

# Medical Image Analysis (MIA)

(Medizinische Bildanalyse)

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710.076 2 VO

710.077 1 KU

Martin Urschler

*Institute for Computer Graphics and Vision, TU Graz*

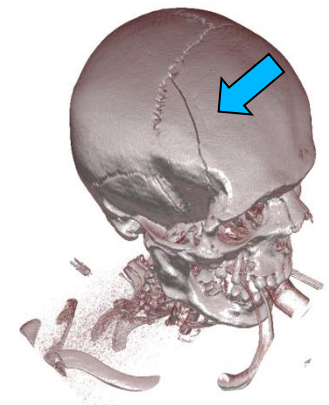
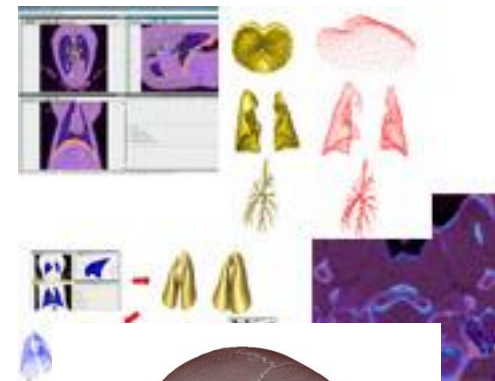
SS 2016



# 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



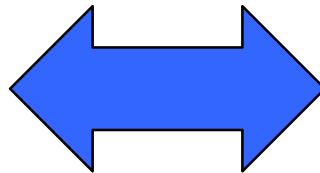
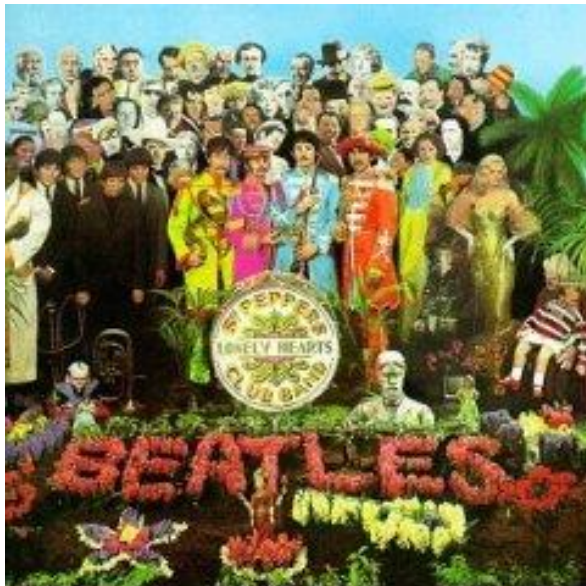
# About You

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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

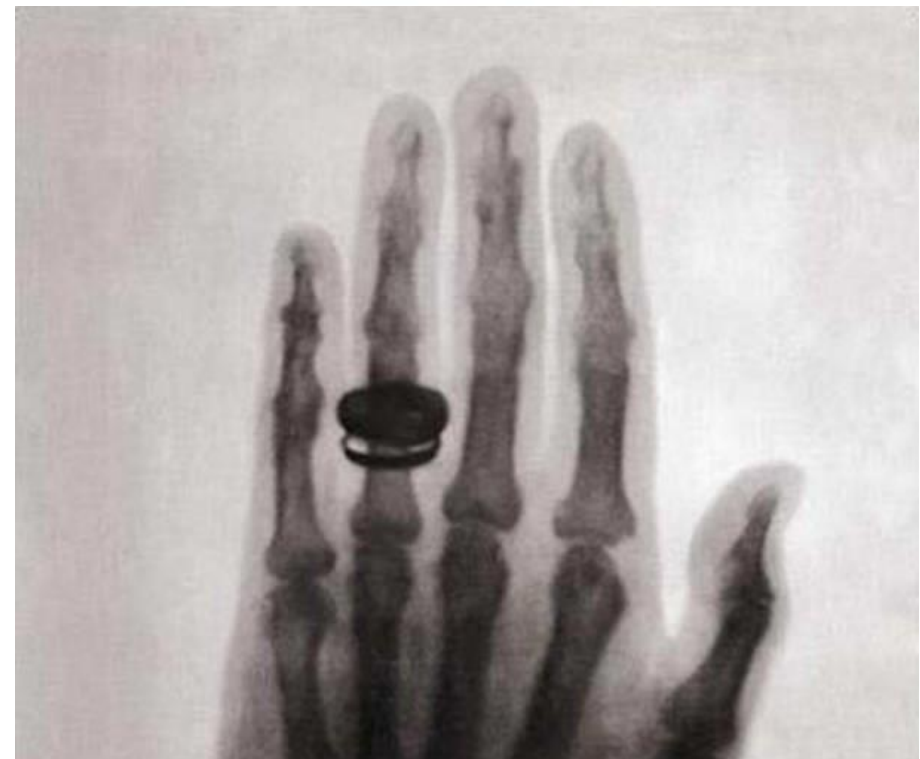
## First X-ray Image

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)

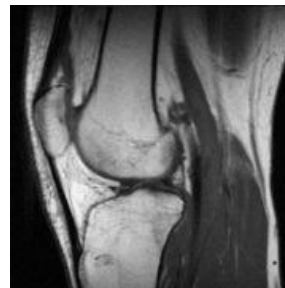
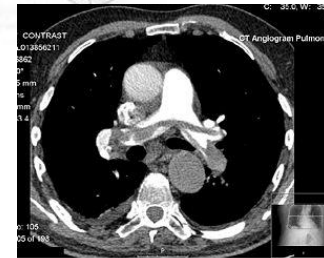
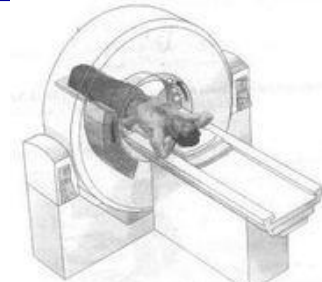
*Godfrey Hounsfield* & *Allan Cormack*

Nobel Prize in Medicine 1979

- Magnetic Resonance Imaging

*Paul Lauterbur* & Sir *Peter Mansfield*

Nobel Prize in  
Medicine 2003



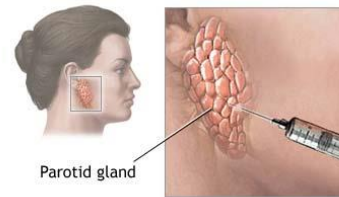
*Images taken from: Wikipedia*





# 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



A "core" sample of the gland is taken with a needle to be biopsied

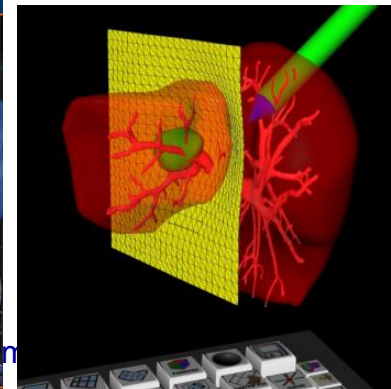
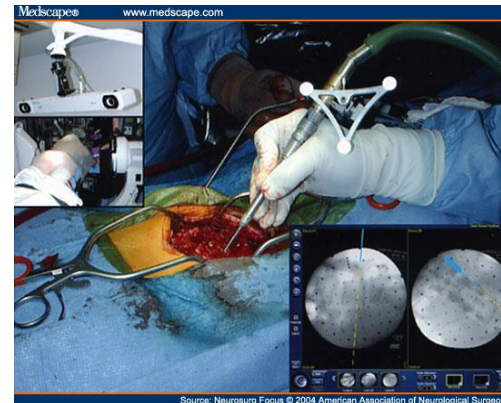
ADAM.



*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



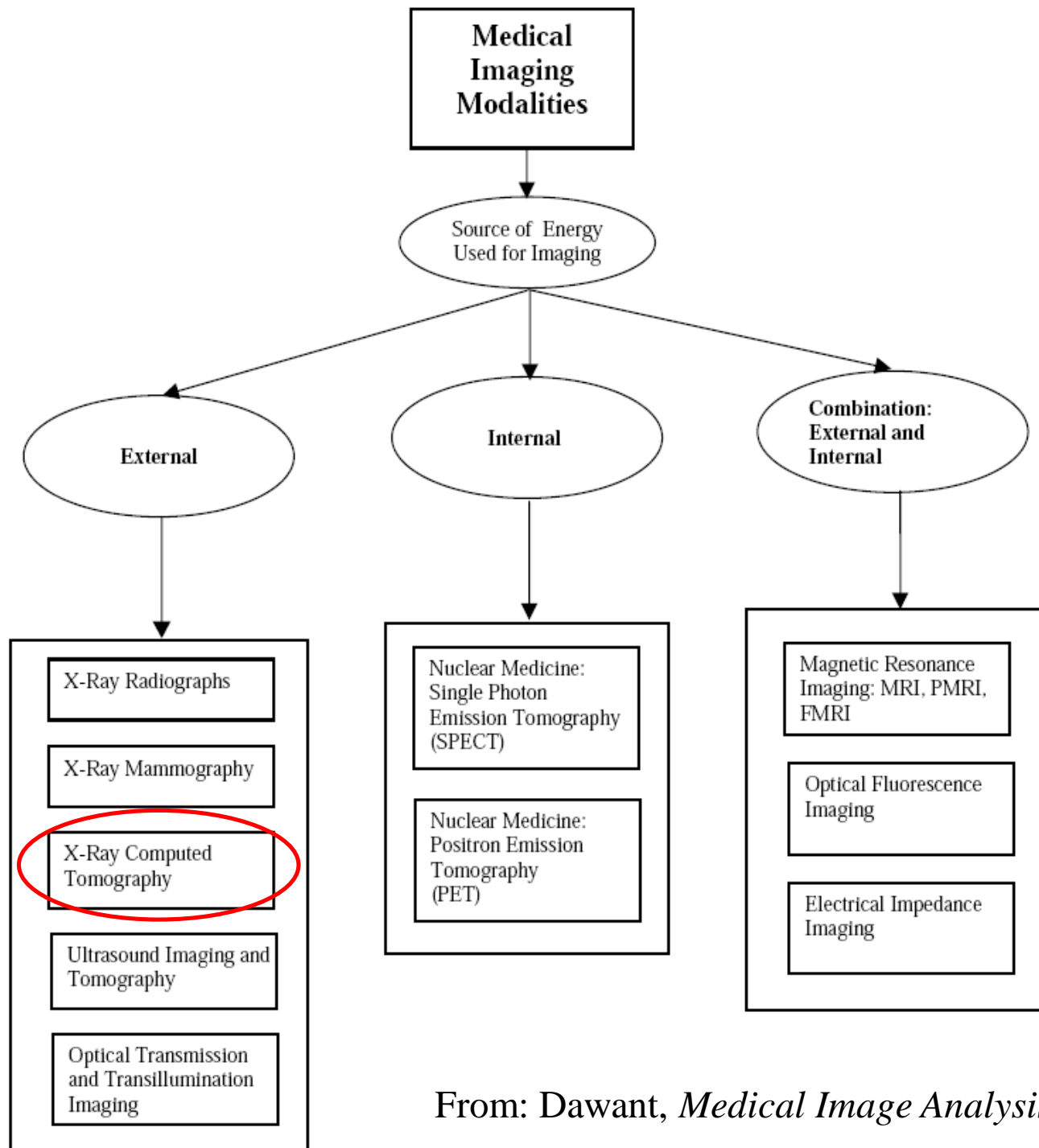


# Imaging Modalities

Acquiring information about:

