SELECTED TOPICS ON BIOMEDICAL IMAGE PROCESSING

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WHO IS E.S.

- **Follow me…….**

Directory

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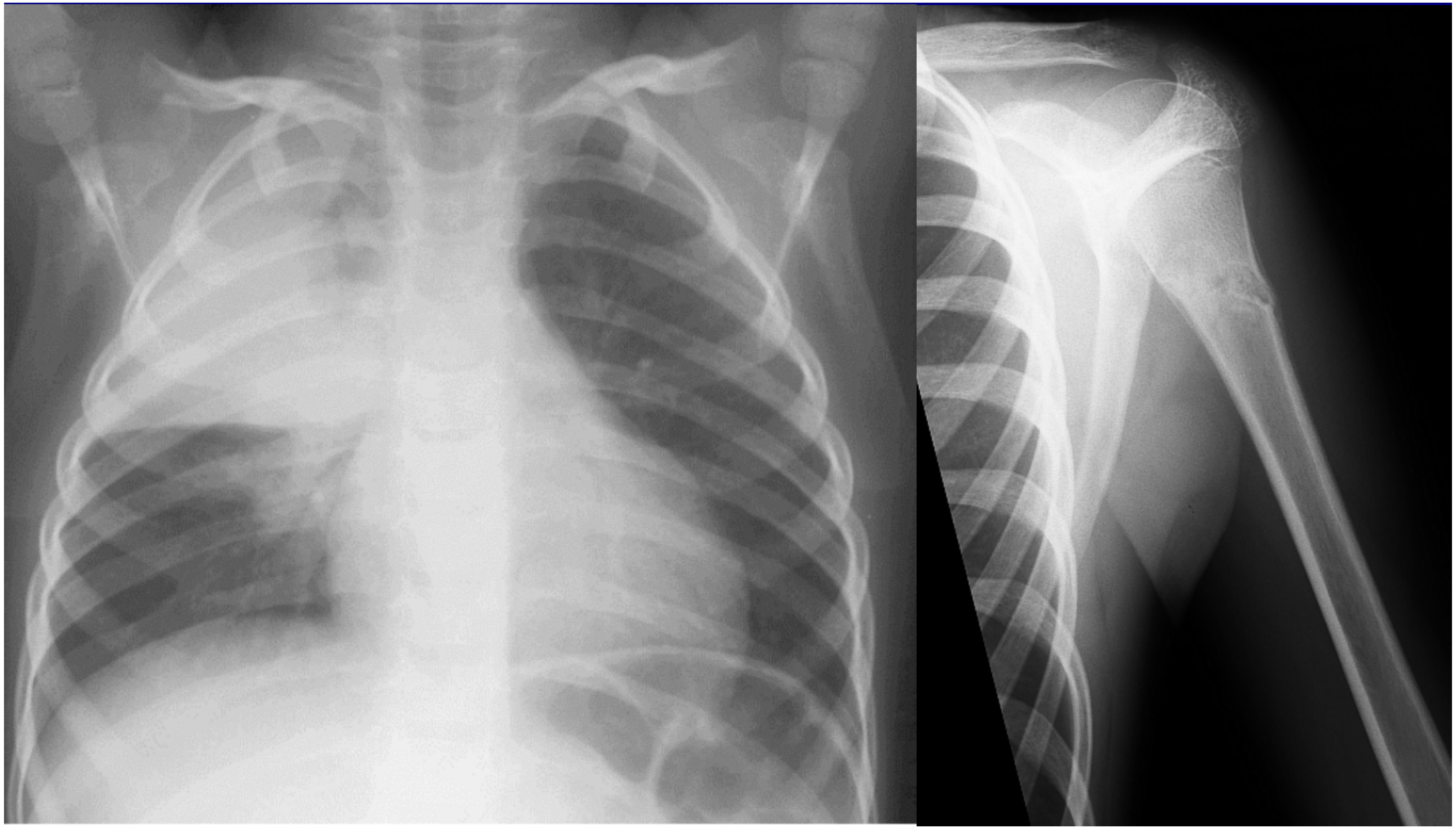
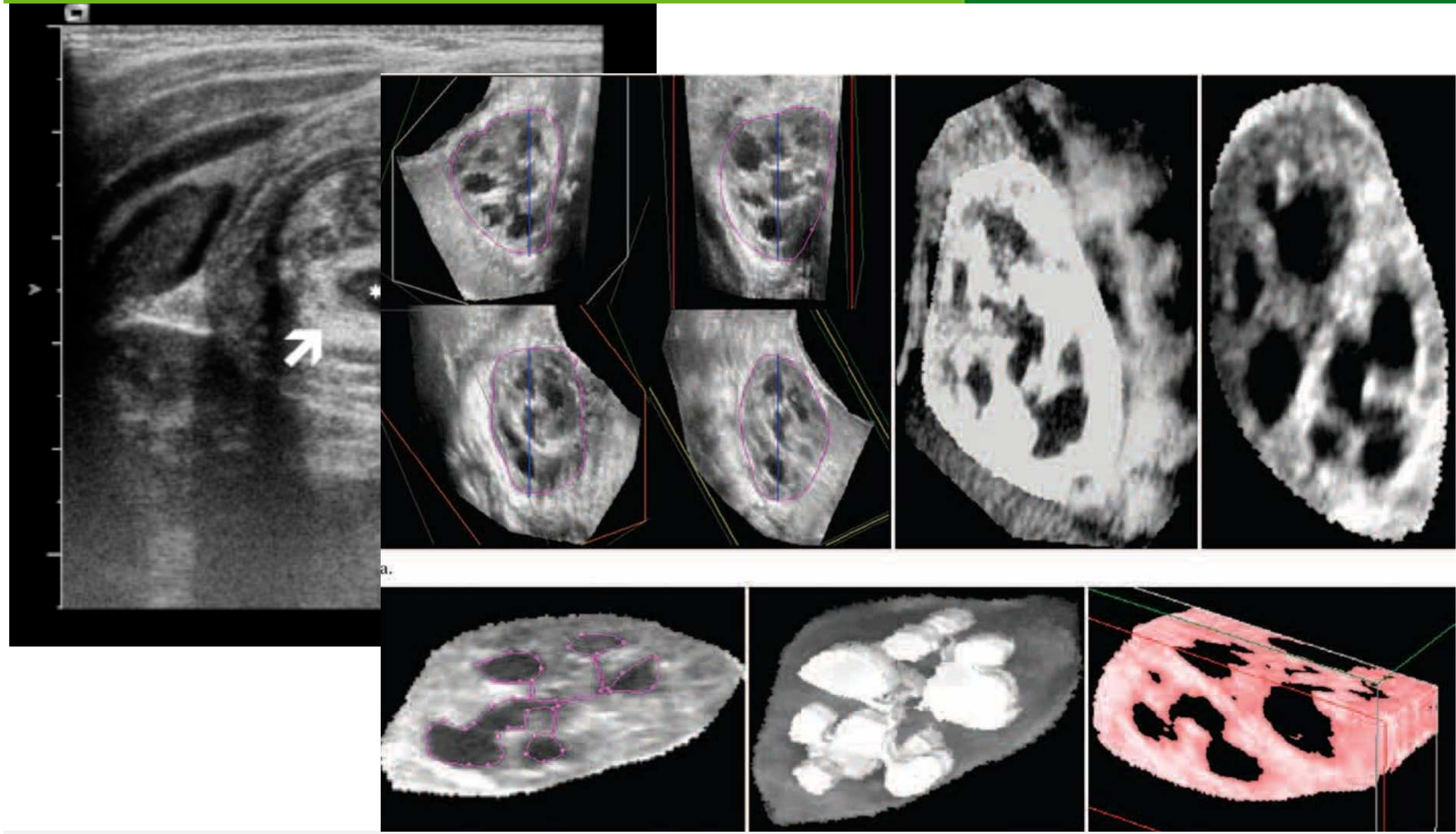
- Images in Medicine
- Examples:
  - Image Enhancement
    - Image Processing for LTS
    - Virtual Dissection of the Colon
  - Computer Aided Diagnosis
    - Detection of breast cancer
  - Virtual Reality
    - Virtual Liver Surgery Planer

