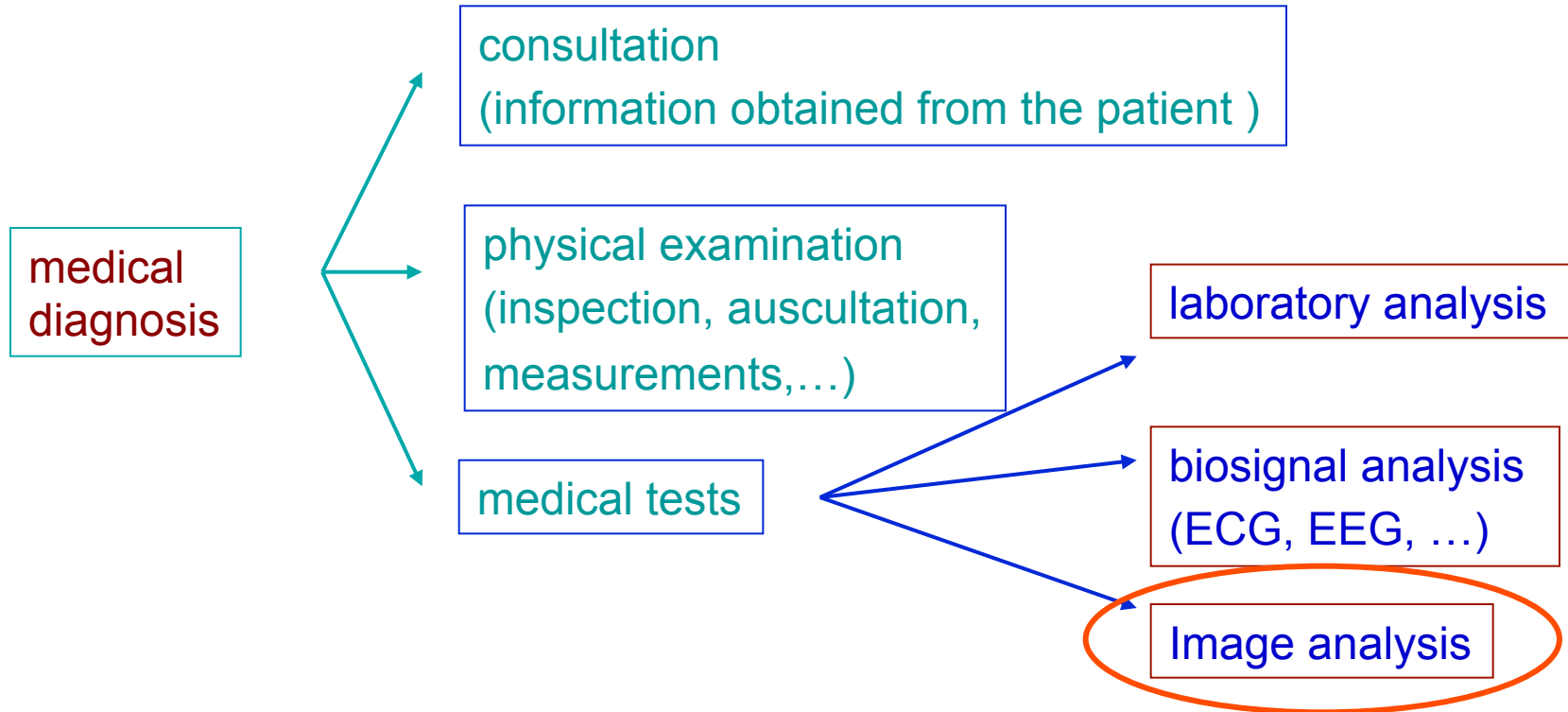
Rewolution in medical diagnosis

- Advances in microeletronics and computer science
- Development of tissue imaging technology
- Qualitative diagnosis -> quantitave diagnosis
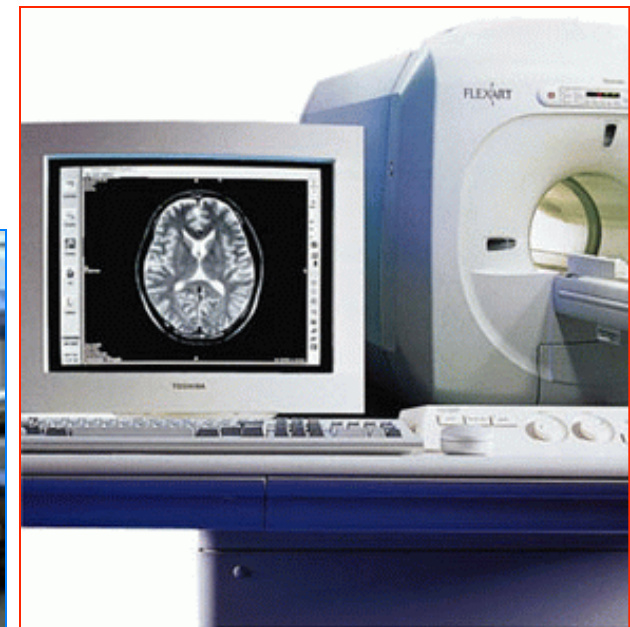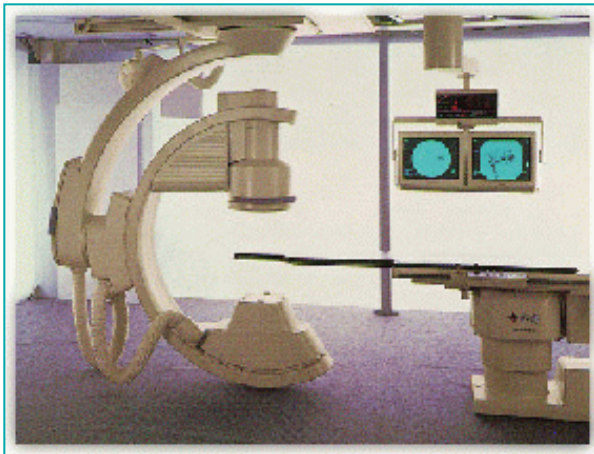
Medical Diagnosis
- determination of the identity of a possible disease or disorder

```
                              ┌─────────────────────────────────────────┐
                              │ consultation                            │
                           ↗  │ (information obtained from the patient ) │
                              └─────────────────────────────────────────┘

┌───────────┐                 ┌───────────────────────────┐      ┌──────────────────────┐
│ medical   │ →               │ physical examination      │      │ laboratory analysis  │
│ diagnosis │                 │ (inspection, auscultation,│      └──────────────────────┘
└───────────┘                 │ measurements,…)           │  ↗
                              └───────────────────────────┘      ┌──────────────────────┐
                           ↘  ┌──────────────┐                   │ biosignal analysis   │
                              │ medical tests│ →                 │ (ECG, EEG, …)        │
                              └──────────────┘  ↘                └──────────────────────┘
                                                                 ┌──────────────────────┐
                                                                 │ Image analysis       │
                                                                 └──────────────────────┘
```

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Monochrome image as a 2D function

$f(x,y)$

y

x

$$(x,y) \rightarrow f(x,y)$$
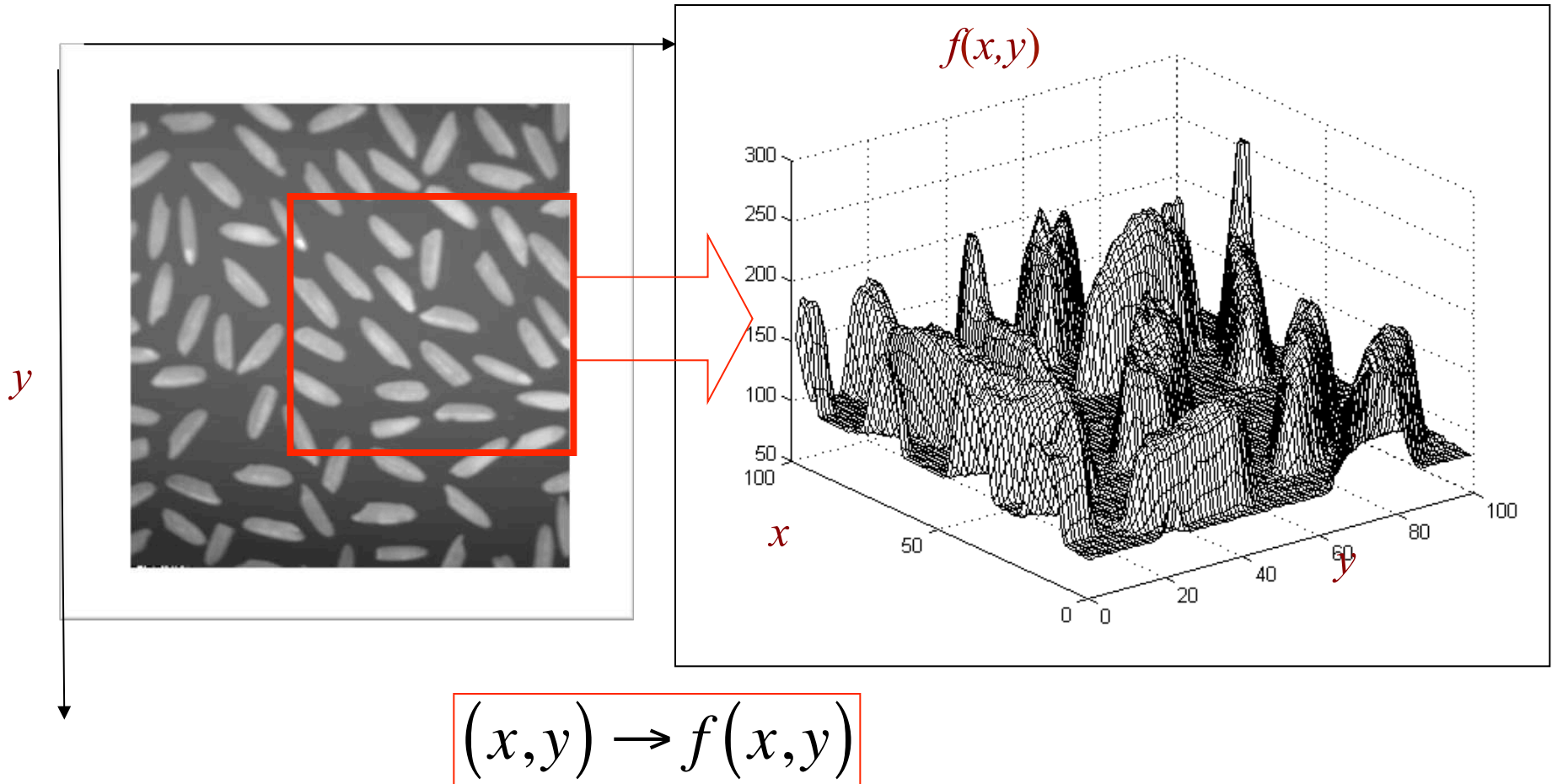
Image brightness profile

