MEDICAL IMAGE PROCESSING

GLOTSOS DIMITRIS

dimglo@uniwa.gr

Medical Image and Signal Processing Lab (MEDISP)

Department of Biomedical Engineering

University of West Attica

March 2019

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

4. Case study: Early detection of melanoma:

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

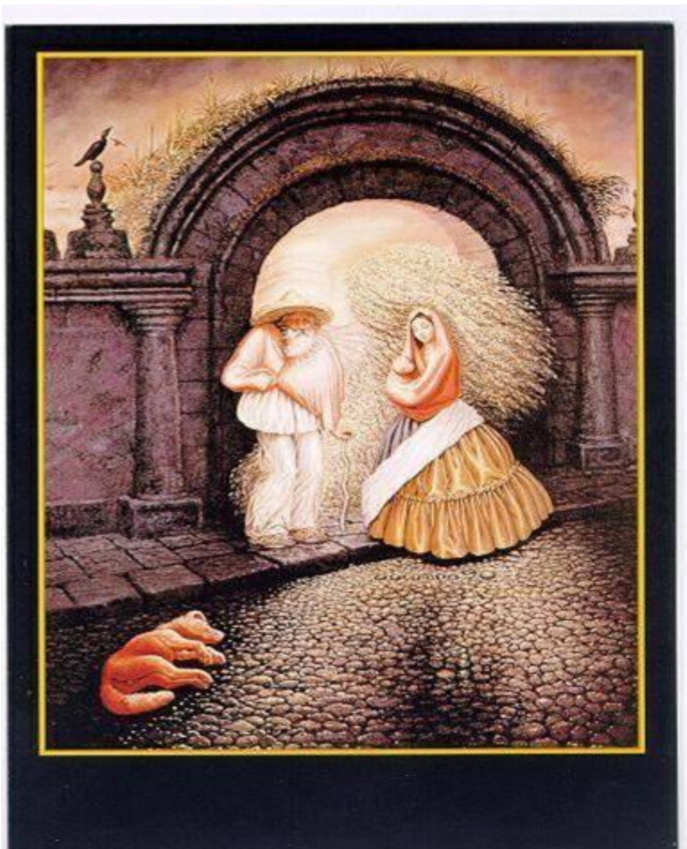
α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

4. Case study: Early detection of melanoma:

INTRODUCTION

Perception



Nine People

There are 9 people in the attached picture.

If you find 6, you have ordinary powers of observation

Find 7, you have above average powers of observation.

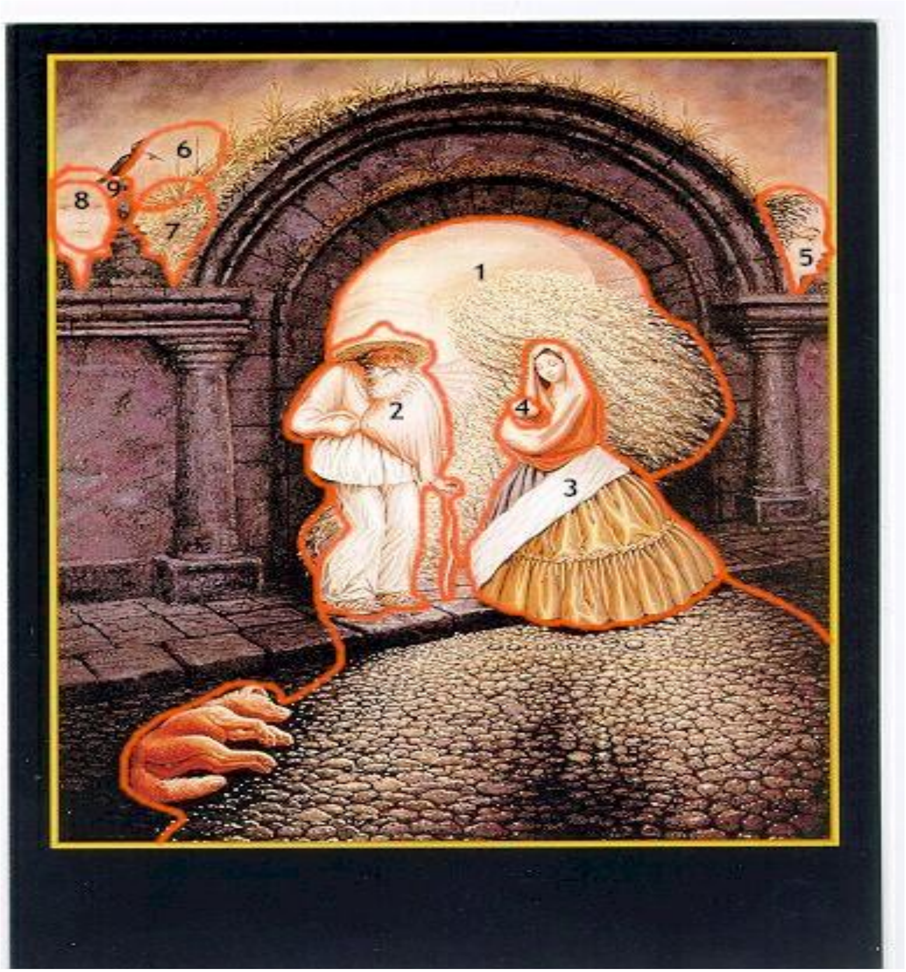
Find 8, you are very observant. Congratulate yourself!

Find 9, you are extremely observant, very intuitive, and creative. You can rival the observant powers of Sherlock Holmes!

Source: http://www.qsl.net/w5www/9people.html

INTRODUCTION

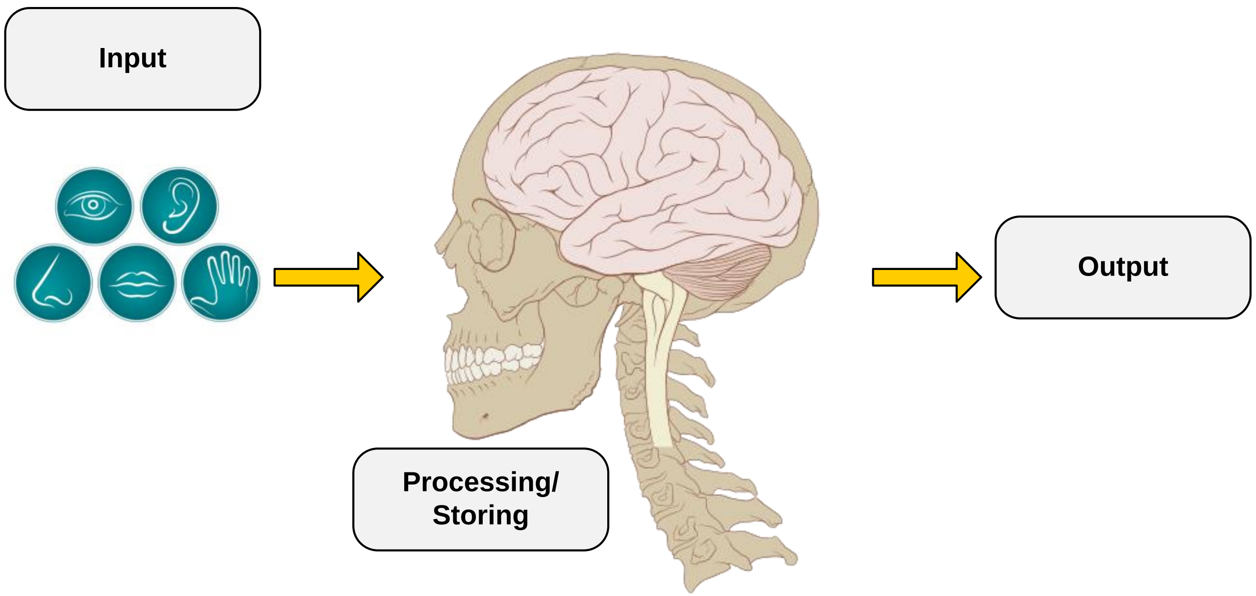
Perception



INTRODUCTION

Information Processing System

The basic model of information system for humans involves thee distinctive stages:
1.Input: The information perceived by the human senses **(vision, hearing, touch, taste, smell)**
2.Processing/Storage: Coding, storing, forwarding and interpreting of the information **(brain, memory)**
3.Output: Response **(behavior)**



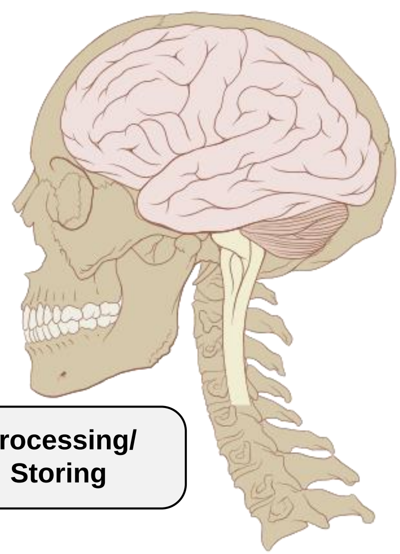
Source: https://en.wikipedia.org/wiki/Human_brain
https://www.livescience.com/60752-human-senses.html

INTRODUCTION

Information Processing System

Example: Breast cancer diagnosis
1.Input: The physician reviews an x-ray mammogram **(senses, information, data)**
2.Processing/Storage: The visual stimulus is converted into an electrical signal that is being forward to the central processing unit, the brain. The brain compares the x-ray mammogram in question with the knowledge of other x-ray mammograms that the physician learnt from his previous experience **(brain, central processing unit)**
3.Output: The physician makes the necessary correlations and he/she decides whether this new x-ray mammogram has imaging findings indicative of pathology **(response, outcome)**

Input



Processing/ Storing

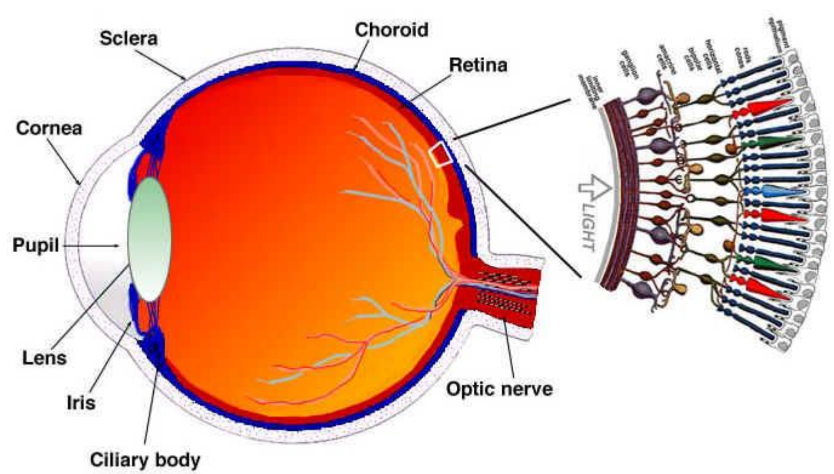
Output

Source: https://en.wikipedia.org/wiki/Human_brain
https://www.livescience.com/60752-human-senses.html

INTRODUCTION

Information Processing System

1.Input: The information perceived by the human senses **(vision, hearing, touch, taste, smell)**



Source: http://www.biologymad.com/nervoussystem/eyenotes.htm

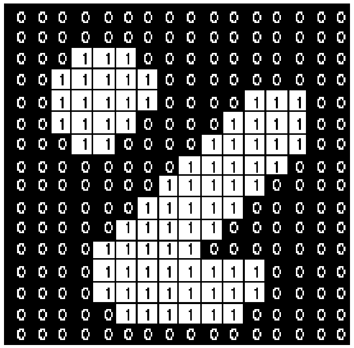
-senses

•Cones: Color detection (6-7 million)

•Rods: Photons detection (90-120 millions), more sensitive, peripheral vision, night vision

•Digital Detectors!!!

0 or 1

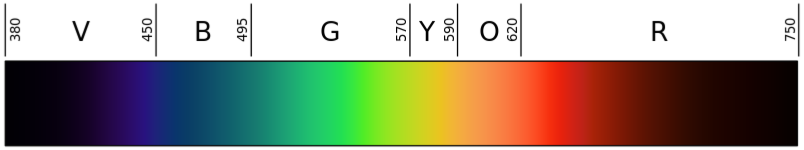


INTRODUCTION

Information Processing System

1.Input: The information perceived by the human senses **(vision, hearing, touch, taste, smell)**

-Visible light (detected by the human visual system)
-Light waves have amplitude (intensity) and wavelength (color)



-Light sources emit all wavelengths, however, each light source has a predominant spectrum of wavelengths giving the light source its distinct color (i.e. candle light is at 560-600nm and is perceived as yellowish)

-If the light source emits all wavelengths equally, then we have white light

-What the human visual system perceives as color is the reflection of specific wavelengths of light

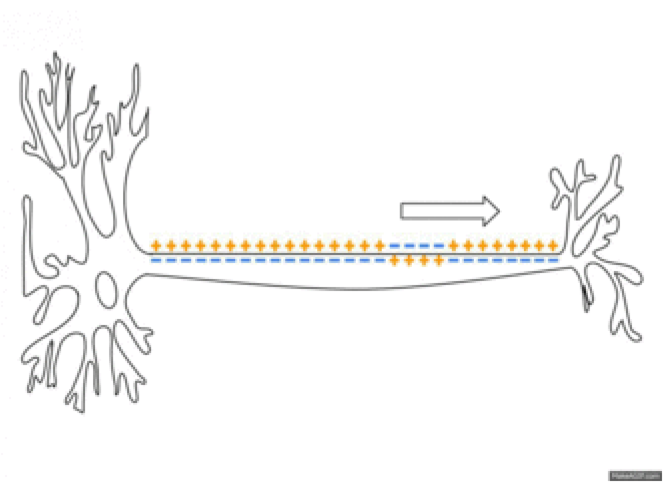
Source: http://www.well.ox.ac.uk/_asset/file/the-zeiss-guide-to-the-basics-of-light-microscopy.pdf

INTRODUCTION

Information Processing System

2. Processing/Storage: Coding, storing, forwarding and interpreting of the information **(brain, memory)**

Memory models
1. Senses memory: Vey short, <1sec, i.e. looking a something, when you close your eyes the image remains for a short time
2.Short Term Memory: Relatively short, <1min, i.e. you read a sentence and when you reach the end of the sentence you can still remember the begging of the sentence
3.Long Term Memory: Very long, lifetime memory. Practically endless in size. The information travels from the short term memory to the long term memory and it can be stored using the process of repetitions and correlations.

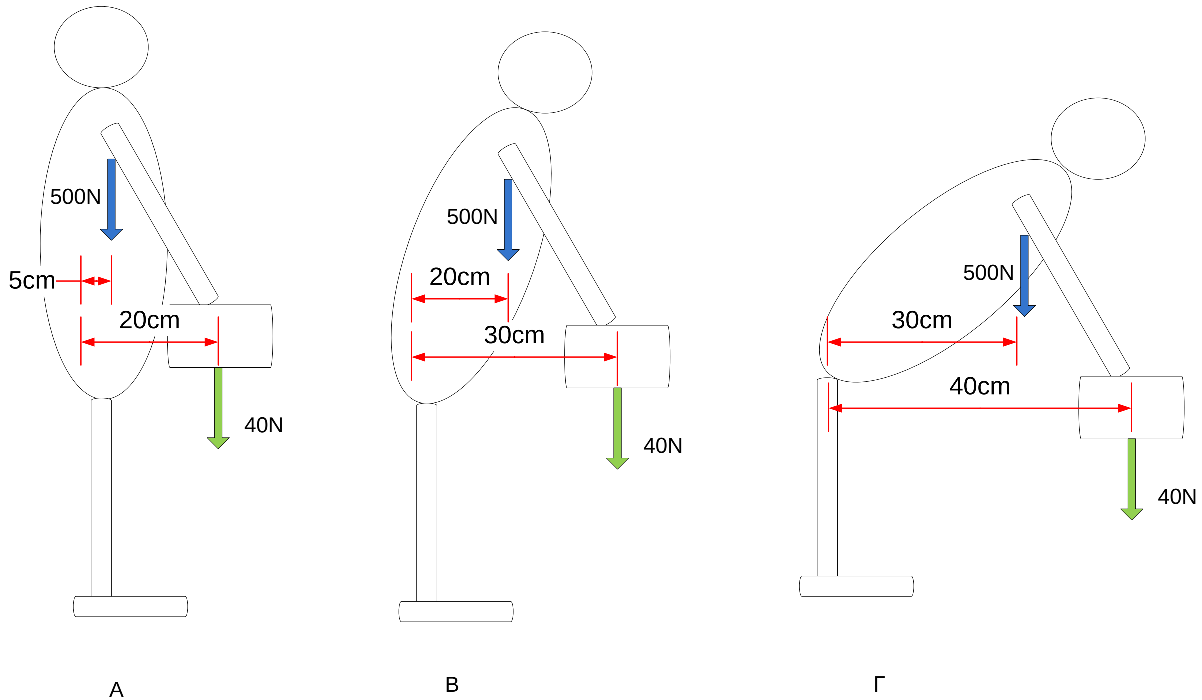


Source: https://en.wikipedia.org/wiki/Action_potential

INTRODUCTION

Information Processing System

3. Output: Response **(behavior)**



INTRODUCTION

What is a medical image

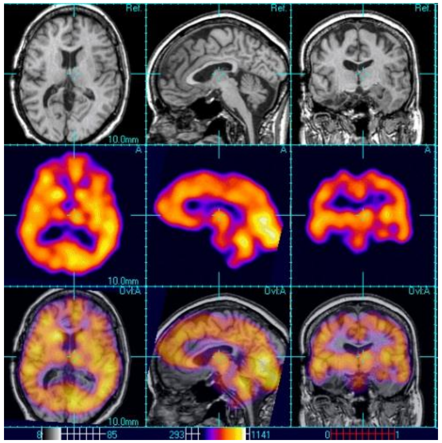
Definition:
Monitoring/recording of the geometric distribution of certain physical property

-characteristics

•Anatomical: Static distribution of a certain physical property, Skeleton.

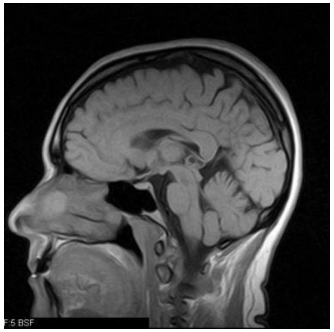
•Physiological/Functional: Functionality or Metabolism of organs, Glucose consumption in brain.

physical property: X-rays attenuation



physical property: Distribution drug labeled with radioisotope

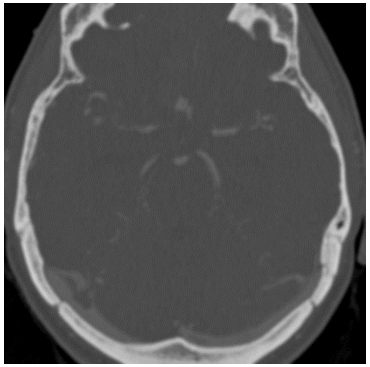
physical property: Ultrasound reflection



physical property: Electromagnetic signals

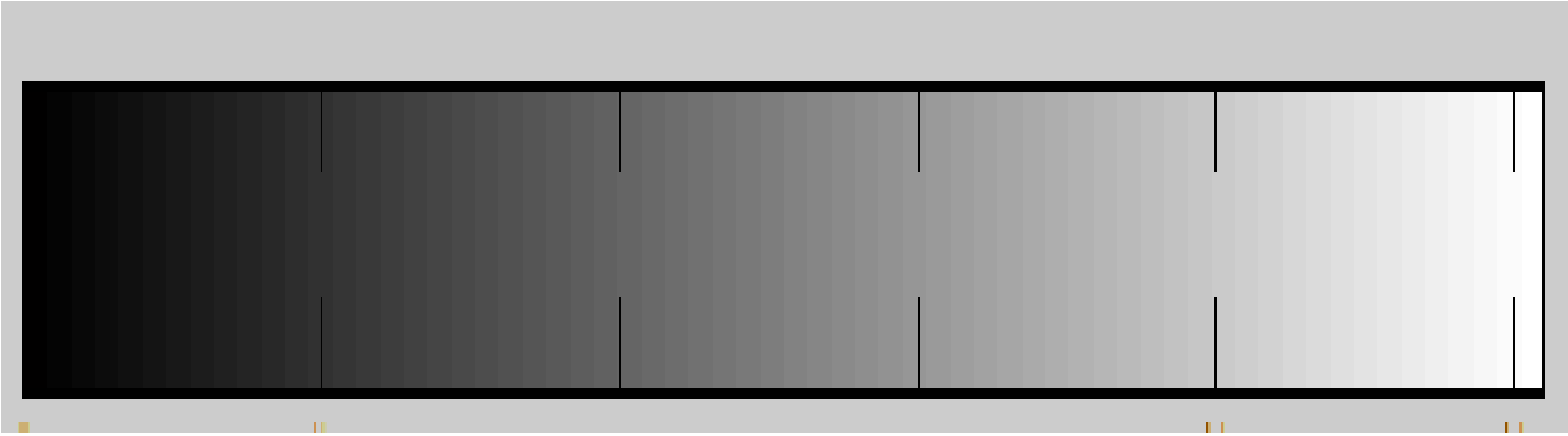
INTRODUCTION

Visual Perception – A low contrast system



-BRIGHTNESS PERCEPTION

•The visual system may differentiate about 64 different grades of brightness – Low contrast



INTRODUCTION

What is medical image processing

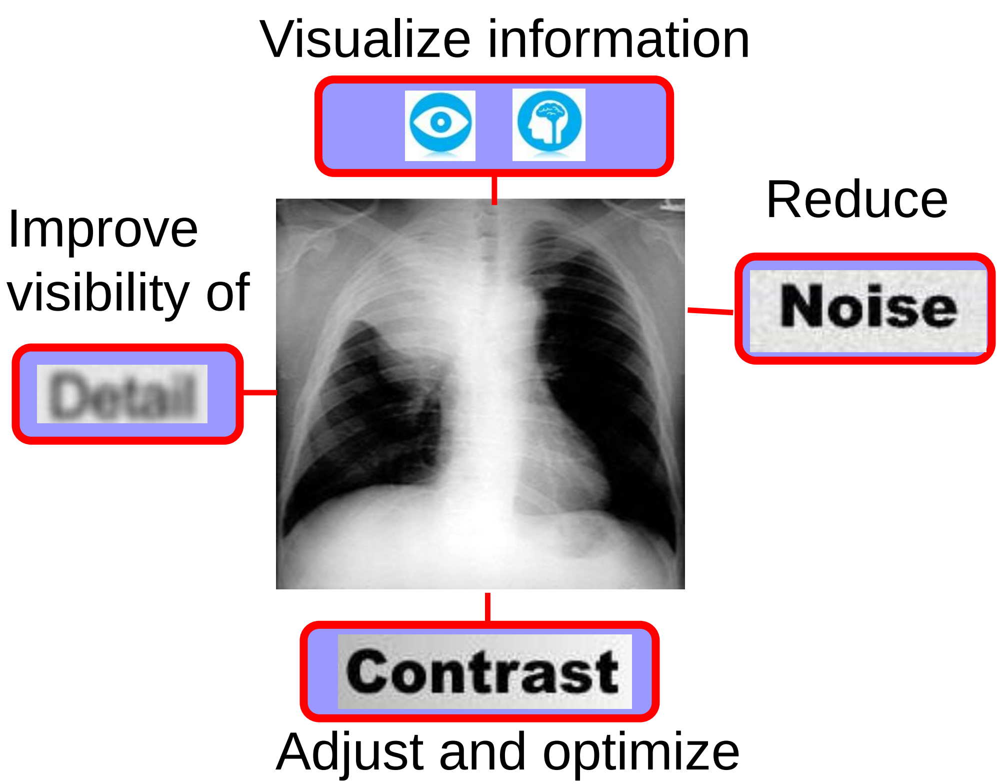
Definition:

Digital image processing refers to the reversible modification of the image in the form of a matrix of numerical values.

[Gonzalez RC, Woods RE, “Digital image processing”, Prentice Hall; 2002]

Aim:

Enhance, **restore**, **extract**, **understand** and **code** information



LECTURE CONTENTS

1. **Introduction**

2. **Digital Imaging Systems**

   α. X-ray radiography
   β. X-ray mammography
   γ. X-ray Computed Tomography (CT)
   δ. Ultrasonography
   ε. Nuclear Magnetic Resonance Imaging (MRI)
   στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
   ζ. Thermography
   η. Hybrid Systems (PET-CT, MRI-PET)
   θ. Microscopy

3. **Decision Support Systems**

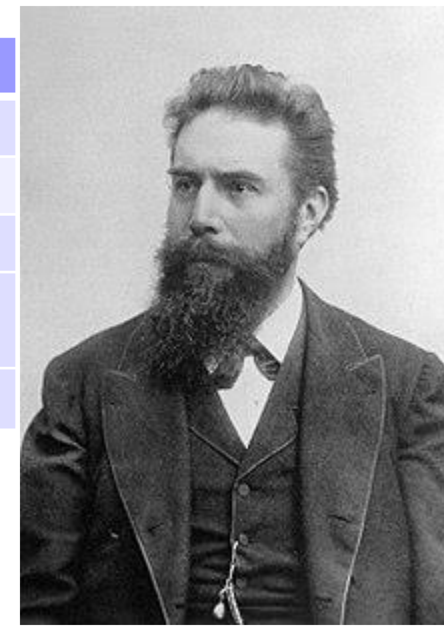
4. **Case study: Early detection of melanoma:**

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Brief historical survey

Year	Researcher	Accomplishment
1895	Röntgen	Discovery of x-rays
1896	Edwin Frost	First radiographs for medical purposes
1901	Röntgen	Nobel price
1902	Codman	First scientific report that x-rays may induce carcinogenesis
1913	Coolidge	X-ray tube construction



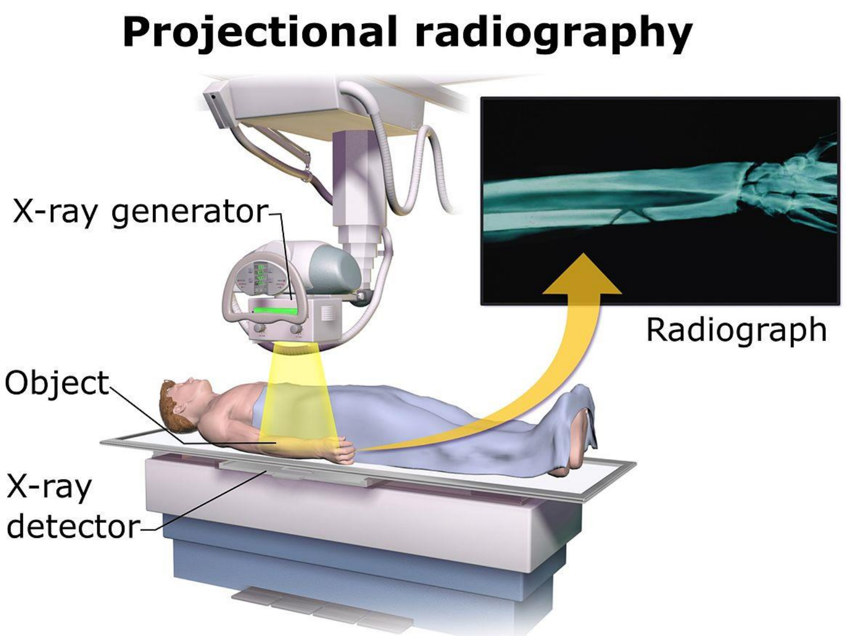
Wilhelm Conrad Roentgen: 1845 – 1923, German engineer and physicist

Source: https://en.wikipedia.org/wiki/Wilhelm_R%C3%B6ntgen, https://en.wikipedia.org/wiki/X-ray

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Basic principles

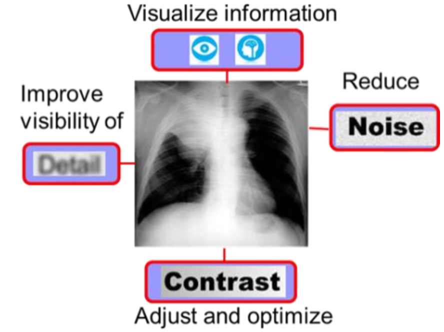


Πηγές: https://en.wikipedia.org/wiki/X-ray_machine

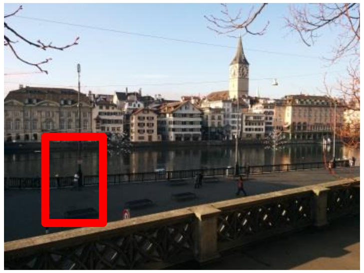
X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Image enhancement: Goal: Improve details



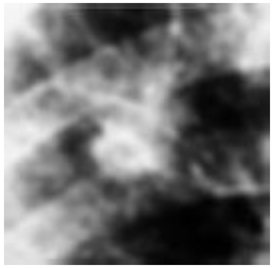
•Low frequency

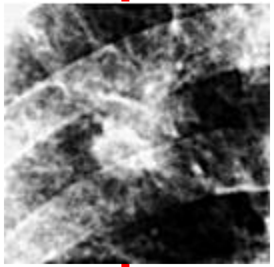


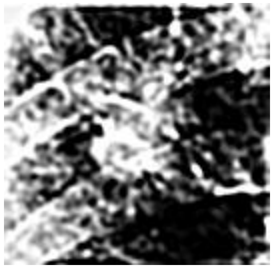
•High frequency

•Basic shape-overview (no noise)

•If interested in retaining the basic information of the image, then keep low frequencies, reduce high frequencies, thus, reduce noise—optical effect: blurring







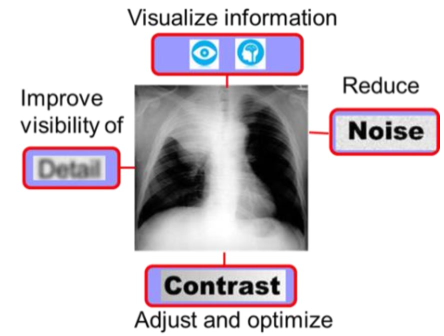
•Details + noise

•If interested in enhancing details, then keep high frequencies, reduce low frequencies, thus, increase noise—optical effect: edge enhancement

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Image enhancement: Goal: Improve details



Original Image

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

Enhance edges

Transformation

$$\frac{1}{k} \cdot \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad k=1, \text{ Roberts}$$

STEP 1: Matrix scan rows 1:3, columns 1:3

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

$$\begin{bmatrix} 30 & 31 & 12 \\ 17 & 12 & 25 \\ 12 & 8 & 17 \end{bmatrix} \times \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \times 1/1$$

X1: (30*0 + 31*0 + 12*0 + 17*0 + 12*(-1) + 25*0 + 12*0 +8*1 + 17*0) * 1/1 = -4 → **0**

STEP 2: Matrix scan rows 1:3, columns 2:4

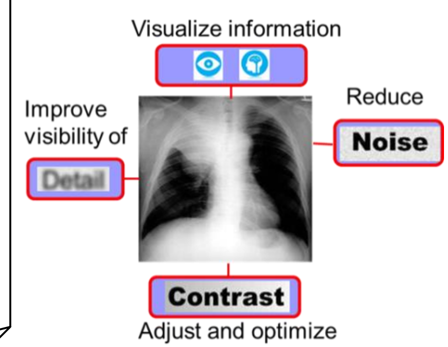
30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

$$\begin{bmatrix} 31 & 12 & 9 \\ 12 & 25 & 10 \\ 8 & 17 & 9 \end{bmatrix} \times \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \times 1/1$$

X2: (31*0 + 12*0 + 9*0 + 12*0 + 25*(-1) + 10*0 + 8*0 +17*1 + 9*0) * 1/1 = -8 → **0**

Enhanced Image

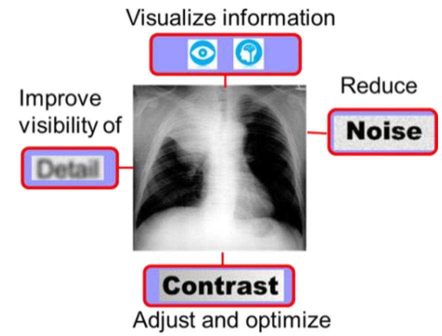
30	31	12	9
17	**0**	**0**	10
12	**4**	**9**	9
31	12	26	22



X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Image enhancement: Goal: Improve details



Original Image

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

Enhance edges

Transformation

$$\frac{1}{k} * \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad k = 1, \text{ Roberts}$$

STEP 3: Matrix scan rows 2:4, columns 1:3

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

$$\begin{bmatrix} 17 & 12 & 25 \\ 12 & 8 & 17 \\ 31 & 12 & 26 \end{bmatrix} \text{ x } \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \text{ x } 1/1$$

X3: (17*0 + 12*0 + 25*0 + 12*0 + 8*(-1) + 17*0 + 31*0 +12*1 + 26*0) * 1/1 = 4 ➔ **4**

STEP 4: Matrix scan rows 2:4, columns 2:4

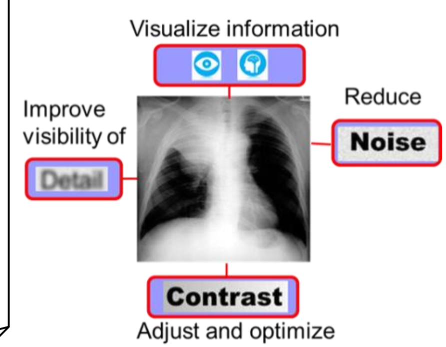
30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

$$\begin{bmatrix} 12 & 25 & 10 \\ 8 & 17 & 9 \\ 12 & 26 & 22 \end{bmatrix} \text{ x } \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \text{ x } 1/1$$

X4: (12*0 + 25*0 + 10*0 + 8*0 + 17*(-1) + 9*0 + 12*0 +26*1 + 22*0) * 1/1 = 9 ➔ **9**

Enhanced Image

30	31	12	9
17	**0**	**0**	10
12	**4**	**9**	9
31	12	26	22

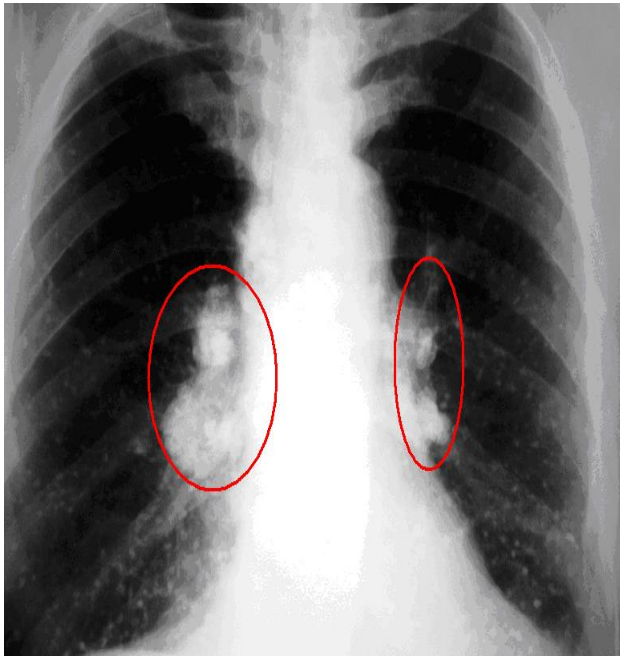


X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Lung examinations

normal

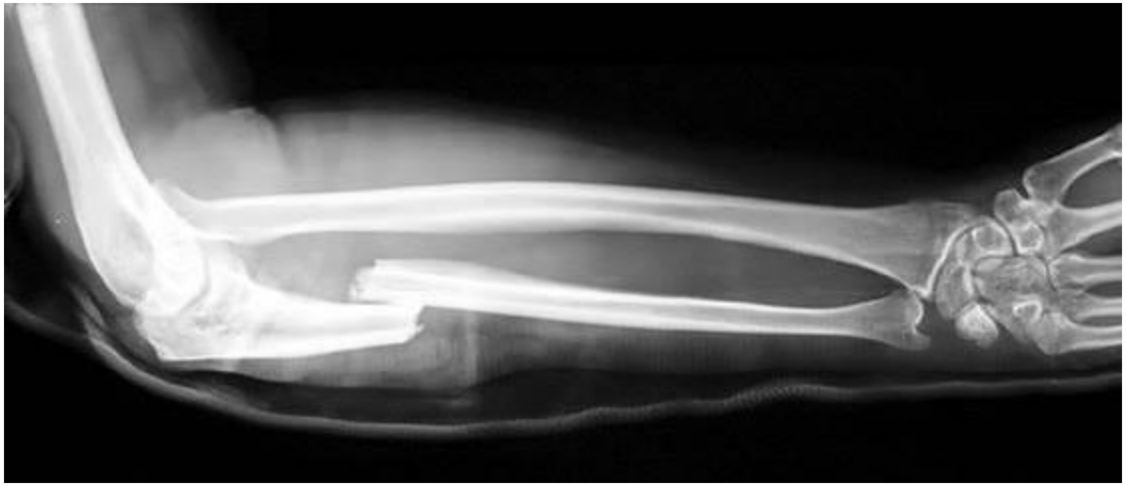


pathological

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Bone fracture examinations

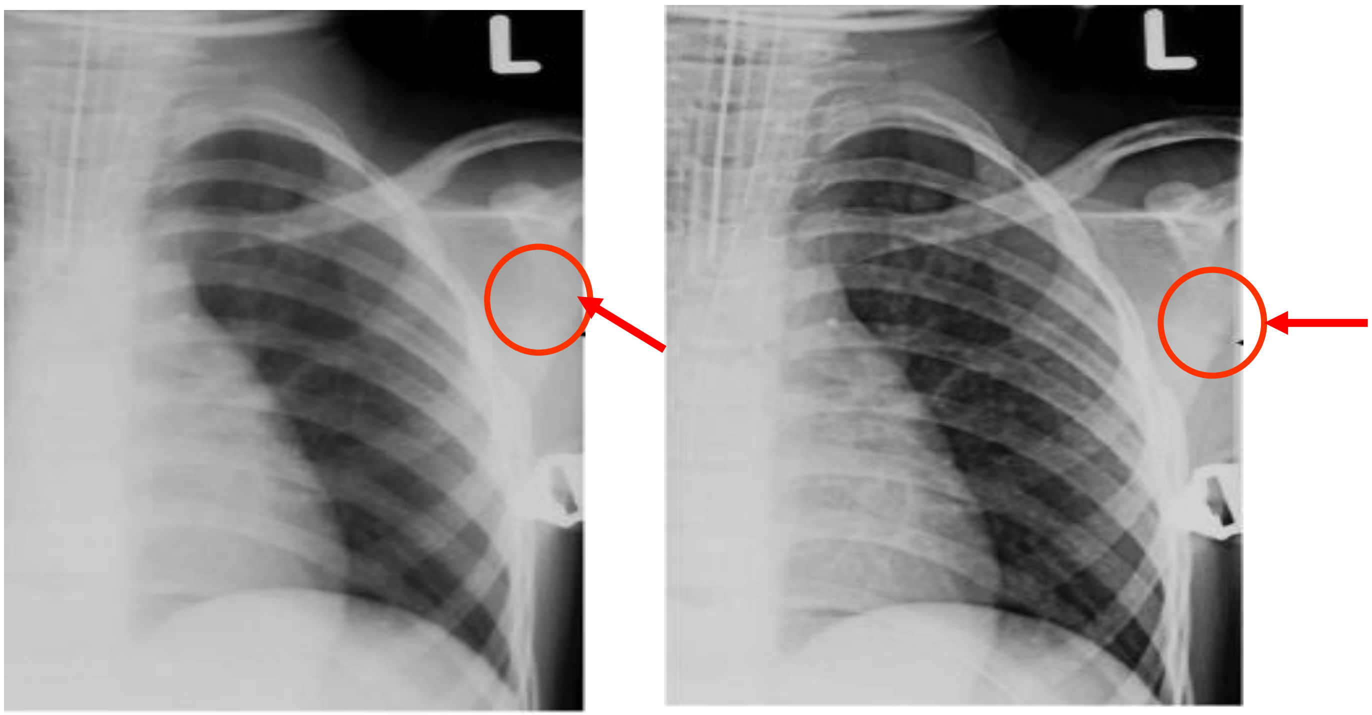


Source: https://commons.wikimedia.org/wiki/File:Monteggia_Fracture.jpg

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Bone fracture examinations

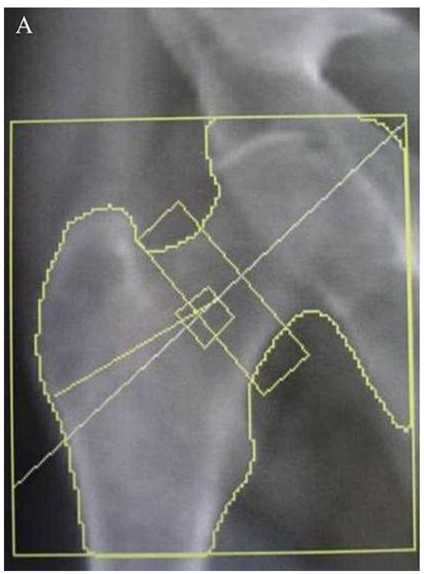


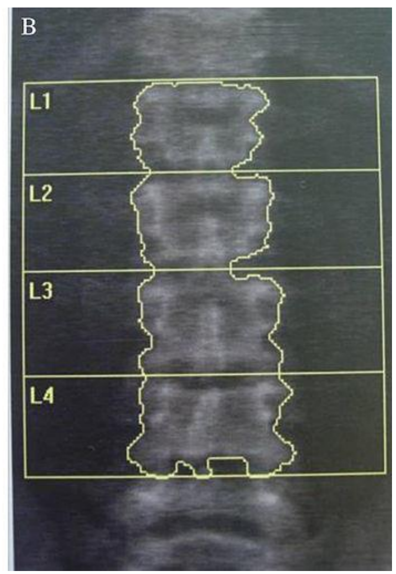
Source: Offieach et al (Clinical Radiology) 2006

