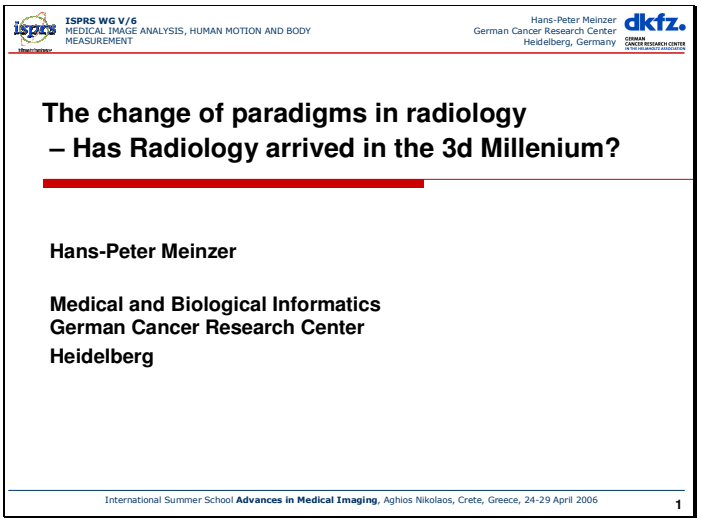
1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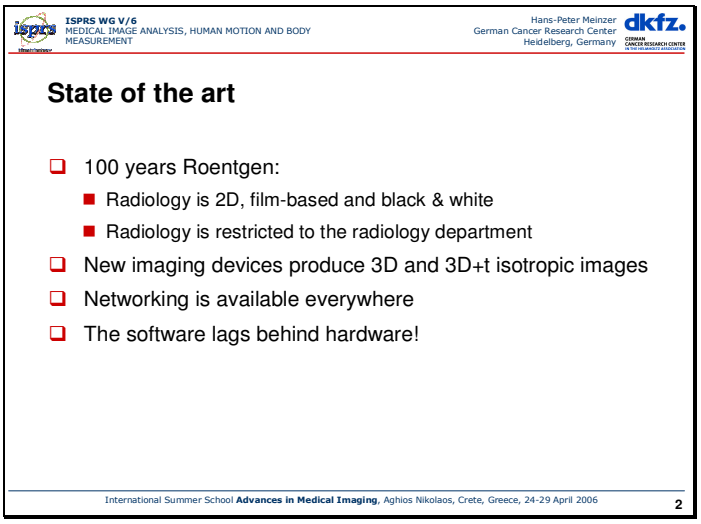
German Cancer Research Center
Heidelberg, Germany
dkfz.
The change of paradigms in radiology
– Has Radiology arrived in the 3d Millenium?
Hans-Peter Meinzer
Medical and Biological Informatics
German Cancer Research Center
Heidelberg
International Summer School Advances in Medical Imaging, Aghios Nikolaos, Crete, Greece, 24-29 April 2006
1

2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State of the art
100 years Roentgen:
Radiology is 2D, film-based and black & white
Radiology is restricted to the radiology department
New imaging devices produce 3D and 3D+t isotropic images
Networking is available everywhere
The software lags behind hardware!
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3

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German Cancer Research Center
Heidelberg, Germany

State of the art

- After 20 years visualization is a nearly solved problem
- Driving spirit was Lucas Film (among others)
- In the field of medical imaging R. Robb, K.H. Höhne, B. Lorensen and approx. a dozen of other people have to be complimented

4

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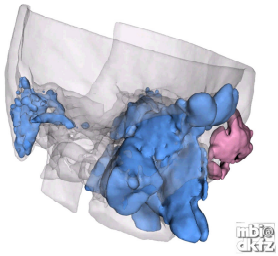
State of the art

Volume visualization

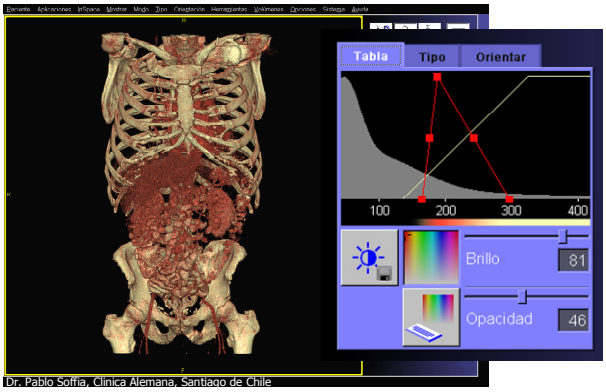


Surface visualization

- Both techniques have their own applications or may be combined

5

State of the art



Dr. Pablo Soffia, Clinica Alemana, Santiago de Chile

6

Achilles´ heel in 2D-3D-4D…

- is the signal-to-symbol gap, i.e. the automatic classification of a signal (pixel, voxel) into high-level entities fails
  - a table, an artery, an aortic arch aneurysm, a fractured arm

7

Achilles´ heel in 2D-3D-4D…

- A human beeing perceives ‚connected entities'
- The computer perceives nothing but pixels
- Radiologists can´t tell HOW they see WHAT
- No explanation, no model, no algorithm, no implementation, no software, no application

8

Segmentation in clinical routine

Methods used in practice mainly are

- manual or
- semi automatic and
- slice based (2D)

9

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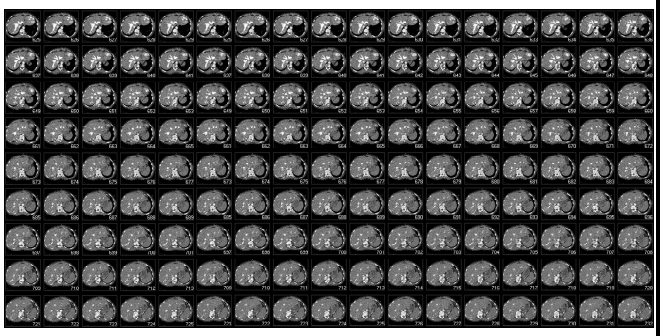
Segmentation in clinical routine



- Slice based segmentation takes too much time and effort!