Distance along profile

RGB color image

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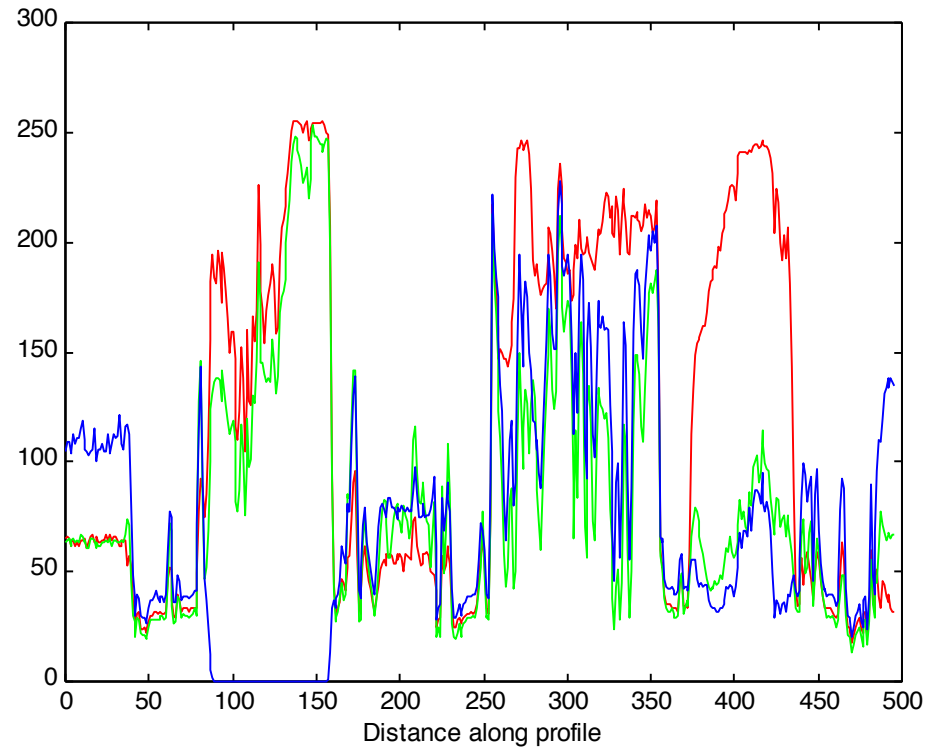Instytut Elektroniki
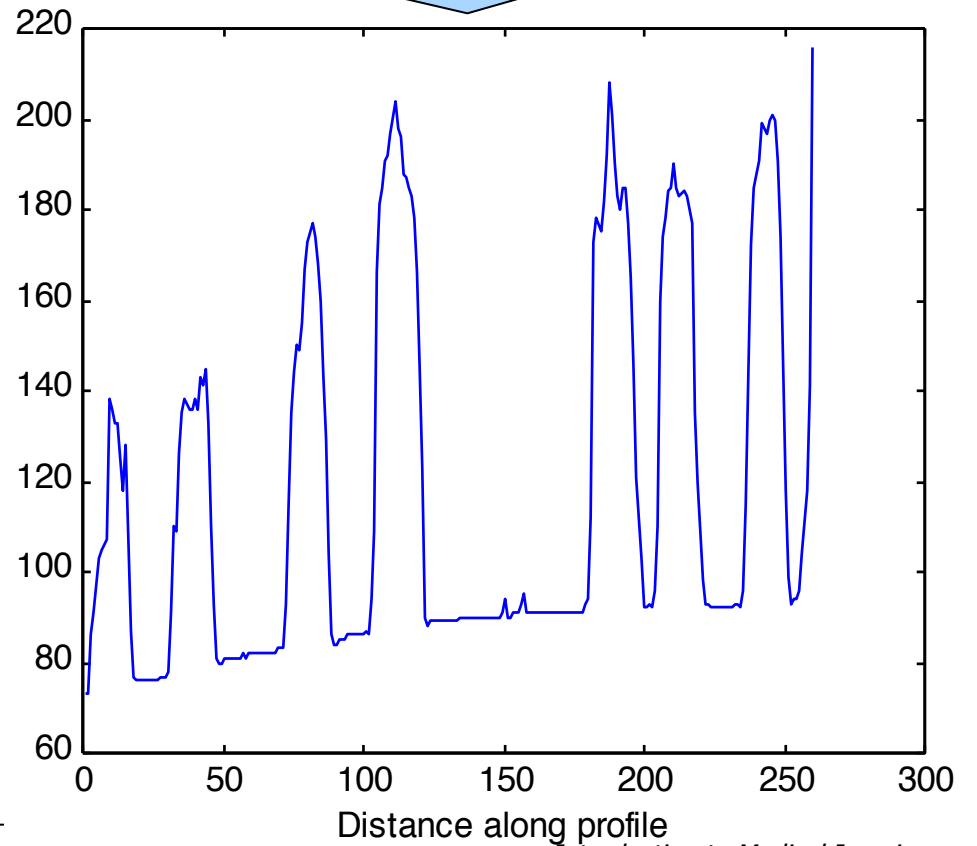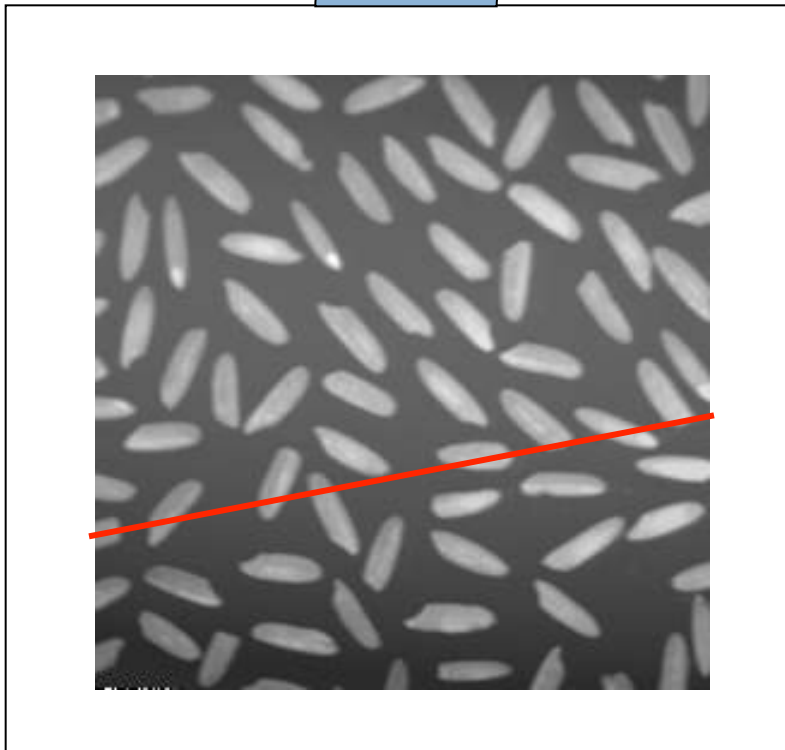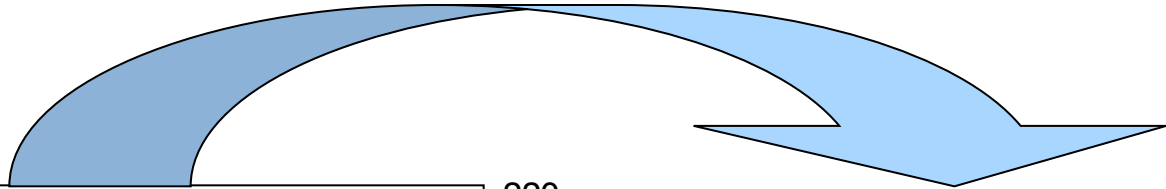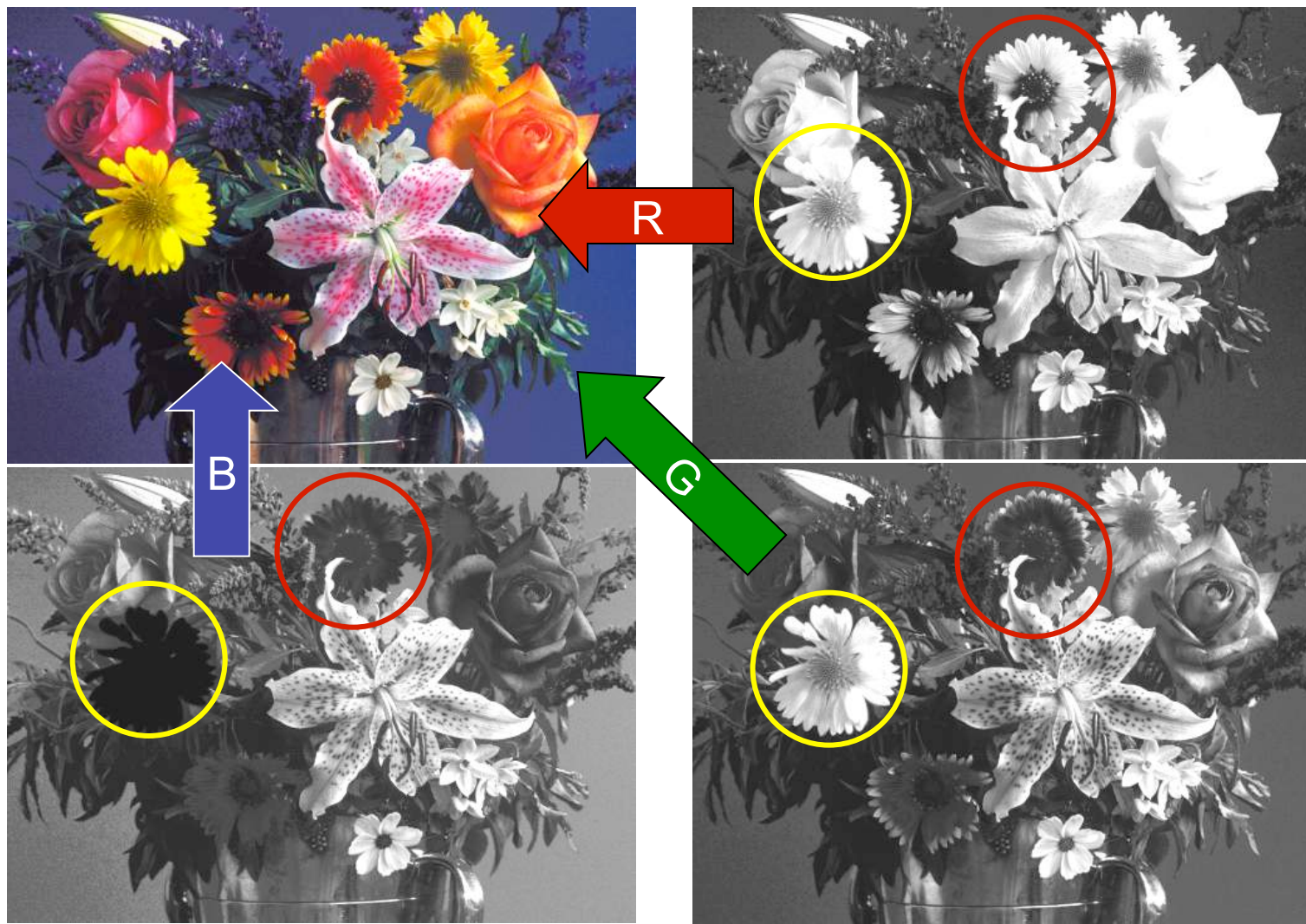
RGB color image
color components profiles

RGB image and colour components profiles

Digital image

discretisation

+

quantization

pixel (*picture element*)

Introduction to Medical Imaging

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Digital image as pixel array

(0,0)   X

$f(x,y)$

BUILDING.TIF

. . . .

. . 15 17 18 . .

. . 20 31 14 . .