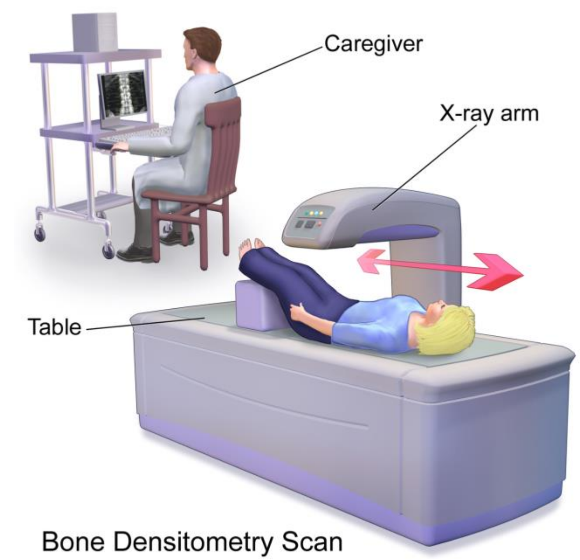
X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Bone composition







Πηγές: https://commons.wikimedia.org/wiki/File:Morbus_Fabry_DXA_01.jpg, https://en.wikipedia.org/wiki/Dual-energy_X-ray_absorptiometry

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Teeth examination

Πηγές:
https://www.radiologyinfo.org/en/info.cfm?pg=panoramic-xray, https://commons.wikimedia.org/wiki/File:X-ray_of_all_32_human_teeth.jpg

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

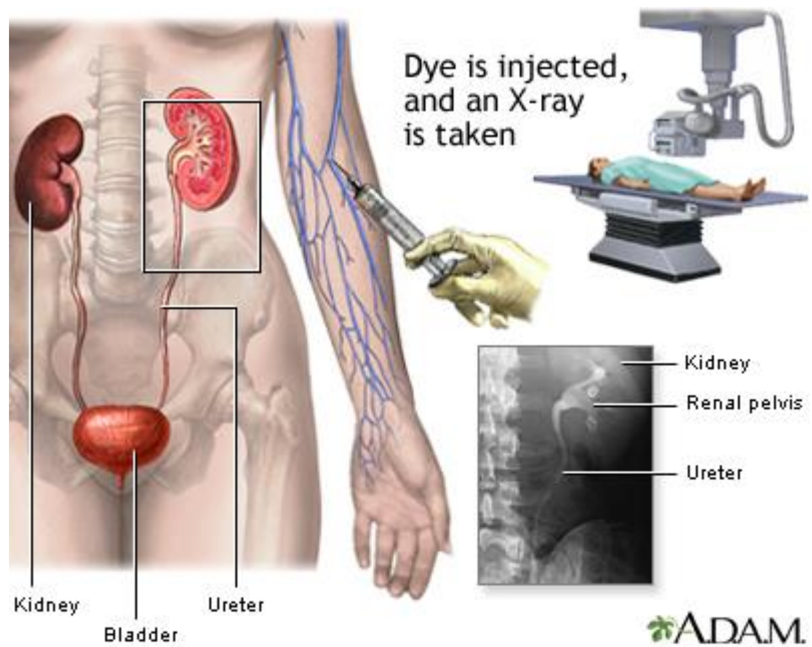
Applications: Soft tissues

Πηγές: https://en.wikipedia.org/wiki/Abdominal_x-ray, https://www.radiologyinfo.org/en/info.cfm?pg=abdominrad

X-RAY RADIOGRAPHY/RADIOLOGY

Projection x-ray radiography/radiology

Applications: Pyelography



Πηγές:
https://en.wikipedia.org/wiki/Intravenous_pyelogram,
https://medlineplus.gov/ency/imagepages/19245.htm

LECTURE CONTENTS

1. **Introduction**
2. **Digital Imaging Systems**

   α. X-ray radiography
   β. X-ray mammography
   γ. X-ray Computed Tomography (CT)
   δ. Ultrasonography
   ε. Nuclear Magnetic Resonance Imaging (MRI)
   στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
   ζ. Thermography
   η. Hybrid Systems (PET-CT, MRI-PET)
   θ. Microscopy
3. **Decision Support Systems**
4. **Case study: Early detection of melanoma:**

MAMMOGRAPHY

Mammography (x-ray)

Brief historical survey

Year	Researcher	Accomplishment
1913	Albert Salomon	He studies 3000 mammograms, recognizes the need and the contribution of x-ray radiography in breast cancer detection
1949	Raul Leborgne	He proposes breast compression for better imaging quality
1966		Presentation of the first system designed only for mammography
1990s		Digital mammography, less dose, higher imaging quality

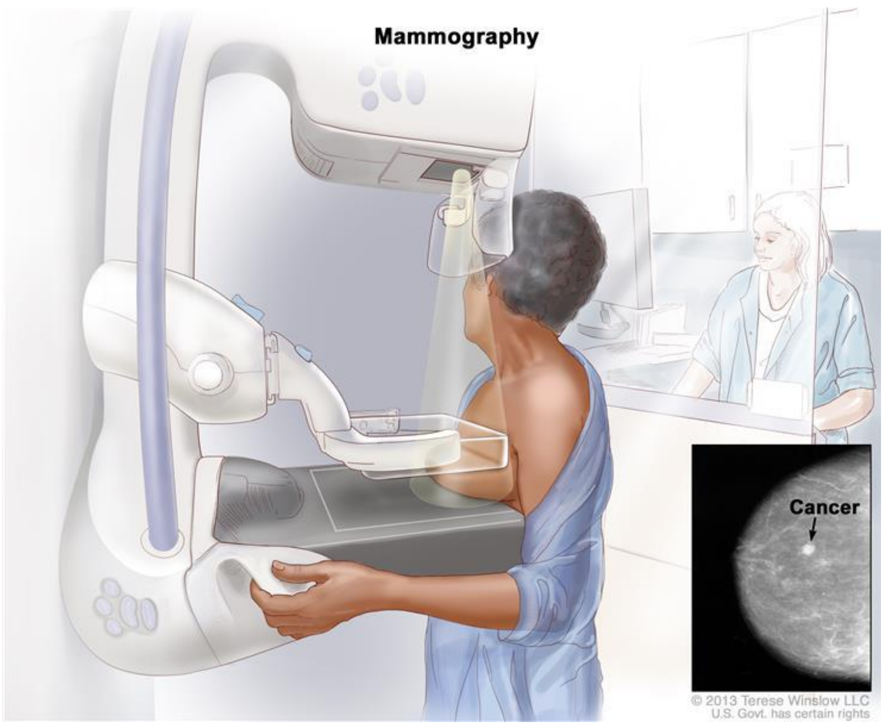
Albert Salomon: 1883 – 1976, German surgeon

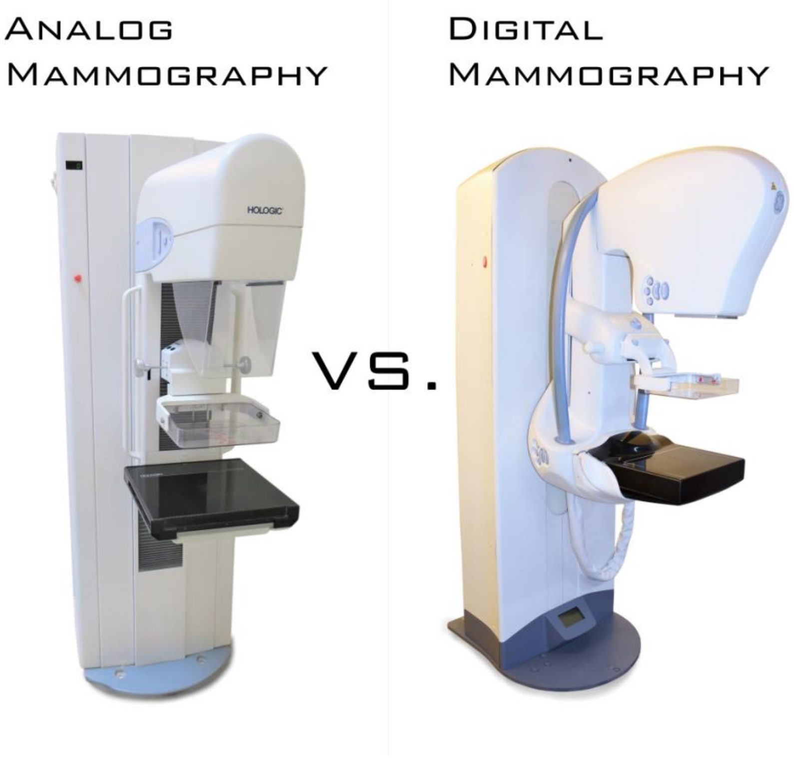
Source: https://en.wikipedia.org/wiki/Albert_Salomon_(surgeon)

MAMMOGRAPHY

Mammography (x-ray)

Basic principles





Πηγές: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/mammogram, https://lbnmedical.com/digital-and-analog-mammography-machines-advantages-and-disadvantages/

MAMMOGRAPHY

Mammography (x-ray)

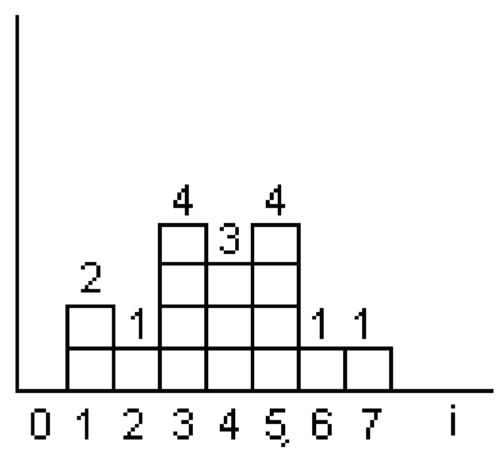
Contrast Enhancement: Improve the contrast between region of interest and background

Original Image

7	4	5	6
1	4	3	5
5	3	2	1
4	3	3	5

Transformation

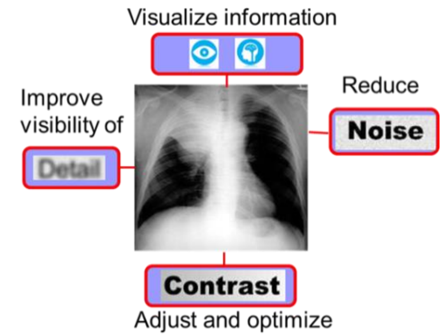
i	h(i)	q(i)
0	0	2
1	2	2
2	1	2
3	4	2
4	3	2
5	4	2
6	1	2
7	1	2



Enhanced Image

7	3	5	7
0	4	1	5
6	2	1	0
4	2	3	6

Histogram modification with histogram equalization: redistribution of image tones in such a way that each tone will appear with the same frequency at the final image



MAMMOGRAPHY

Mammography (x-ray)

Contrast Enhancement: Improve the contrast between region of interest and background

Original Image

7	4	5	6
1	4	3	5
5	3	2	1
4	3	3	5

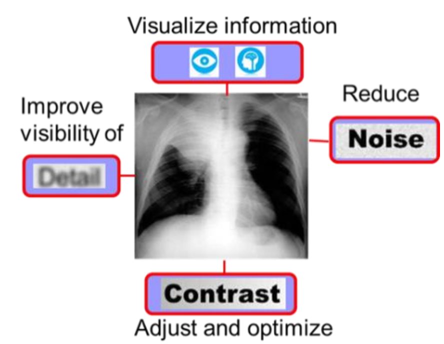
Transformation

i	h(i)	CDFh(i)	q(i)	CDFq(i)	
0	1	$1_{(0)}$	2	2	Compression
1	0	$1_{(0)}$	2	4	
2	0	$1_{(0)}$	2	6	
3	2	$3_{(0)}$	2	8	
4	6	$9_{(3)}$	2	10	Expansion
5	2	$11_{(4)}$	2	12	
6	3	$14_{(6)}$	2	14	
7	2	$16_{(7)}$	2	16	

Enhanced Image

7	3	5	7
0	4	1	5
6	2	1	0
4	2	3	6

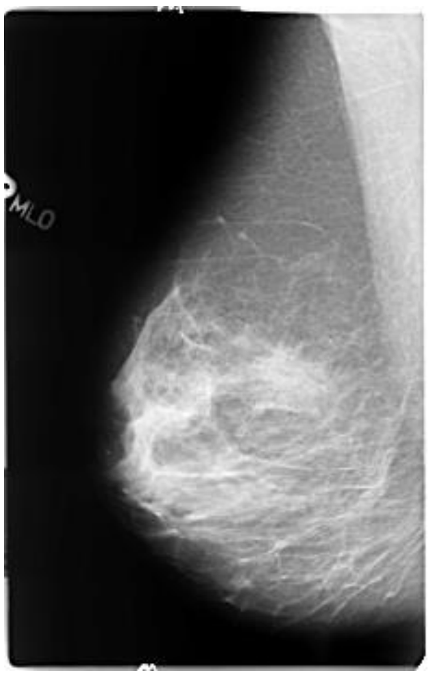
Histogram modification with histogram equalization: redistribution of image tones in such a way that each tone will appear with the same frequency at the final image



MAMMOGRAPHY

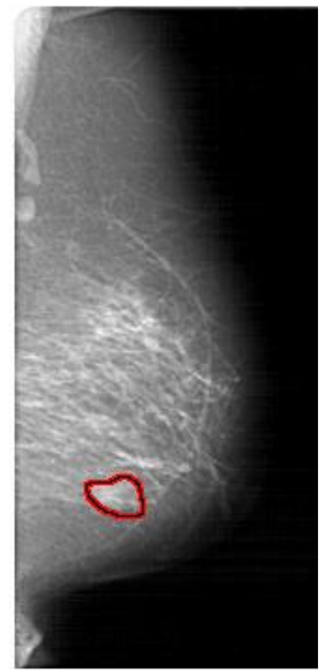
Mammography (x-ray)

Applications: Normal, benign and malignant breasts



normal

malignant



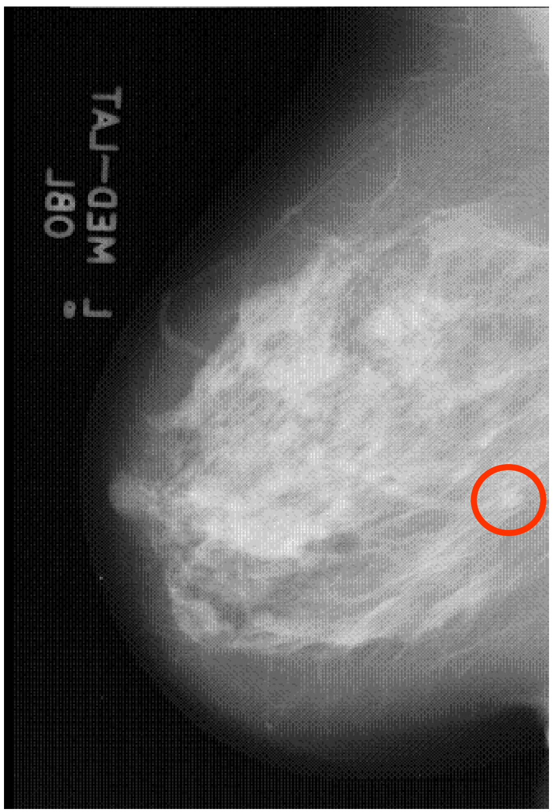
benign

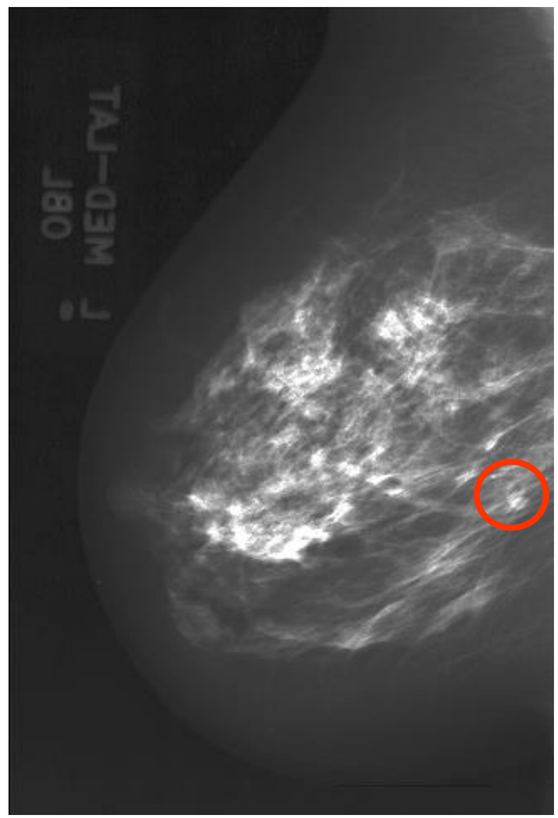
Source: The Digital Database for Screening Mammography, Michael Heath, Kevin Bowyer, Daniel Kopans, Richard Moore and W. Philip Kegelmeyer, in Proceedings of the Fifth International Workshop on Digital Mammography, M.J. YAfe, ed., 212-218, Medical Physics Publishing, 2001. ISBN 1-930524-00-5.

MAMMOGRAPHY

Mammography (x-ray)

Applications: Mass detection



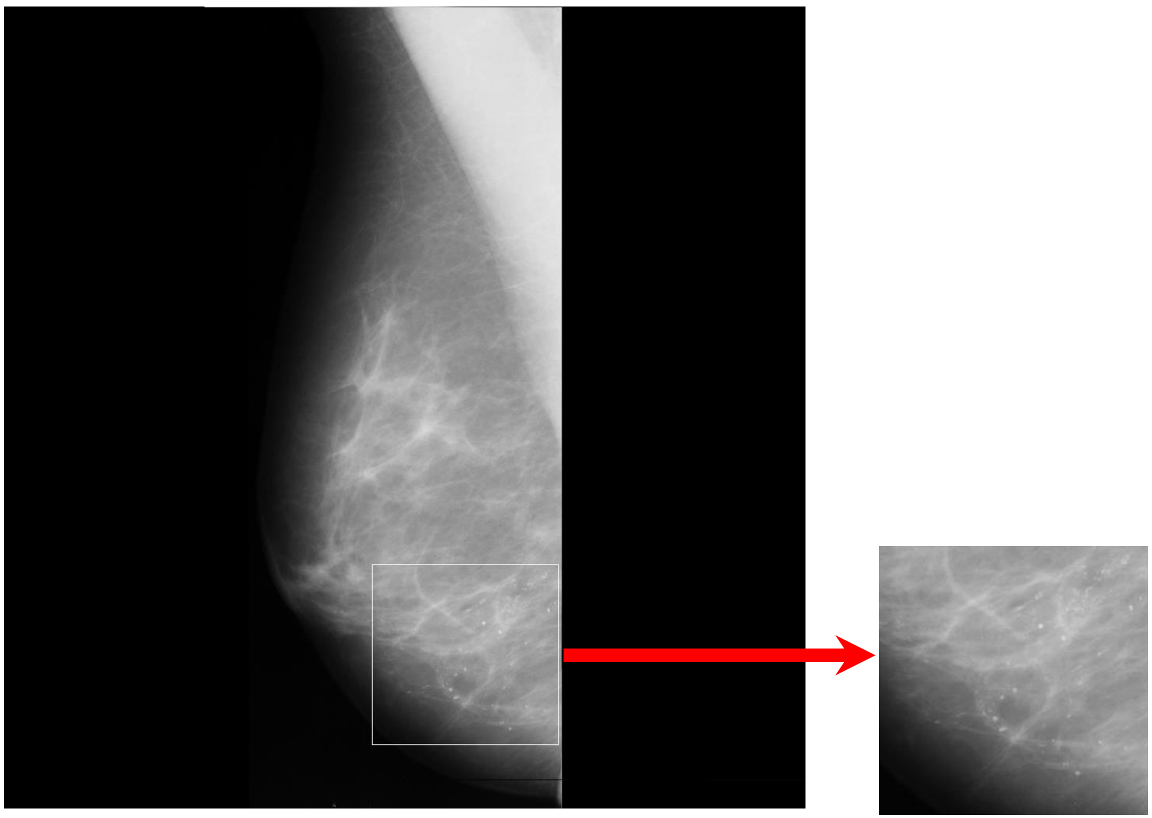


Source: Sakellaropoulos et al, British Journal of Radiology, 2000

MAMMOGRAPHY

Mammography (x-ray)

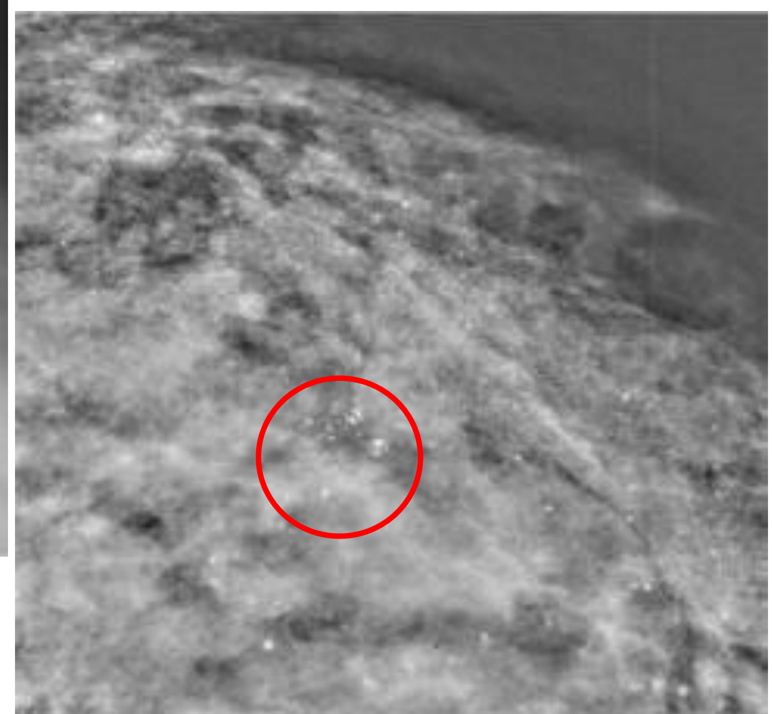
Applications: Micro calcifications detection



MAMMOGRAPHY

Mammography (x-ray)

Applications: Micro calcifications detection

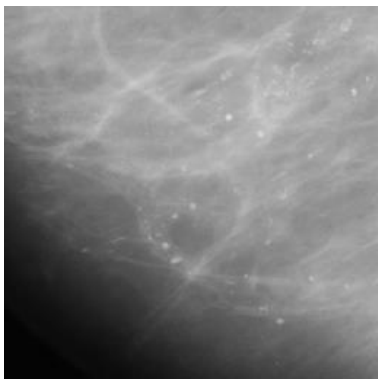


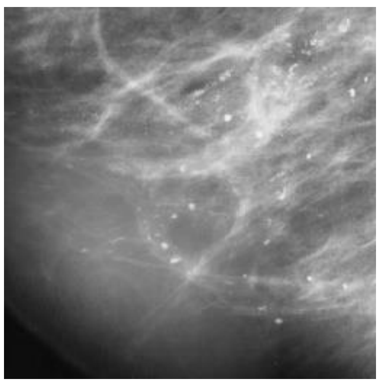
Source: Sakellaropoulos et al, British Journal of Radiology, 2000

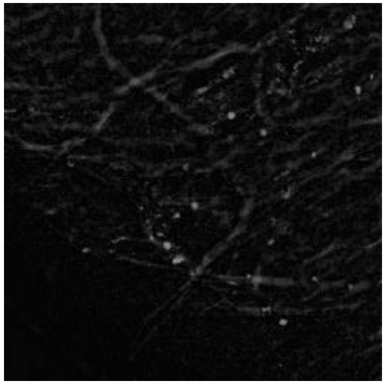
MAMMOGRAPHY

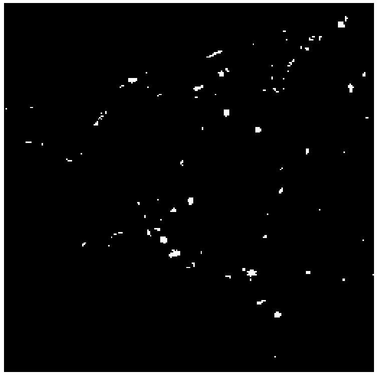
Mammography (x-ray)

MICROCALCIFICATIONS DETECTION









Source: P. Bougioukos et al, "Fast Enhancement of Mammographic Images using Wavelets and CLAHE on a Distributed Processing System", 3rd European Medical and Biological Engineering Conference, Prague, Czech Repurlic, 2005.

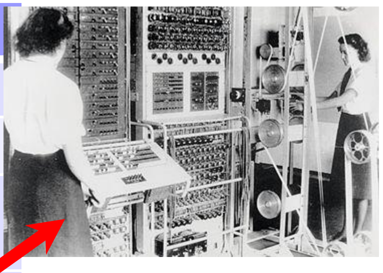
LECTURE CONTENTS

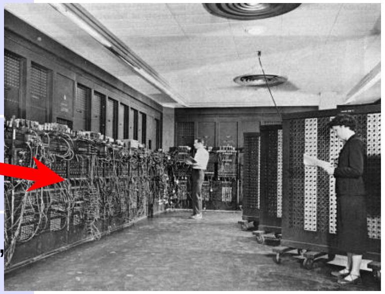
COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Brief historical survey

Year	Researcher	Accomplishment
1895	Röntgen	X-ray discovery
1896	Edwin Frost	First radiographies on film
1936	Turing	Turring Machine, a hypothetical computer
1943	Tommy Flowers	Colossus (a machine for decoding encrypted messages of Germans during the 2nd world war)
1946	John Mauchly and J. Presper Eckert	ENIAC (Electronic Numerical Integrator And Computer), 50 tones, 1800 square meters!!!
1965	Pier Giorgio Perotto	Olivetti, First personal computer, Programma 101, 3200 dollars, NASA uses this computer for the expedition on the moon, 1969





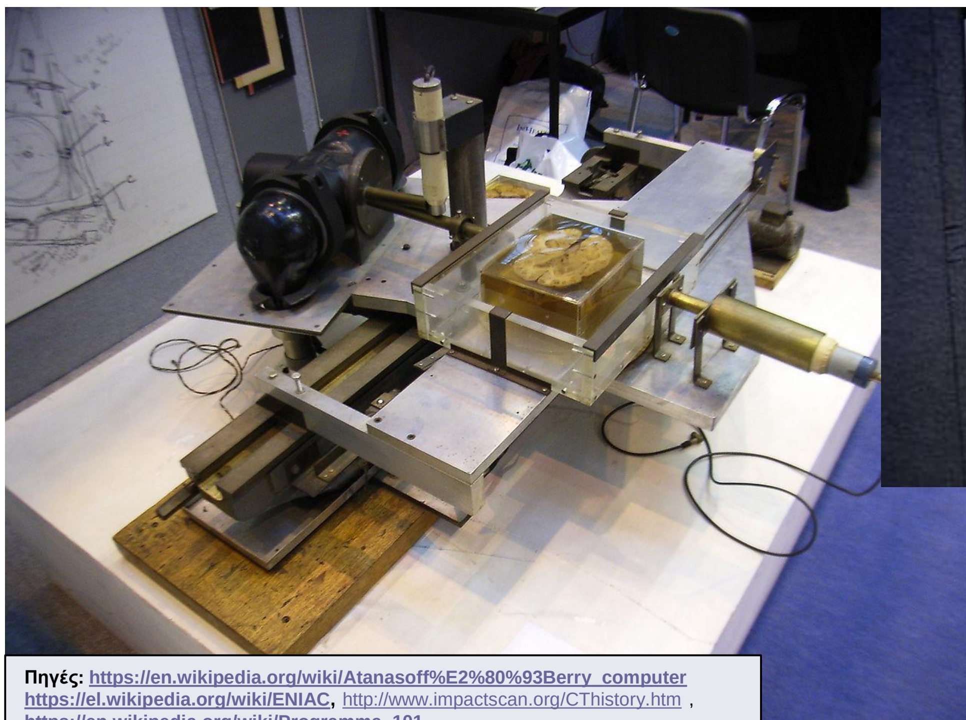
Πηγές: https://en.wikipedia.org/wiki/Atanasoff%E2%80%93Berry_computer https://el.wikipedia.org/wiki/ENIAC, http://www.impactscan.org/CThistory.htm , https://en.wikipedia.org/wiki/Programma_101

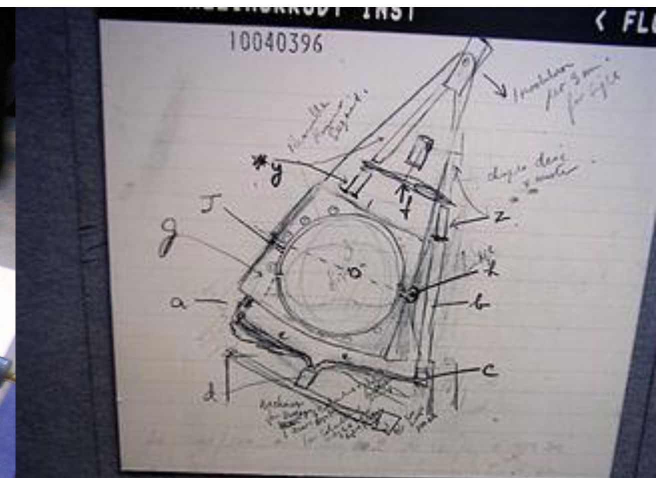
COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Brief historical survey

Year	Researcher	Accomplishment
1963, 1968	Cormack, Hounsfield	First experimental designs of computed tomography





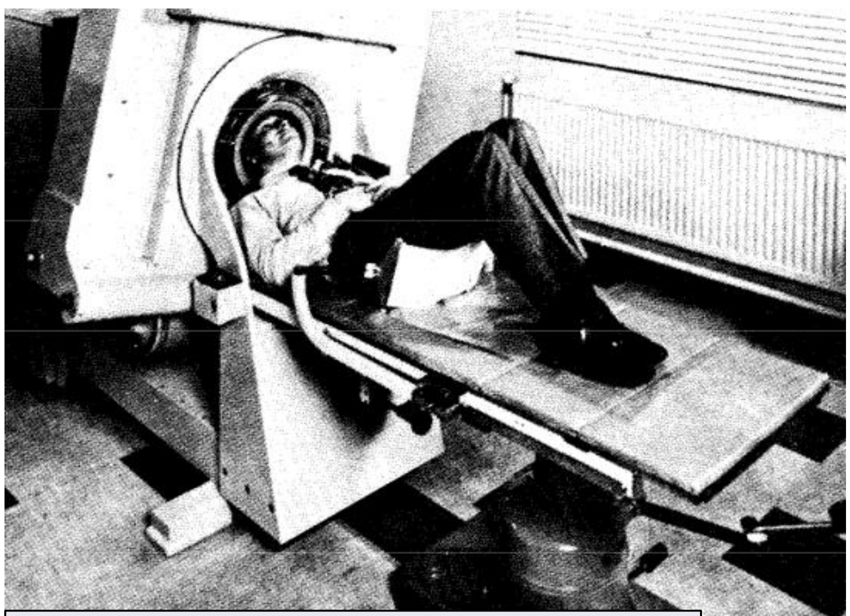
Πηγές: https://en.wikipedia.org/wiki/Atanasoff%E2%80%93Berry_computer https://el.wikipedia.org/wiki/ENIAC, http://www.impactscan.org/CThistory.htm , https://en.wikipedia.org/wiki/Programma_101

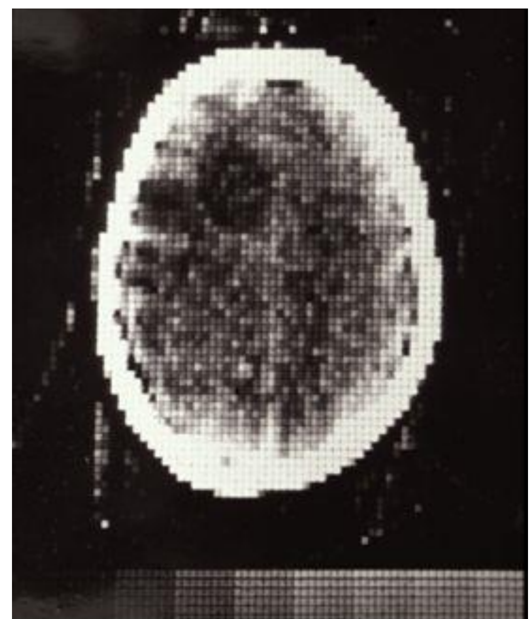
COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Brief historical survey

Year	Researcher	Accomplishment
1971		First installation of CT unit in a hospital, London, UK
1972		First clinical scan, patient with suspected brain lession





Πηγές: https://www.nobelprize.org/nobel_prizes/medicine/laureates/1979/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Brief historical survey

Year	Researcher	Accomplishment
1979	Cormack, Hounsfield	Nobel price

The Nobel Prize in Physiology or Medicine 1979

Allan M. Cormack
Prize share: 1/2

Godfrey N. Hounsfield
Prize share: 1/2

The Nobel Prize in Physiology or Medicine 1979 was awarded jointly to Allan M. Cormack and Godfrey N. Hounsfield *"for the development of computer assisted tomography"*

Hounsfield: 1919 – 2004, English Electrical Engineer

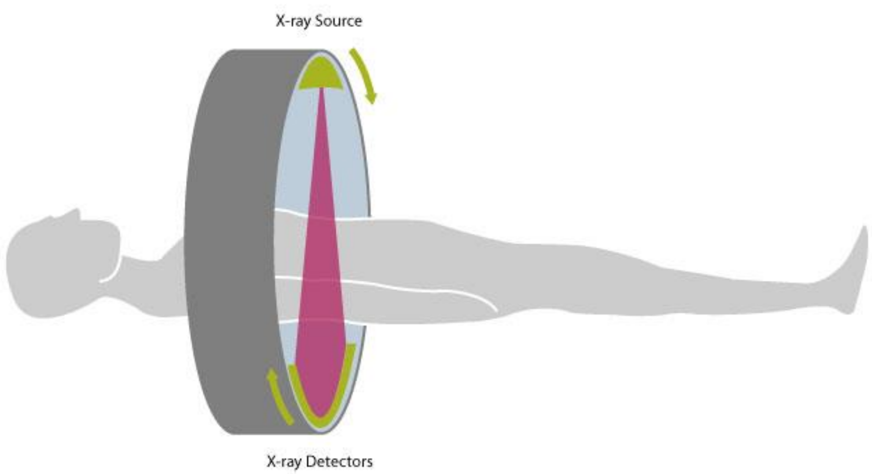
Cormack: 1924 – 1998, South African physicist

Source: https://www.nobelprize.org/nobel_prizes/medicine/laureates/1979/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Basic principles



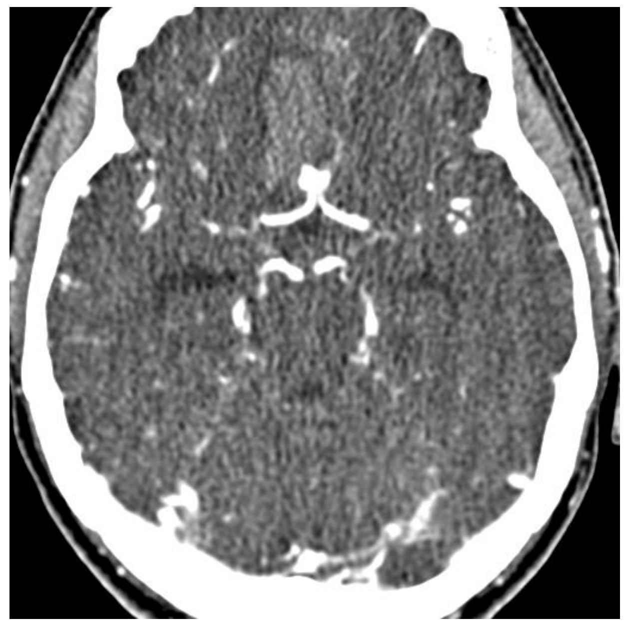
Source: https://en.wikipedia.org/wiki/X-ray_machine

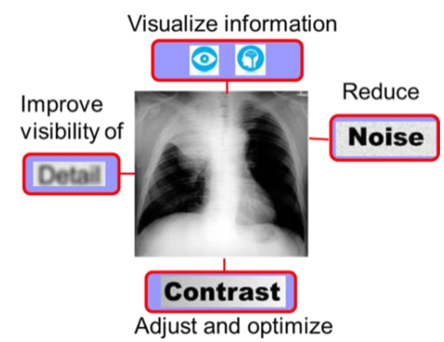
COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Image Visualization: Goal: Transform Numbers to Image

0	0	255	255	128	100	255	0	0	0
0	255	120	123	130	179	130	200	0	0
150	255	90	140	158	178	150	200	255	0
140	255	110	120	137	120	138	180	255	0
160	255	100	130	120	190	130	156	255	130
0	40	255	255	130	170	160	140	255	0
0	0	50	255	255	255	255	255	0	0
0	0	60	255	255	255	255	0	0	0



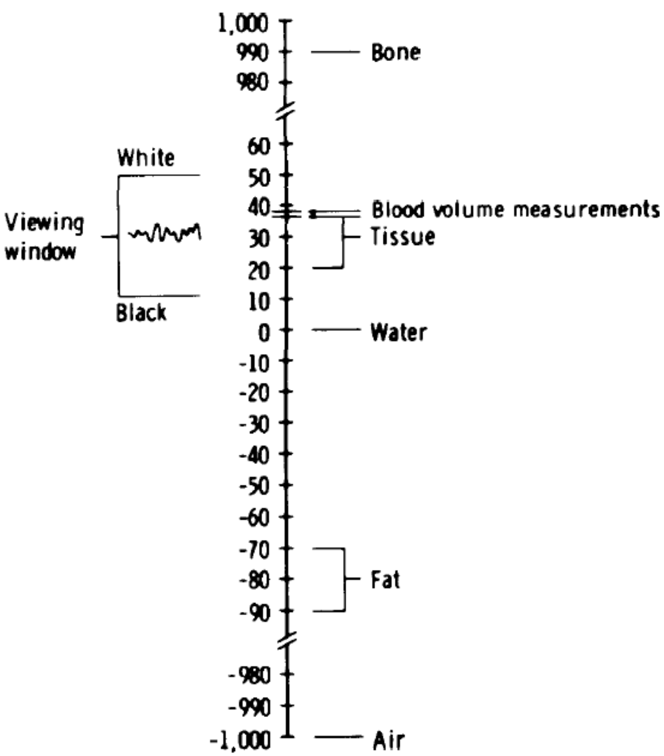


COMPUTED TOMOGRAPHY

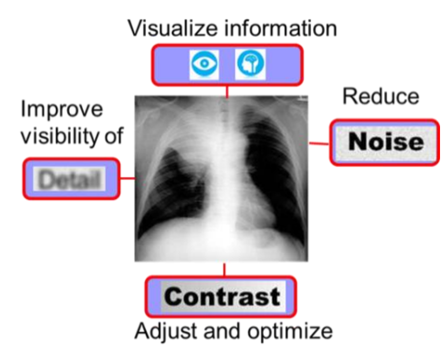
Computed Tomography (x-ray)

Image Visualization: Goal: Transform Numbers to Image

Hounsfield scale



The range of tones between black and white seen on the picture can be restricted to a very small part of the scale. This "window" can be raised or lowered according to the absorption value of the material we wish to compare: for example, it must be raised to see the tissue of the heart or lowered to see detail within the air of the lung. The sensitivity can be increased by reducing the "window" width, where the absorption difference between the liver and other organs can be more clearly differentiated.