Medical Imaging



Medical Imaging



Medical Imaging

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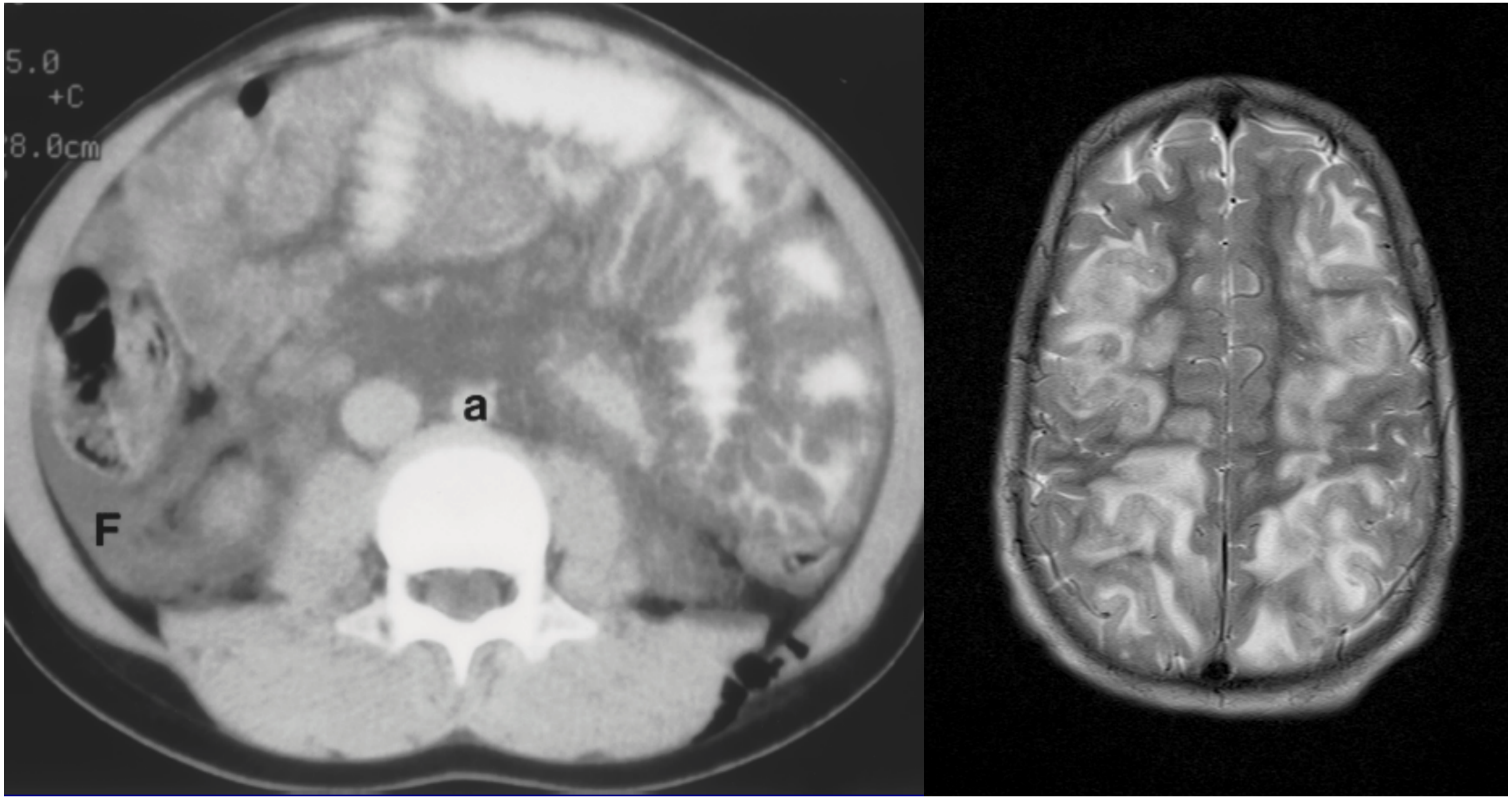

Medical Imaging

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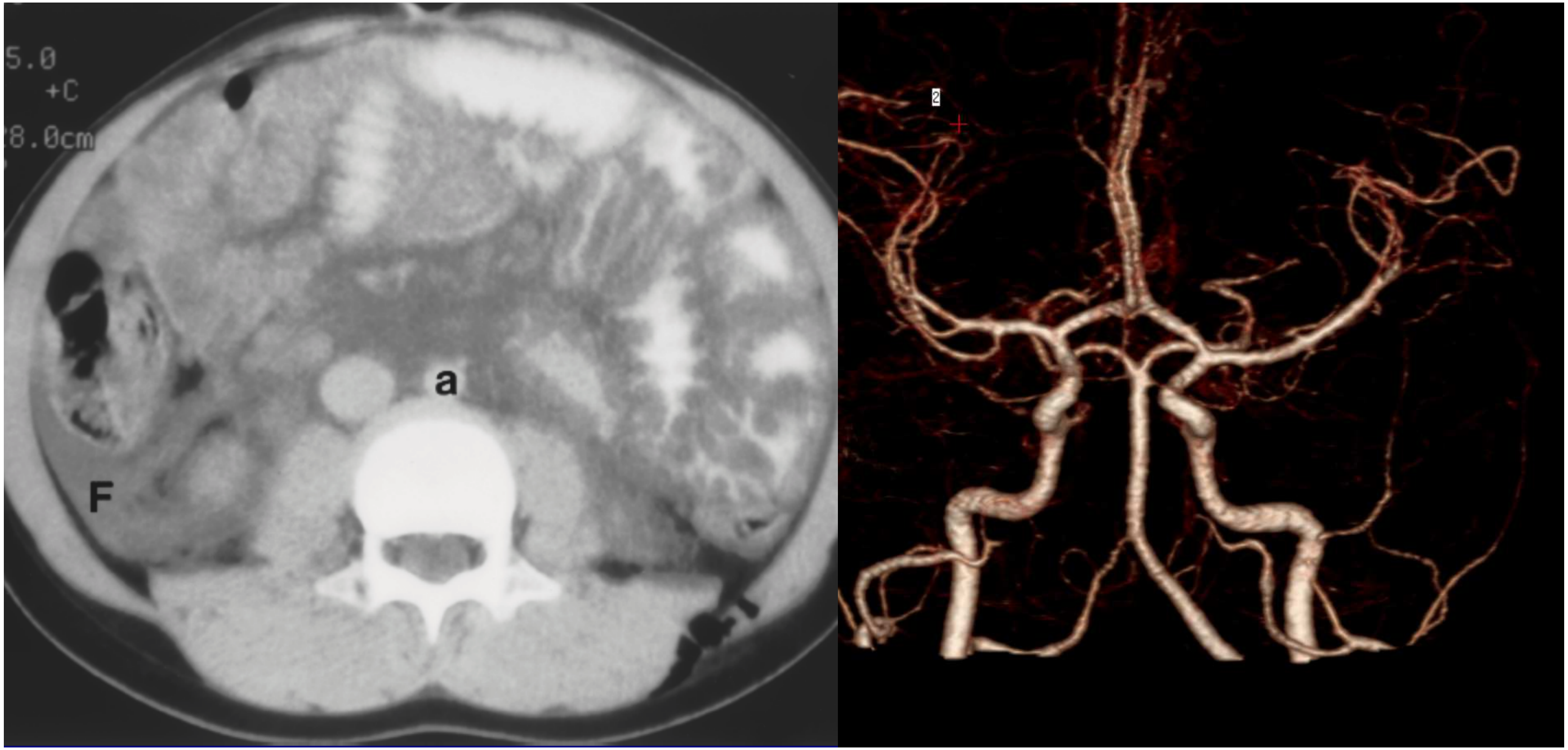
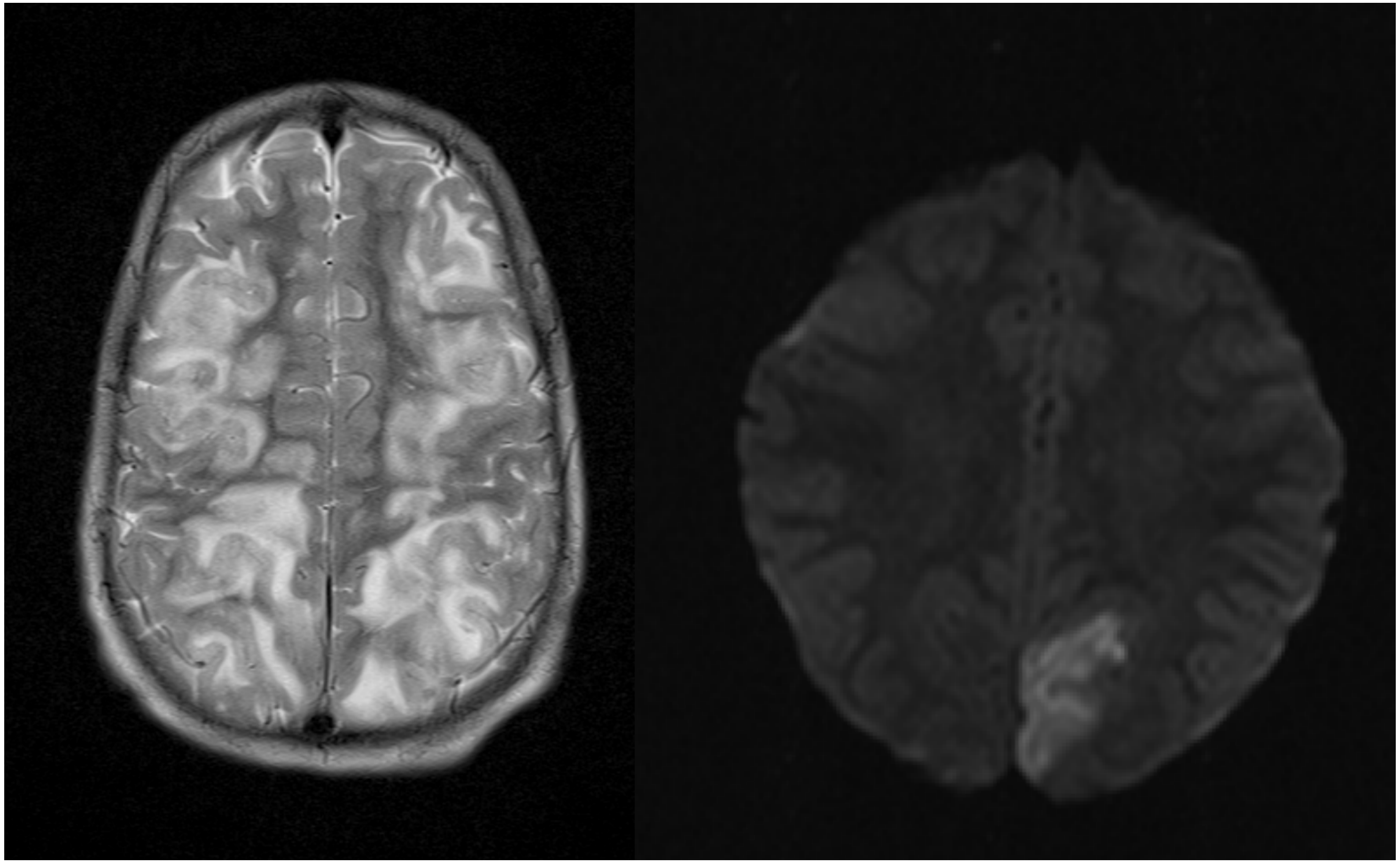