. . . .
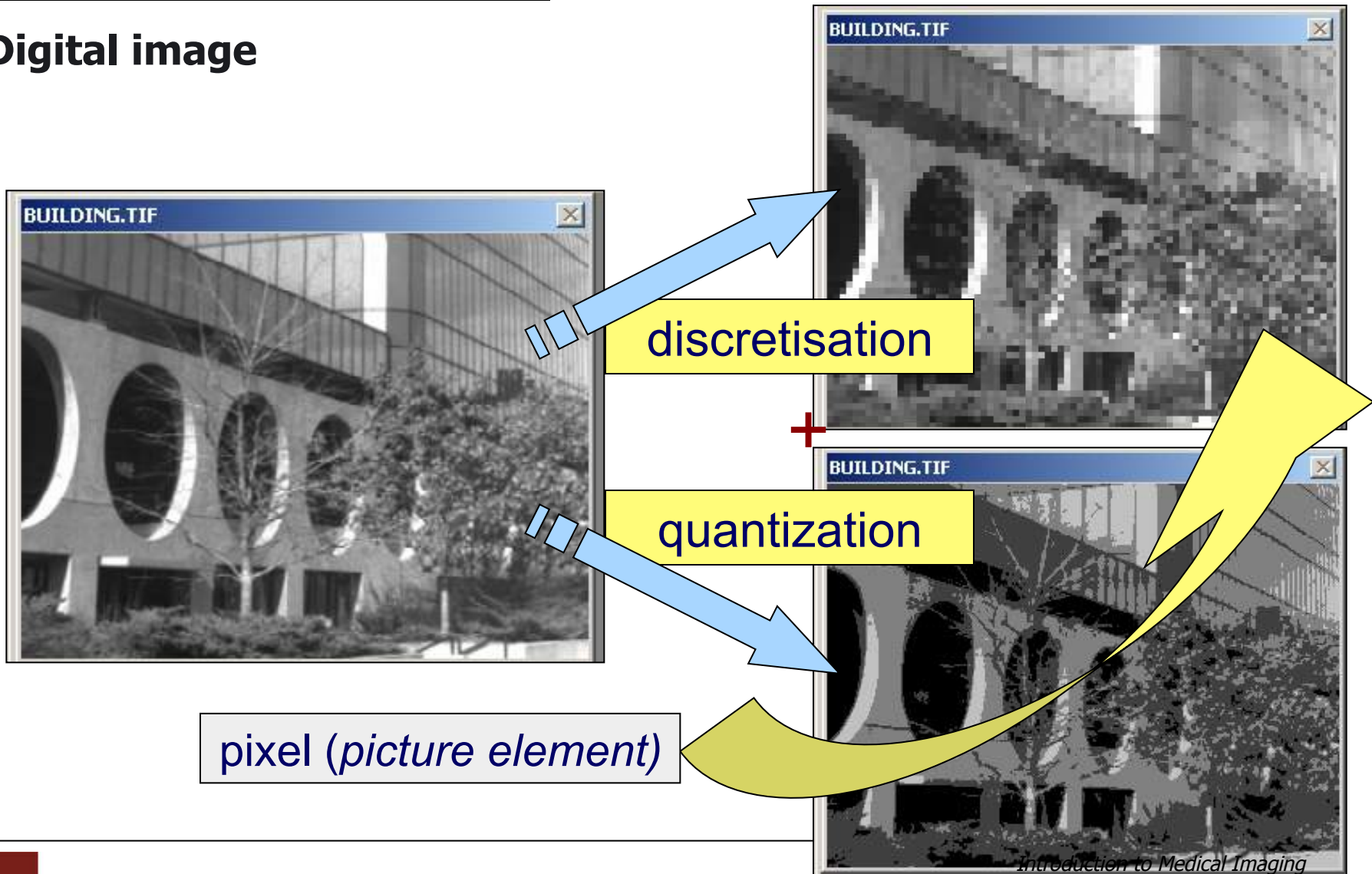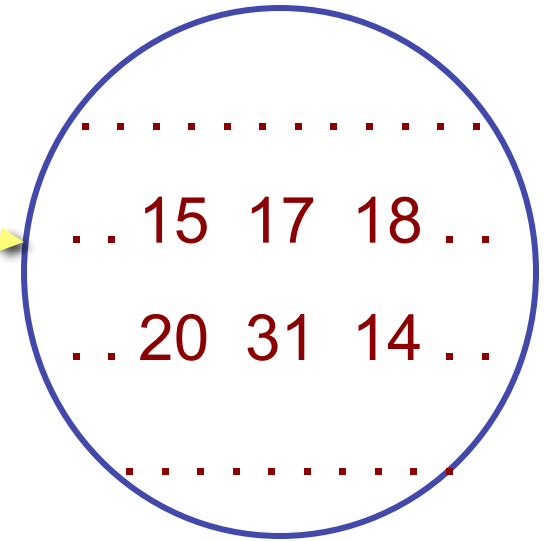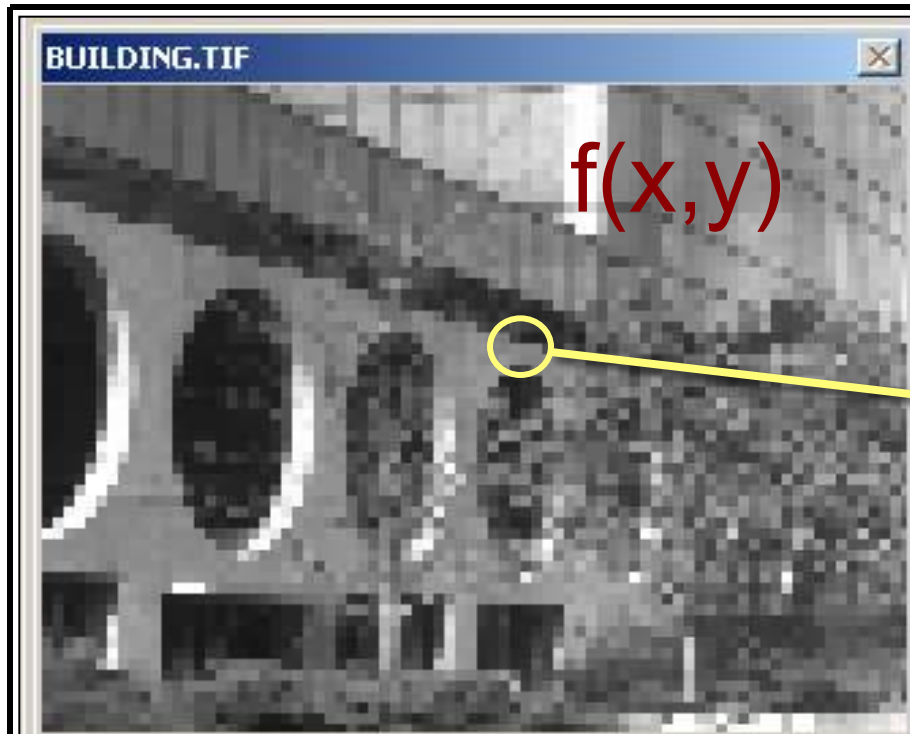
Y

Digital image as pixel array

Digital image $f(x,y)$:

2D array (M,N),
ie. of M rows and N columns,
of nonnegative elements assuming
a limited number of levels

$$f(x,y) = 0, 1, ..., L-1$$

$$x = 0, 1, ..., N-1$$
$$y = 0, 1, ..., M-1$$

(e.g. $L=256$)

Color digital image?

Color digital RGB image
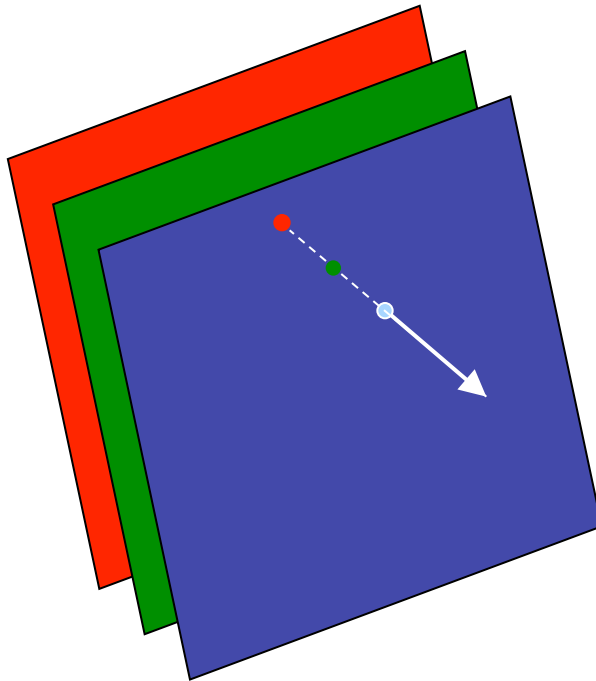
If each of the color component is 8 bit coded then 2^{24} different colors can be obtained

$$f(x, y) = (f_R, f_G, f_B)$$

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Color indexed image

f=25
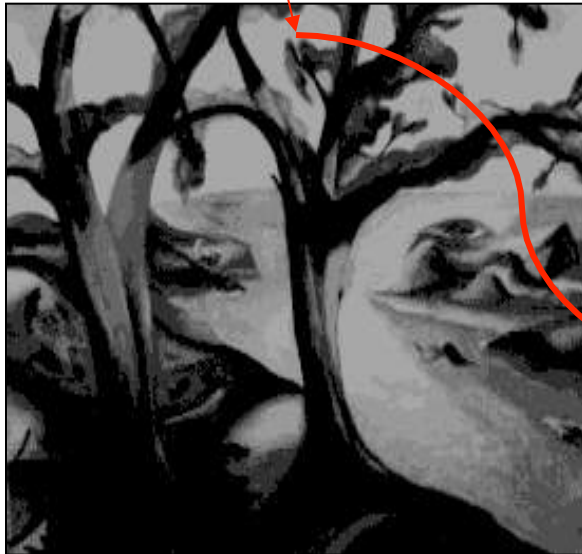
Monochrome image

	R	G	B
0			
1			
2			
.			
.			
.			
	.	.	.
25	**0.21**	**0.3**	**0.99**

Colour palette
(look-up table)
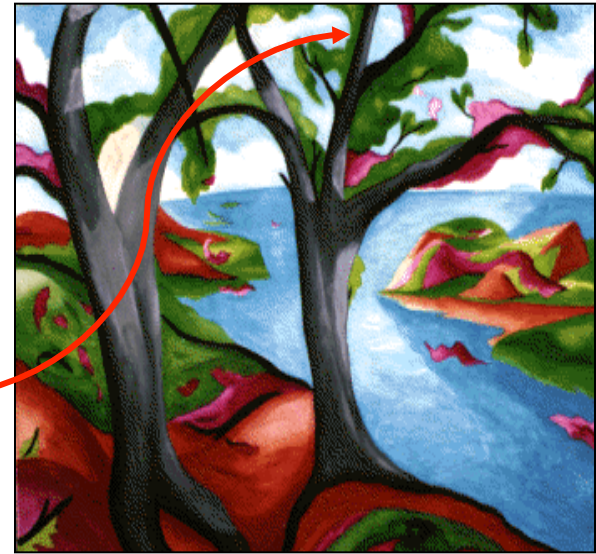
Color image

3D images

(0,0,0)

x

2	17	44	69	12	39
78	21	4	54	67	9	69
34	74	23	59	6	81	50	61
	90	48	31	43	12	69	54	20
		49	99	12	2	33	2	53
			72	23	218	28	70	87

f(x,y,z)

z

y
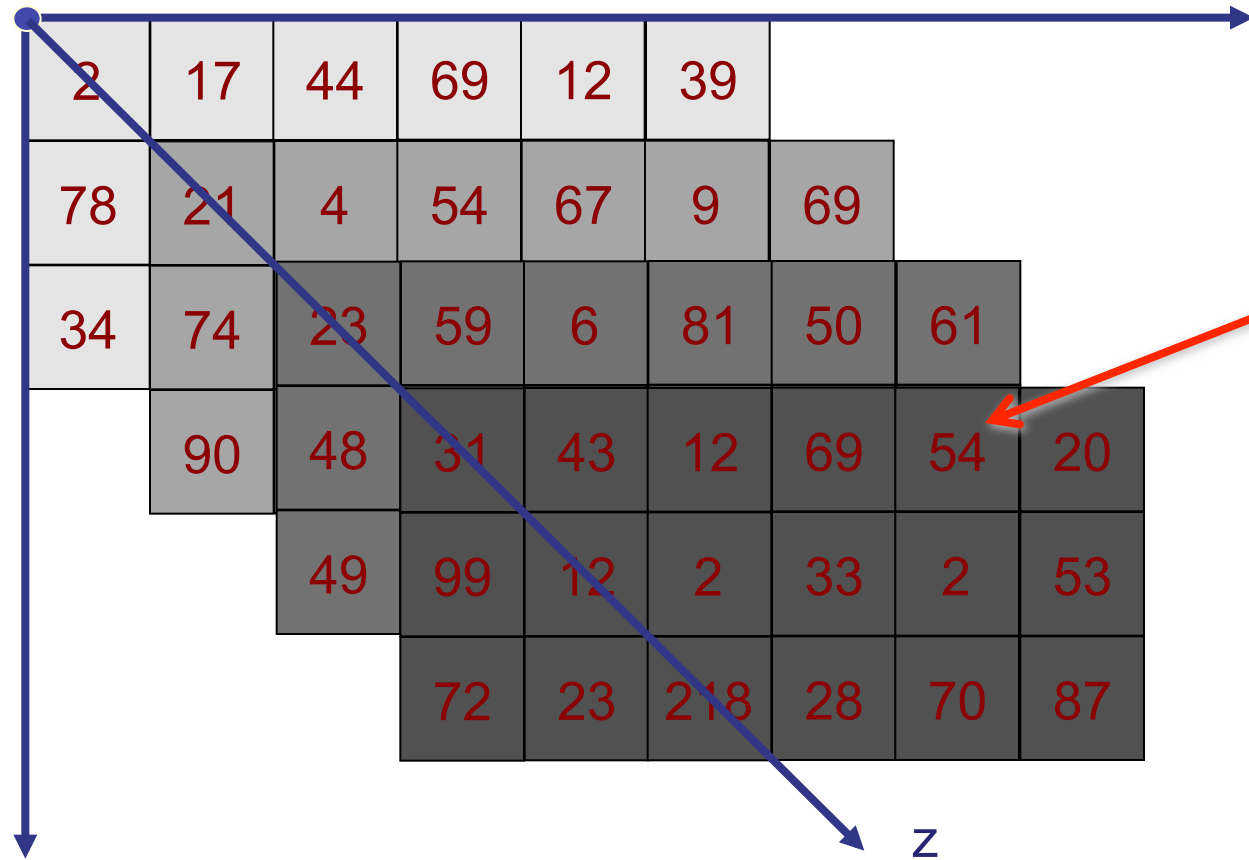
3D images can evolve in time – 4D images

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Electromagnetic spectrum

frequency [Hz]

10^{24} 10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^8 10^6 10^4 10^2

X rays

microwaves

gamma rays

radio waves

Visible light

ultraviolet

infrared waves

400   500   600   700   [nm]

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Computer vision system

Image Processing

Segmentation

Feature Estimation

Image Acquisition

Computer + software + knowlegde database

features: geometrical, topological, texture …

Data Analysis

(recognition, classification, interpretaction)

„healthy tissue"

The History of Medical Imaging

CT+MRI, PET+MRI
(Gen. Electric, 2010)

CT tomography
(A. Cormack, G. Hounsfield, 1972)

MRI tomography
(P. Lauterbur, P. Mansfield, 1973
since 80ties)

angiography
(E. Moniz, 1927)

ultrasonography
(I. Edler, C. Hertz, 1953)

radiography
(J. Hall-Edwards, 1896)

Endoscopic capsule
(Given Imaging, 2001)

PET tomography
(M. Ter-Pogossian et.al., 1973)

Termography
(since 60thies, XX c.)

endoscopy
(B. Hirschowitz, since 70ties)

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Why so many imaging modalities?

