Medical Image Analysis (MIA)

(Medizinische Bildanalyse)

710.076 2 VO
710.077 1 KU

Martin Urschler

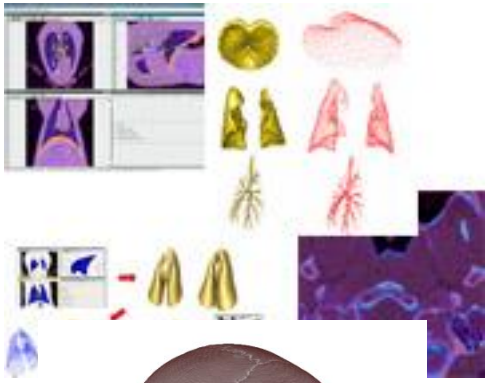
Institute for Computer Graphics and Vision, TU Graz

SS 2016

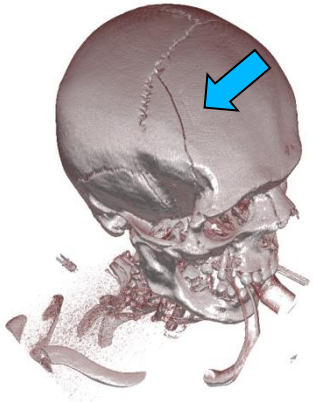
About Me

- Telematik 1995-2001 - PhD program 2002-2007
- Stays in Iowa City, Prof. Milan Sonka `02 & `03

- 2004-2007: PhD project
  „Nonlinear Registration Methods for Medical Intra-Modality Applications“



- 2007-2008: working on Face Analysis



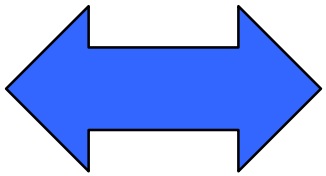
- 2009-now: LBI for Clinical Forensic Imaging

About You

1. ICG courses? (CGCV, BVME, Robot Vision, AKCV, Math. Grundlagen)
2. Algorithm for reconstruction of an image from measured CT x-ray signals?
3. Example of edge-preserving denoising model?
4. Algorithm for rigidly registering 2 sets of corresponding points (how to get a transformation matrix)?
5. What is the difference between generative and discriminative learning?

Question

- Where is the link?



Godfrey Hounsfield @ ***EMI*** Central Research Laboratories:
First Commercial CT Scanner (~1971, 4 minute scan, 2 slices of 80x80)

Images Play an Important Role in Medicine

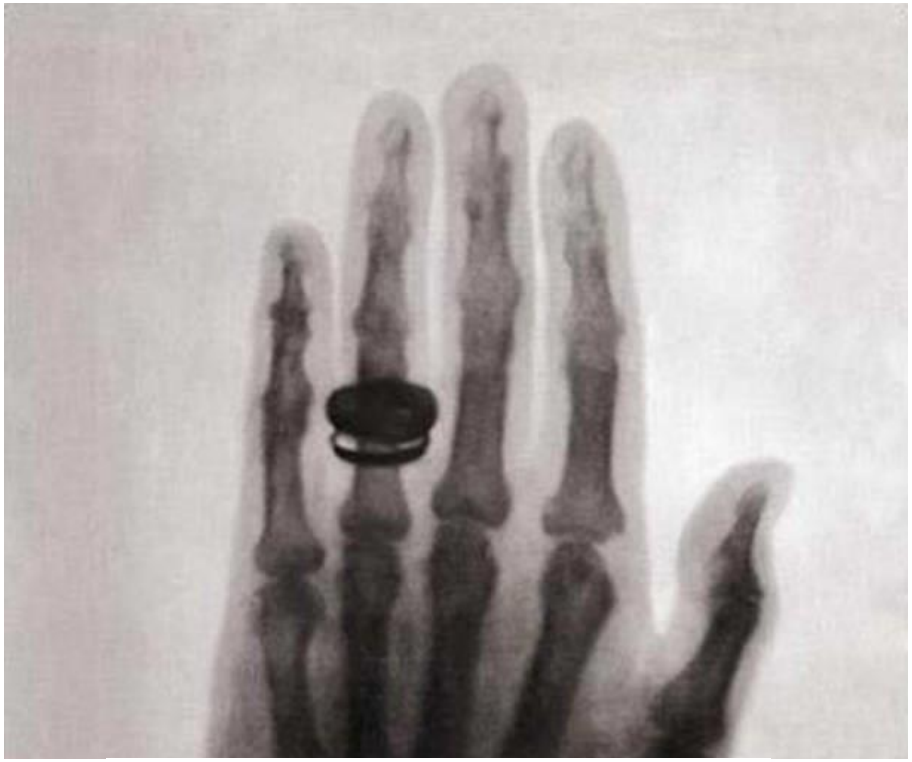
First X-ray Image

First Nobel Prize in Physics 1901!

The hand of Mrs. Wilhelm Roentgen: the first X-ray image, 1895

In Otto Glasser, ***Wilhelm Conrad Röntgen and the early history of the Roentgen rays.*** *London, 1933. National Library of Medicine.*

The announcement of Roentgen's discovery, illustrated with an X-ray photograph of his wife's hand, was hailed as one of mankind's greatest technological accomplishments, an invention that would revolutionize every aspect of human existence.



Additionally, 3D Imaging Revolutionized Medicine

- Ability to look inside the body …
- Computed Tomography

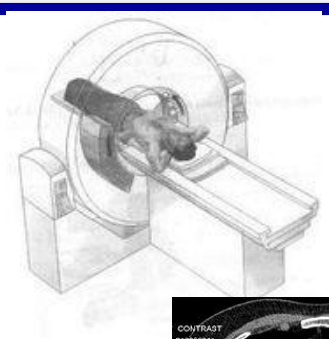
  "tomography“: Greek *tomos* (slice) & *graphein* (to write)

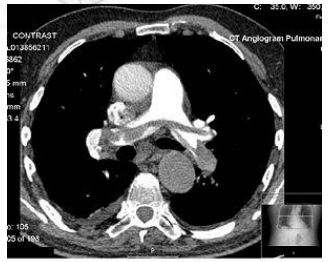
  Godfrey Hounsfield & *Allan Cormack*

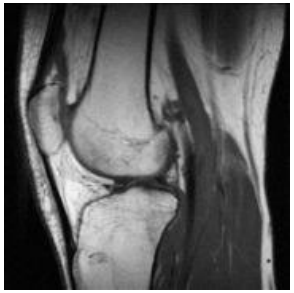
  Nobel Prize in Medicine 1979
- Magnetic Resonance Imaging

  Paul Lauterbur & Sir *Peter Mansfield*

  Nobel Prize in Medicine 2003



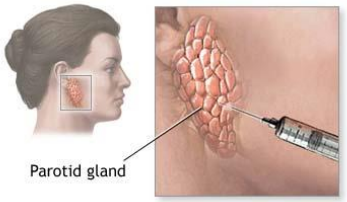




Images taken from: Wikipedia

Medical Investigations without Images

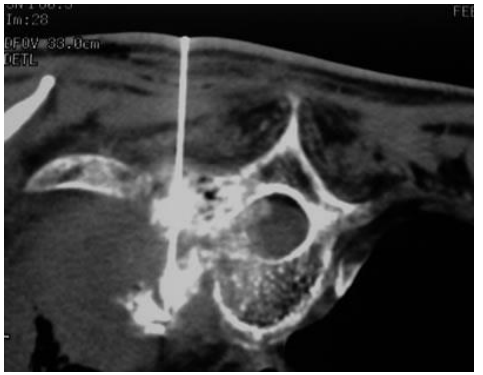
- Non invasive
  - Observe output of system – symptoms
  - Observe external signals: ECG, EEG, …
  - Take elements from the system and test them: blood, urine, …
- Minimally invasive
  - Needle biopsy
- Invasive
  - Surgery

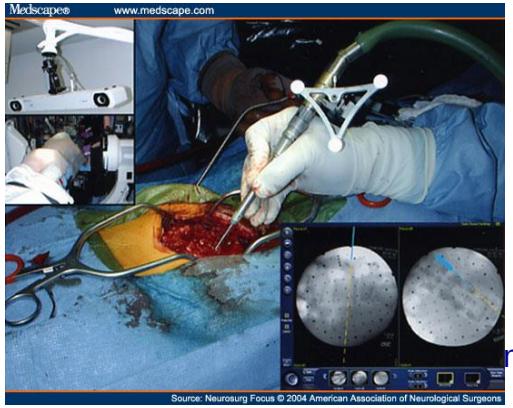


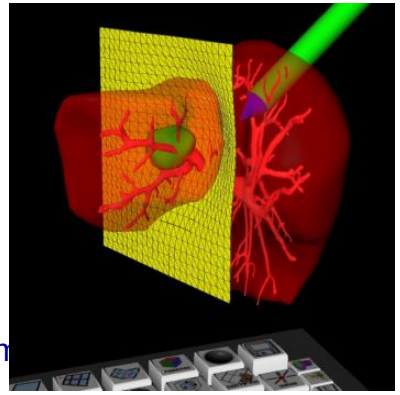
Images taken from: Wikipedia

Medical Investigations with Images

- General Diagnosis
  - Heart, Brain, Lung, Liver
  - Perfusion, Tumor Screening
- Minimally Invasive Interventions
  - Thermal (Radio Frequency) Ablation
- Surgical Planning & Image Guided Surgery
  - Organ Resection





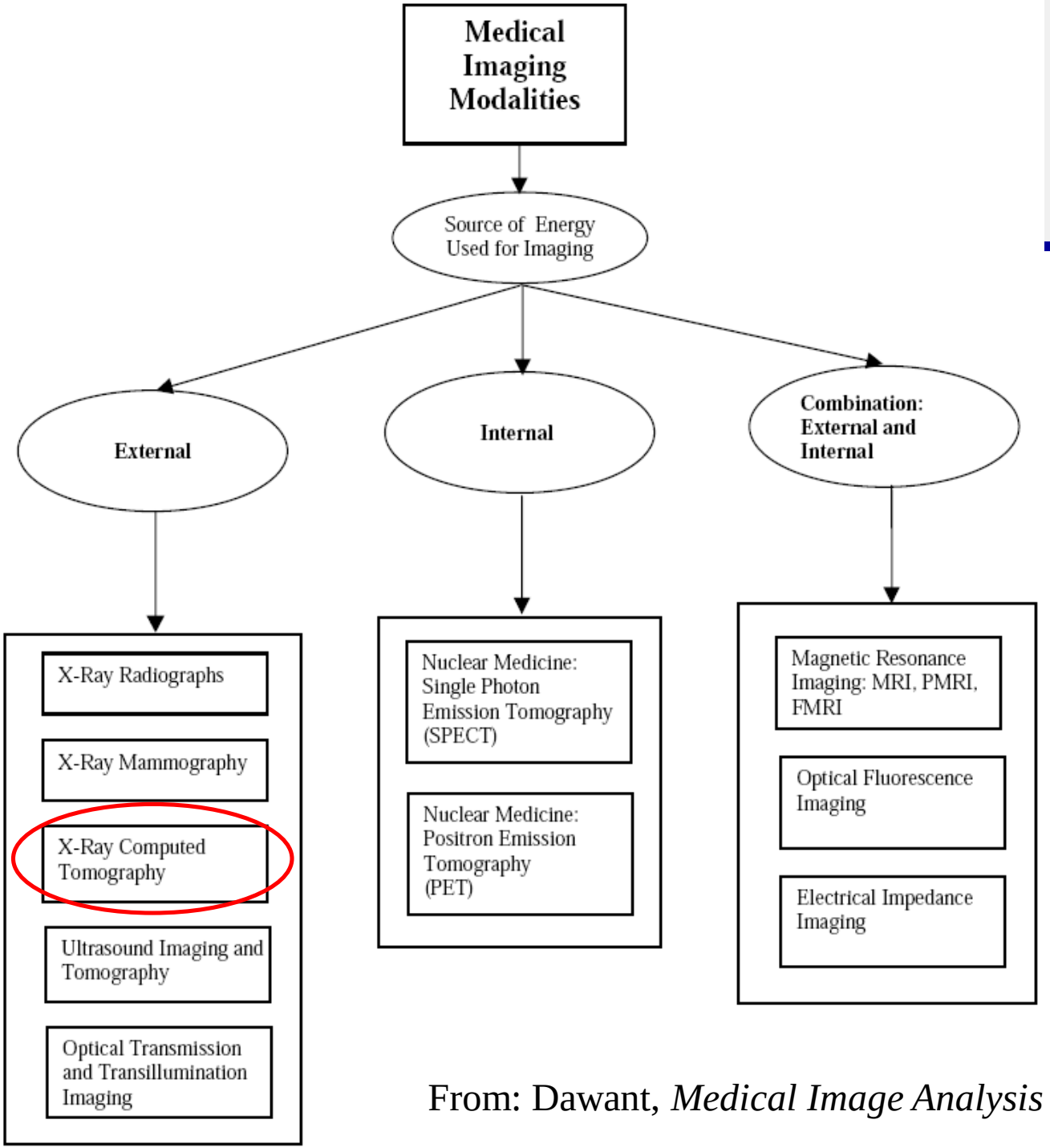


Imaging Modalities

Acquiring information about:

- Anatomy
- Physiology (Function)

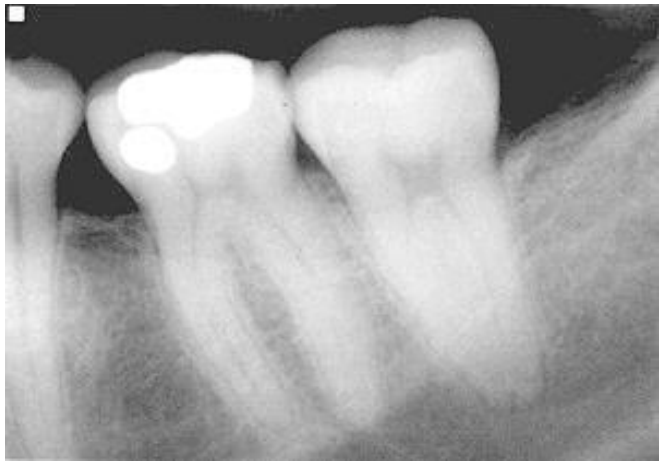
in 2D, 3D, or 4D



From: Dawant, *Medical Image Analysis*

X-Ray Radiographs / Mammography

Bone

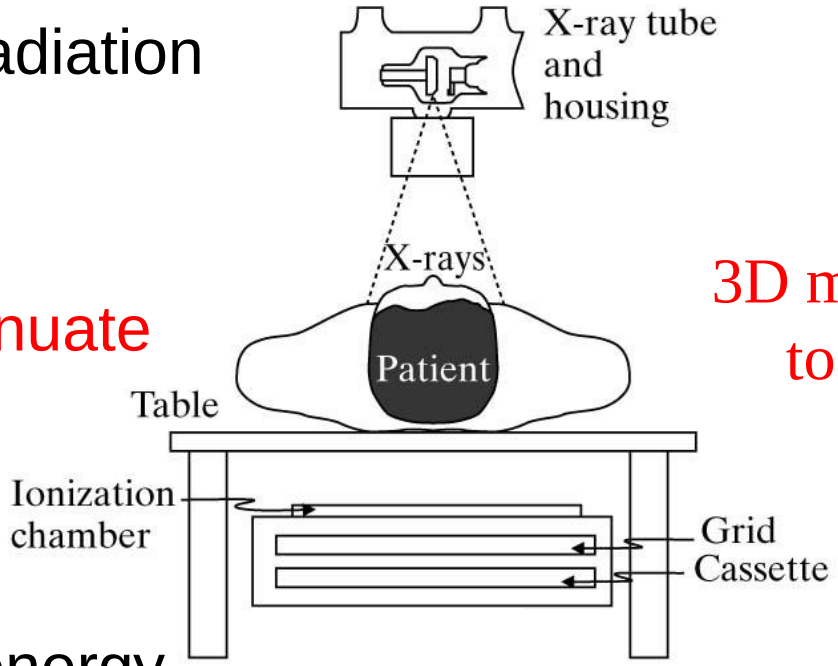


Teeth

Breast

X-Ray Radiographs - Principle

- Source emits x-ray radiation
- Different tissues attenuate radiation differently
- Detector measures remaining radiation energy

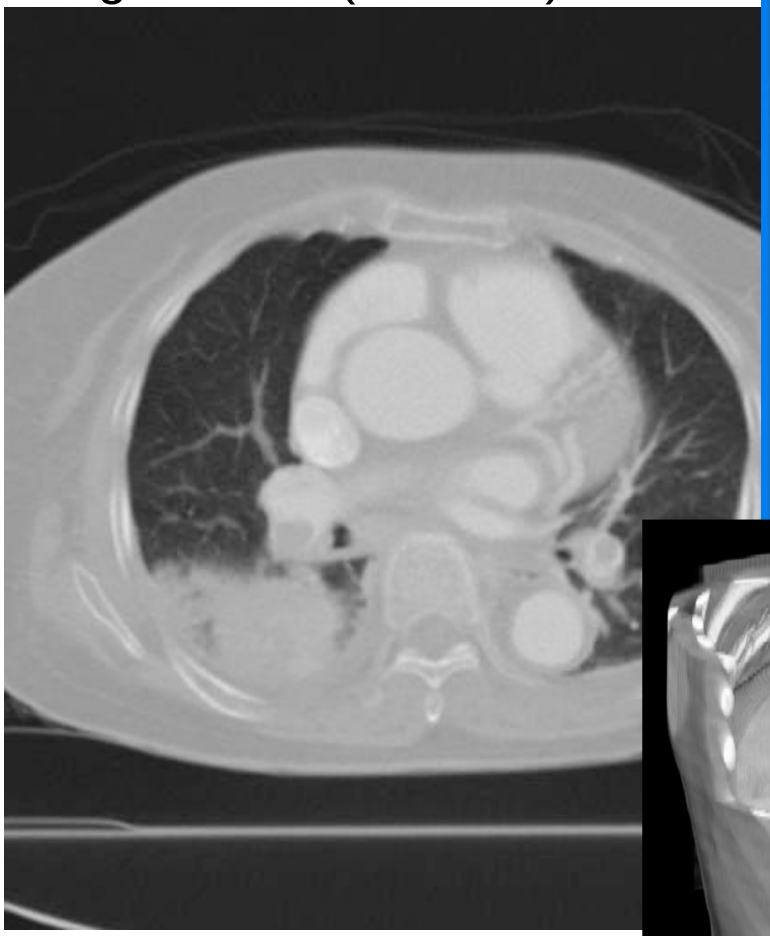


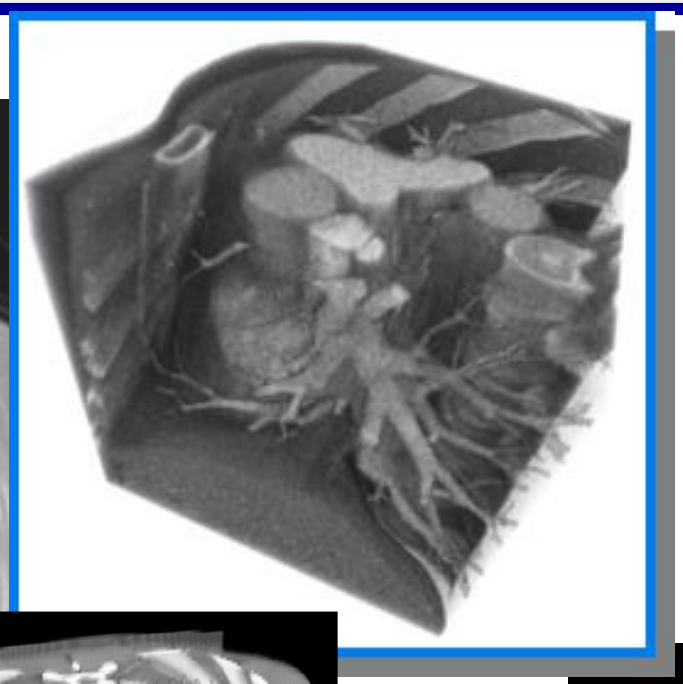
3D mapped to 2D!

Figure 5.2

X-Ray Computed Tomography (CT)

Lung & Heart (contrast)





Brain

Liver

Coronary Arteries M

X-Ray CT Principle

- "Rotating X-Ray Acquisition"
  - Practice: rotate device not patient!

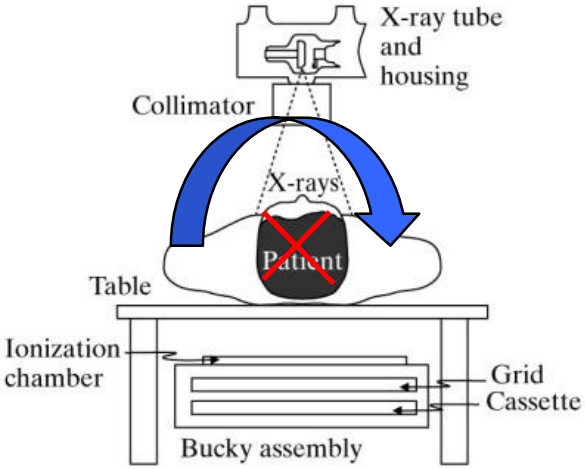
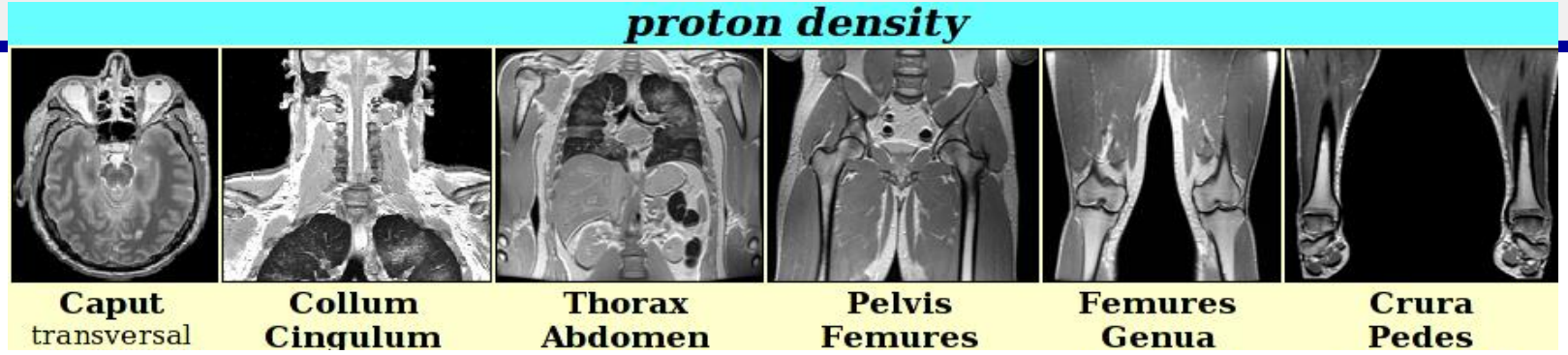
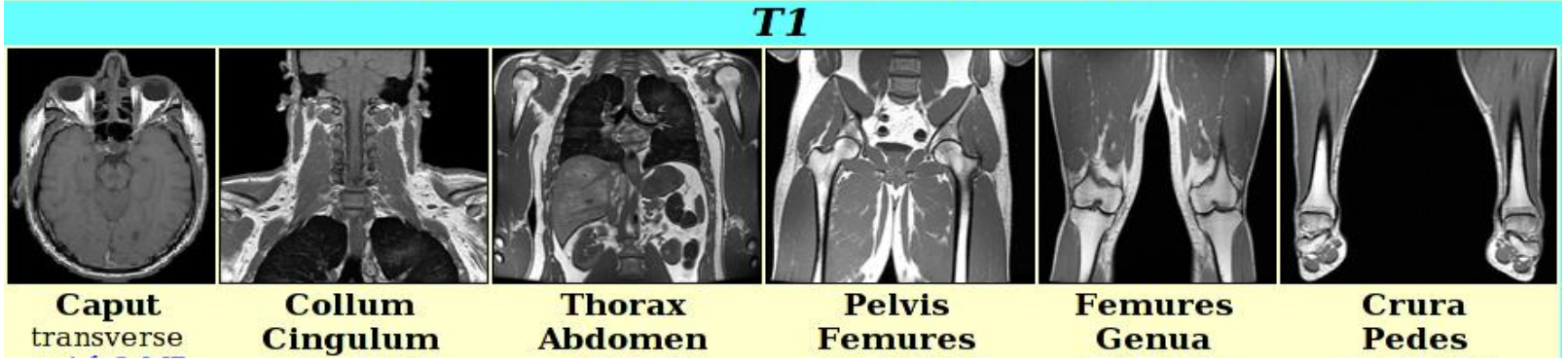