Medical Imaging



Medical Imaging

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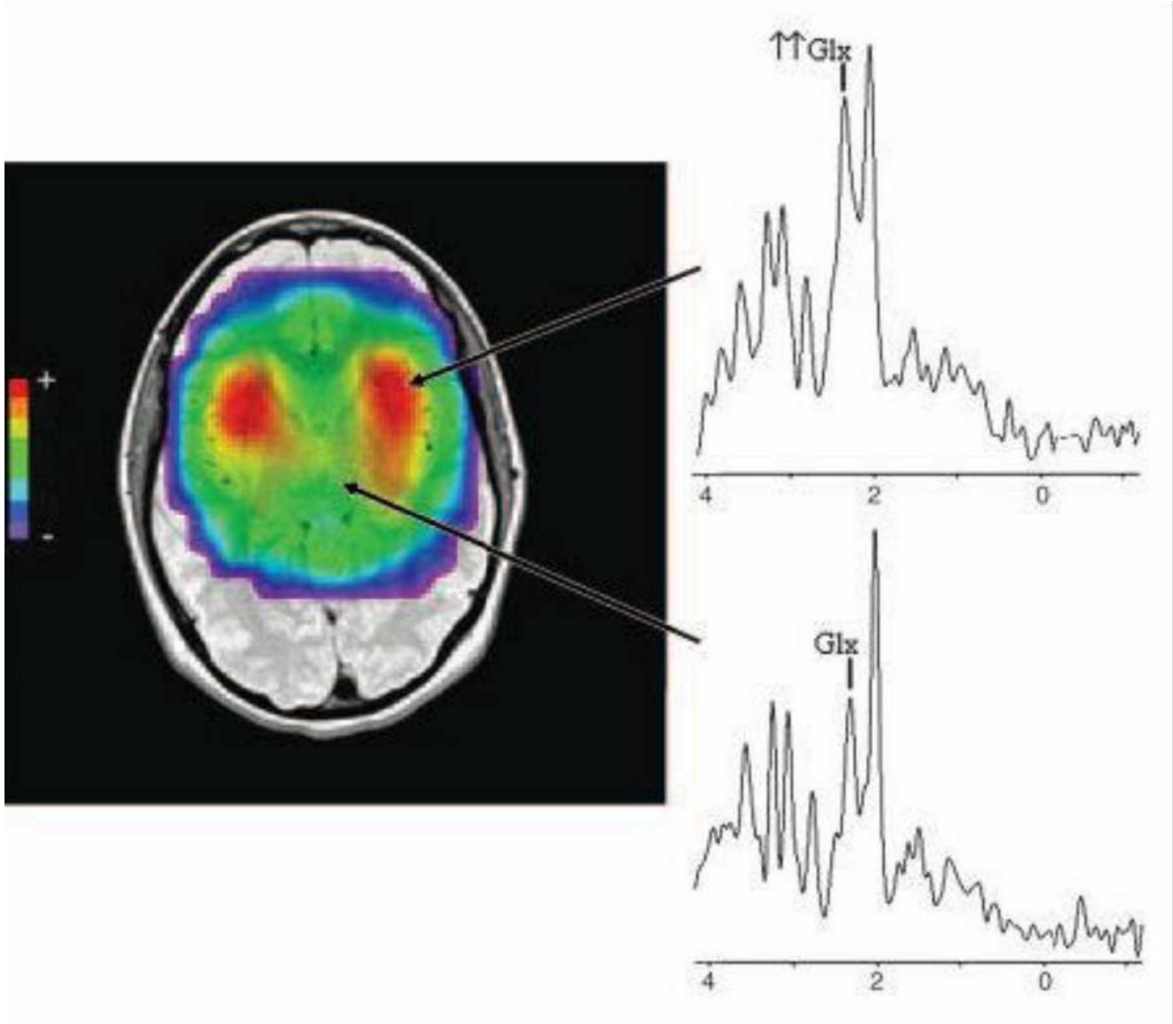
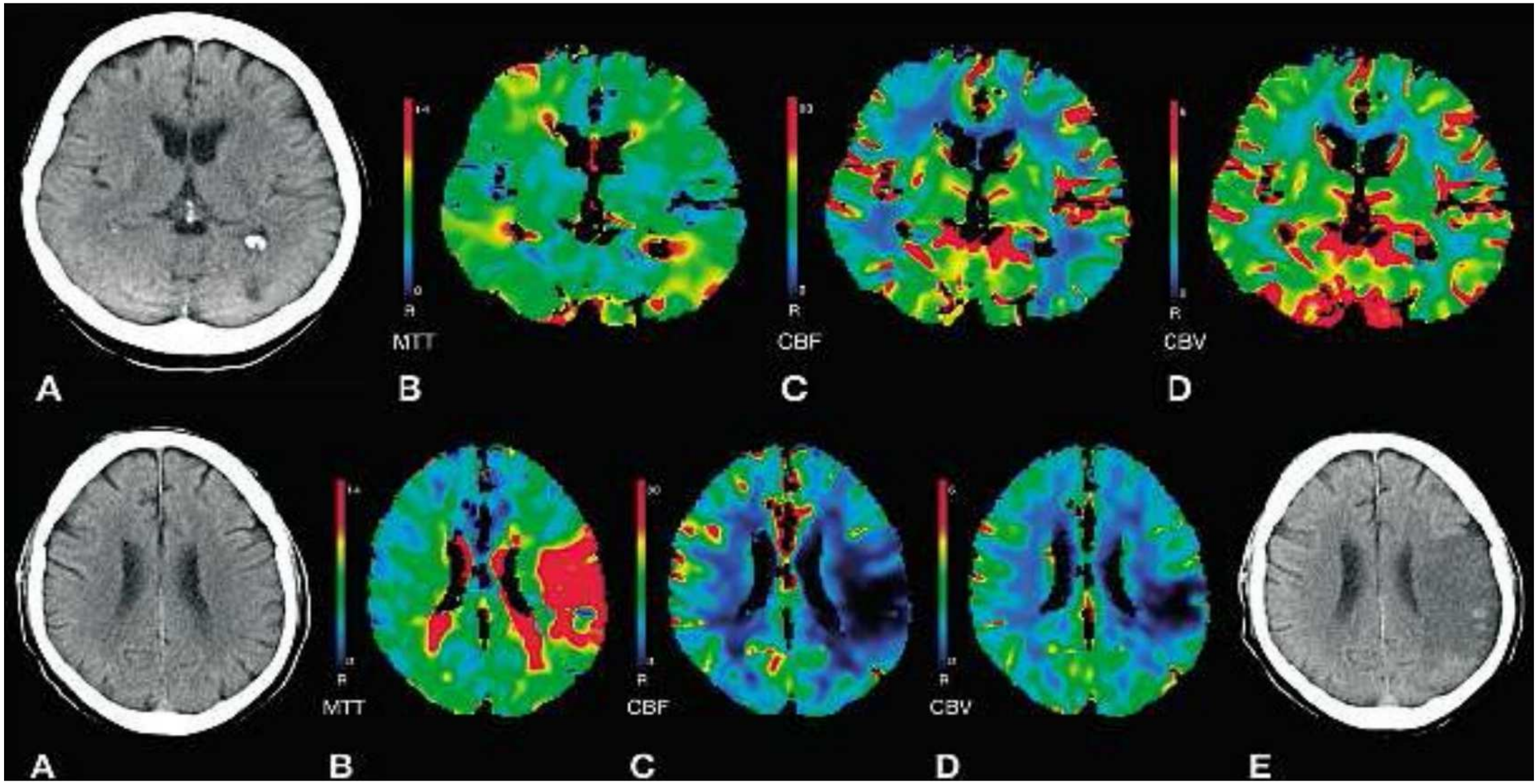


Medical Imaging



Medical Imaging

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Medical Imaging

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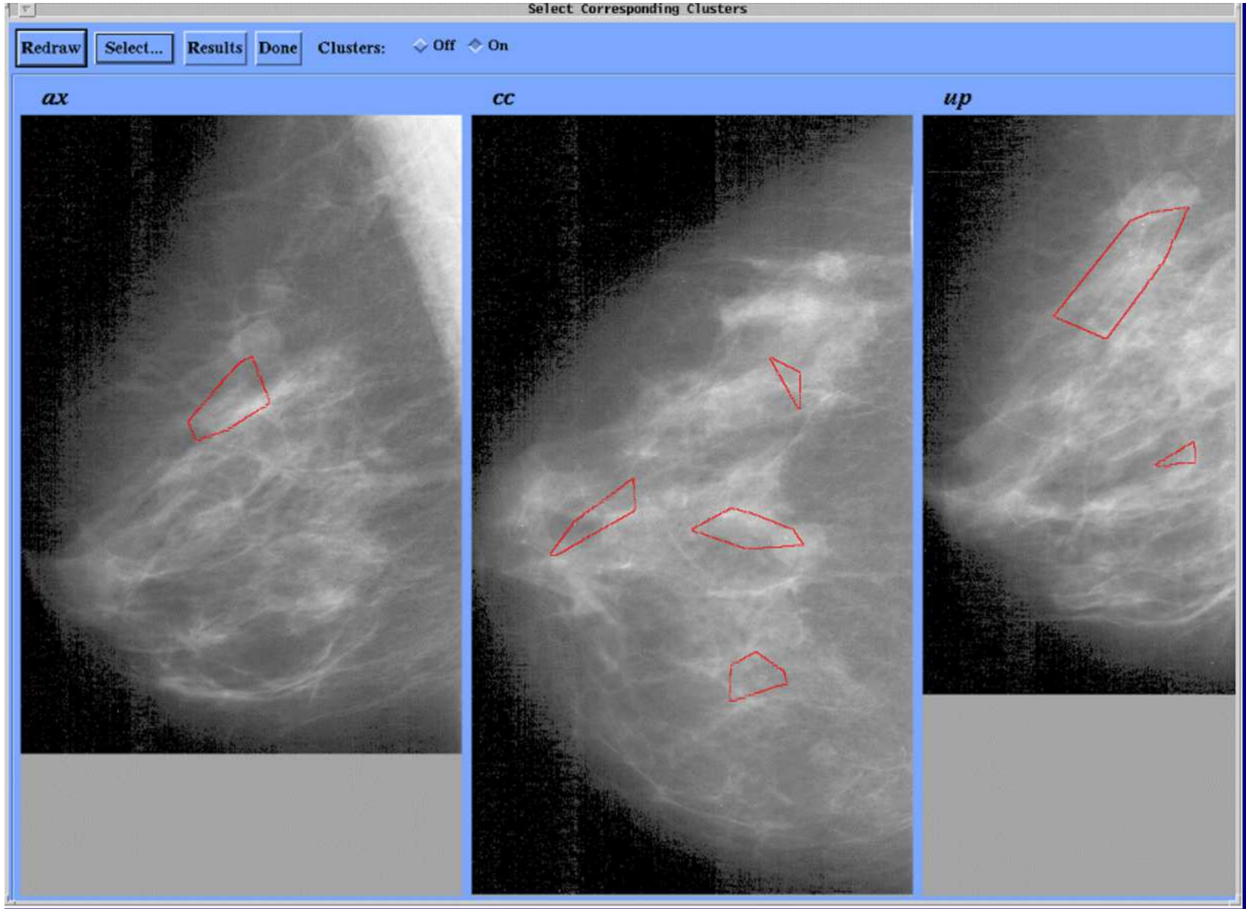