- Anatomy
- Physiology (Function)

in 2D, 3D, or 4D



From: Dawant, *Medical Image Analysis*



# X-Ray Radiographs / Mammography

Bone



Breast

Teeth



# X-Ray Radiographs - Principle

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

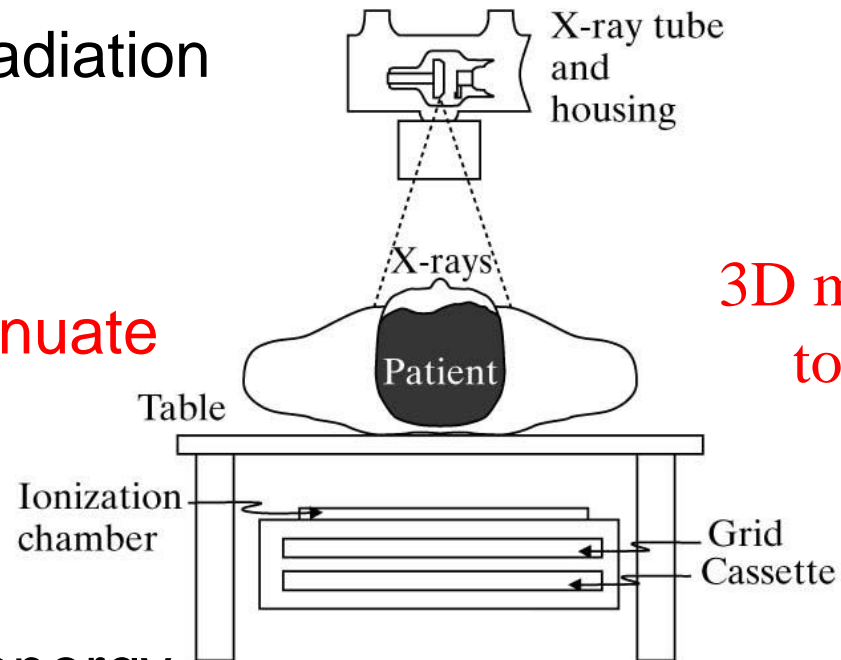
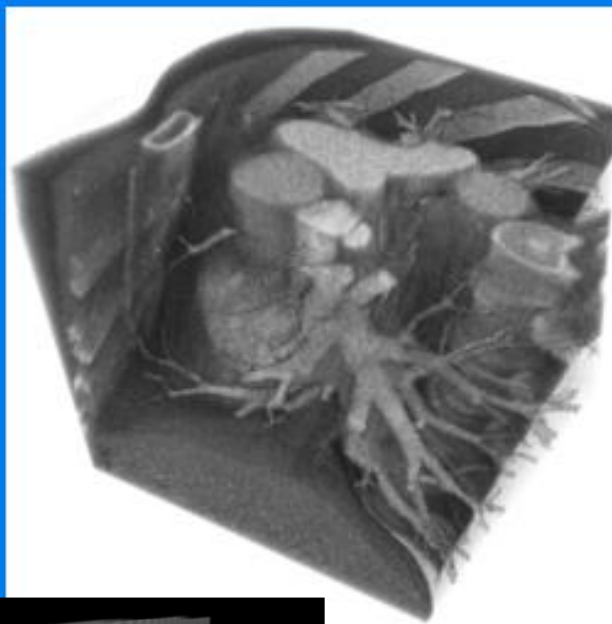
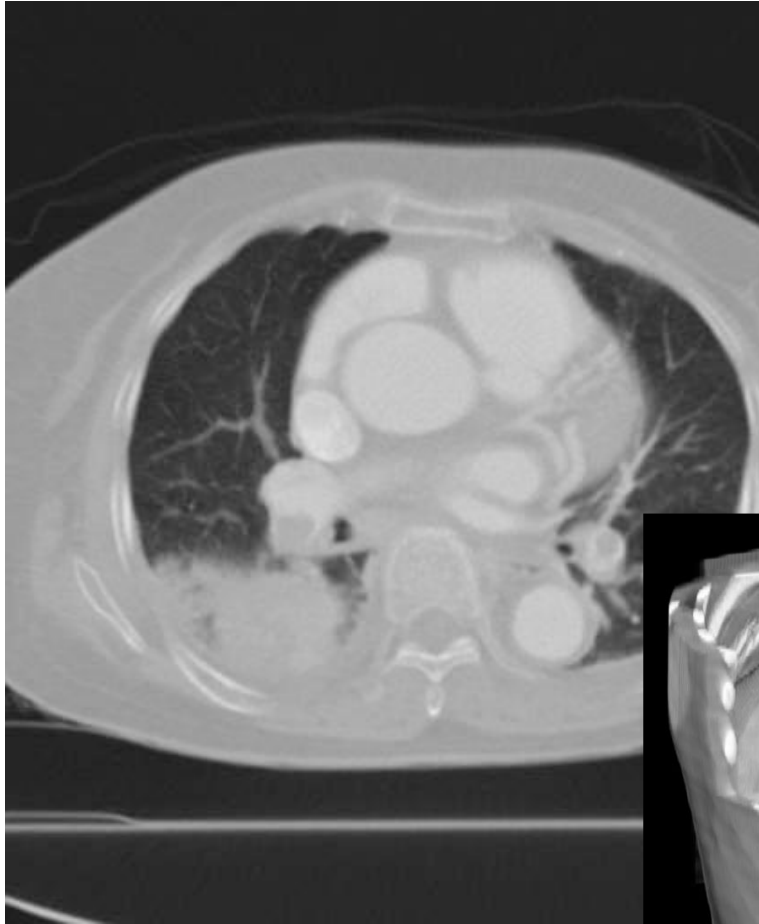


Figure 5.2

*Medical Imaging Signals and Systems*, by Jerry L. Prince and Jonathan Links.  
ISBN 0-13-065353-5. © 2006 Pearson Education, Inc., Upper Saddle River, NJ. All rights reserved.

# X-Ray Computed Tomography (CT)

Lung & Heart (contrast)



Brain



Liver

Coronary  
Arteries



# X-Ray CT Principle

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

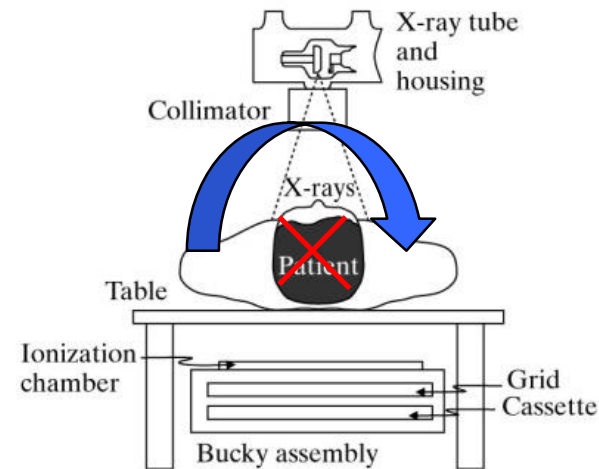


Figure 5.2

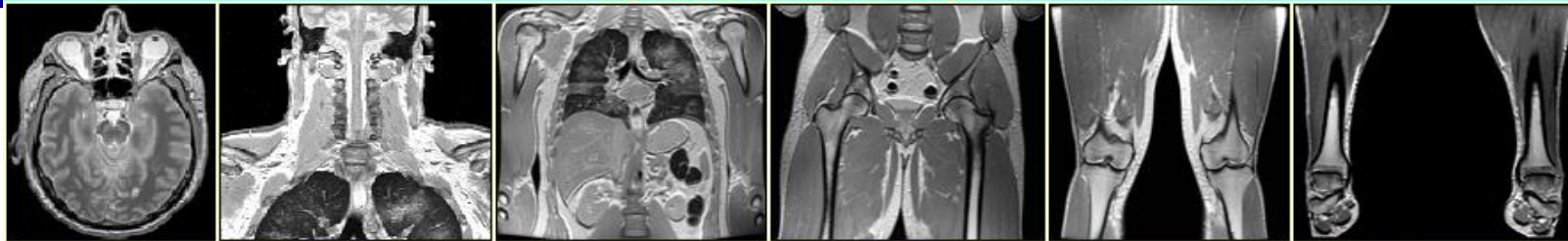
*Medical Imaging Signals and Systems*, by Jerry L. Prince and Jonathan Links.  
ISBN 0-13-065353-5. © 2006 Pearson Education, Inc., Upper Saddle River, NJ. All rights reserved.