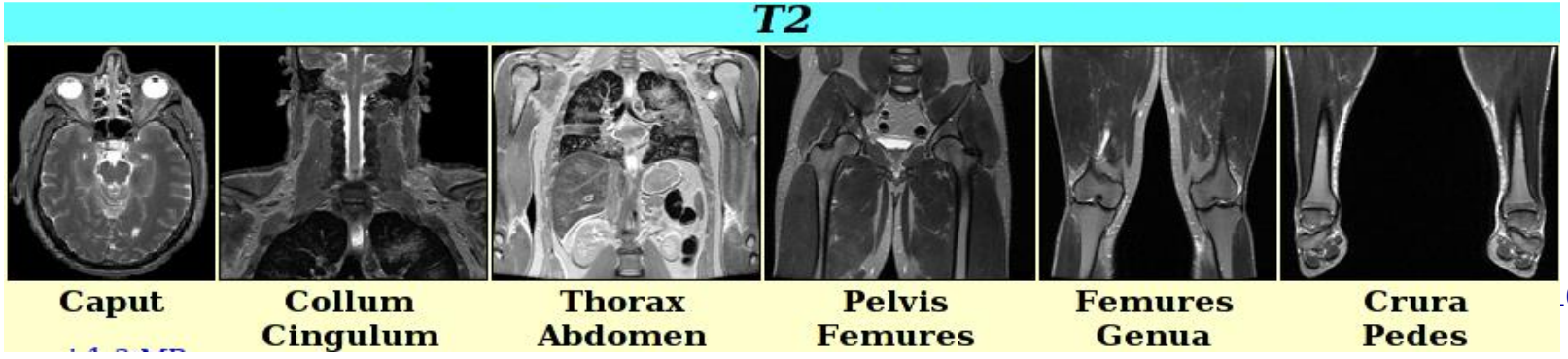
Figure 5.2

- Mathematical ("Computed") Reconstruction
  - Solution of an Inverse Problem
- See coming Lecture

Magnetic Resonance Imaging

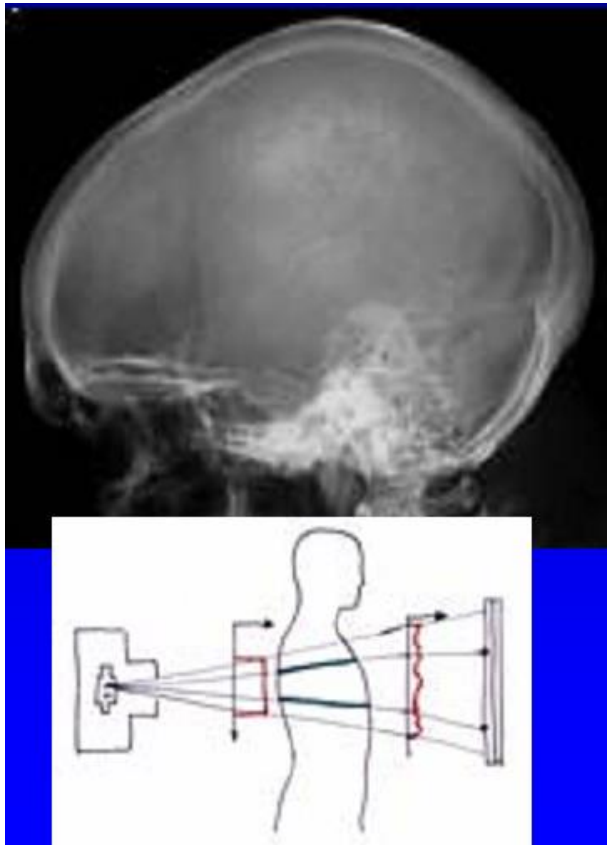




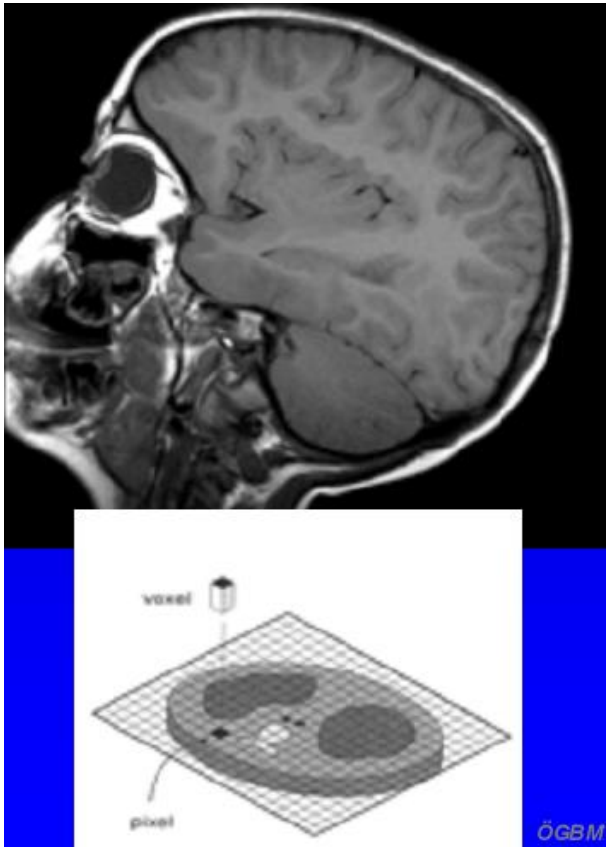


Why MRI?

- X-Ray, invasive!

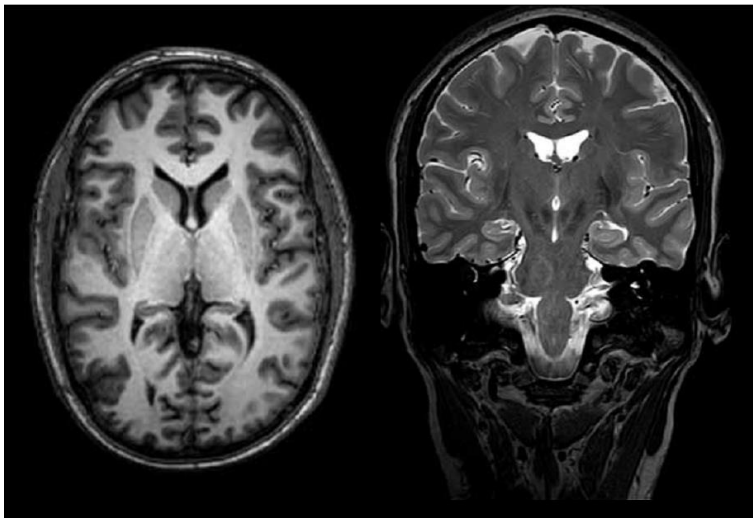


- MRI, non invasive;
  Better soft tissue contrast



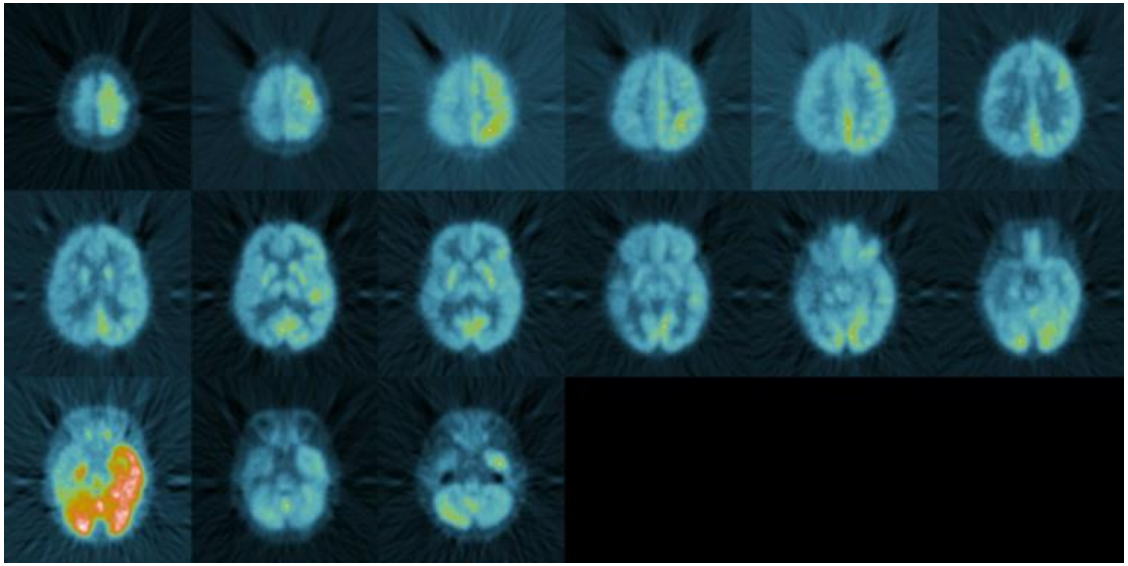
MRI – Principle

- Nuclei with magnetic angular moment (hydrogen) aligned in static magnetic field
- Add external energy (RF EM waves) -> alignment is disturbed
- Removing RF energy reestablishes alignment
- This relaxation is tissue dependent -> protocol T1,T2
- Measurements of signal during relaxation by induction of current (using same RF antennas)

