InnoSoc
Innovative ICT Solutions
for the Societal Challenges

Medical Image processing

Detecting maleficient leisons with non-invasive methods

Szilvia Nagy

nagysz@sze.hu

Széchenyi István University
Faculty of Mechanical, Computatonal and Electrical Engineering
Hungary

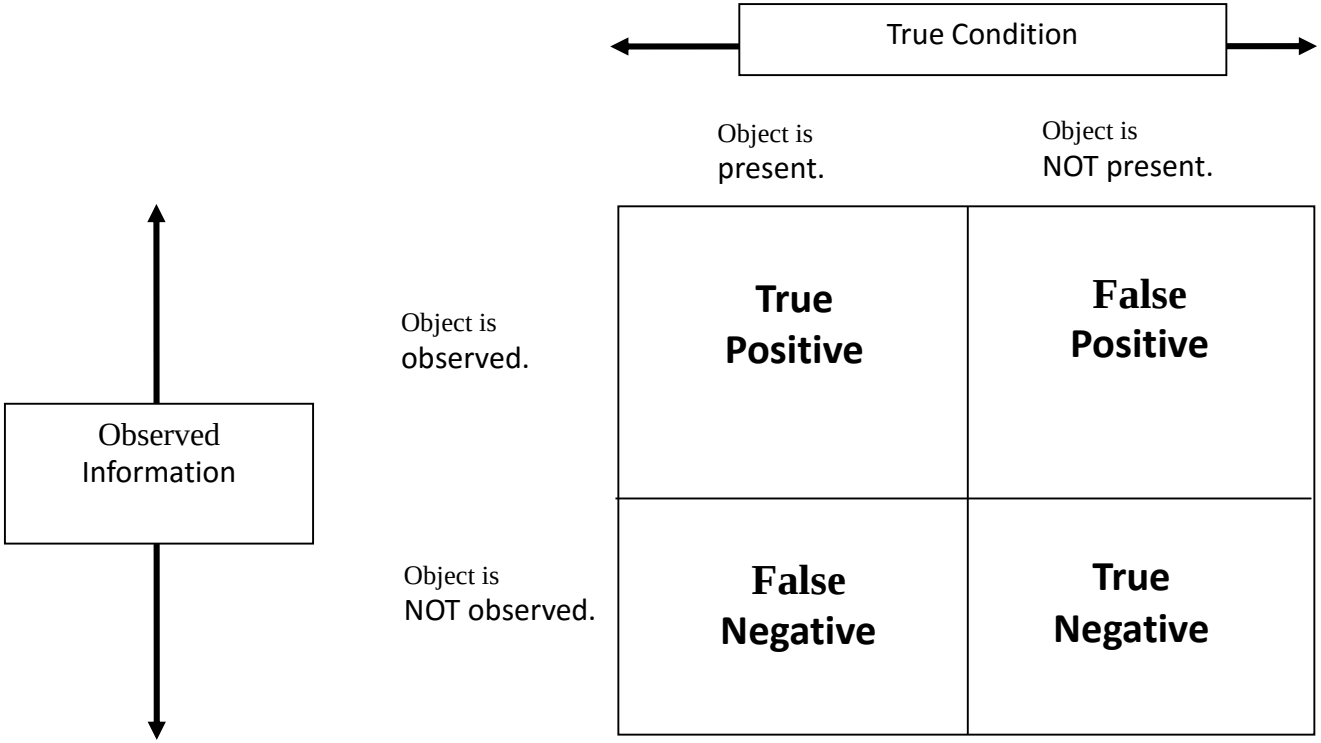
21st April 2016, Zagreb

Steps of image processing

- **Imaging with cameras or other detectors**
  - enlighting, reflection, other environmental effects
- **Enhancement**
  - Correction, elimination of disturbancies, unnecessary details
  - filtering, contrast enhancement
- **Feature extraction**
  - local/global(statistic) picture characterisation
  - determination of the characteristic points
  - thresholding, edge detection, shape detection

Steps of image processing

- **Diagnosis**



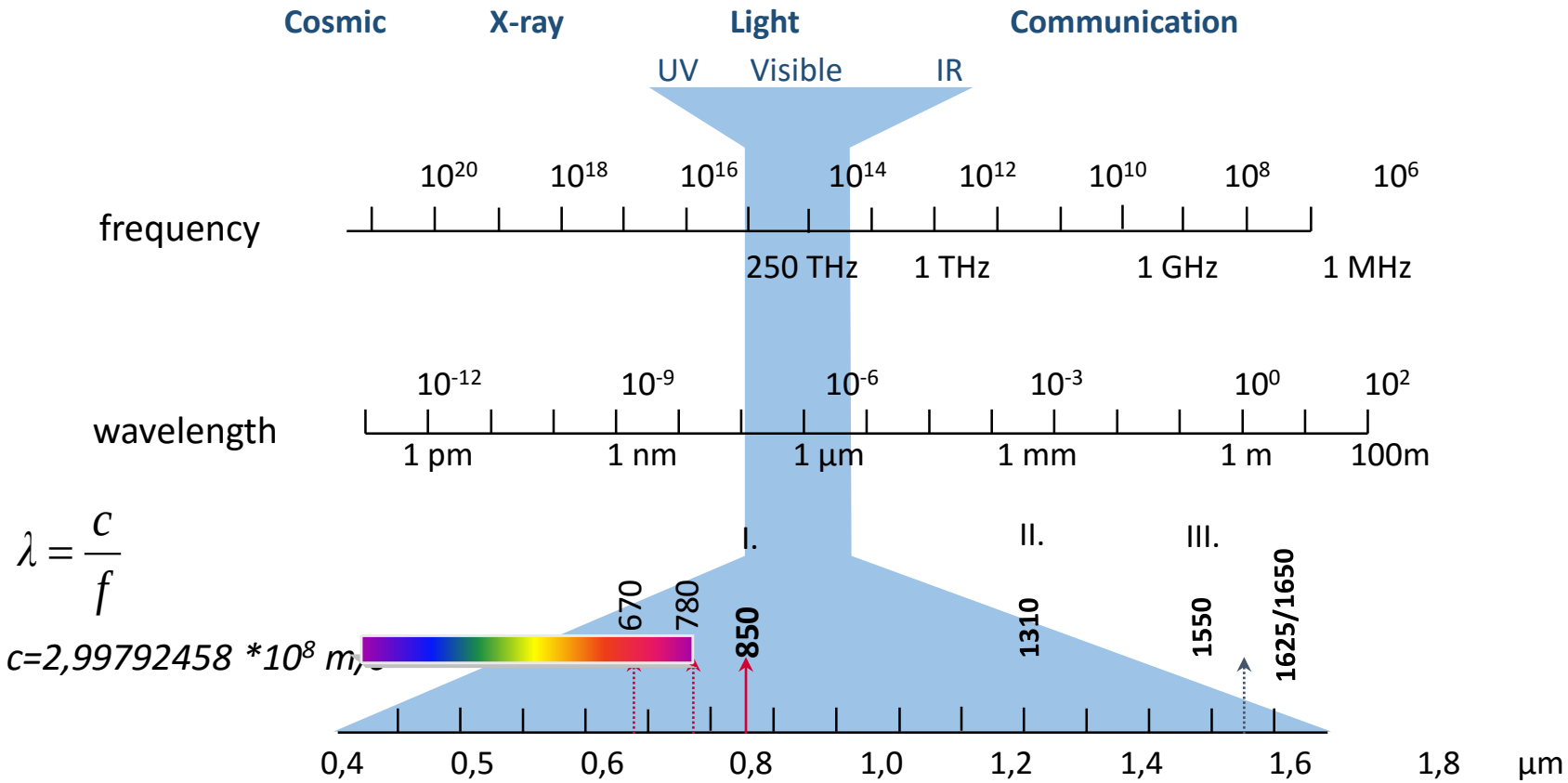
Medical Image Analysis, by Atam P. Dhawan, IEEE Press, 2003.

Steps of image processing

- **Imaging**
  - Source type -- location
    - external
    - internal
    - combined
  - Source type
    - electromagnetic wave
    - sound or density wave
    - particle
    - other electronic based sensor
  - Direct or computed
  - Transmission, reflection or emission

Medical Imaging Methods

- Light and other electromagnetic waves



$$\lambda = \frac{c}{f}$$

*c=2,99792458 *10⁸ m/s*

Medical Imaging Methods

- X-ray
  - deccelerating electrons (inner shell)
  - projective image (projective geometry)

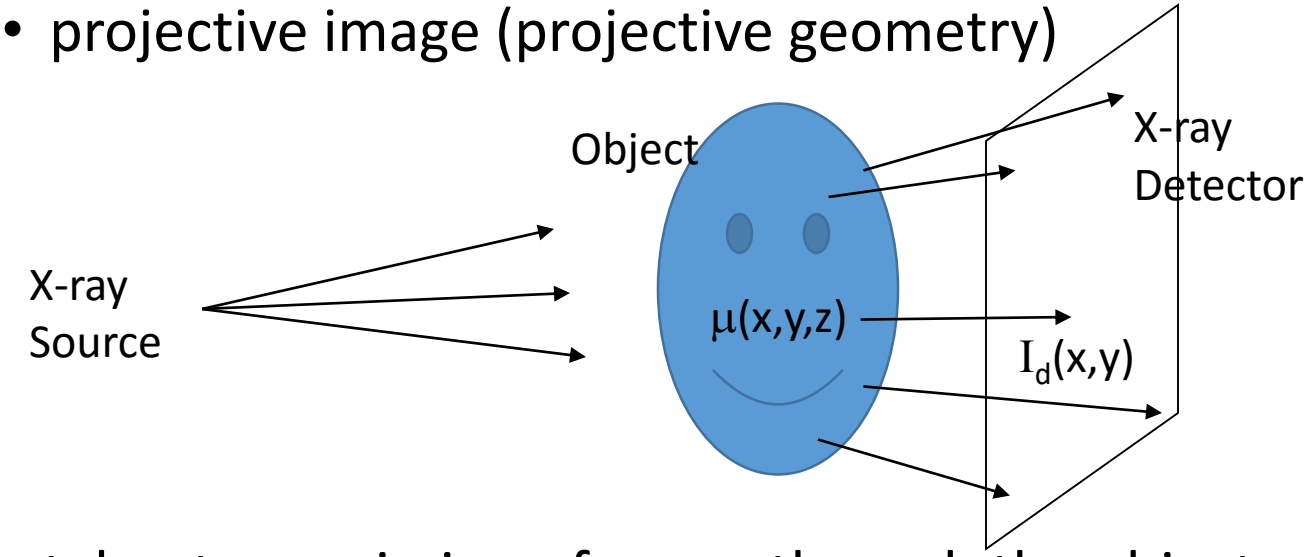


Image takes transmission of x-rays through the object

$$I_d(x,y) = I_0 \exp\left(\int \mu(x,y,z)\,dl\right)$$

https://sites.google.com/a/simplescience.info/www/biagraphies/laureateerontgen

Medical Imaging Methods

- X-ray
  - deccelerating electrons (inner shell)
  - projective image (projective geometry)
  - also tomography

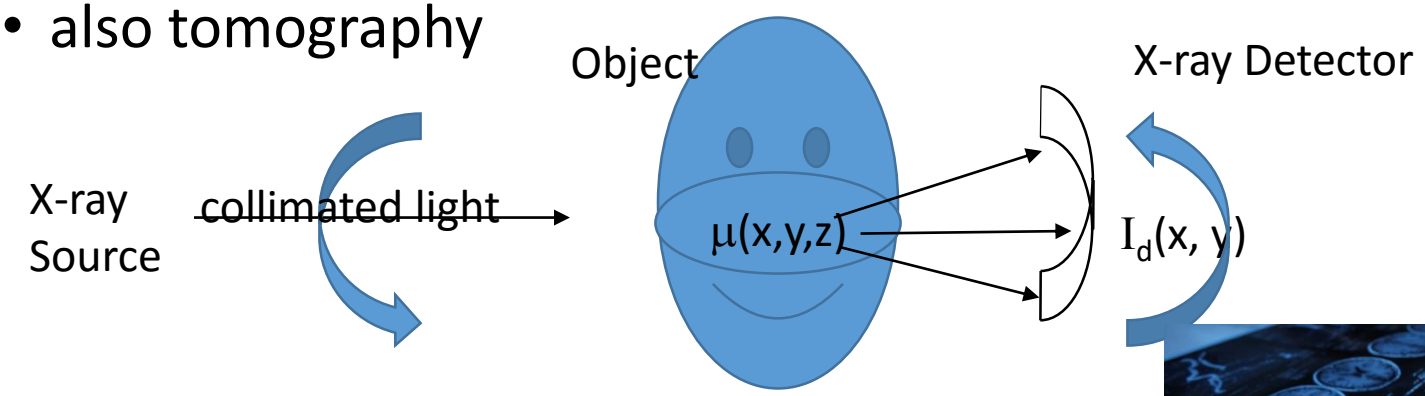


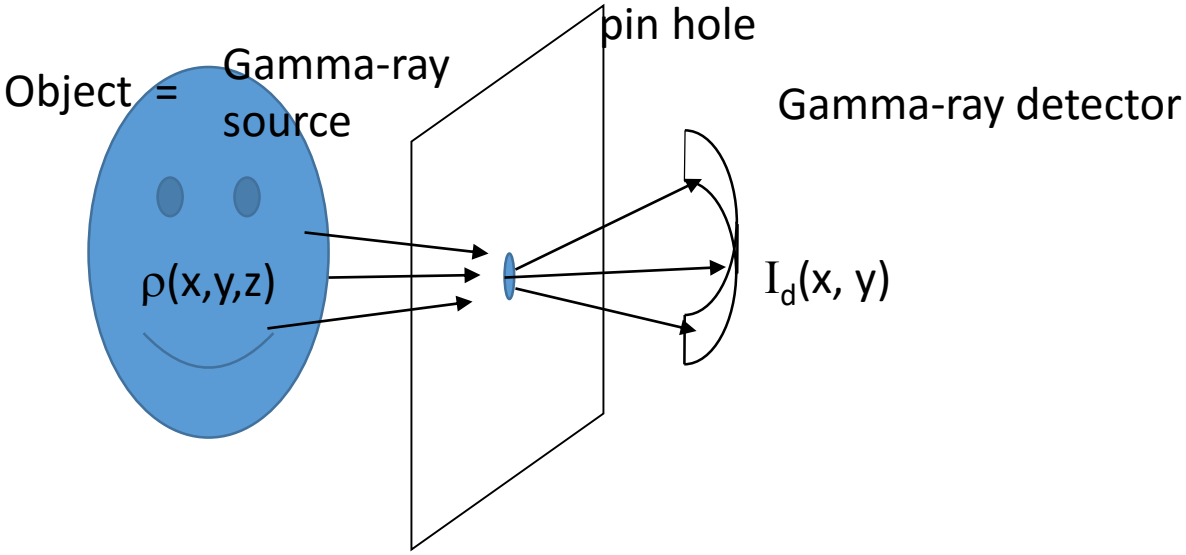
Image takes transmission of x-rays through the object