Medical Imaging

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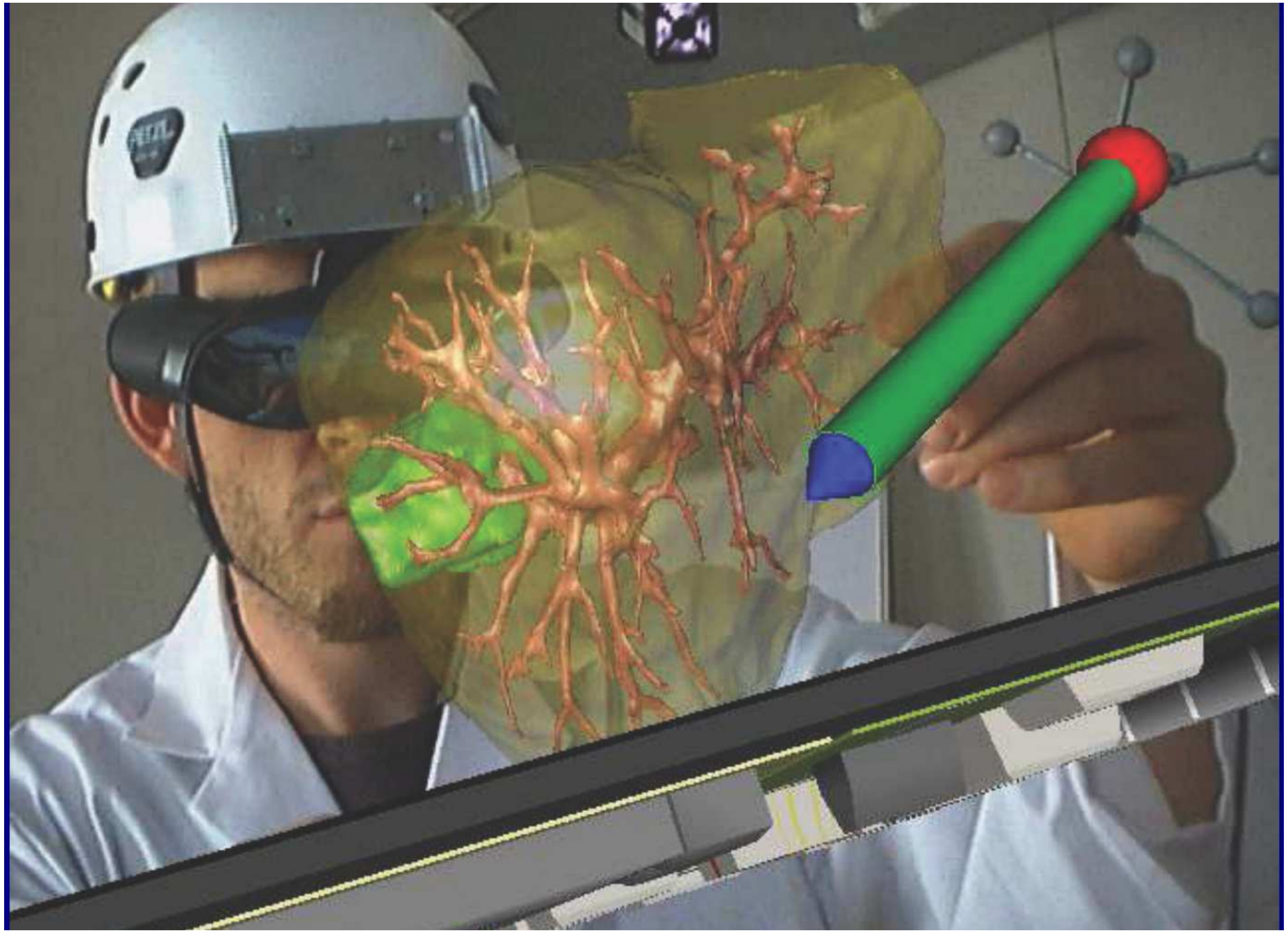

Radiology - Tomorrow

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Tracking of Respiration

Own Development

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Tracking of Respiration

Own Development

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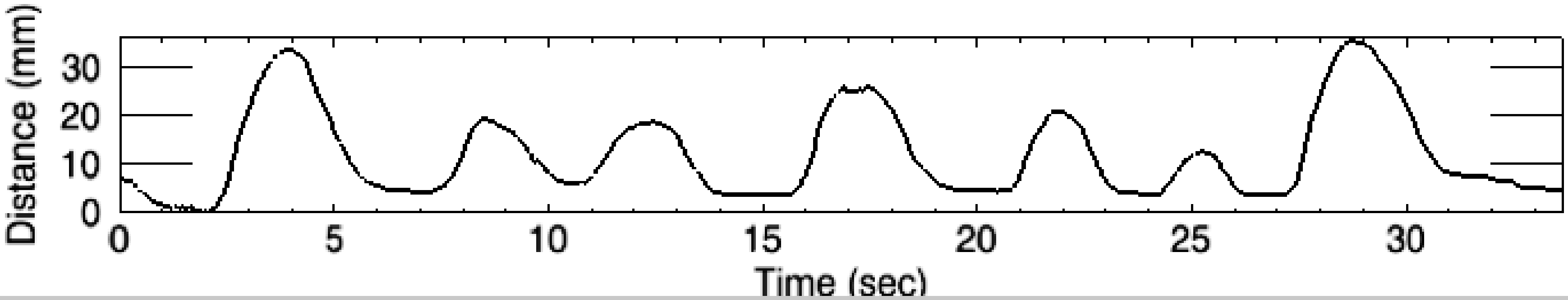
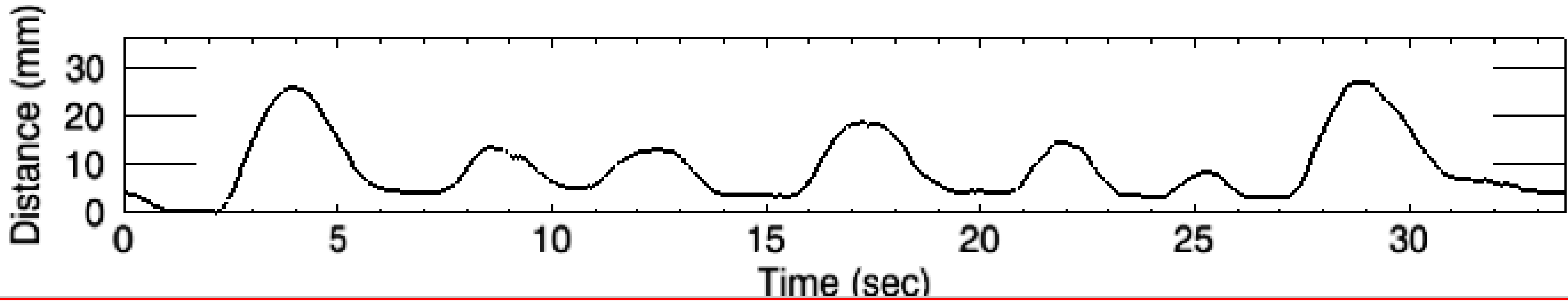
- **Tracking of Respiration**