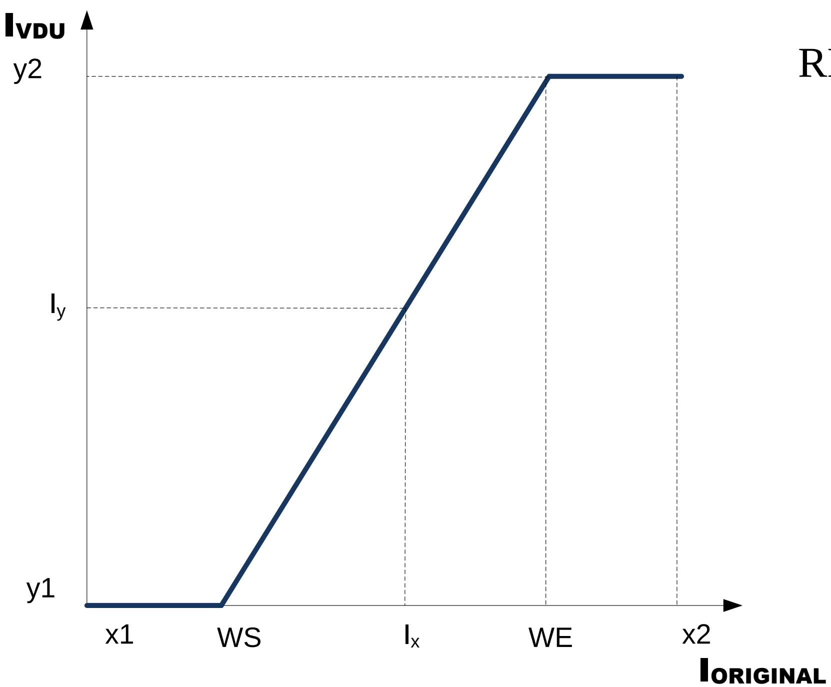


COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Image Visualization: Intensity Windowing

Simple Window



REGION 1 : If I_x <WS then I_y =y_1

REGION 2 : If WS<=I_x <=WE then $\frac{WE - WS}{I_x - WS} = \frac{y_2 - y_1}{I_y - y_1}$

REGION 3 : If I_x >WE then I_y =y_2

WW (Window Width)

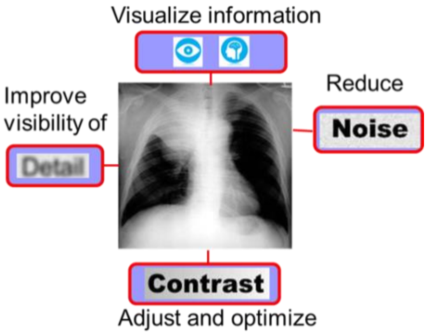
WL (Window Level)

WS (Window Start)

WE (Window End)

$$WS = WL - \frac{WW}{2}$$

$$WE = WL + \frac{WW}{2}$$



COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

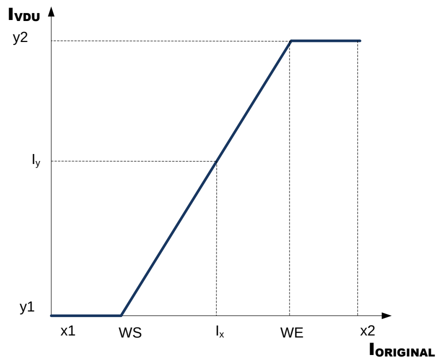
Image Visualization: Intensity Windowing

Image matrix (5 bit)

$$A1 = \begin{bmatrix} 30 & 29 & 12 \\ 17 & 12 & 25 \\ 12 & 8 & 17 \end{bmatrix}$$

Numbers

Transformation



WW=10, WL=15
WS=10, WE=20

$$I_x = 30, I_y = 7$$

$$I_x = 29, I_y = 7$$

$$I_x = 12, I_y = \frac{(7-0)(12-10)}{20-10} + 0 = 1,4 \rightarrow 1$$

$$I_x = 17, I_y = \frac{(7-0)(17-10)}{20-10} + 0 = 4,9 \rightarrow 5$$

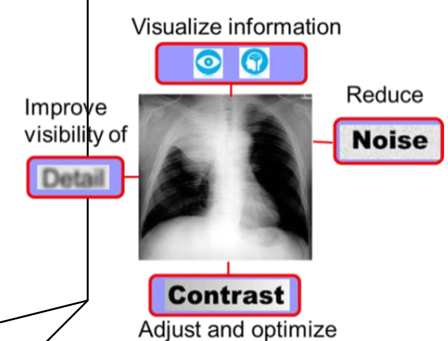
$$I_x = 25, I_y = 7$$

$$I_x = 8, I_y = 0$$

Image (3 bit)

$$A2 = \begin{bmatrix} 7 & 7 & 1 \\ 5 & 1 & 7 \\ 1 & 0 & 5 \end{bmatrix}$$

Pixels

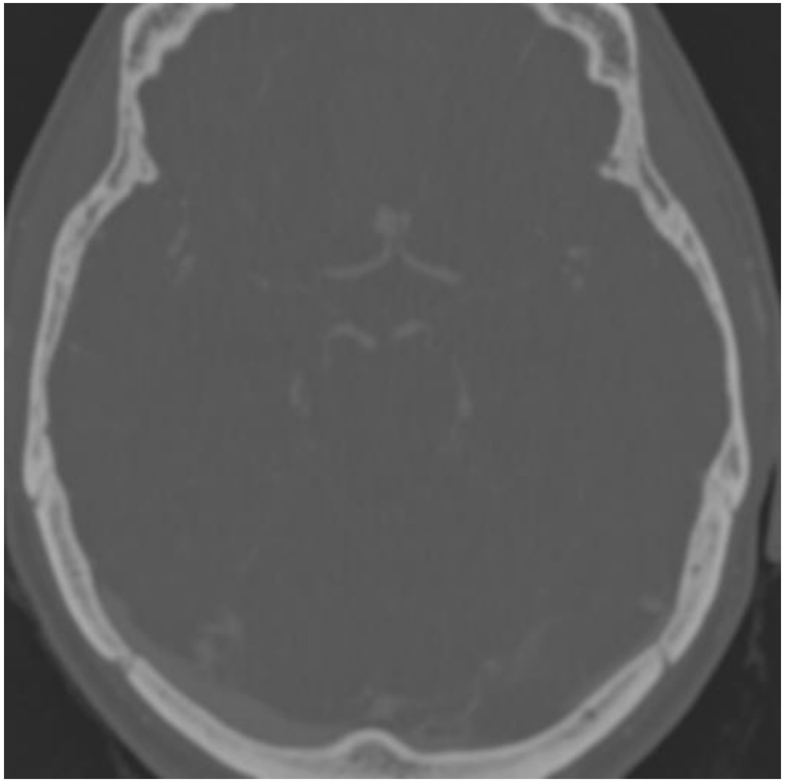


COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Image Visualization: Intensity Windowing

Applications: Brain



Linear display

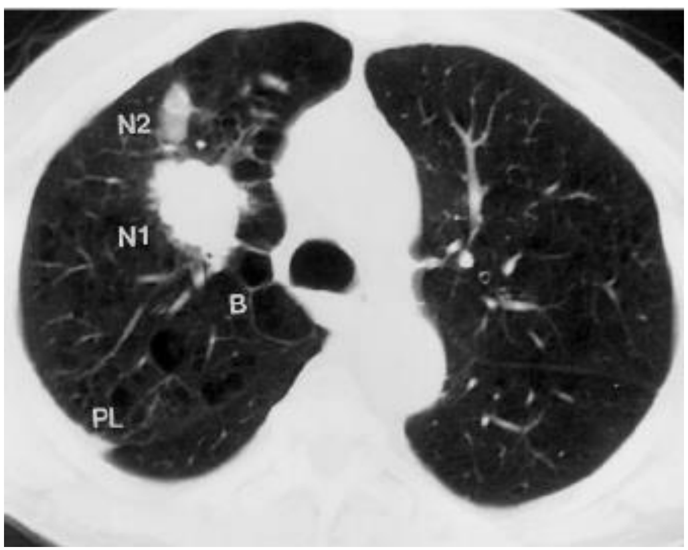
Simple Window

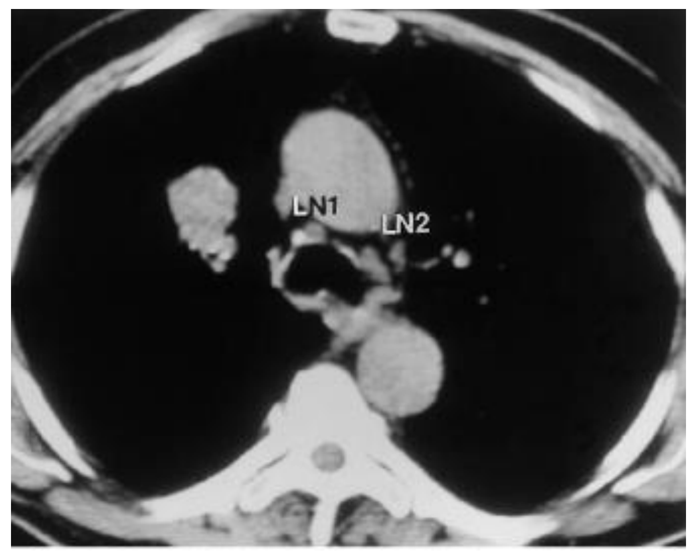
COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Image Visualization: Intensity Windowing

Applications: Lungs



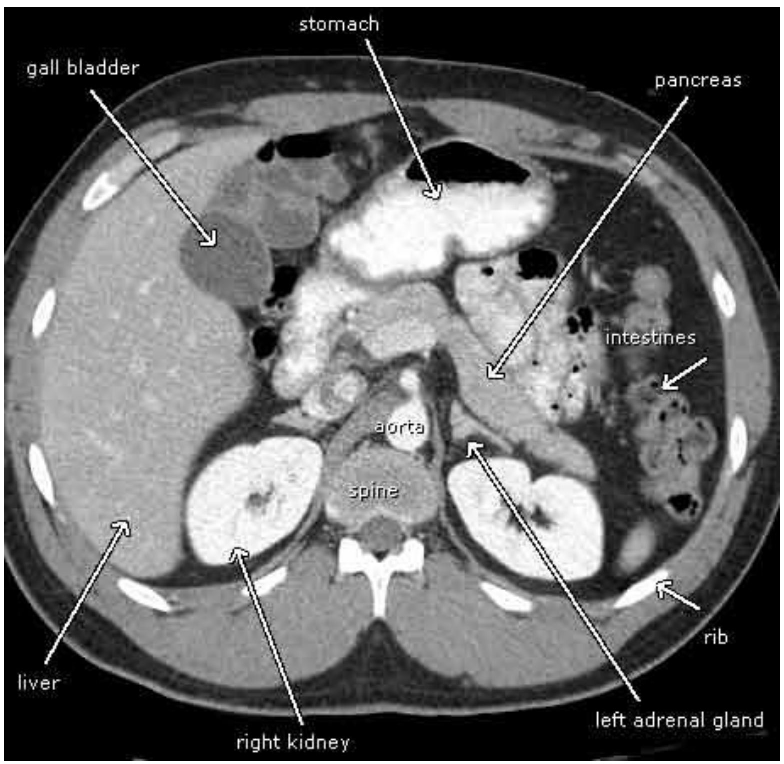


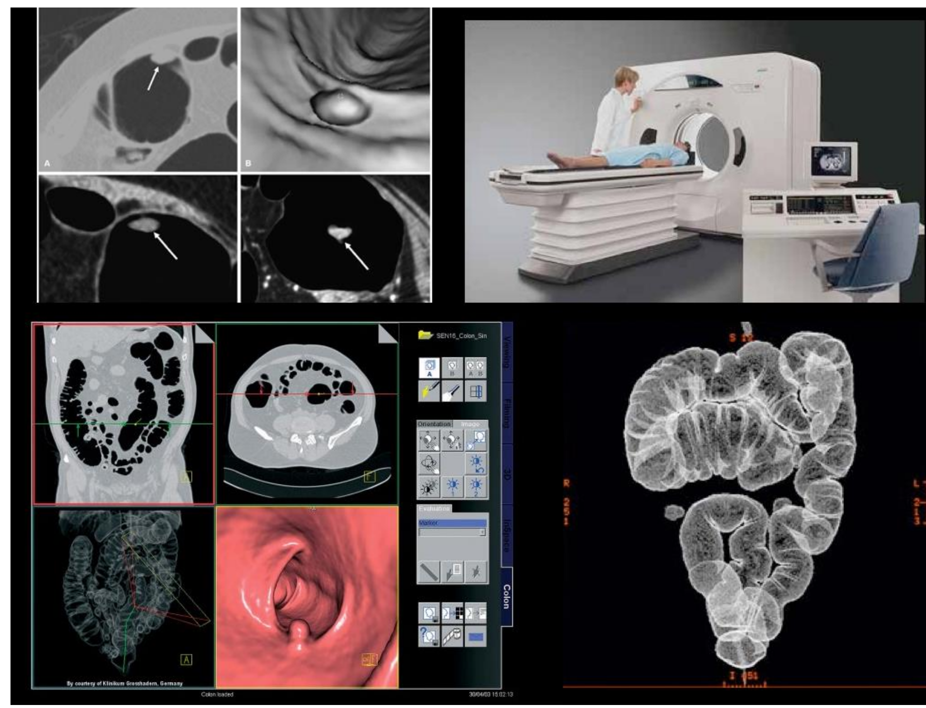
Source: Source: LM Fayad et al., Chest CT Window Settings With Multiscale Adaptive Histogram Equalization: Pilot Study, Radiology 223 (3), 845-852. 6 2002

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Soft tissues



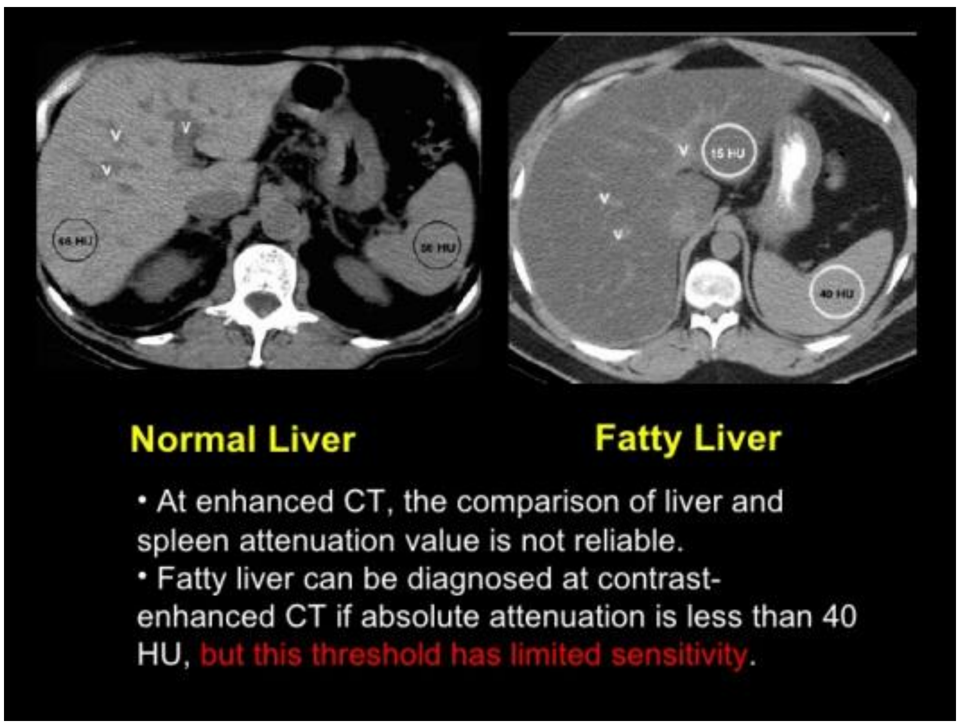


Source: https://www.radiologyinfo.org/en/info.cfm?pg=abdominct, http://www.limitsofebm.org/inconsistencies-and-anomalies/a-tale-of-colon-cancer-screening/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Soft tissues (fatty liver)

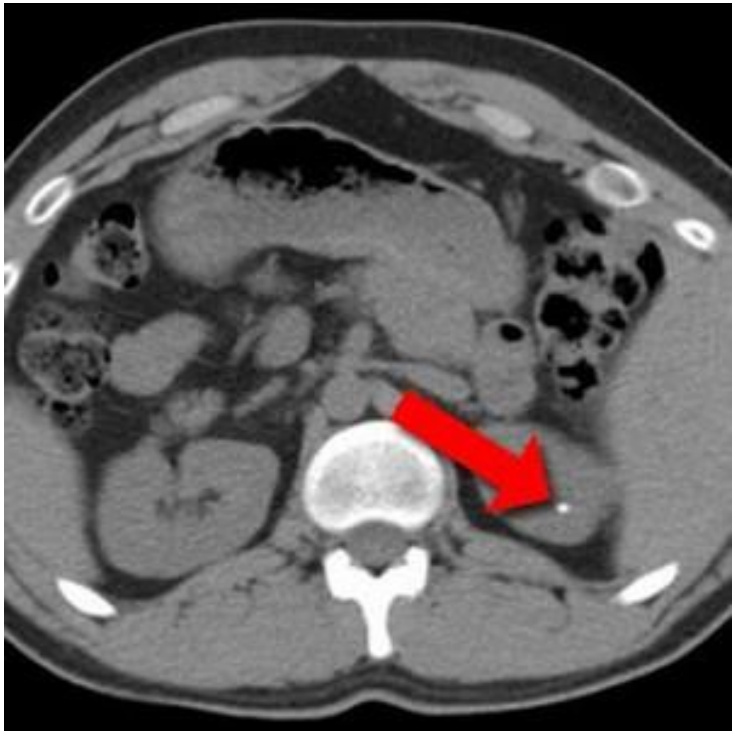


Source: https://sugarytooth.wordpress.com/2017/09/01/fatty-liver-nash-nafld/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Soft tissues (stone in kidney)

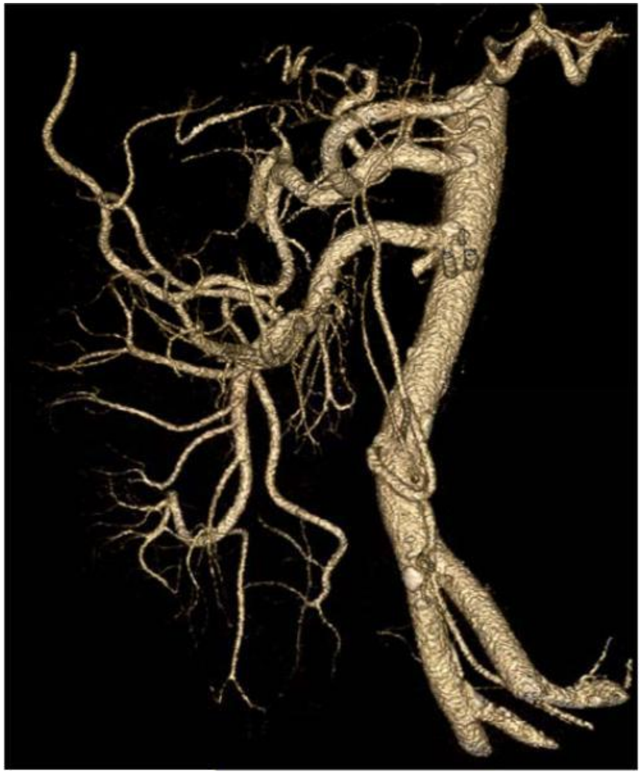


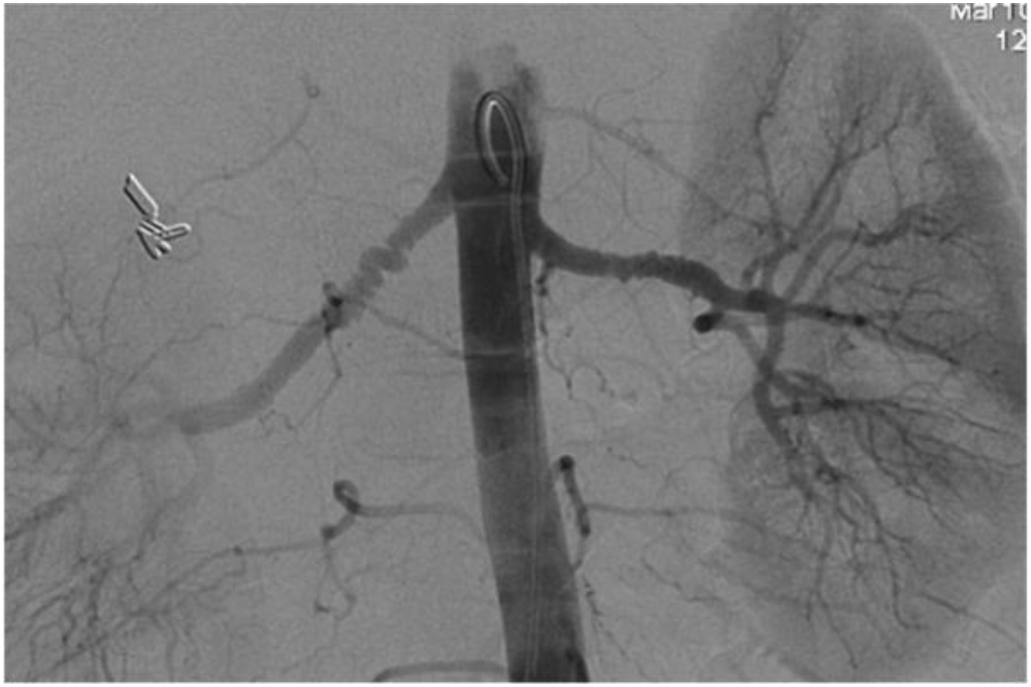
Source: https://kidneystones.uchicago.edu/patients/kidney-stone-ct-image2/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Vessel studies



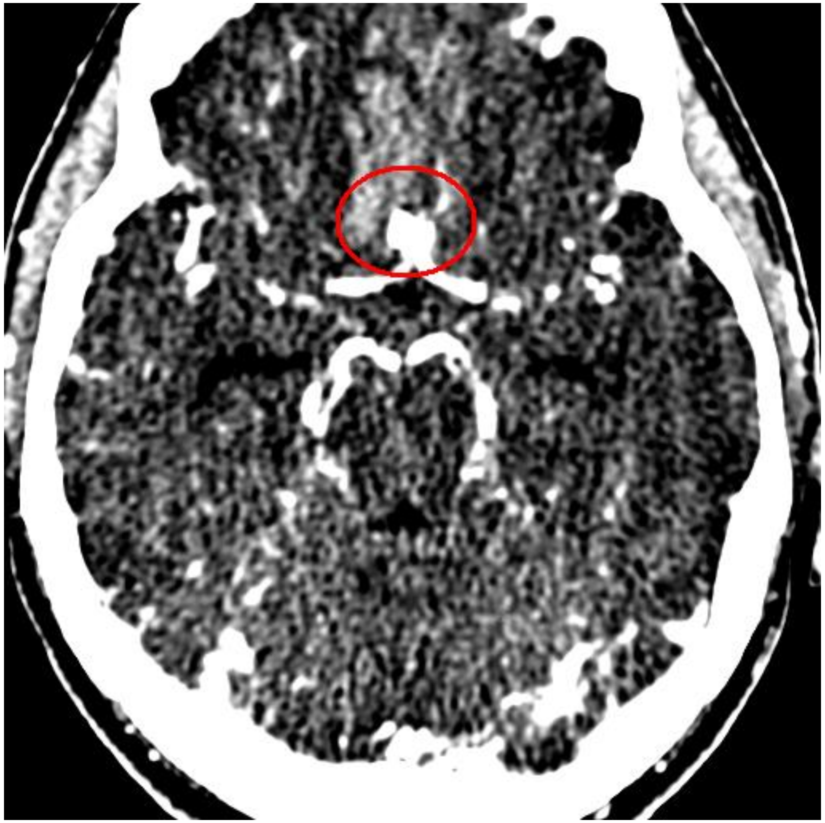


Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2901244/

COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Brain hemorrhage



COMPUTED TOMOGRAPHY

Computed Tomography (x-ray)

Applications: Brain cancer

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

4. Case study: Early detection of melanoma:

ULTRASONOGRAPHY

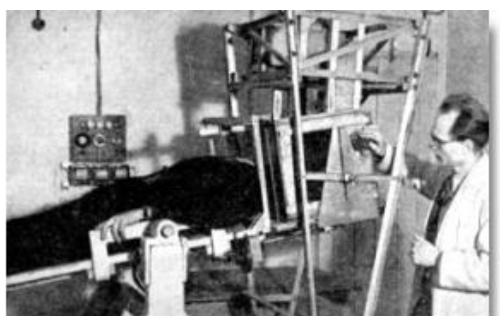
Ultrasonography

Brief historical survey

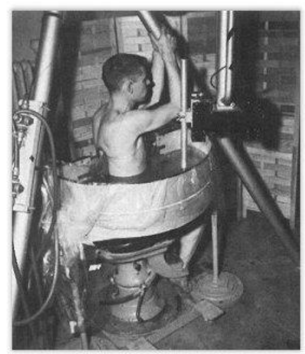
Year	Researcher	Accomplishment
1936	Turing	Turring Machine, a hypothetical machine that could perform automatically calculations
1942	John Vincent Atanasoff and Clifford Berry	Atanasoff-Berry Computer (ABC), a computer able to solve linear equations
1942	Karl Dussik	Fist ultrasound system used for imaging of brain cancer

Karl Dussik: 1908 – 1968, Austrian neurologist and psychiatrist

Karl Theo (Theodore) Dussik
1908 - 1968



Dussik and his ultrasonic apparatus in 1946

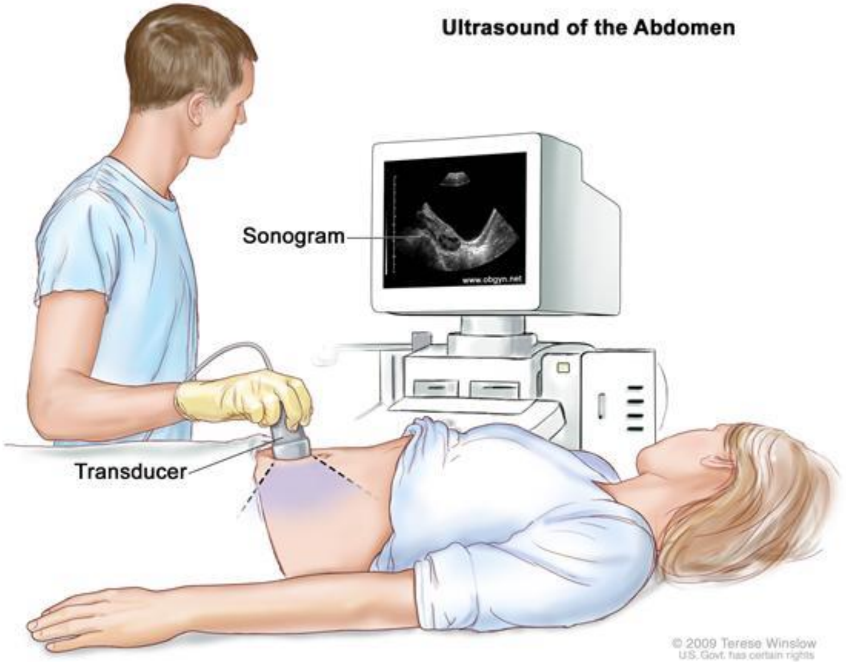


Πηγές: https://en.wikipedia.org/wiki/Colossus_computer, http://www.ob-ultrasound.net/dussikbio.html

ULTRASONOGRAPHY

Ultrasonography

Basic principles

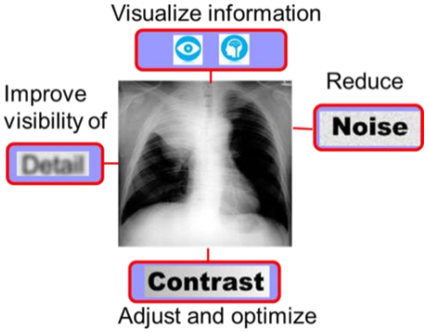


Source: https://www.nibib.nih.gov/science-education/science-topics/ultrasound

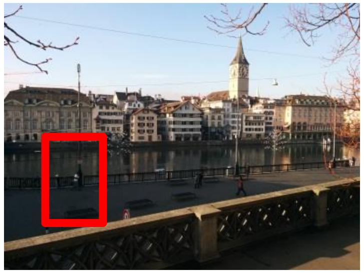
ULTRASONOGRAPHY

Ultrasonography

Image enhancement: Goal: Reduce noise

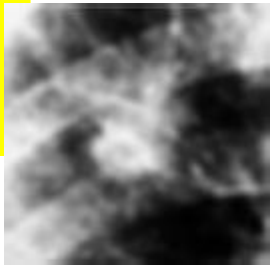


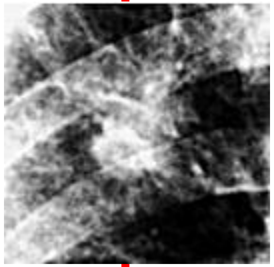
•Low frequency



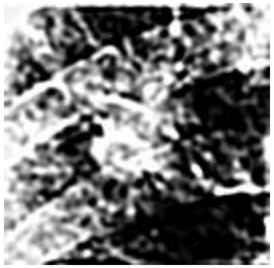
•Basic shape-overview (no noise)

•If interested in retaining the basic information of the image, then keep low frequencies, reduce high frequencies, thus, reduce noise—optical effect: blurring





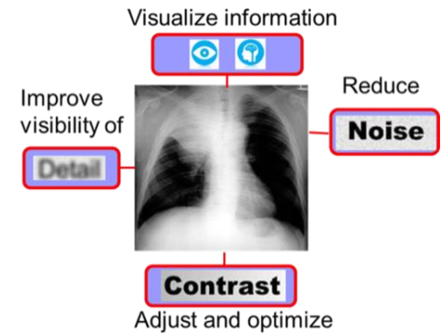
•High frequency



•Details + noise

•If interested in enhancing details, then keep high frequencies, reduce low frequencies, thus, increase noise—optical effect: edge enhancement

ULTRASONOGRAPHY



Ultrasonography

Image enhancement: Goal: Reduce noise

Original Image

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

Smooth out variations

Transformation

3x3 median filter

STEP 1: Matrix scan rows 1:3, columns 1:3

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

30	31	12
17	**12**	25
12	8	17

➔

30	31	12
17	**17**	25
12	8	17

SORT: 8 12 12 12 **17** 17 25 30 31
X1=17

STEP 2: Matrix scan rows 1:3, columns 2:4

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

31	12	9
12	**25**	10
8	17	9

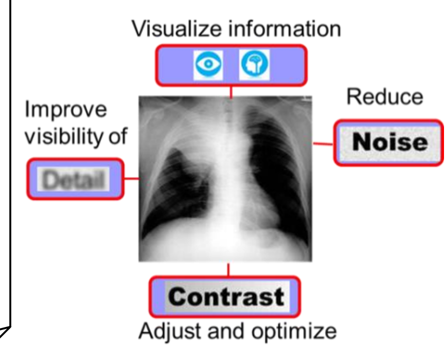
➔

31	12	9
12	**12**	10
8	17	9

SORT: 8 9 9 10 **12** 12 17 25 31
X2=12

Enhanced Image

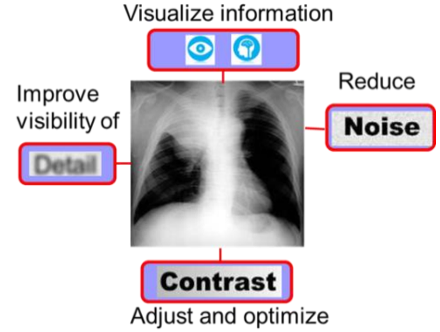
30	31	12	9
17	**17**	**12**	10
12	**17**	**12**	9
31	12	26	22



ULTRASONOGRAPHY

Ultrasonography

Image enhancement: Goal: Reduce noise



Original Image

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

Smooth out variations

Transformation

3x3 median filter

STEP 3: Matrix scan rows 2:4, columns 1:3

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

17	12	25
12	**8**	17
31	12	26

➔

17	12	25
12	**17**	17
31	12	26

SORT: 8 12 12 12 **17** 17 25 26 31

X3=17

STEP 4: Matrix scan rows 2:4, columns 2:4

30	31	12	9
17	12	25	10
12	8	17	9
31	12	26	22

12	25	10
8	**17**	9
12	26	22

➔

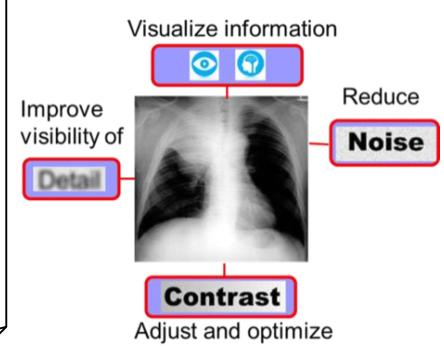
12	25	10
8	**12**	9
12	26	22

SORT: 8 9 10 12 **12** 17 22 25 26

X4=12

Enhanced Image

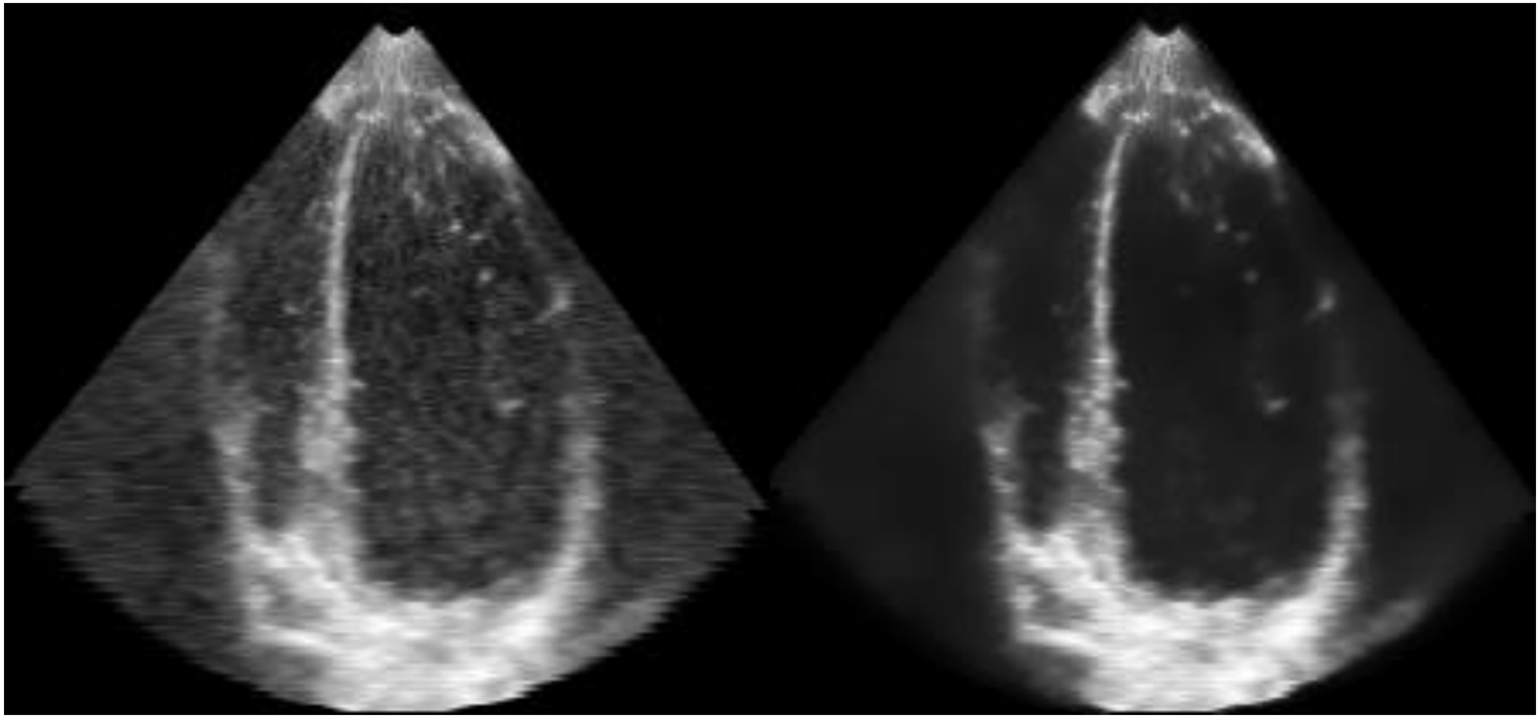
30	31	12	9
17	**17**	**12**	10
12	**17**	**12**	9
31	12	26	22



ULTRASONOGRAPHY

Ultrasonography

DENOISING – LOW PASS



Original image

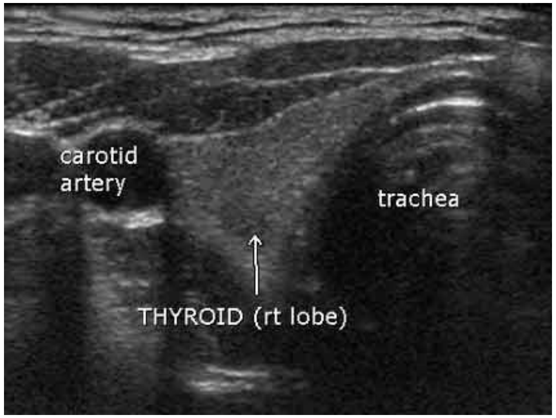
Denoised image

Πηγές: https://www.lpi.tel.uva.es/node/510

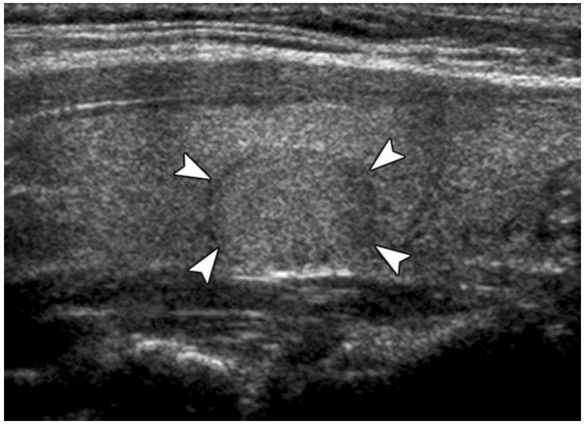
ULTRASONOGRAPHY

Ultrasonography

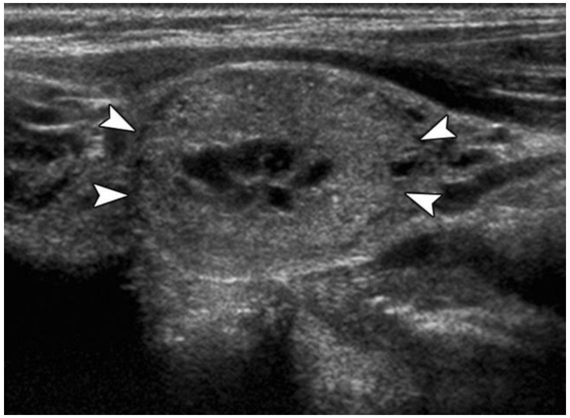
Applications: Thyroid



normal



malignant



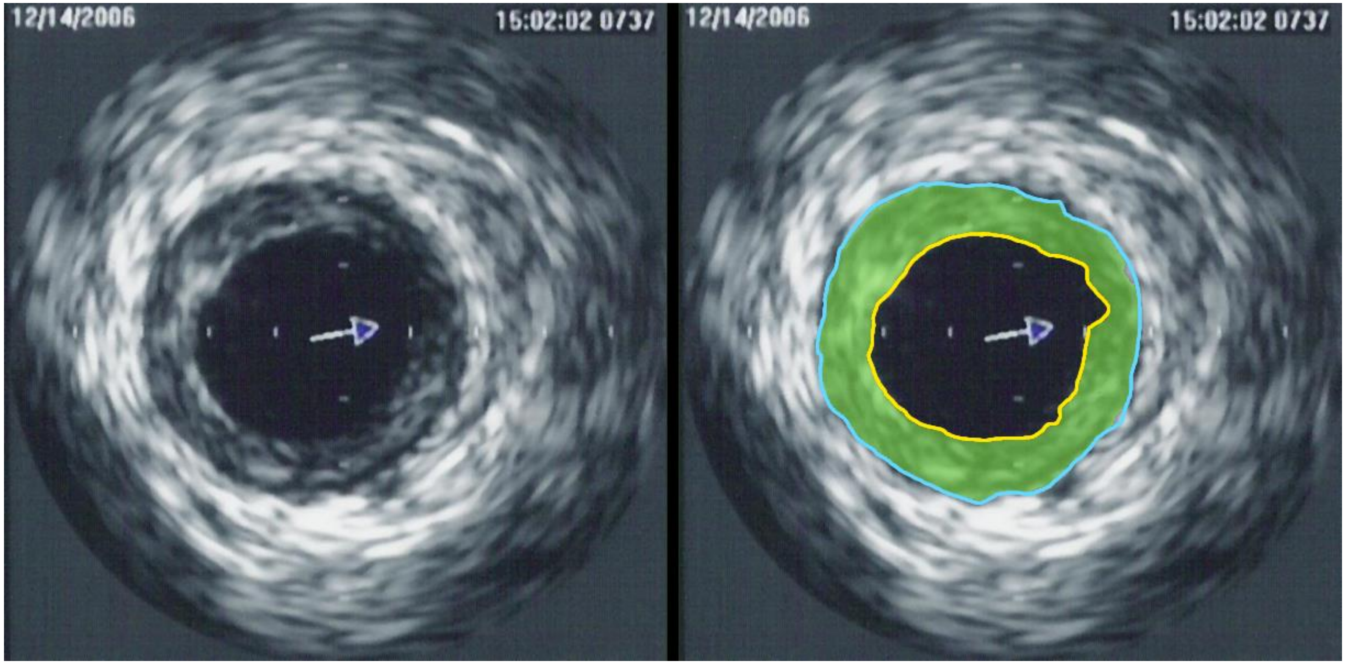
benign

Πηγές:
http://www.radiologyinfo.org/en/photocat/gallery3.Cm?pid=1&image=gen-us-thyroid.jpg&pg=us-thyroid