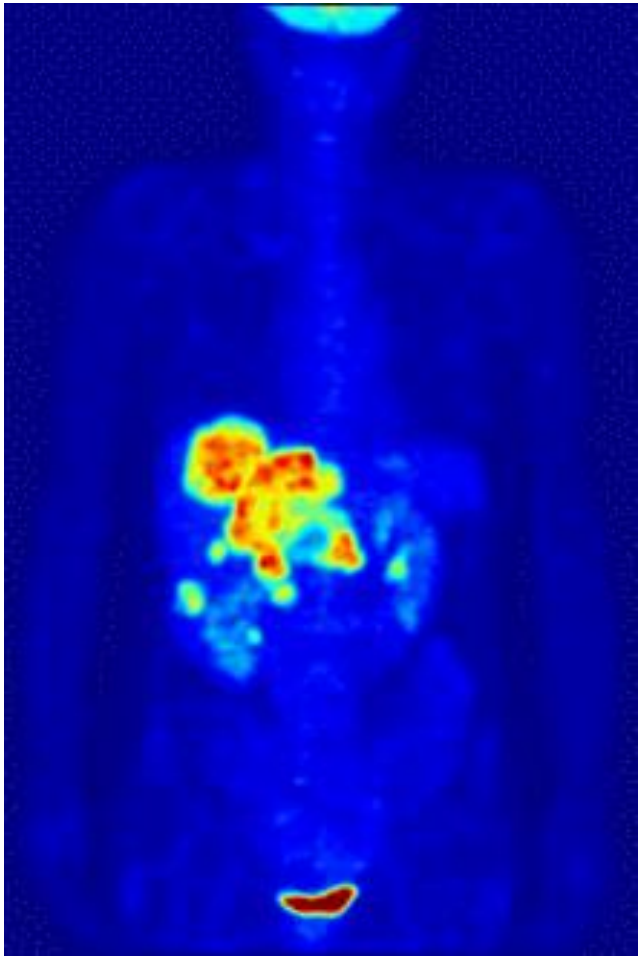


T1, axial T2, coronal

Nuclear Medicine: PET



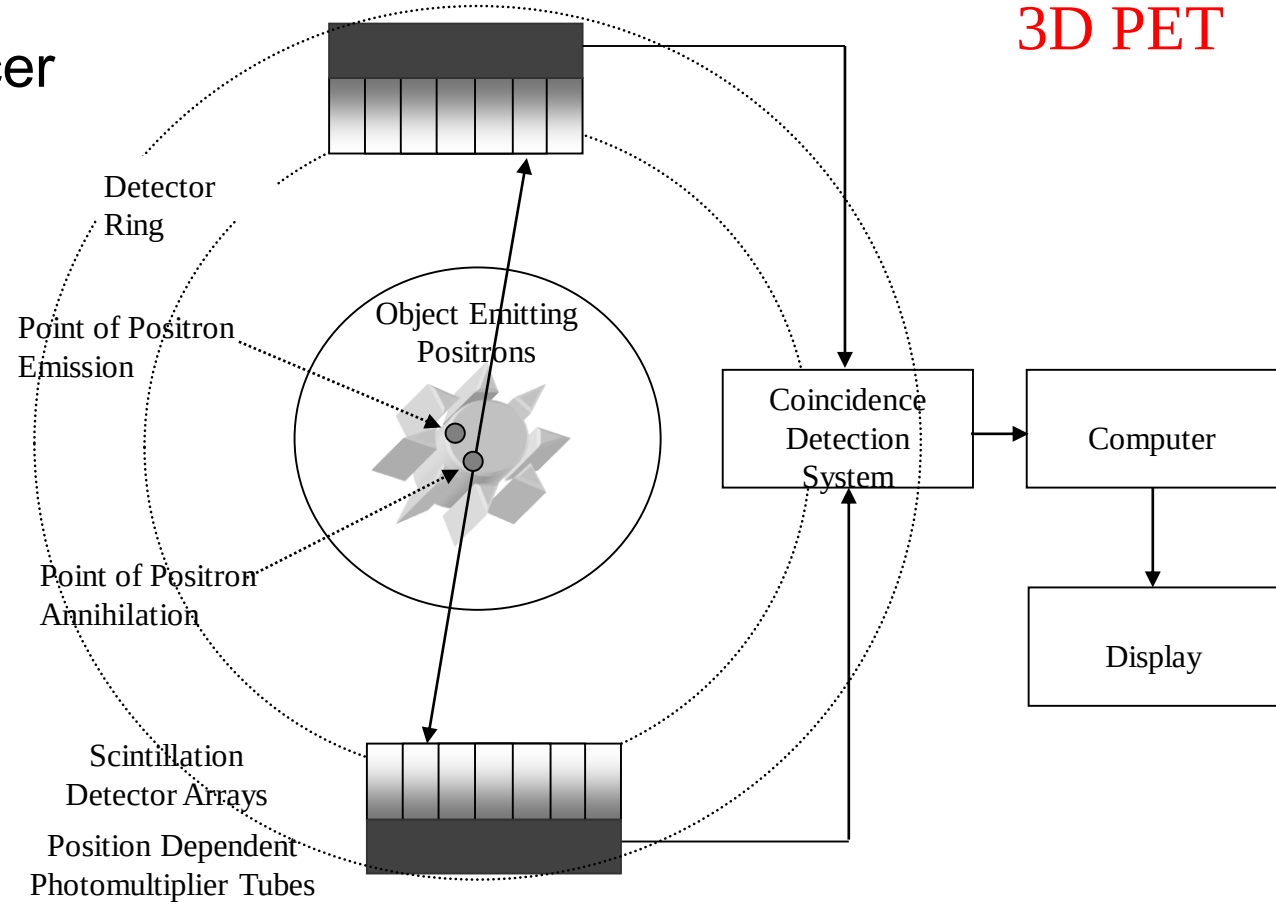
Radiotracer:
Fluorodeoxyglucose
(FDG)



Depict places of positron emission

Nuclear Medicine - Principle

- Radioactive Tracer
- Radionuclides -> Positrons
- Annihilation emits Ionizing Radiation
- Gamma Ray Detection
- Physiology
- Low Resolution, long Acquisition



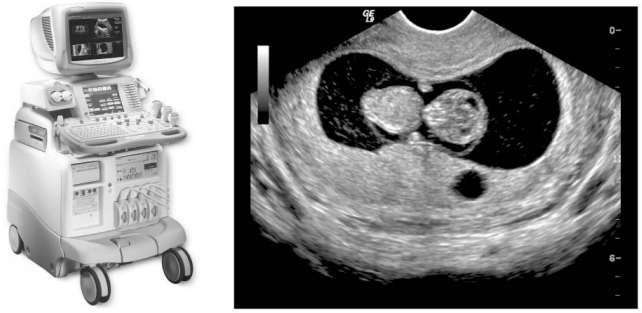
Ultrasound Imaging

Heart

Fetus

Ultrasound Imaging - Principle

- Image signal from sound echos
- Electrical-to-acoustical transducers
  - Piezoelectrical crystals transmit & receive sound waves (current – pressure wave)
  - Ultra-sound betw. 1 – 18 Mhz (higher f, better resolution, less depth)
- Inexpensive, mobile
- Only possible for soft tissue (elastic medium)
- Very noisy



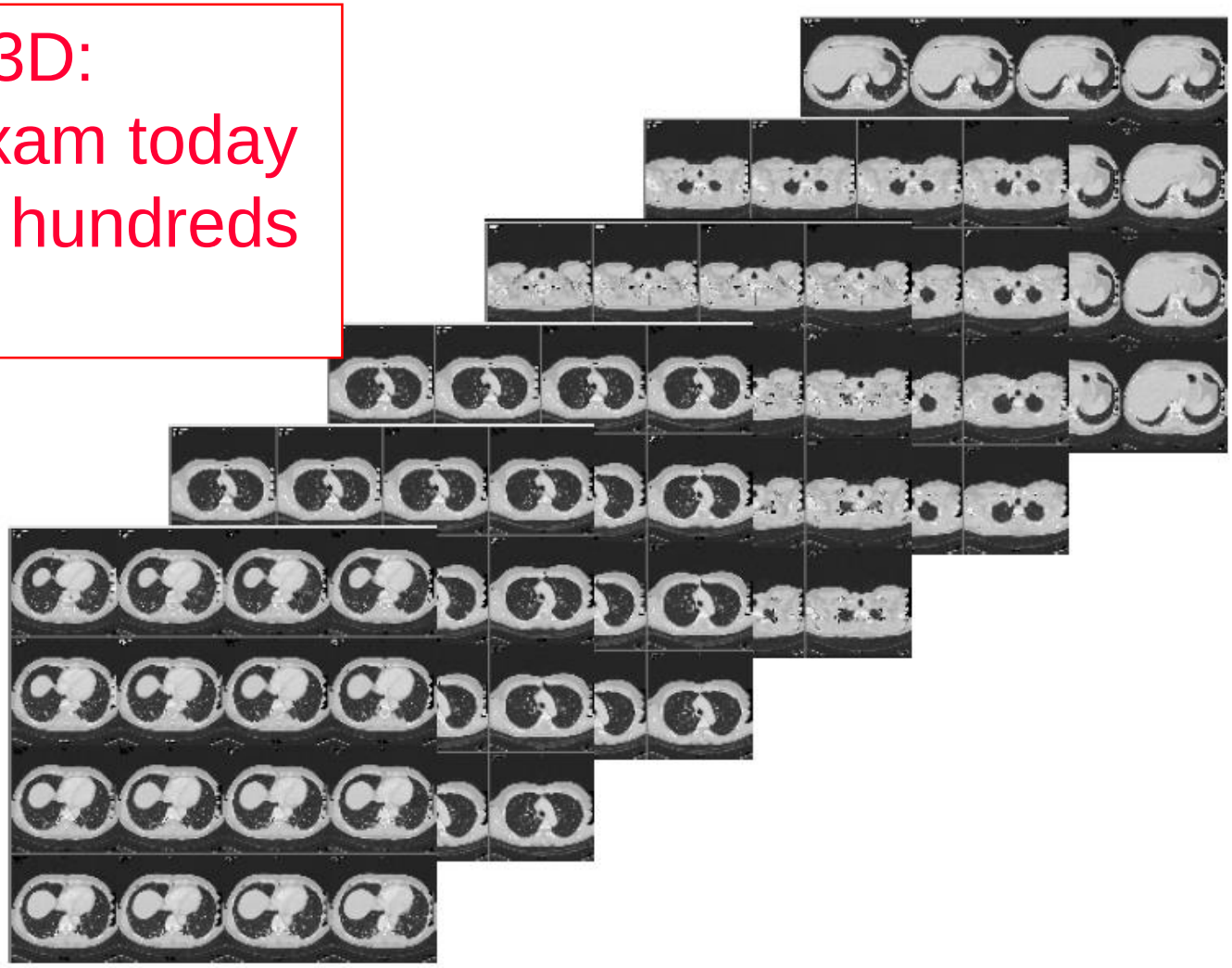
(a) (b)

Figure 1.4

Back to Hi-Res data -> Saying: A picture is worth a 1000 words!

But 500 of them… ?

Problem with 3D:
A single CT exam today easily creates hundreds of images!



Traditional Analysis/Evaluation of Medical Images

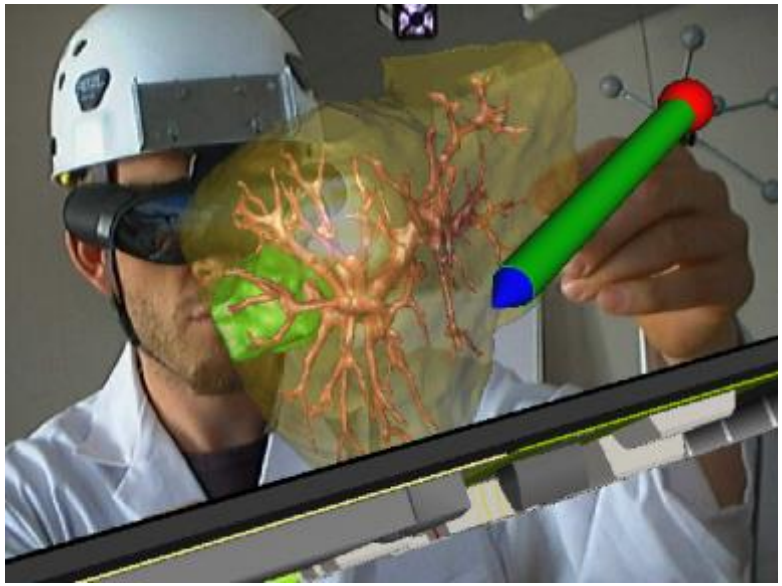
Goal: ***Support*** Physicians by
Computer Aided Analysis of Medical Data

Technical & Scientific Issues

- How to handle this overwhelming amount of information?
- How to improve image quality (SNR, contrast) in balance with dose considerations?
- How to register/fuse different data sources?
- How to represent/preprocess/visualize this data?

Medical Image Analysis – Applications / Benefits

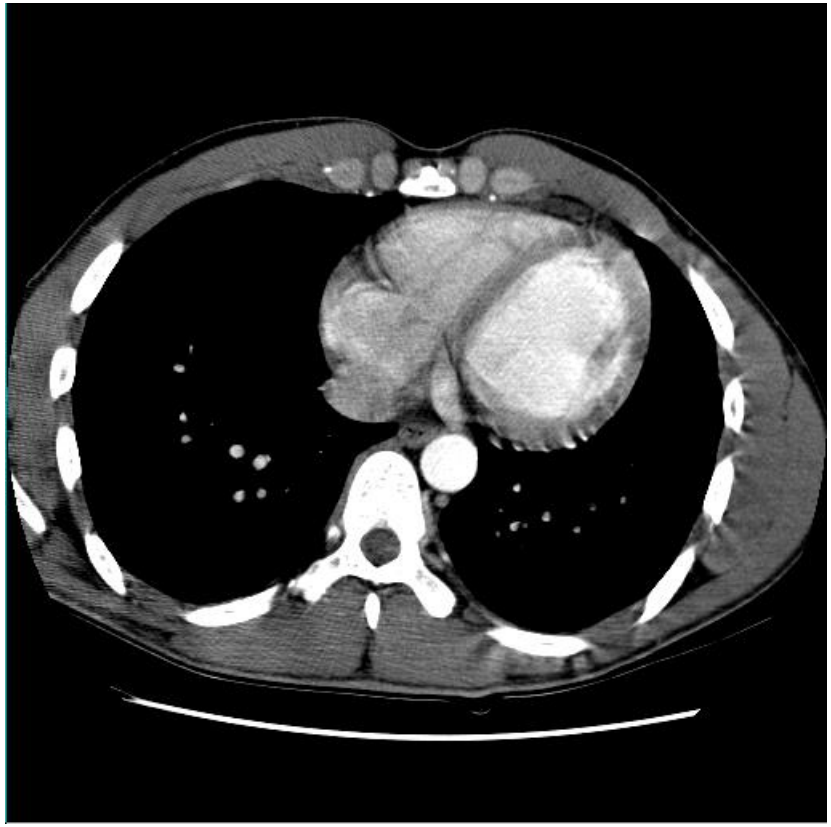
- Medical Imaging technology is advancing at fast pace → new applications:
  - Diagnosis
  - Planning
  - Therapy
  - Surgery
  - Medical education/training
  - …