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



# Magnetic Resonance Imaging

## *proton density*



**Caput**  
transversal

**Collum**  
Cingulum

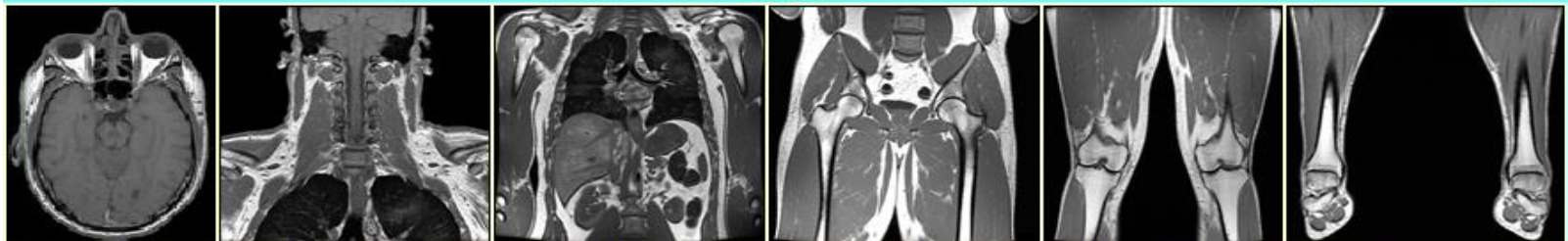
**Thorax**  
Abdomen

**Pelvis**  
Femures

**Femures**  
Genua

**Crura**  
Pedes

## *T1*



**Caput**  
transverse

**Collum**  
Cingulum

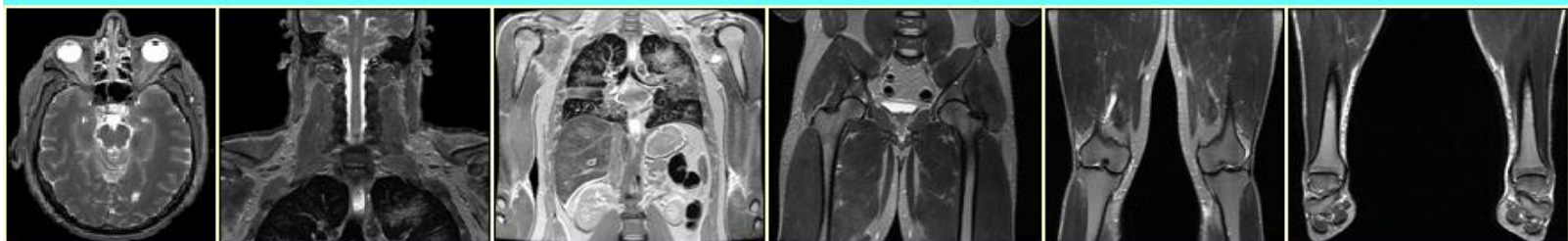
**Thorax**  
Abdomen

**Pelvis**  
Femures

**Femures**  
Genua

**Crura**  
Pedes

## *T2*



**Caput**

**Collum**  
Cingulum

**Thorax**  
Abdomen

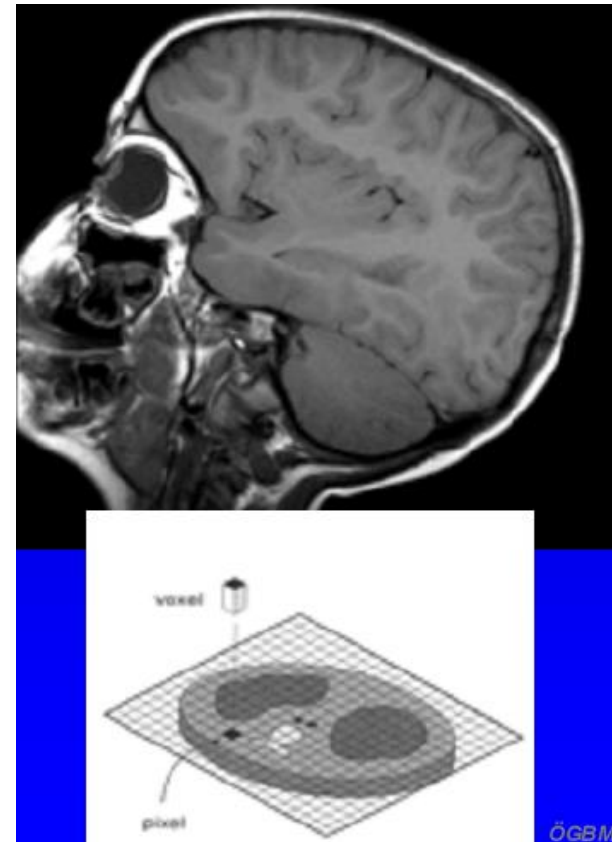
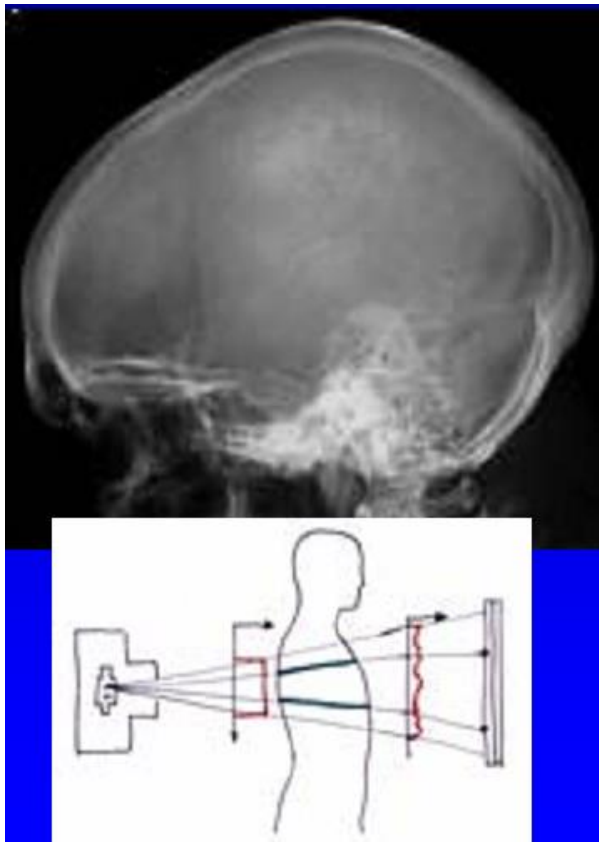
**Pelvis**  
Femures

**Femures**  
Genua

**Crura**  
Pedes

# Why MRI?

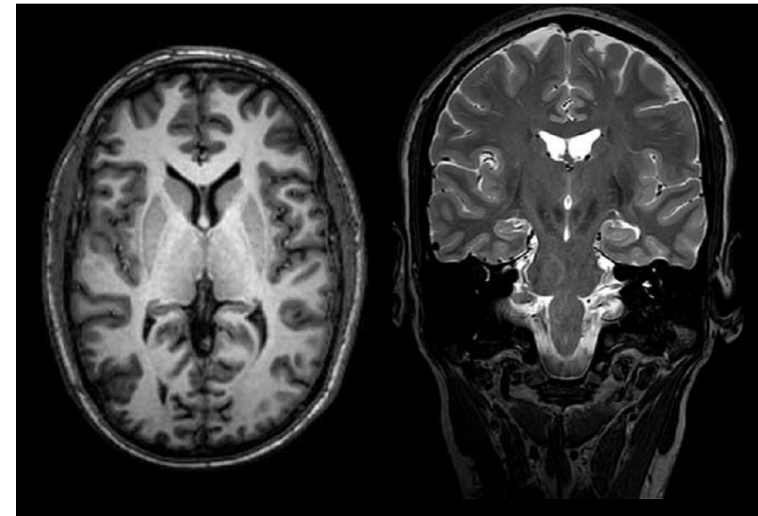
- X-Ray, invasive!
- MRI, non invasive;  
Better soft tissue contrast



ÖGBM

# MRI – Principle

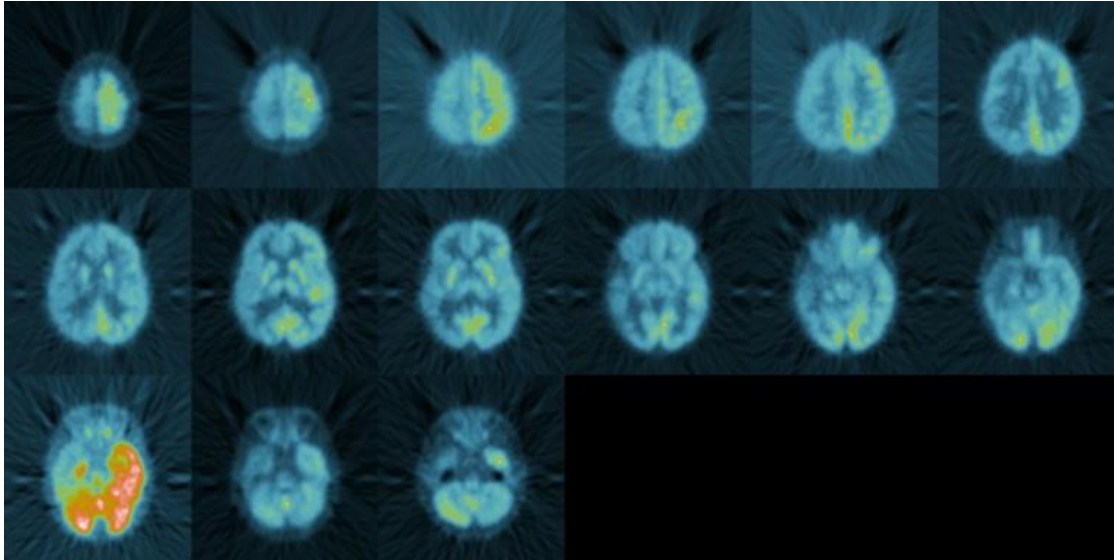
- **Nuclei** with **magnetic angular moment** (hydrogen) aligned in **static** magnetic field
- Add external energy (**RF EM** waves)  
-> alignment is disturbed
- Removing RF energy reestablishes alignment
- This **relaxation** is tissue dependent -> protocol T1,T2
- Measurements of signal during relaxation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



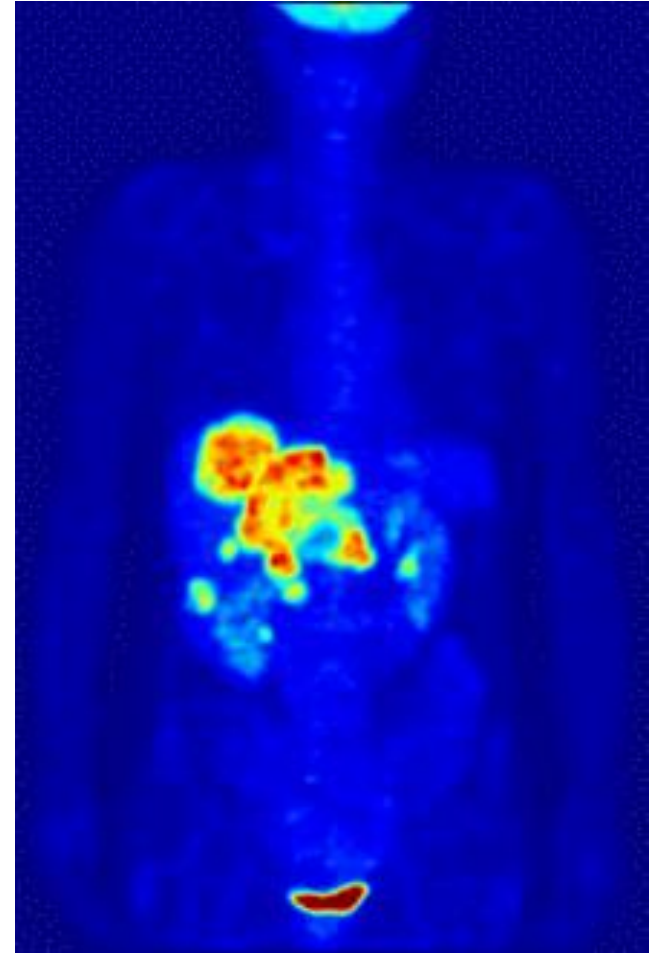
T1, axial

T2, coronal

# Nuclear Medicine: PET



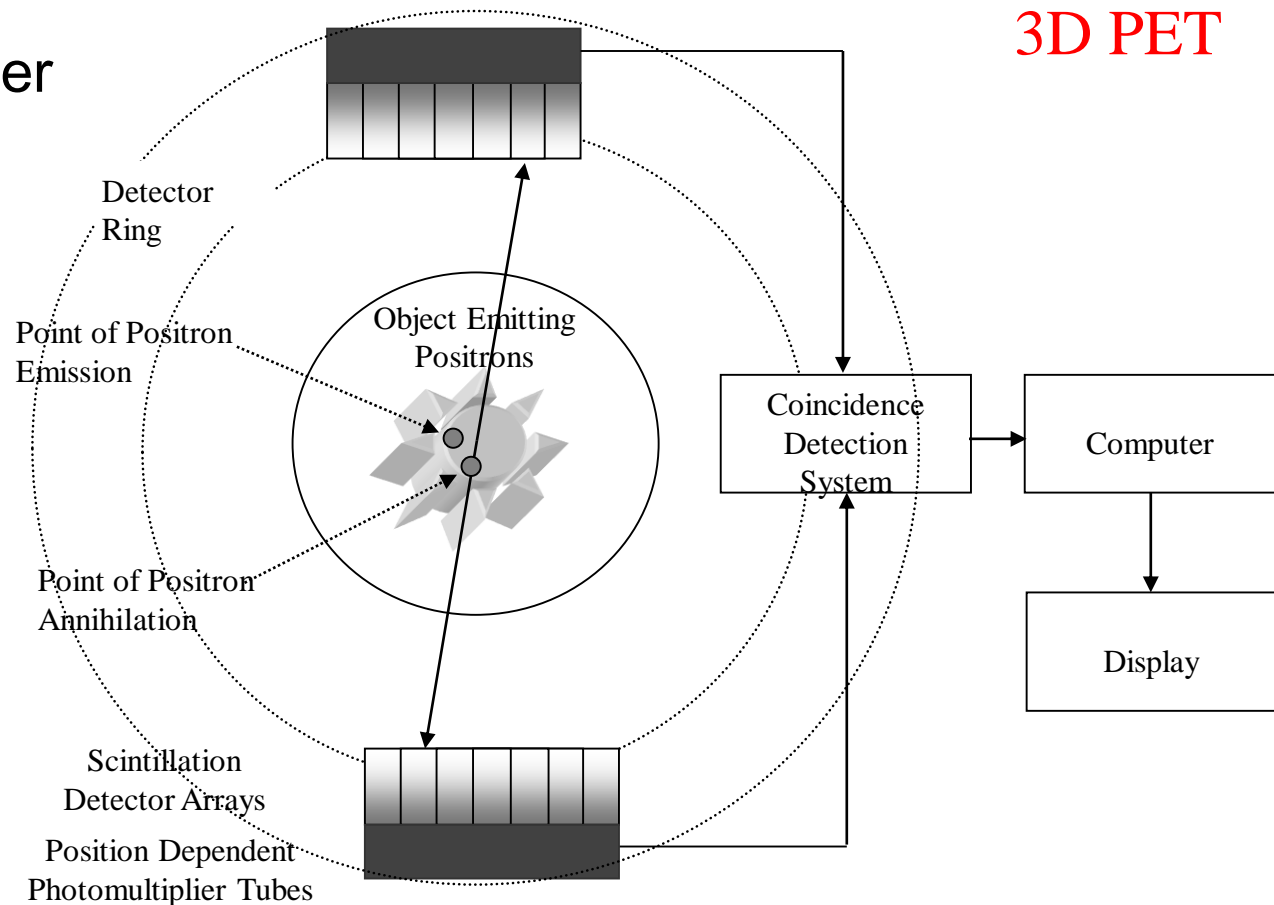
Radiotracer:  
Fluorodeoxyglucose  
(FDG)