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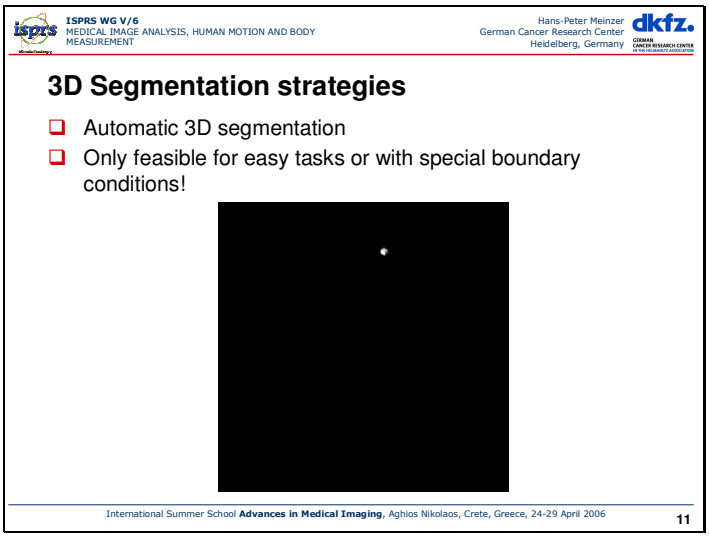
Segmentation in clinical routine

- The most beautiful algorithms worth nothing if they are not
  - **FAST**,
  - **ROBUST**, i.e. work with data from daily routine (GIGO)
  - **SMOOTHLY INTEGRATED** into clinical workflows

11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3D Segmentation strategies
Automatic 3D segmentation
Only feasible for easy tasks or with special boundary conditions!
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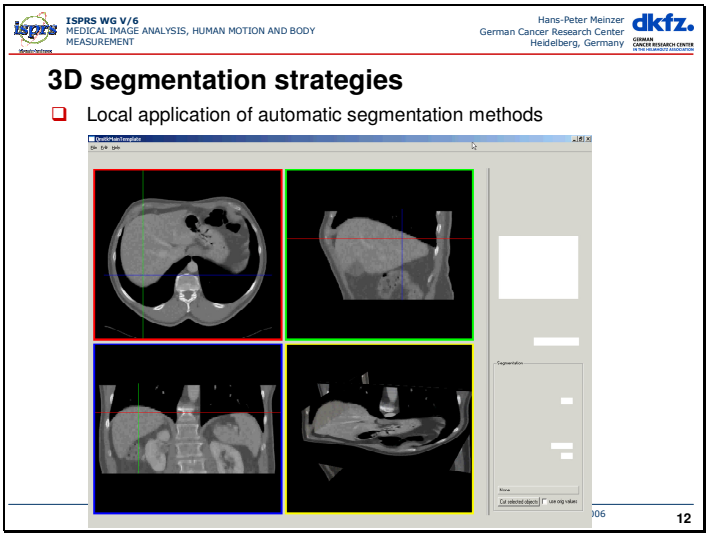
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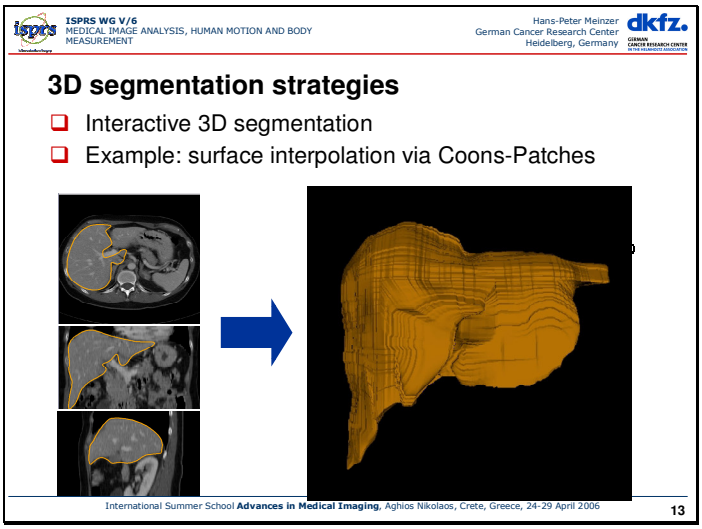
3D segmentation strategies
Local application of automatic segmentation methods
12

13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3D segmentation strategies
Interactive 3D segmentation
Example: surface interpolation via Coons-Patches
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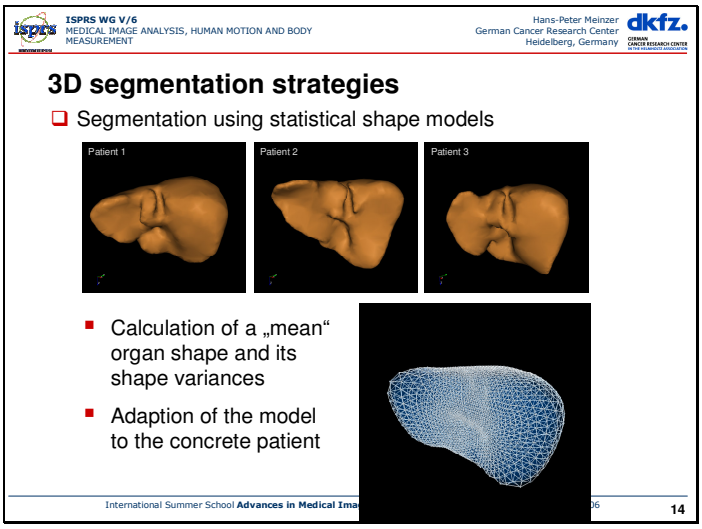
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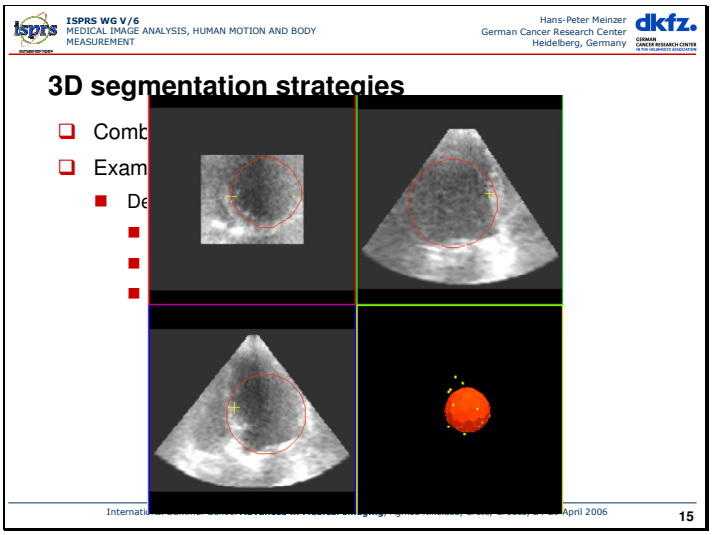
3D segmentation strategies
Segmentation using statistical shape models
Patient 1
Patient 2
Patient 3
Calculation of a „mean“ organ shape and its shape variances
Adaption of the model to the concrete patient
14