- Some application examples next

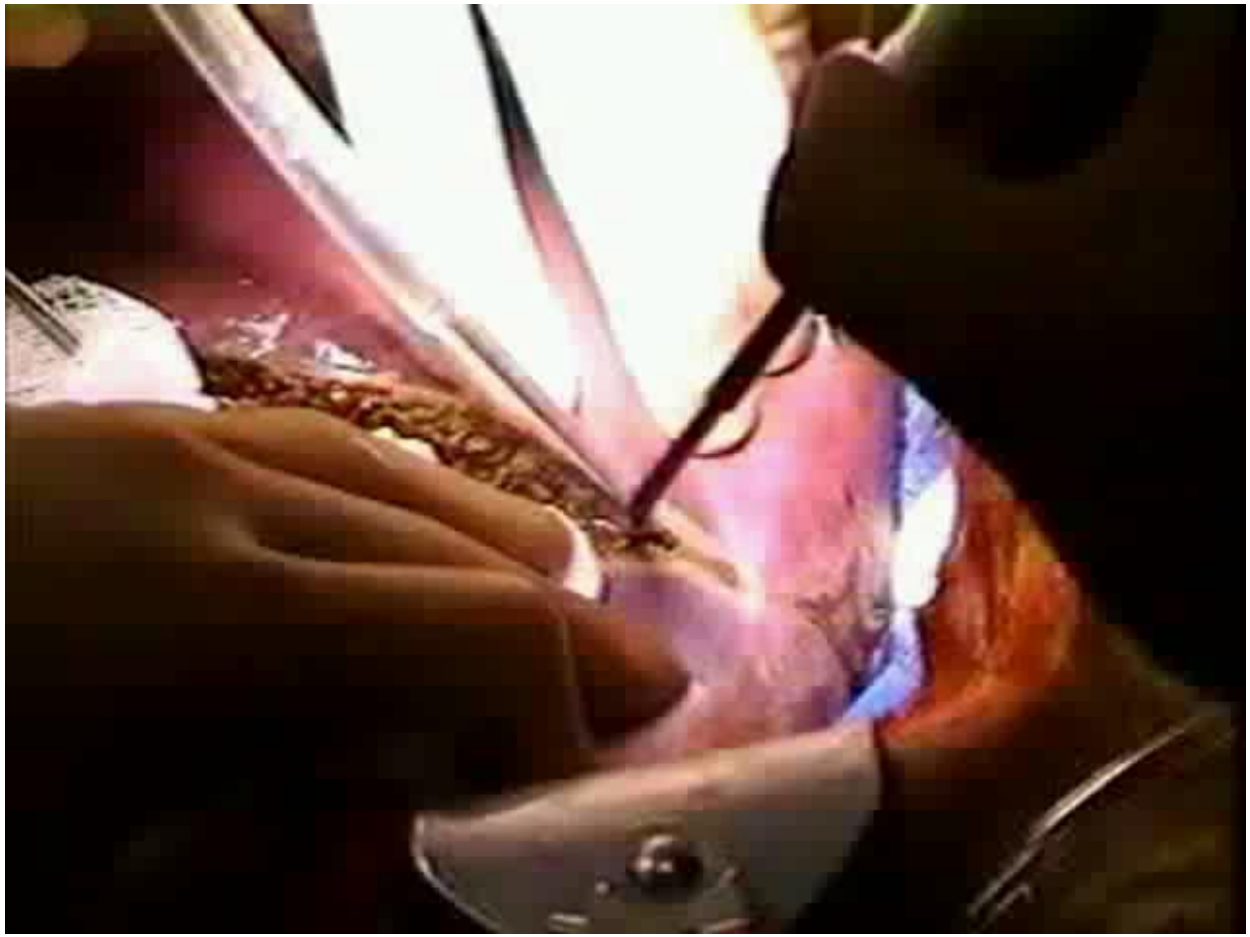
Example Applications – Liver Resection

- Liver Tumor
- How much of the liver tissue may be removed?

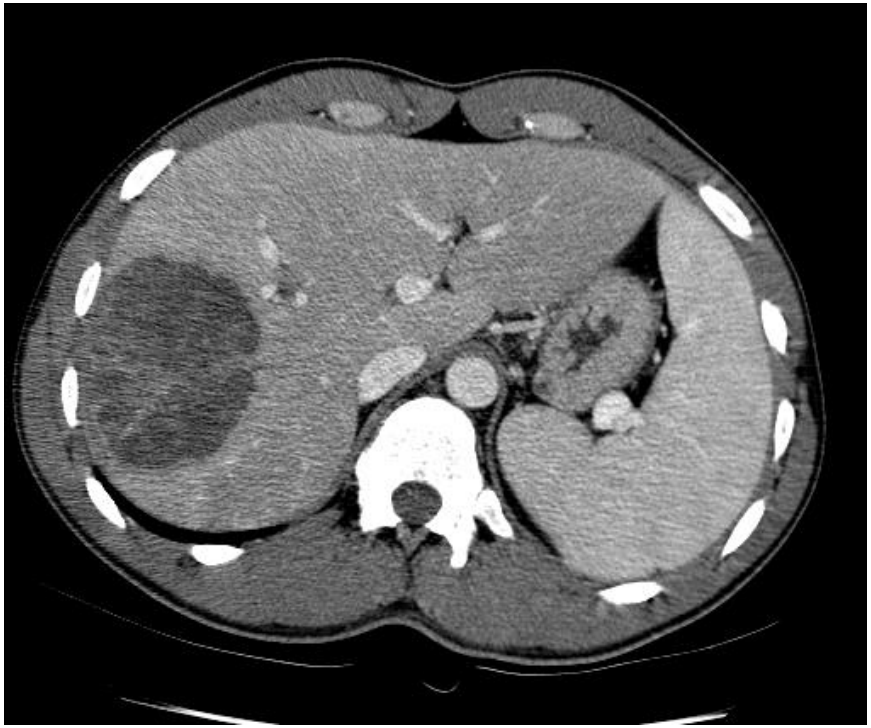


CT Data

Example Applications – Liver Resection



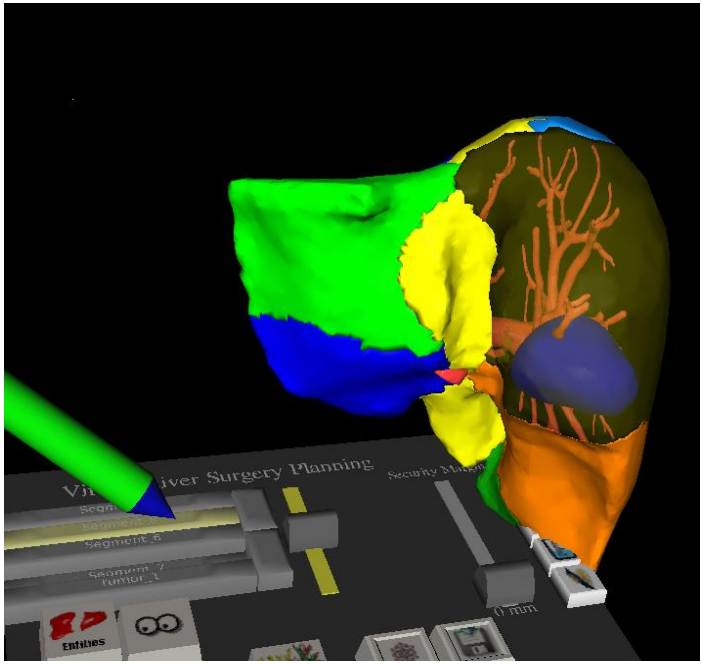
Surgical Planning (Liver Resection)



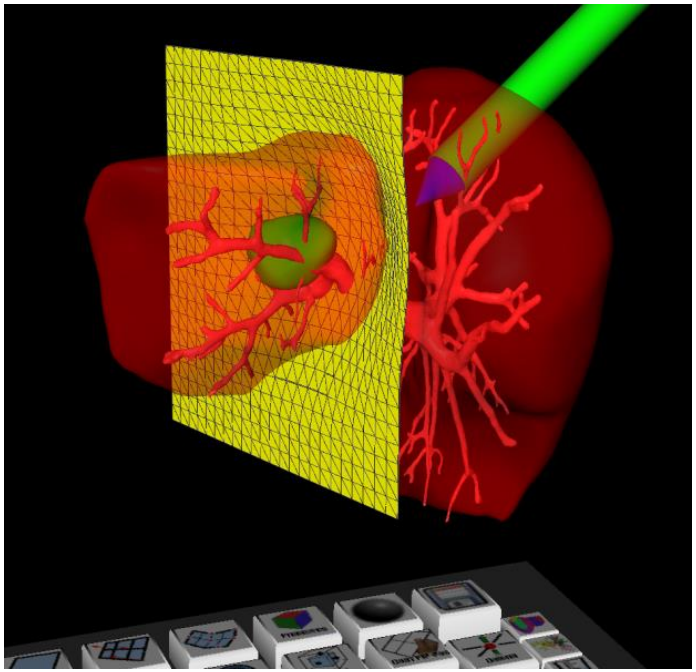
CT Data → Virtual Surgical Planning

Surgical Planning (Liver Resection)