Depict places of positron emission

# Nuclear Medicine - Principle

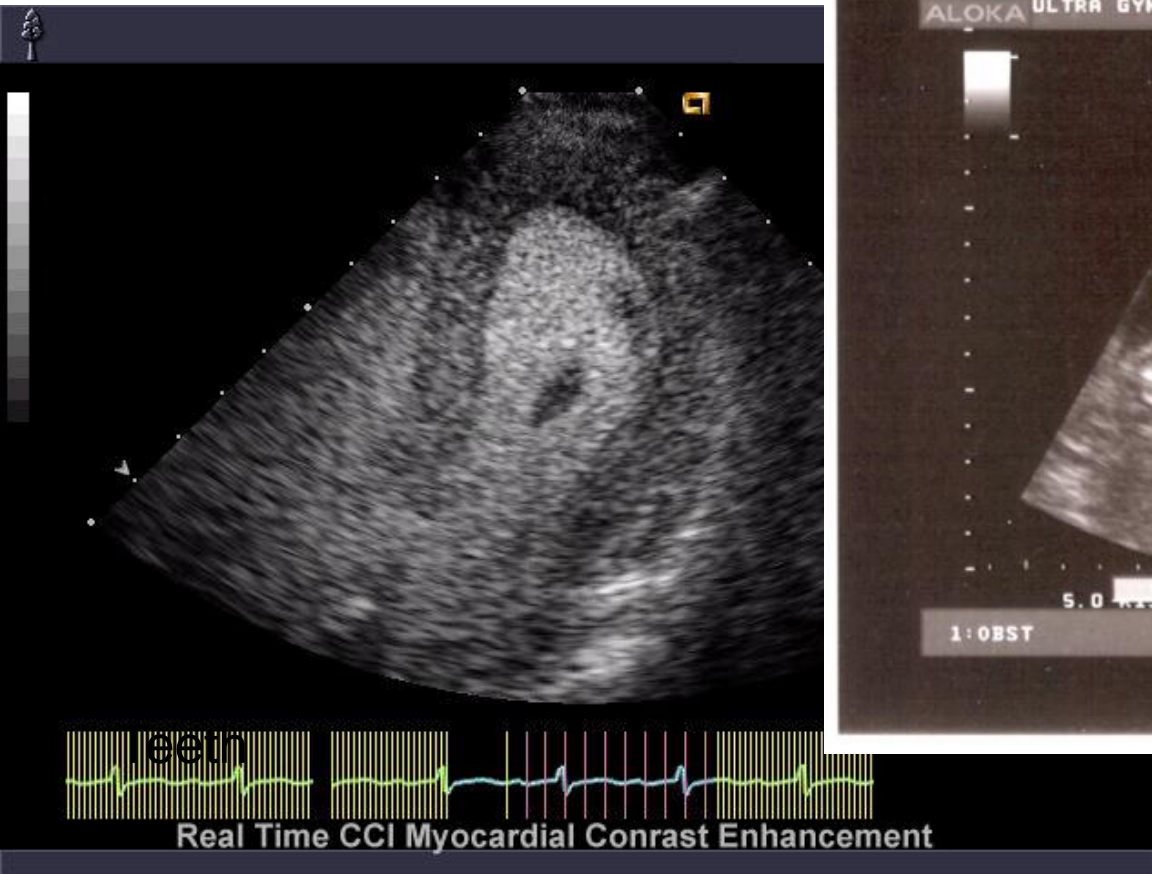
- Radioactive Tracer
- Radionuclides -> Positrons
- Annihilation **emits** Ionizing Radiation
- Gamma Ray **Detection**
- Physiology
- Low Resolution, long Acquisition





# 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

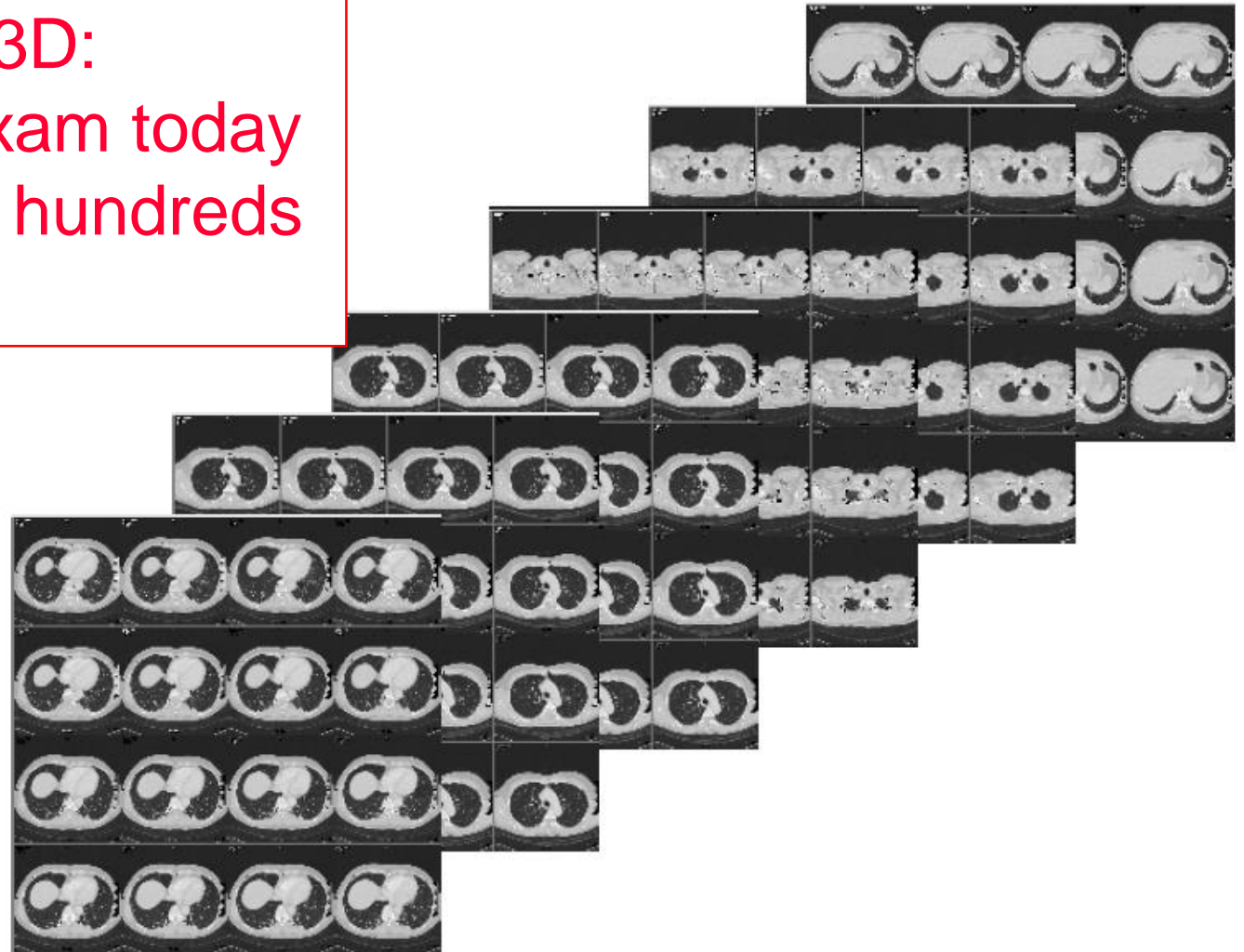


# Back to Hi-Res data -> Saying: A picture is worth a 1000 words!



# 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





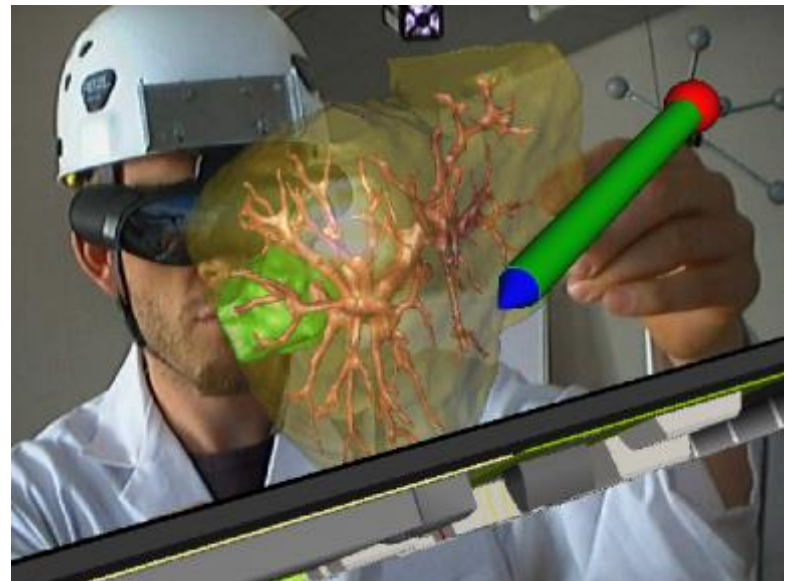
# Technical & Scientific Issues

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- 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