15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3D segmentation strategies
Comb
Exam
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April 2006
15

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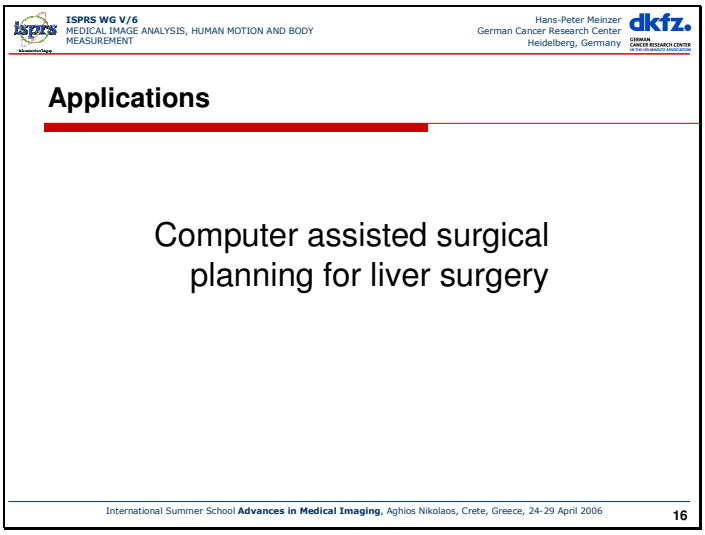
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Applications
Computer assisted surgical planning for liver surgery
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Why do we need 3D planning?

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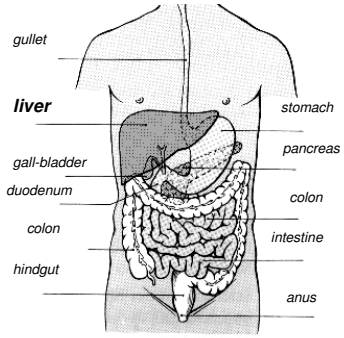
Anatomy of the liver

- Most important metabolizing organ
- High variability
- Regeneration



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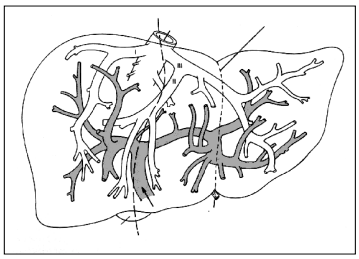
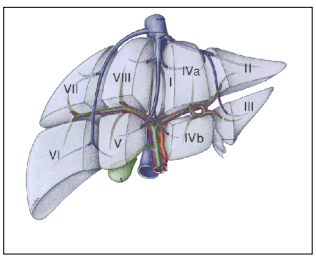
Anatomy of the liver



The venous vessels of the liver



Hepatic segments are defined by junctions of the vessels

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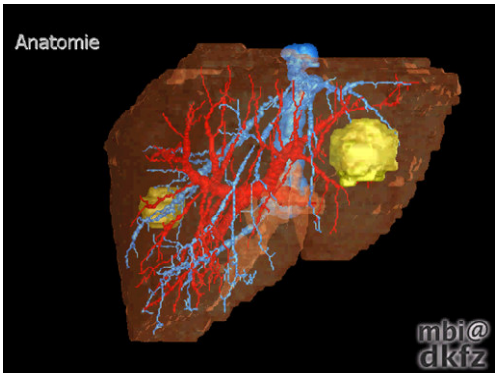
An example



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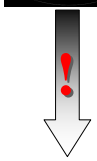
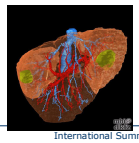
The workflow





- Data transfer
- Registration of image volumes
- Segmentation of liver and tumor
- Segmentation of vessels
- Separation of vessel systems
- Calculation of resection proposals and their volumes
- Presentation of planning results

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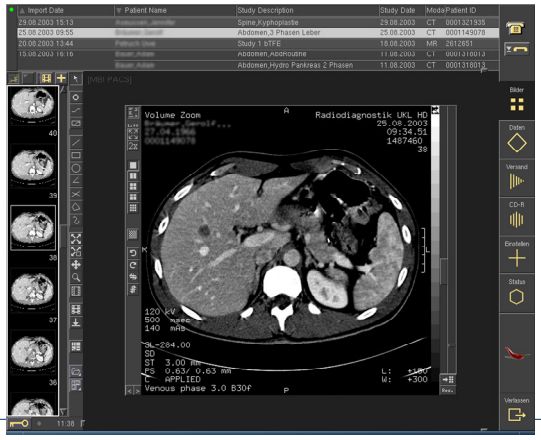
Data Transfer