ULTRASONOGRAPHY

Ultrasonography

Applications: Vessel studies



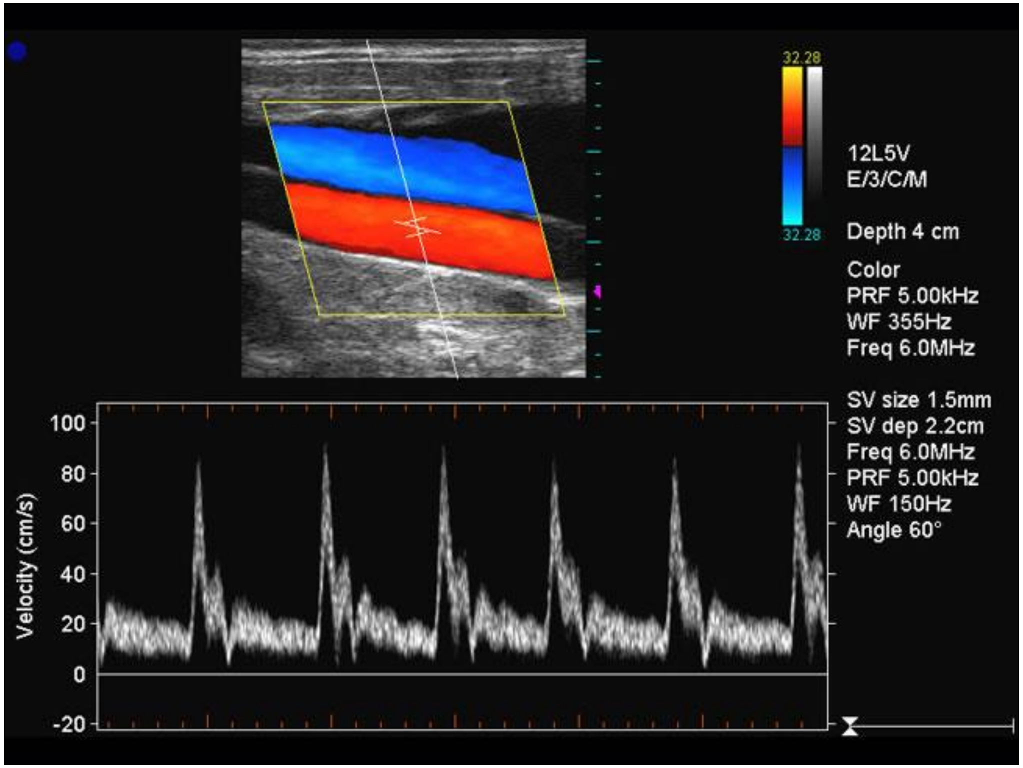
Source: https://en.wikipedia.org/wiki/Medical_ultrasound

Atheromatic plaques

ULTRASONOGRAPHY

Ultrasonography

Applications: Vessel studies (triplex)

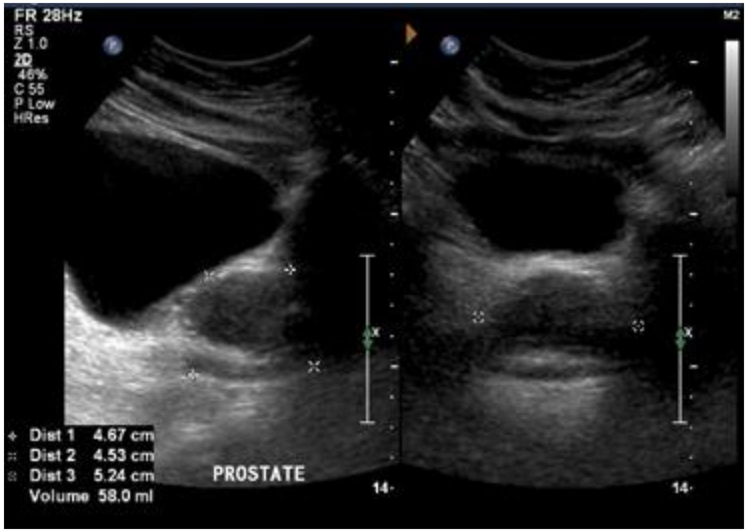


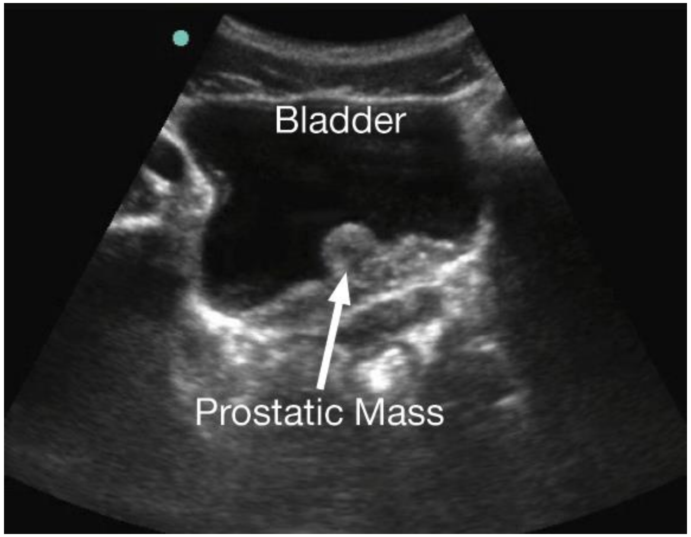
Πηγές: http://www.ultrasoundpaedia.com/normal-prostate/, http://epmonthly.com/article/second-chance-on-bladder-ultrasound/

ULTRASONOGRAPHY

Ultrasonography

Applications: Prostate cancer



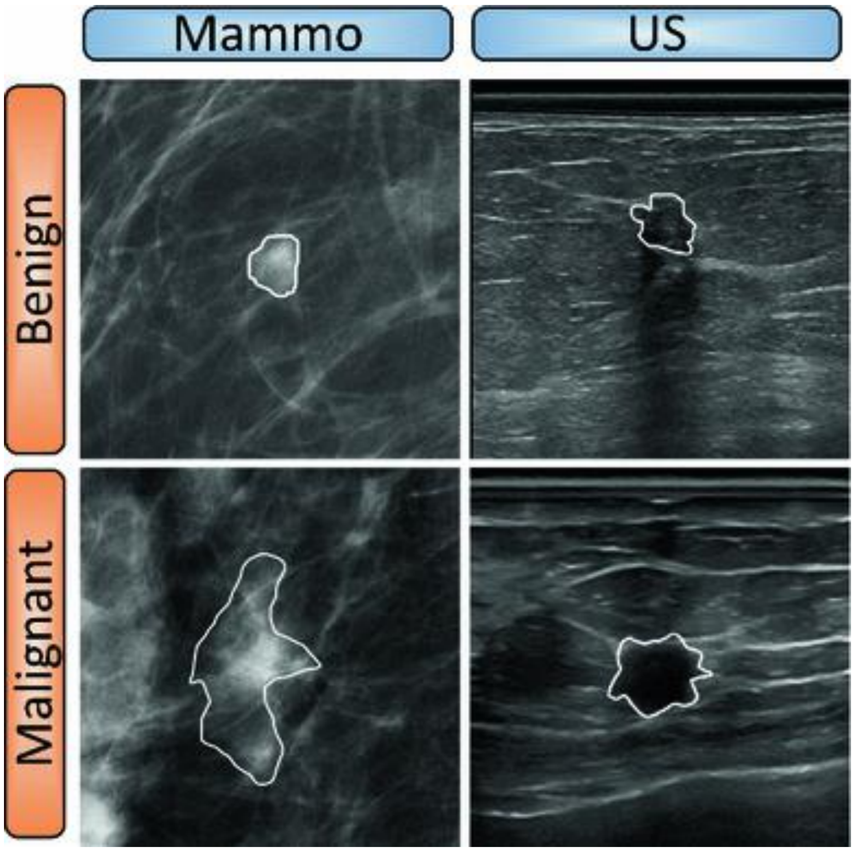


Πηγές: http://www.ultrasoundpaedia.com/normal-prostate/, http://epmonthly.com/article/second-chance-on-bladder-ultrasound/

ULTRASONOGRAPHY

Ultrasonography

Applications: Breast cancer



Non ionizing radiation

Safe and economical examination

Source: Sidiropoulos et al. Multimodality GPU-based computer-assisted diagnosis of breast cancer using ultrasound and digital mammography images (2013) International Journal of Computer Assisted Radiology and Surgery, 8 (4), pp. 547-560.

LECTURE CONTENTS

1. **Introduction**

2. **Digital Imaging Systems**
    α. X-ray radiography
    β. X-ray mammography
    γ. X-ray Computed Tomography (CT)
    δ. Ultrasonography
    ε. Nuclear Magnetic Resonance Imaging (MRI)
    στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
    ζ. Thermography
    η. Hybrid Systems (PET-CT, MRI-PET)
    θ. Microscopy

3. **Decision Support Systems**

4. **Case study: Early detection of melanoma:**

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Brief historical survey

Year	Researcher	Accomplishment
1946	Bloch, Purcell	First researchers that studied the phenomena of nuclear magnetic resonance imaging
1952	Bloch, Purcell	Nobel price
1971	Damadian	He showed that NMRI can be used to discriminate normal from cancerous tissues
1977		First application with humans
2003	Lauterbur, Mansfield	Nobel price

Raymond Damadian: 1936 – , American physician

Paul Christian Lauterbur: 1929 – 2007, American chemist

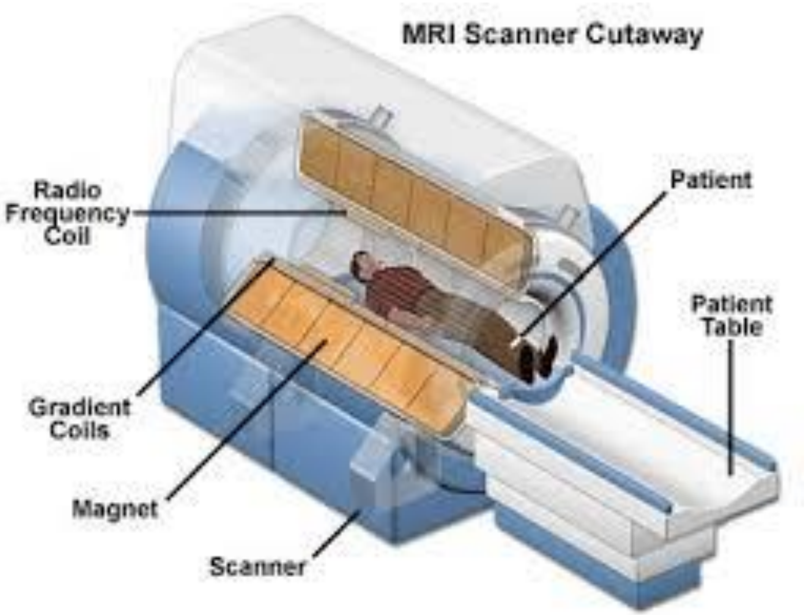
Peter Mansfield: 1933 – 2017, English physicist

Πηγές: https://en.wikipedia.org/wiki/Paul_Lauterbur, https://en.wikipedia.org/wiki/Peter_Mansfield

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Basic principles



Source: http://www.iambiomed.com/equipments/mri.php,

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Image Segmentation: Define the borders of the region of interest

Original Image

100	128	110	90
128	210	220	240
90	214	210	180
90	200	64	30

Transformation

Threshold: 150

220>150→1

128<150→0

214>150→1

90<150→0

100<150→0

240>150→1

110<150→0

210>150→1

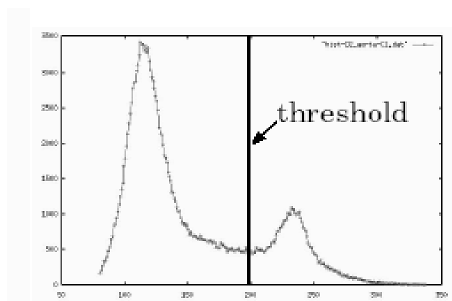
240>150→1

64<150→0

200>150→1

180>150→1

30<150→0



Segmented Image

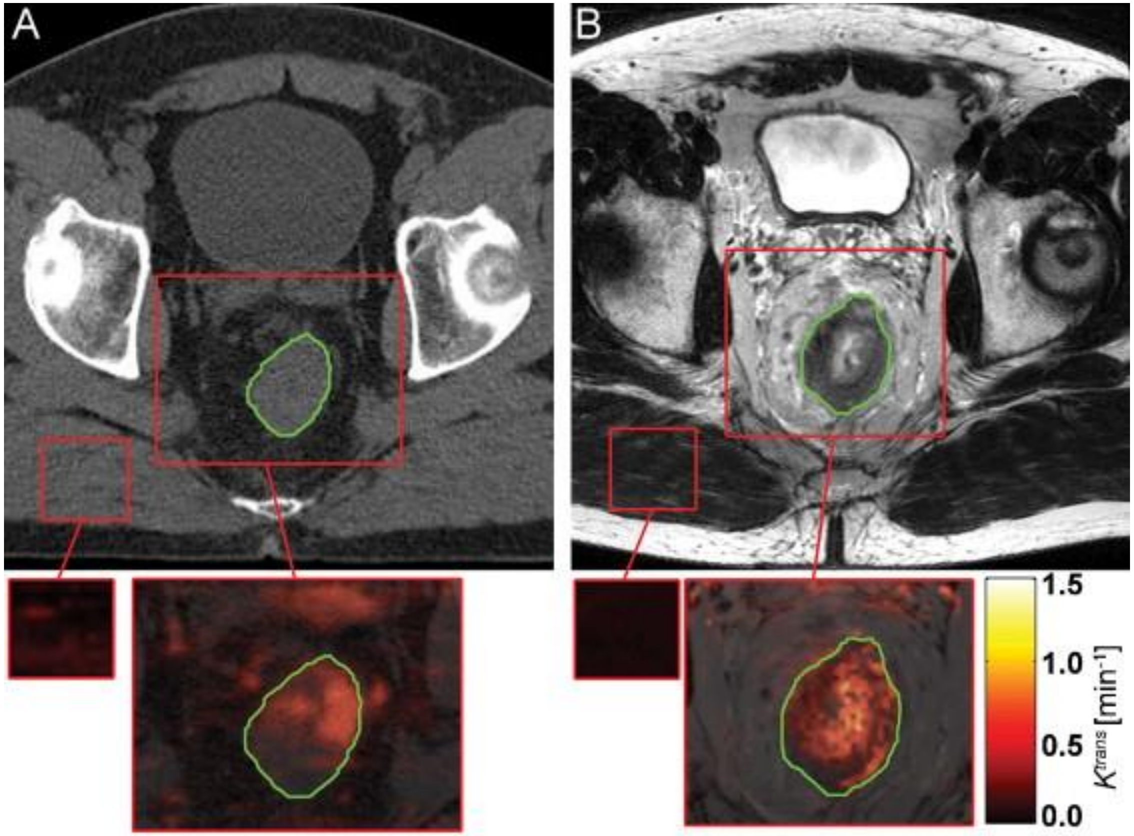
0	0	0	0
0	1	1	1
0	1	1	1
0	1	0	0

- Fast and effective
- Define a value (the threshold)
- All pixels with value greater (or lower) than the threshold are marked with 1 (region of interest), whereas all remaining values are marked with 0 (background regions)

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Applications: Soft tissues



Source: Roel G.J. Kierkels**,** Comparison Between Perfusion Computed Tomography and Dynamic Contrast-Enhanced Magnetic Resonance Imaging in Rectal Cancer, International Journal of Radiation Oncology*Biology*Physics, 77(2), 400-408, 2010

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

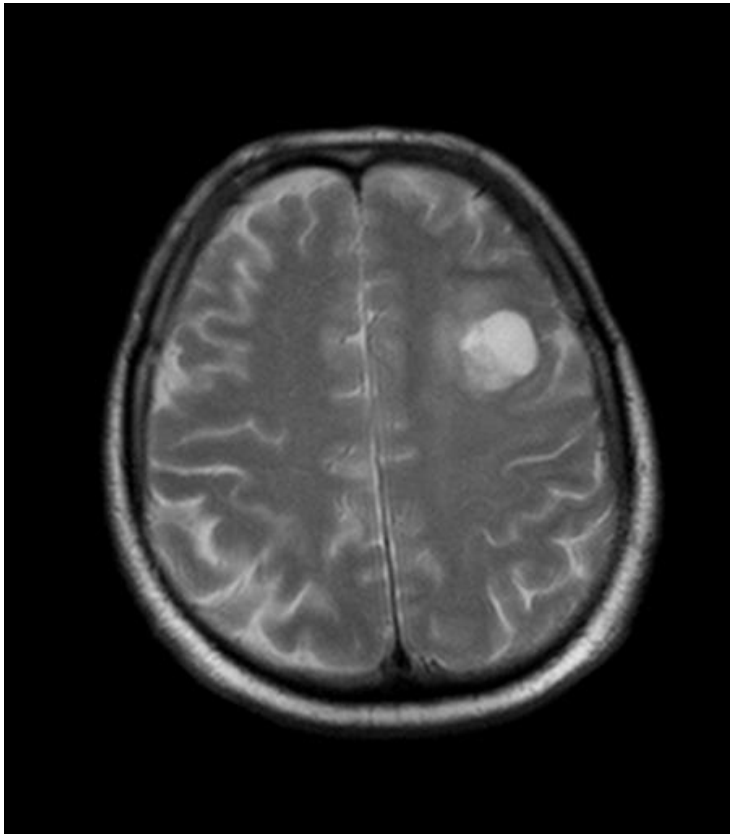
Applications: Bones, knee

Source: Kostopoulos, et al. Pattern-recognition system, designed on GPU, for discriminating between injured normal and pathological knee cartilage (2013) Magnetic Resonance Imaging, 31 (5), pp. 761-770.

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

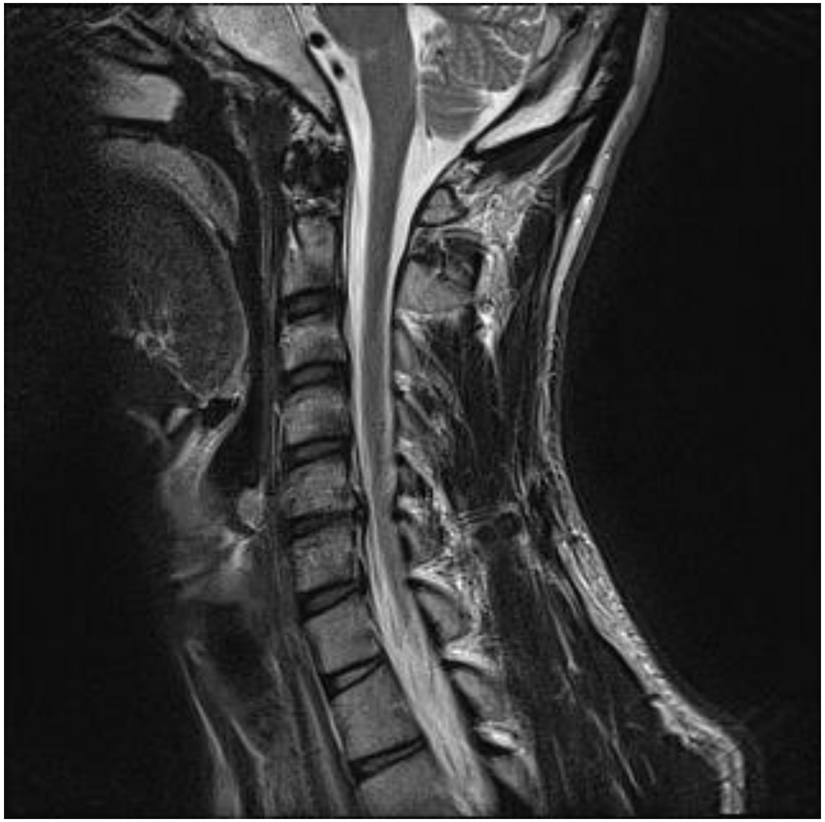
Applications: Brain cancer

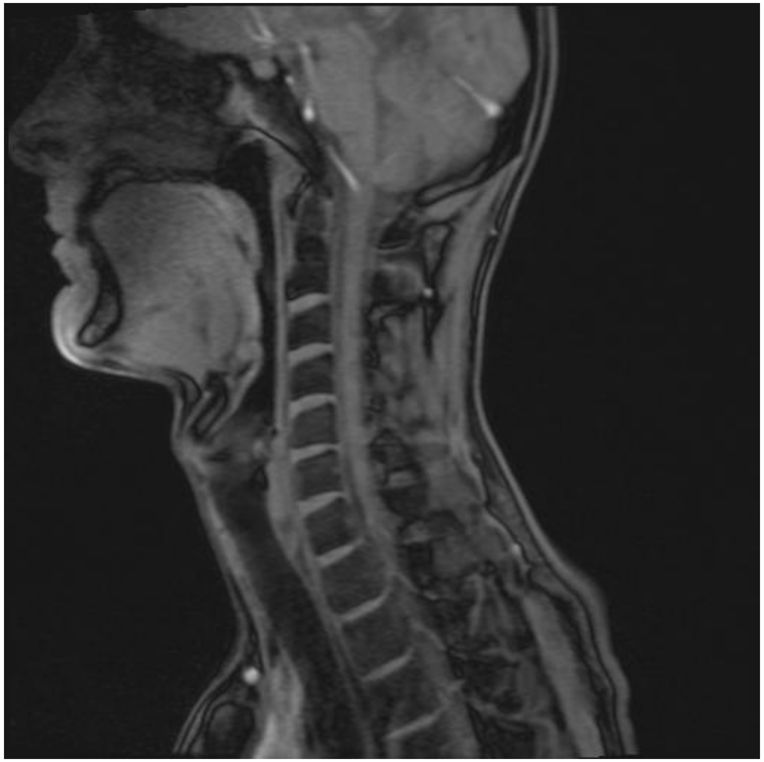


MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Applications: Spinal cord, neck

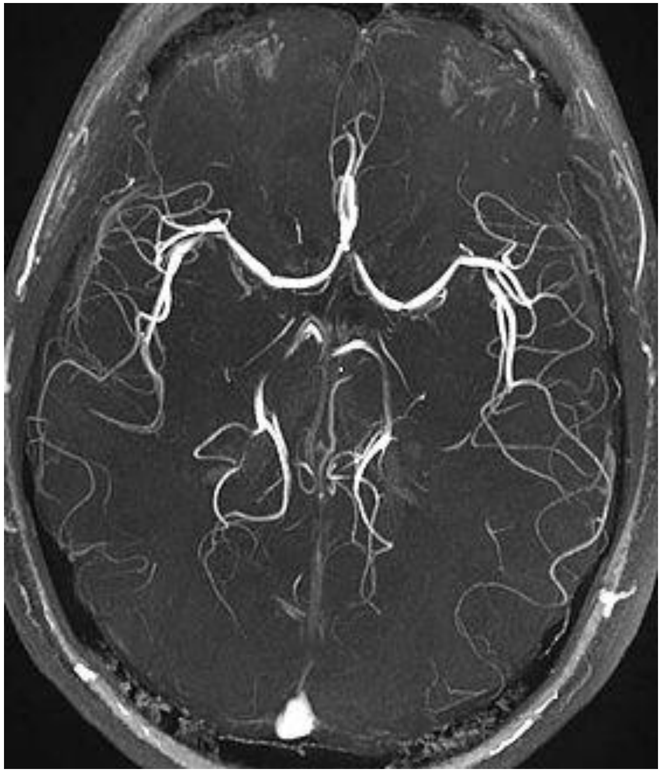




MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Applications: Vessel studies

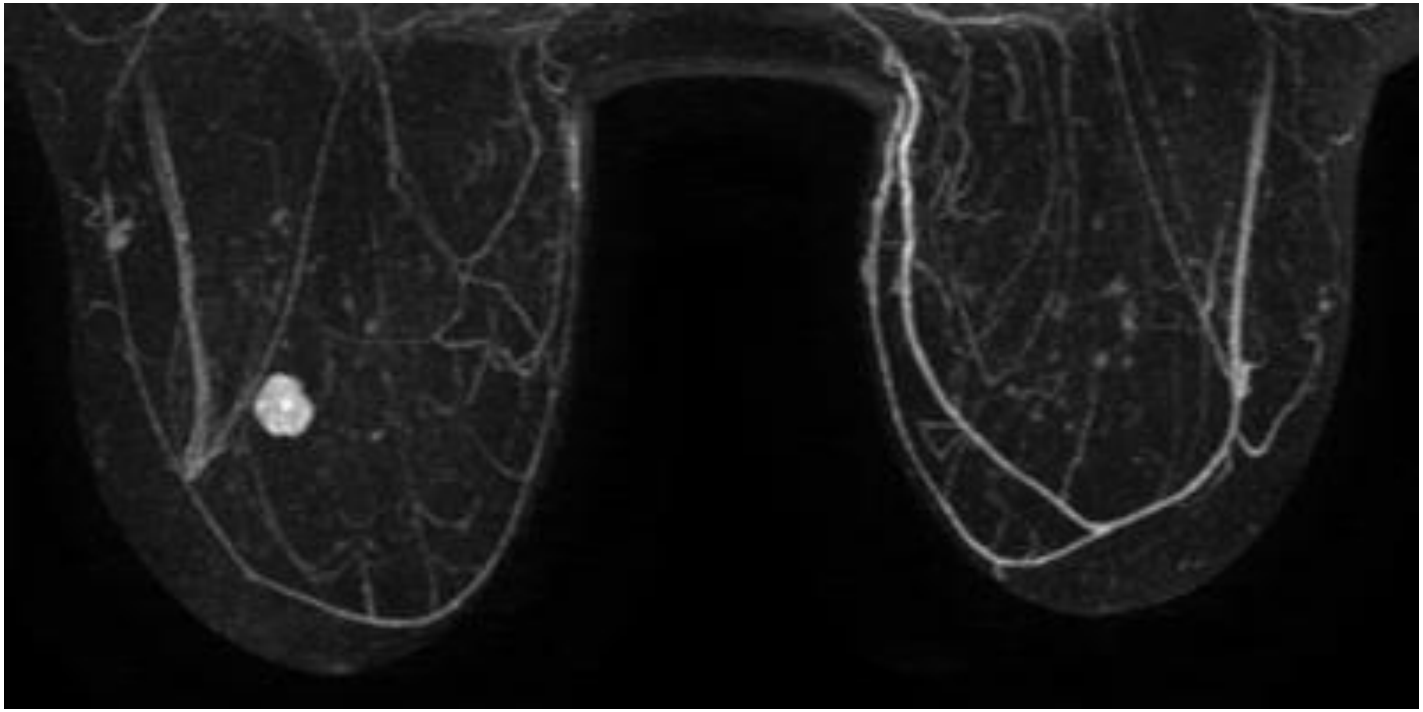


Source: https://en.wikipedia.org/wiki/Magnetic_resonance_angiography

MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

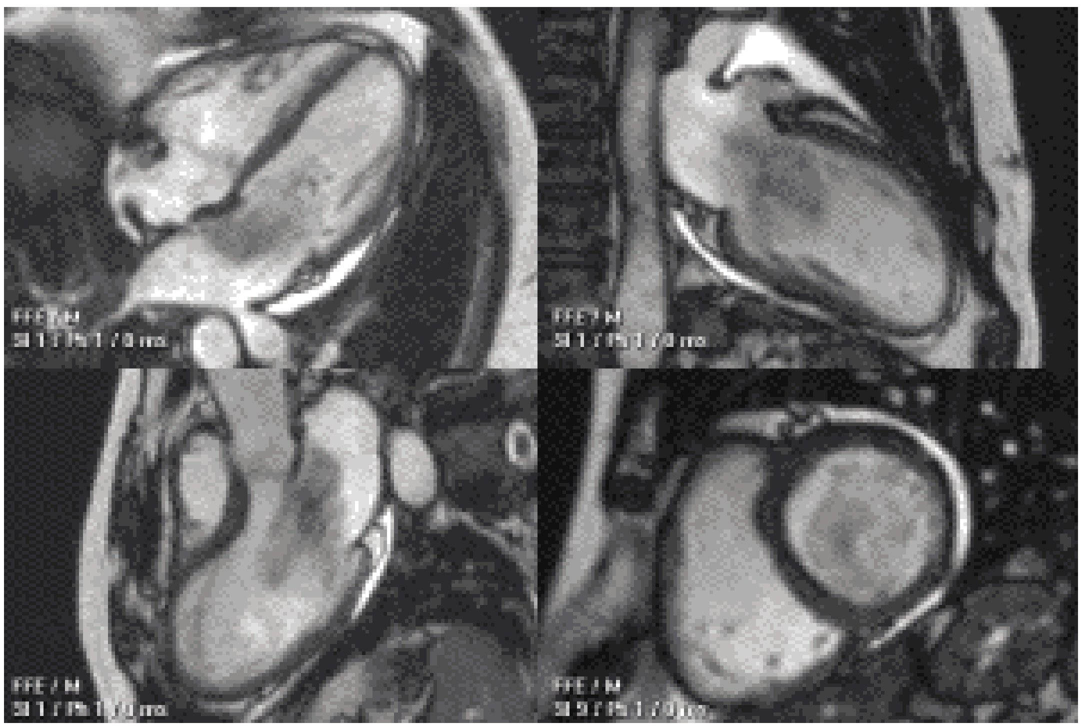
Applications: Mammography



MAGNETIC RESONANCE IMAGING TOMOGRAPHY

Nuclear Magnetic Resonance Imaging (MRI)

Applications: Heart



Source: https://en.wikipedia.org/wiki/Cardiac_magnetic_resonance_imaging

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

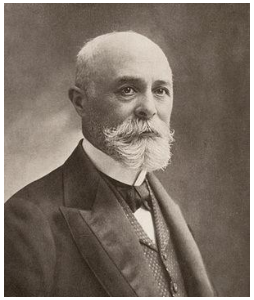
4. Case study: Early detection of melanoma:

SCINTIGRAPHY

Nuclear medicine

Brief historical survey

Year	Researcher	Accomplishment
1896	Henri Bequerel	Experiments with Uranium
1898	Marie Skłodowska Curie	Discovery of Polonium and Radium
1903	Bequerel + Marie Curie	Nobel price
1934	Frédéric Joliot-Curie και Irène Joliot-Curie	Artificial production of 30P
1935	Hevesy	He performed experiments with living organism
1957	Hal Anger	First gamma camera



Πηγές: https://en.wikipedia.org/wiki/Marie_Curie, https://en.wikipedia.org/wiki/Henri_Becquerel

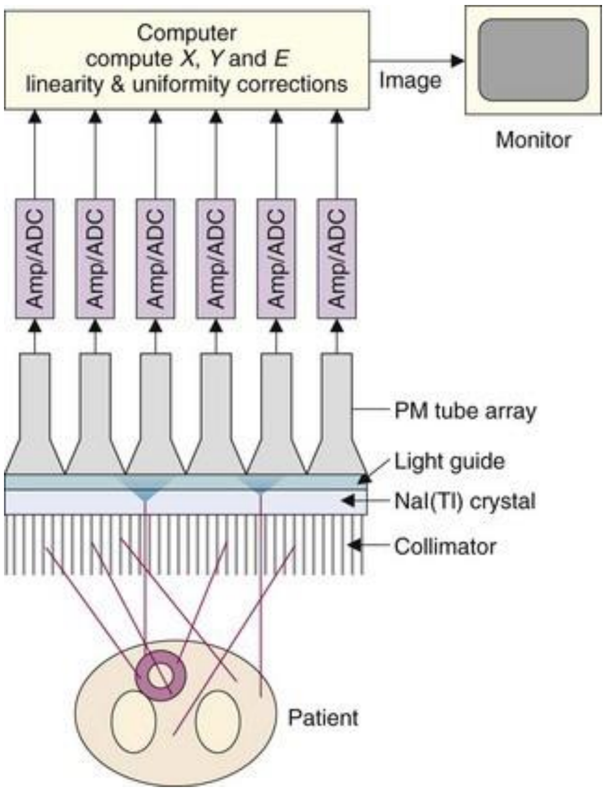
Marie Skłodowska Curie : 1867 – 1934, Polish Physicist and chemist

Henri Becquerel: 1852 – 1908, French Physicist

SCINTIGRAPHY

Nuclear medicine

Basic principles (gamma camera)



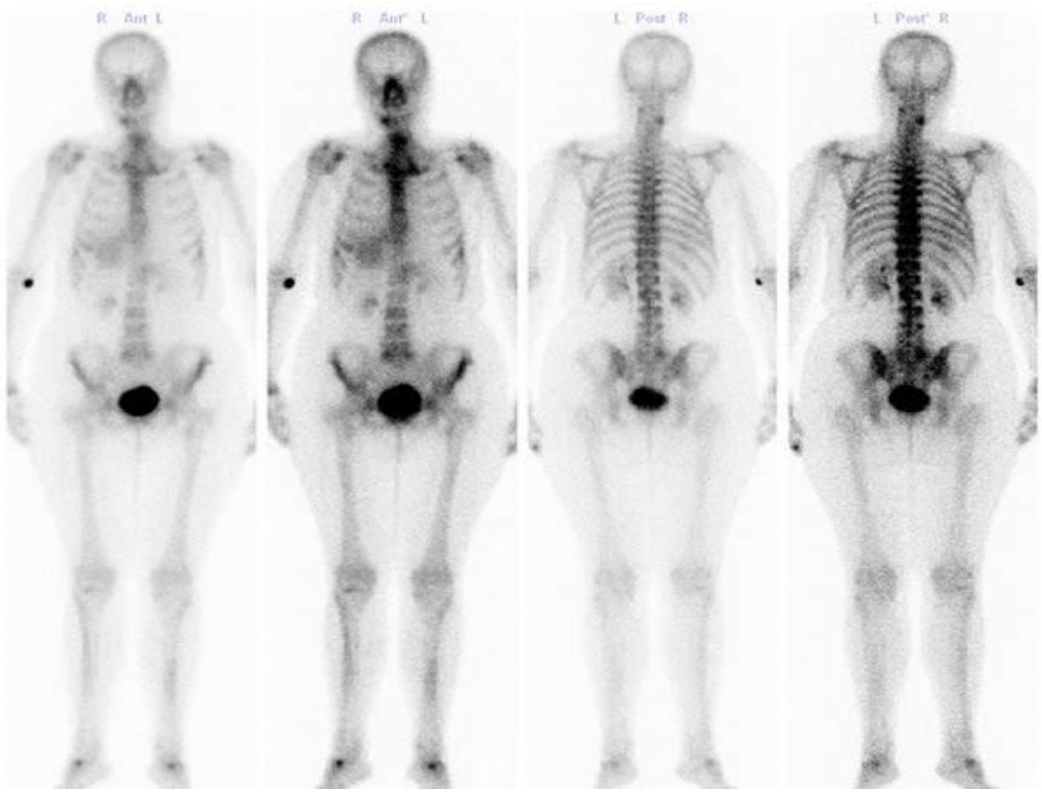
Gamma camera
SPECT
PET

Source: https://radiologykey.com/the-gamma-camera-basic-principles/

SCINTIGRAPHY

Nuclear medicine

Applications: Bones

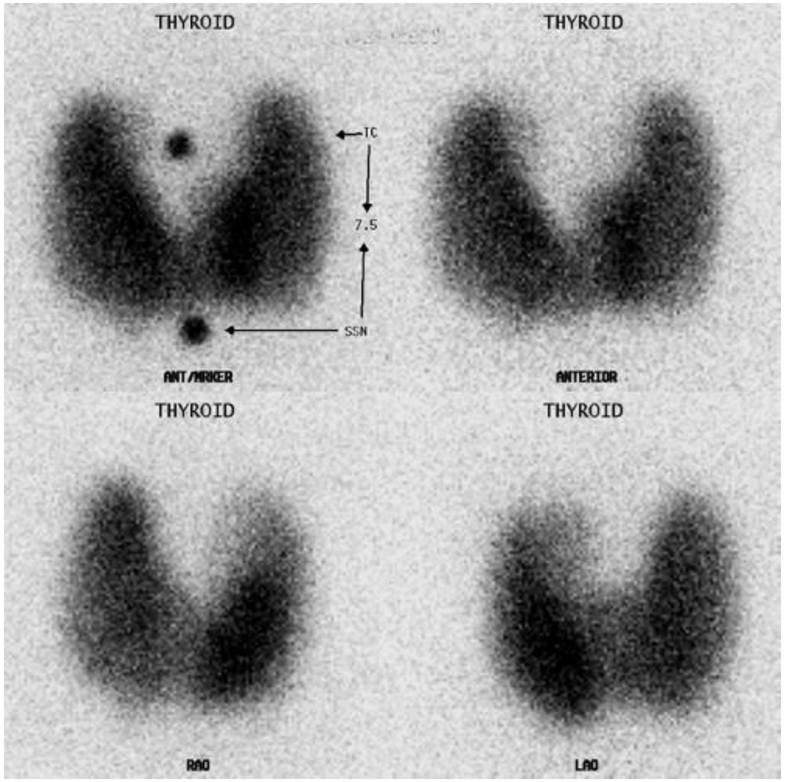


Source: http://www.qmedicine.co.in/top%20health%20topics/B/Bone%20Scan.html

SCINTIGRAPHY

Nuclear medicine

Applications: Thyroid

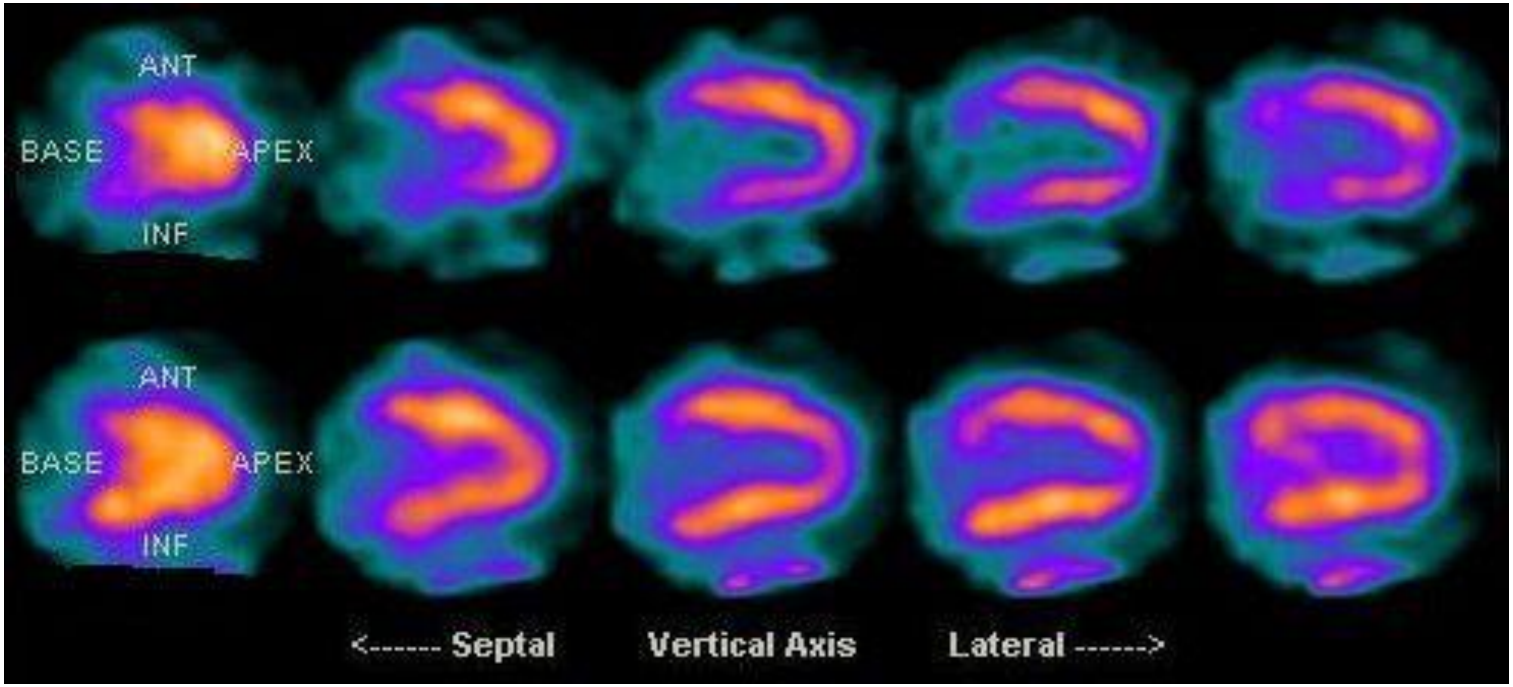


Source: https://radiologykey.com/introduction-to-nuclear-medicine-3/

SCINTIGRAPHY

Nuclear medicine

Applications: Cardiac studies



Source:
https://www.google.gr/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwjZ_LOdhZfaAhXDKVAKHdLTCjcQjhx6BAgAEAM&url=https%3A%2F%2Fcommons.wikimedia.org%2Fwiki%2FFile%3ACardiac_nuclear_medicine_scans_comparing_attenuation_correction.jpg&psig=AOvVaw2wbv1BmCdduCOL8jo9Vh_q&ust=1522602106628139