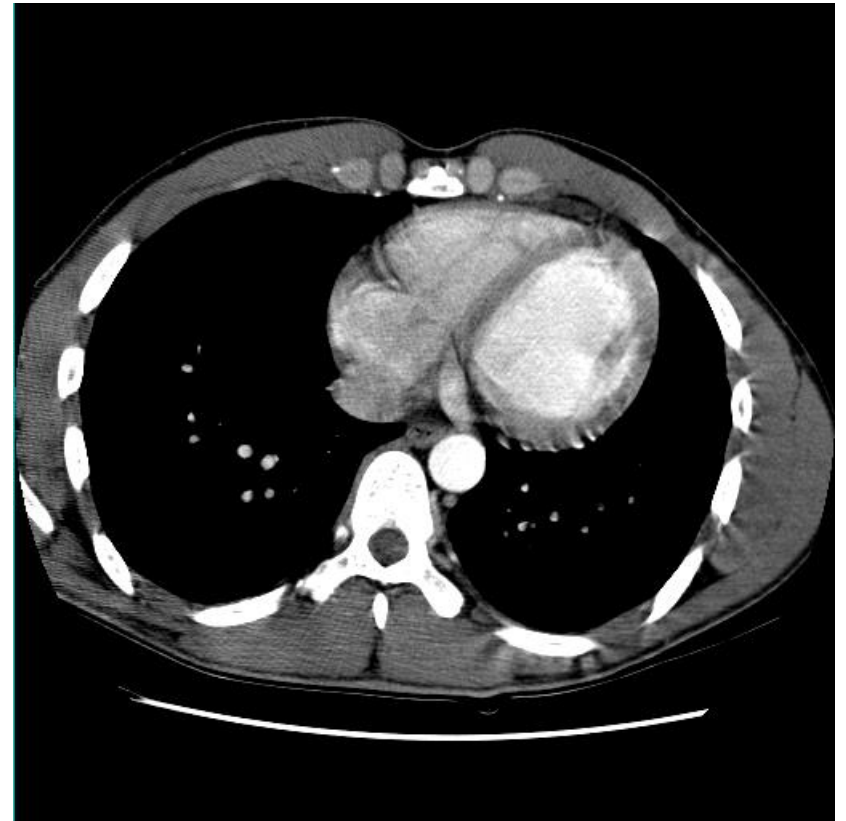
- Medical Imaging technology is advancing at fast pace → new applications:
  - Diagnosis
  - Planning
  - Therapy
  - Surgery
  - Medical education/training
  - ...



- Some application examples next

# Example Applications – Liver Resection

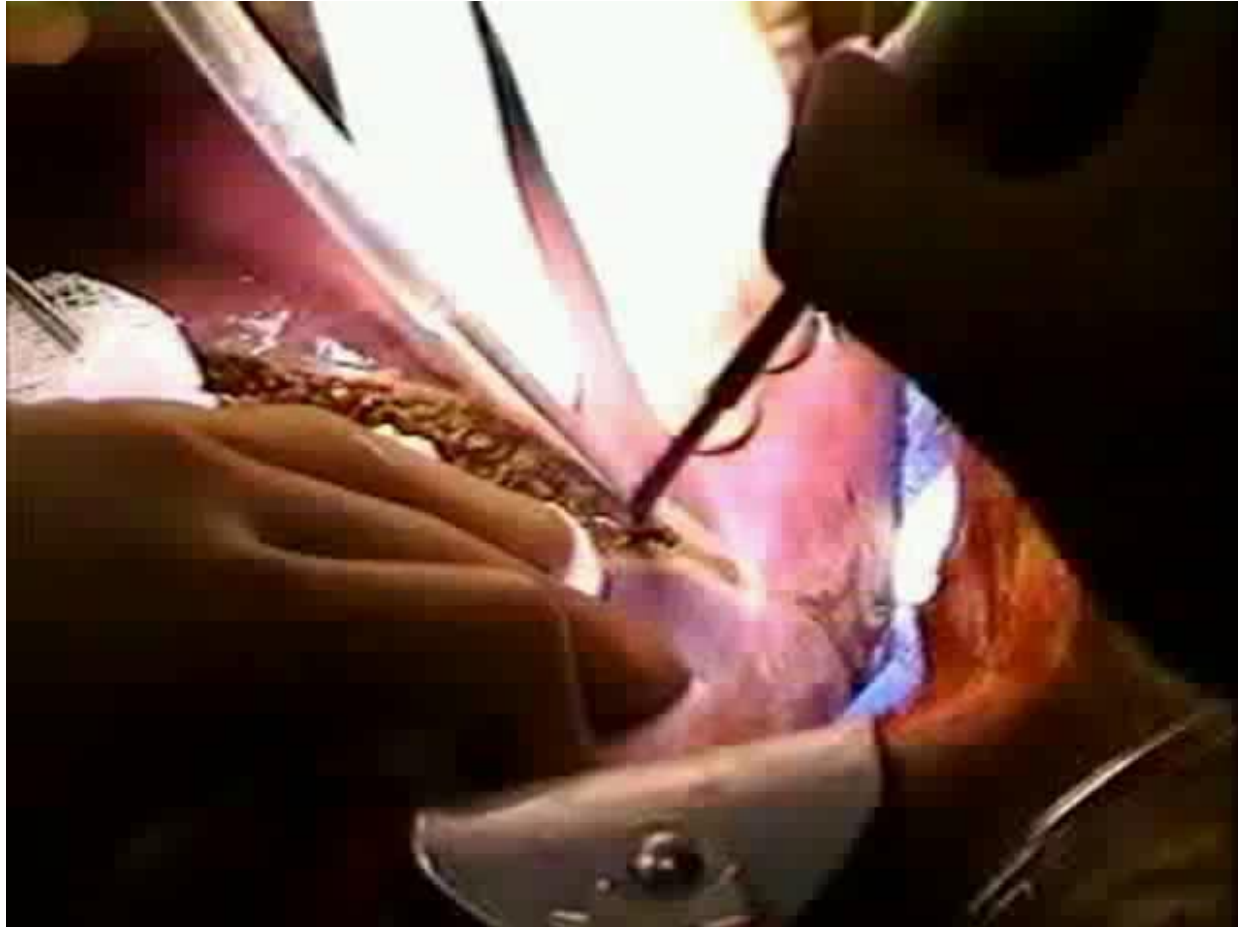
- Liver Tumor
- How much of the liver tissue may be removed?



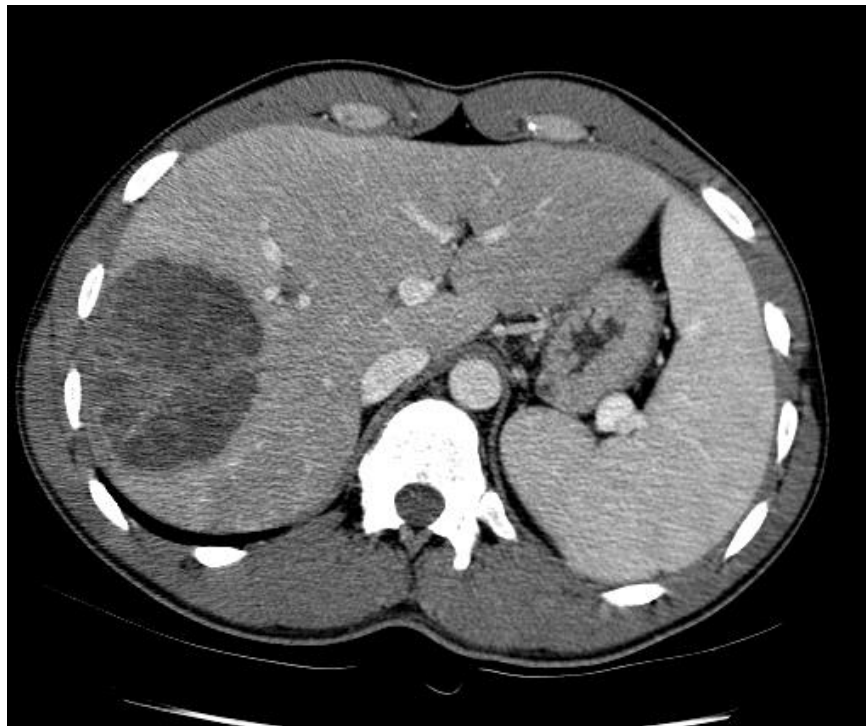
CT Data

# Example Applications – Liver Resection

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# Surgical Planning (Liver Resection)