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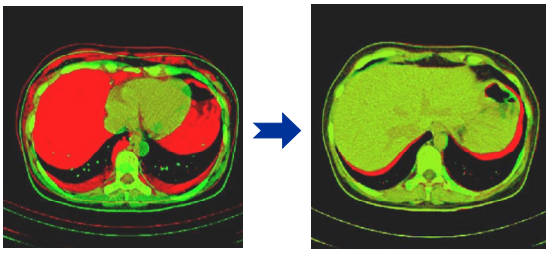
Registration

- Fusion of image data from the same patient showing different anatomical structures
- Facilitates combined 3D visualization of liver veins, portal tree, arteries and bile duct



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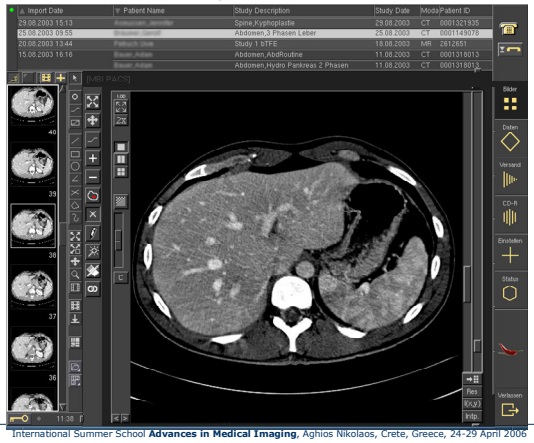
Segmentation



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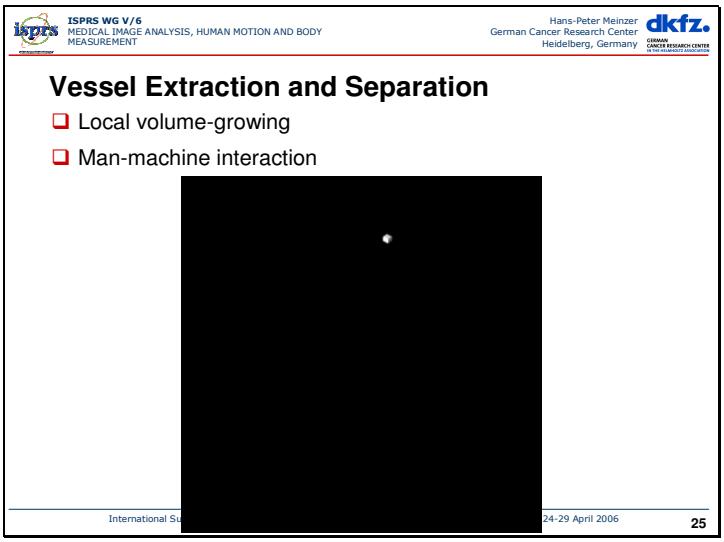
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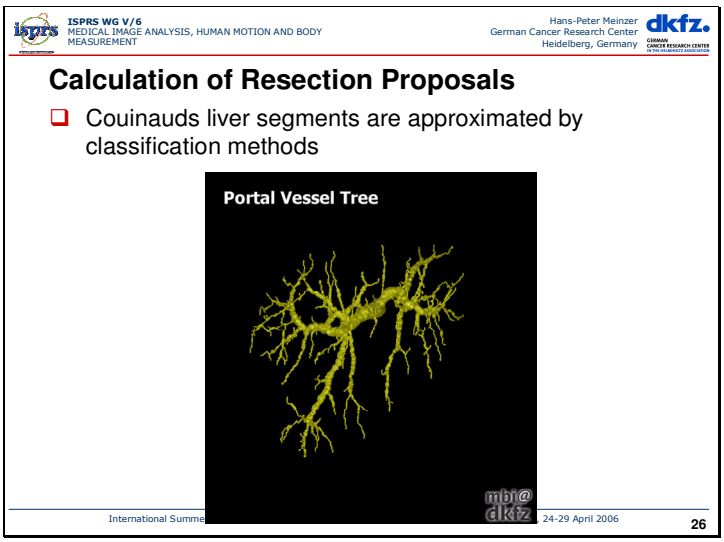
Vessel Extraction and Separation
Local volume-growing
Man-machine interaction
International Su
24-29 April 2006
25

26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Calculation of Resection Proposals
Couinauds liver segments are approximated by classification methods
Portal Vessel Tree
mbi@dkfz
International Summe
24-29 April 2006
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Integration in the OR
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Planning of living donor liver transplantations

- Combined depiction of the portal tree, liver veins, arteries and bile ducts
- Volumetry of liver and graft
- Evaluation of different potential donors
- Computer assisted operation planning is a mandatory step for each living-donor liver transplantation performed in Heidelberg!

30

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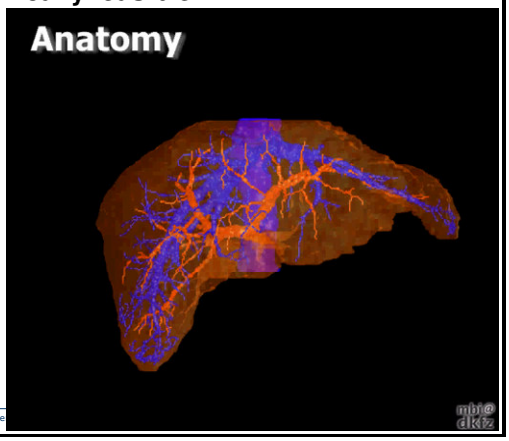
Case I: Anatomically feasible

- Donor
  - 50 year old Wife
  - Calculated graft size: 728 ml / 662 g / 61%
  - Real graft size: 726 ml / 660 g / 61%
- Recipient
  - 54 year old Husband
  - End stage liver cirrhosis based on hepatitis B



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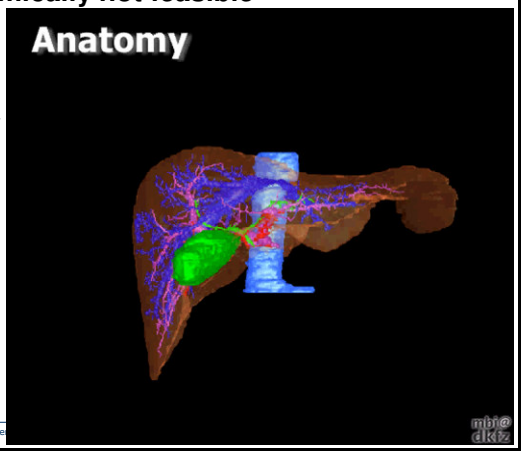
Case II: Anatomically not feasible