- Sonography (53%-77% lesions)
- CT (l. vasculature gold standard)
- MRI (91% benign – malignant discrimination)
- PET (highest sensitivity in tumor detection)
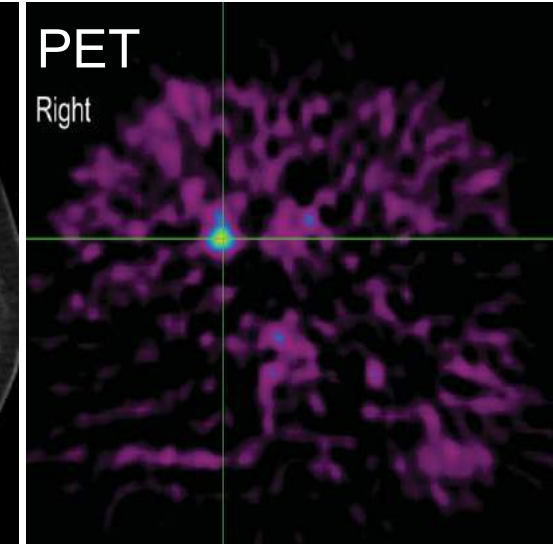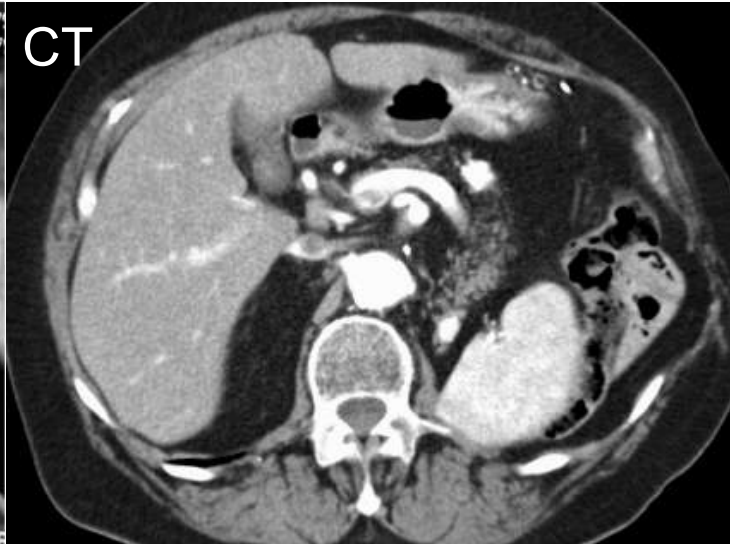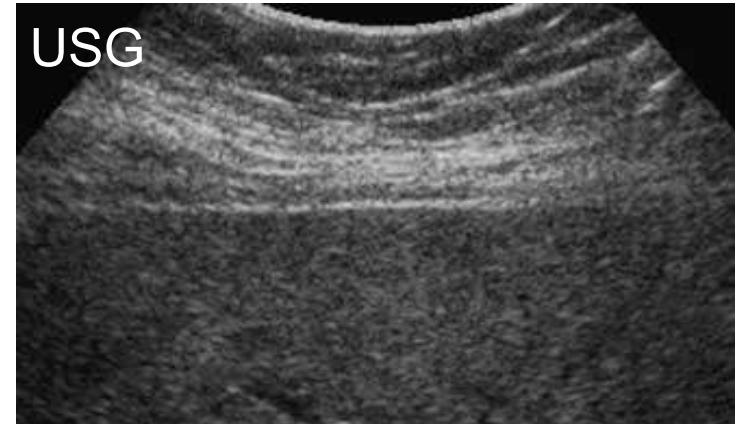
Radiography

Roentgen radiation (X-ray radiation), discovered and described by Wilhelm Röntgen in 1895, Nobel prize in physics in 1901.

10^{24} 10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12}

Gamma radiation

ultraviolet

Visible light

X-rays

5pm-100pm (hard)
100pm-10nm (soft)

Ms. Röntgen hand x-ray

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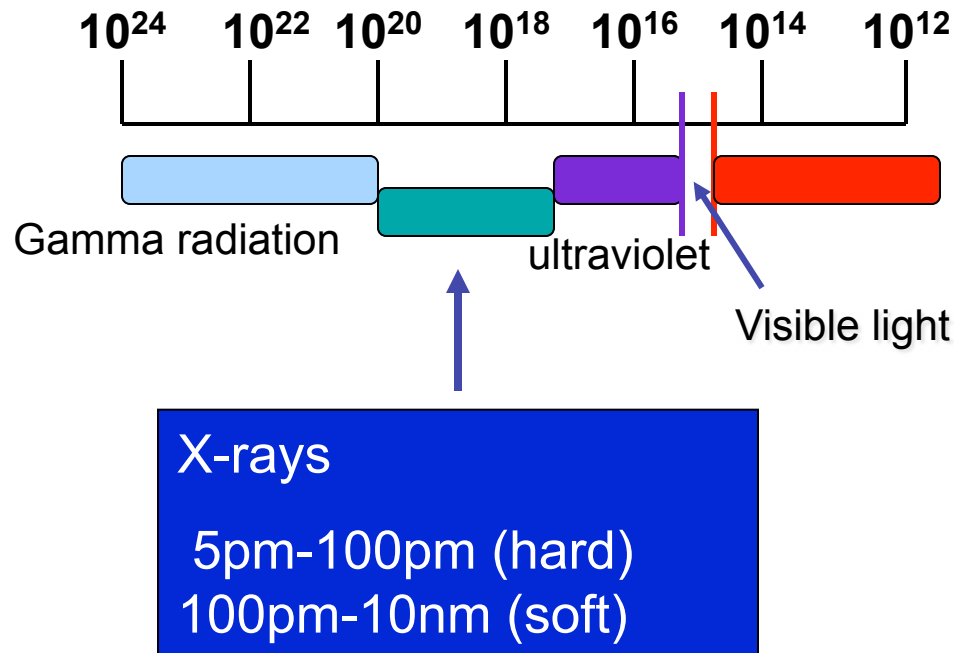
Radiography

- film images,
- digital images,
- invasive examination,
- limited quality,
- low equipment price, mobility

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Radiography

Applications:

orthopedics

pulmunology

dentistry

Diagnosis:

breast cancer (mammography)

osteoporosis

dr Piotr Cichy

www.kavo.pl, Gendex

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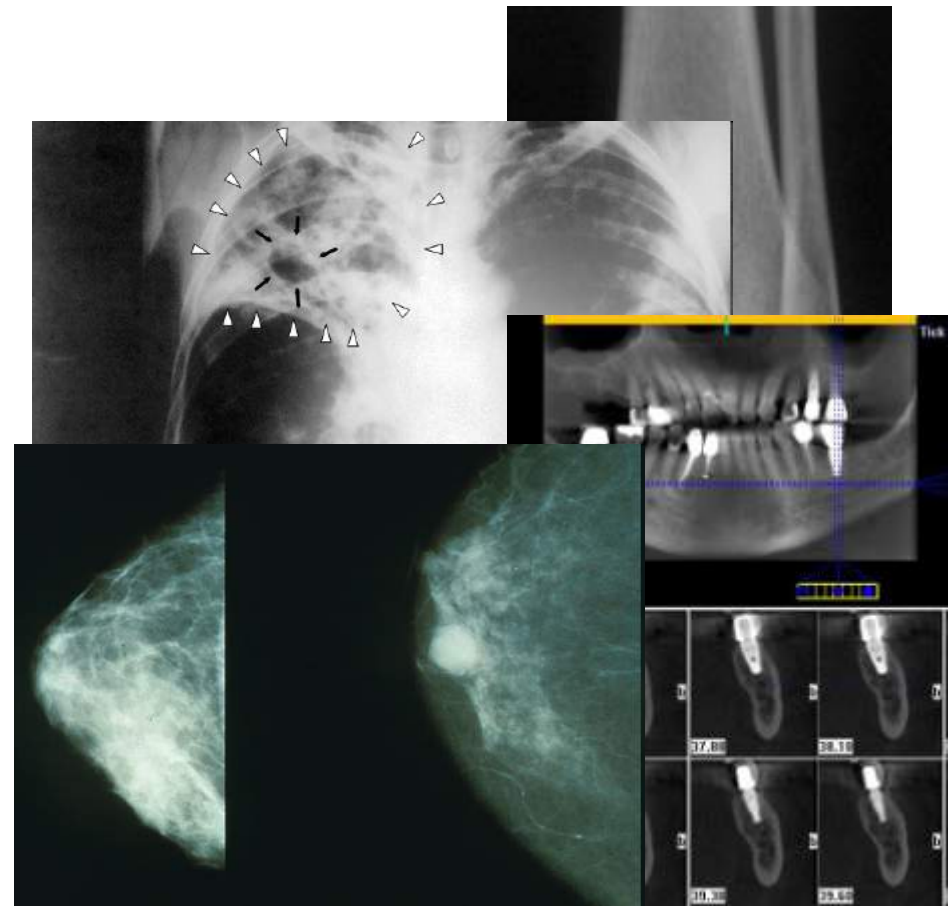
Analysis of wrist radiograms
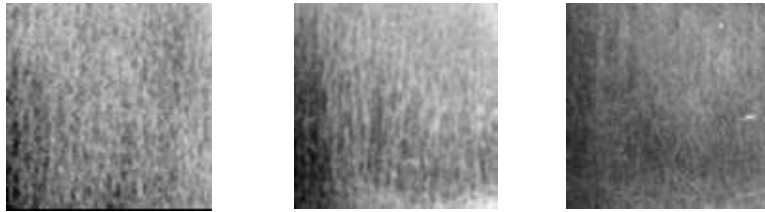
Control (1)   Osteoporosis (3)

Osteopenia (2)

Markov Random Field model

Liniear Discriminant Analysis
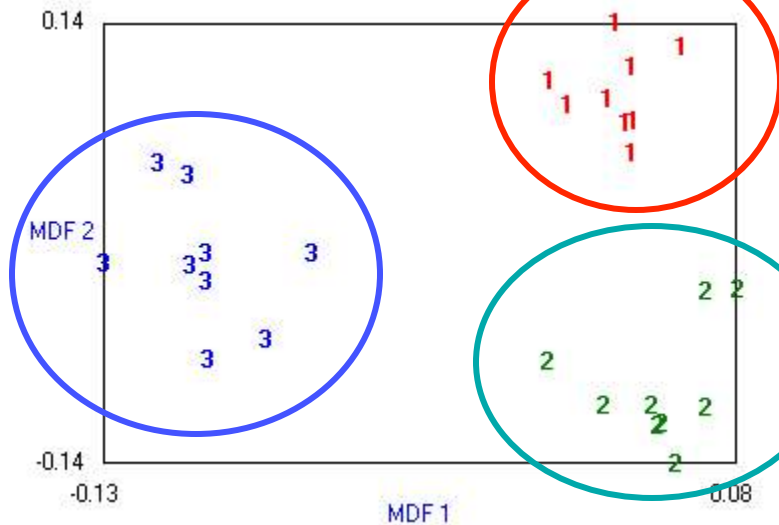
Classification error: 0%
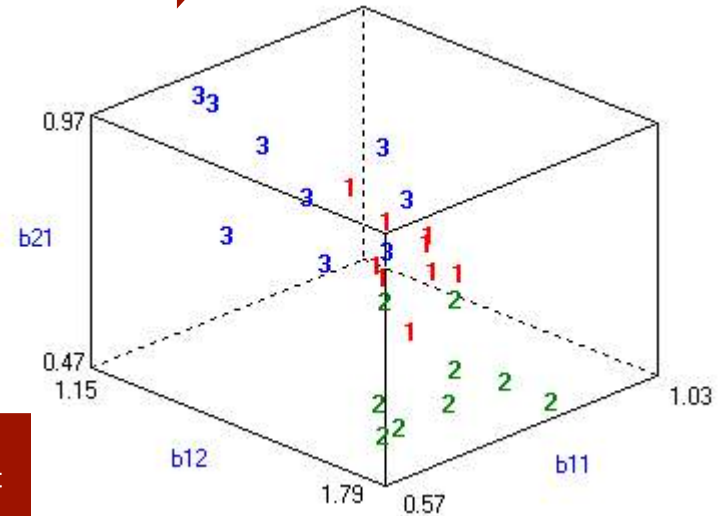
Classsifcation error: 9%