SCINTIGRAPHY

Nuclear medicine

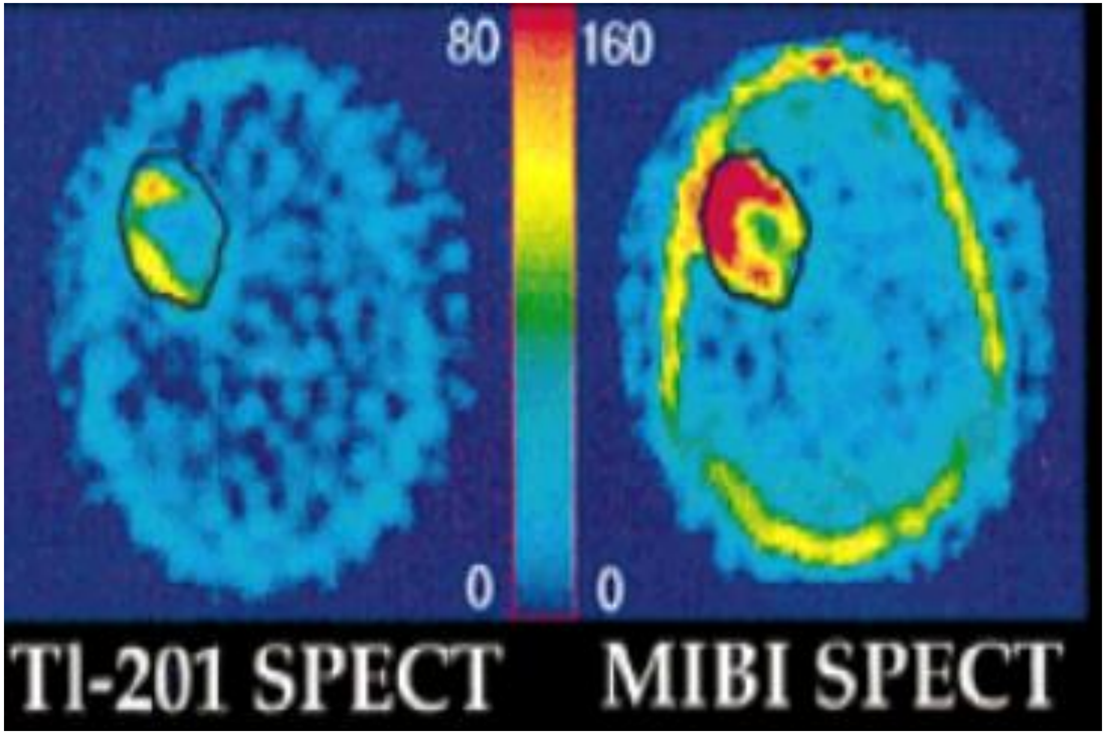
Applications: Breast, soft tissues

Source: https://radiologykey.com/introduction-to-nuclear-medicine-3/

SCINTIGRAPHY

Nuclear medicine

Applications: Brain cancer



Source: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3101722

LECTURE CONTENTS

1. **Introduction**

2. **Digital Imaging Systems**

   α. X-ray radiography
   β. X-ray mammography
   γ. X-ray Computed Tomography (CT)
   δ. Ultrasonography
   ε. Nuclear Magnetic Resonance Imaging (MRI)
   στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
   ζ. Thermography
   η. Hybrid Systems (PET-CT, MRI-PET)
   θ. Microscopy

3. **Decision Support Systems**

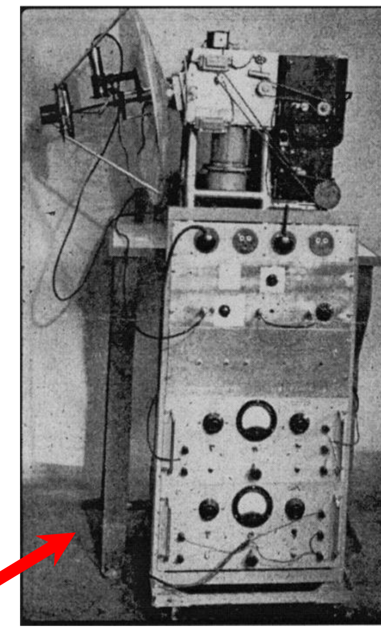
4. **Case study: Early detection of melanoma:**

THERMOGRAPHY

Infrared imaging

Brief historical survey

Year	Researcher	Accomplishment
1595	Gallileo Gallilei	Discovery of the thermometer
1871	Carl Wunderlich	Discovery of medical thermometer
1800s	William Herschel	He discovers a part of light spectrum that corresponds to thermal radiation
1929	UK	Construction of thermal camera for military purposes
1940s	Horvath and Hollander	Utilization of temperature for medical purposes
1959	Pyroscan	First examination of thermography for joints

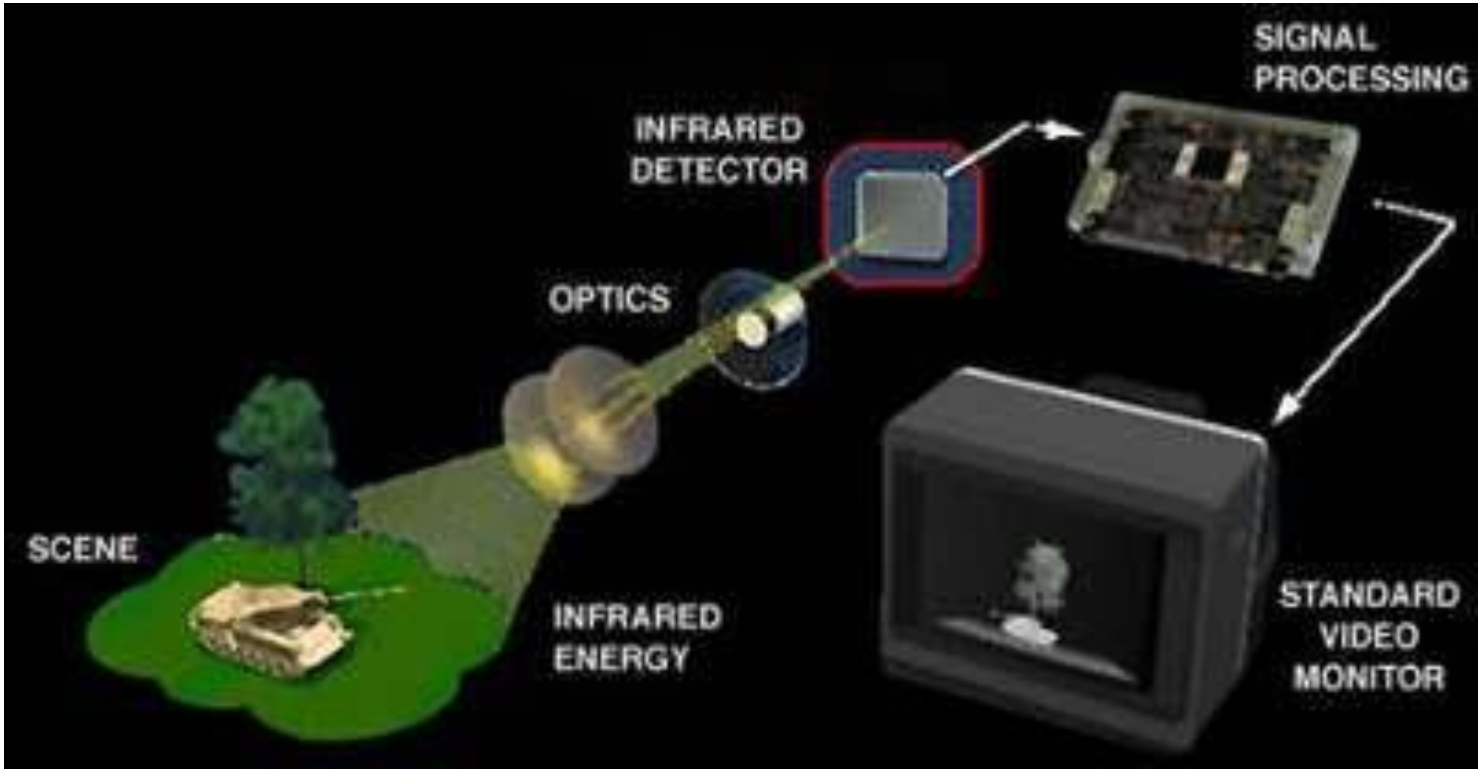


Source:
https://academic.oup.com/rheumatology/article/43/6/800/1784527

THERMOGRAPHY

Infrared imaging

Basic principles

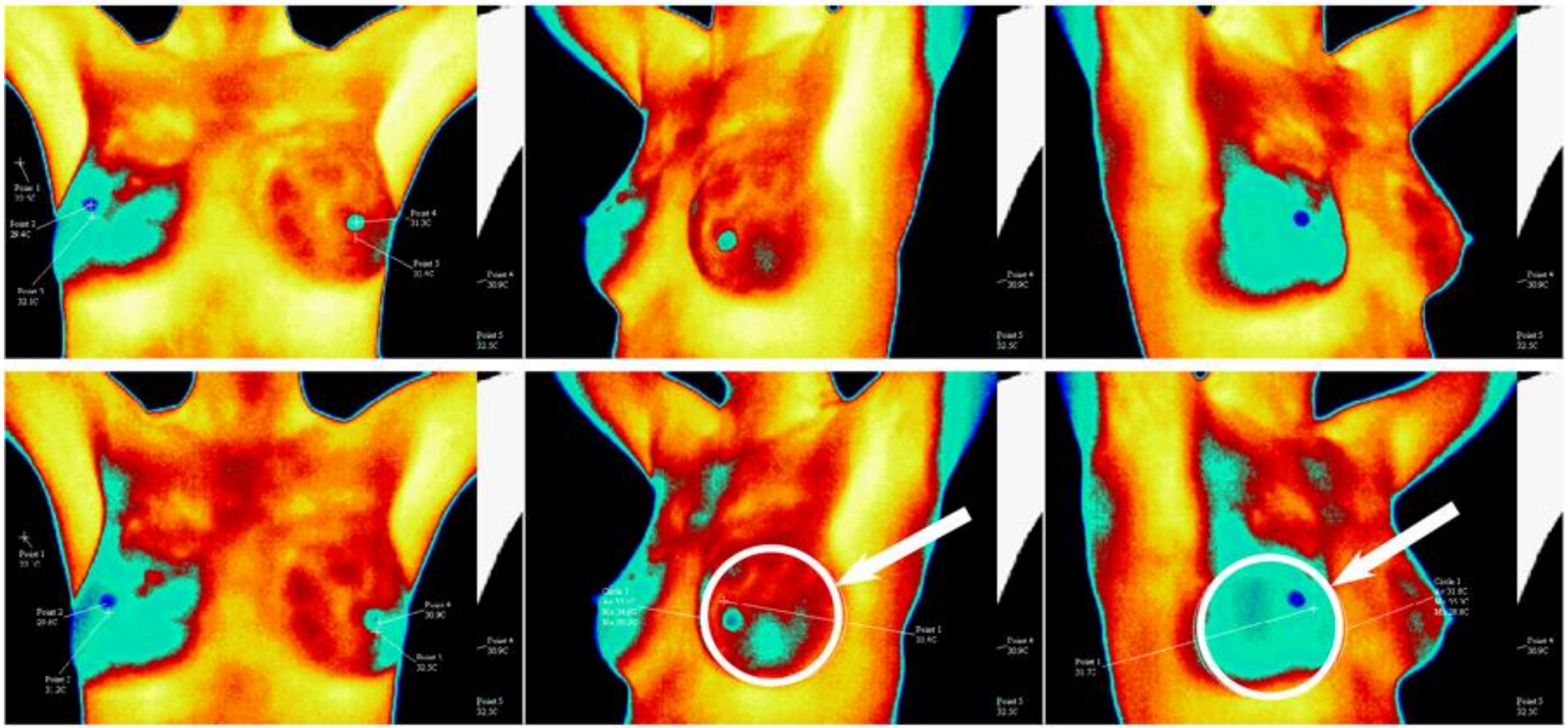


Source: https://electronics.howstuffworks.com/gadgets/high-tech-gadgets/nightvision2.htm

THERMOGRAPHY

Infrared imaging

Applications: Mammography

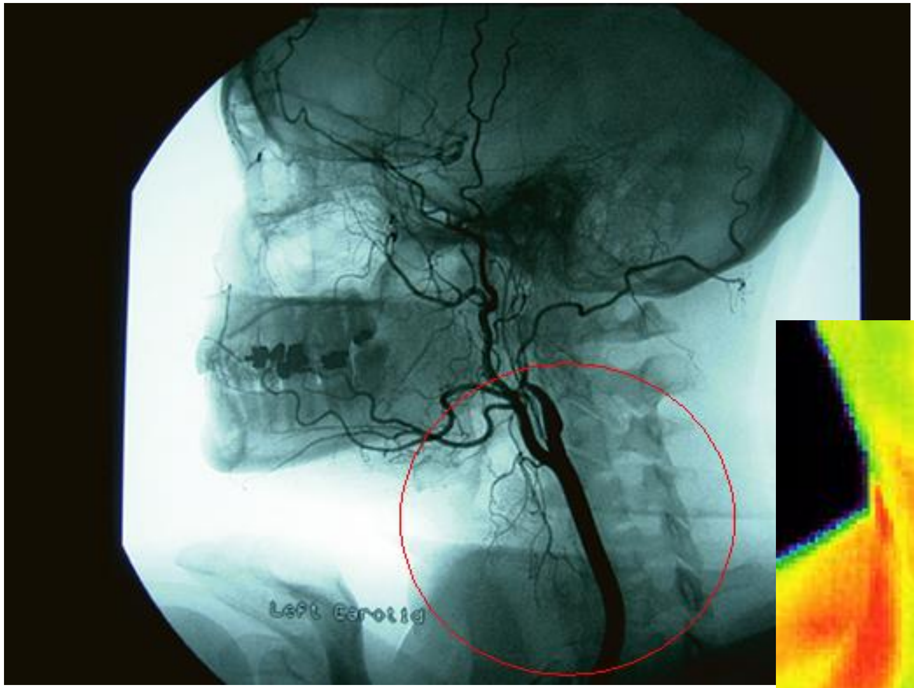


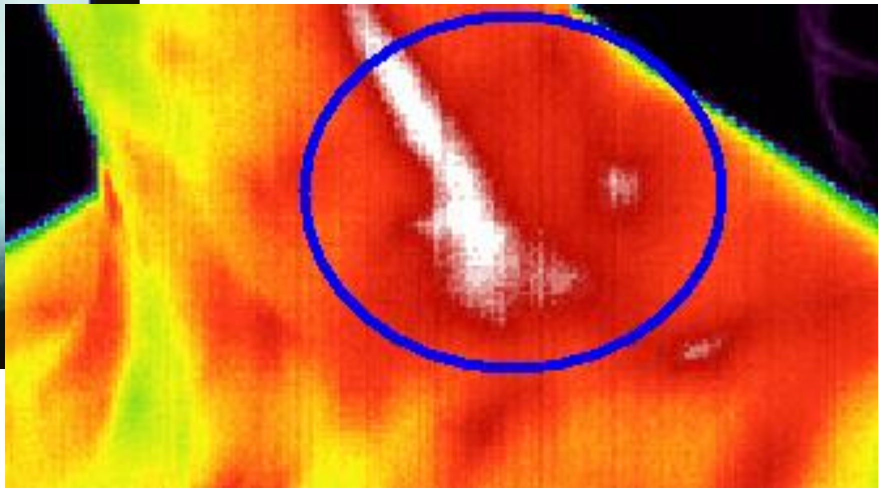
Source: http://clinicalthermography.com/breast-thermography-overview-ppnf/

THERMOGRAPHY

Infrared imaging

Applications: Vessel investigation

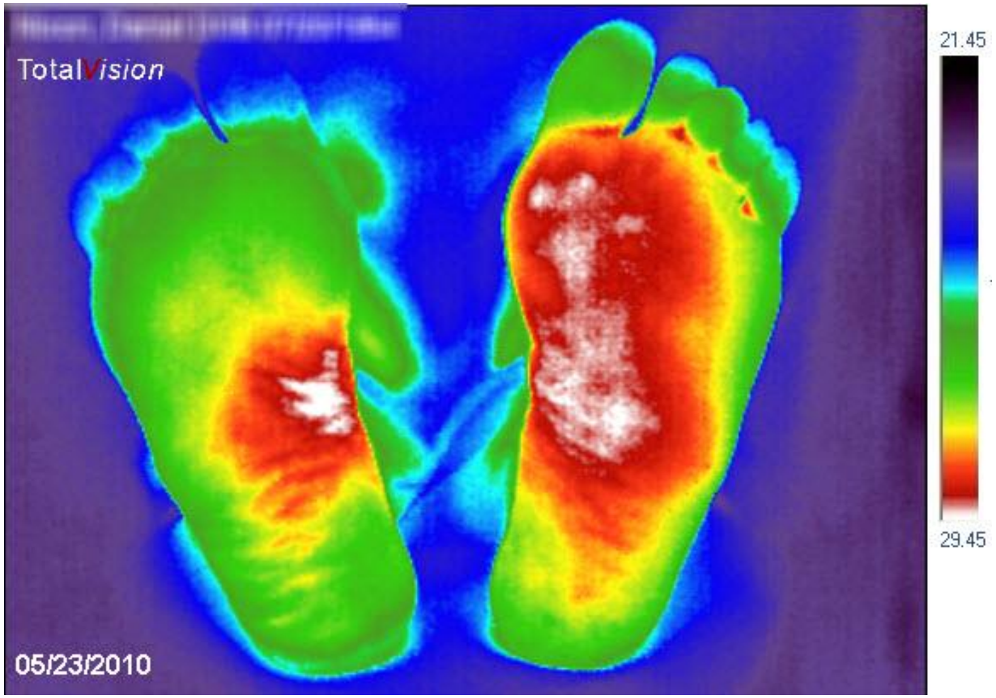




THERMOGRAPHY

Infrared imaging

Applications: Diabetes



Source: https://electronics.howstuffworks.com/gadgets/high-tech-gadgets/nightvision2.htm

THERMOGRAPHY

Infrared imaging

Applications: Spinal cord

Source: https://electronics.howstuffworks.com/gadgets/high-tech-gadgets/nightvision2.htm

LECTURE CONTENTS

1. **Introduction**

2. **Digital Imaging Systems**

   α. X-ray radiography
   β. X-ray mammography
   γ. X-ray Computed Tomography (CT)
   δ. Ultrasonography
   ε. Nuclear Magnetic Resonance Imaging (MRI)
   στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
   ζ. Thermography
   η. Hybrid Systems (PET-CT, MRI-PET)
   θ. Microscopy

3. **Decision Support Systems**

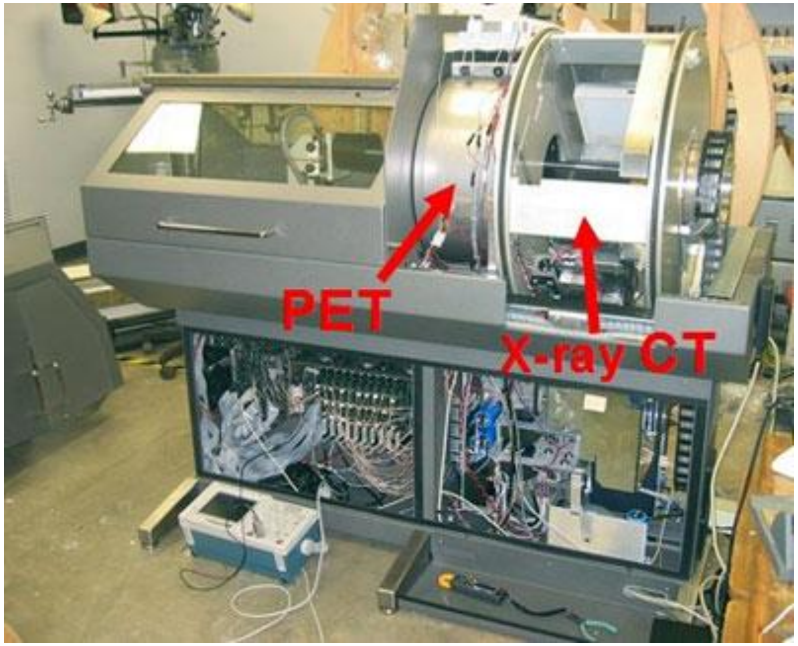
4. **Case study: Early detection of melanoma:**

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Brief historical survey

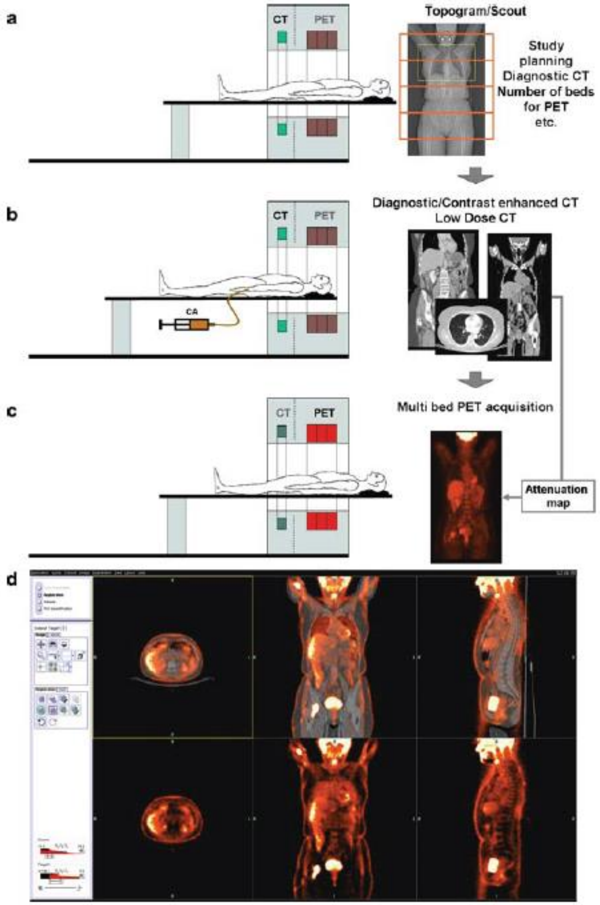
Year	Researcher	Accomplishment
1999	Townsend, Nutt	First hybrid PET-CT



Source: http://www.mdanderson.org/education-and-research/departments-programs-and-labs/labs/pet-development-laboratory/research/micro-pet-ct-camera/index.html

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)



PET-CT

1.Quick body scan to specify region of interest

2.Thorough CT scan

3.PET scan

4.Registration and fusion of CT and PET images

Source: http://link.springer.com/chapter/10.1007%2F978-3-540-72718-7_6#page-1

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

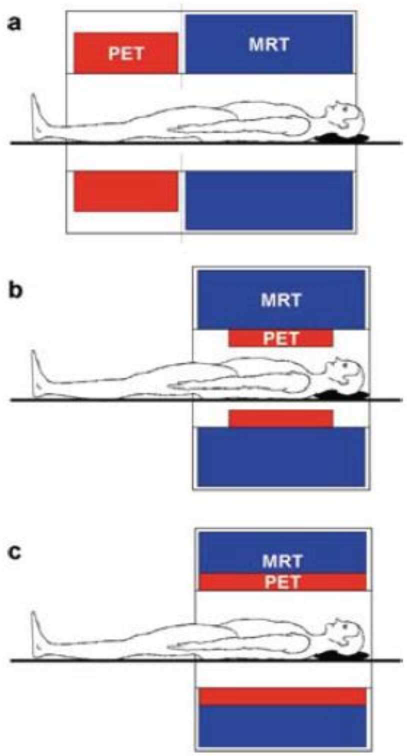
-PET-CT applications:

•Oncology

- PET/CT improves sensitivity in staging of cancer with 84% accuracy against 63-64% accuracy when using only PET or only CT CT (Antoch et al. (2004))
- PET/CT provides about 50% more information thatn using only PET or only CT (BarShalom et al. (2003)), something that changes treatment planning in 14% of patients included in the study
- PET/CT contributes in optimal treatment radiotherapy planning (Herrmann (2005);Scarfone et al. (2004))

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)



PET-MRI

-Sometimes CT doesn't obtain sufficient contrast for soft tissues even though contrast agents might be utilized

-The necessary dose is high for CT

-The significant advantage of PET/CT is when imaging lungs and bones

-For soft tissues (i.e. brain, vital organs), PET/MRI has excellent resolution and contrast

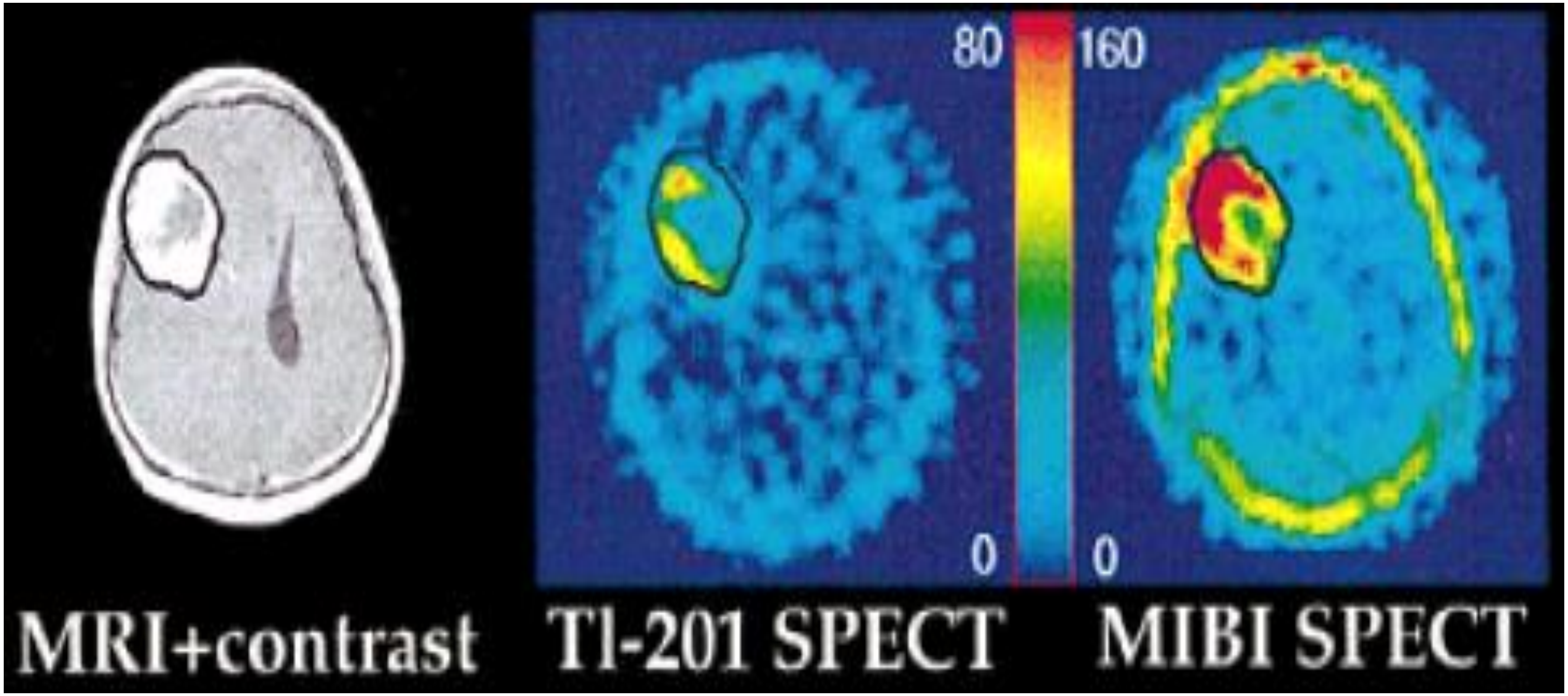
-MRI does not use ionizing radiation

Source: http://link.springer.com/chapter/10.1007%2F978-3-540-72718-7_6#page-1

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Brain

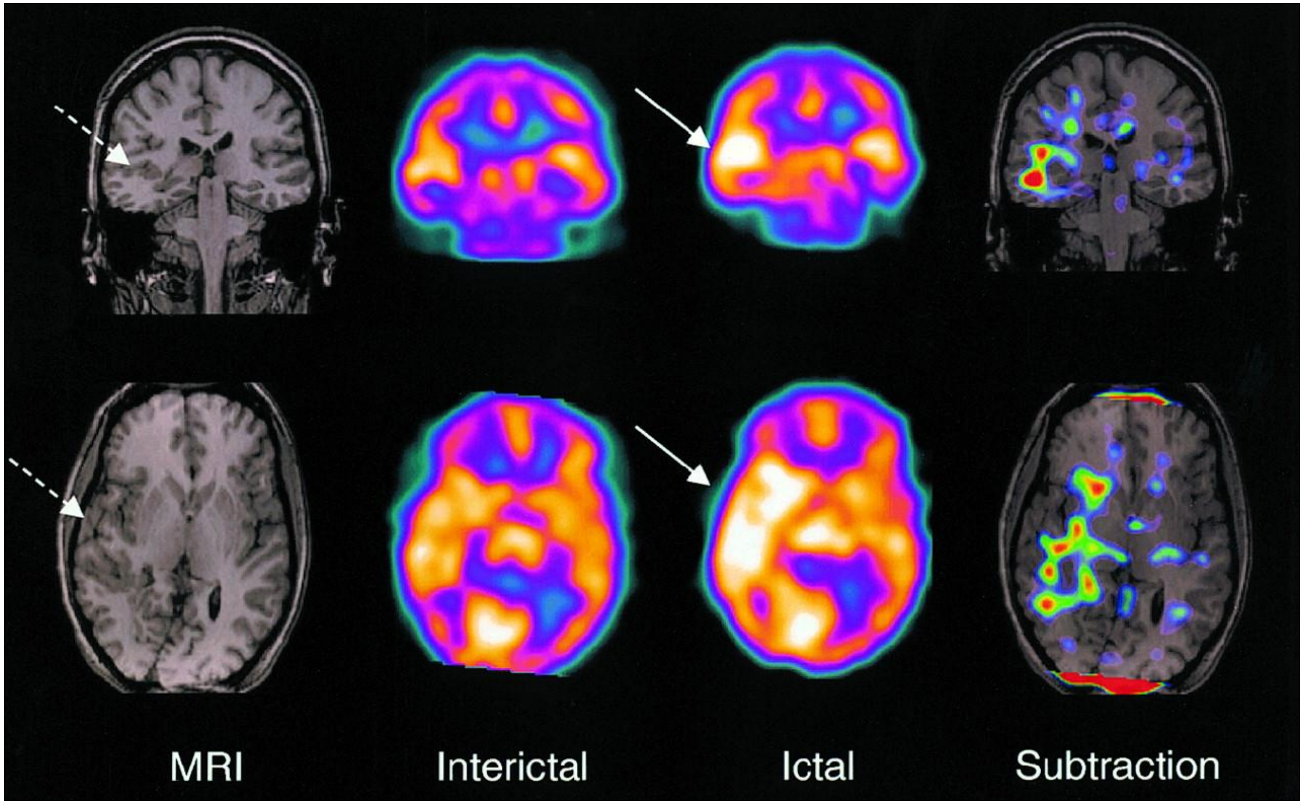


Source: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3101722/

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Brain

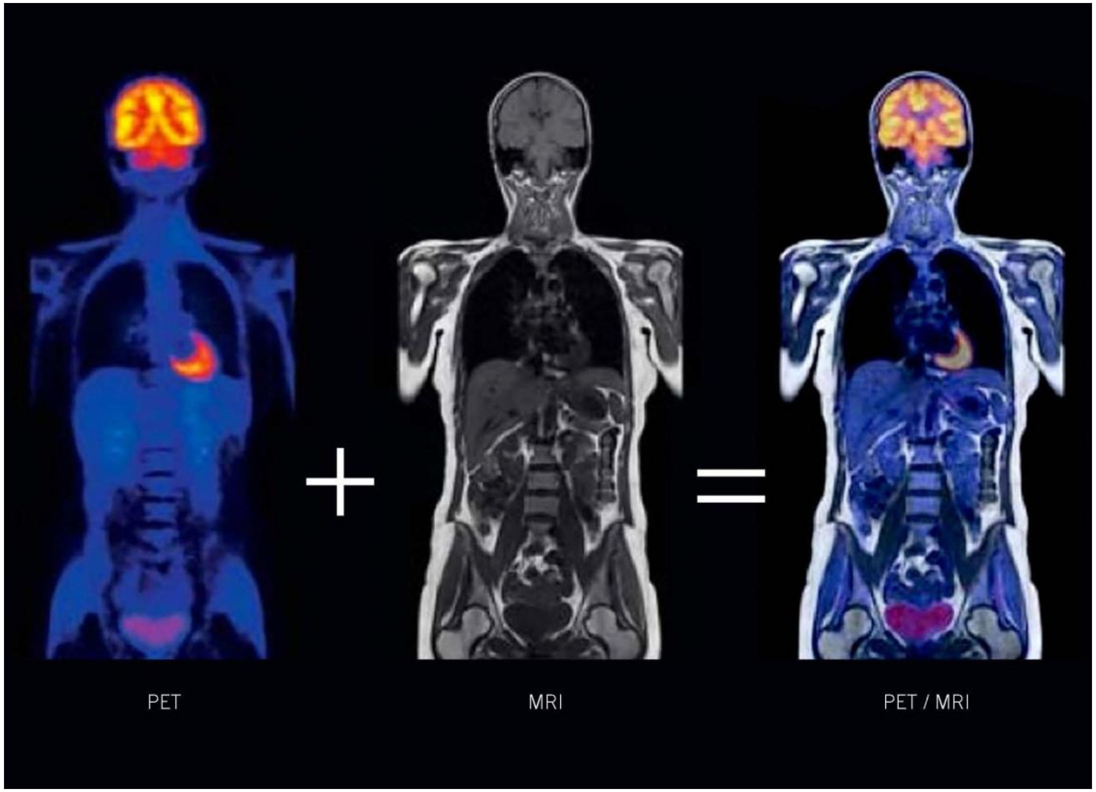


Source:
http://jnm.snmjournals.org/content/41/10/1619/F1.expansion.html

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Soft tissues

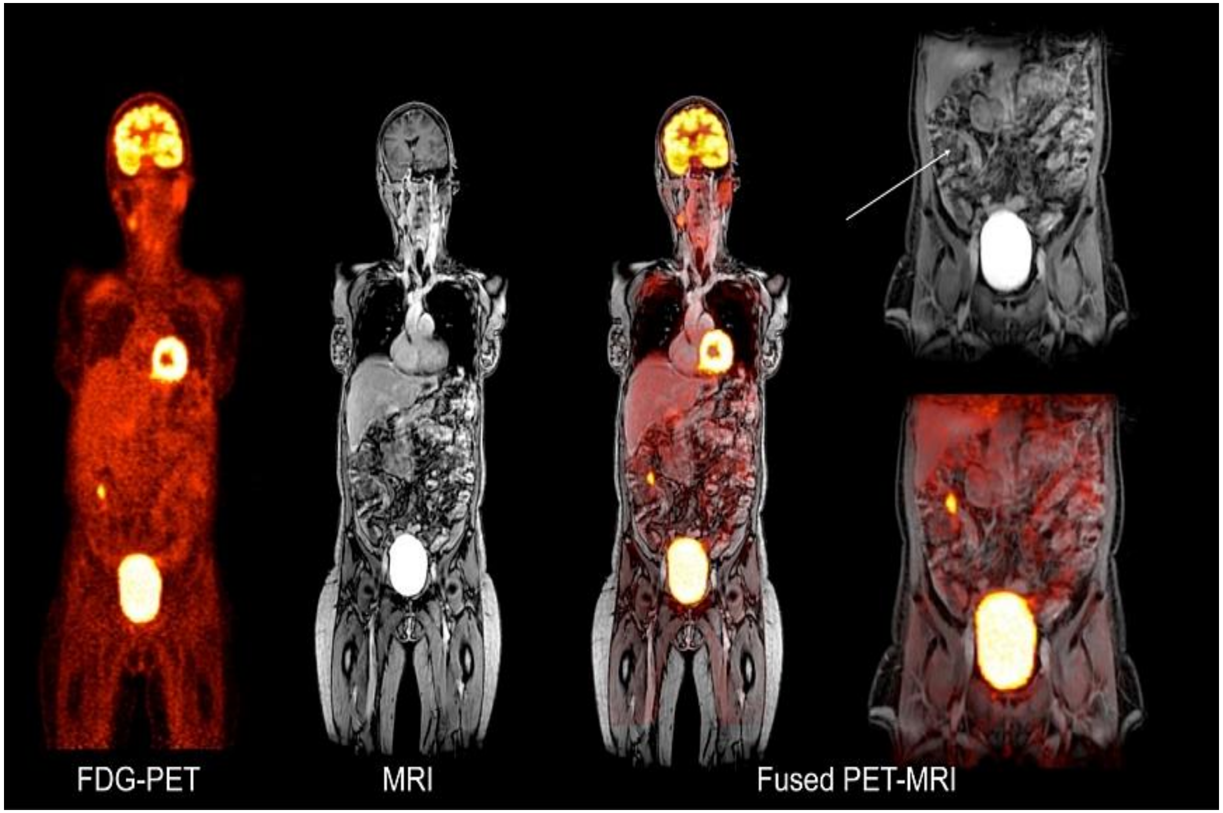


Source: http://link.springer.com/chapter/10.1007%2F978-3-540-72718-7_6#page-1

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Soft tissues

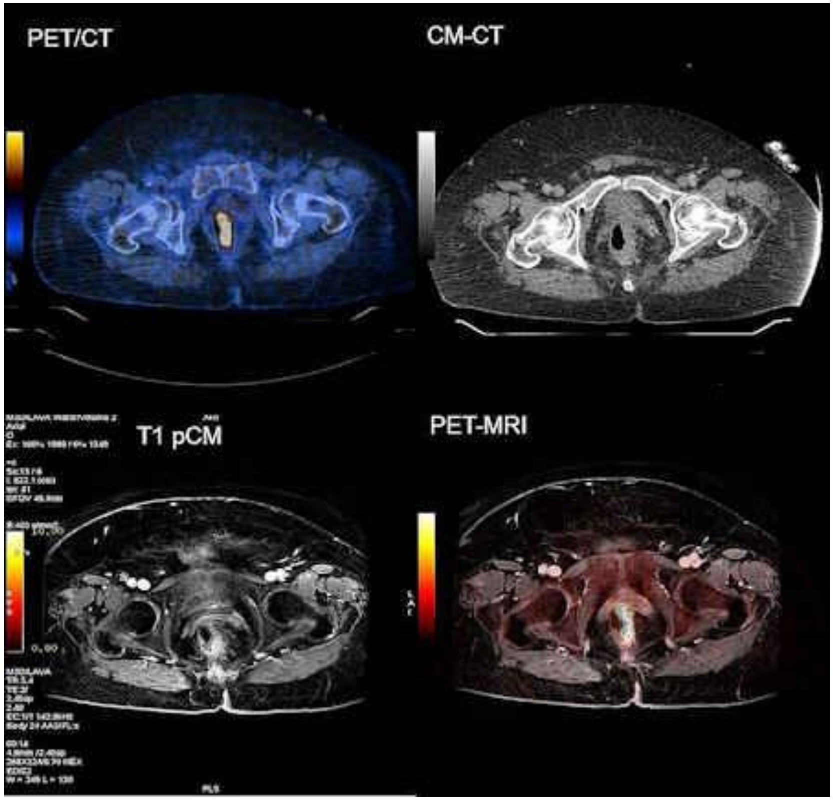


Source: http://www.intechopen.com/books/inflammatory-bowel-disease/the-imaging-of-inflammatory-bowel-disease-current-concepts-and-future-directions