- Donor
  - 39 year old Mother (single)
  - Calculated graft size based on portal supply area (strategy 1): 895 ml / 814 g / 72 %
  - Calculated graft size based on venous drainage area (strategy 2): 770 ml / 700 g / 57 %
- Recipient
  - 15 year old Son
  - Beginning liver cirrhosis based on toxication



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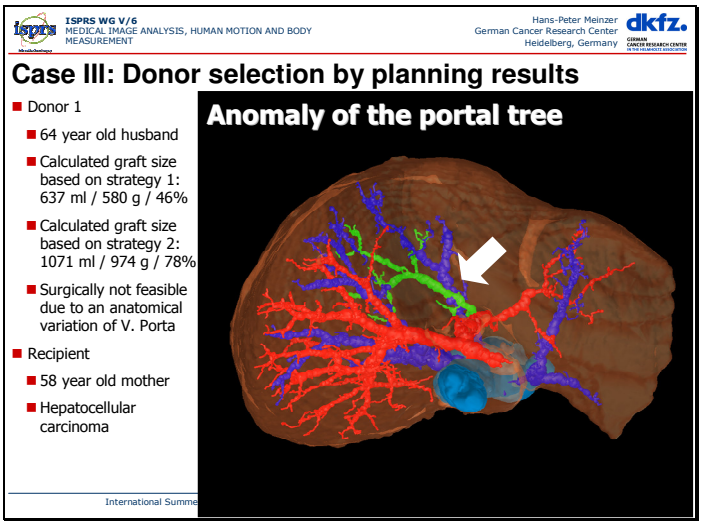
Case III: Donor selection by planning results

- Donor 1
  - 64 year old husband
  - Calculated graft size based on strategy 1: 637 ml / 580 g / 46%
  - Calculated graft size based on strategy 2: 1071 ml / 974 g / 78%
  - Surgically not feasible due to an anatomical variation of V. Porta
- Recipient
  - 58 year old mother
  - Hepatocellular carcinoma

33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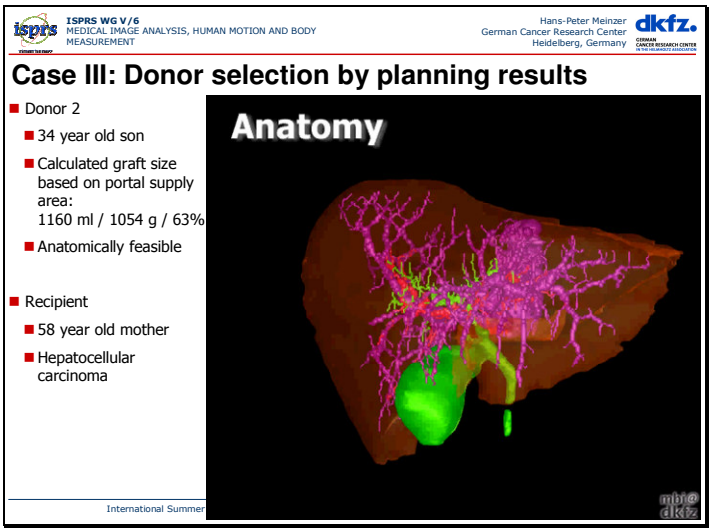
Case III: Donor selection by planning results
Donor 1
64 year old husband
Calculated graft size based on strategy 1: 637 ml / 580 g / 46%
Calculated graft size based on strategy 2: 1071 ml / 974 g / 78%
Surgically not feasible due to an anatomical variation of V. Porta
Recipient
58 year old mother
Hepatocellular carcinoma
Anomaly of the portal tree
International Summe

34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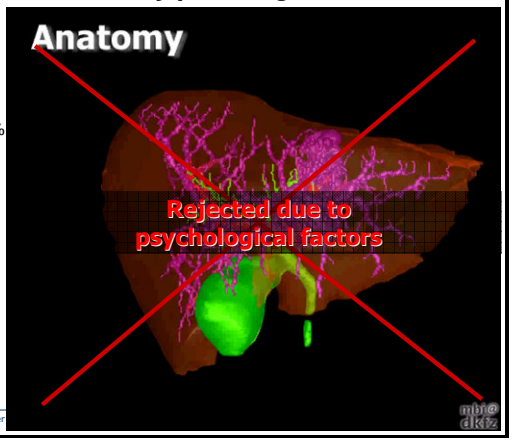
Case III: Donor selection by planning results
Donor 2
34 year old son
Calculated graft size based on portal supply area:
1160 ml / 1054 g / 63%
Anatomically feasible
Recipient
58 year old mother
Hepatocellular carcinoma
Anatomy
International Summer

35

Case III: Donor selection by planning results

- Donor 2
  - 34 year old son
  - Calculated graft size based on portal supply area: 1160 ml / 1054 g / 63%
  - Anatomically feasible
- Recipient
  - 58 year old mother
  - Hepatocellular carcinoma



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Applications

Computer assisted surgical planning for pancreas surgery

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Pancreatic Cancer

- In Germany 10.500 incidences per year
  - 3% of all cancer deseases
  - 5th most frequent cause of death
- 5-year survival rate 0.4 %
- At the time of diagnosis 80% to 90% may not be cured anymore
- Risk factors
  - Smoking,
  - Increased consumption of animal fats
  - Chronic inflammation of the pancreas