Ultrasonography

- low image quality,
- difficult for interpretation,
- blood flow examination
(Doppler effect USG),
- non-invasive examination,
- low equipment price, mobility
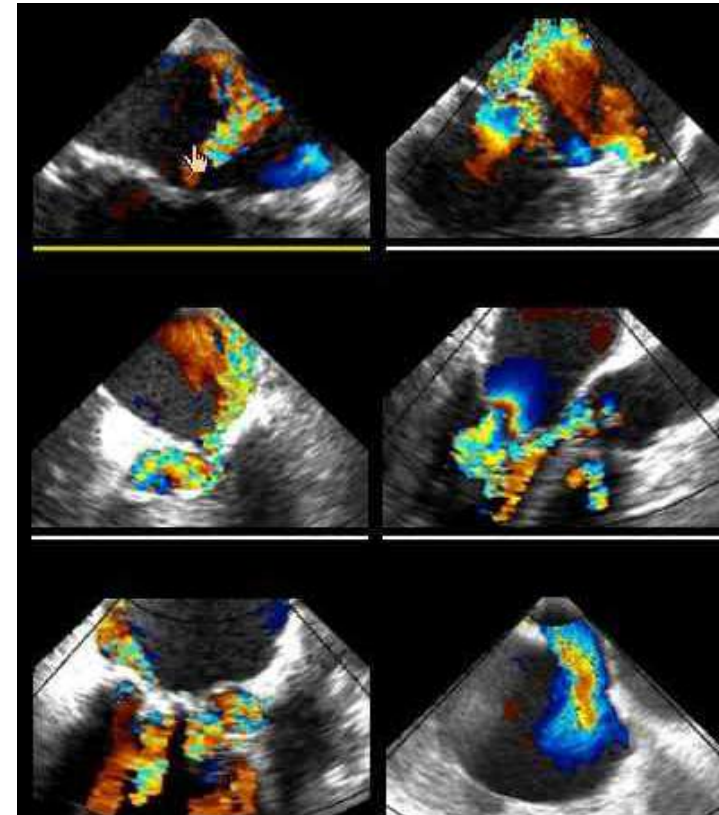
Ultrasonography

Applications:

cardiology

ginecology&obstetrics

urology

gastrology

......

Diagnosis:

prostate, urinary bladder

uterus
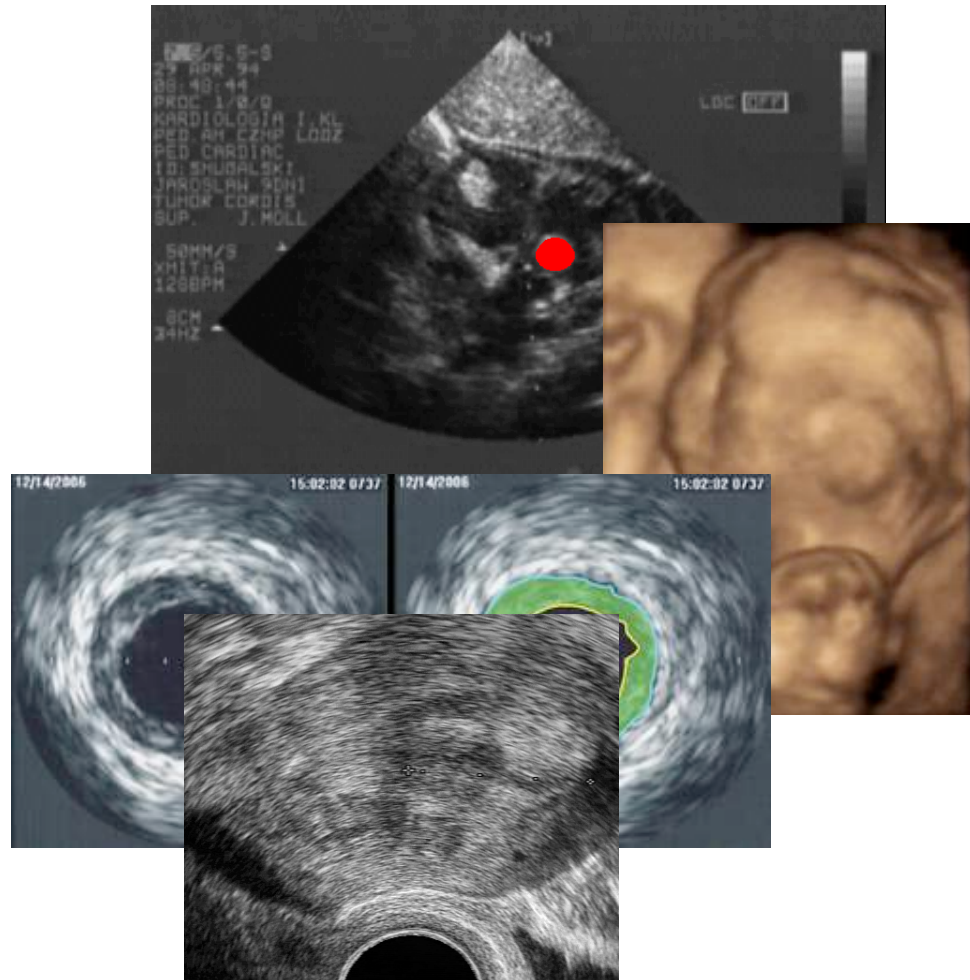
Analysis of heart echo images (classification)

trombi (1)

malignant (2)

benign(3)

Statistical features

NDA: f_1 f_2

g_1 g_2 g_3 …
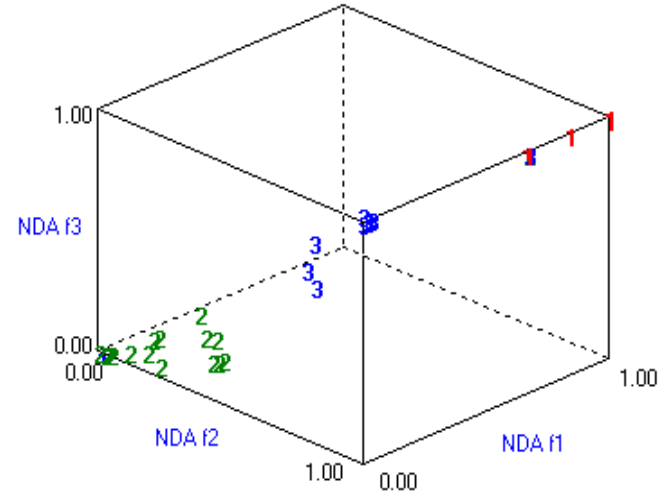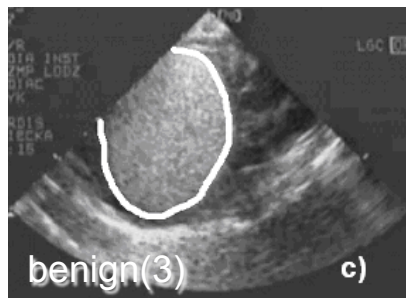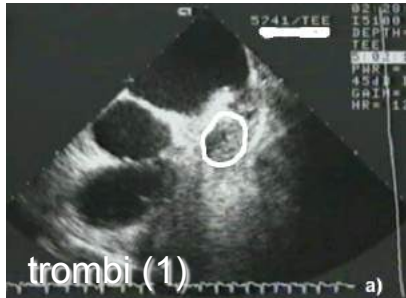
Classification error: 10% (55 images)

NDA f3

NDA f2

NDA f1

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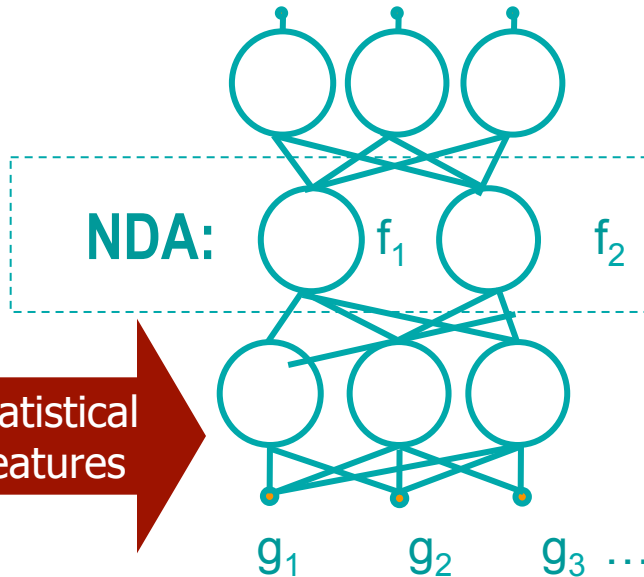
Analysis of heart echo images (segmentation)

Ststistical features

Feature map

Multilayer perceptron

Oscillator network
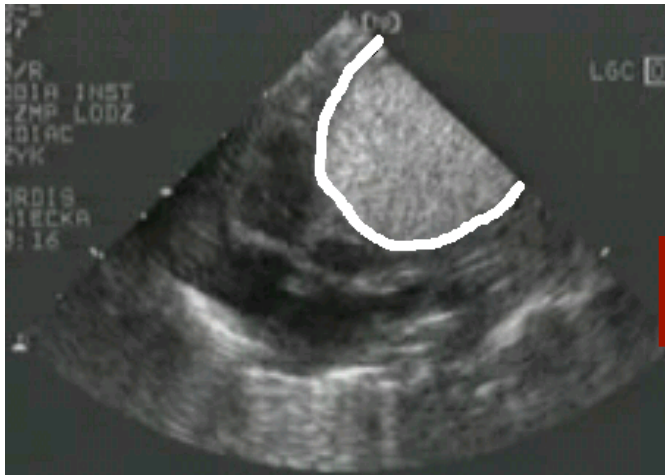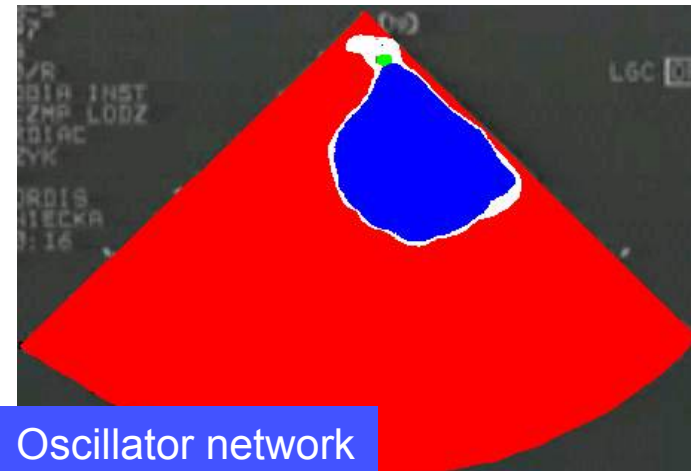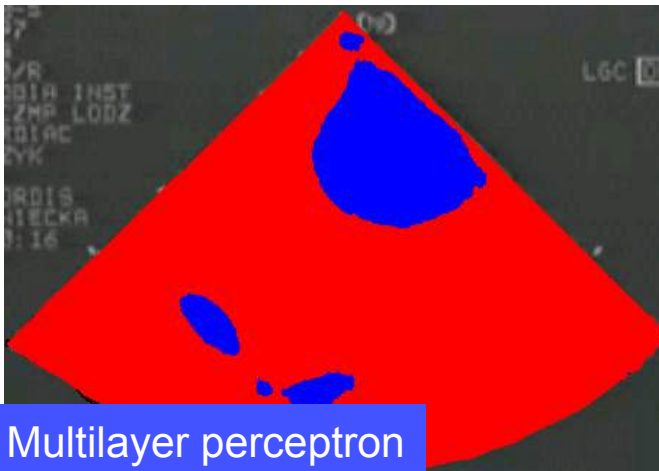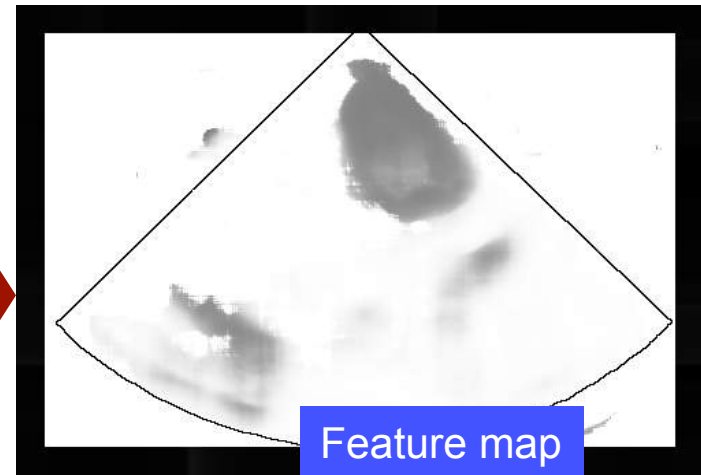
Computed Tomography (CT)