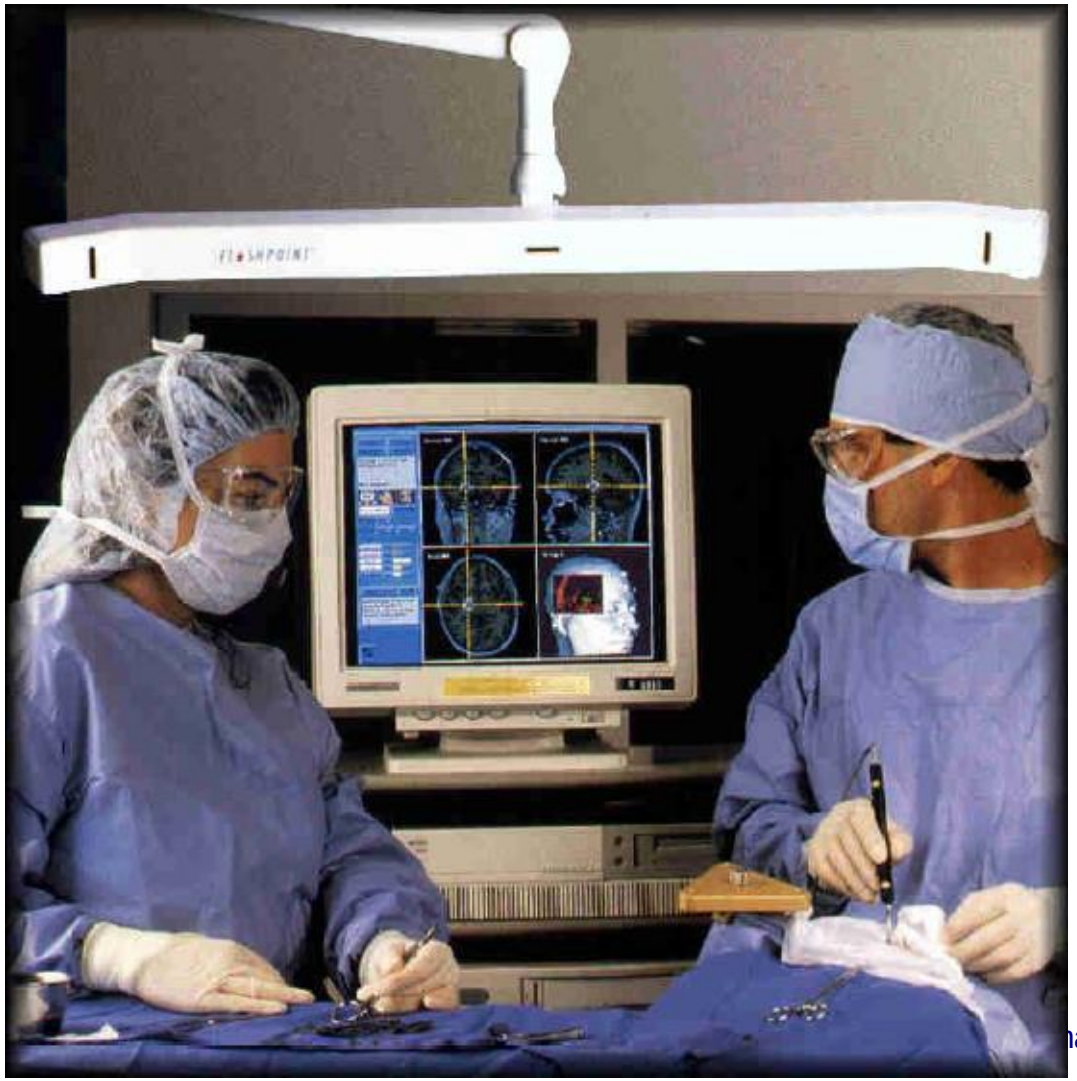
- Anatomical Resection



- Atypical Resection

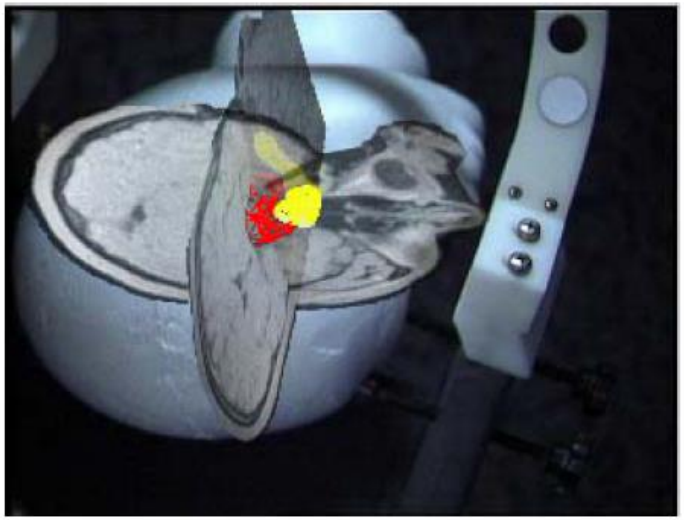


Interoperative Navigation (1)



Interoperative Navigation (2)

Virtual Reality &
Augmented Reality
Techniques

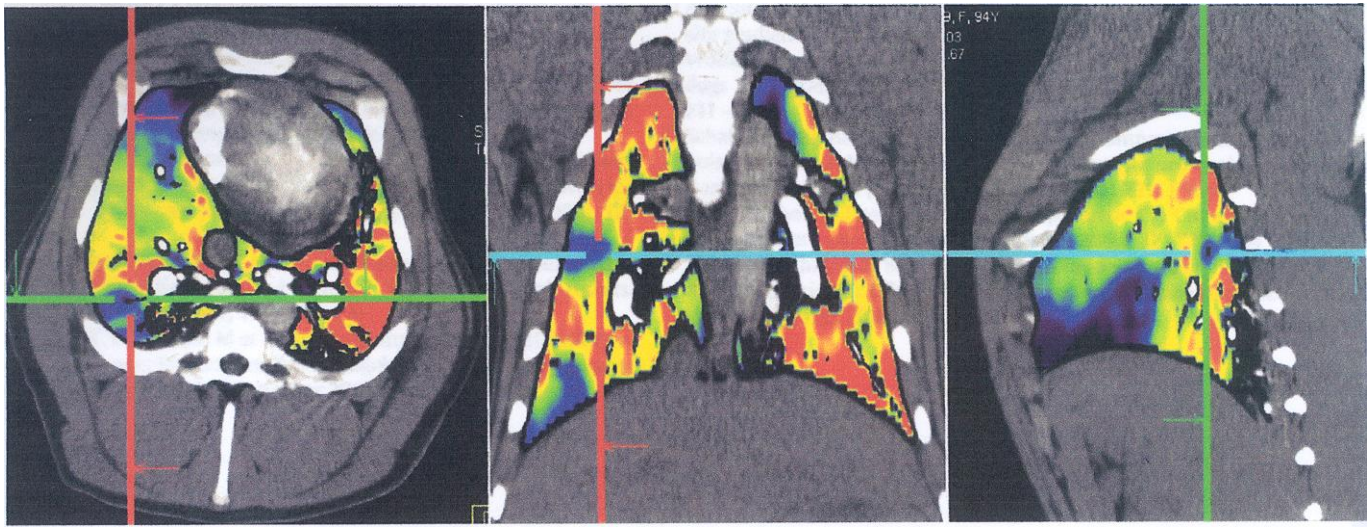


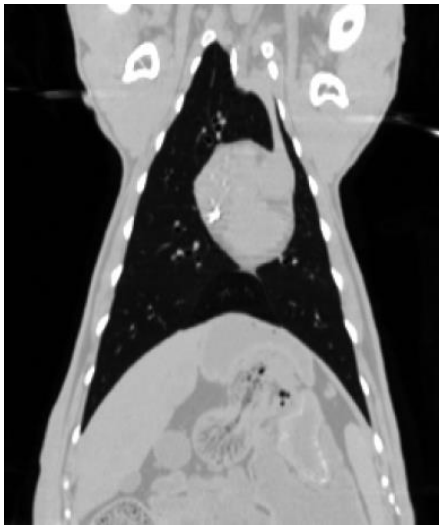
Siemens Corporate Research, Princeton, USA

VarioscopeAR,
Wolfgang Birkfellner, AKH, Wien

Andrew State, UNC

Functional Imaging – Lung Perfusion

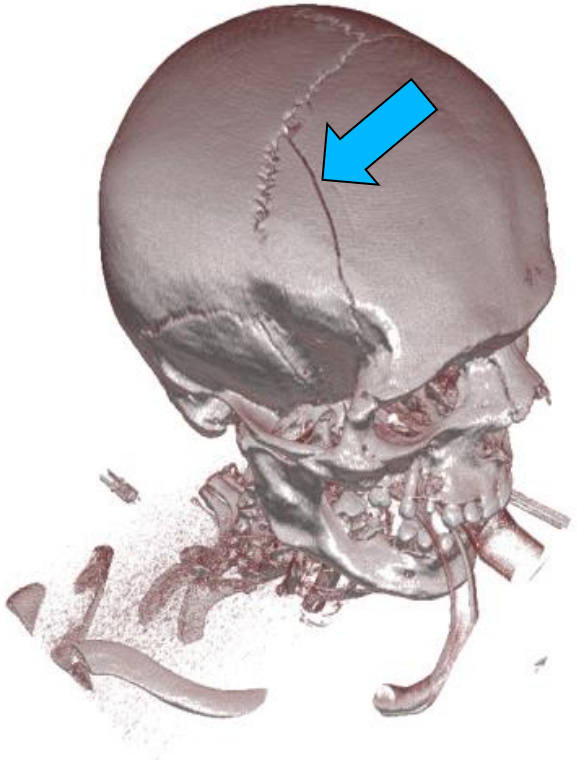




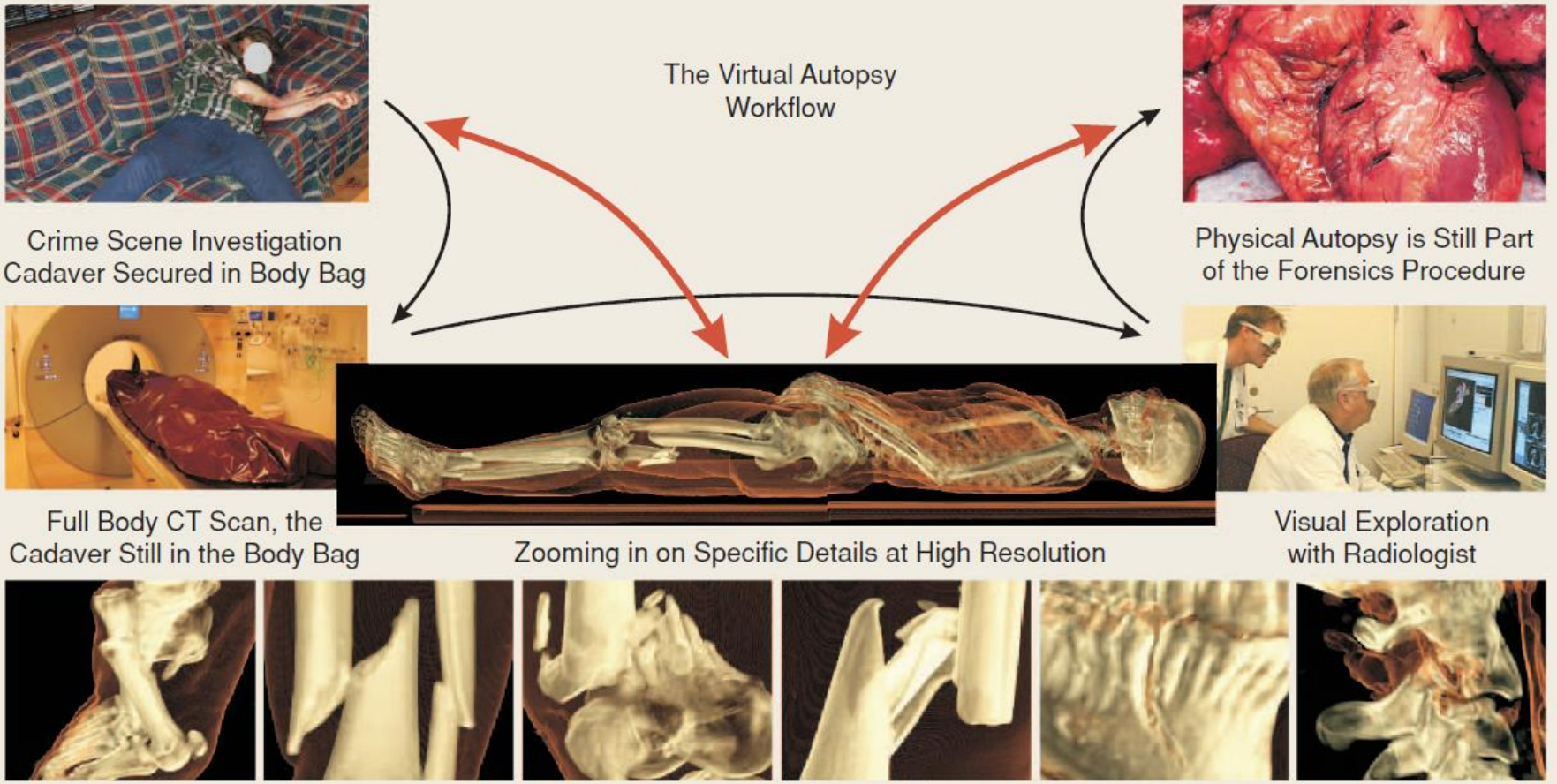
- Subtraction - Breathing Differences
- Nonlinear Motion Compensation

Clinical Forensic Imaging (1)

- Ludwig-Boltzmann Institut, Graz
- Use MR,CT for Forensic Applications
- Establish Usage in Court



Clinical Forensic Imaging (2)



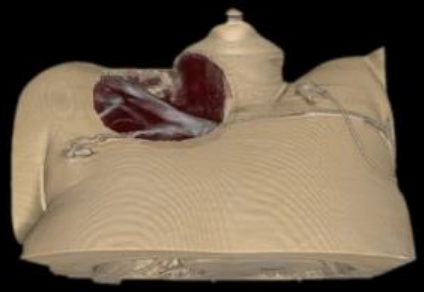
Ljung et al. 2007 *Forensic Virtual Autopsies by Direct Volume Rendering*

Clinical Forensic Imaging (3)