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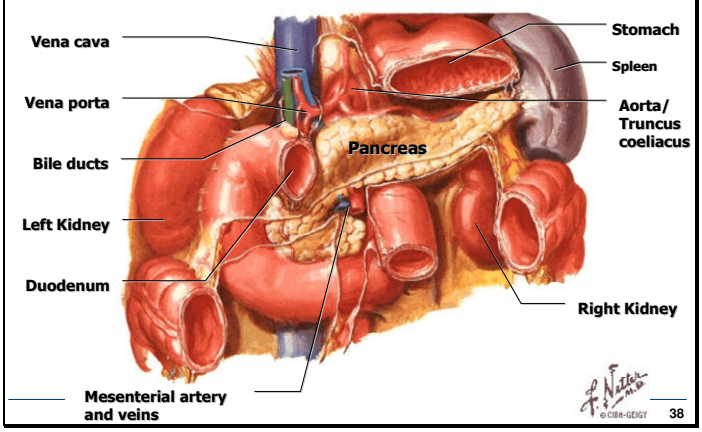
Anatomy



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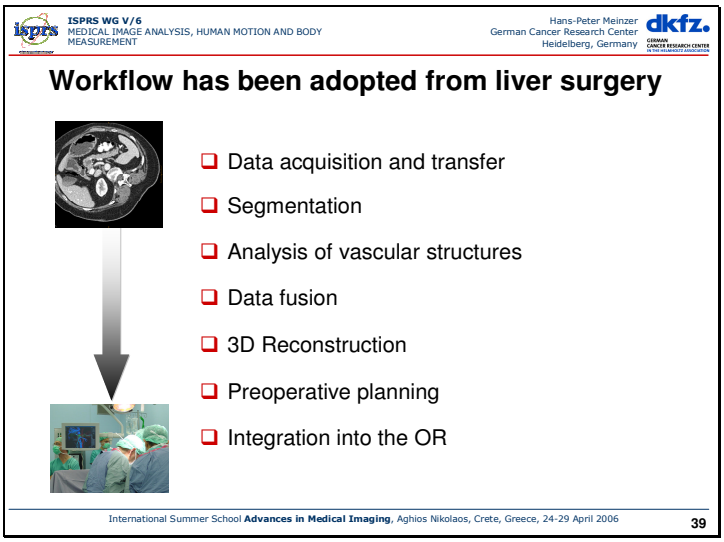
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Heidelberg, Germany
dkfz.
Workflow has been adopted from liver surgery
Data acquisition and transfer
Segmentation
Analysis of vascular structures
Data fusion
3D Reconstruction
Preoperative planning
Integration into the OR
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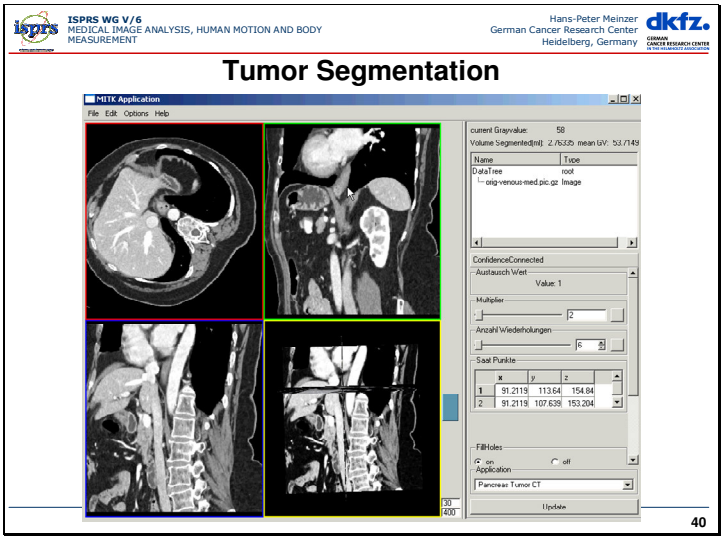
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Tumor Segmentation
MITK Application
File Edit Options Help
ConfidenceConnected
Multiplier
Anzahl Wiederholungen
Saal Punkte
FillHoles
Application
Pancreas Tumor CT
Update
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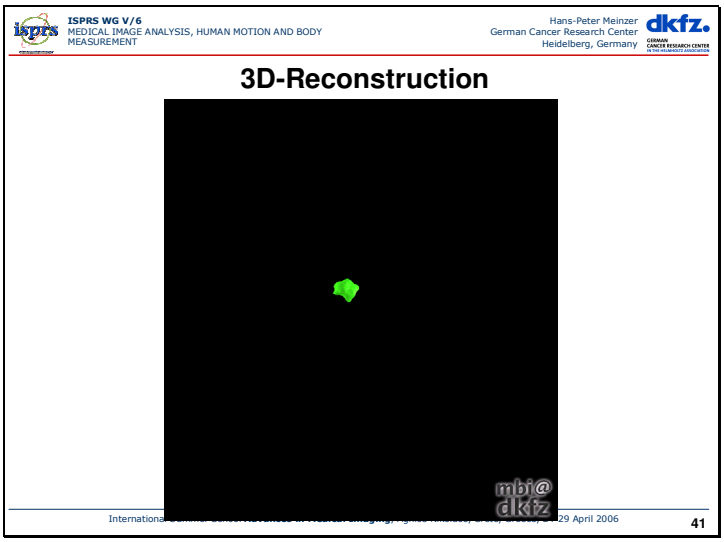
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3D-Reconstruction
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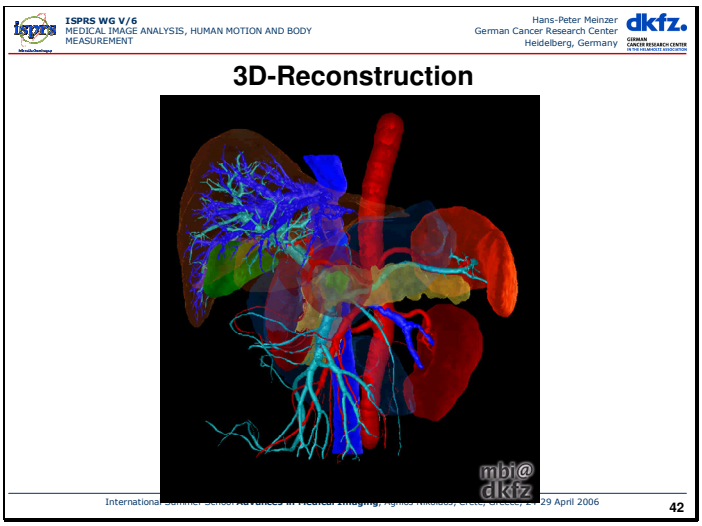
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3D-Reconstruction
mbi@dkfz
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Integration into the OR