CT Data

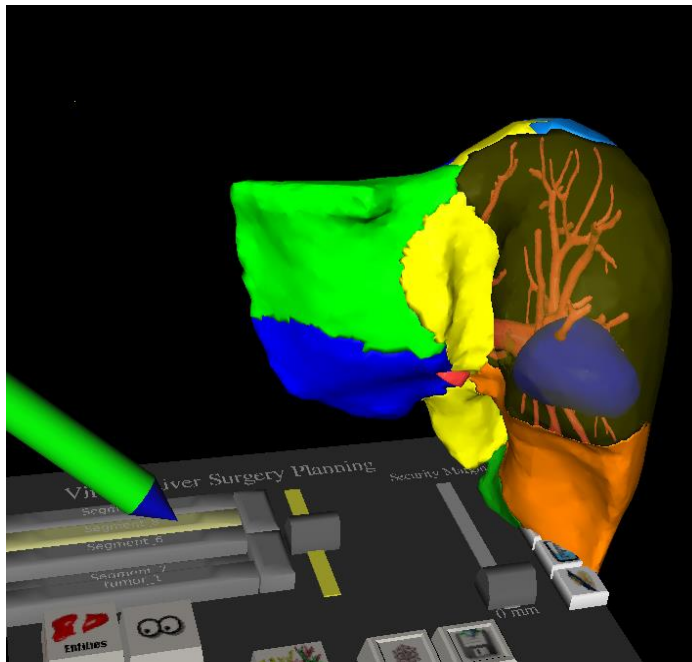


Virtual Surgical Planning

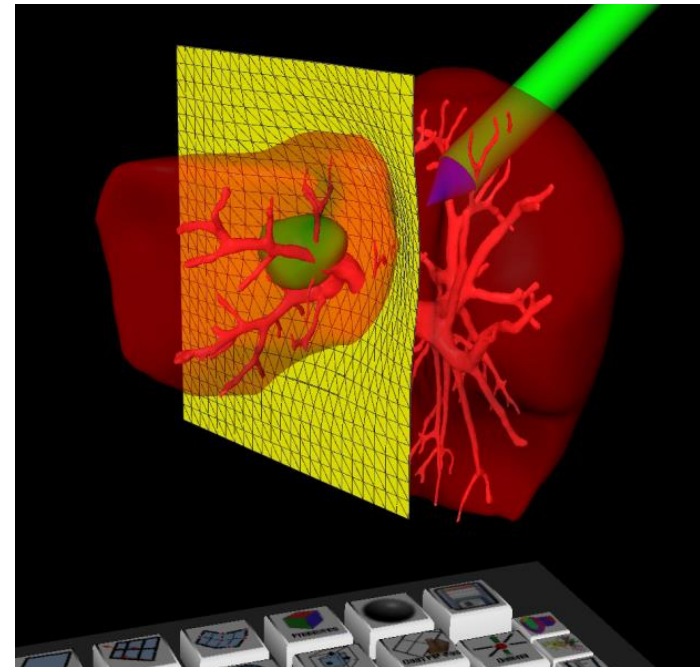


# Surgical Planning (Liver Resection)

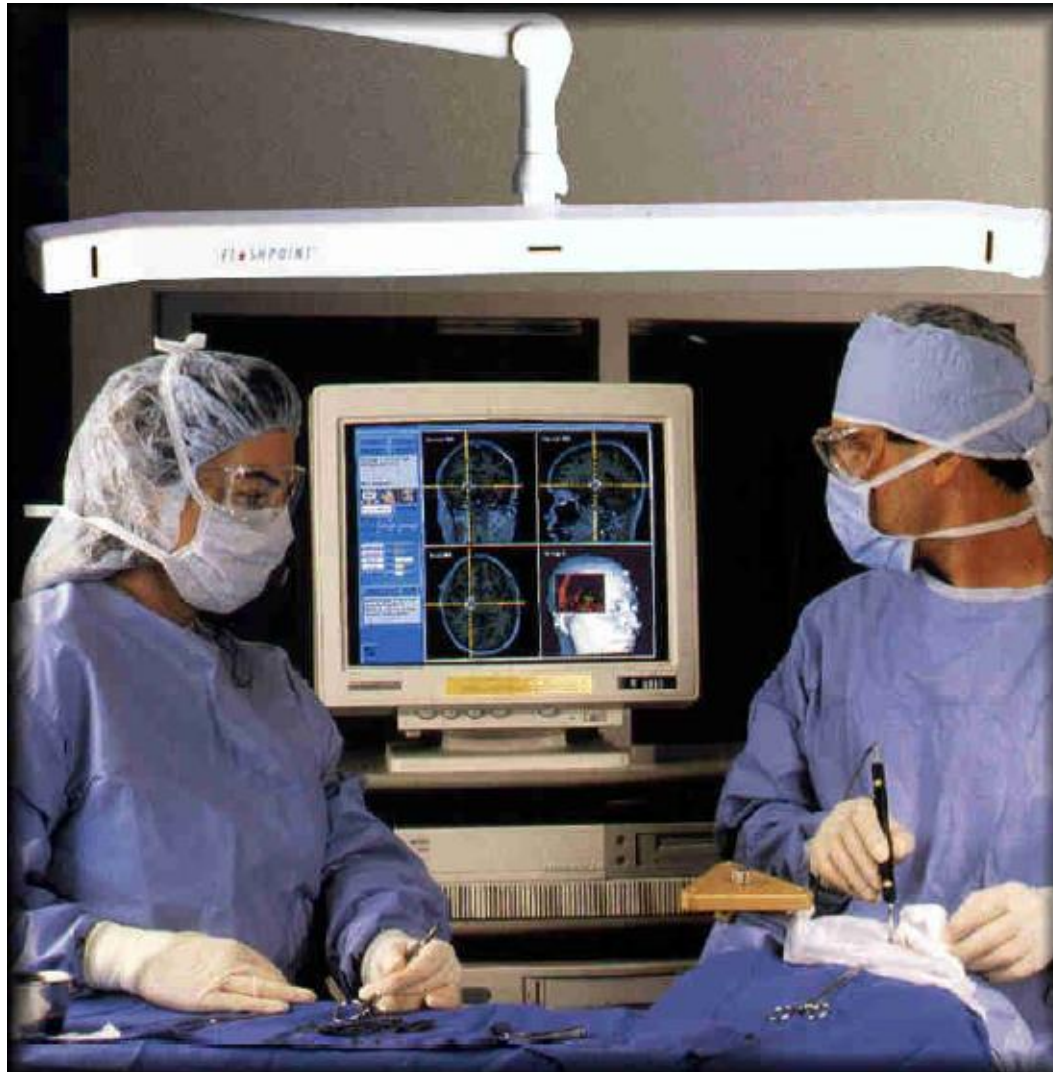
- Anatomical Resection



- Atypical Resection

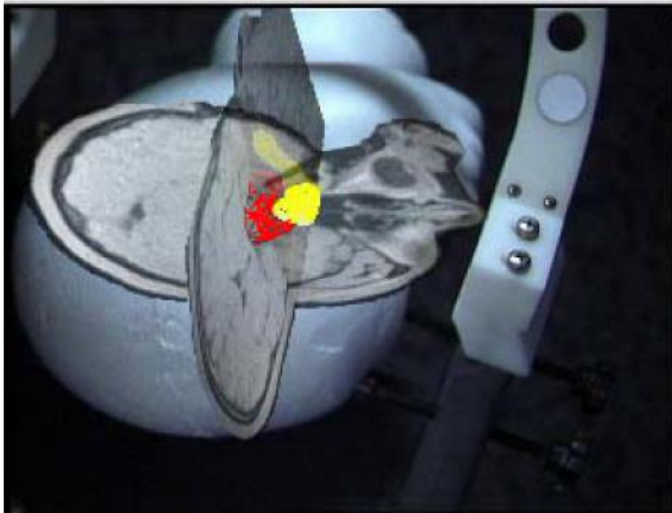


# Interoperative Navigation (1)



# Interoperative Navigation (2)

## Virtual Reality & Augmented Reality Techniques



Siemens Corporate Research, Princeton, USA



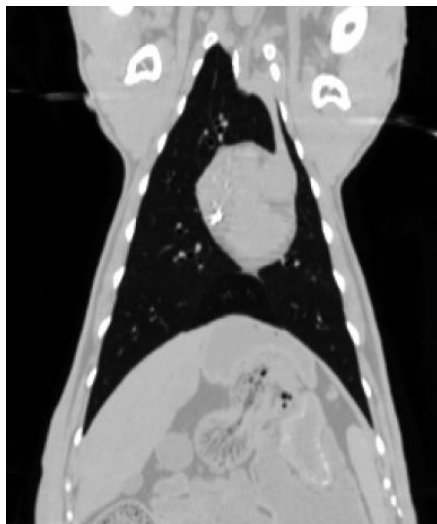
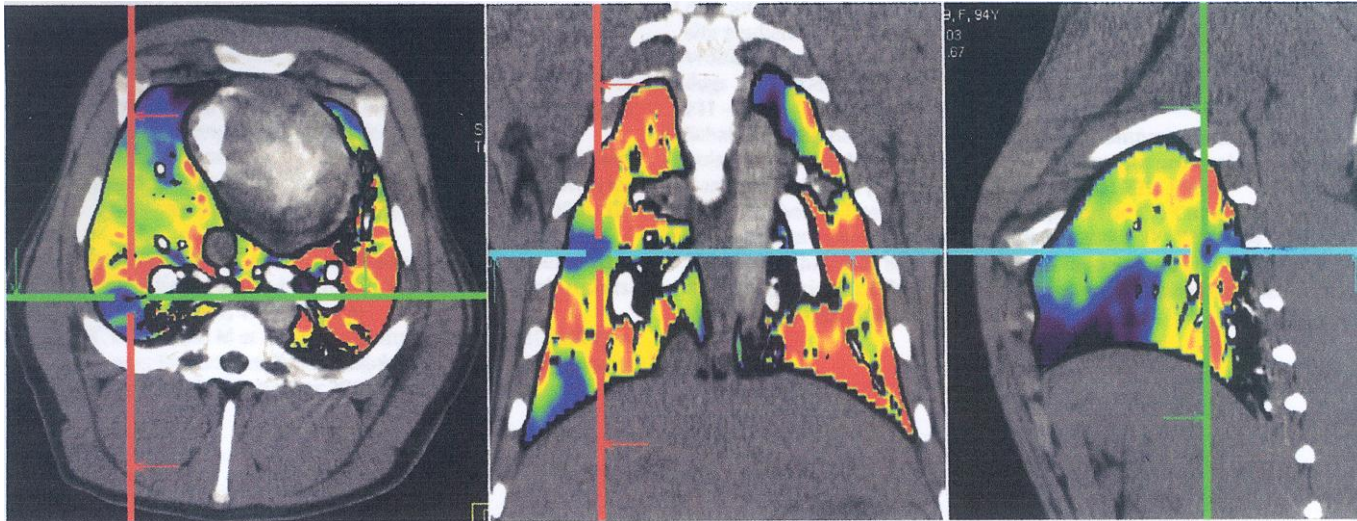
VarioscopeAR,  
Wolfgang Birkfellner, AKH, Wien



Andrew State, UNC 31



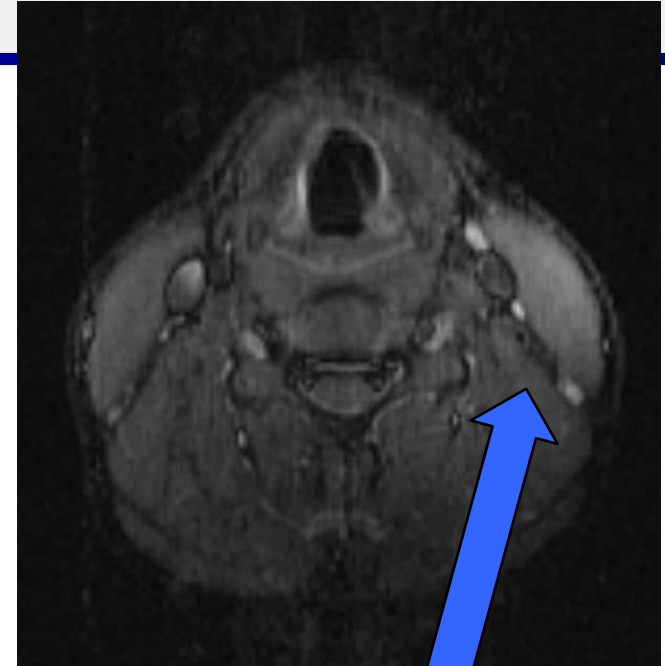
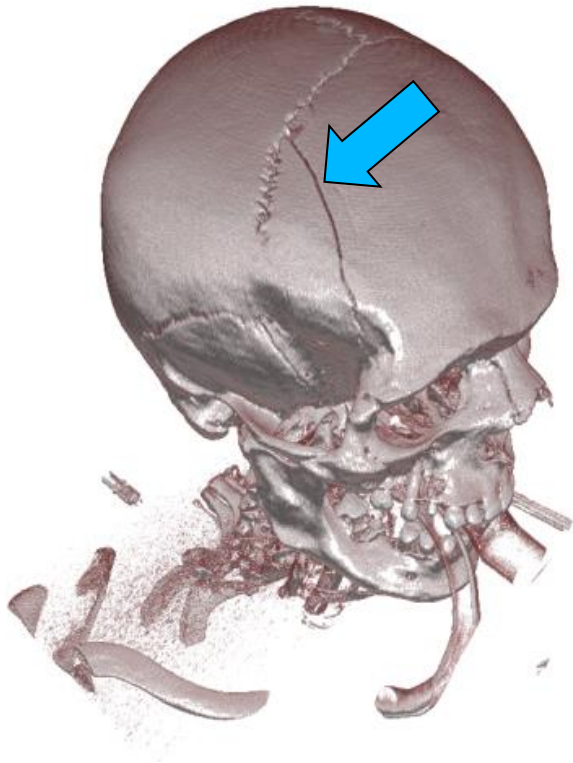
# Functional Imaging – Lung Perfusion



- 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)