$$I_d(x,y) = I_0 \exp\left(\int \mu(x,y,z)\,dl\right)$$

Medical Imaging Methods

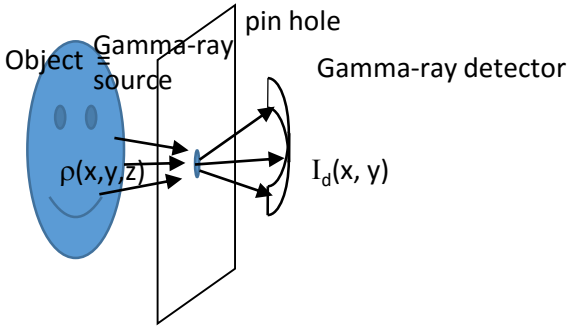
- Gamma ray
  - usually applied in scintigraphy

radiopaedia.org



Medical Imaging Methods

- Gamma ray
  - usually applied in scintigraphy
  - Large pinhole →more photons, better SNR, but blurry
  - Half lives long enough for the detection, but as short as possible for the minimzation of the doseage
  - Isotopes of atoms compatible with biological functions
  - No depth info→ combination with tomography

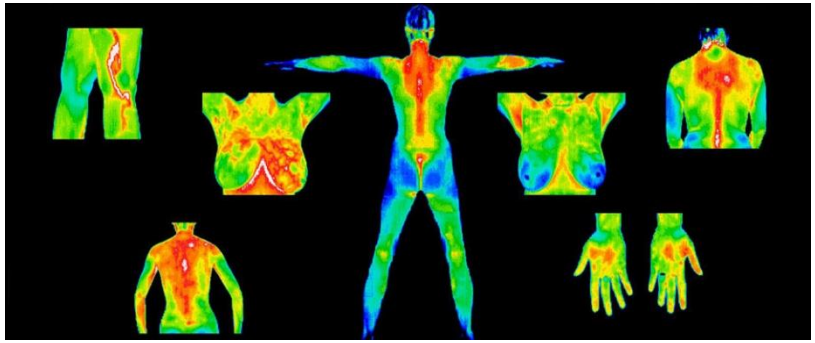


Medical Imaging Methods

- Visible light detectors
  - Photoplates/films with photosensitive layer
  - Photomultiplyers
  - Photodiodes (PIN, APD)
  - Phototransistors
  - Change coupled devices
  - Active pixel sensors
- Used in
  - microscopes, endoscopes, scintillation detectors
  - Other equipments for visualization

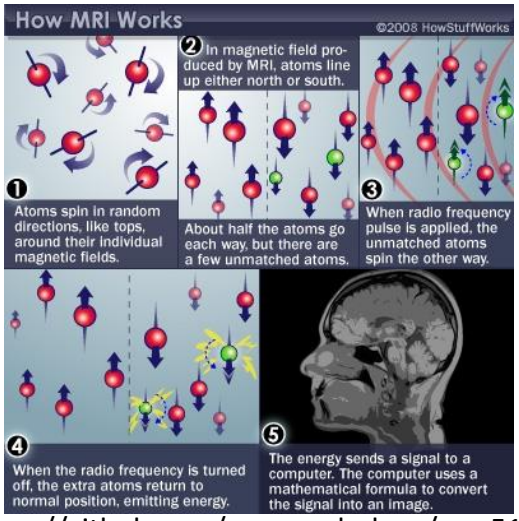
Medical Imaging Methods

- Infrared light
  - from thermal scans



www.clinicofnaturalmedicine.eu

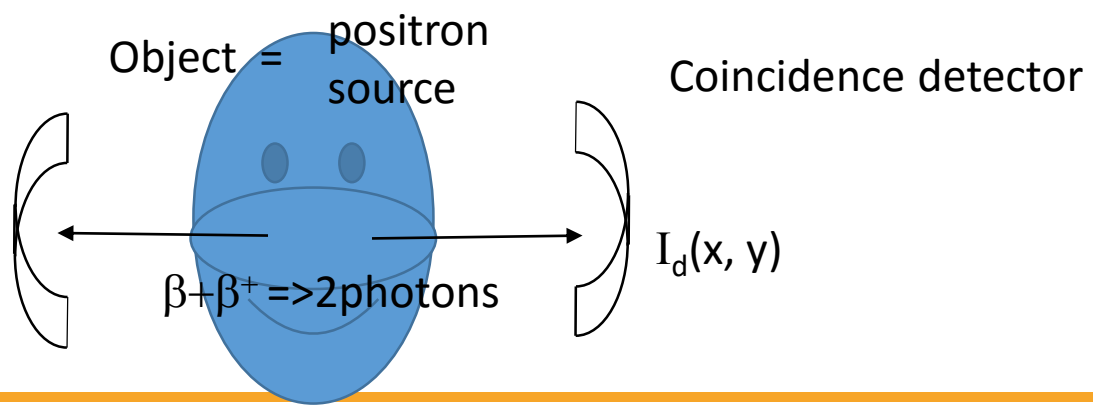
- RF
  - Radio frequency signal can arise from RF sources, like radars, or the NMR – MRI like devices



https://github.com/psu-psychology/psy-511-scan-fdns/blob/master/lectures/figs/mri-steps.jpg

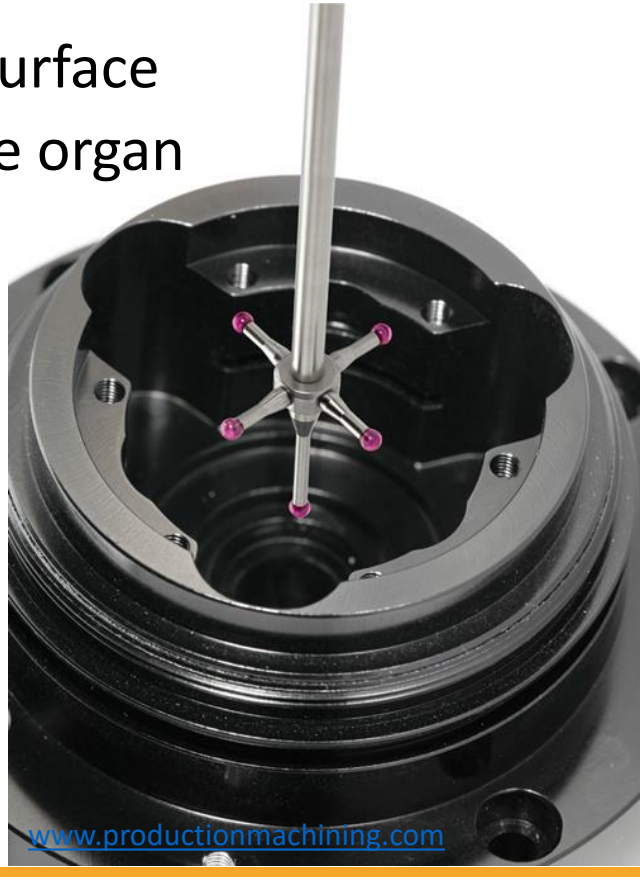
Medical Imaging Methods

- Positrons
  - positrons are the carrier of medical information in PET
  - Positron emitting isotope (^{18}F, ^{11}C) is bonded to e.g. clucose in order to follow the metabolism
  - positron emergegs from the body and annihilates with an electron
  - photons are detected with a coincidence detector



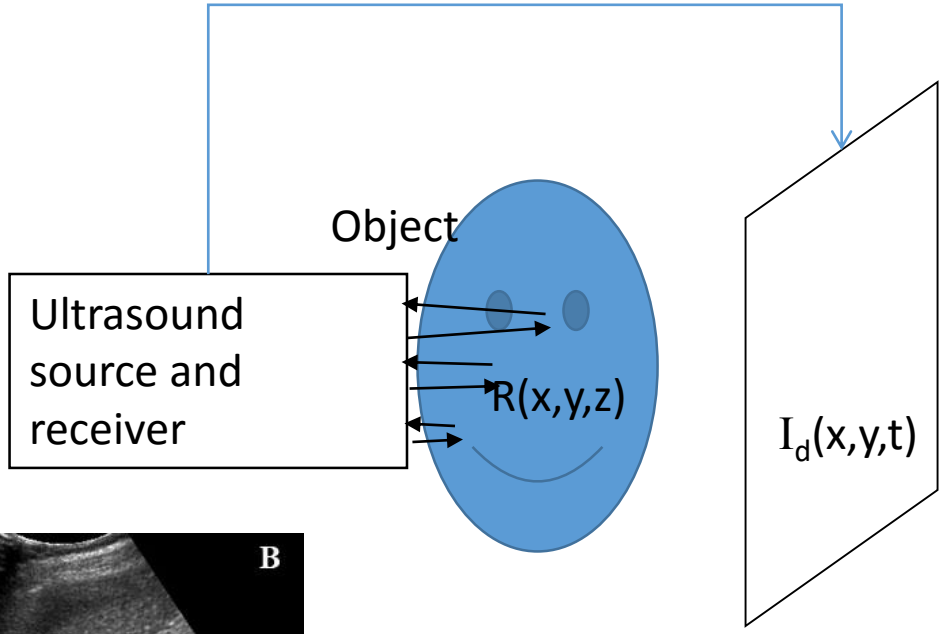
Medical Imaging Methods

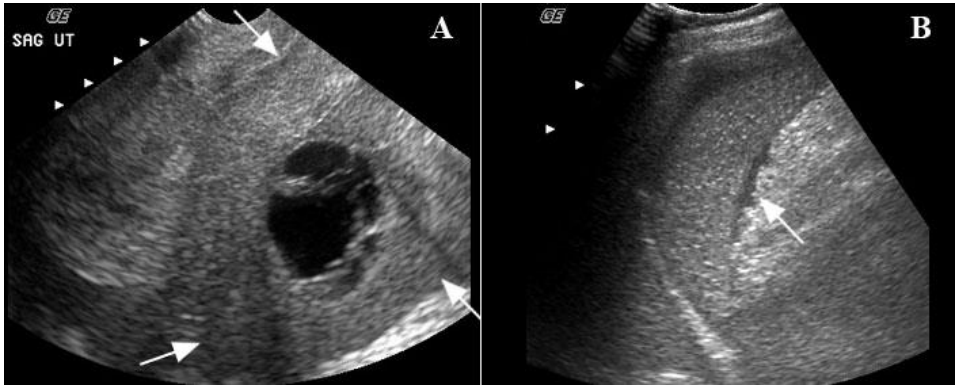
- Tactile
  - detect the elasticity, hardness of the surface
  - tactile sensors touch the surface of the organ
    - ultrasound
    - MEMS
    - optical
    - capacitive
    - inductive
    - piezo
  - Tactile maps or tactile displays


www.productionmachining.com

Medical Imaging Methods

- Ultrasound
  - reflectometer, like sonars
  - wave focusing
  - direct imaging

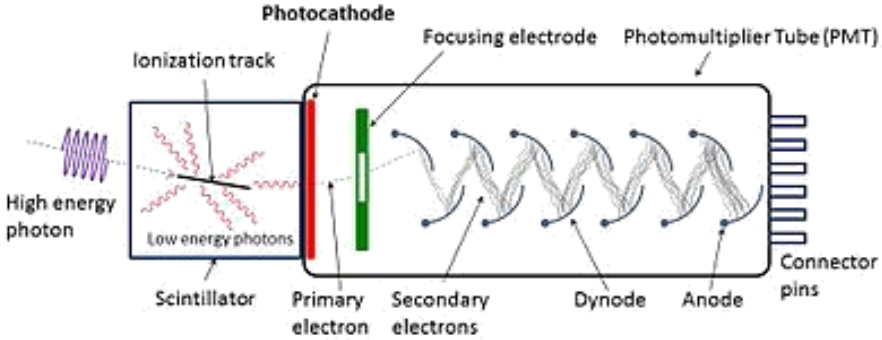




www.mghradrounds.org

Medical Imaging Methods

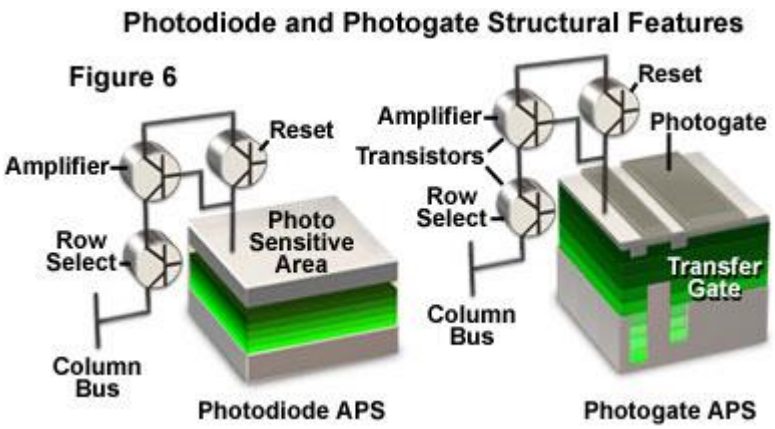
- Detectors: Visible light from gamma: scintillation and photomultiplier tube