TU Graz

Ludwig Boltzmann Institut
Klinisch-Forensische Bildgebung

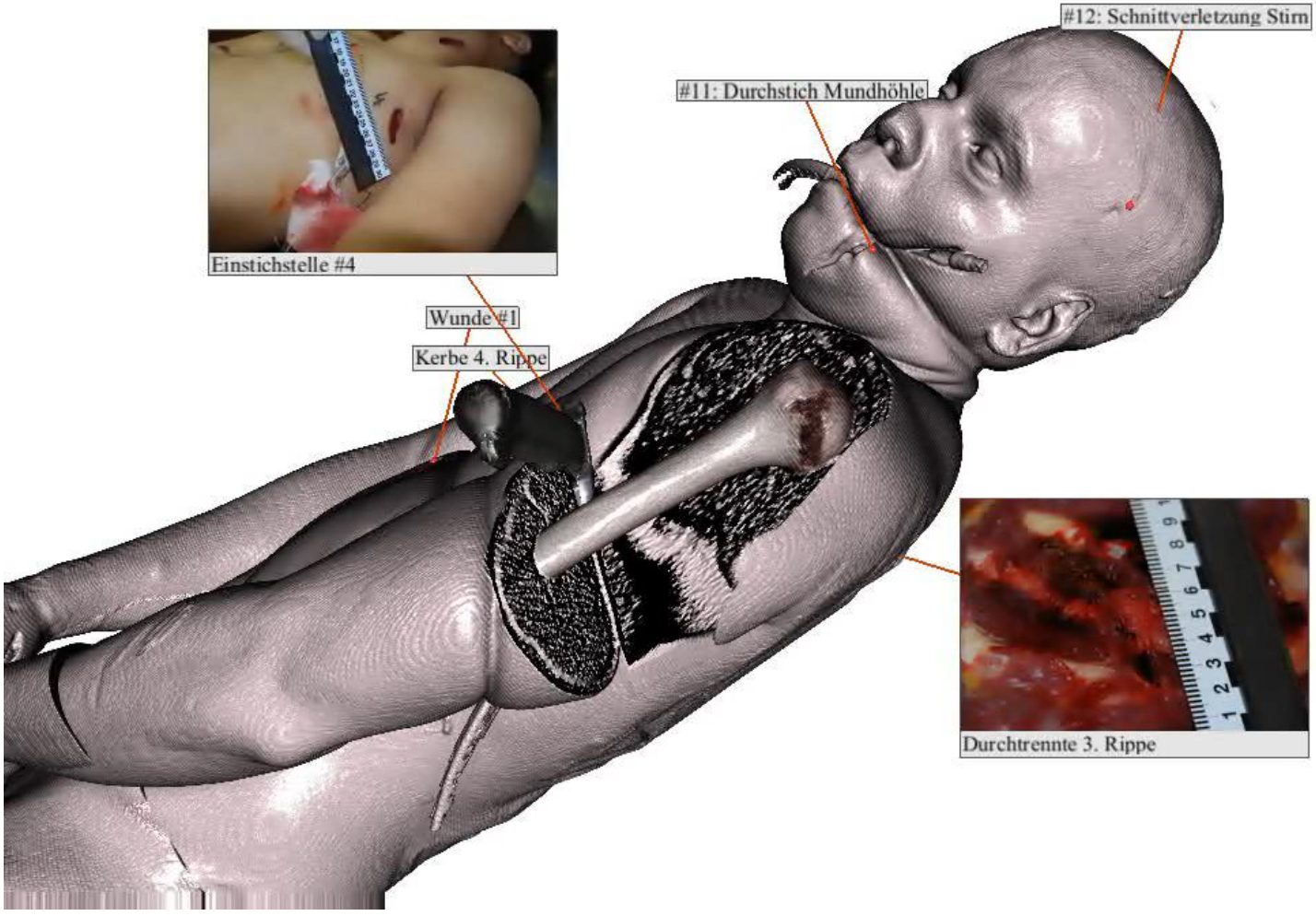
Medizinische Universität Graz



Martin Urschler
Alexander Bornik
Eva Scheurer
Kathrin Yen
Horst Bischof
Dieter Schmalstieg

Forensic Case Analysis from 3D Imaging Modalities through Interactive Visualization

Clinical Forensic Imaging (4)



Medical Image Analysis (MIA) is …

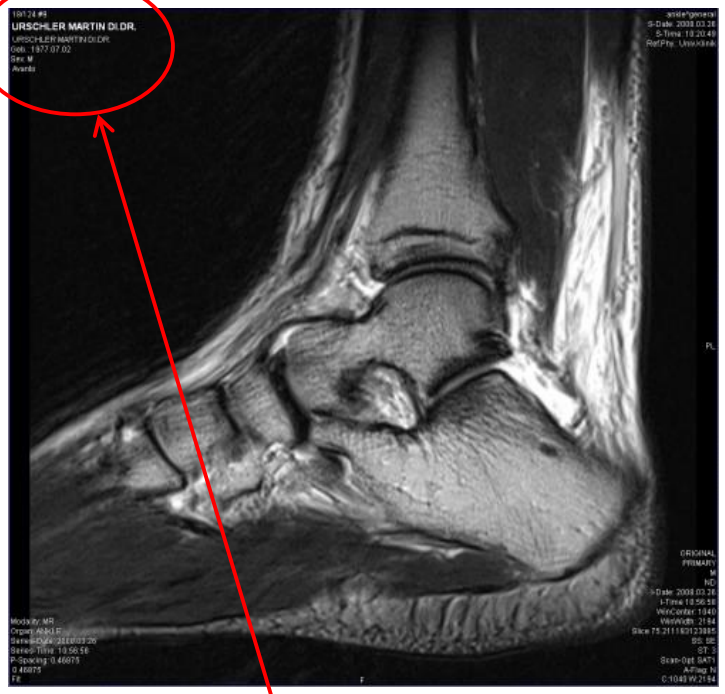
… highly interdisciplinary:

- Engineering Scientists
  - Acquisition – Physics, Signal Processing
  - Analysis – Computer Vision
  - Visualization – Computer Graphics
- Physicians (Radiology, Nuclear Medicine, Surgery, Legal Medicine…)
- Industry
- BioTechMed initiative of Graz Universities!

MIA requires …

… understanding of …

Physiology/Anatomy



Imaging Modality

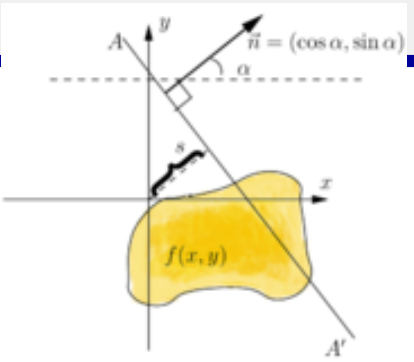
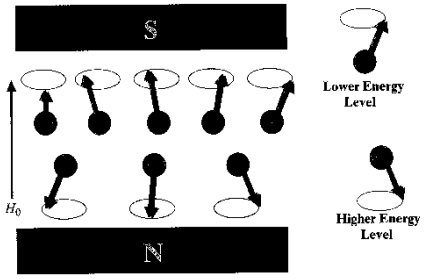


Image Formation



Imaging Physics

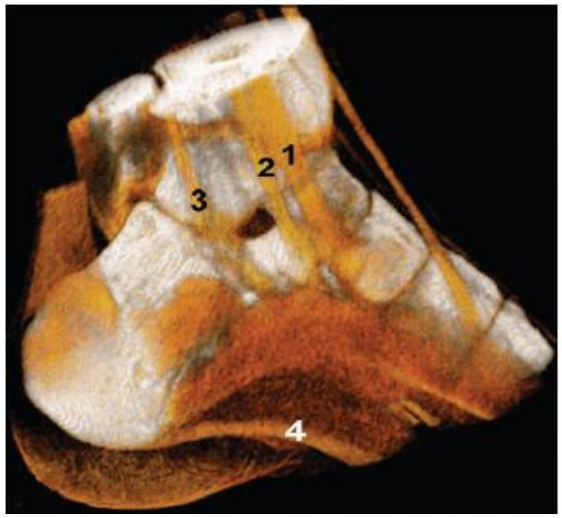
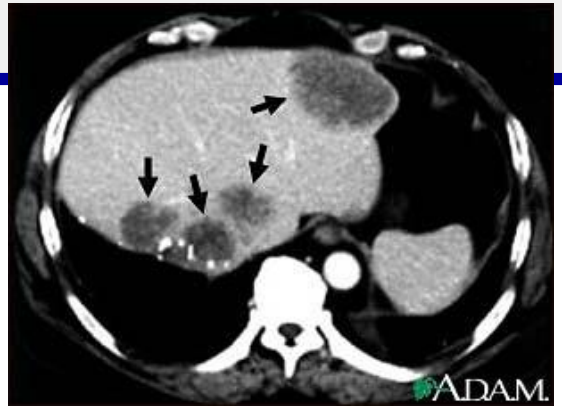


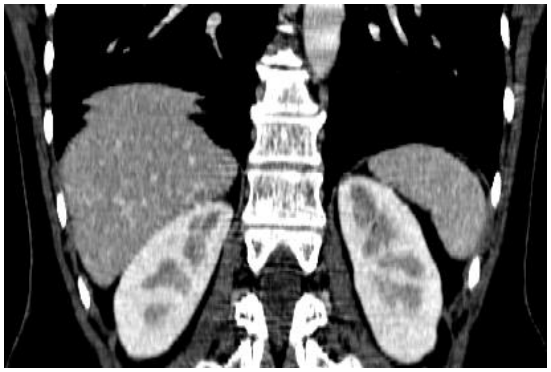
Image Analysis

(Ethical Issues)

MIA – Challenges

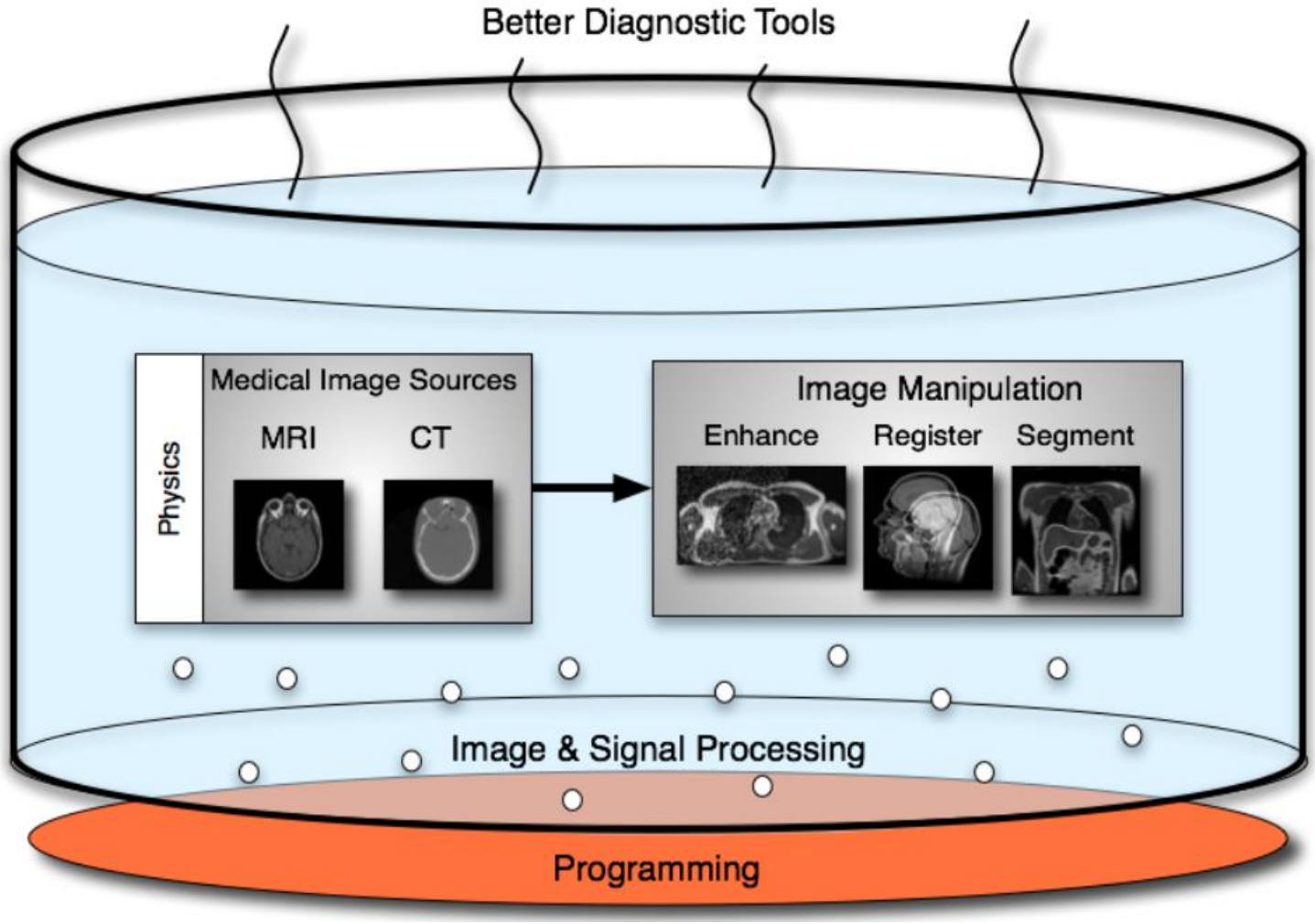
- Anatomical variation
- Pathological variation
- Variation in image quality
- Variation due to movement