Crime Scene Investigation  
Cadaver Secured in Body Bag



Full Body CT Scan, the  
Cadaver Still in the Body Bag



Zooming in on Specific Details at High Resolution



Physical Autopsy is Still Part  
of the Forensics Procedure

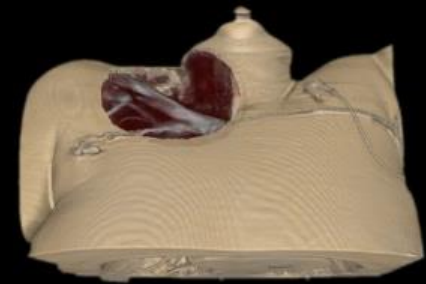


Visual Exploration  
with Radiologist

The Virtual Autopsy  
Workflow

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

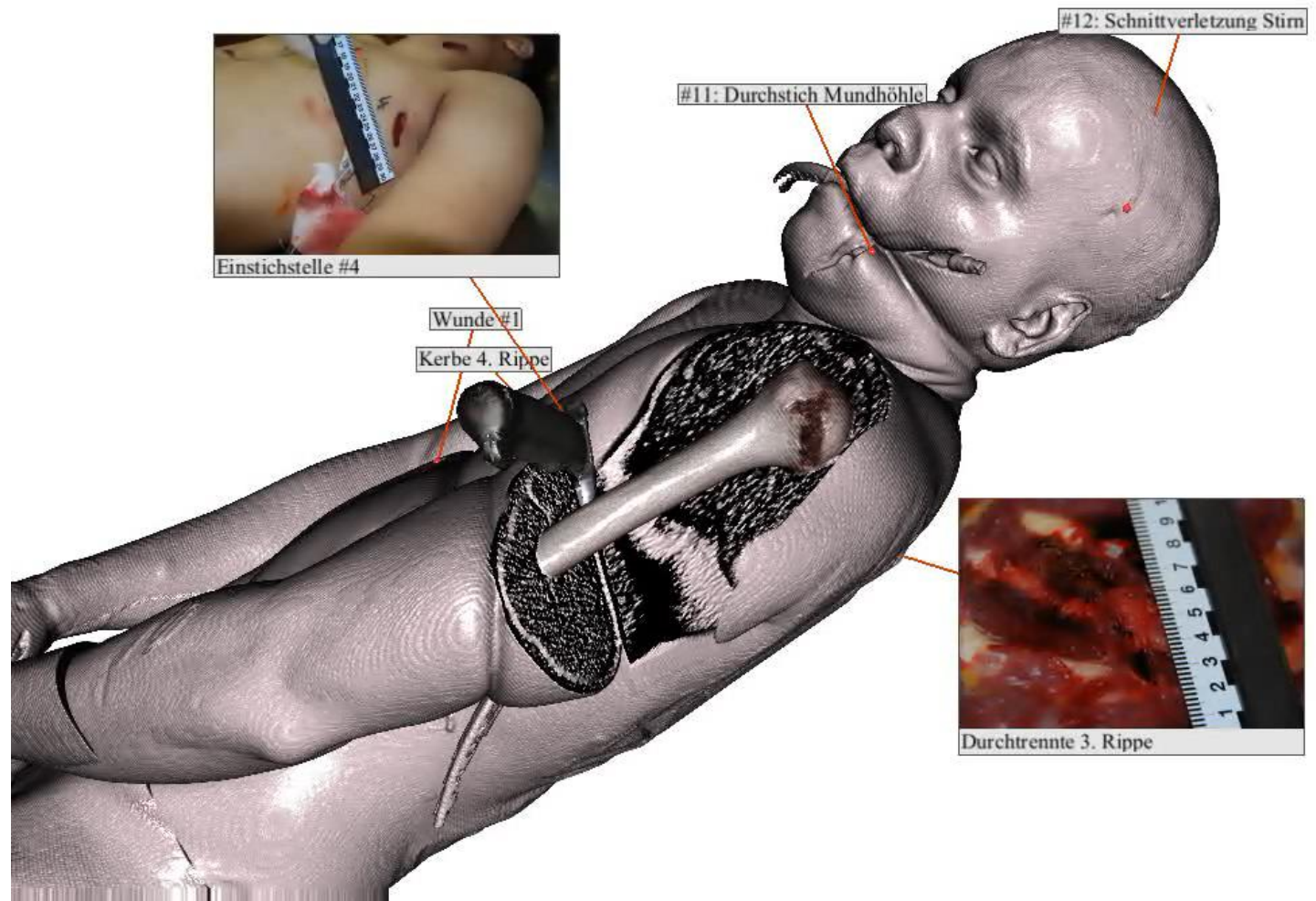
# Clinical Forensic Imaging (3)



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 ...

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... highly interdisciplinary:

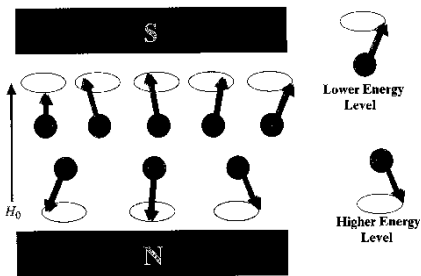
- **Engineering Scientists**
  - Acquisition – Physics, Signal Processing
  - Analysis – Computer Vision
  - Visualization – Computer Graphics
- **Physicians** (Radiology, Nuclear Medicine, Surgery, Legal Medicine...)
- **Industry**
- **BioTechMed** initiative of Graz Universities!



# MIA requires ...



Physiology/Anatomy



Imaging Physics

... understanding of ...



Imaging Modality

(Ethical Issues)

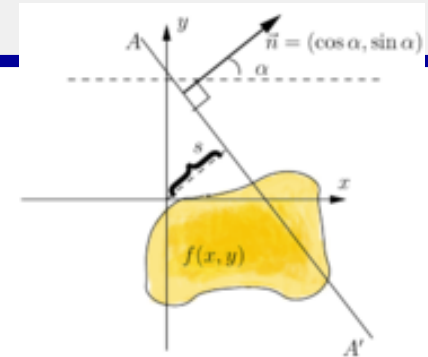


Image Formation

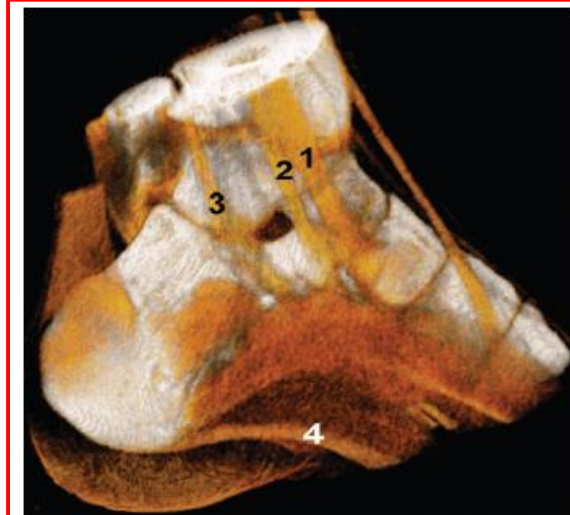


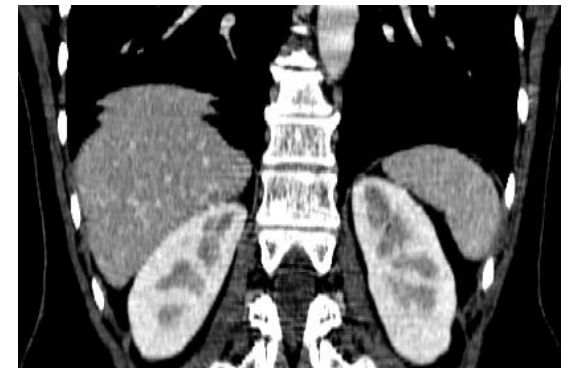
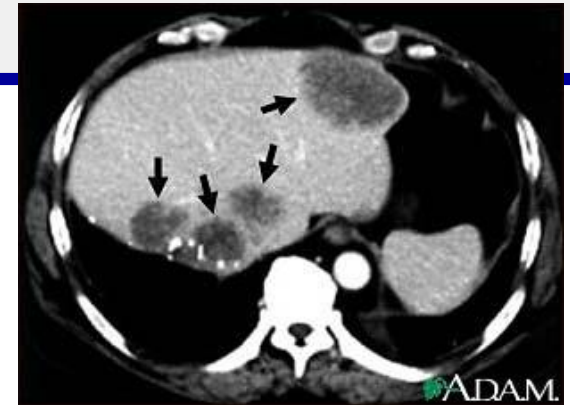
Image Analysis