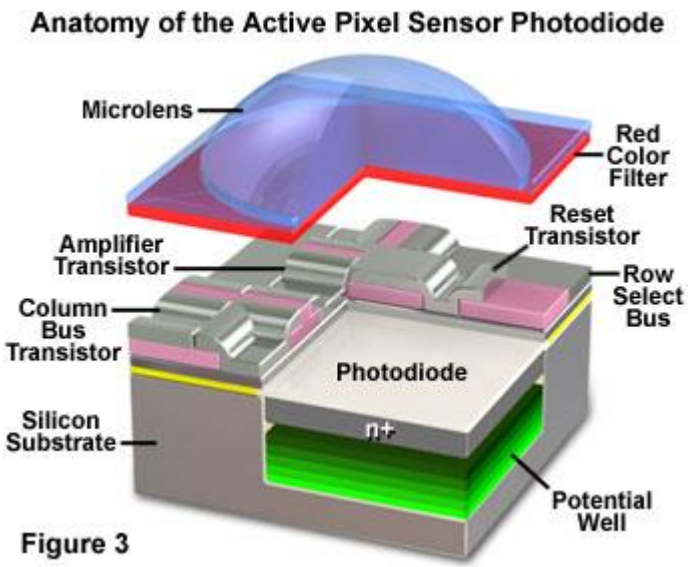


- Visible light from electronic signals: computed visualization 2D, 3D or 2D slices

Medical Imaging Methods

- Methods: active pixel sensor
  - not storing
  - phototransistors or photodiodes

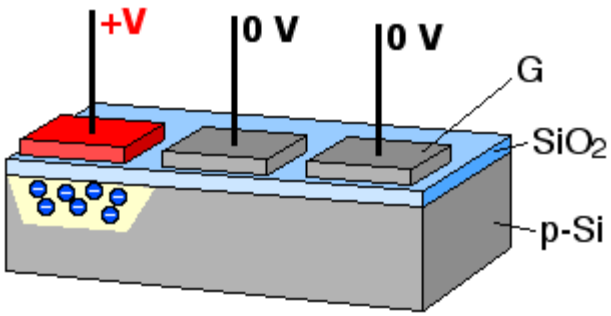


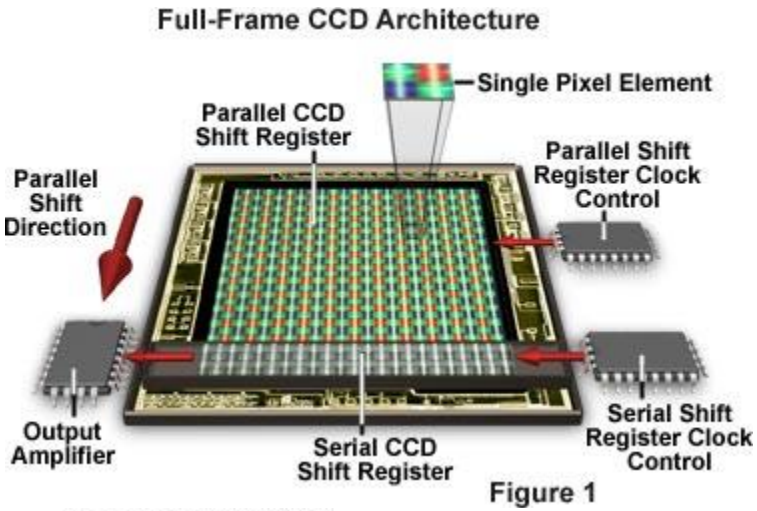


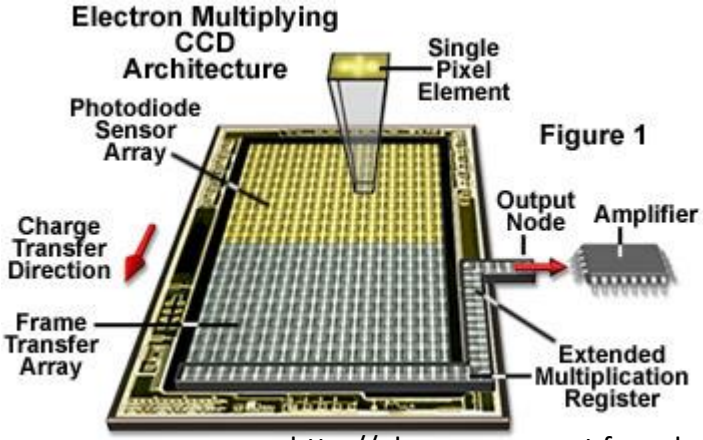
www.olympusmicro.com

Medical Imaging Methods

- Methods: CCD





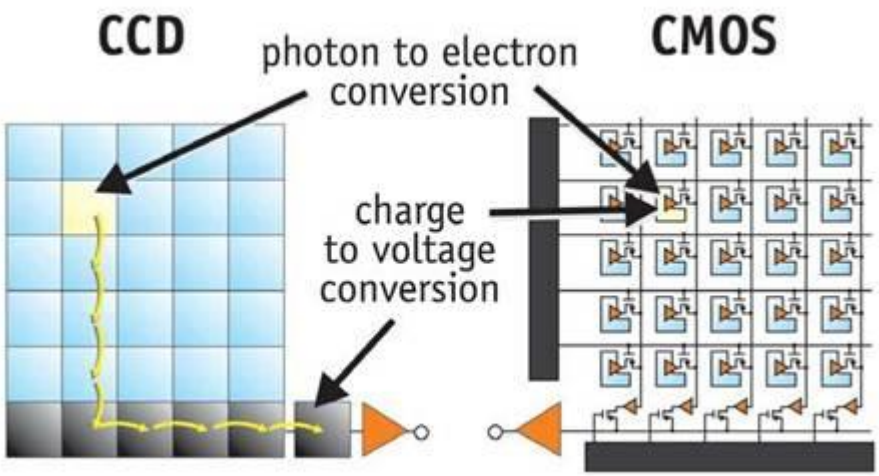


By Michael Schmid - animated drawing created myself, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=347838

http://olympus.magnet.fsu.edu/primer/digitalimaging/concepts/emccds.html

Medical Imaging Methods

- CCD vs APS

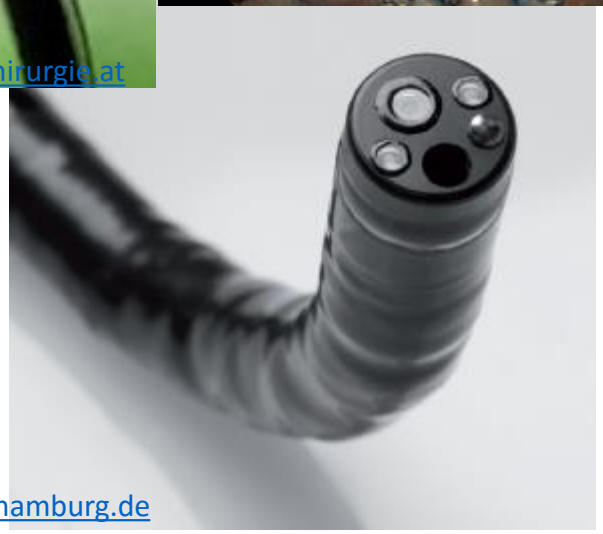


meroli.web.cern.ch

Medical Imaging Methods

- Methods: CCD
- endoscopes

www.sanfte-chirurgie.at

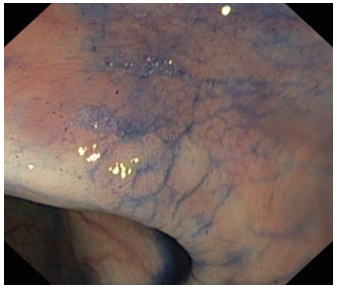


www.endo-tech-hamburg.de

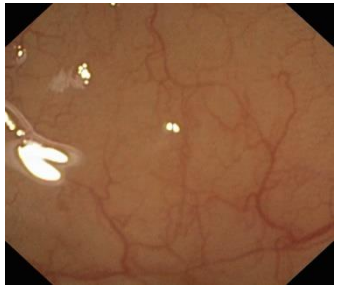
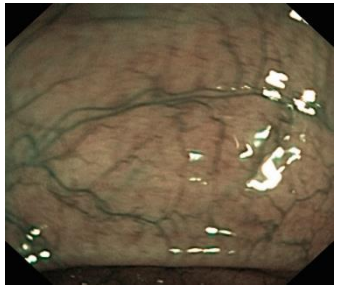
Medical Imaging Methods

Petz Aladár Megyei oktatókórház Győr

- Endoscopes
  - Using contrast coloured liquid dye can enhance structure

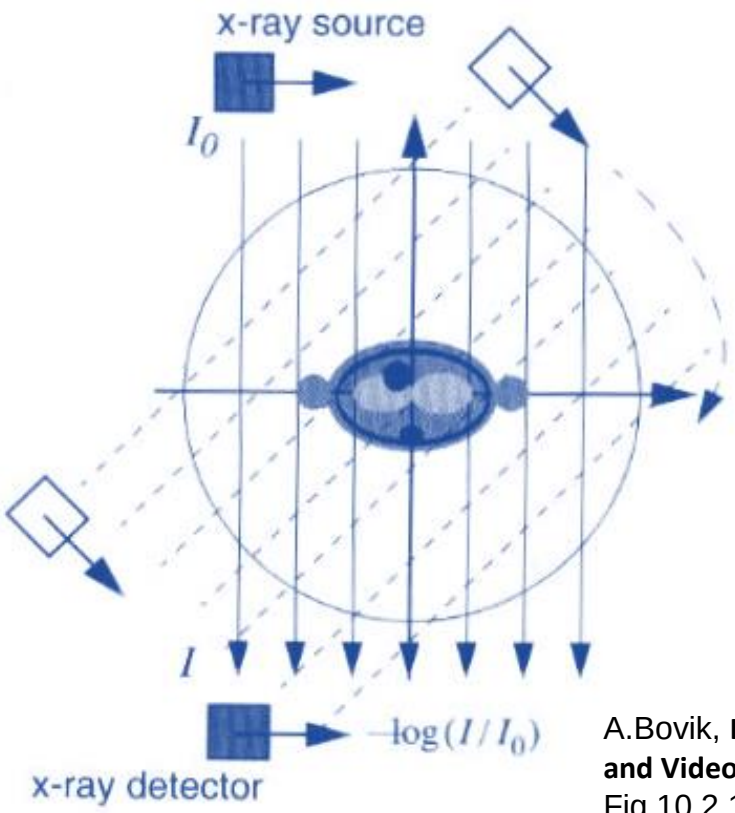


  - Narrow band imaging can increase contrast around veins

Medical Imaging Methods

- Methods: Tomograpy



A.Bovik, **Handbook of Image and Video Processing** Fig.10.2.1)

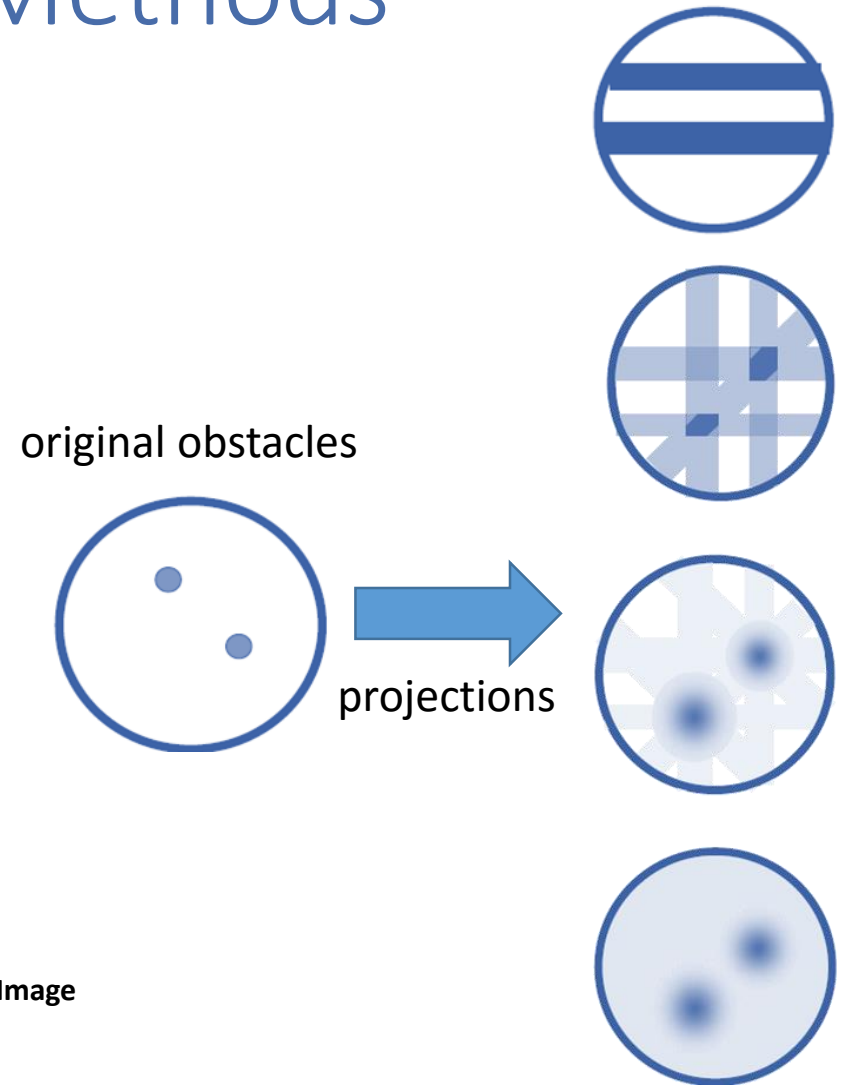


Image processing basics

- **Image Description**
- **Image Processing**
- **Graphics**
- **Image Analysis**