• cross-section images
(not a projections)
• not applicable for soft tissues,
• very good image quality,
• invasive examination,
• high equipment price
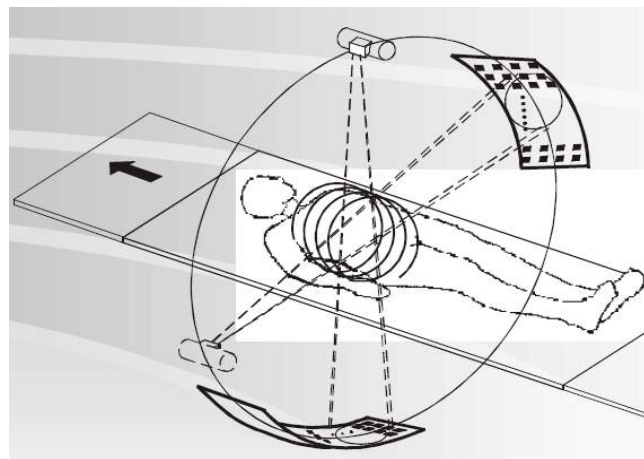
biomech.pwr.wroc.pl/
konferencja/Cierniak.pdf

Computed Tomography (CT)

Applications:

neurology

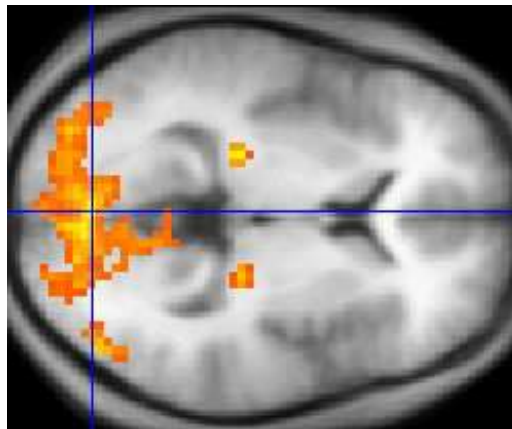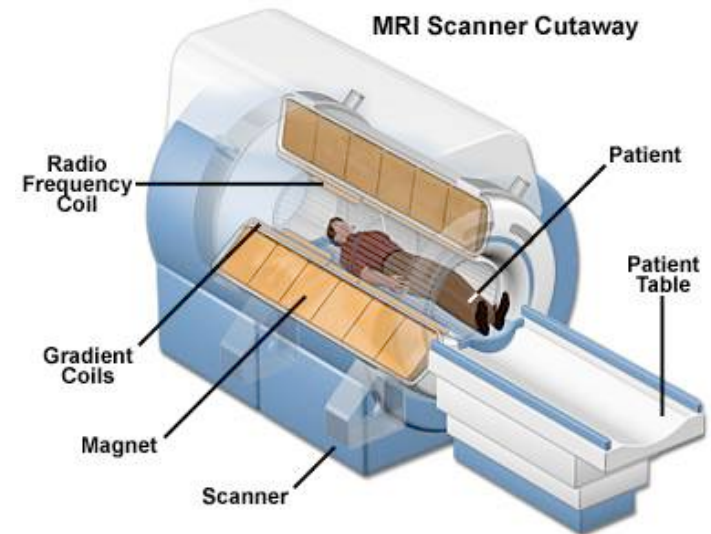cardiology

pulmunology

gastroenterology

......

Diagnosis:

brain tumors

kidney, liver

lung diseases

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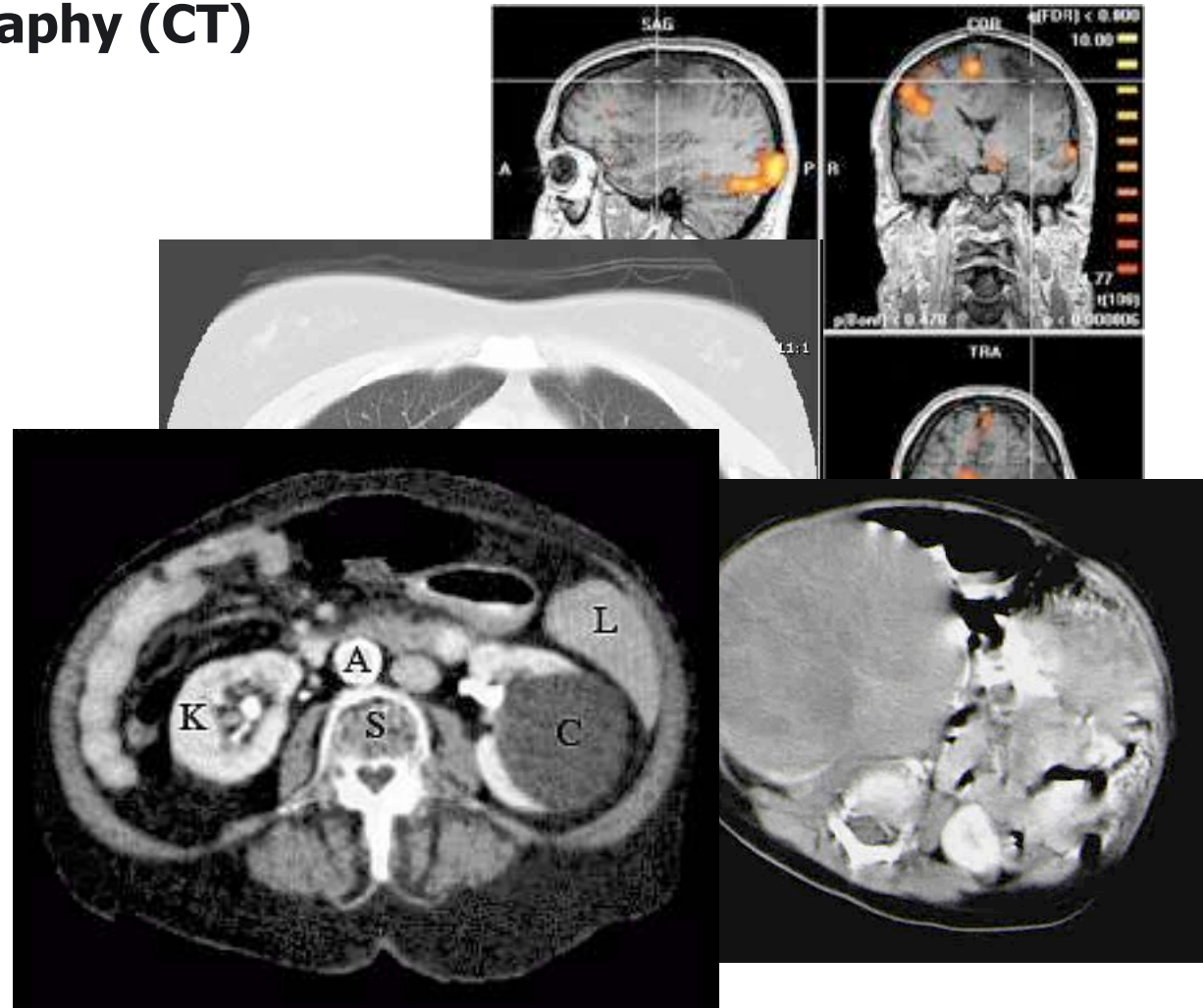
Magnetic Resonance Imaging (MRI)

- effective for soft tissues,
- functional tomography (BOLD),
- MR angiography,
- very good image quality,
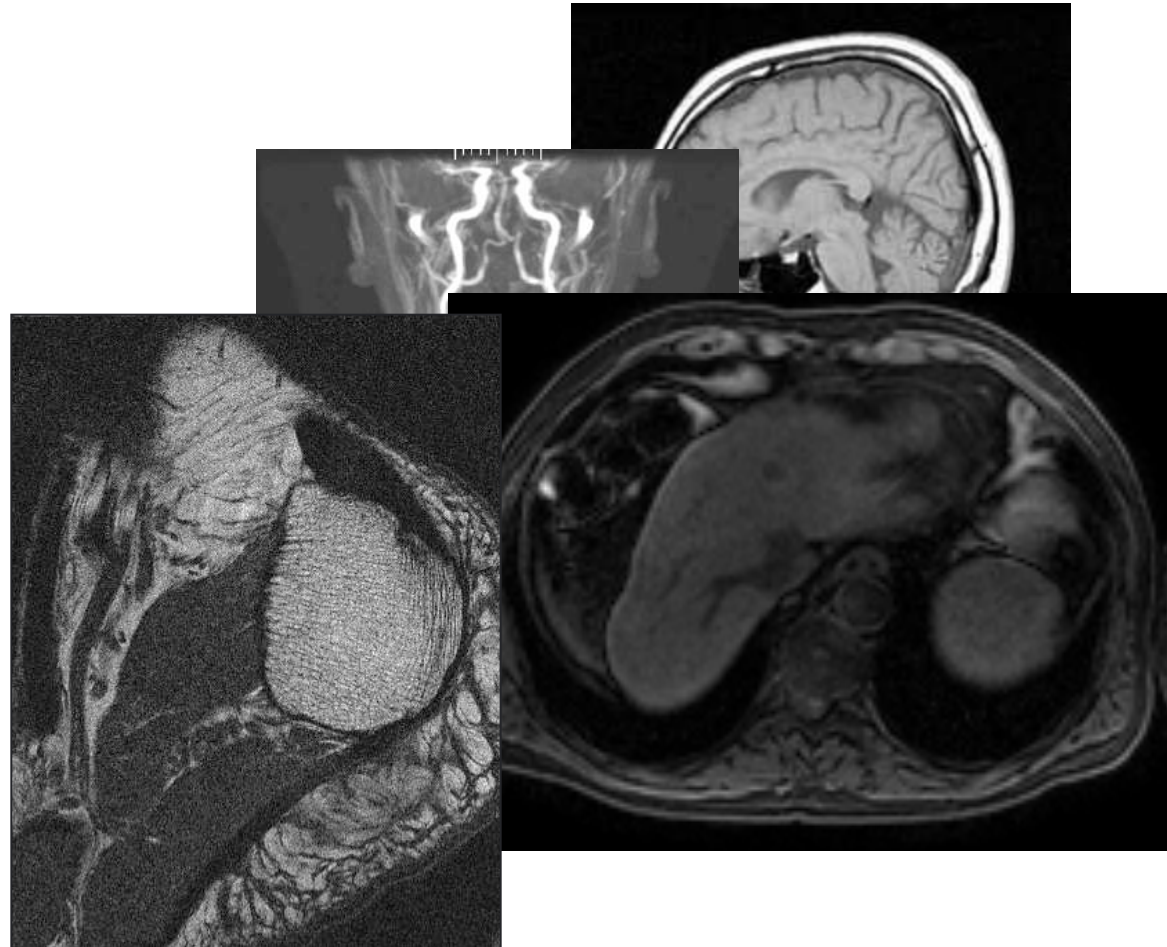- non-invasive examination,
- high equipment price

MRI Scanner Cutaway

Magnetic Resonance Imaging (MRI)

Applications:

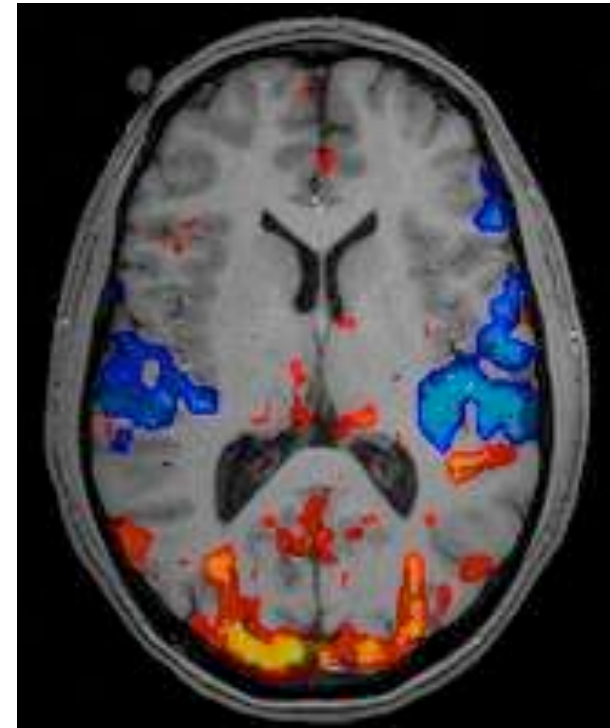neurology

angiography

gastroenterology

......