Own Development

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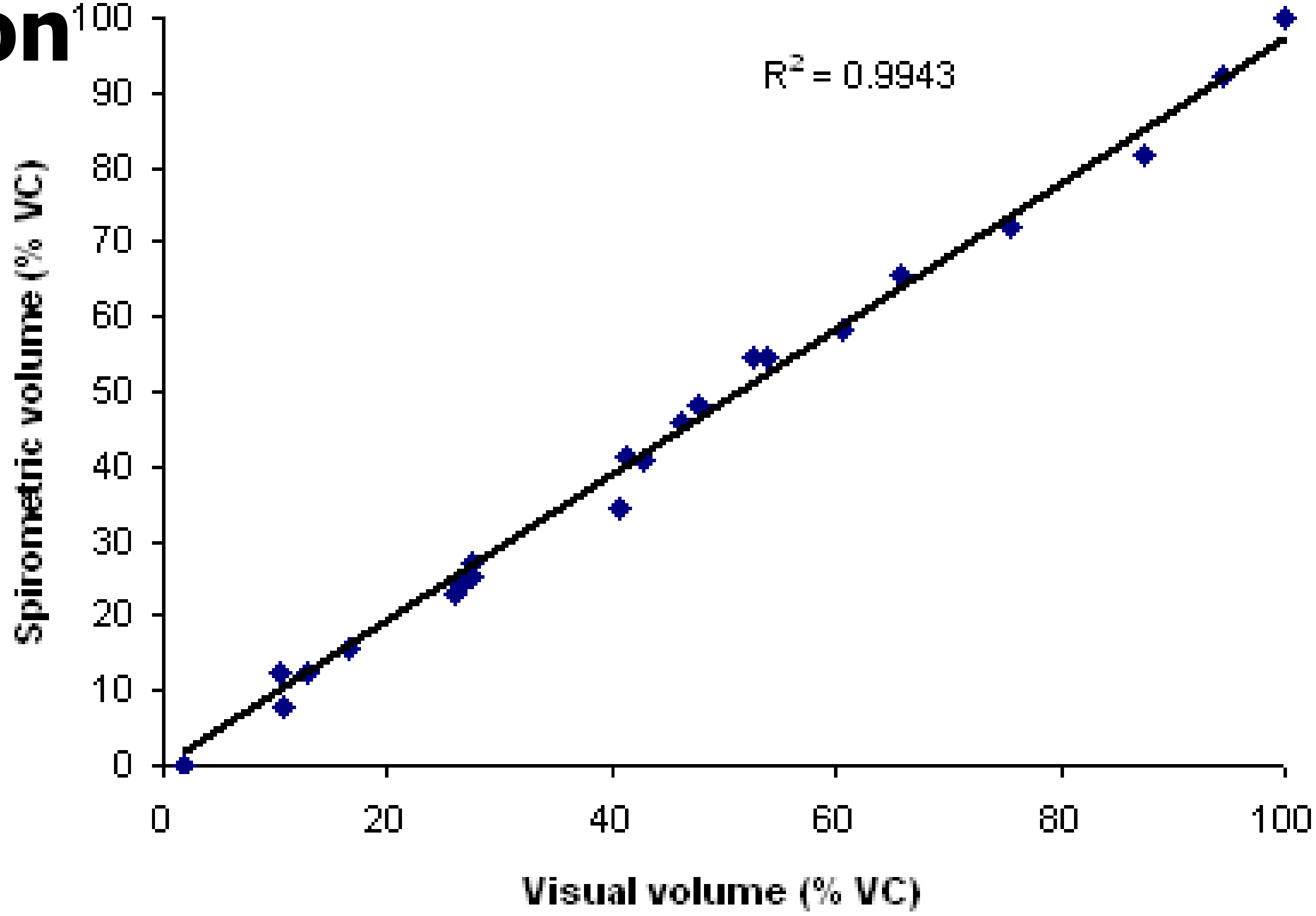
Tracking of Respiration



EIT

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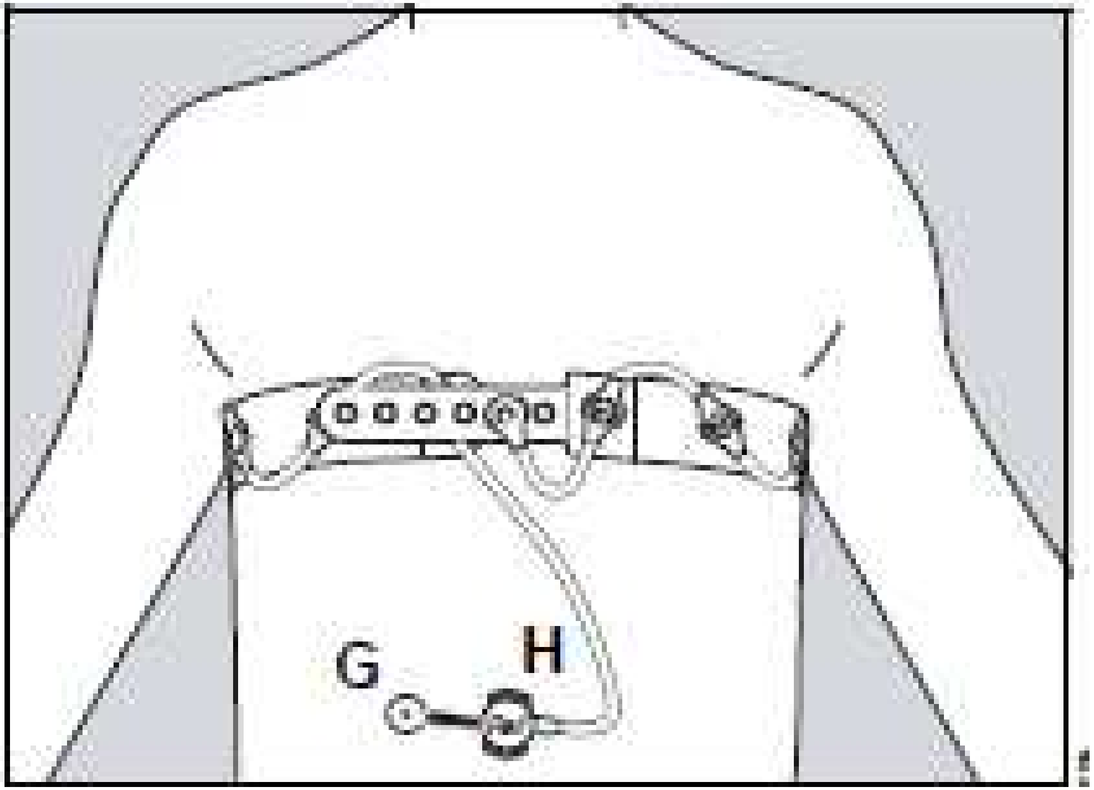
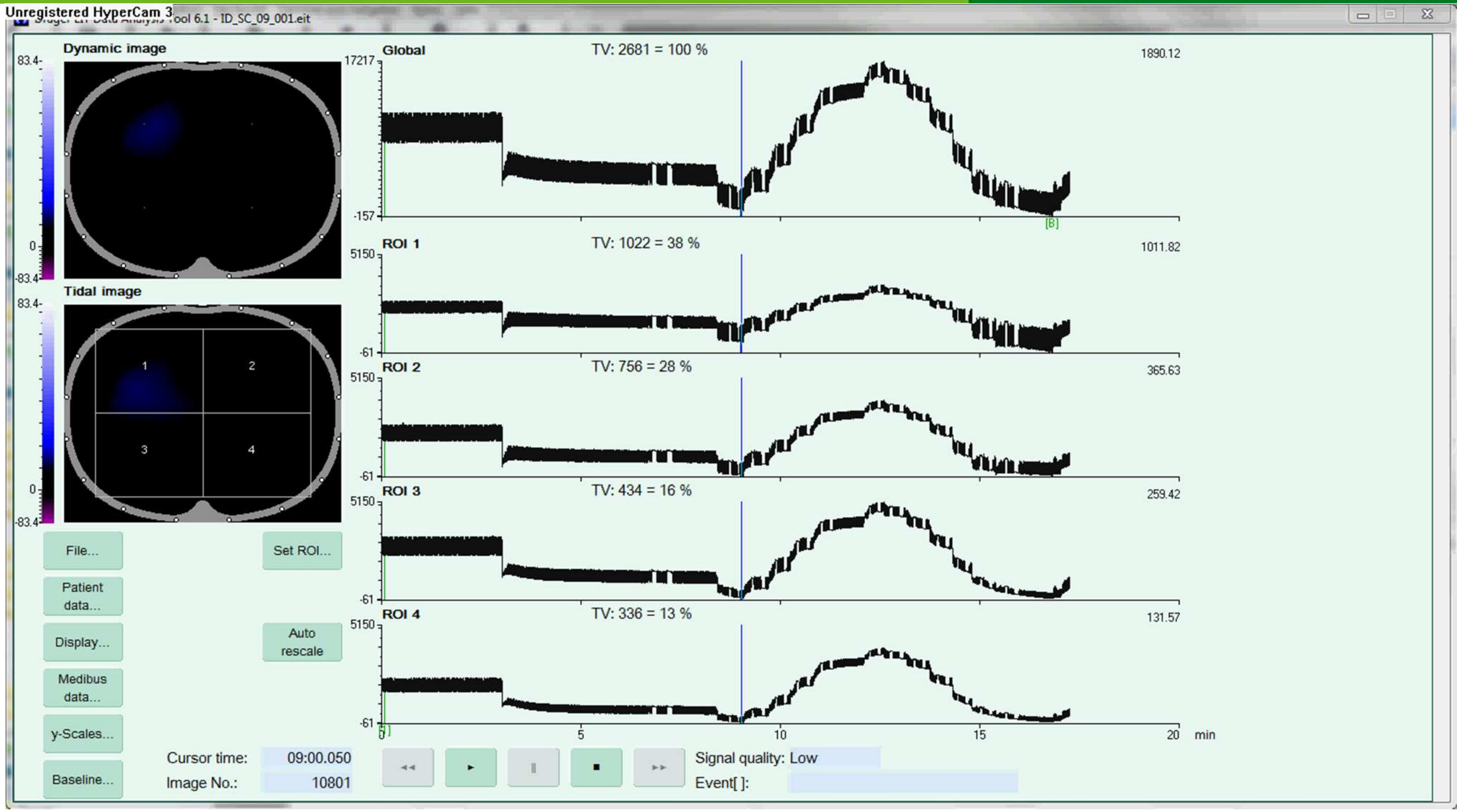
PulmoVista 500