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Soft tissues (intestines)

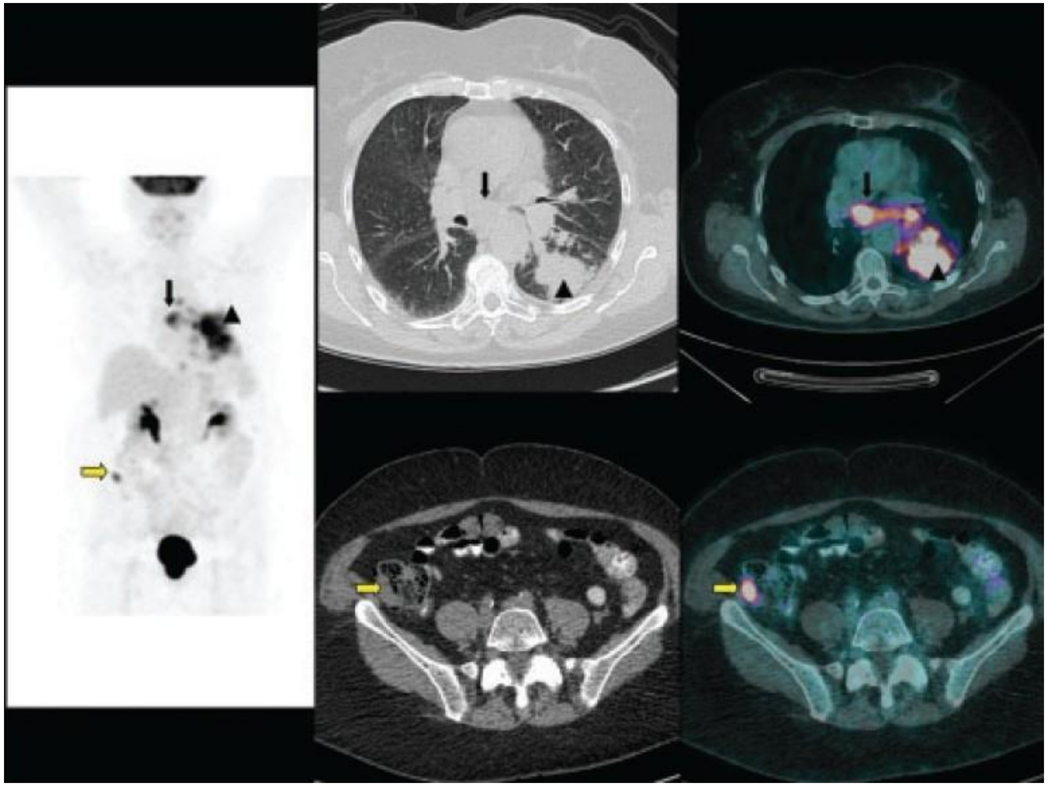


Source: http://www.auntminnieeurope.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=607257

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Lung

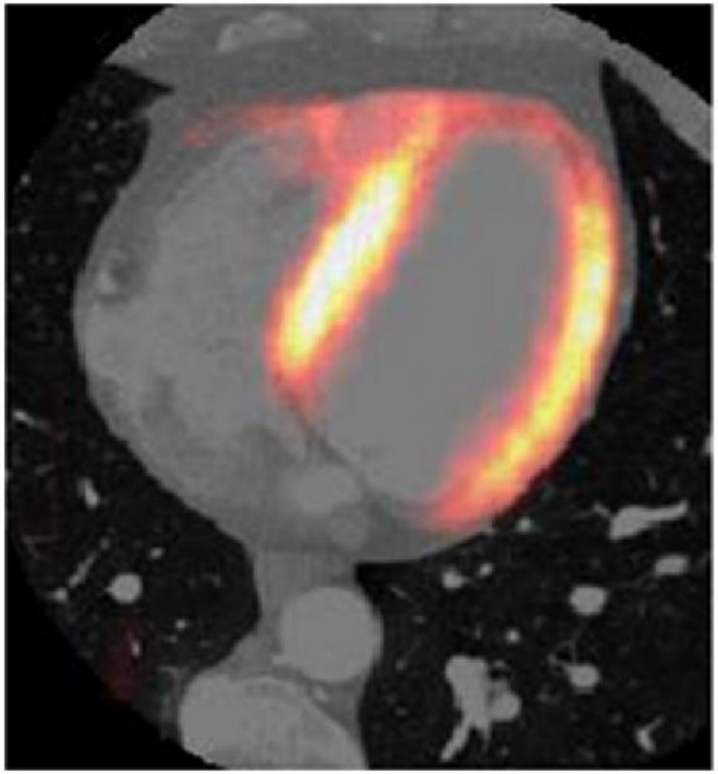


Source: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3101722/

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Cardiac studies

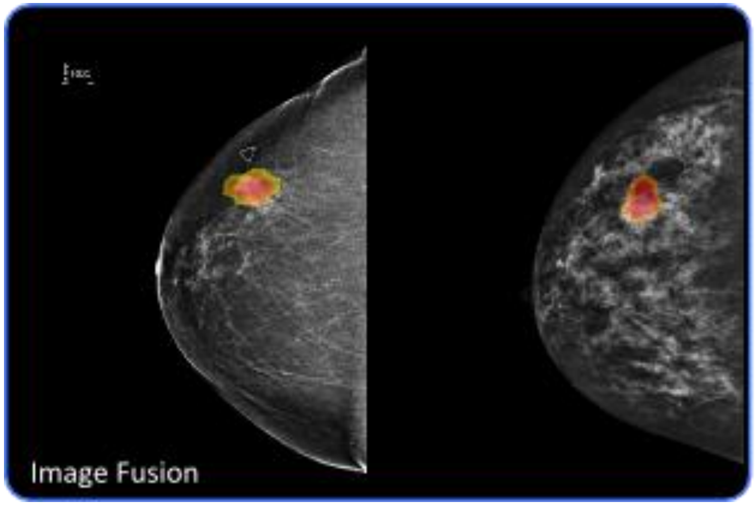


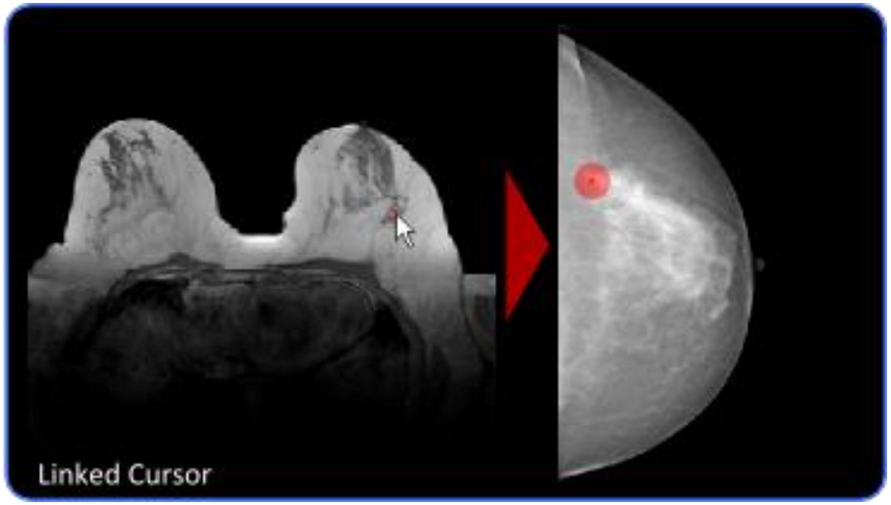
Source: http://www.hindawi.com/journals/tswj/2012/567067/

HYBRID SYSTEMS

Anatomy (Morphology) + Functionality (Metabolism)

Applications: Mammography





Source: http://ipelsdf1.lsdf.kit.edu/index.php/nav-pro-projects/nav-pro-act-mbir

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

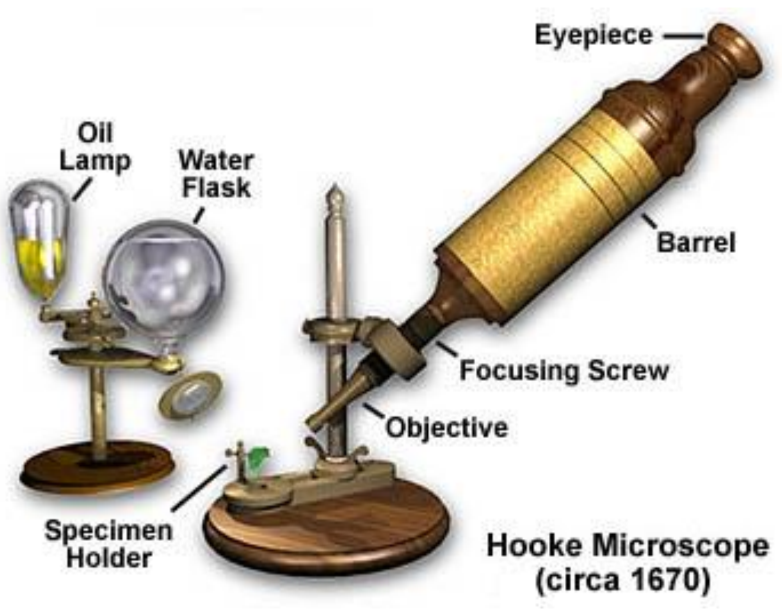
4. Case study: Early detection of melanoma:

MICROSCOPY

Tissues, cells, proteins, genes

Basic principles

Year	Researcher	Accomplishment
1670	Robert Hooke	Presents a study for the investigation of seemingly invisible objects. First time reference to the work 'cell'



Robert Hooke: 1635 – 1703, English philosopher, architect, scientist

-Μικρό (Micro-small)

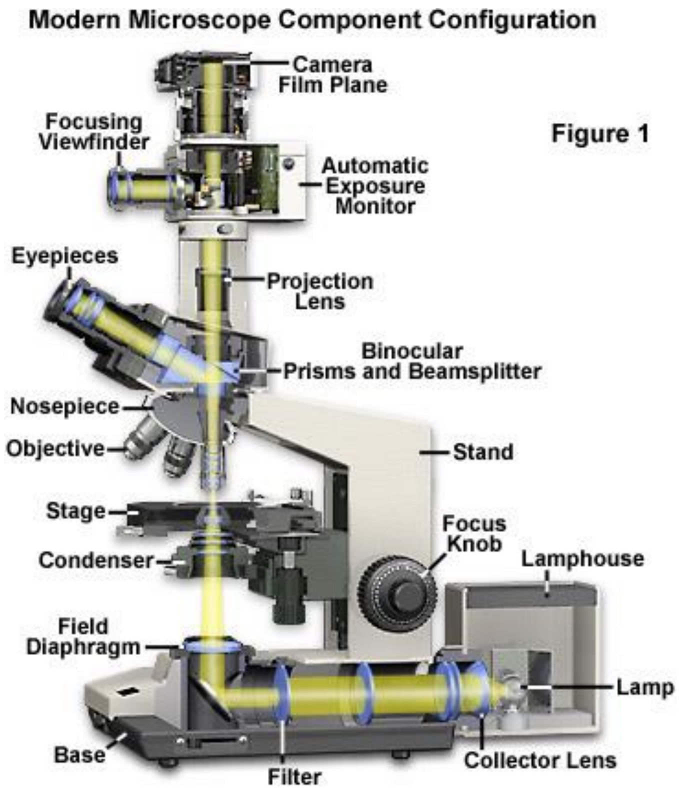
-Σκοπώ (Scope-to visually observe, to examine, to investigate)

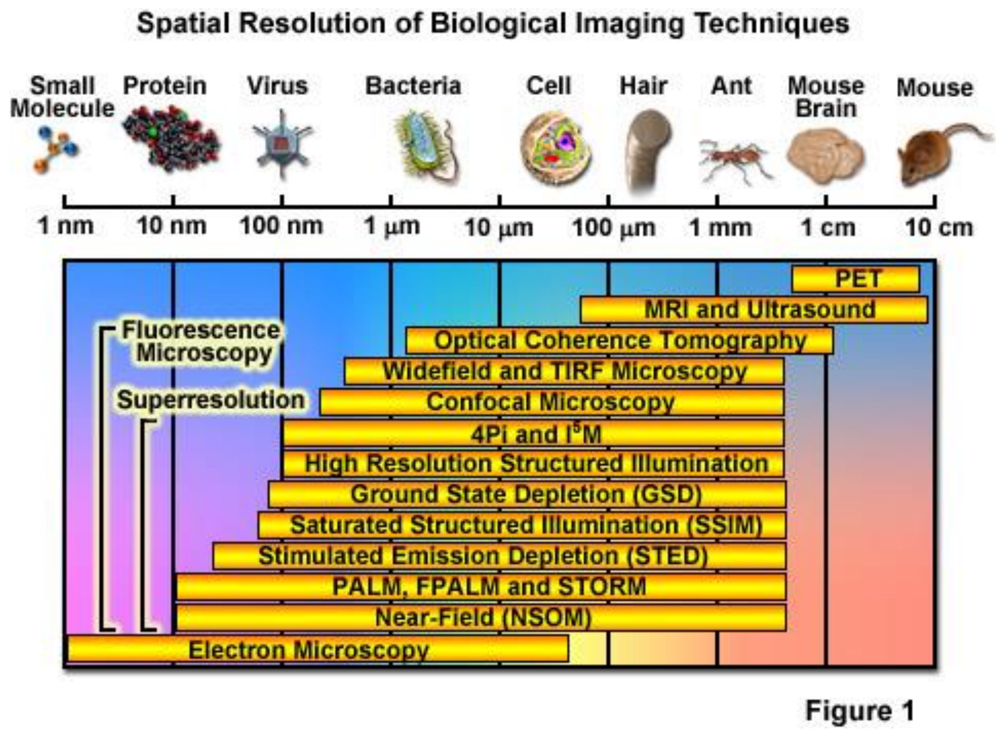
Source: http://micro.magnet.fsu.edu/primer/museum/hooke.html

MICROSCOPY

Tissues, cells, proteins, genes

Basic principles





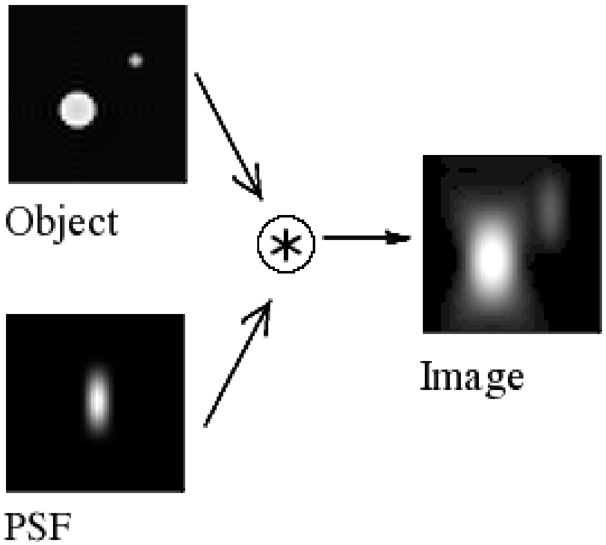
Source: http://zeiss-campus.magnet.fsu.edu/articles/superresolution/introduction.html

MICROSCOPY

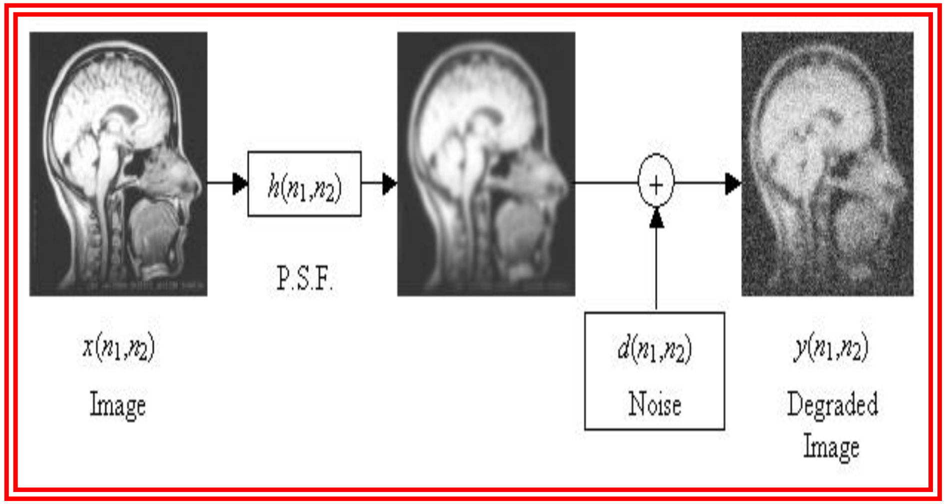
Tissues, cells, proteins, genes

Deconvolution: Model sources of image degradation and apply an inverse process to remove them

- Improve visual presentation of the image + prepare image for segmentation
- **Why the image has poor quality? Why we need to enhance the image?**



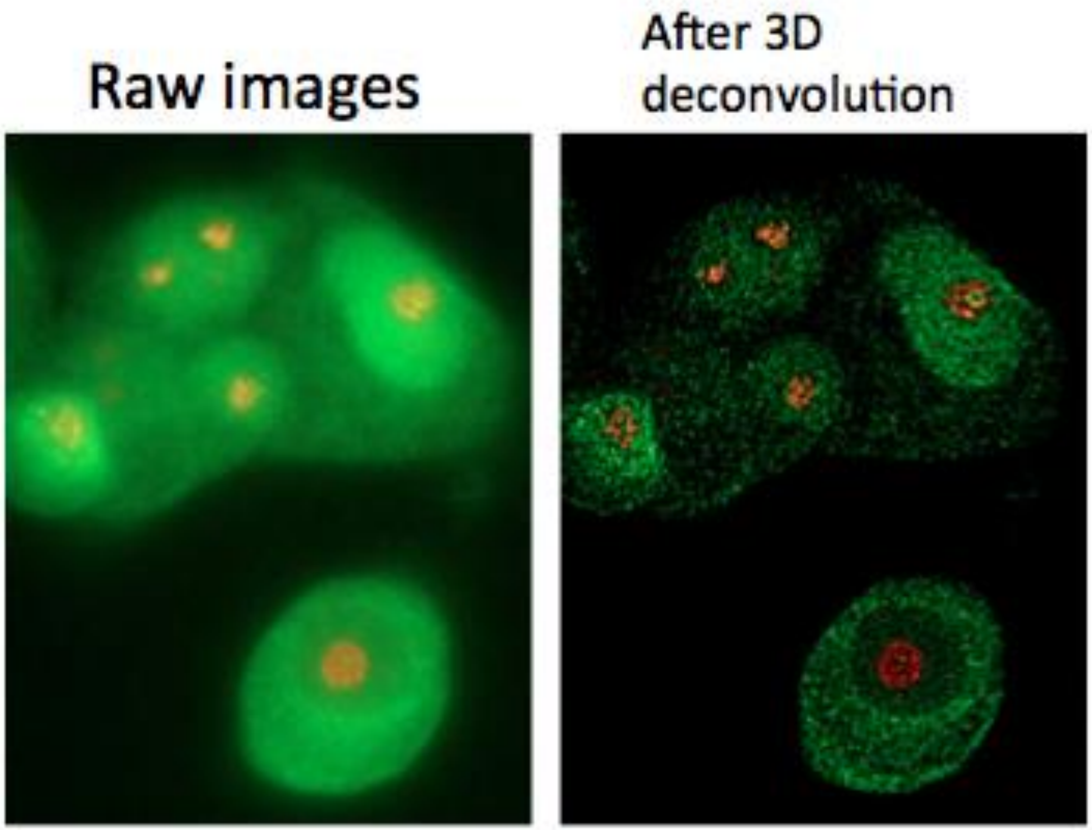
Degradation model



MICROSCOPY

Tissues, cells, proteins, genes

Deconvolution: Model sources of image degradation and apply an inverse process to remove them

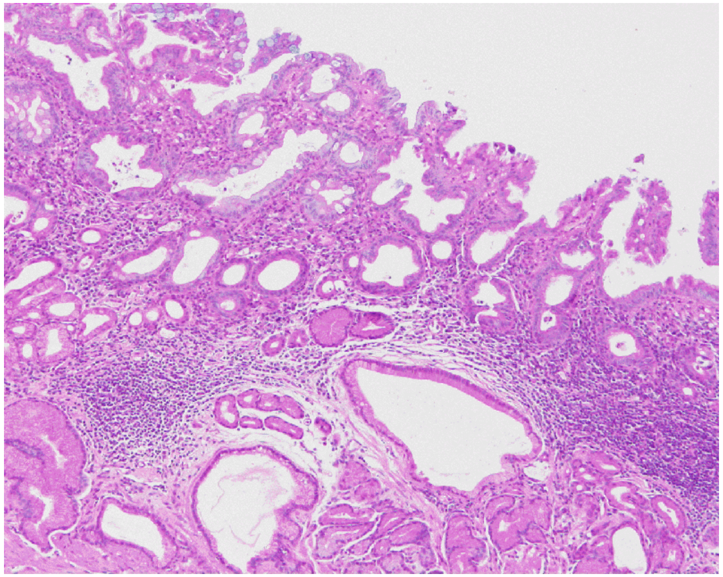


Source: https://www.sccp.sc.edu/Microscopy_Flow_Cytometry_Core_Facilities

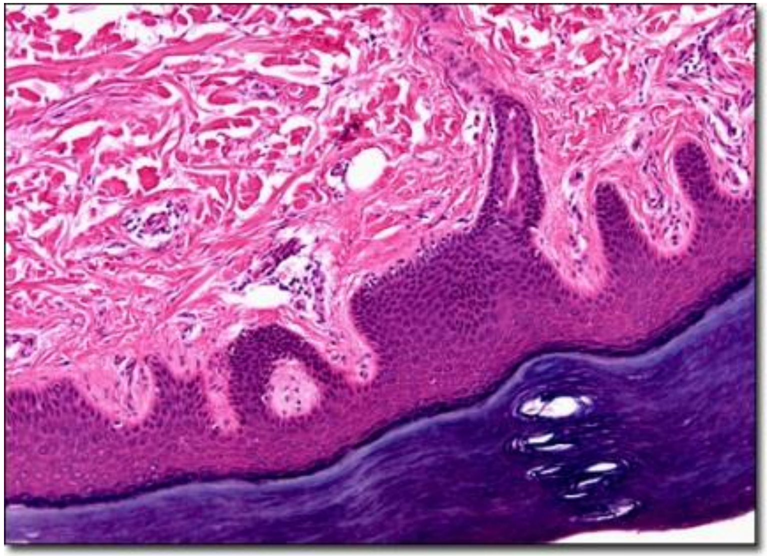
MICROSCOPY

Tissues, cells, proteins, genes

Applications: Histology



Stomach wall



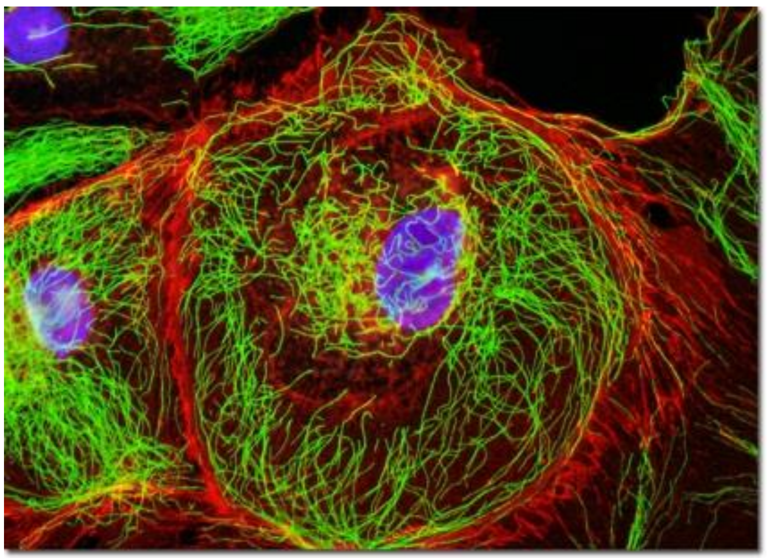
Skin

Πηγές: http://www.nikon.com/products/instruments/resources/tech/guide/overview/index_04.htm , http://micro.magnet.fsu.edu/primer/anatomy/brightfieldgallery/plantarskin10xlarge.html

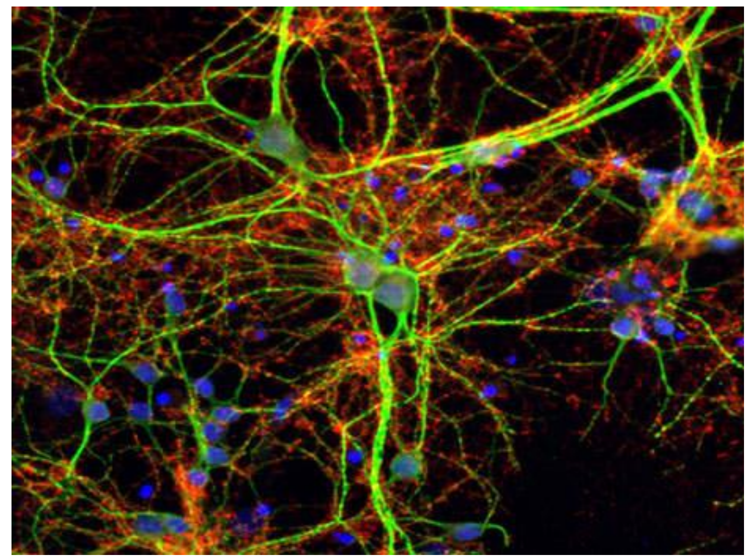
MICROSCOPY

Tissues, cells, proteins, genes

Applications: Histology



Mouse kidney



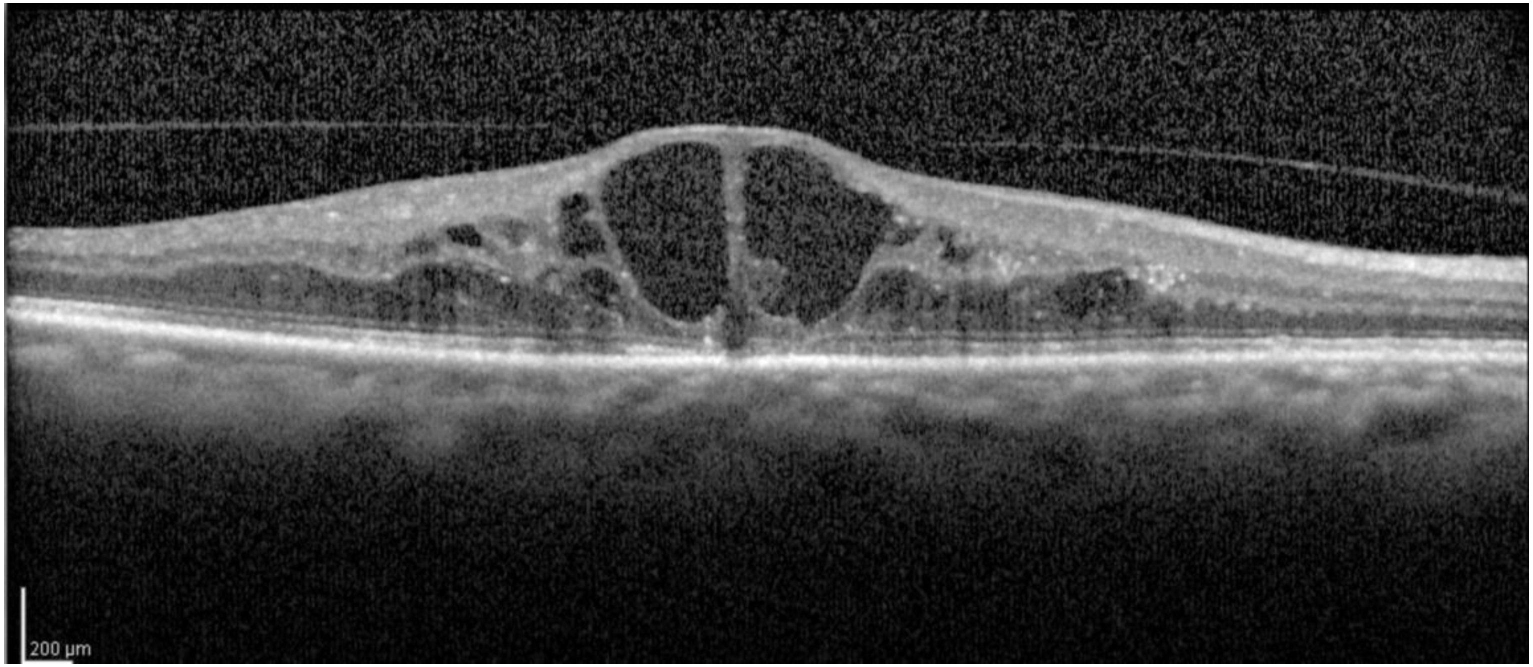
Neural cells

Πηγές: http://www.nikon.com/products/instruments/resources/tech/guide/overview/index_04.htm, http://www.piercenet.com/method/fluorescent-probes

MICROSCOPY

Tissues, cells, proteins, genes

Applications: Ophthalmology



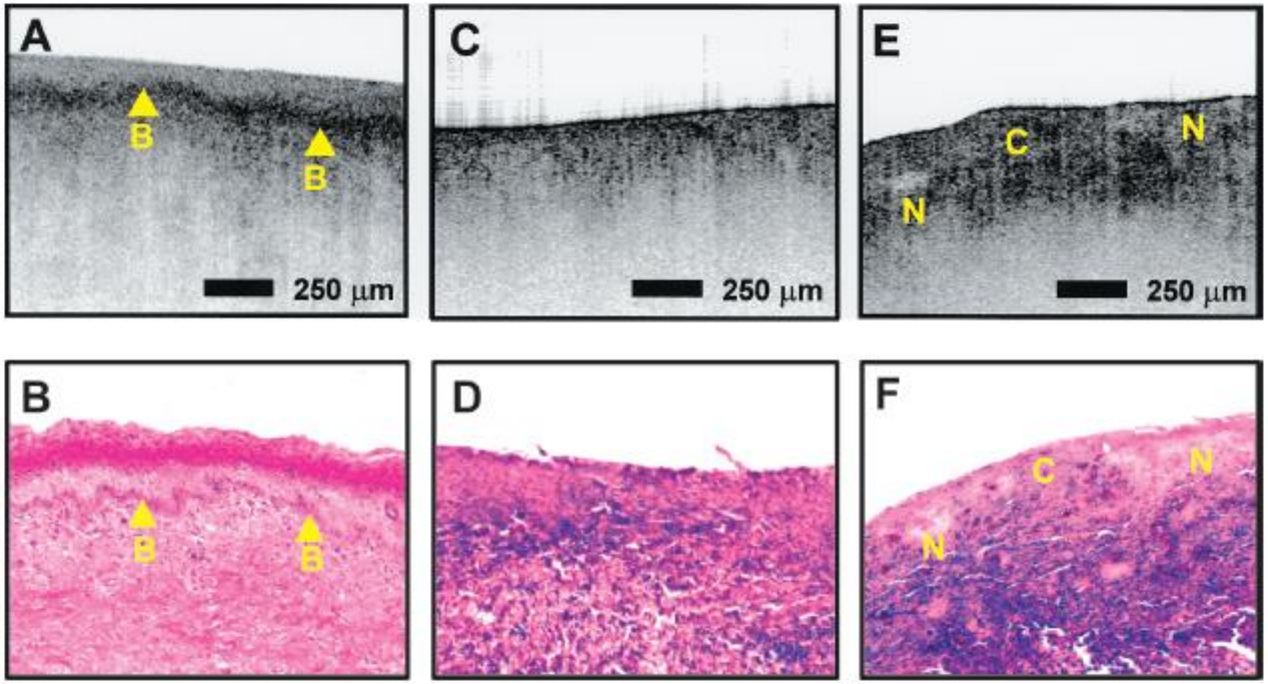
Edema in a diabetic patient

Source: http://diabetesmanager.pbworks.com/w/page/17680181/Diabetic%20Retinopathy

MICROSCOPY

Tissues, cells, proteins, genes

Applications: Uterus cancer

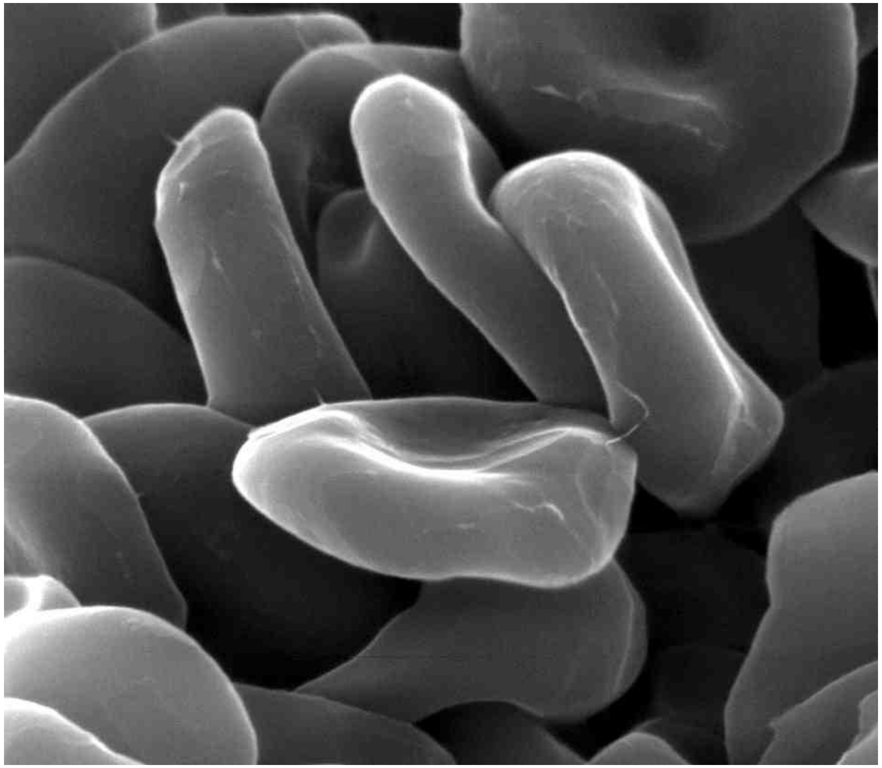


Source: http://k-space.org/ymk/OCT.pdf

MICROSCOPY

Tissues, cells, proteins, genes

Applications: Electronic microscope



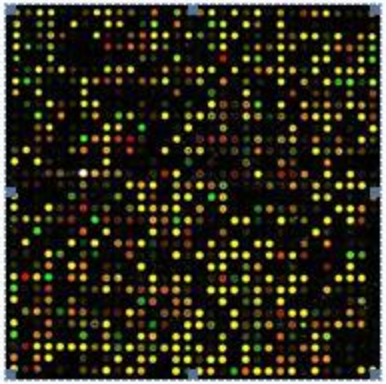
Blood cells

Source: http://www.nature.com/nnano/journal/v6/n4/fig_tab/nnano.2011.55_F1.html

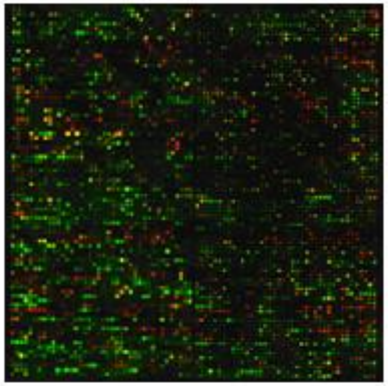
MICROSCOPY

Tissues, cells, proteins, genes

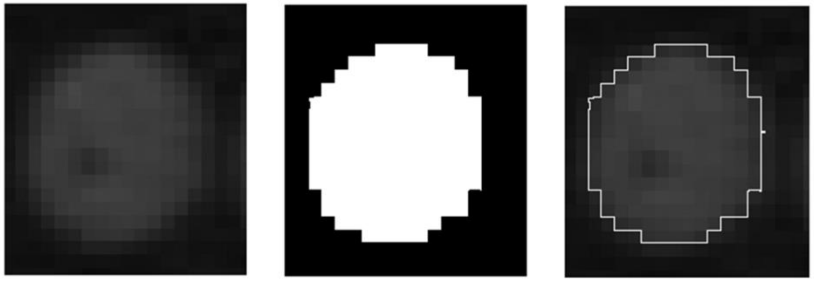
Applications: Study of genes and proteins (microarrays)

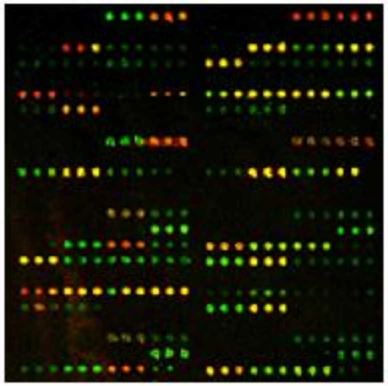


(a)



(b)





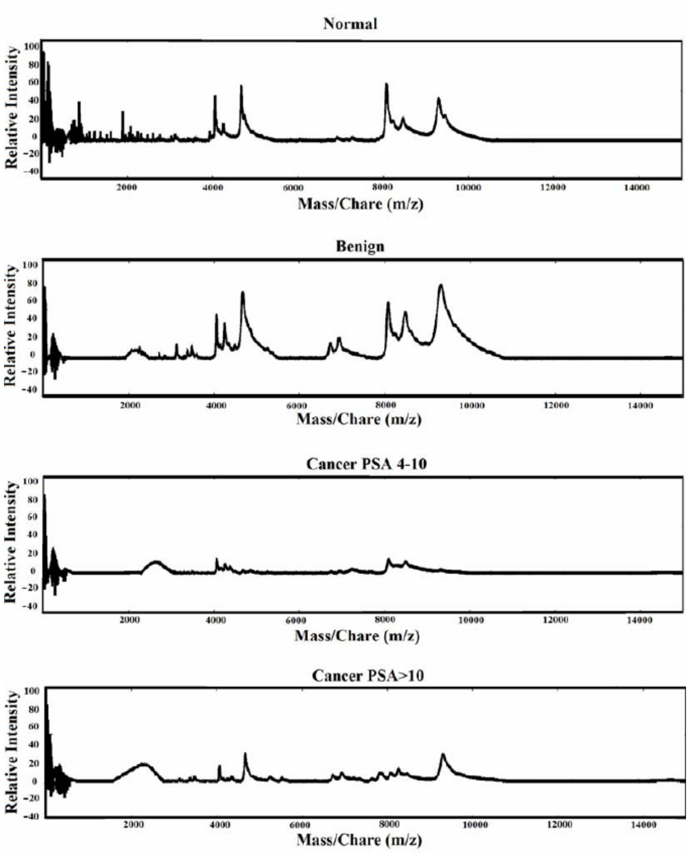
(c)

(d)

MICROSCOPY

Tissues, cells, proteins, genes

Applications: Study of biomarkers (proteomics)



LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

4. Case study: Early detection of melanoma:

DECISION SUPPORT SYSTEMS

Second Opinion – Standardization - Automation

Why decision support systems?