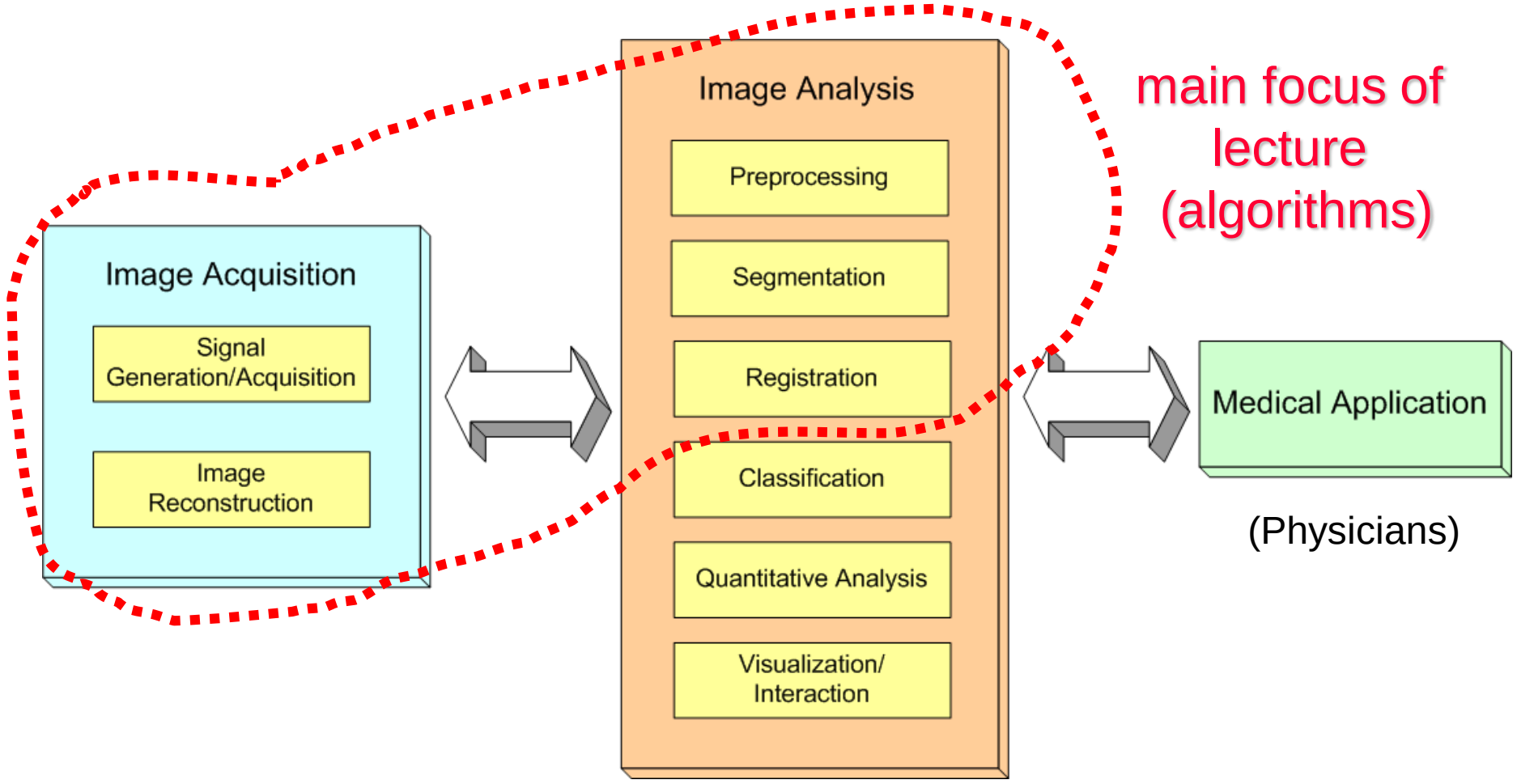


- Goal: Preserve and enhance real clinical information rather than introduce additional artifacts

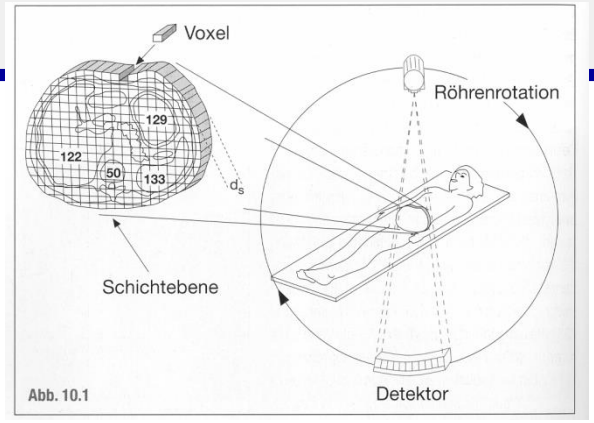
MIA - Concept


Better Diagnostic Tools
Physics
Medical Image Sources
MRI
CT
Image Manipulation
Enhance
Register
Segment
Image & Signal Processing
Programming

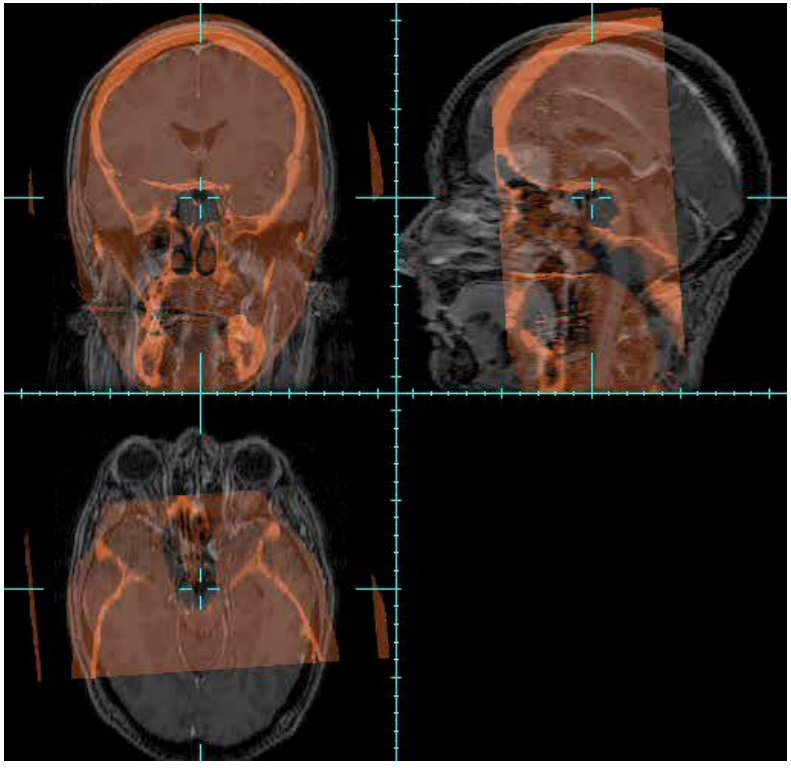
Lecture - Topics



Lecture - Topics

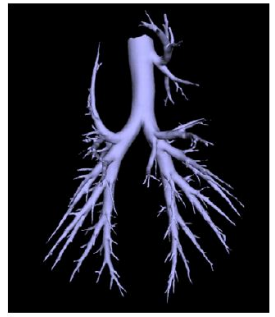


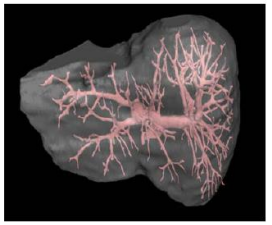
- Imaging Modalities
  - Computed Tomography, Backprojection & Image Reconstruction
- Image Registration
  - Point-, Surface-, Intensity-Based
  - Rigid, Affine, Nonlinear

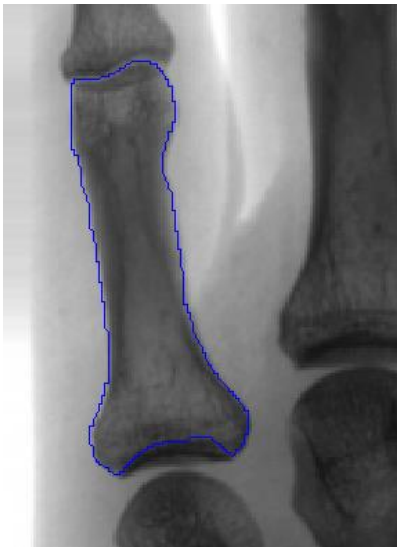


Lecture - Topics

- Denoising
  - Variational Approaches
- Segmentation
  - Low-Level Features, Variational Approaches
  - Vascular Structures
  - Model-Based Shape & Appearance







Organization

Office Hours: by appointment

Room E.3.10, ICG,

Inffeldgasse 16, 2

Email: **urschler@icg.tugraz.at**

Organization - VO

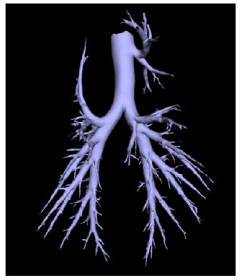
VO: Monday, 15.00 s.t. – 17.00 h, ICG

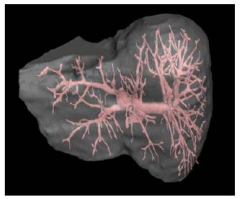
Type: - Powerpoint slides (with ‘holes’)
- assisted by blackboard & Matlab
- papers & book chapters

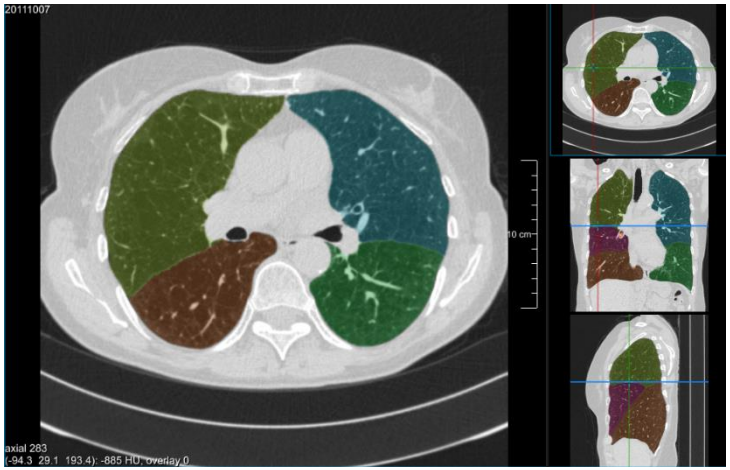
Exam: - end of semester
- 3 written exams per semester

Organization - KU

- Goal: Extraction of Vascular Structures from Lung CT
  - Vessel Enhancement Filter for Airways, Vascular Structures, Fissures
  - Lung Lobe Segmentation
- Tools: C++, ITK, ITK-Snap
- Groups of 2







Slides & Material

Slides in PDF-format & additional material located in subversion (e.g. TortoiseSVN) repository:

https://svn.tugraz.at/MedicalImageAnalysisVOKU2016

Updates Monday morning before lecture, or after lecture (in this case handouts will be provided)

Homework video

https://www.youtube.com/watch?v=9SUHgtREWQc

Computed Tomography: History and physics

Answer four questions till next lecture:

1. *Effect of X-ray attenuation on bone & lungs*
2. *Two drawbacks of radiography vs. CT*
3. *How is standard CT reconstruction algo. called?*
4. *Advantage of spiral CT design vs. previous ones?*

END

Questions are welcome!

(Not just now, but during the whole lecture!)

See you next week!