EIT



Unregistered HyperCam 3
Dynamic image
Tidal image
Global
TV: 2681 = 100 %
ROI 1
TV: 1022 = 38 %
ROI 2
TV: 756 = 28 %
ROI 3
TV: 434 = 16 %
ROI 4
TV: 336 = 13 %
File...
Patient data...
Display...
Medibus data...
y-Scales...
Baseline...
Set ROI...
Auto rescale
Cursor time: 09:00.050
Image No.: 10801
Signal quality: Low
Event[ ]:
min

Image Enhancement

- **Image Processing for LTS**

Image Enhancement

- **Virtual Dissection of the Colon**

Image Enhancement

- **Computer Aided Diagnosis**

Computer Aided Diagnosis

- **Automated Detection of Breast Cancer**

Virtual Reality

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- **Virtual Liver Surgery Planer**

ColonCa – Medical Background

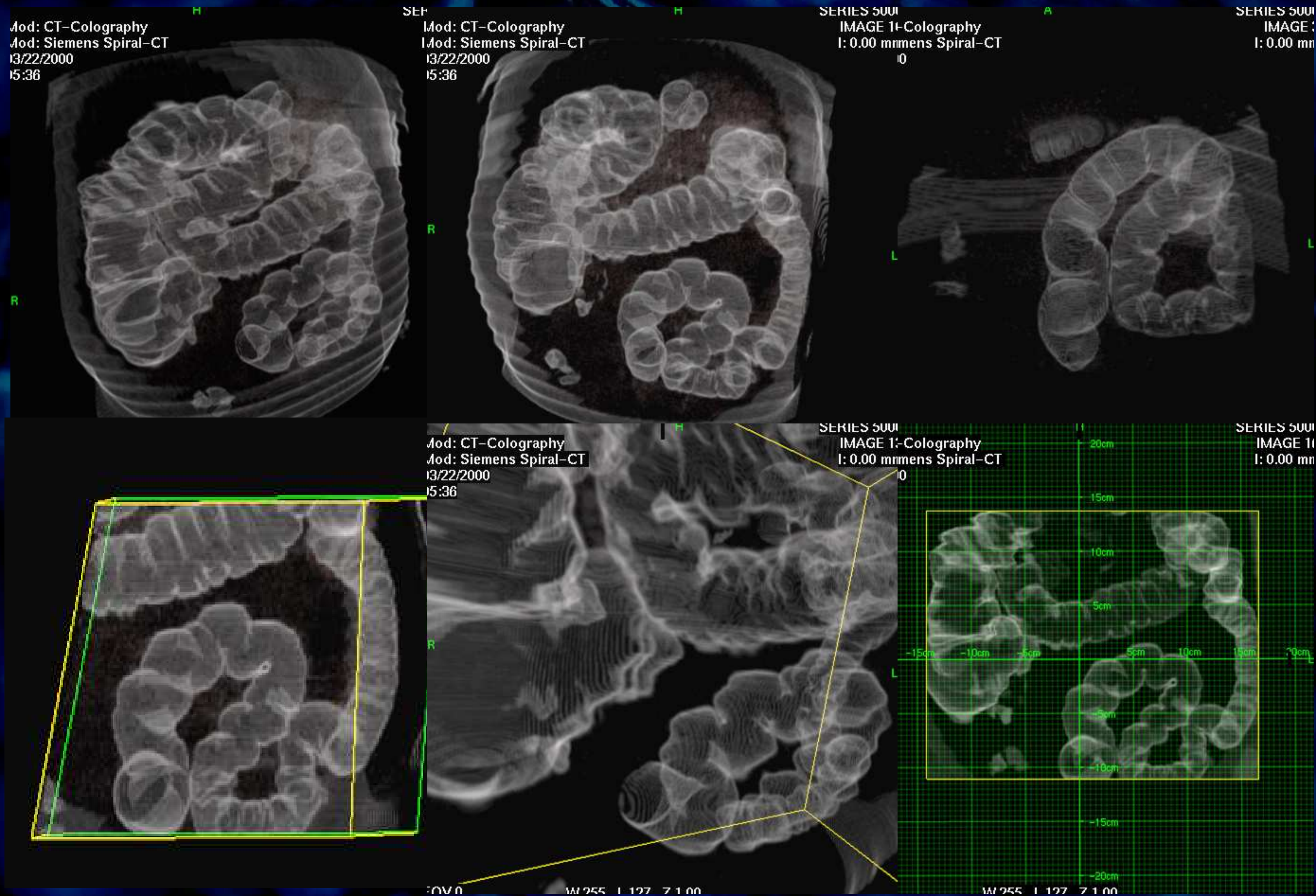
- ☑ 3. Most common Ca
- ☑ 2
- ☑ 1
- ☑ S
  ac
- ☑ C T:

Only complete in 85 – 90%
Misses 10 – 20% of all Ca
Perforation (1:1500)
Only part of the of the
colonic visualized

3D Visualization of the Colon:

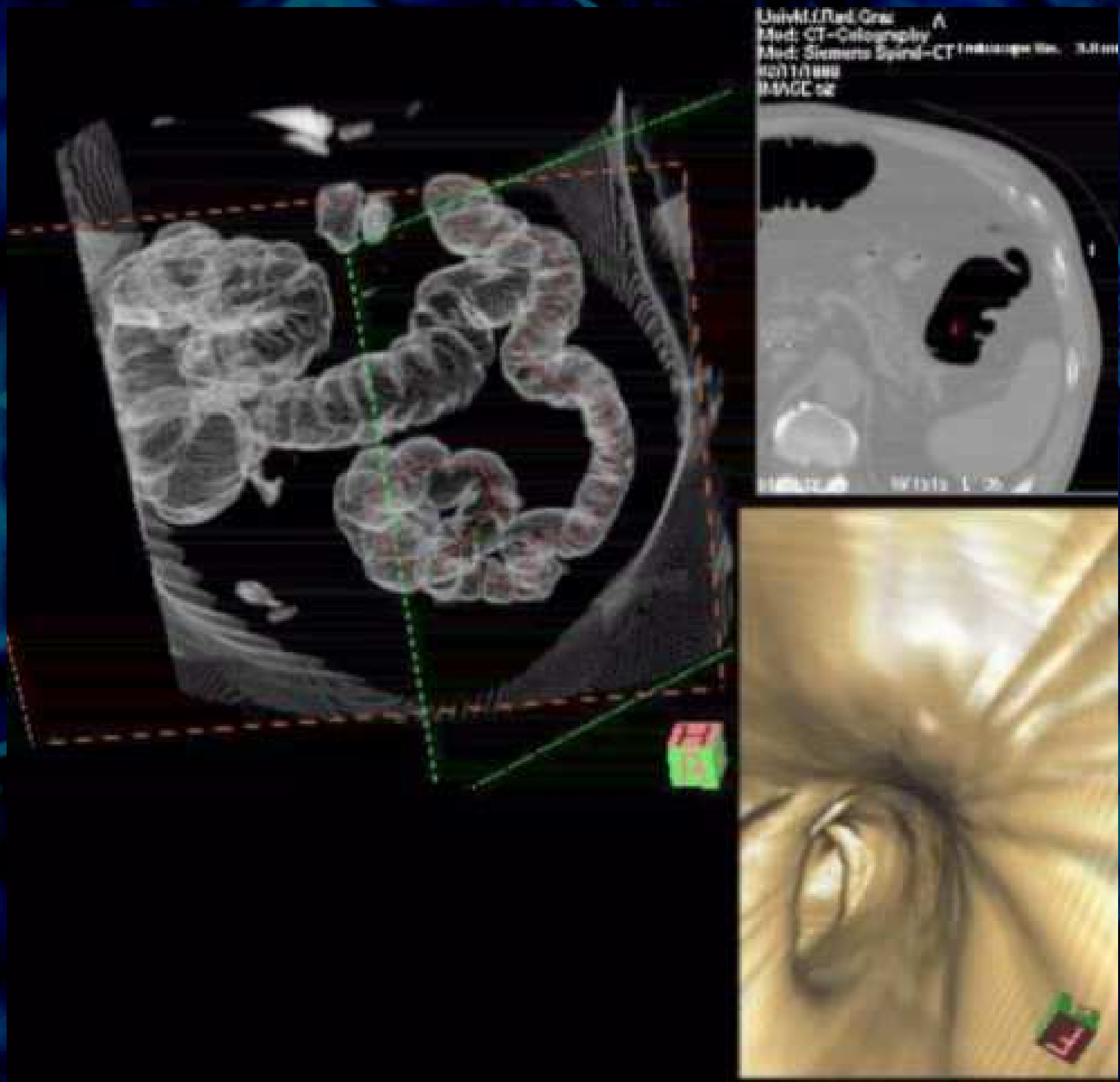
- ☑ CT Pneumocolon
- ☑ „Interactive Slicing“
- ☑ „Fly through“ (CT-colonoscopy)
- ☑ Virt. Dissection

„CT Pneumocolon"



„Interactive Slicing"

„Fly Through"



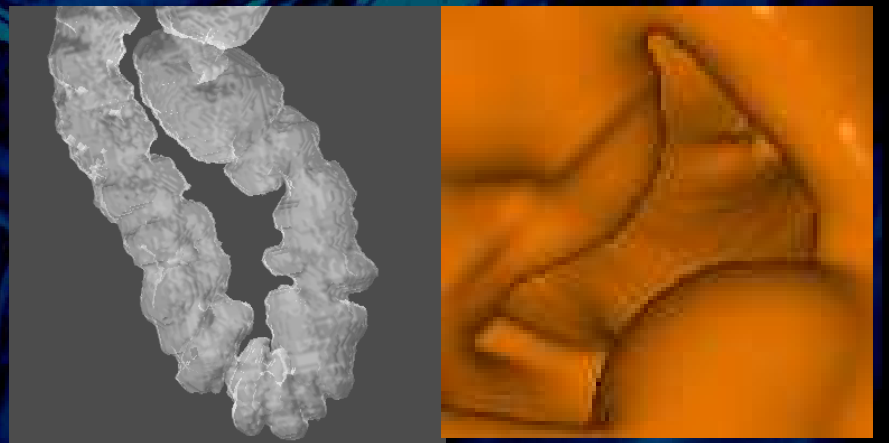
Problems - General:

☑ **Post processing of cross sectional data:**

- time consuming
- hardware intensiv (expensive!)
- specialized staff necessary

Problems - CT colonoscopy

- ☑ **Path planning for automated „fly through" complicated and even operator dependent**
- ☑ **Endoscopic view display just a small proportion of the colonic surface -> Ante and - retrograde views necessary**



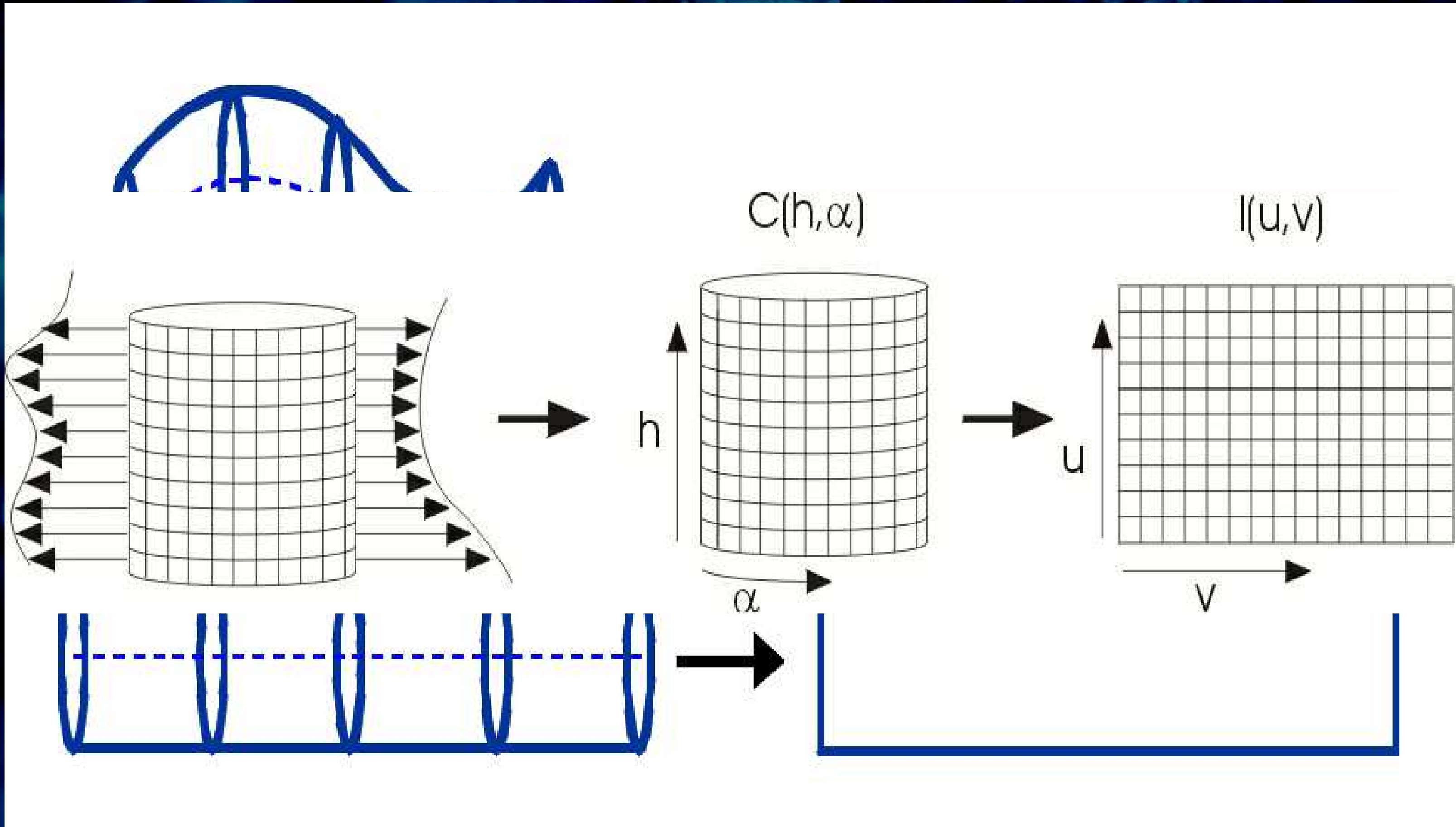
What do you wanna have for CT - colonoscopy?

- ☑ Inspection of total colonic surface
- ☑ Fast tool
- ☑ Minimal interaction
- ☑ No operator influence
- ☑ Easy and quick to report
- ☑ (Hardware independent)

„Virtual dissection"

☑ **Stretch the colon and cut it along it`s longitudinal axis similiar to the pathologist`s table**

„Virtual dissection"



„Virtual dissection"
- How to do?

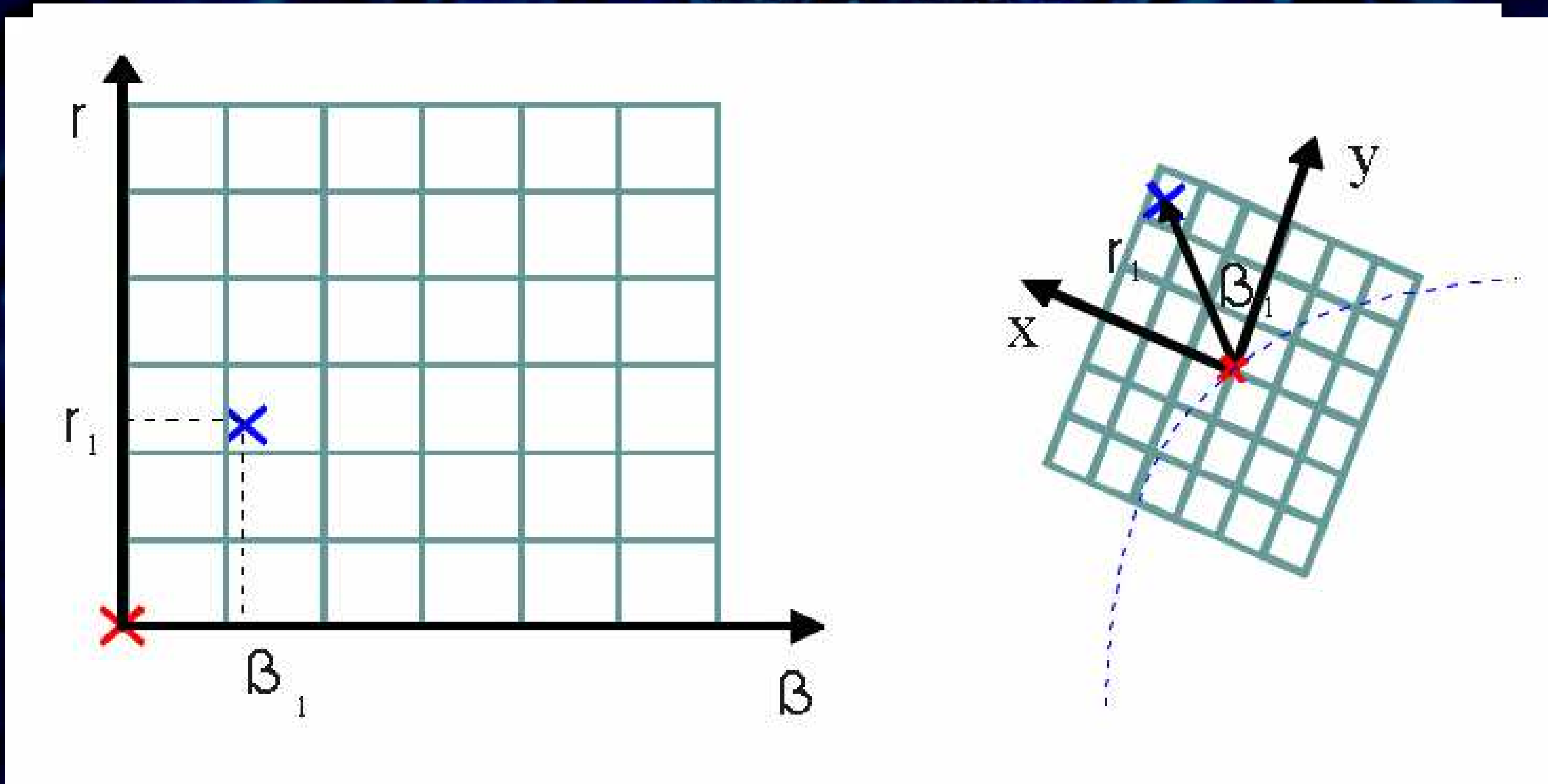
- ☑ Data aquisition
- ☑ Segmentation - Fuzzy connected
- ☑ Extraction of the centerline (Skeletonisation - Thining)
- ☑ Calculation of the cross sections
- ☑ „Remapping“ to 2D

Virt.Diss. - Data Aquisition

☑ **MRDCT**

- Slice thickness 2.5mm
- Reconstruction: 1.25mm slice thickness, increment 0.5 - 1.0mm (~600-700 images)