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Advantages for the patient

- The surgeon has a wide variety of information more than before
- Surgery gets more calculable
- More security for the patient
- Patients can be selected better before surgical interventions
- The real influence on the surgical outcome is yet unclear
- A study comprising 60 patients analyses the influence of preoperative surgery on the surgical strategy

45

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Heidelberg, Germany

Applications

Computer assisted analysis of heart defects and reproduction of heart models

46

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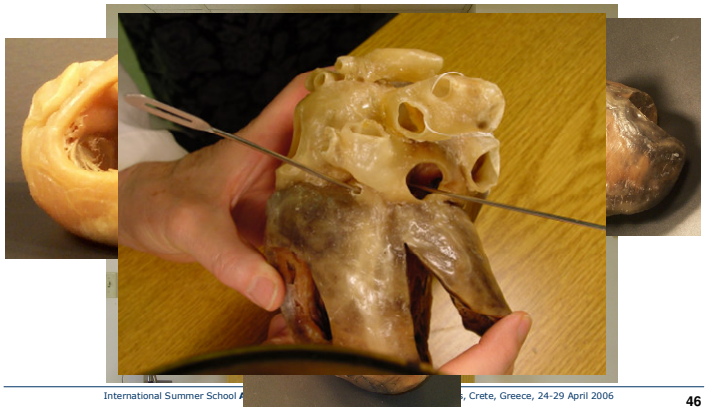
Heidelberg, Germany

Waxed heart models at the Harvard Medical School, Boston



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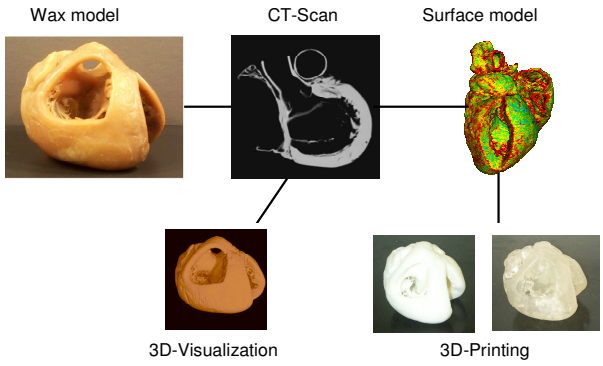
Reproduction methods



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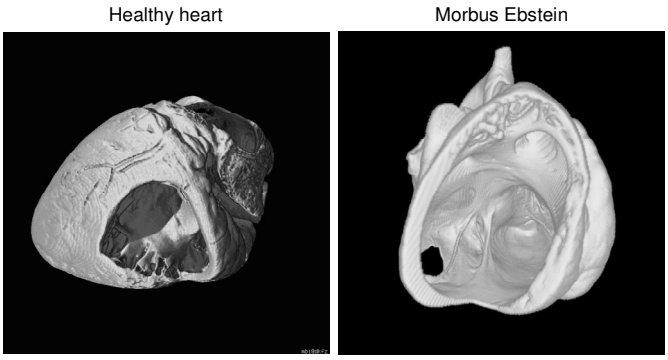
3D Reconstruction



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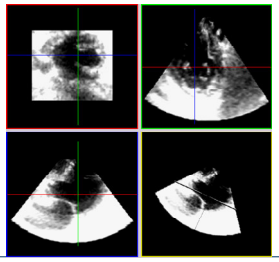
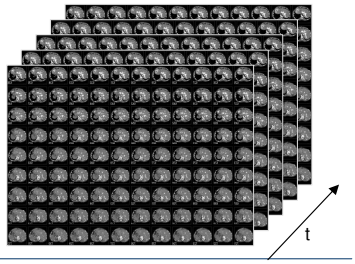
The next steps

- Quantification of dynamic processes gets feasible by the use of new imaging devices
- 4D CT / MRI / Ultrasound is available in clinical routine
- 4D is 3D + t !





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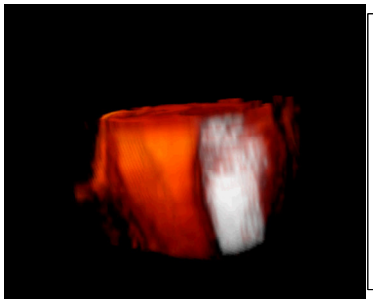
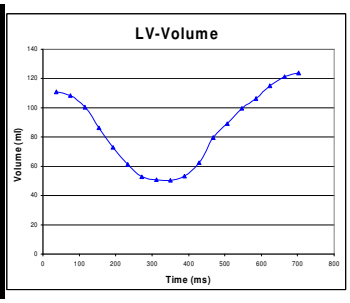
Volumetry of heart cavities

- k-t-blast imaging technique
- Breathhold: only once for 17s





[University of Tübingen, ETH Zürich, DKFZ]

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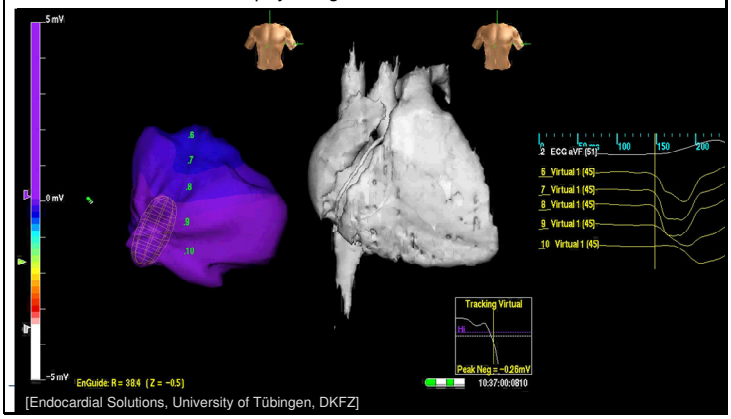
Electrophysiology