1/ Improving medical decision making (accuracy, intra, inter observer variability)
2/ Automation, requirement to investigate at the same time hundreds of different parameters
3/ Standardization

Medical errors can be as high as 15%, Graber, The incidence of diagnostic error in medicine, BMJ Qual Saf 2013

Medical errors comprise the 3rd biggest death factor in USA (Medical error—the third leading cause of death in the US, BMJ 2016;)

Decision support systems have been shown to improve medical decision accuracy by 10-20% (Brown, David G. 2001, Kunio Doi, 2007, Ayman El-Baz, 2013)

Second Opinion – Standardization - Automation

Brief historical survey

Year	Researcher	Accomplishment
1936	Turing	Turring Machine, a hypothetical computer
1943	Tommy Flowers	Colossus (a machine for decoding encrypted messages of Germans during the 2nd world war)
1954	Nash	He expresses the idea that computers might be used as second opinion tools in medicine
1959	Ledley	Proposes a mathematical model that could be applied in diagnosis
1961	Warner	Proposes a mathematical model that could be applied in cardiac studies
1970	University of Pittsburgh	INTERNIST I, maybe the first integrated decision support system

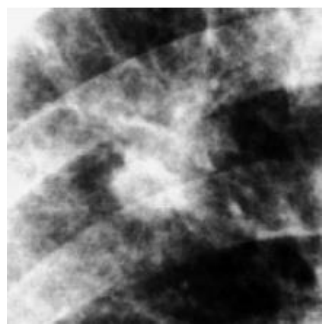
DECISION SUPPORT SYSTEMS

Second Opinion – Standardization - Automation

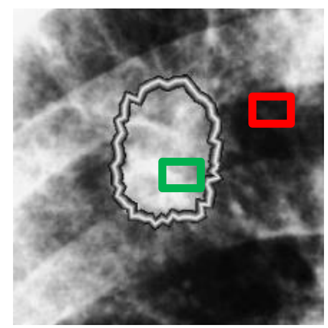
Basic principles

Original Image

Image enhancement



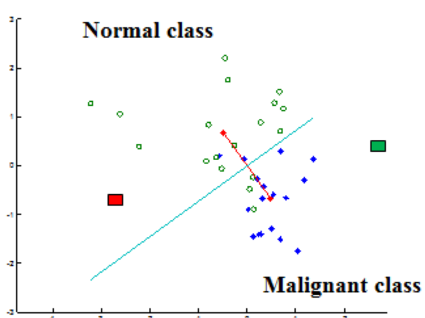
Boundary detection



Conversion to numbers

Area	2017
Density (mean)	197.50024
Diameter (mean)	50.826889
Fractal Dim.	1.1513762
Heterogeneity	.37382251
Perimeter	239.53957
Radius (max)	40.009121

Artificial Intelligence

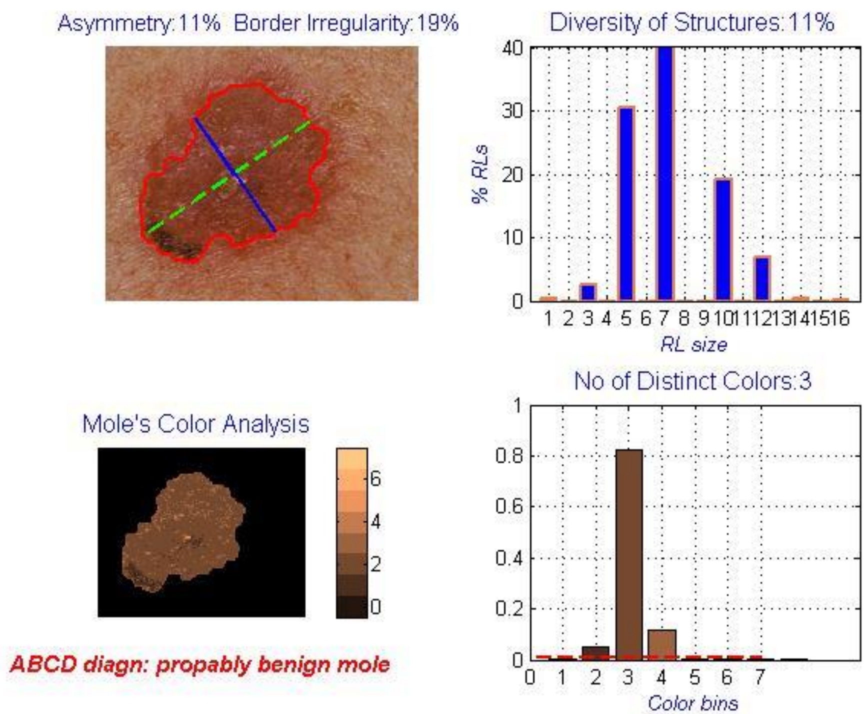


Decision making

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Early detection of melanoma



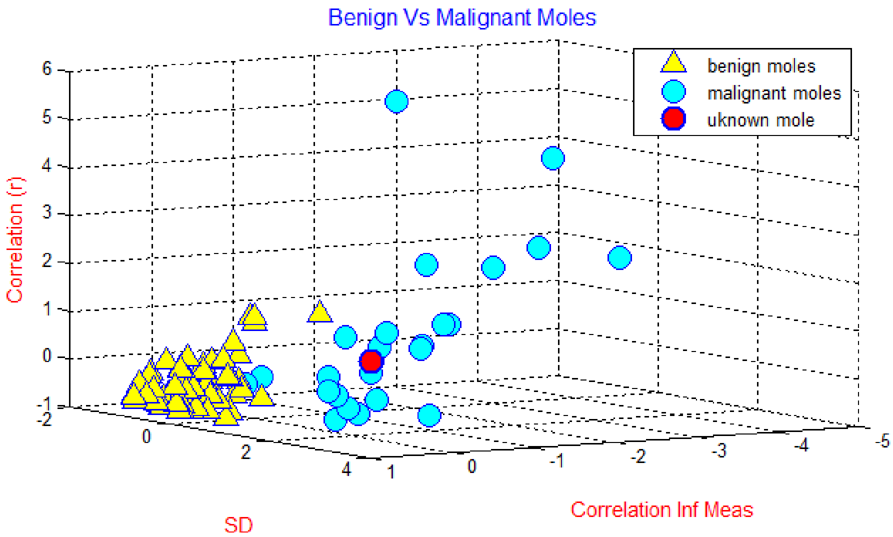
Source: S. A. Kostopoulos, P. A. Asvestas, I. K. Kalatzis, G. C. Sakellaropoulos, Th. H. Sakkis, D. A. Cavouras, D. T. Glotsos, Adaptable Pattern Recognition System for discriminating Melanocytic Nevi from Malignant Melanomas using plain photography images from different image databases., International Journal of Medical Informatics, 2017

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Early detection of melanoma

mole to be characterized



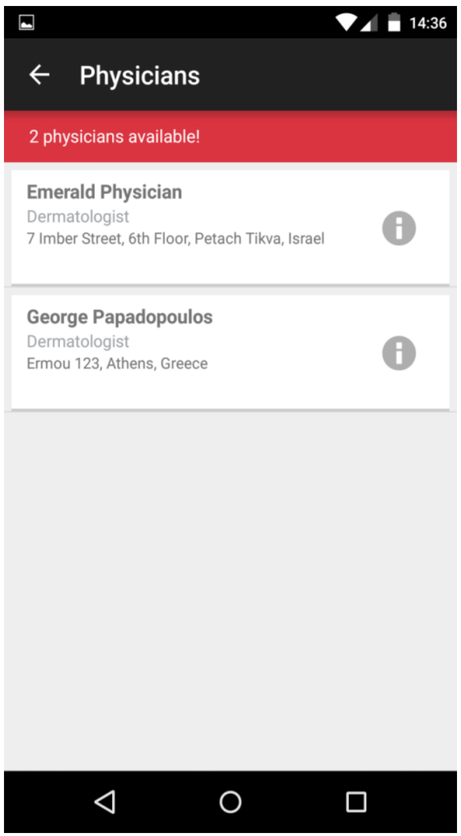
DSS assessment: probably melanoma

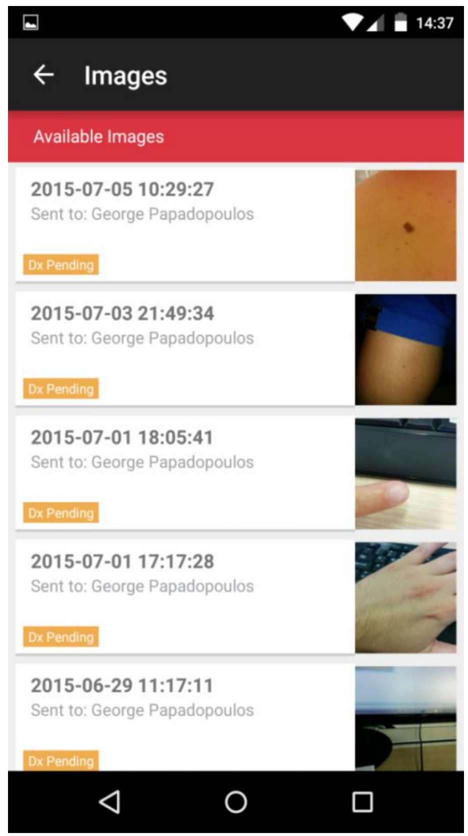
Source: S. A. Kostopoulos, P. A. Asvestas, I. K. Kalatzis, G. C. Sakellaropoulos, Th. H. Sakkis, D. A. Cavouras, D. T. Glotsos, Adaptable Pattern Recognition System for discriminating Melanocytic Nevi from Malignant Melanomas using plain photography images from different image databases., International Journal of Medical Informatics, 2017

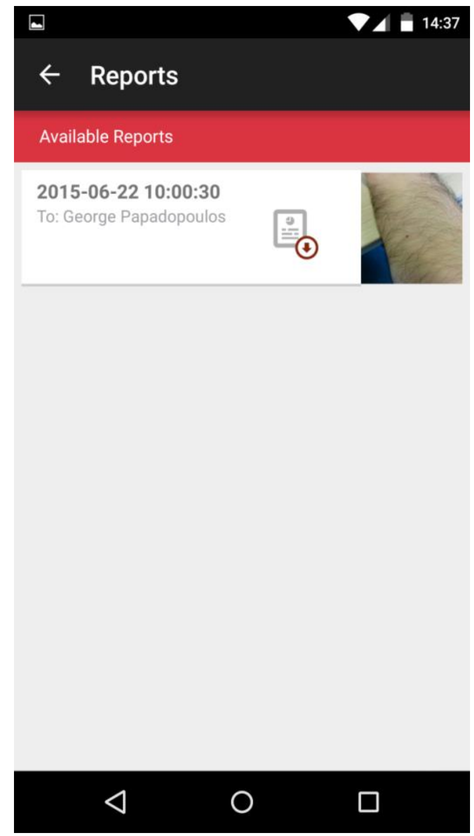
DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Early detection of melanoma



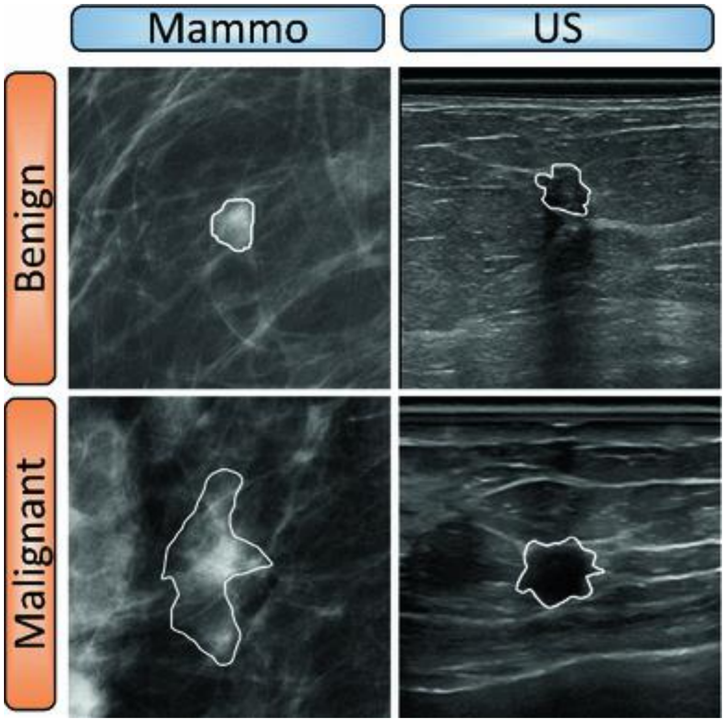




DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Breast cancer

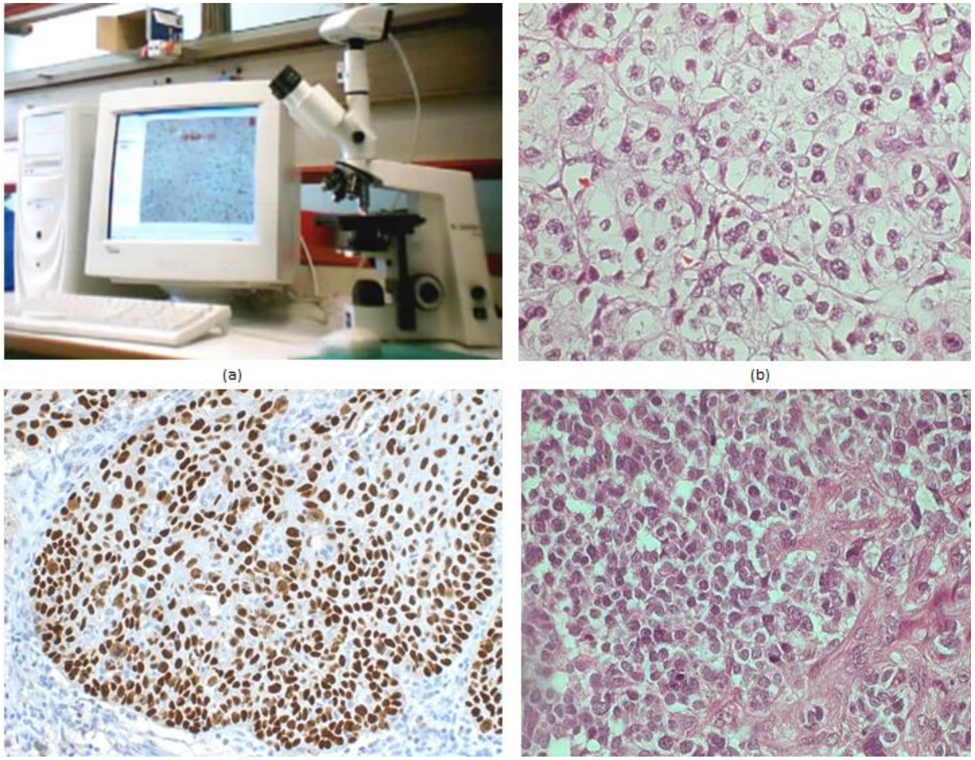


Source: Sidiropoulos et al. Multimodality GPU-based computer-assisted diagnosis of breast cancer using ultrasound and digital mammography images (2013) International Journal of Computer Assisted Radiology and Surgery, 8 (4), pp. 547-560.

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Malignancy grading in histopathology



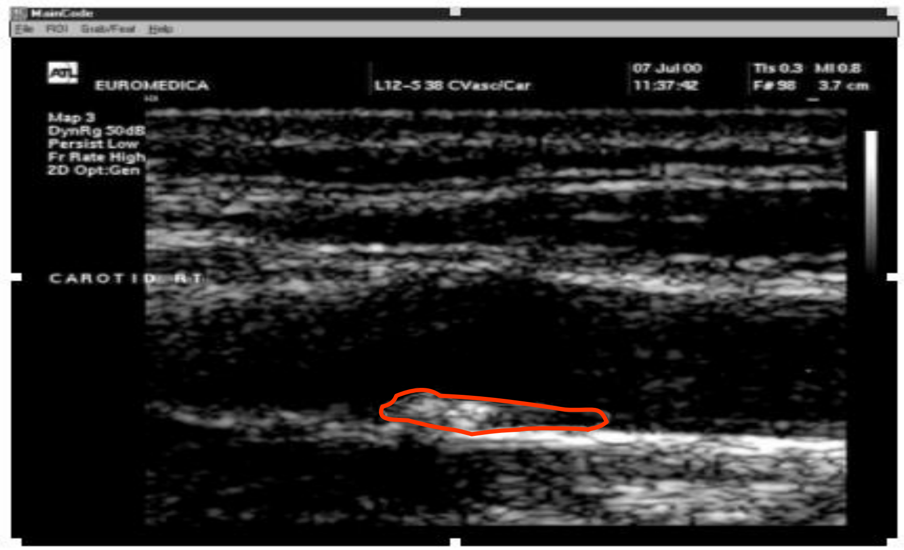
(a) (b) (c) (d)

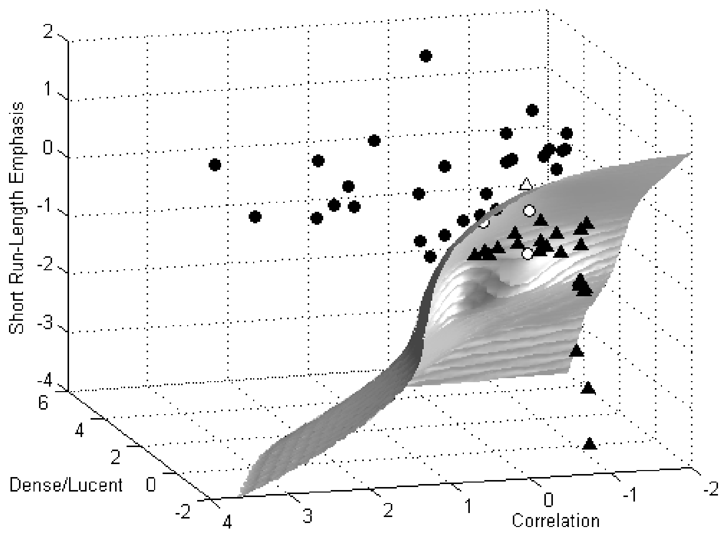
Πηγές: *Glotsos, D., Kalatzis, I., Spyridonos, P., Kostopoulos, S., Daskalakis, A., Athanasiadis, E., Ravazoula, P., Nikiforidis, G., Cavouras, D. Improving accuracy in astrocytomas grading by integrating a robust least squares mapping driven support vector machine classifier into a two level grade classification scheme (2008) Computer Methods and Programs in Biomedicine, 90 (3), pp. 251-261. Kostopoulos, S., Glotsos, D., Cavouras, D., Daskalakis, A., Kalatzis, I., Georgiadis, P., Bougioukos, P., Ravazoula, P., Nikiforidis, G.Computer-based association of the texture of expressed estrogen receptor nuclei with histologic grade using immunohistochemically-stained breast carcinomas (2009) Analytical and Quantitative Cytology and Histology, 31 (4), pp. 187-196.*

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Localization of atheromatic plaques



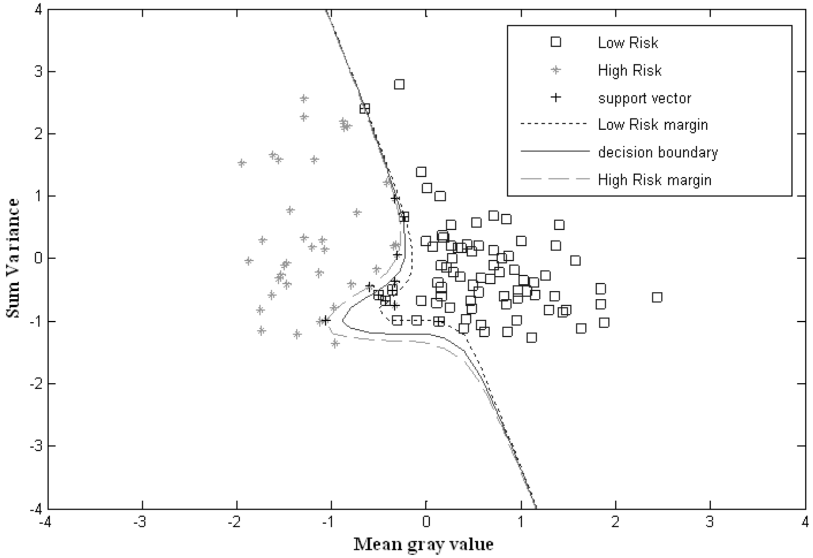


Source: *N. Pilliouras, I. Kalatzis, P. Theocharakis, N. Dimitropoulos, and D. Cavouras, "Development of the Probabilistic Neural Network - Cubic Least Squares Mapping (PNN-LSM3) classifier to assess carotid plaque's risk", Pattern Recognition Letters, Vol. 25, No 2, pp. 249-258, January 2004.*

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Risk evaluation of thyroid nodules



Source: *Tsantis S., Glotsos D., Kalatzis I., Dimitropoulos N., Nikiforidis G., Cavouras D. "Automatic Contour Delineation of Thyroid Nodules in Ultrasound Images Employing the Wavelet Transform Modulus-Maxima Chains", 1st International Conference "From Scientific Computing to Computational Engineering" (1st IC-SCCE), Athens, Greece, September 18-10, 2004.*

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Discriminating patients with diabetes

SPECT images for determining cerebral abnormalities 223

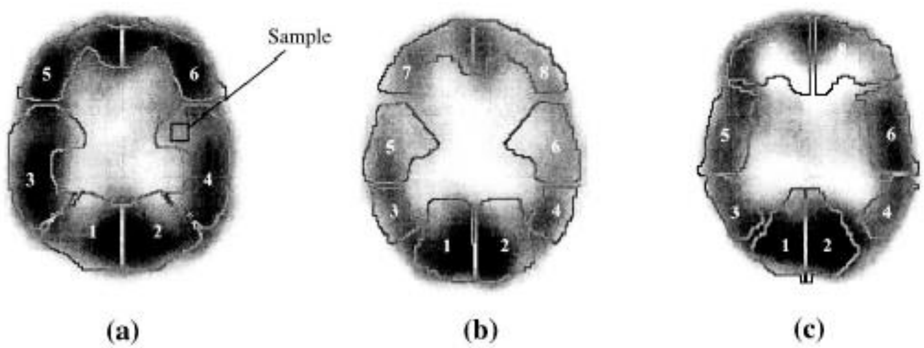


Figure 1. Three brain SPECT transverse slices (a), (b), and (c), segmented into regions of interest (ROIs). Each ROI was automatically divided into numerous small square image-samples, such as in (a).

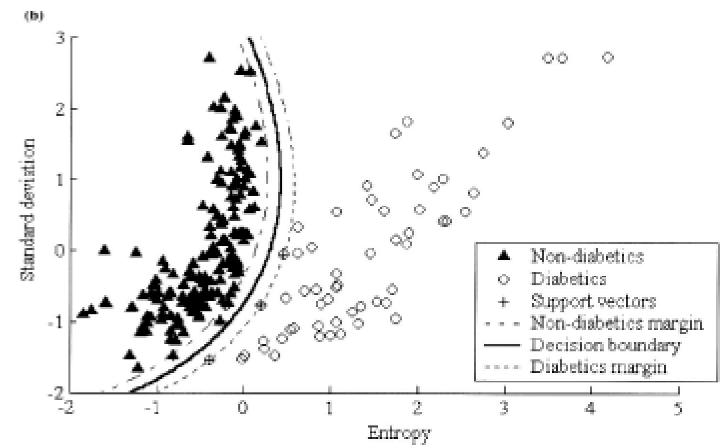


Figure 3. 'Standard deviation–Entropy' plots (normalized values) and decision boundaries drawn by (a) the LSMD classifier and (b) the SVM classifier, for the ROI corresponding to the right occipital lobule.

Source: *Kalatzis, D. Pappas, N. Piliouras, and D. Cavouras, "Support Vector Machines Based Analysis of Brain SPECT Images for Determining Cerebral Abnormalities in Asymptomatic Diabetic Patients", Medical Informatics and the Internet in Medicine, Vol. 28, No 3, pp. 221-230, September 2003.*

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

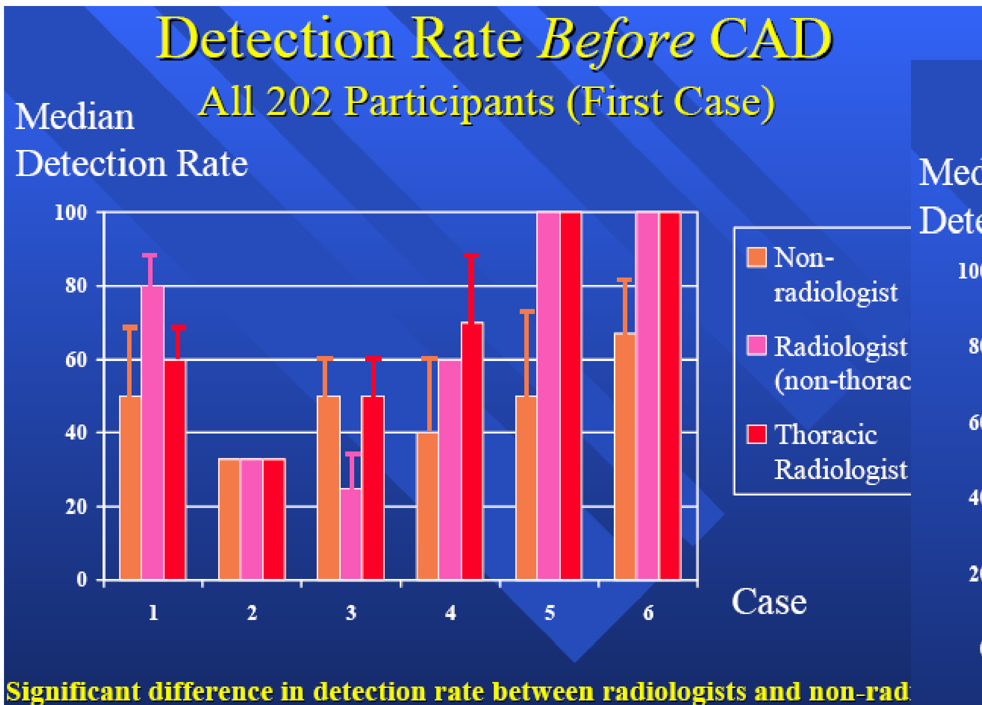
Applications: Commercial packages

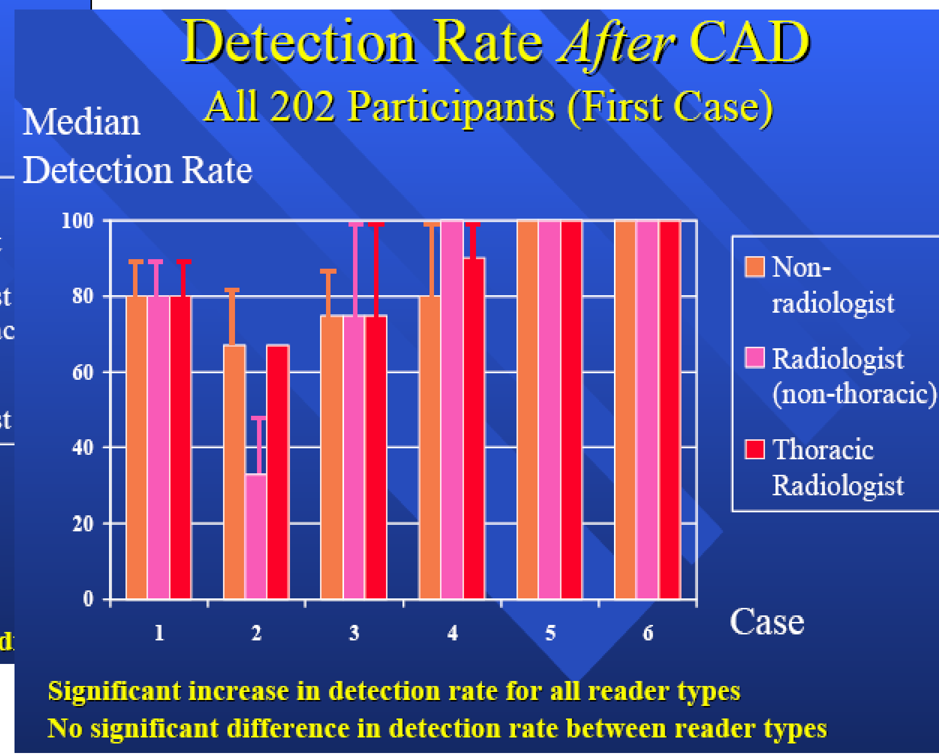
	Indicative commercial software packages	Pathology
1	R2 Image Checker	Breast cancer, FDA Approval-First FDA approved system
2	CADX (qualia)	Breast cancer, FDA Approval
3	Kodak	Breast cancer, FDA Approval
4	SecondLook® Digital	Breast cancer
5	Advantage ALA, GE, v7.4.63; Extended Brilliance Workspace, Philips, EBW v3.0; Lungcare I, Siemens, Somaris 5 VB 10A-W; Lungcare II, Siemens, Somaris 5 VE31H; OncoTreat, MEVIS v1.6; Vitrea, Vital images v3.8.1	Lung cancer

DECISION SUPPORT SYSTEMS

Diagnosis, prognosis, treatment planning, …

Applications: Breast cancer





Source: *Brown et al, Computer-aided Lung Nodule Detection in CT, 2005*

LECTURE CONTENTS

1. Introduction

2. Digital Imaging Systems

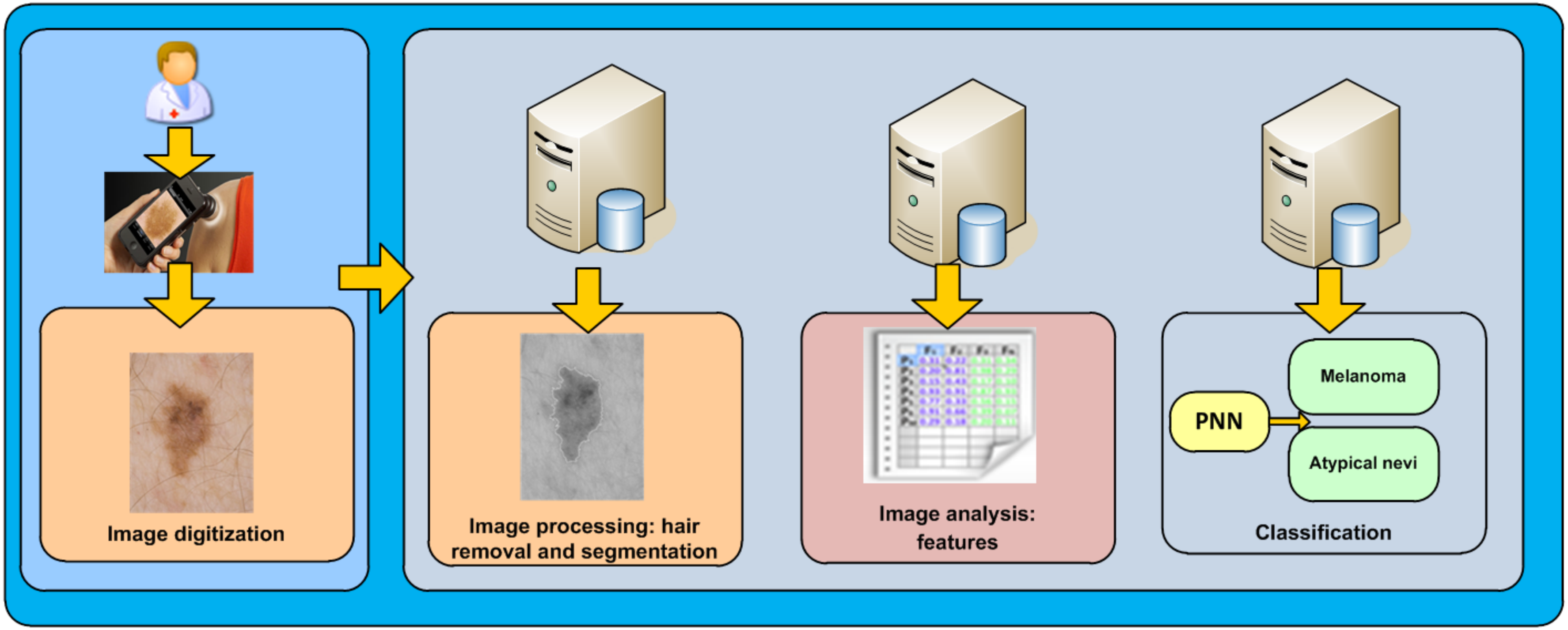
α. X-ray radiography
β. X-ray mammography
γ. X-ray Computed Tomography (CT)
δ. Ultrasonography
ε. Nuclear Magnetic Resonance Imaging (MRI)
στ. Scintigraphy (Nuclear Medicine – SPECT, PET gamma camera)
ζ. Thermography
η. Hybrid Systems (PET-CT, MRI-PET)
θ. Microscopy

3. Decision Support Systems

4. Case study: Early detection of melanoma:

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

Decision Support System Workflow

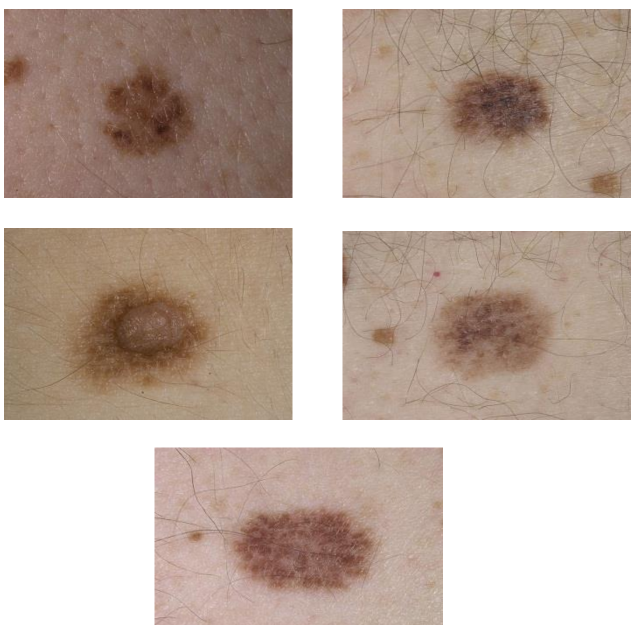


TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

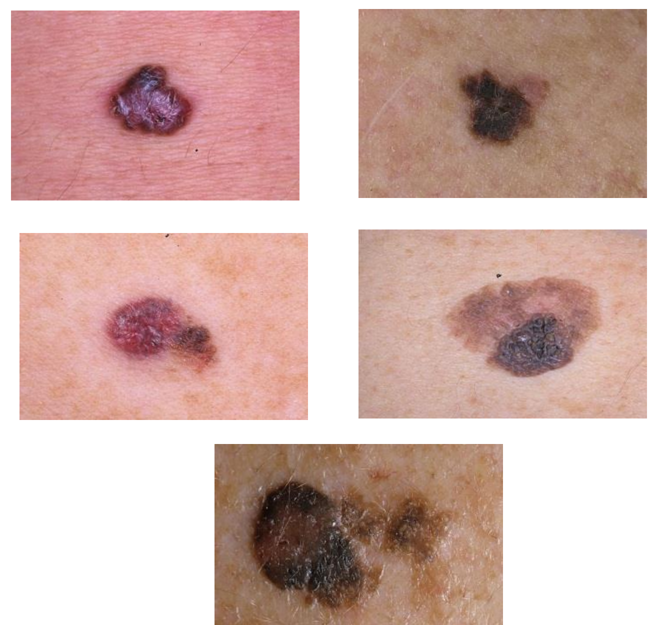
MATERIAL: DERMOSCOPY + PLAIN PHOTOGRAPHY IMAGES

- 44 dysplastic (clark's nevi) and 44 malignant melanoma lesions
- dermatology database Dermnet, www.dermnet.com

atypical nevi

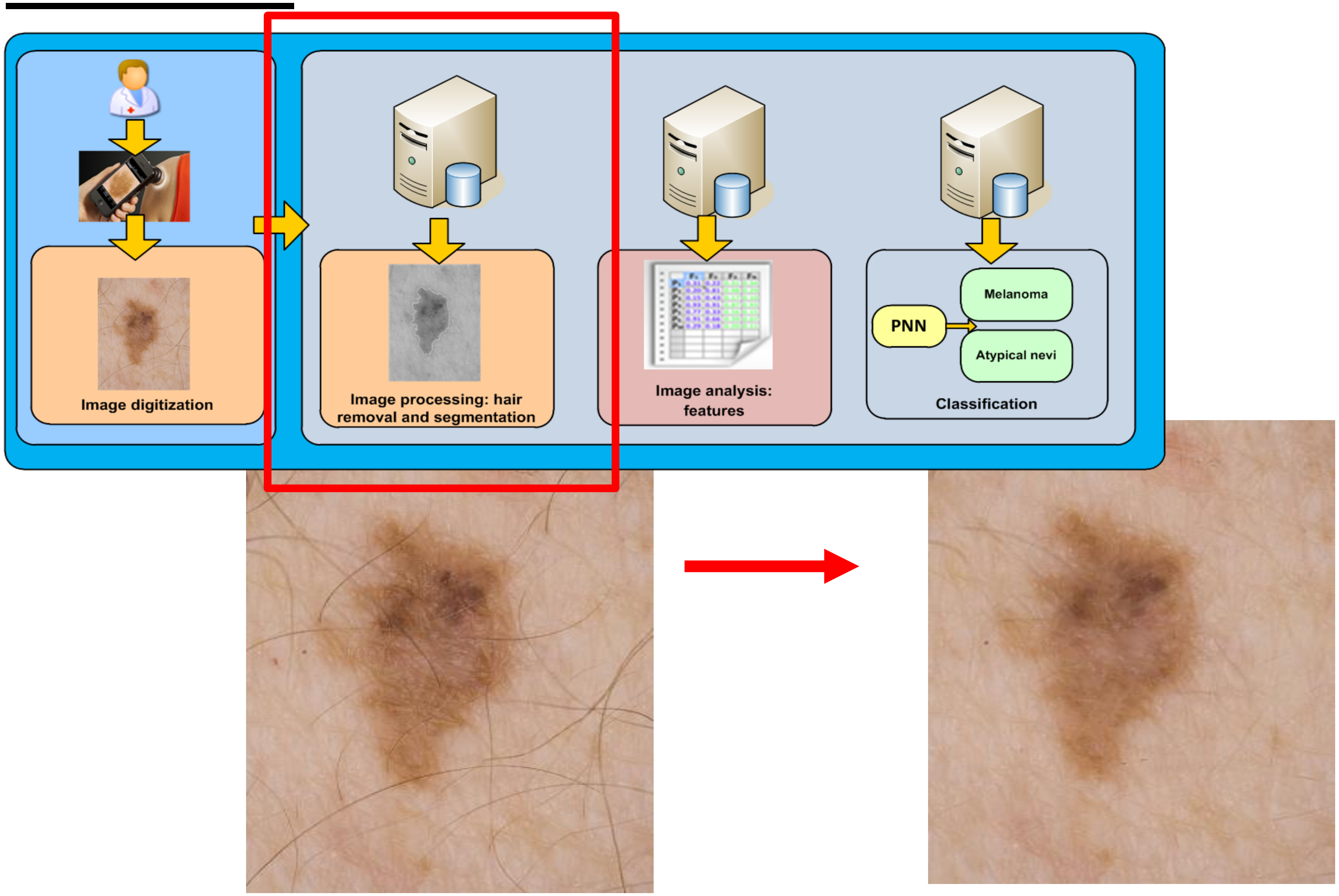


melanoma



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

<u>Dull Razor</u>: Hair removal



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

Segmentation:

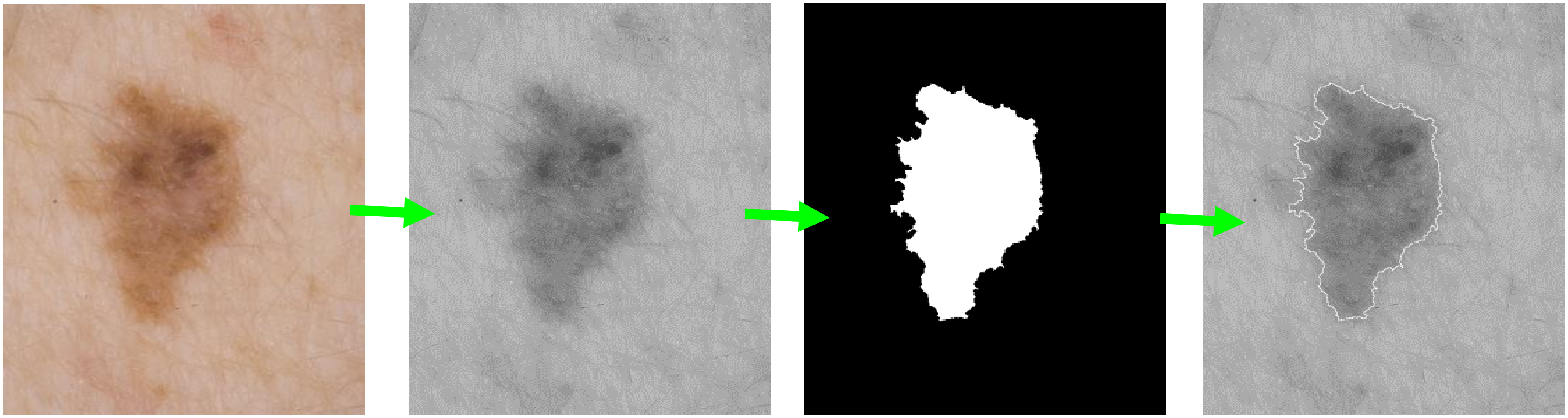
a/ separate brighter from darker pixels, Otsu threshold

b/ elimination of stray pixels outside and inside the mole's region

c/ morphological opening/closing for smoothing of boundaries

d/ edge-detection Roberts filter

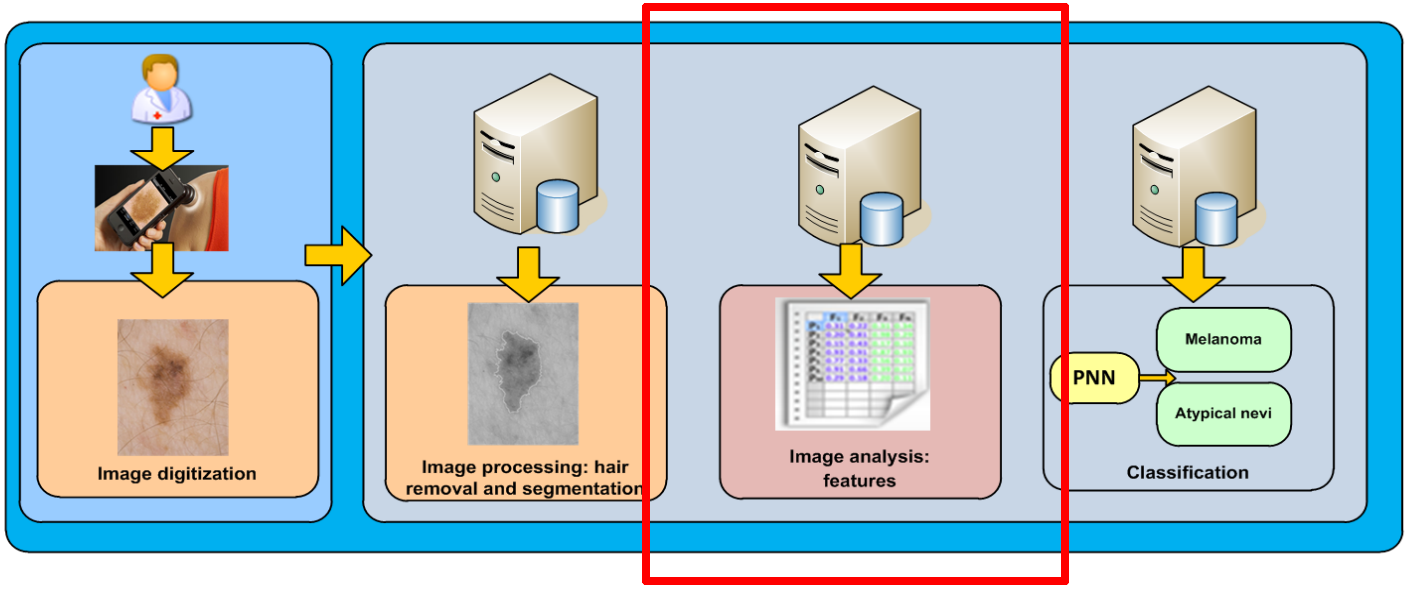
e/ gradient flow vector for final segmentation



METHODS: FEATURE EXTRACTION

<u>Feature calculations</u>:

- i/ textural feature
- ii/ morphological features
- iii/ symmetry features
- iv/ color features



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

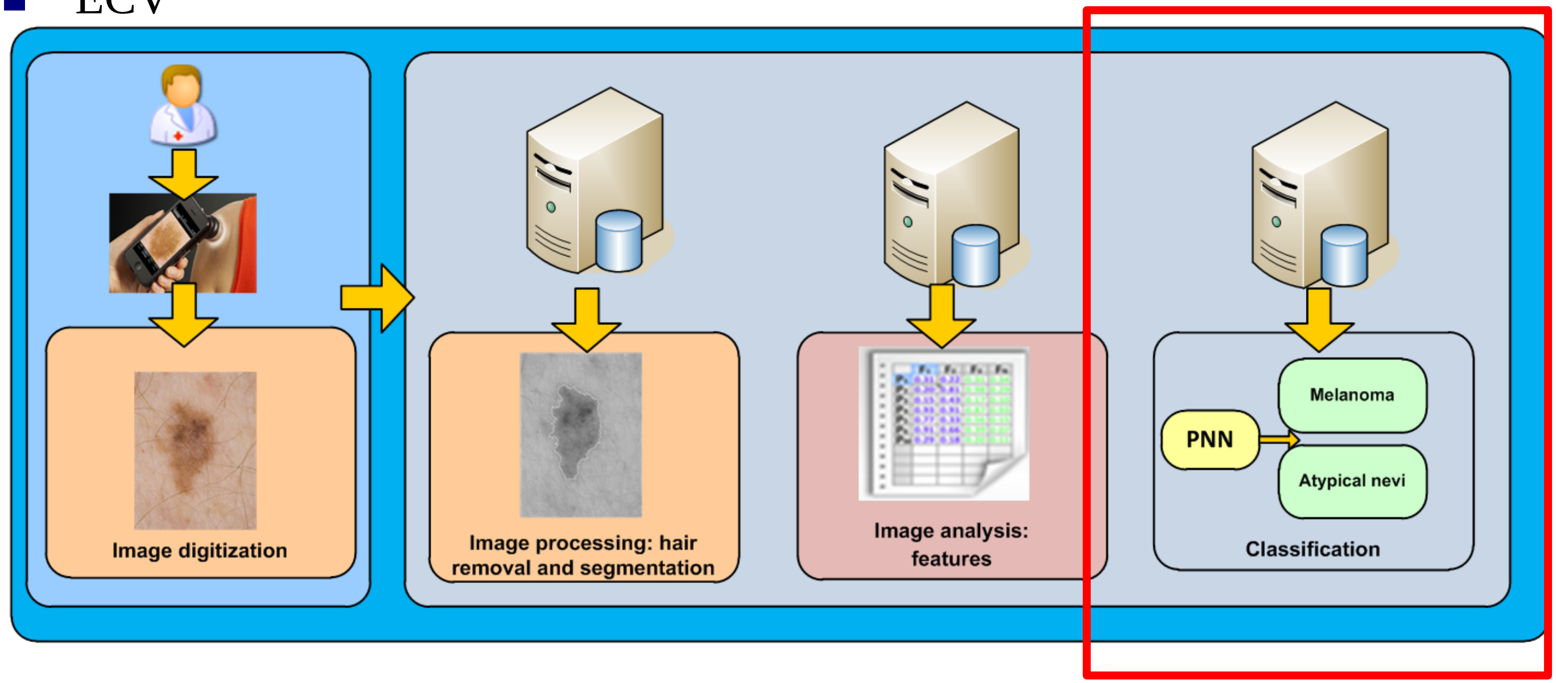
METHODS: PATTERN RECOGNITION SYSTEM

PATTERN RECOGNITION

- PNN classifier
- Exhaustive search
- Leave-one-out
- ECV

IMPLEMENTATION

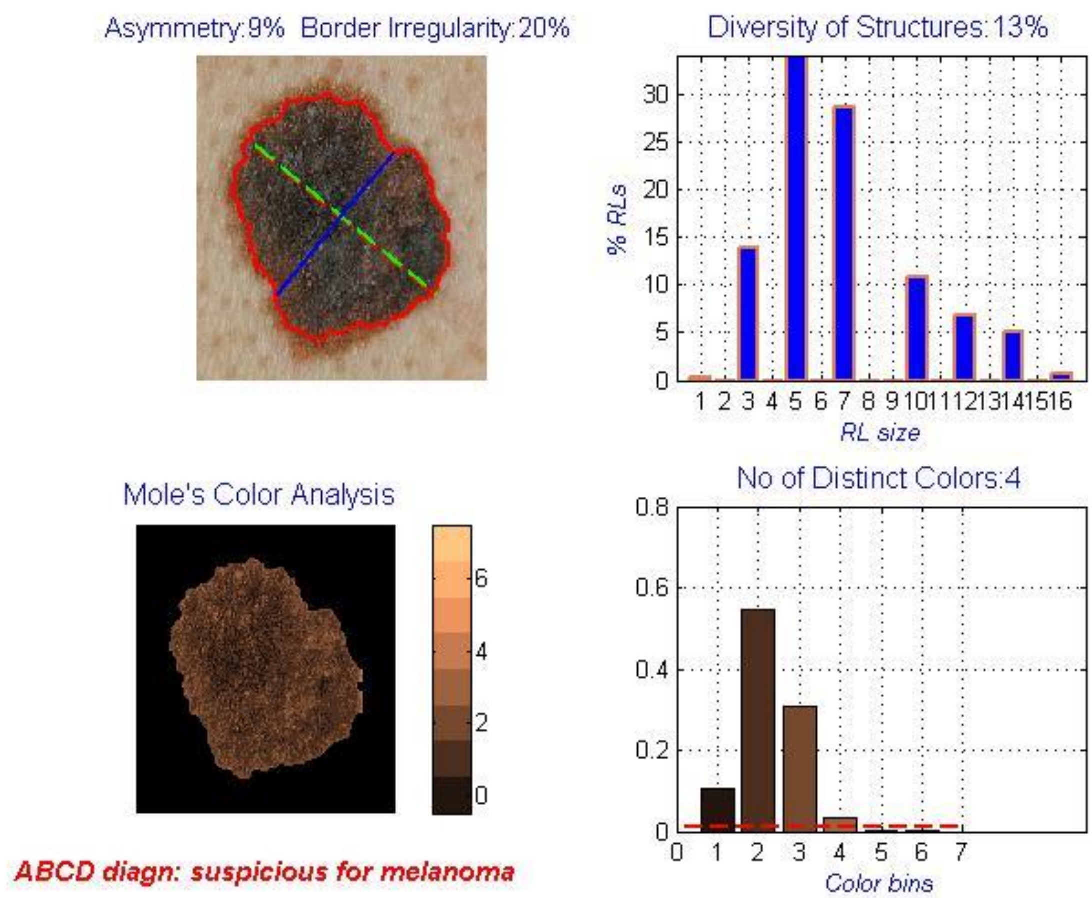
- Design on GPU card (GeForce 580GTX) using CUDA programming framework and C++ programming language



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

1/ Decision support based on ABCD criteria

CASE 1

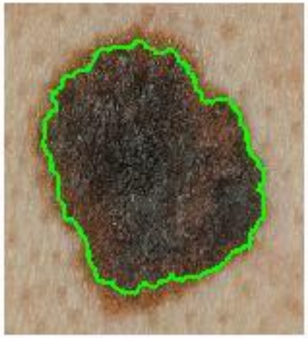


TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

2/ Decision support based on correlation of images

CASE 1

mole to be characterized



similar melanoma

similar melanoma

similar melanoma

3-MI-matching diagn: probably melanoma

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

3/ Decision support based on nearest neighbors

CASE 1

mole to be characterized

similar melanoma

similar melanoma

similar melanoma

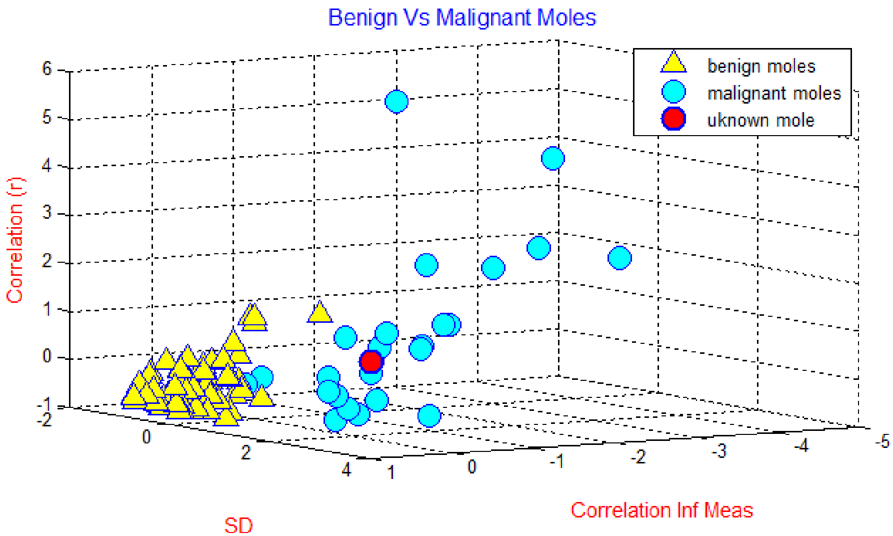
3-NN-matching diagn: probably melanoma

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

4/ Decision support based on pattern recognition

CASE 1

mole to be characterized

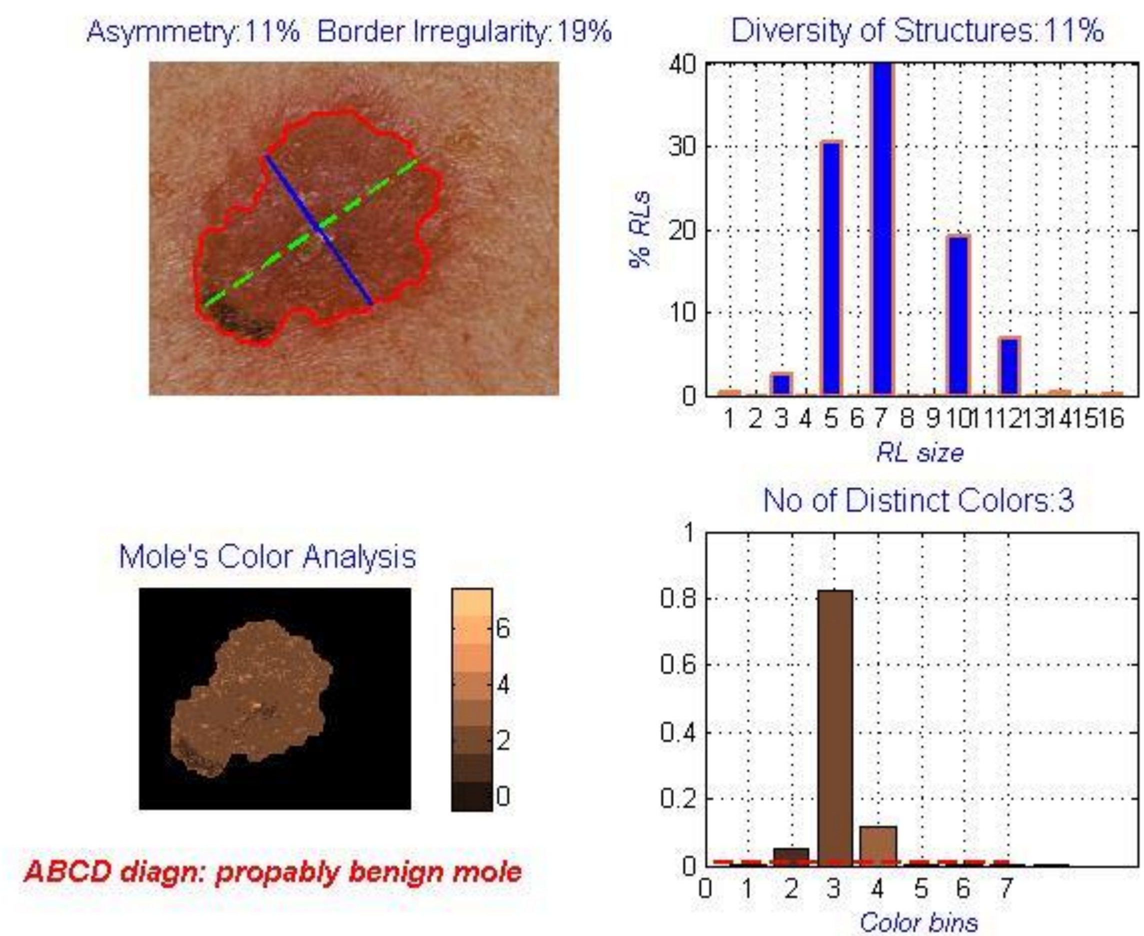


DSS assessment: probably melanoma

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

1/ Decision support based on ABCD criteria

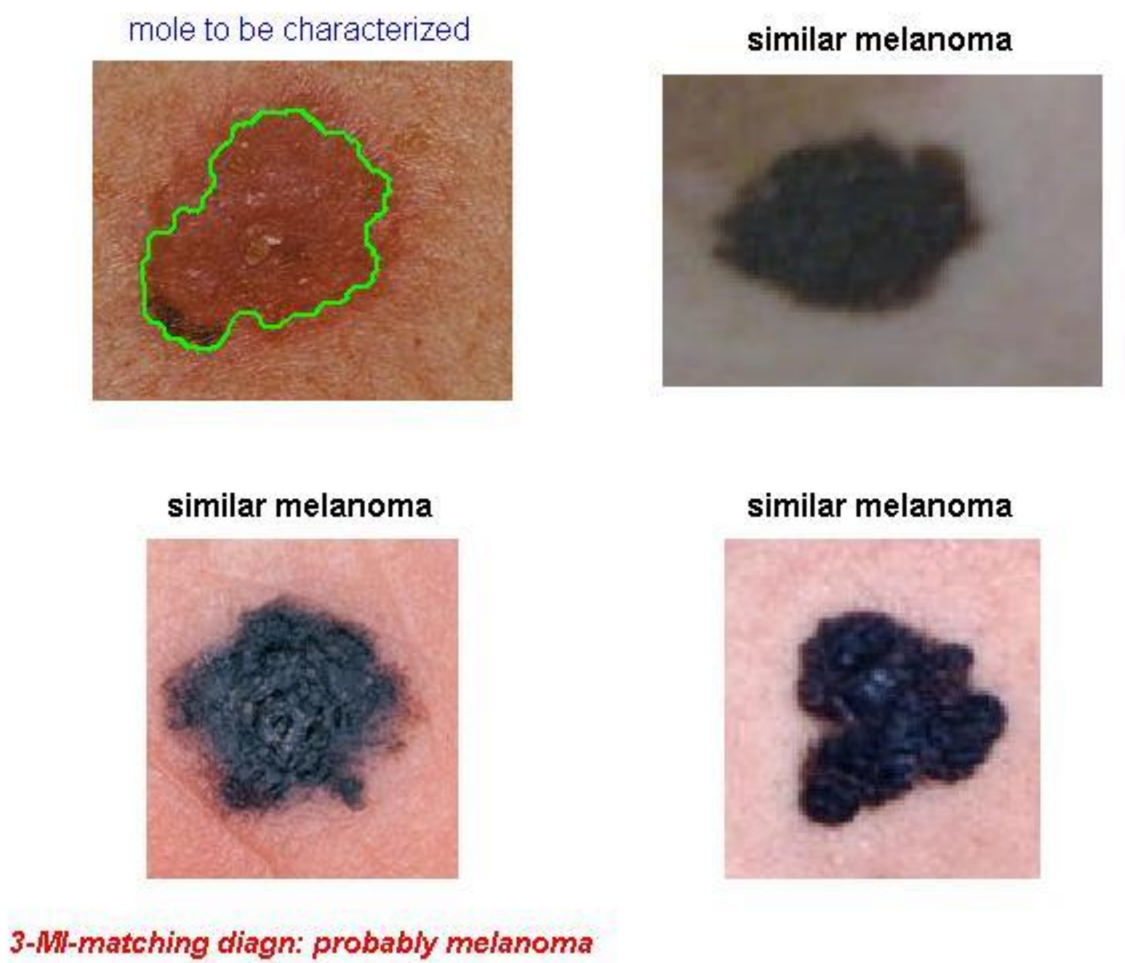
CASE 2



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

2/ Decision support based on correlation of images

CASE 2



TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

3/ Decision support based on nearest neighbors

CASE 2

mole to be characterized

similar melanoma

similar melanoma

similar benign

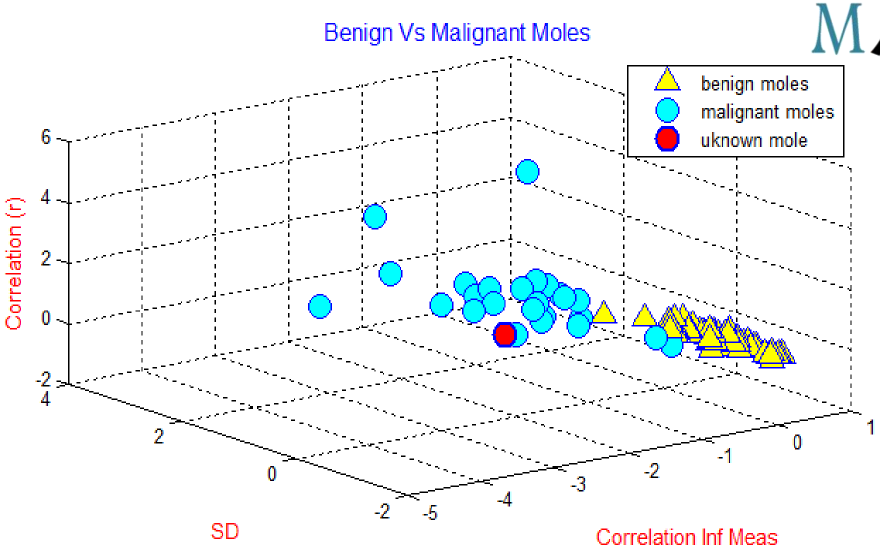
3-NN-matching diagn: probably melanoma

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

4/ Decision support based on pattern recognition

CASE 2

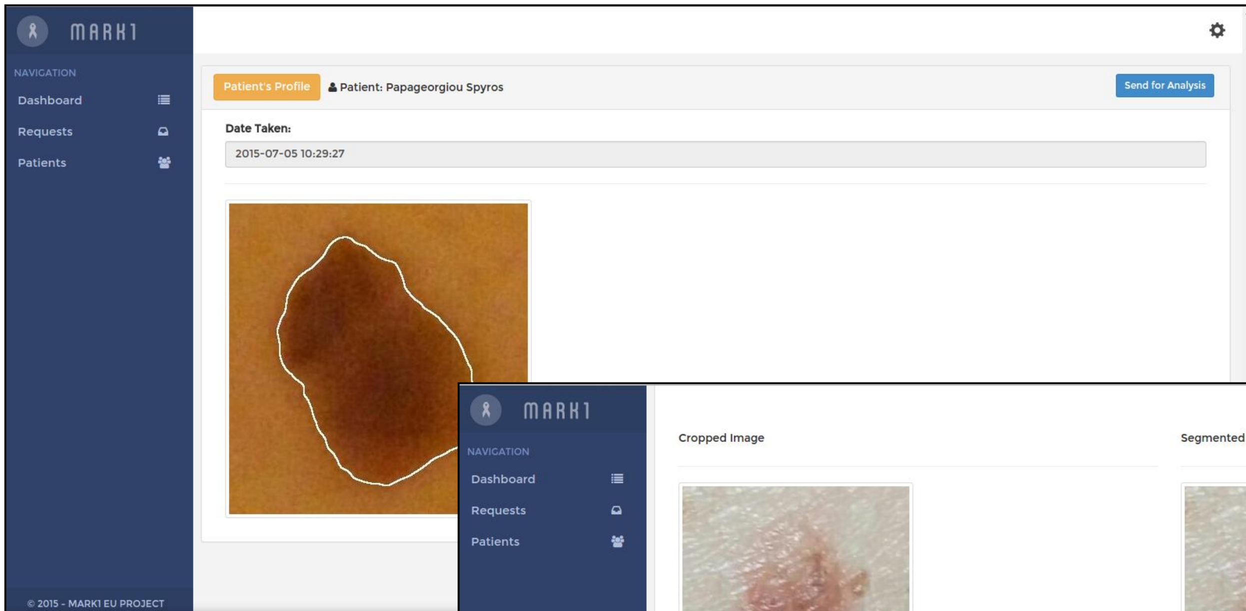
mole to be characterized

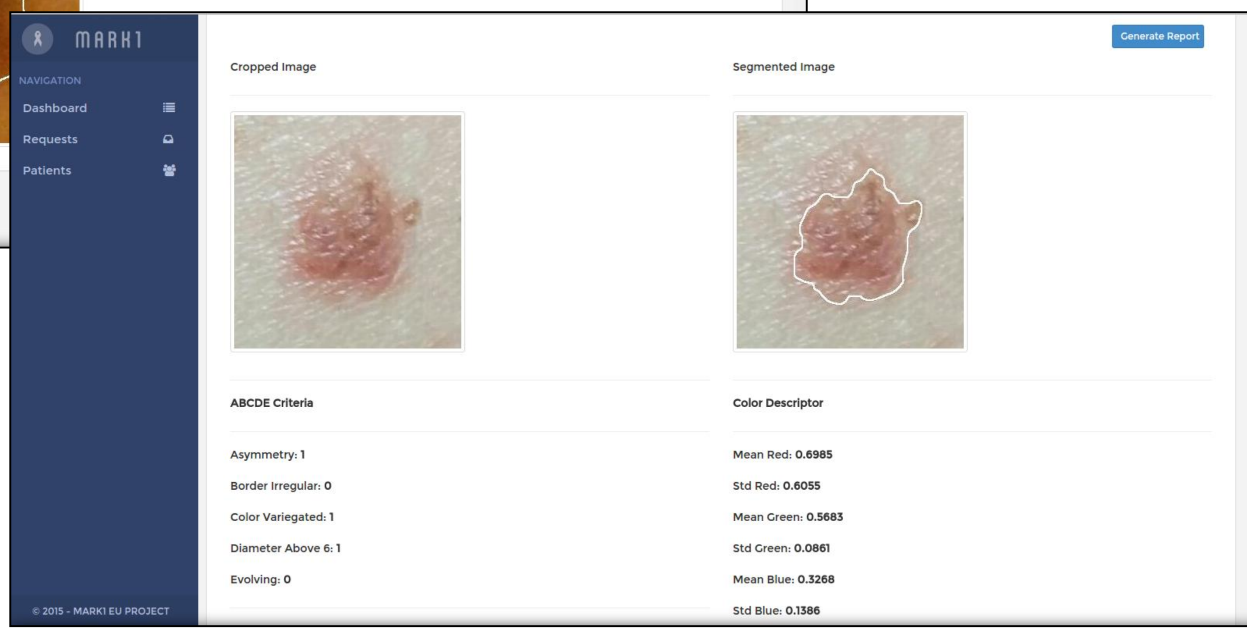


DSS assessment: probably melanoma

TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

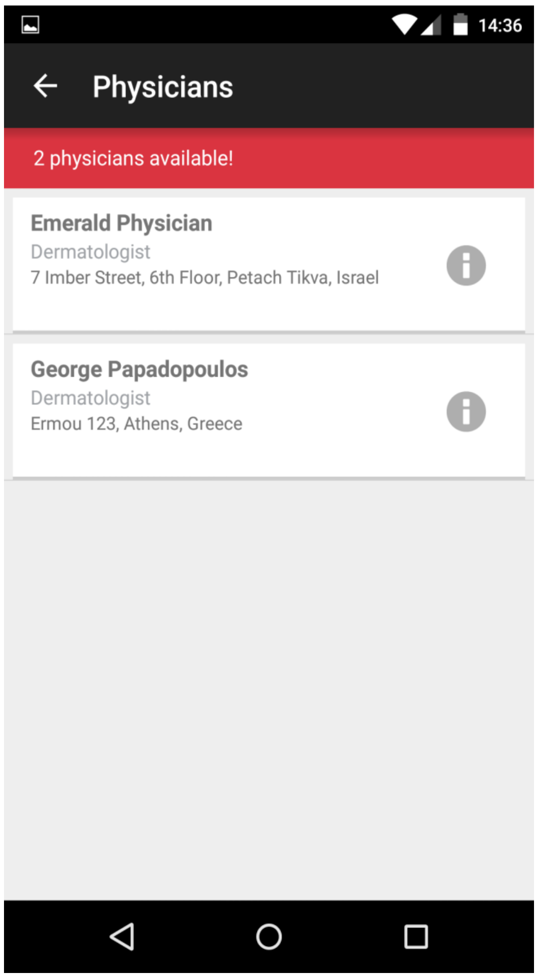
MARK1 Application – Physician

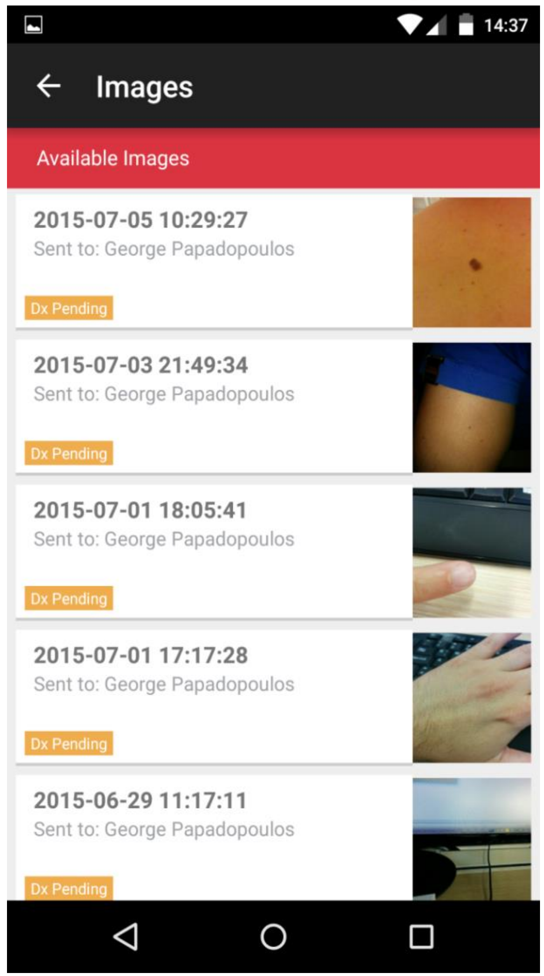


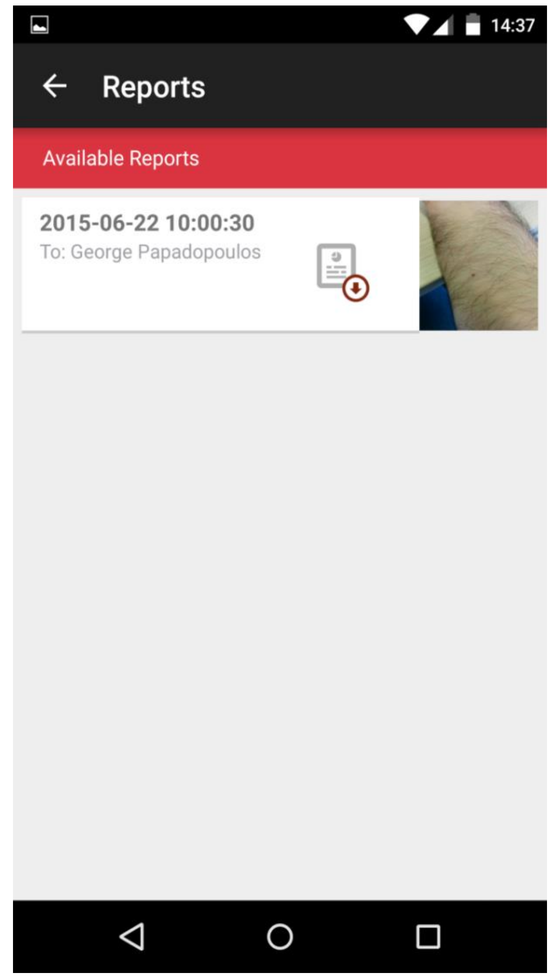


TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

MARK1 Application – Patient

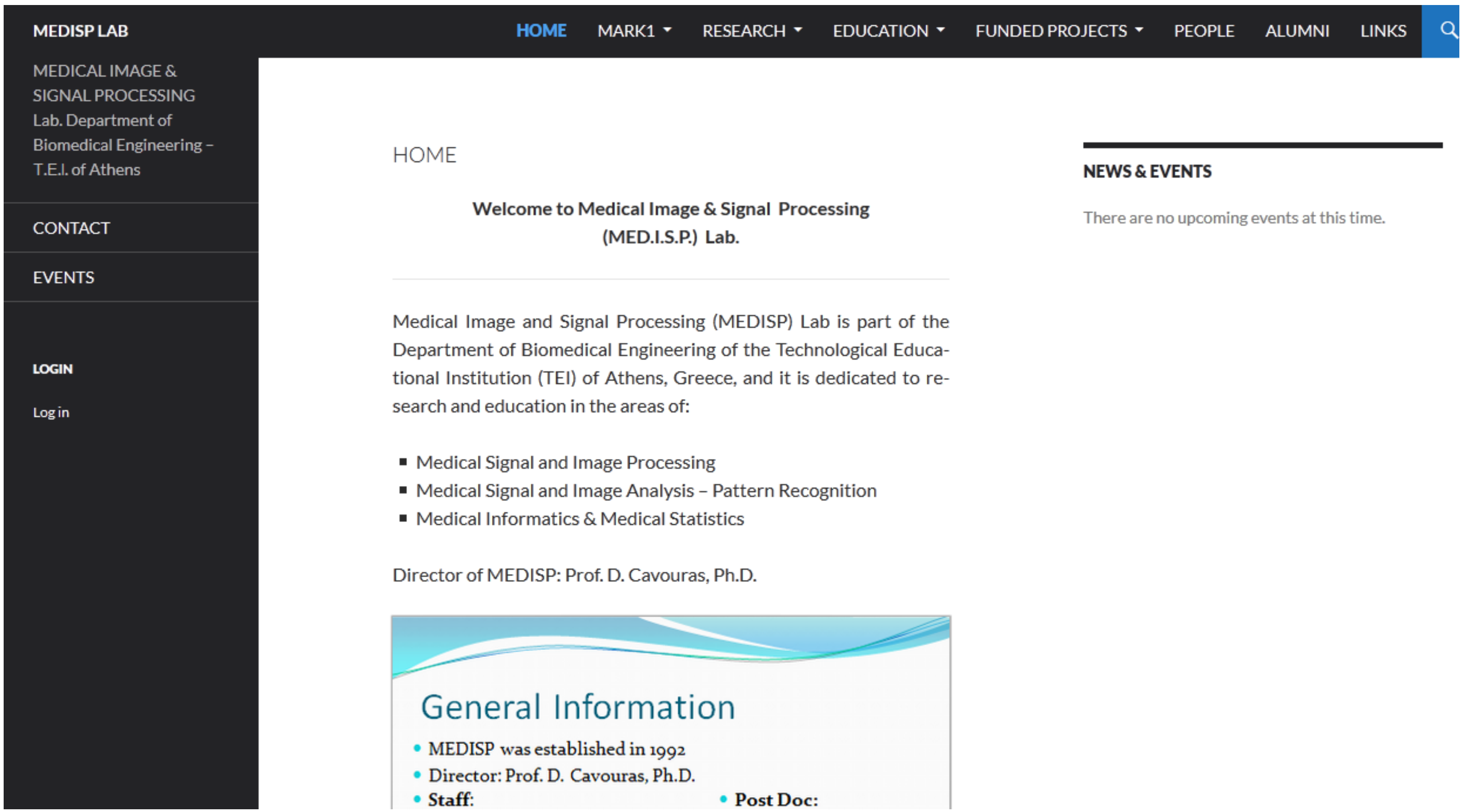






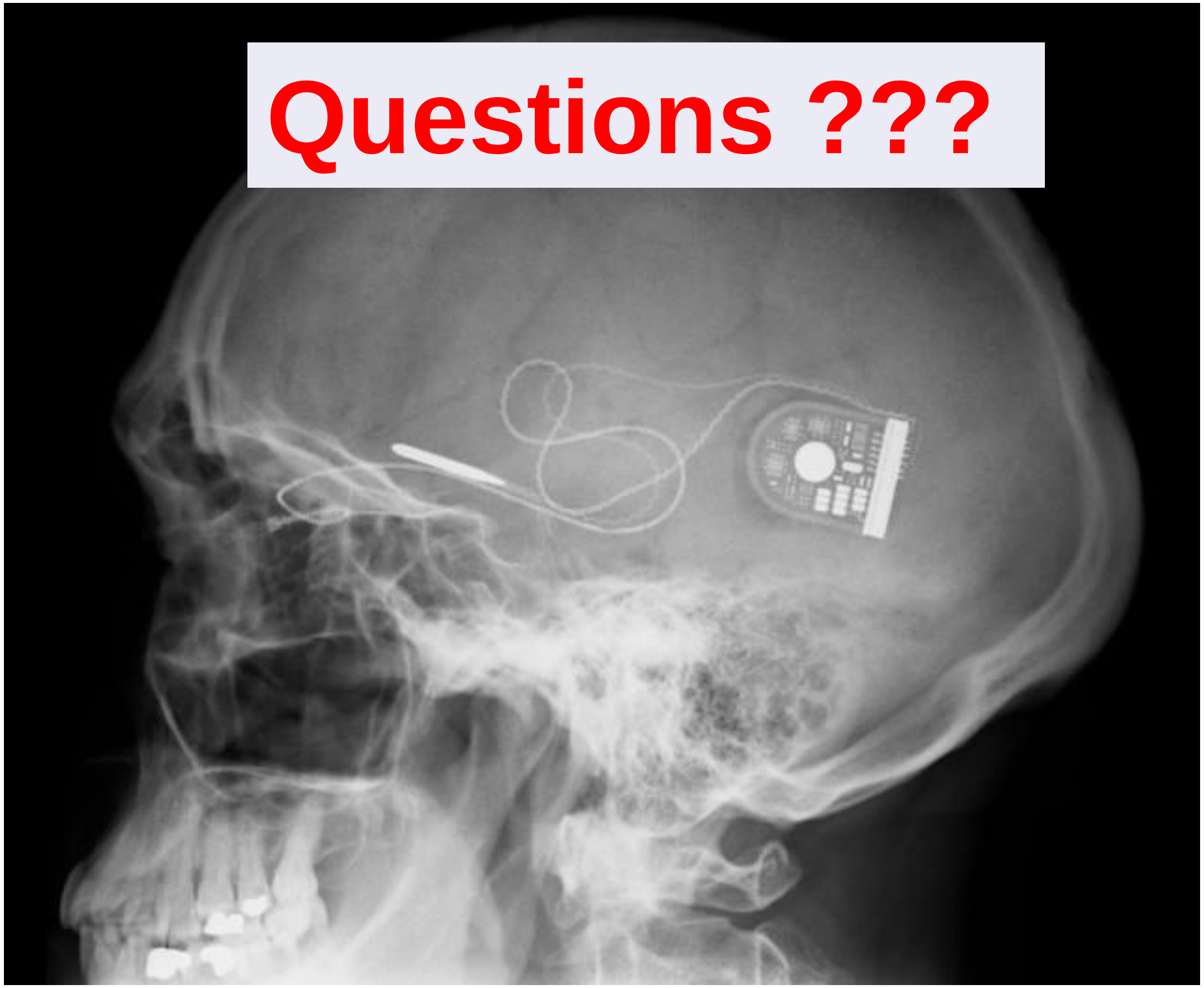
TOWARDS COMMERCIAL CAD SYSTEMS EARLY STAGE MELANOMA DETECTION

MARK1 web site:
http://medisp.bme.teiath.gr/mark1/



FURTHER READING

1. Gonzalez RC, Woods RE, “Digital image processing”, Prentice Hall; 2002
2. Pratt K. William, Digital Image Processing, John Wiley & Sons, 2001
3. Martinez W.L., Martinez A.R., Computational Statistics Handbook with MATLAB®, Chapman & Hall/CRC, 2002
4. Young I. et al, Fundamentals of Image Processing, link
5. Housfield, Computed medical imaging, link
6. Cormack, Early two dimensional reconstruction and recent topics stemming from it, link
7. Mather S., The Principles of Diagnostic Imaging, link



Source: https://www.extremetech.com/extreme/188908-darpas-tiny-implants-will-hook-directly-into-your-nervous-system-treat-diseases-and-depression-without-medication