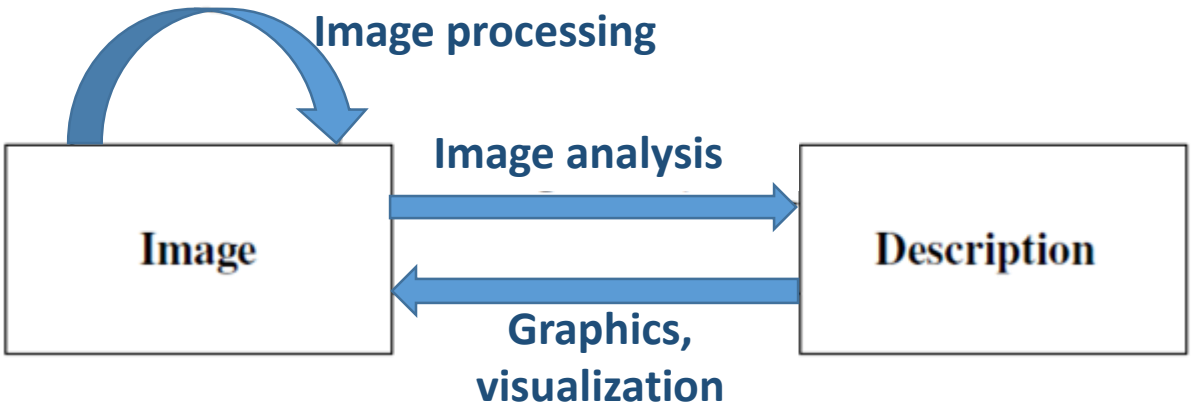


Image processing basics

- Region-based segmentation, grouping
  - edge-linking, detection of connected components, similar parts
- Region description
  - by colour, geometry, texture, weight, area, orientation, size,
- Correspondence, matching
  - Matching of a model or another picture to the picture (see PET-CT or MRI-CT)
  - finding the corresponding points, beacons

Image processing basics

- Operation types
  - local vs. global
  - recursive vs. non-recursive
- Actual operators
  - correlation
  - convolution
  - rotations, translations
  - mean, median
  - Hadamard, Fourier, wavelet and other transforms

Image processing basics

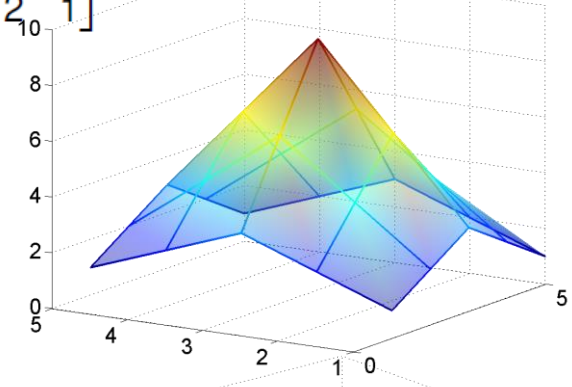
- Filtering as matrix operations

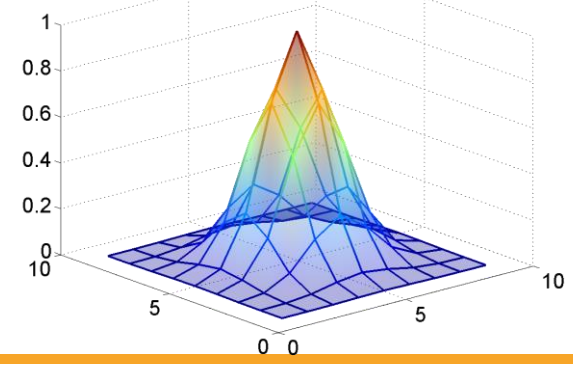
- Filtering as convolution

Image processing basics

- box filter
- average filter
- Gaussian filter
- other filter kernels

$$\begin{bmatrix} 1 & 2 & 3 & 2 & 1 \\ 2 & 4 & 6 & 4 & 2 \\ 3 & 6 & 9 & 6 & 3 \\ 2 & 4 & 6 & 4 & 2 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} * \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$





- Important tasks:
  - treating edges of the image
  - normalization
  - masks

Image processing basics

- Noise types
  - additive vs multiplicative noise
  - salt and pepper noise
  - additive white noise
  - multiplicative non correlated noise
  - quantization noise

  - artefacts of image compression

Image processing basics

- Noise filtering results
  - box filters
    - smoothening of the image
    - blurring of the lines
    - decreasing the maxima, increasing the minima, i.e. decreasing the dinamic range and contrast
    - introducing intermediate values → need for re-quantizing → new noise
    - outliers distort the image
  - median filters
    - outliers usually disappear
    - sometimes edges, lines disappear, too.

Image processing basics

- Filter pyramids
  - filter+ decimation series
  - Laplacian, Gaussian, wavelet, etc
  - result: details and large-scale

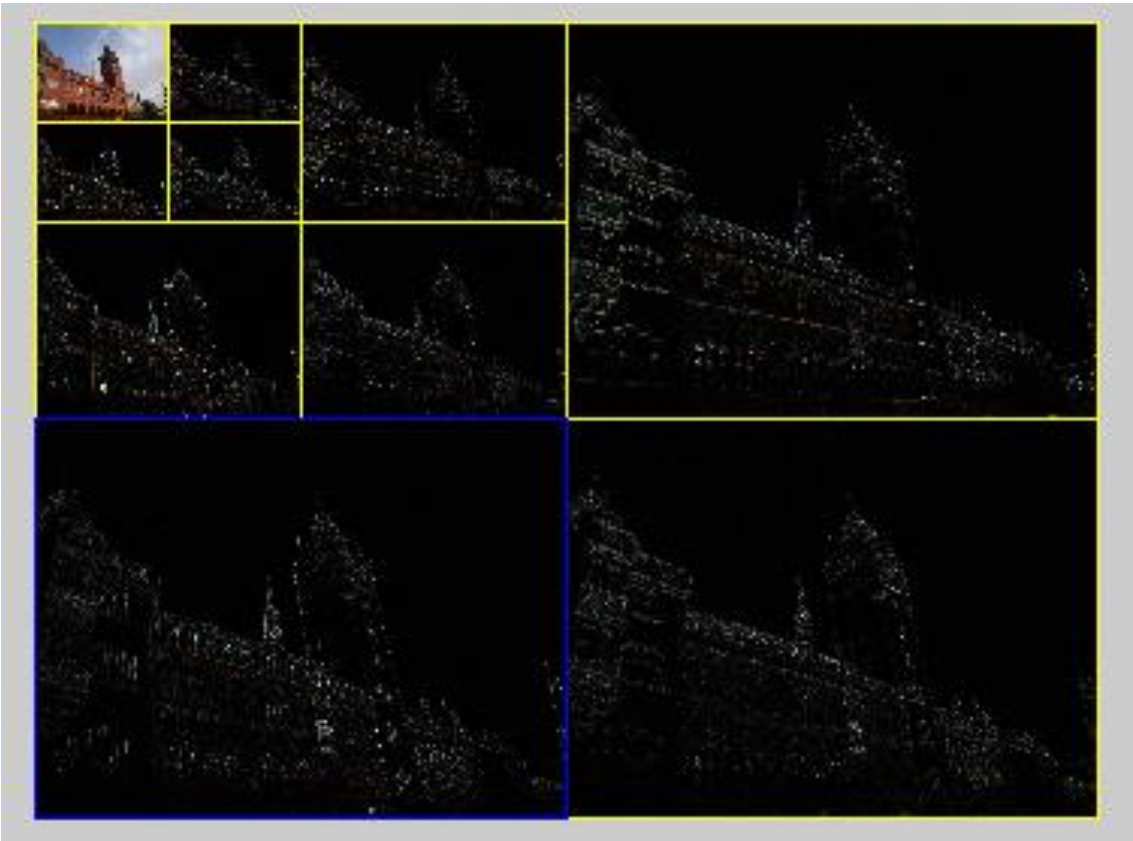


Image processing basics

- Separable and running filters
  - separable if it can be decomposed to more simple filters (usually of less dimension)

$$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 2 & 1 \end{bmatrix}$$

  - Running filter if a sliding window can make the filtering

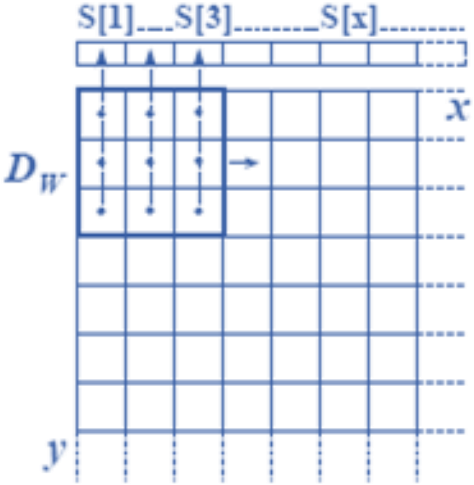


Image processing basics

- Adaptive filters
  - uses different filters at different locations
  - edges of the locations have to be determined
  - neighbours of the pixels have to be treated
    - standard n
    - k nearest
    - sigma $|I_p - I_{neigh}| < \sigma$
    - symmetric

Image processing basics

- Historgram operations
  - thresholding
  - stretching - dinamic range increasing
  - adaptive stretching
  - contrast shifting
  - unimodal, two or multiple modes

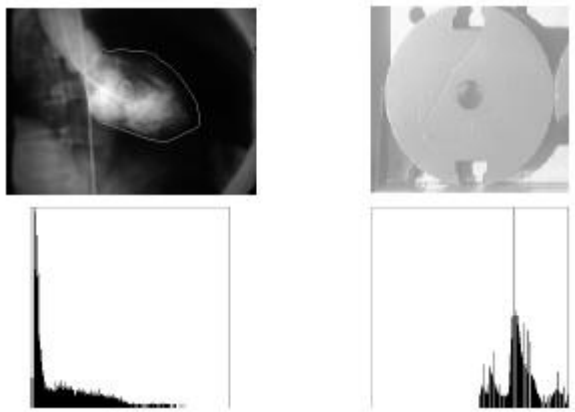


Image processing basics

- Matching
- Similarity, dissimilarity measures
  - sum of square differences
  - cross correlation (normalized, modified normalized, etc)
- Surface or contour fitting
  - robust and slow vs. better localization and quick
- Distortion, rotation, translation operators
- Orientation
- Flexible fitting

Image processing basics

- Thresholding
  - intensity levels – „filling up with water”
  - simple but very sensitive to noise
  - not too good for scanning imagers

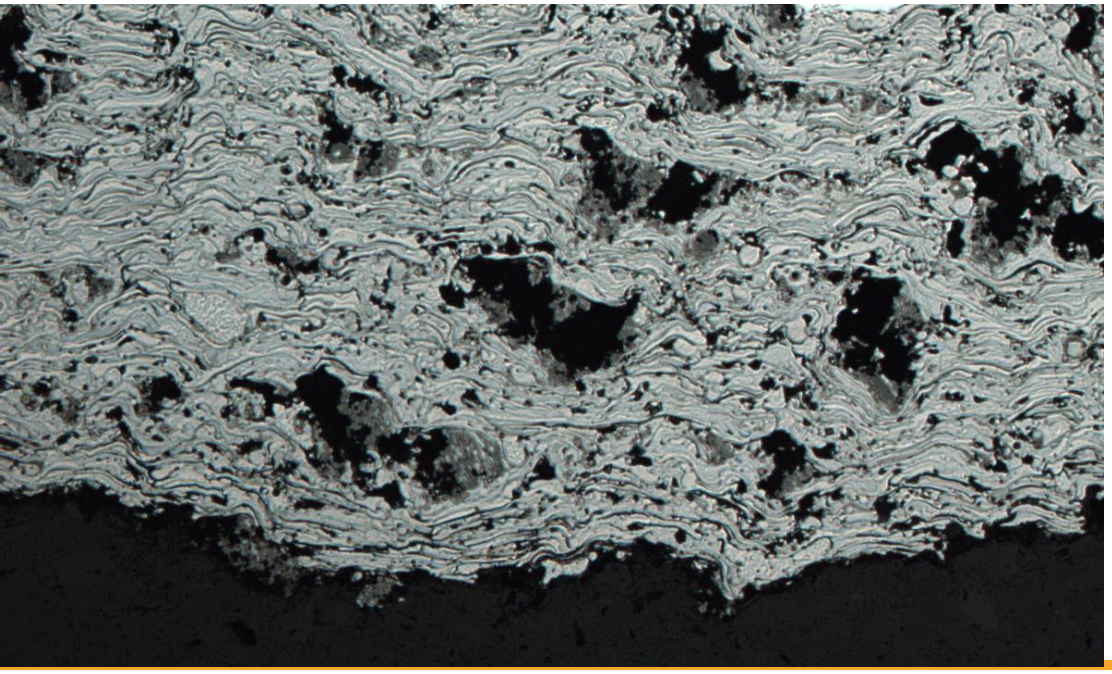
  - finding the threshold levels
  - fitting to histograms
  - Otsu thresholding

Image processing basics

- Edge detection, corner detection
  - derivative operators (value maxima or zero crossing)
  - Fourier or other transforms
  - Canny filters
- Isotropy issues
- Noisy pictures
- Prefiltering of noise and edge blurring
- Corners