Diagnosis:

brain tumors

abdomen organs

osteoporosis

Functional Magnetic Resonance Imaging (fMRI)

Measured brain signal
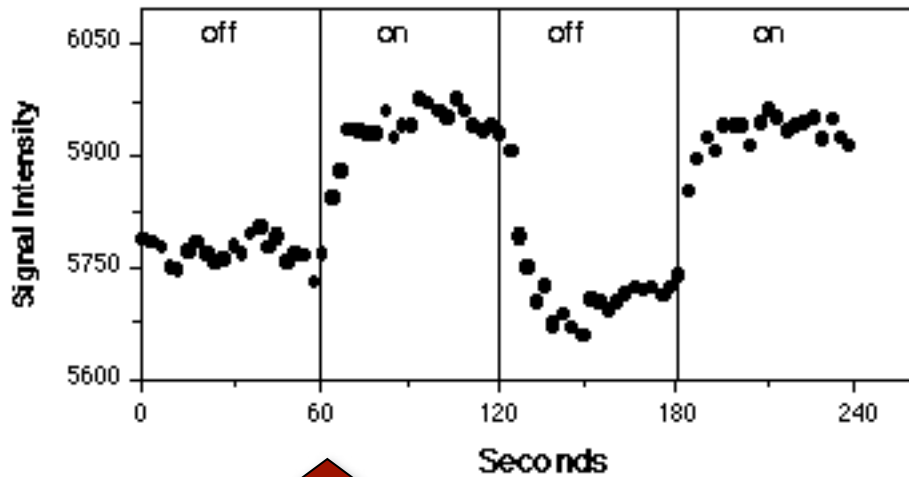
Visual stimulus

Brain activation map
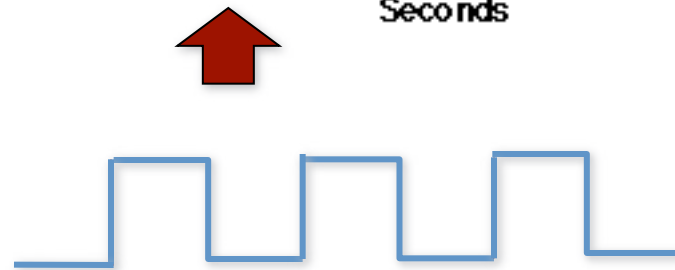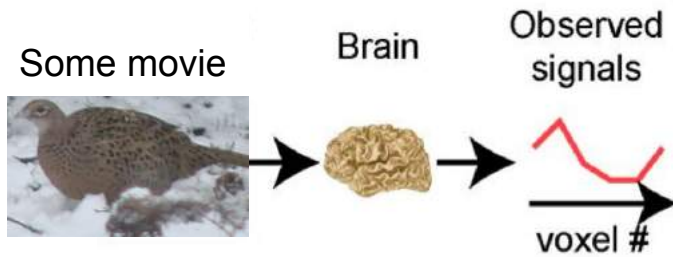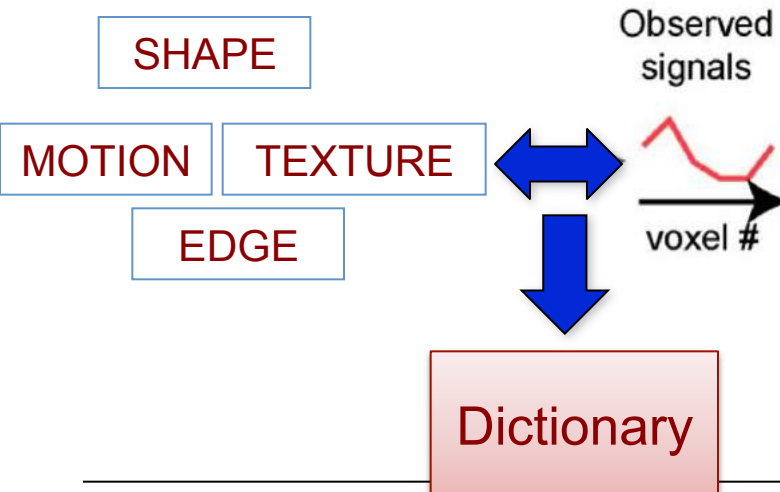
Functional Magnetic Resonance Imaging (fMRI)

Reconstructing visual experiences from brain activity evoked by natural movies (The Gallant Lab, UC Berkeley)

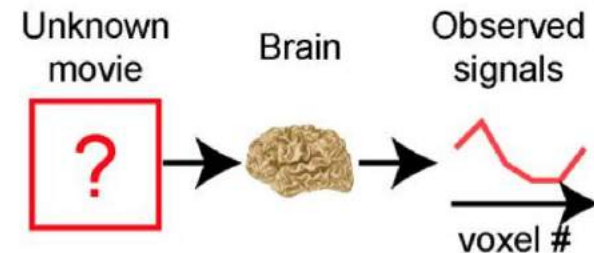[1] Record brain activity while the subject watches several hours of movie trailers.

[2] Build dictionaries (i.e., regression models) that translate between the shapes, edges and motion in the movies and measured brain activity. A separate dictionary is constructed for each of several thousand points at which brain activity was measured.

Functional Magnetic Resonance Imaging (fMRI)

[3] Record brain activity to a new set of movie trailers that will be used to test the quality of the dictionaries and reconstructions.
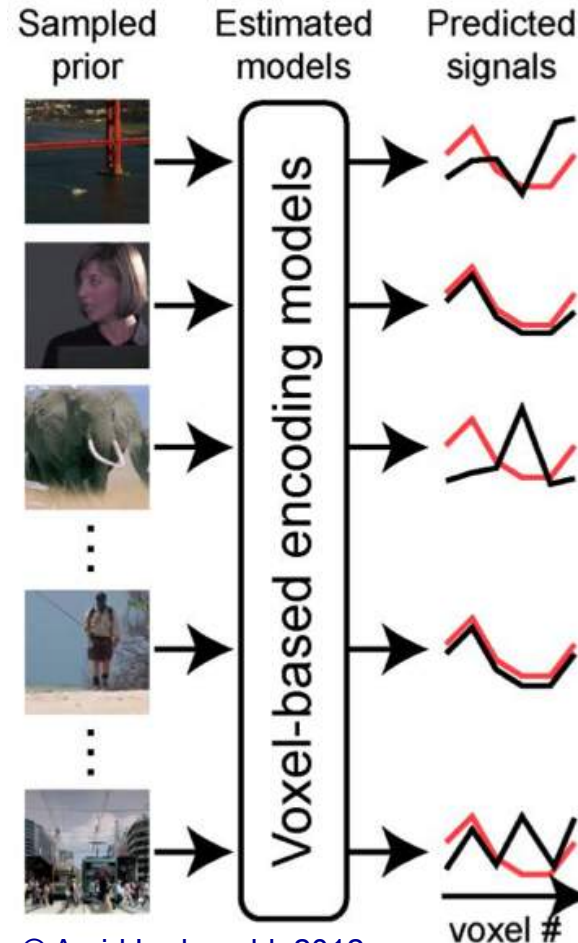

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http://www.youtube.com/watch?v=nsjDnYxJ0bo

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Functional Magnetic Resonance Imaging (fMRI)

[4] Build a random library of ~18,000,000 seconds (5000 hours) of video downloaded at random from YouTube. (Note these videos have no overlap with the movies that subjects saw in the magnet). Put each of these clips through the dictionaries to generate predictions of brain activity. Select the 100 clips whose predicted activity is most similar to the observed brain activity. Average these clips together. This is the reconstruction.
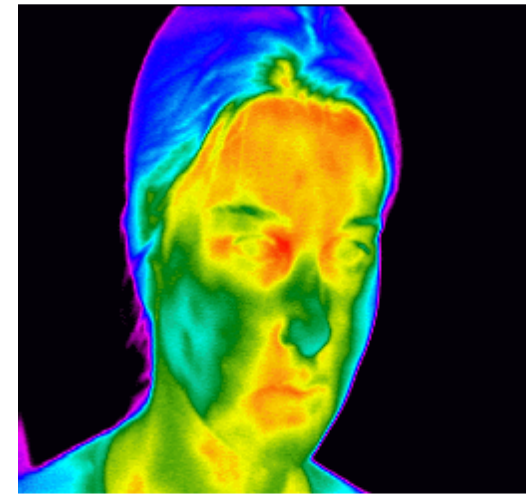
http://www.youtube.com/watch?v=nsjDnYxJ0bo

Sampled prior — Estimated models — Predicted signals

Voxel-based encoding models

voxel #

© Arvid Ludervold, 2012

Medical Termography

- low image quality
- complementary procedure to other diagnostic modalities
- non-invasive examination
- low equipment price, mobility

Nuclear Medicine

- • different approaches (PET, SPECT, Scintigraphy)
- •analysis of molecular changes,
- • often together with CT,
- • short examination time (limited by half-life disintegration of radioisotope),
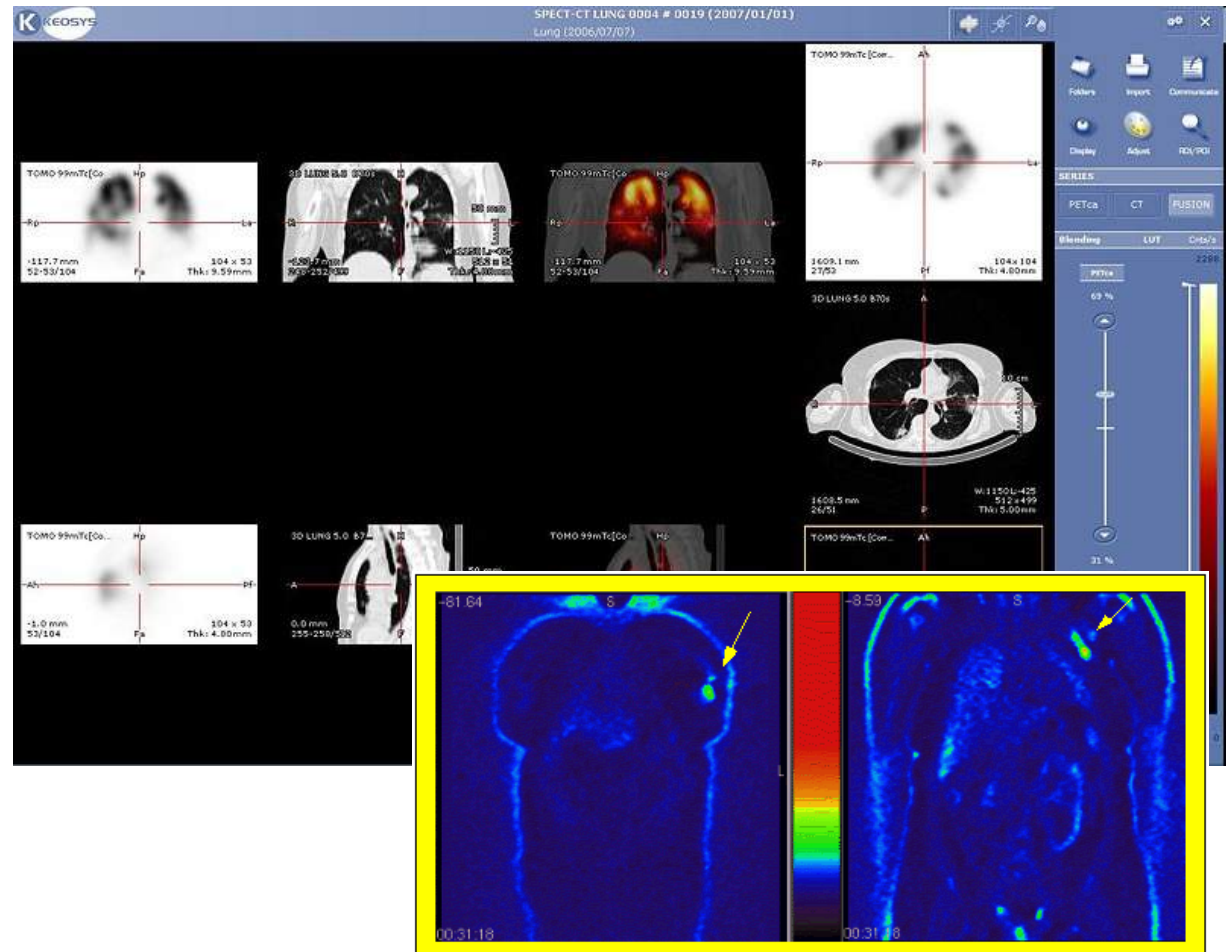- • invasive examination,
- • high equipment price
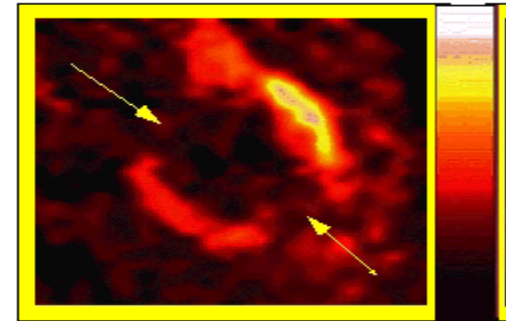
Nuclear Medicine