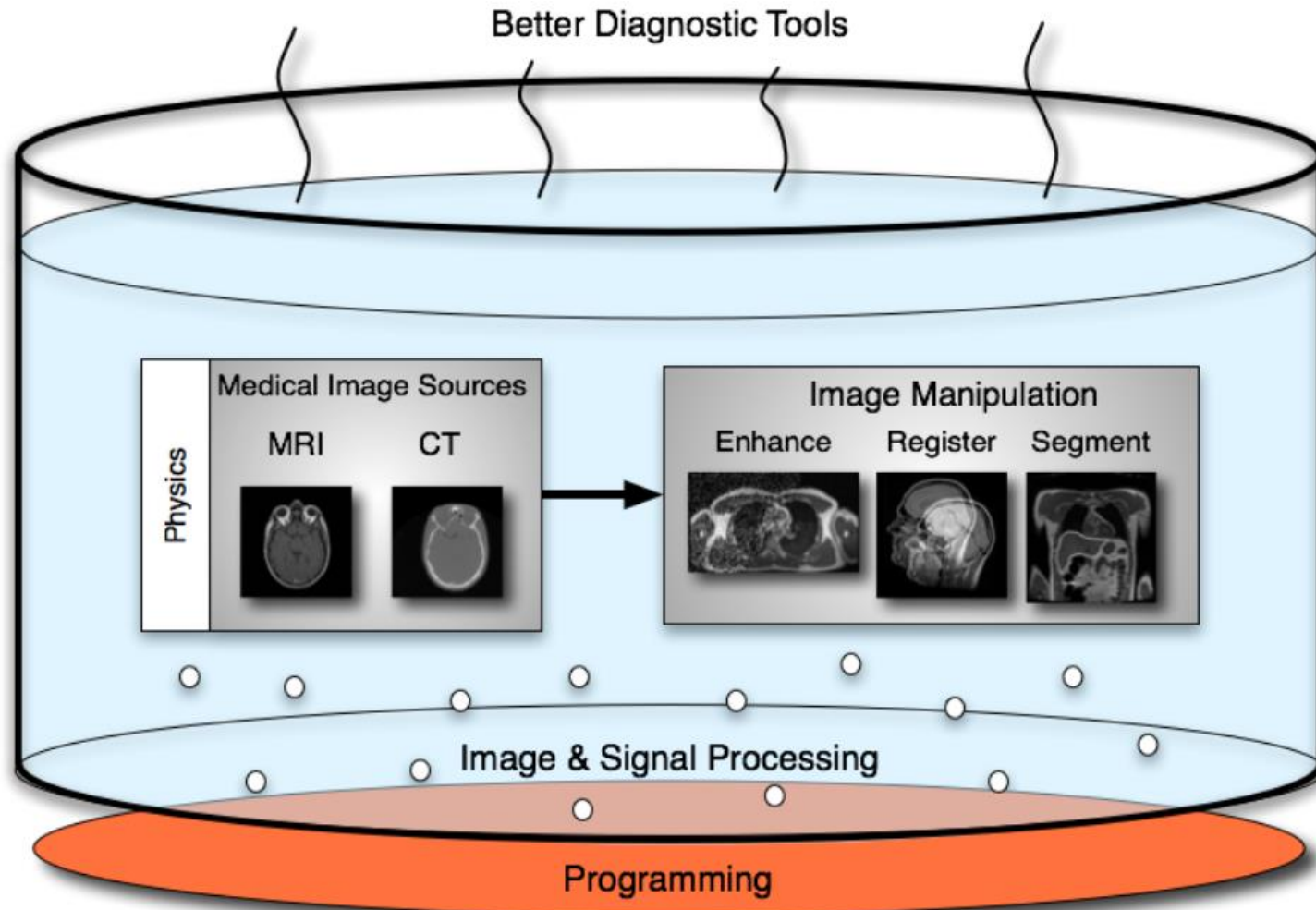
# MIA – Challenges

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

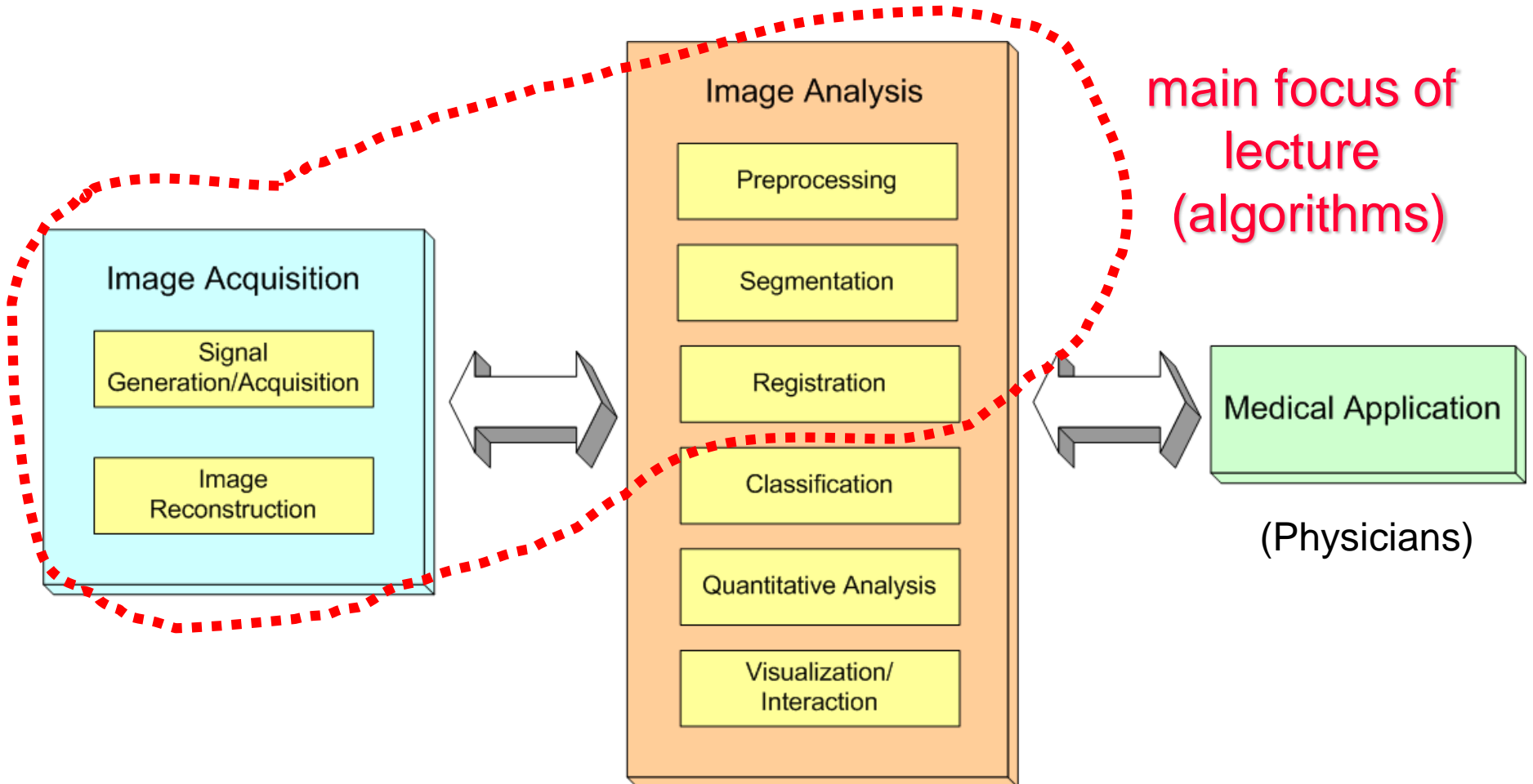


- Goal: Preserve and **enhance real clinical information** rather than introduce additional artifacts

# MIA - Concept

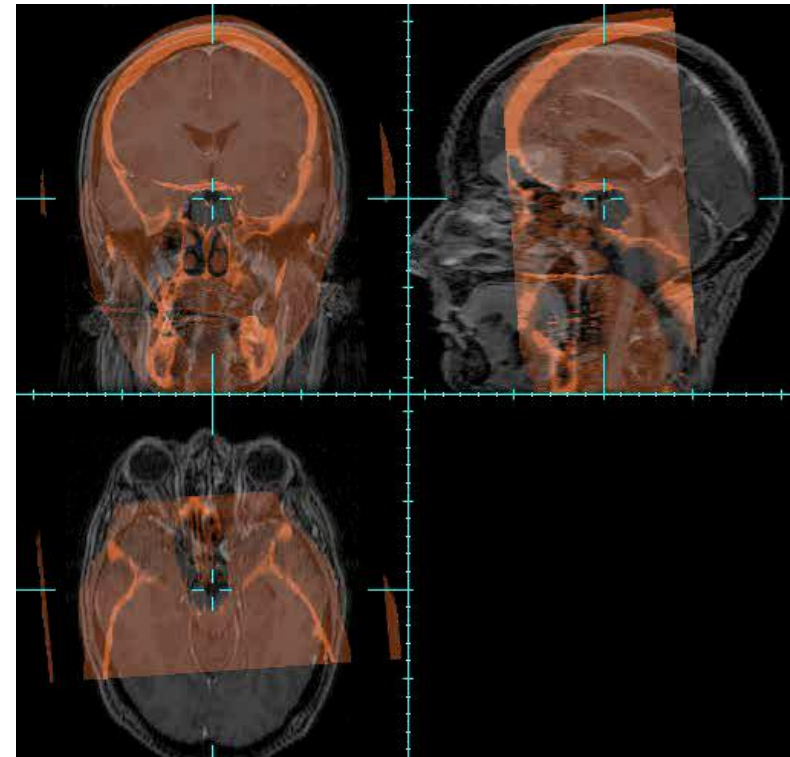
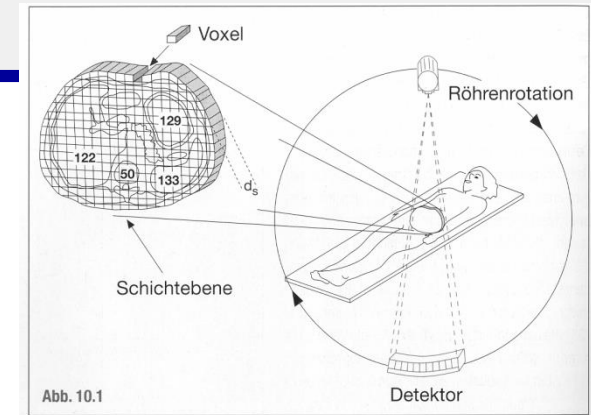


# Lecture - Topics



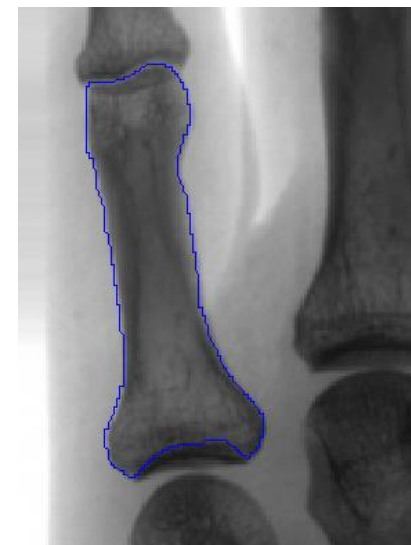
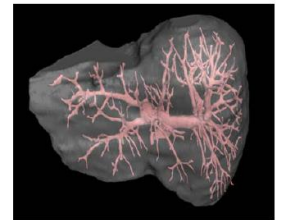
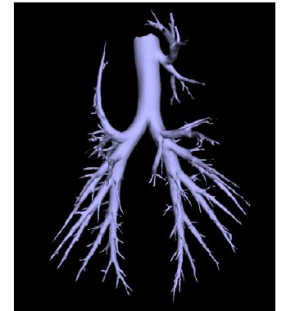
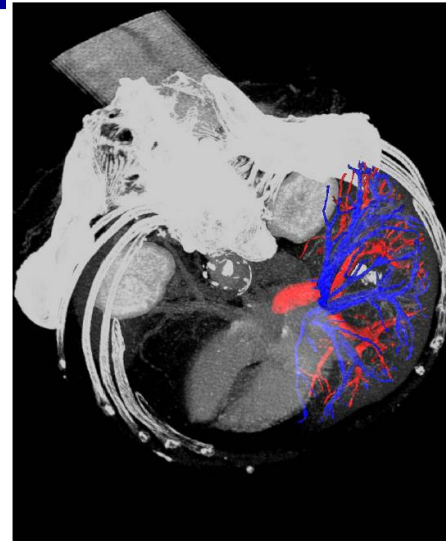
# Lecture - Topics

- 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

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Office Hours: by appointment  
Room E.3.10, ICG,  
Inffeldgasse 16, 2

Email: [urschler@icg.tugraz.at](mailto:urschler@icg.tugraz.at)

# Organization - VO

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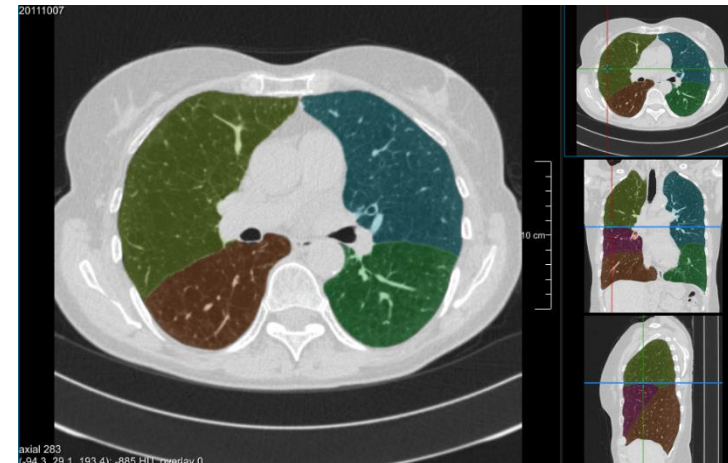
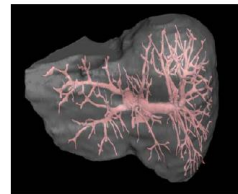
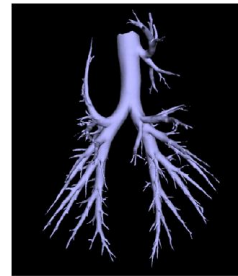
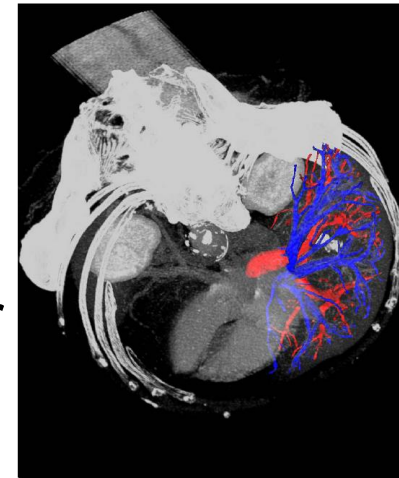
VO: Monday, 15.00 s.t. – 17.00 h, ICG

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



# Slides & Material

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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

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<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

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Questions are welcome!

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

See you next week!