Image processing basics

- Statistical analysis: mean, median, areas, fractal dimensions



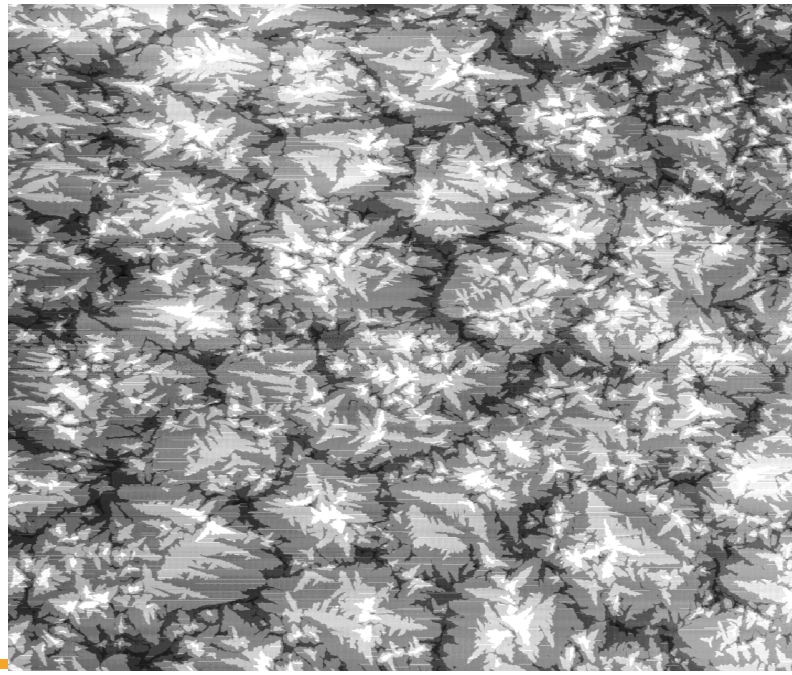


Image processing basics

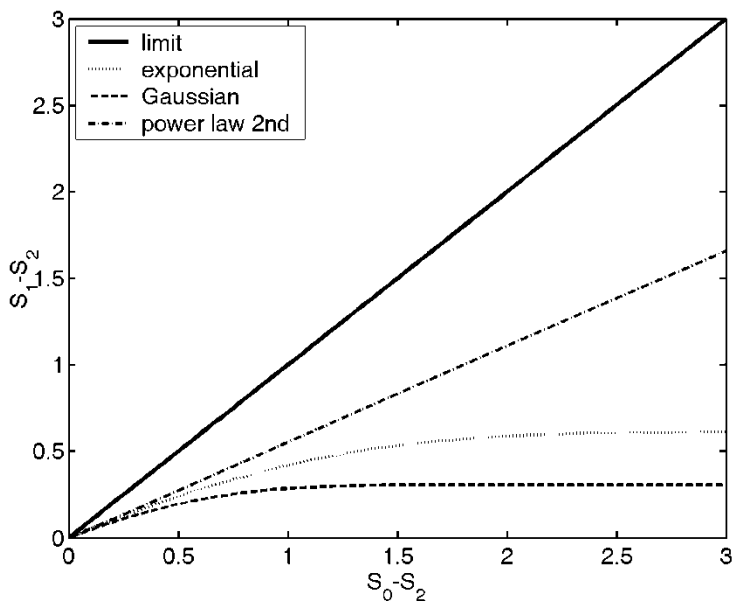
- Statistical analysis: entripies, structural entropy

  Probability distributions over a grid can be characterized by their Rényi entropies:

$$S_n = \frac{1}{1-N} \ln \sum_{i=1}^{N} I_i^n$$

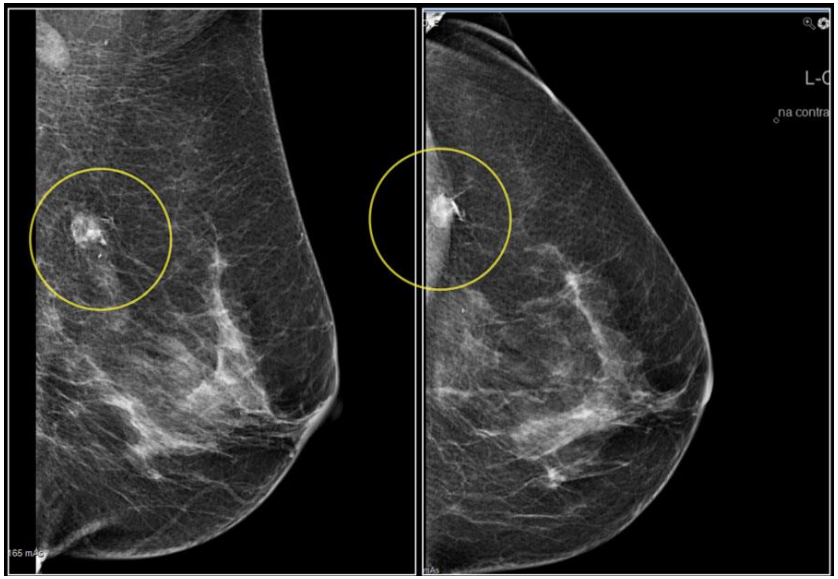
  Structural entropy and filling factor are the difference of two Rényi entropies

$$S_{str} = S_1 - S_2, \qquad \ln q = S_0 - S_2$$

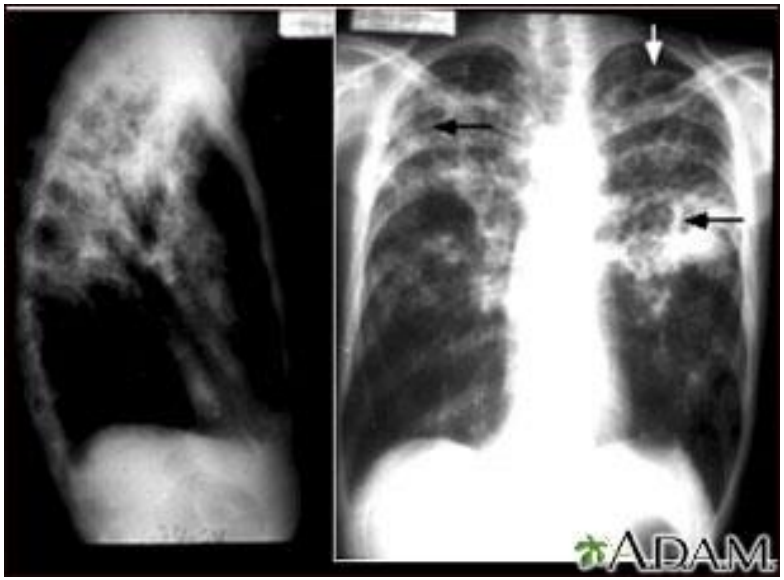


Leisons to be found

- higher intensity areas e.g. on an X-ray image (mammography, tuberculosis filtering)



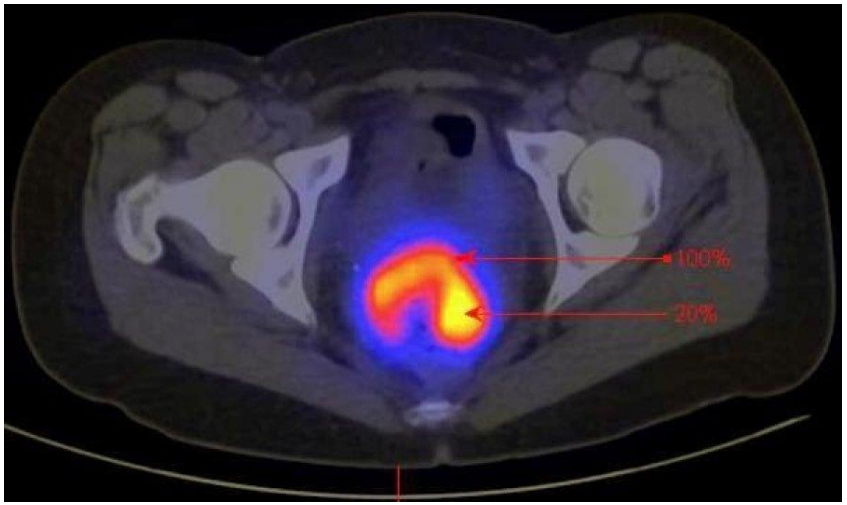
www.radiologyassistant.nl

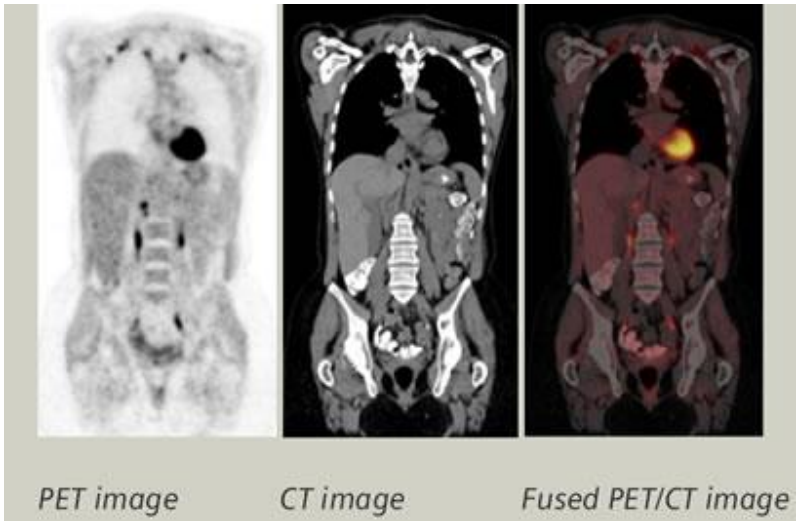


www.nlm.nih.gov

Leisons to be found

- High metabolic activity on a PET-CT



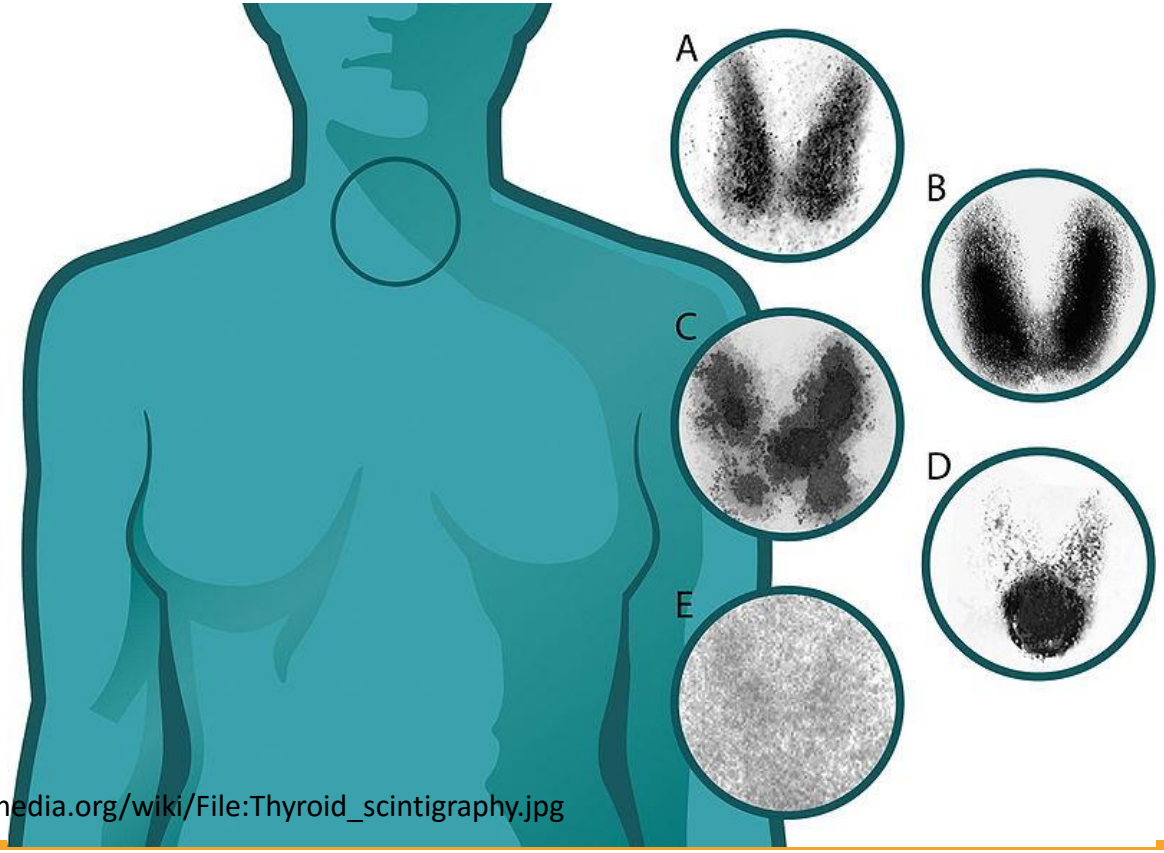


www.sciencedaily.com

www.imagingcenteratcarlstadt.com

Leisons to be found

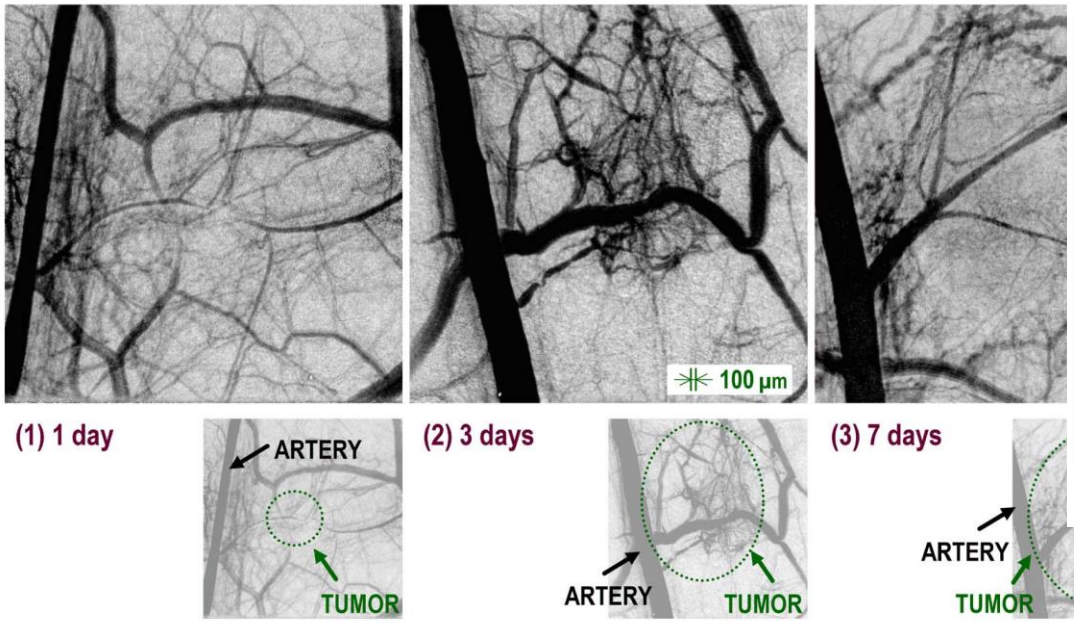
- High iodide concentration for thyroid problems



https://commons.wikimedia.org/wiki/File:Thyroid_scintigraphy.jpg

Leisons to be found

- High density and anomalous clustering of blood vessels



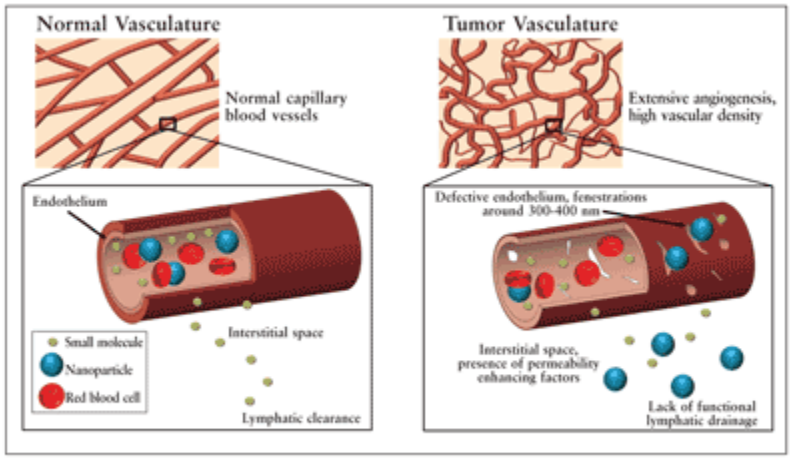


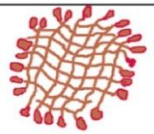
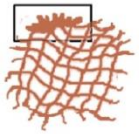
Figure 1. Illustration of the physiological factors that contribute to the enhanced permeation and retention (EPR) effect.