Applications:

almost all medical specialties

Diagnosis:

Huntington, Alzheimer, Parkinson diseases

early stage tumor detection

Endoscopy

• optical images of internal organs,

• additional surgical intervention (laparoscopy),

• endoscopic capsules,

• image processing is necessary,

• invasive examination,

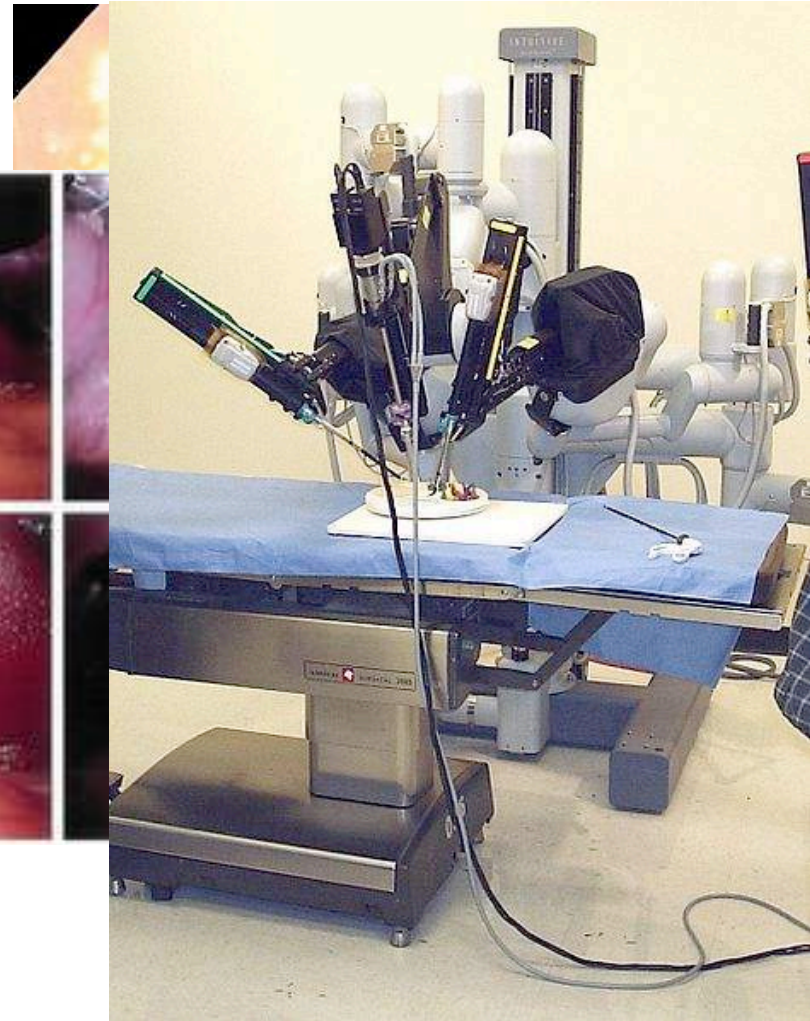• high equipment price

Endoscopy

Applications:
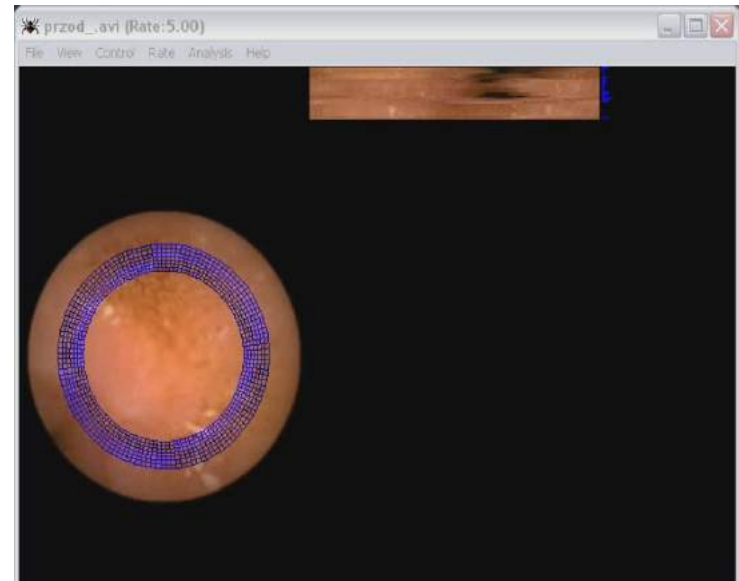
gastrointestinal tract (stomach, intestine, colon)
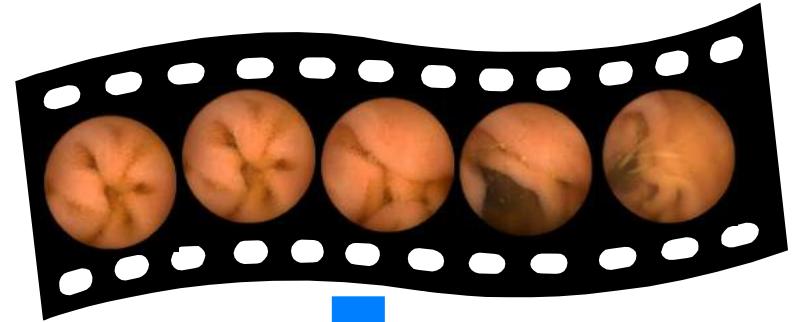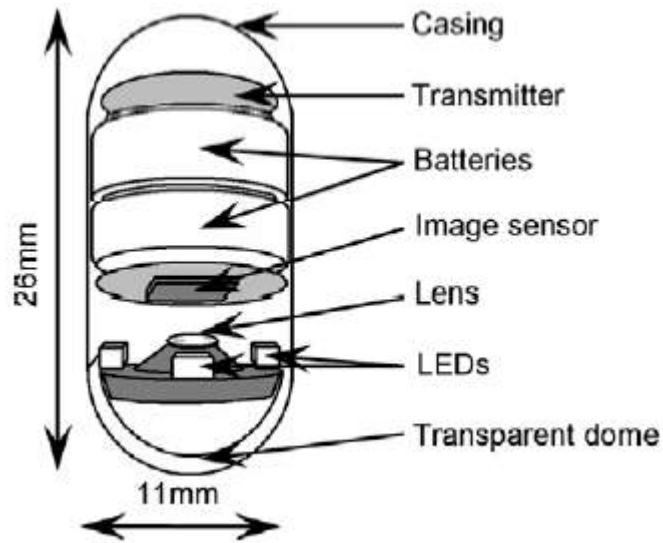
respiratory tract

urinary tract

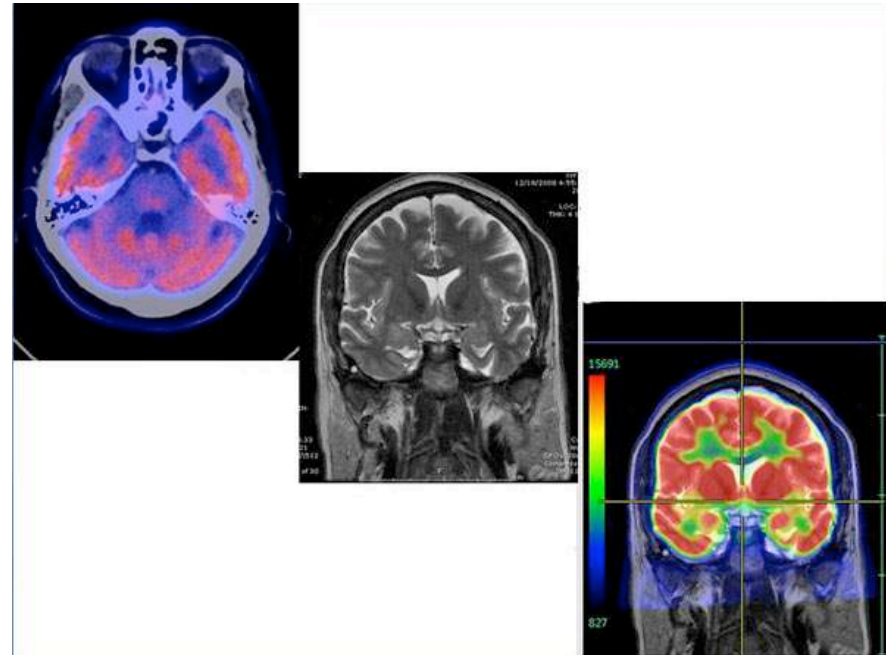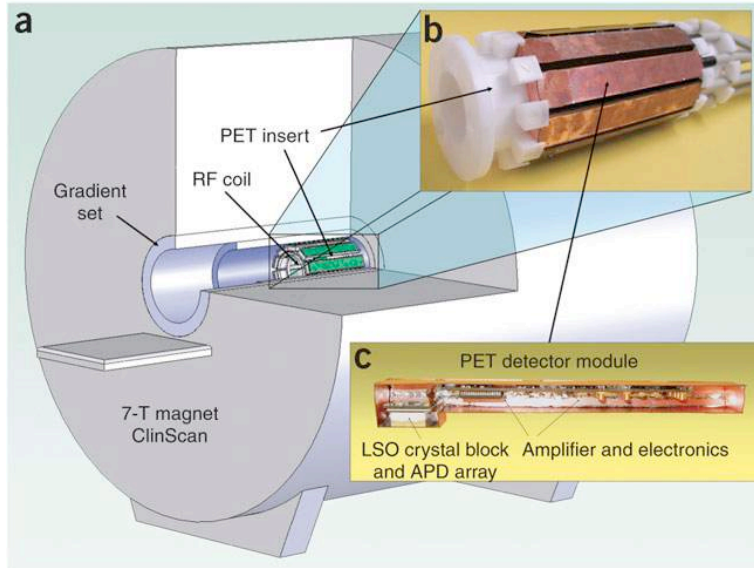## Laparoscopy:

removal of the gallbladder, polyp,…

Endoscopic capsule

dr Piotr Szczypiński, IE

Recent advances: PET + MRI

Imaging device that simultaneously performs positron-emission tomography (PET) and magnetic resonance imaging (MRI) scans, producing more detailed images than either technique alone and thus providing extended diagnostic information.

http://www.youtube.com/watch?feature=player_embedded&v=K2hAcri-ZIE

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References

- W. R. Hendee, E.R. Ritenour, Medical Imaging Physics, Wiley-Liss, 2002
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