- Goal: Fusion of electrophysiological and anatomical data



[Endocardial Solutions, University of Tübingen, DKFZ]

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Applications

Analysis of respiratoty motion and planning of lung interventions

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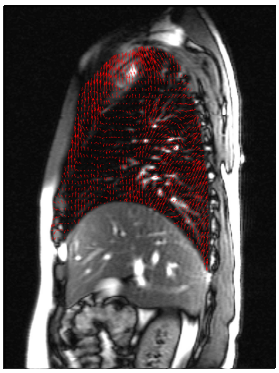
MEDICAL IMAGE ANALYSIS, HUMAN MOTION AND BODY MEASUREMENT

Hans-Peter Meinzer
German Cancer Research Center
Heidelberg, Germany

Lung dynamics

- Analysis of respiratory motion
  - 2D / 3D / 4D
  - Tumor tracking
  - Mobility assessment of risc structures
  - Dynamic volumetry
  - Compliance maps
- Long term goal: radiation therapy under free breathing



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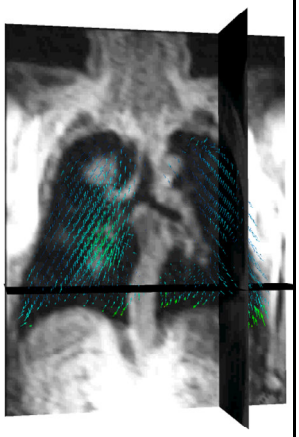

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Lung dynamics

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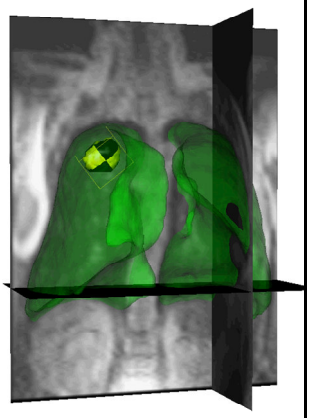

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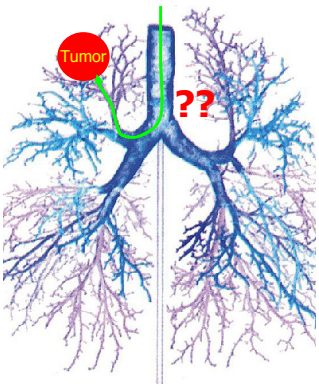
Navigated Brachytherapy



- Brachytherapy
  - Irradiation from the inside of the body
  - Radiation source is placed near the tumor via a catheter
- Problem
  - Complex anatomy of the bronchial tree
  - Where is the tumor?

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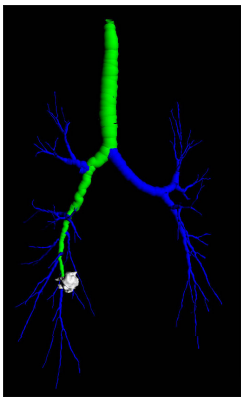
Navigated Brachytherapy



- Preoperative planning
  - Model of the bronchial tree
  - Interactive path planning
  - Simulation
- During intervention
  - Bronchoscopy
  - Calibration
  - Electromagnetic tracking
  - Path is depicted in video stream

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Navigated Brachytherapy

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Has Radiology arrived in the 3d millenium?

It may look like, but…

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Has Radiology arrived in the 3d Millenium?

- A paradigm shift is about to happen
- The transition from 2D to 3D and 3D+t has been caused by new imaging technologies
- 3D segmentation has to replace manual 2D segmentation
- Visualization and quantification now in 3D + t
- Radiology departments have to be linked together

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Has Radiology arrived in the 3d Millenium?

- The presented opportunities of medical imaging are stuck in the radiology department (or even in the laboratory)
- In place implementation (fast, robust and smoothly integrated)
- Centers of Excellence have to provide computer assisted diagnosis and therapy planning as services.
  - If you're doing things everey day, you're doing them well!
  - There is not enough time in clinical routine

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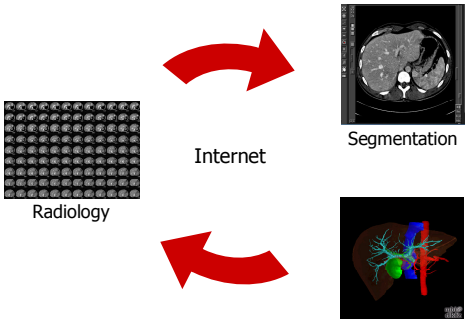
Has Radiology arrived in the 3d Millenium?

- Post-processing as a „laboratory service"?



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Has Radiology arrived in the 3d Millenium?

- Perhaps radiological competence emigrates from the radiology department
- It might happen that computer assisted
  - methods for diagnosis support and
  - methods for therapy planning
- are applied directly in-place
- Image guided therapy support is currently implemented

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Back to the key question…

- Has radiology arrived in the 3d millenium?
- **No!**
- The techniques are available, but
  - are not usable
  - are not integrated into the clinical workflows
  - are not at the right place to the right time

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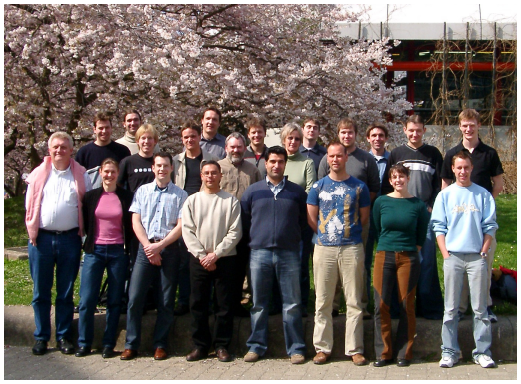
The team…



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Thank you!