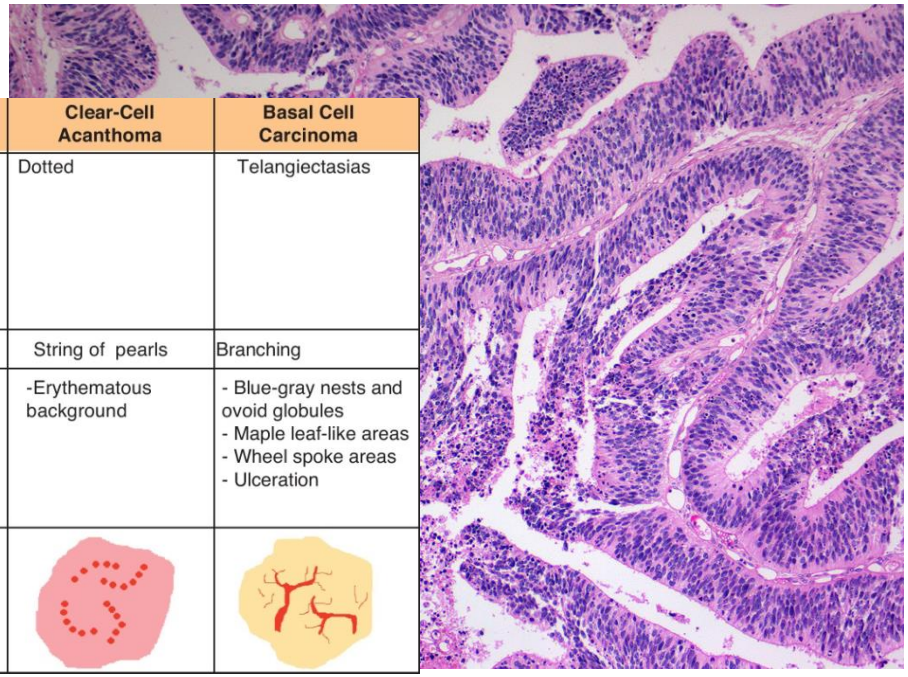
www.uspharmacist.com

www.spring8.or.jp

Leisons to be found

- Special structure in a microscope (melanoma or any type of biopsy)

Lesion	Mature Melanocytic Nevus	Spitz Nevus	Dysplastic Nevus	Melanoma	Clear-Cell Acanthoma	Basal Cell Carcinoma
Type of vessels	Comma	Dotted	Dotted and comma	Thin tumors (< 1 mm): dotted vessels Intermediate tumors (1-2 mm): dotted and linear irregular vessels Thick tumors: polymorphous vessels	Dotted	Telangiectasias
Distribution	Regular	Regular	Regular/irregular	Irregular	String of pearls	Branching
Additional criteria	- Comedo-like openings/milia-like cysts - Terminal hair - Residual brown pigmentation	- Pink background - Melanocytic criteria: -Inverted network - Chrysalis structures	-Melanocytic criteria	- Atypical melanocytic criteria: - Chrysalis structures	-Erythematous background	- Blue-gray nests and ovoid globules - Maple leaf-like areas - Wheel spoke areas - Ulceration
Diagram						

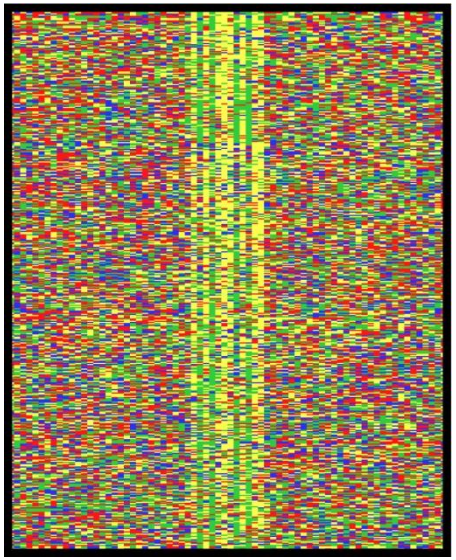


www.actasdermo.org

medicalpicturesinfo.com

Leisons to be found

- Special structure on a gene map



http://science.psu.edu/news-and-events/2012-news/Pugh1-2012

http://infosthetics.com/archives/2007/02/human_dna_rainbow_visualization.html

Leisons to be found

- Special surface pattern and strucure in a coloscope (pit patterns) or
- protrusion/ depression from surface

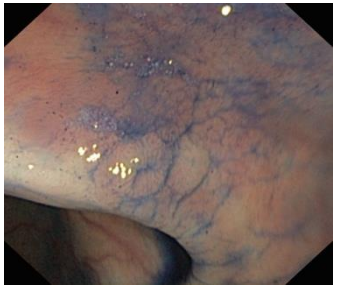
I	normal pattern	Nonneoplastic	No treatment
II	Hyperplastic polyp Serrated adenoma		
IIIs	regular pattern	Neoplastic, adenomatous	Endoscopic resection
IIIL			
IV			
VI	irregular pattern	Neoplastic, cancer	Endoscopic resection or Surgery
VN	non-structure pattern		Surgery

http://www.slideshare.net/shaikhani/japan-git-endoscopy-training-coursemarch-2011

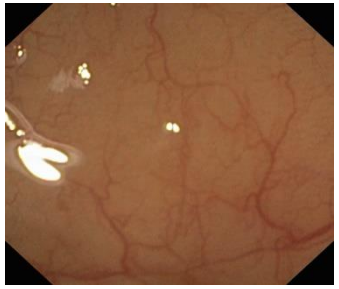
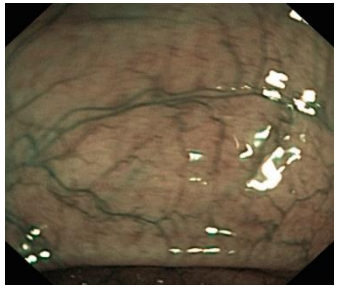
Medical Imaging Methods

Petz Aladár Megyei oktatókórház Győr

- Endoscopes
  - Using contrast coloured liquid dye can enhance structure



  - Narrow band imaging can increase contrast around veins

Colonoscopy

- Coloscopy images
  - are usually compressed
  - are taken from a motion picture from a continuously moving environment
  - have poor enlighting conditions
  - have artefacts
  - have low dynamic/colour range
  - have no scale

  - Contrast material can be used
  - NBI can be used

Colonoscopy

- Coloscopy ir
  - are usually
  - are taken f
    moving en
  - have poor
  - have artefa
  - have low c
  - have no sc

  - Contrast m
  - NBI can be

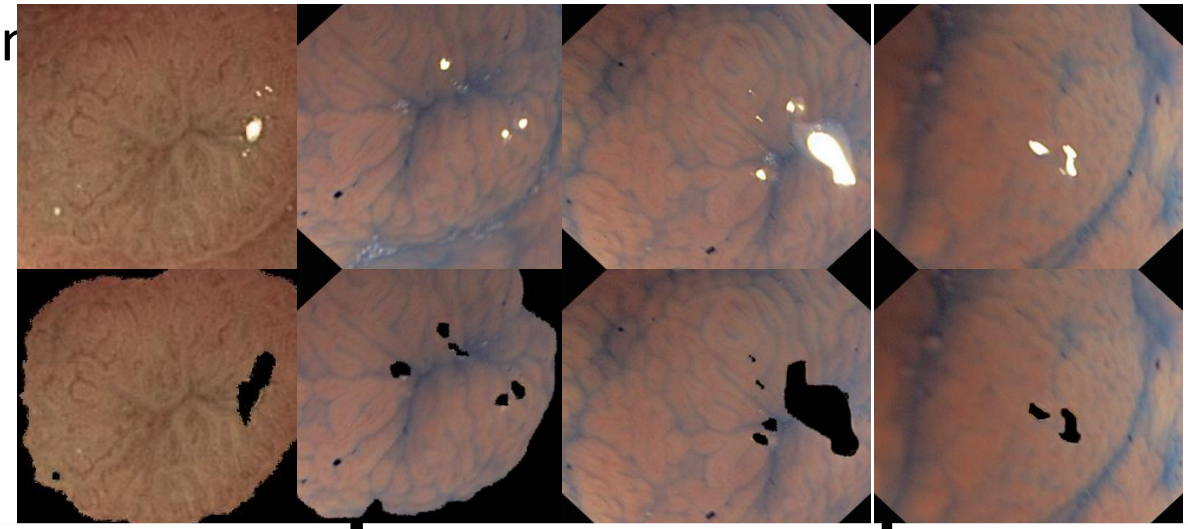
Colonoscopy

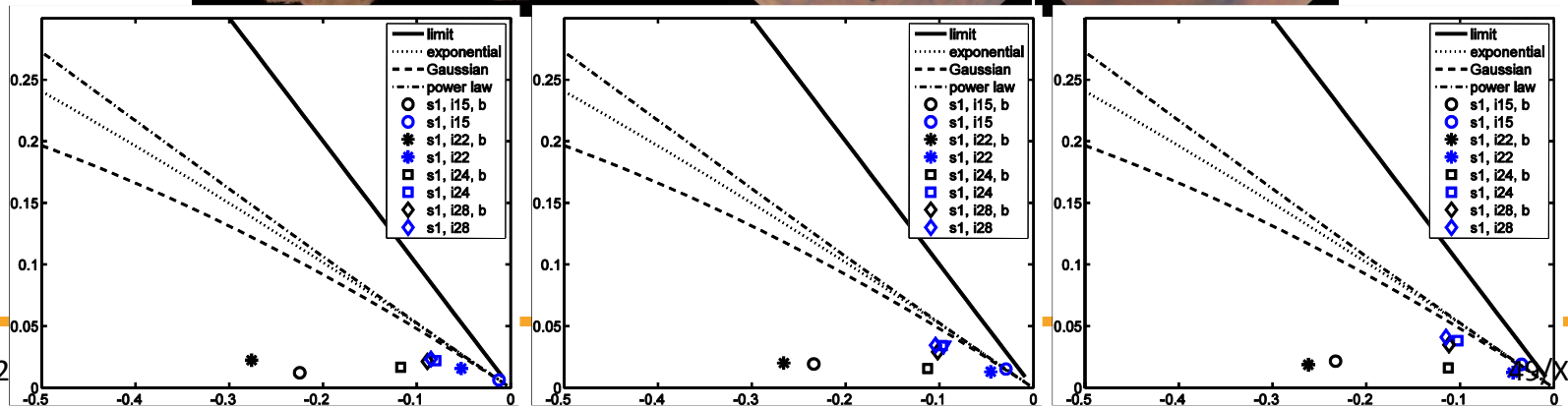
- Coloscopy images
  - are usually compres
  - are taken from a mo
    moving environmen
  - have poor enlightin
  - have artefacts
  - have low dynamic/c
  - have no scale

  - Contrast material ca
  - NBI can be used

Colonoscopy

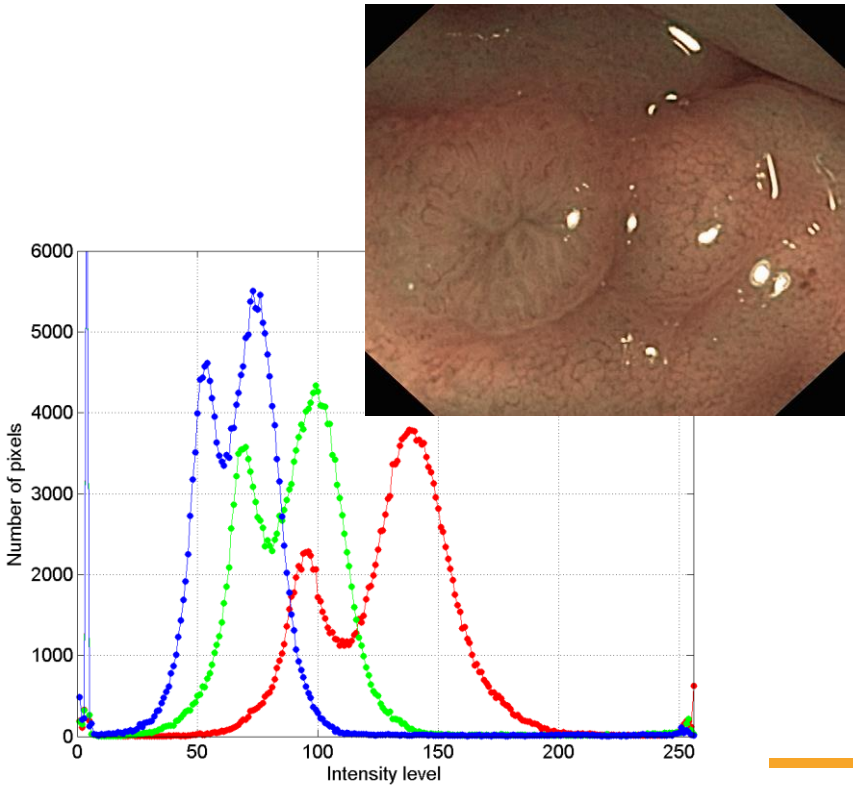
- Coloscopy images
  - sir

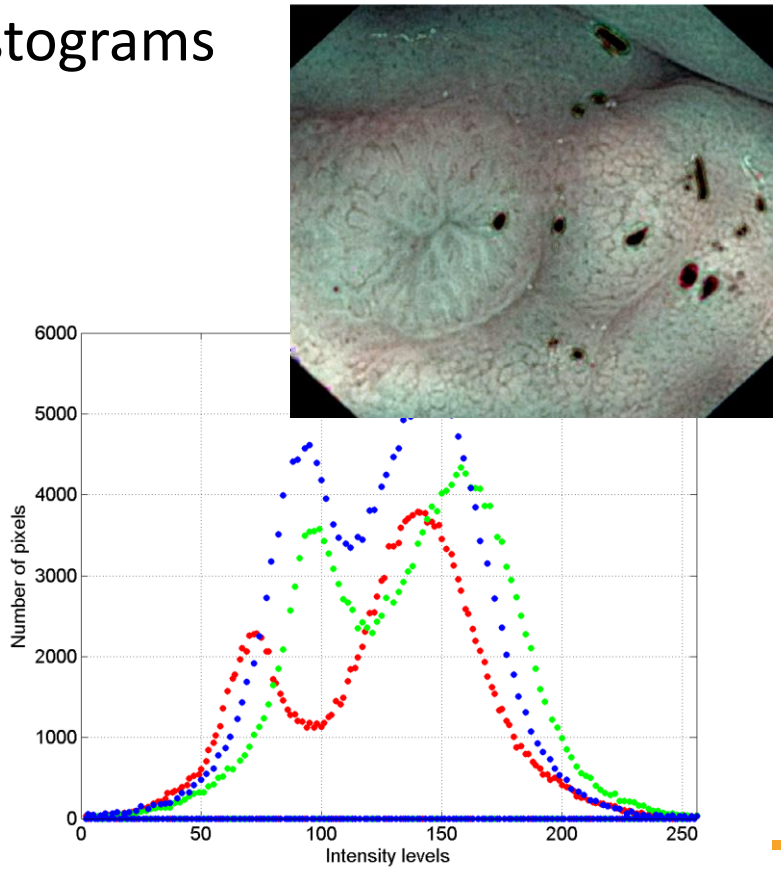




Colonoscopy

- Coloscopy images
  - contrast enhancement with histograms



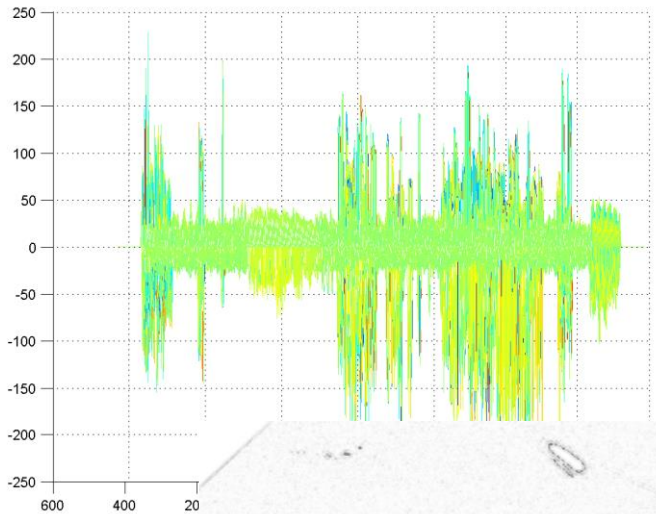


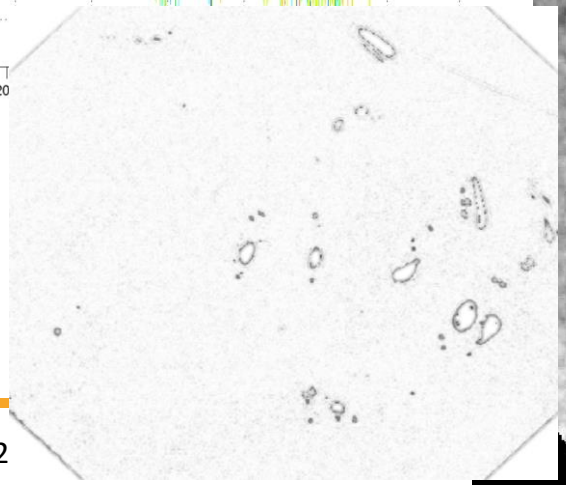
Colonoscopy

- Coloscopy images
  - masking the glares and background, ROI

Colonoscopy

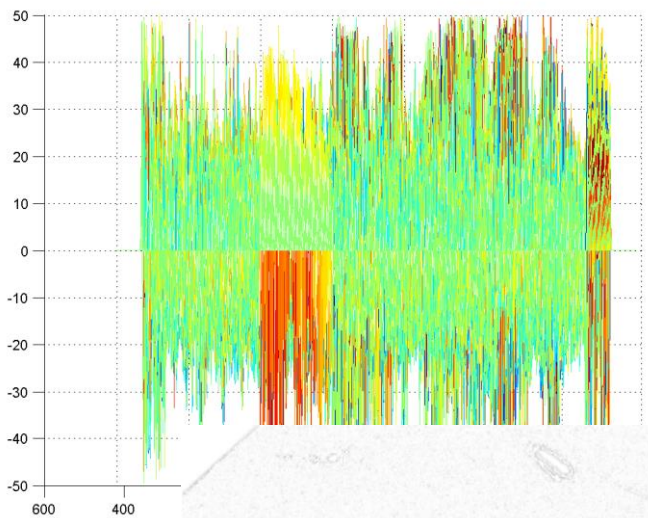
- Coloscopy images

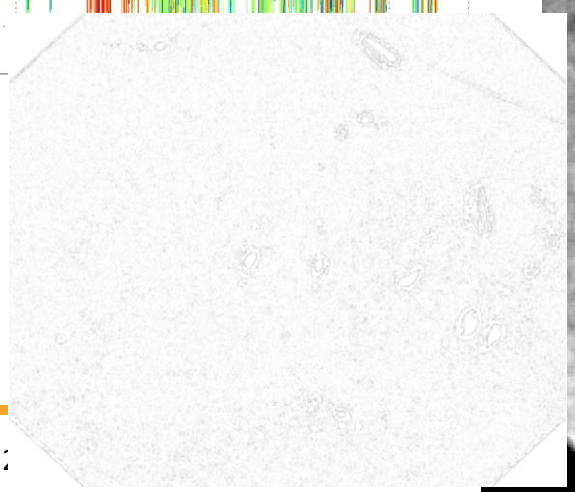




Colonoscopy

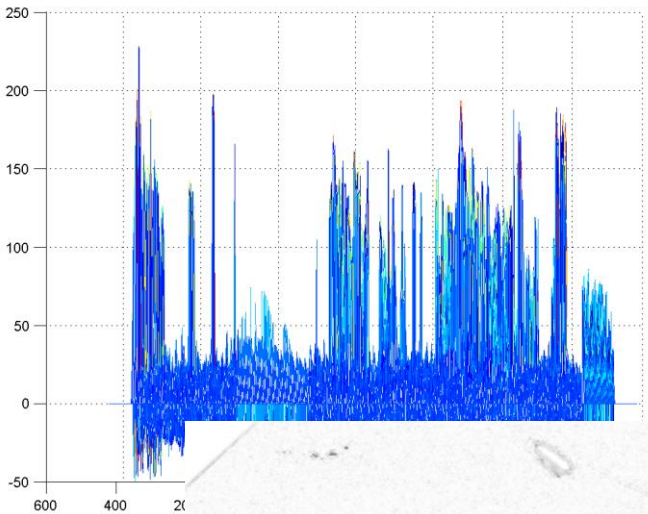
- Coloscopy images

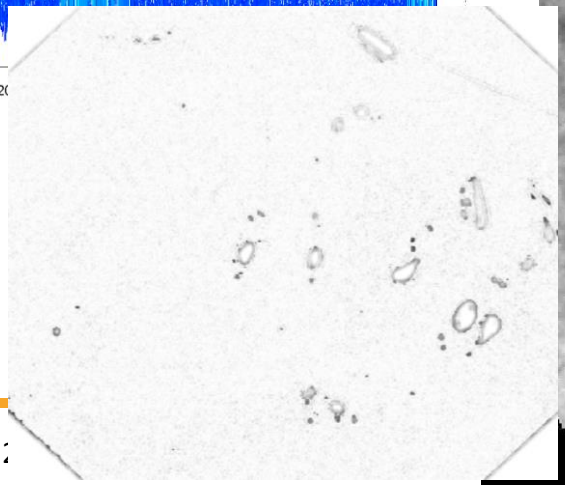


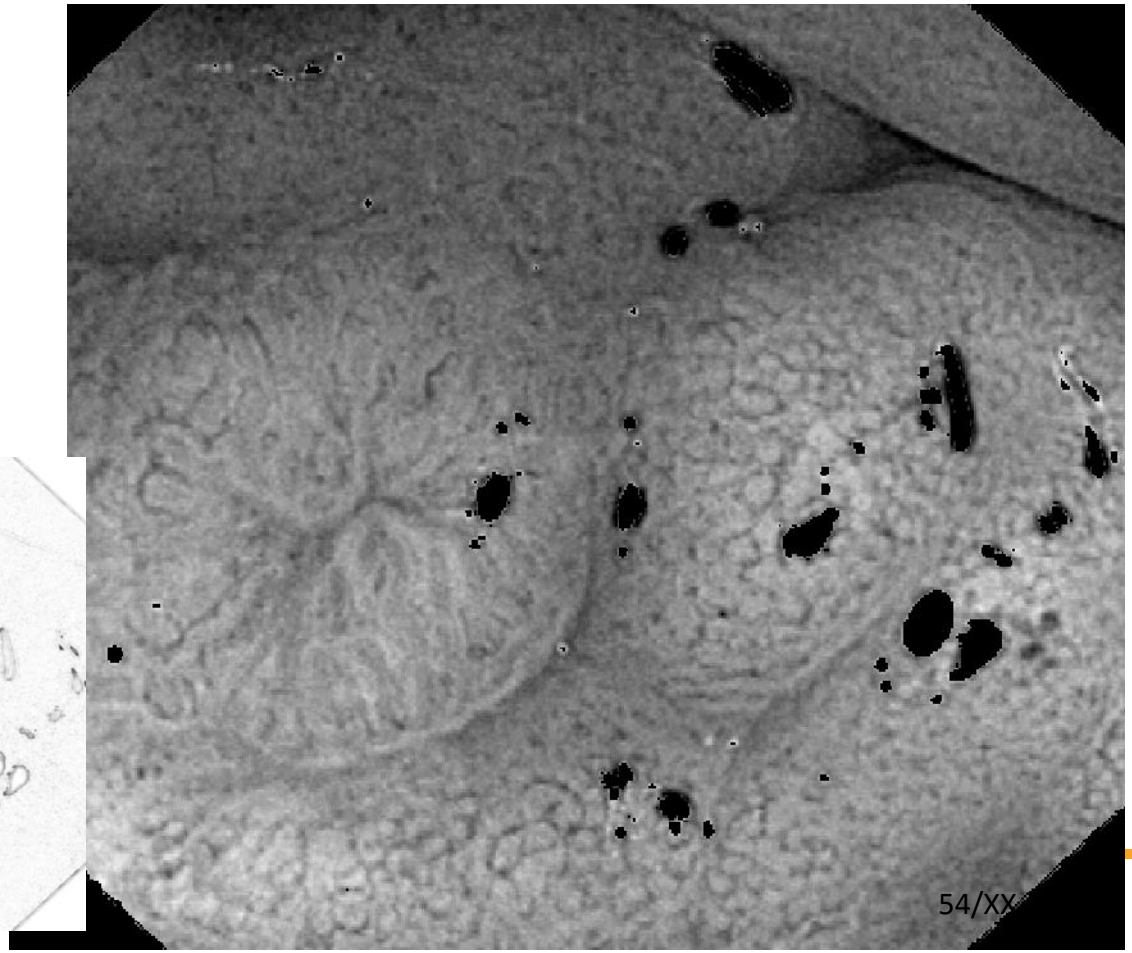


Colonoscopy

- Coloscopy images

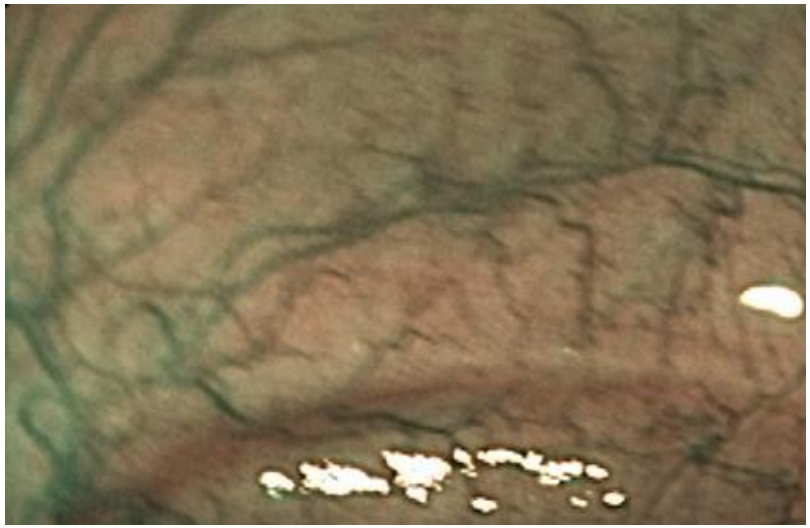


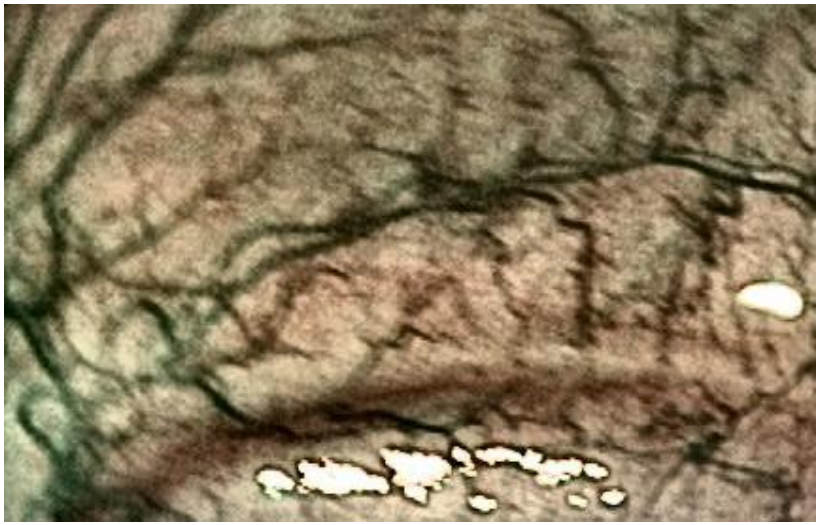




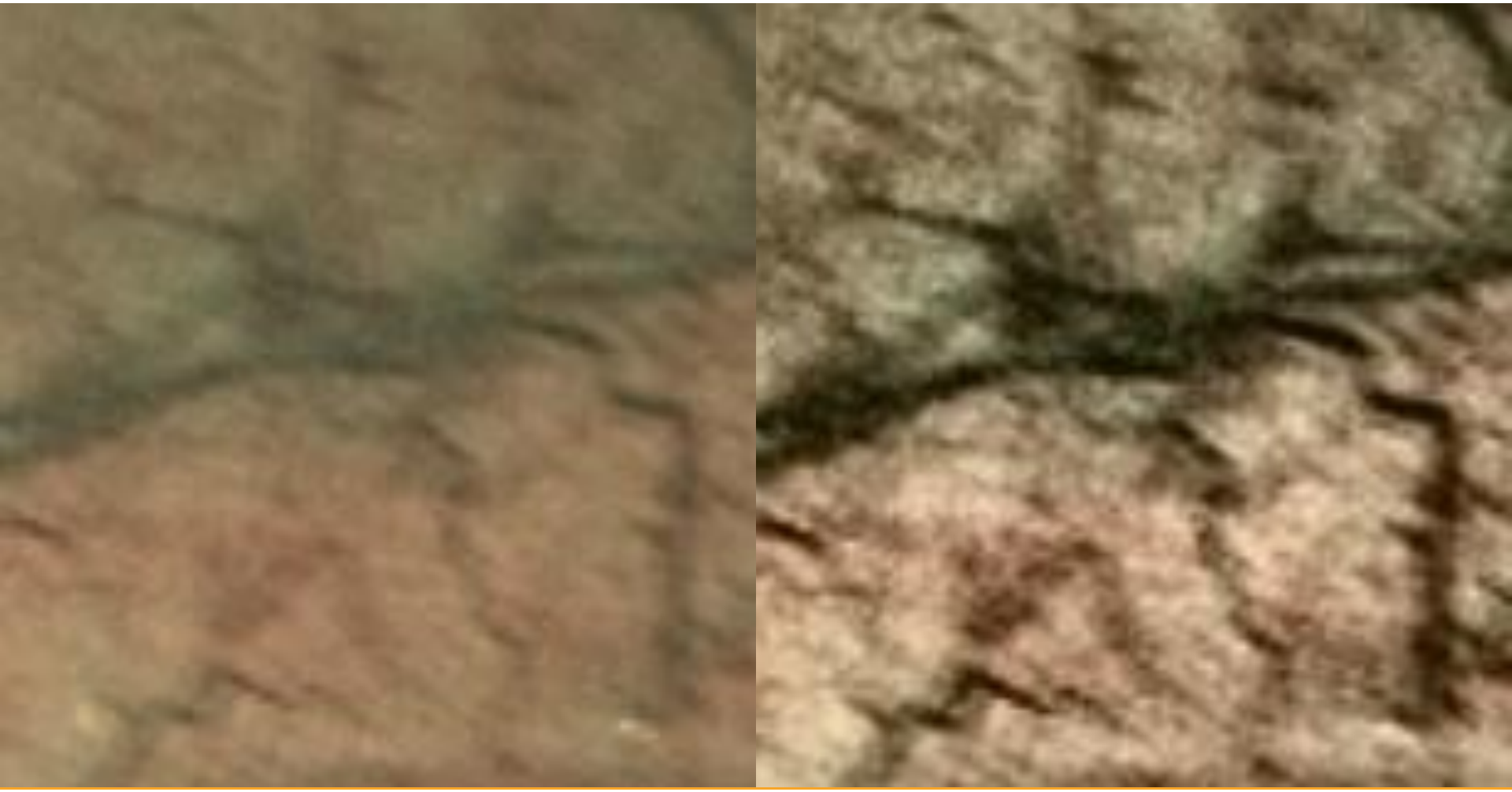
Colonoscopy

- Coloscopy images
  - adaptive contrast enhancement





Colonoscopy



Colonoscopy

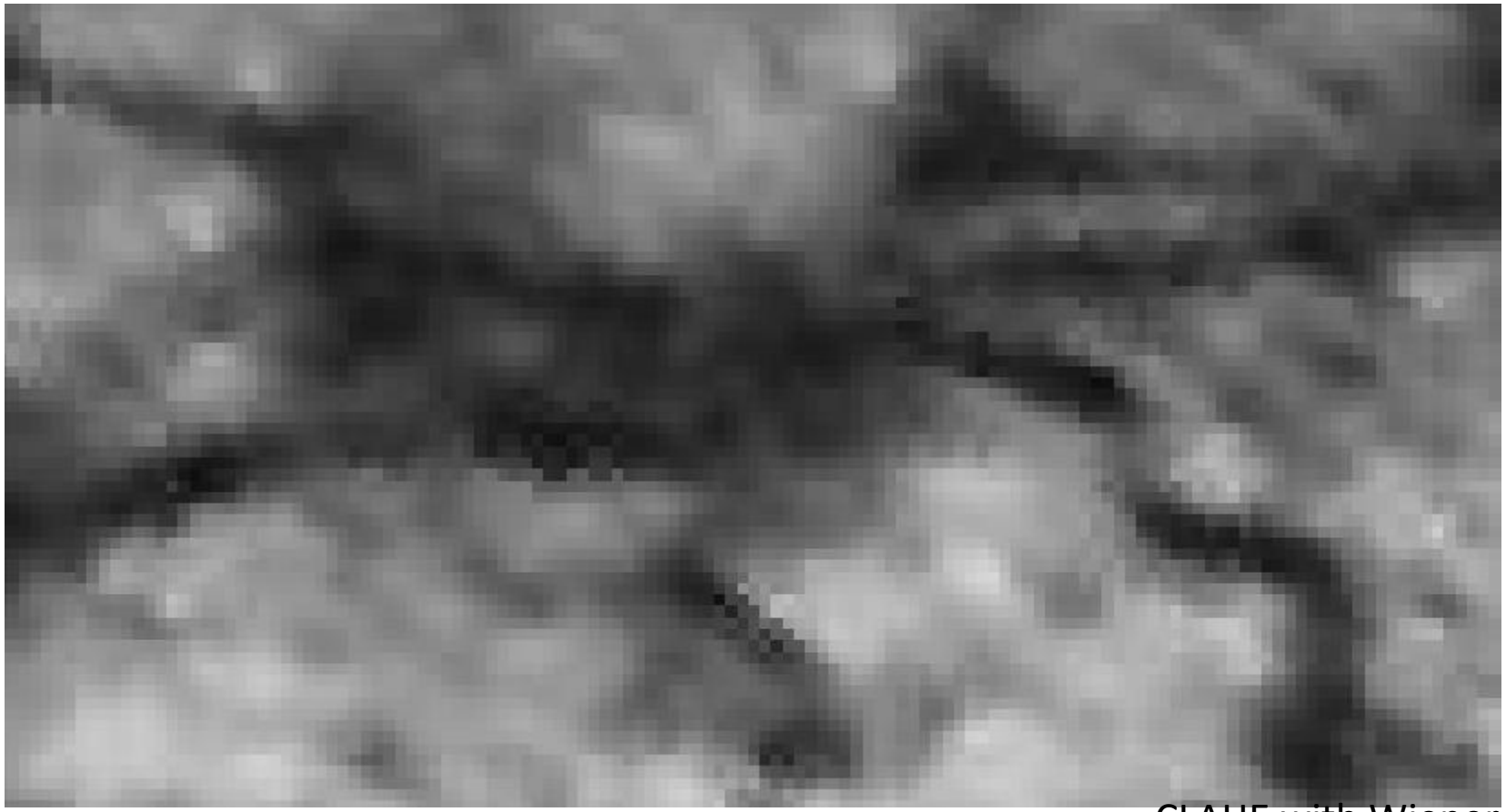
Original

Colonoscopy

-

CLAHE

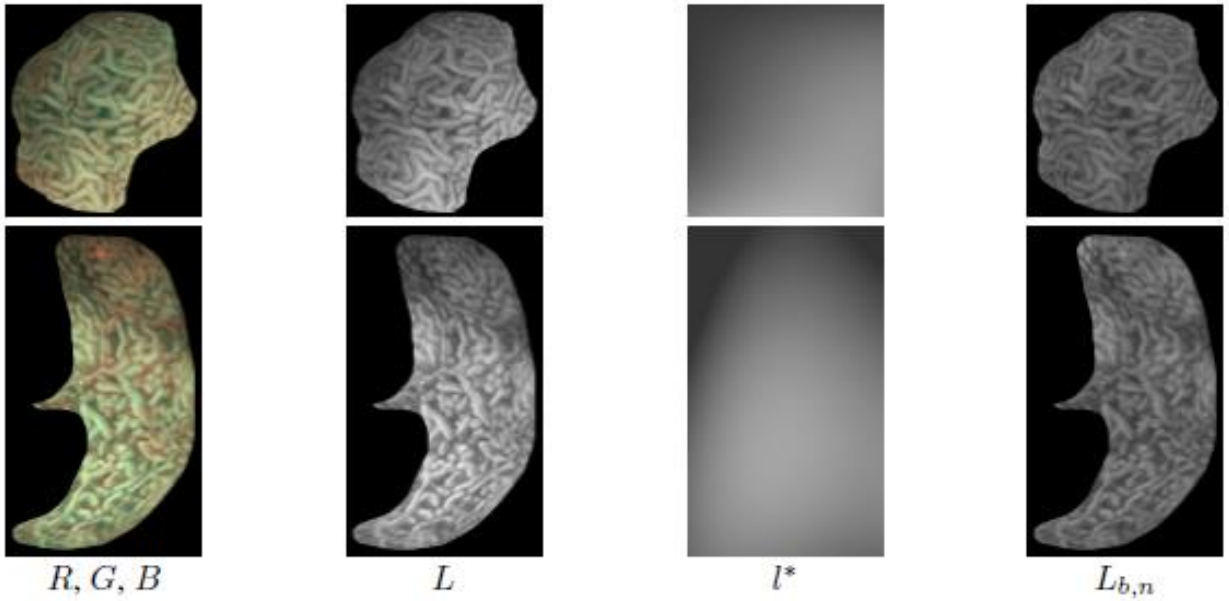
Colonoscopy



CLAHE with Wiener filter

Colonoscopy

$$L_{b,n}[i_x,i_y] = \frac{L_b[i_x,i_y]}{\max(L_b[i_x,i_y])},$$



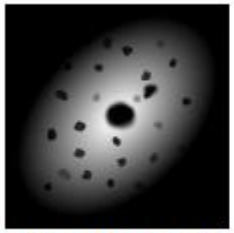
A. Horváth, S. Spindler, M. Szalay, I. Rácz, Preprocessing Endoscopic Images of Colorectal Polyps, Acta Technica Jaurinensis, Vol 9, No 1, pp. 65-82

Colonoscopy

$$T[i_x,i_y] = \frac{1}{D[i_x,i_y]} \sum_{l=-k}^{k} \sum_{j=-k}^{k} (L[i_x+j,i_y+l]Q[i_x+j,i_y+l])K[j,l]$$

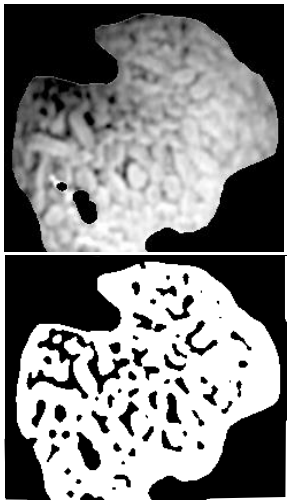
$$D[i_x,i_y] = \sum_{l=-k}^{k} \sum_{j=-k}^{k} Q[i_x+j,i_y+l]K[j,l].$$

$$Q[i_x,i_y] = \begin{cases} 1, & \text{if } (i_x,i_y) \text{ is inside ROI,} \\ 0, & \text{otherwise.} \end{cases}$$



T-1/3: sI*ID3+ noise

T-4/3: sIV*ID3 +noise



A. Horváth, S. Spindler, M. Szalay, I. Rácz, Preprocessing Endoscopic Images of Colorectal Polyps, Acta Technica Jaurinensis, Vol 9, No 1, pp. 65-82

InnoSoc
Innovative ICT Solutions
for the Societal Challenges

Co-funded by the
Erasmus+ Programme
of the European Union

Unska 3, HR-10000 Zagreb,
Croatia
innosoc@fer.hr

sociallab.education/innosoc
facebook.com/innosoc
twitter.com/innosoc

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.