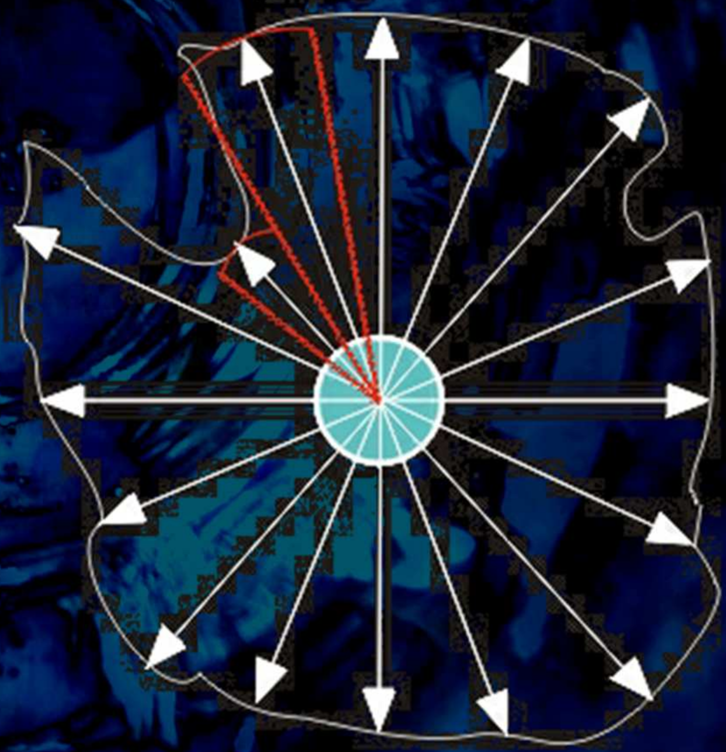
Virt.Diss. - Cross sections



Virt.Diss. - Remapping

☑ **Constant Angle Sampling**

- No distortion in the y direction but adds area distortion.
- Can miss objects.
- No sense of “size”.
- The surface is not sampled uniformally

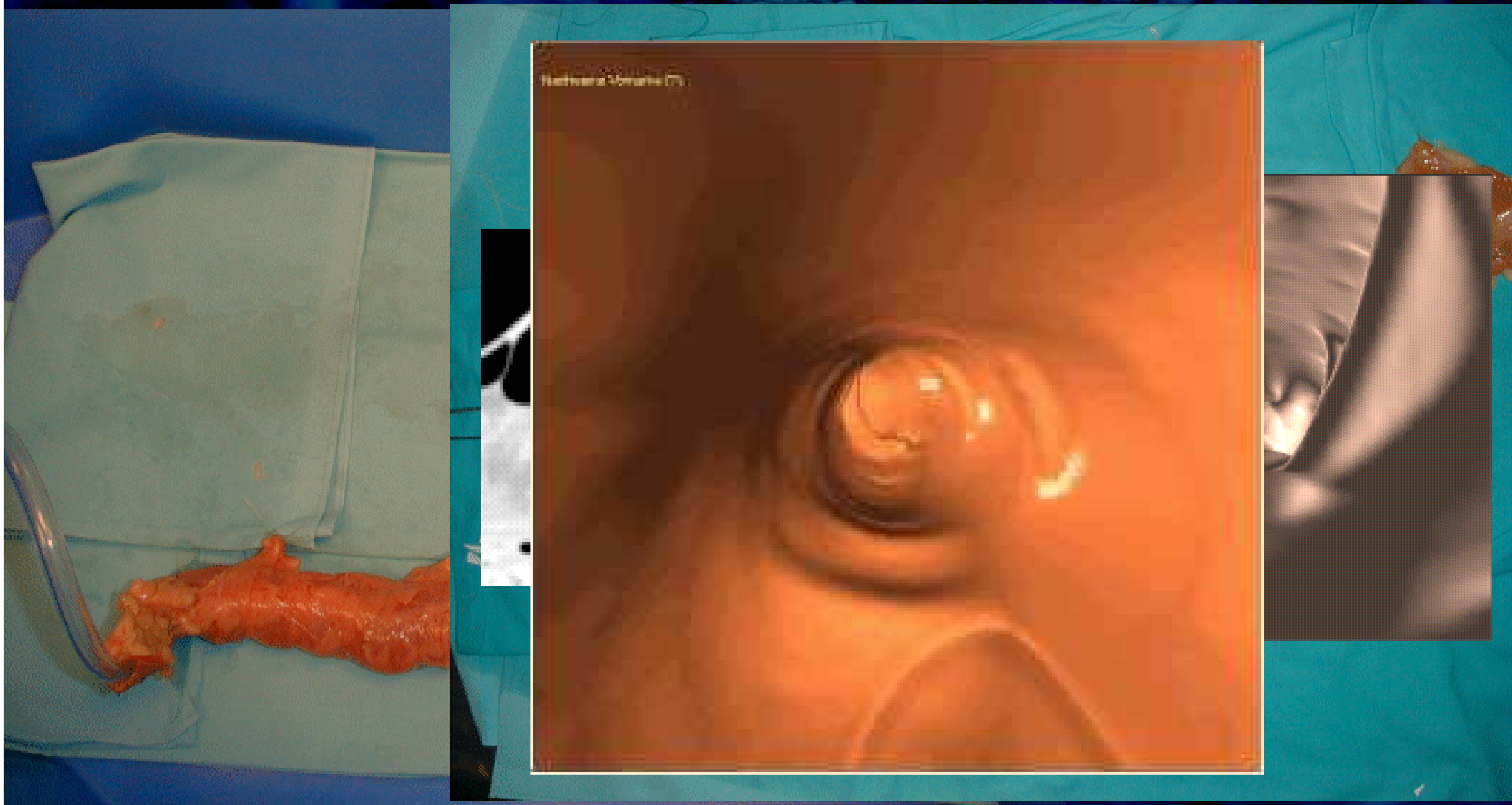


Virt.Diss. - Remapping

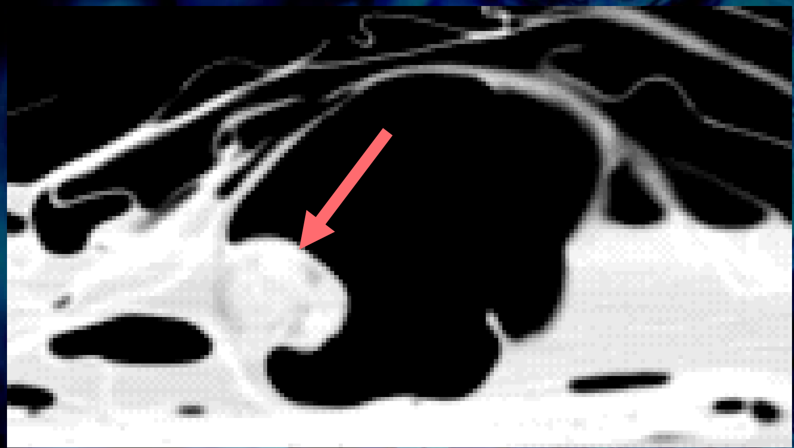
- ☑ **Perimeter Sampling**
  - Surface Sampled uniformally.
  - No missing elements. If sample step small enough.
  - Area Preservation.
  - Deformation in the y direction- Shrinking
  - Deformation increasing with distance to the vertical center line.

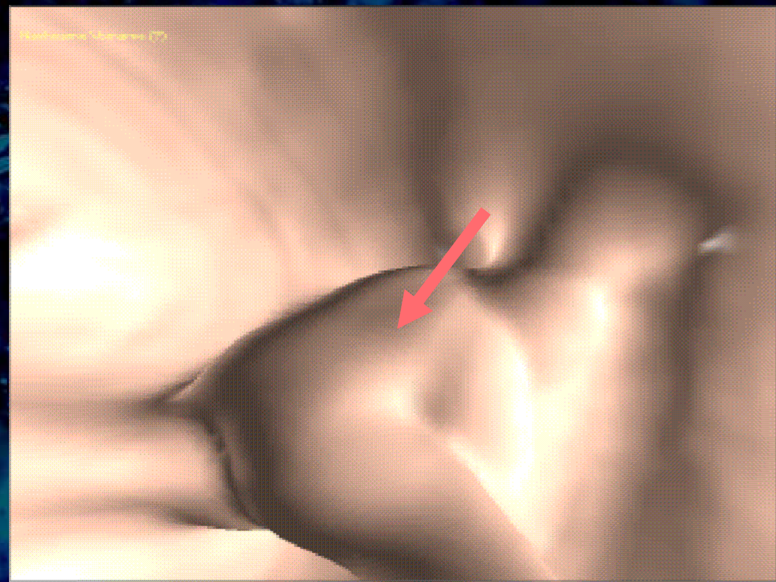
Phantoms - Technical

Phantoms - Cadaveric



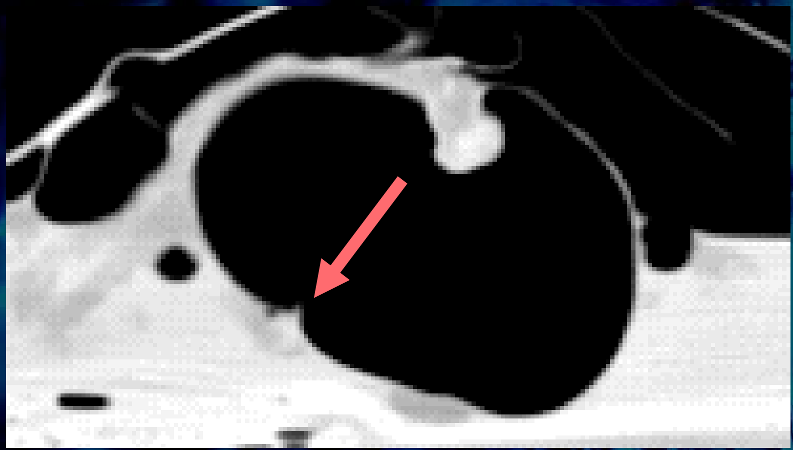
Phantoms - Cadaveric Artific. Polyps (n=13)

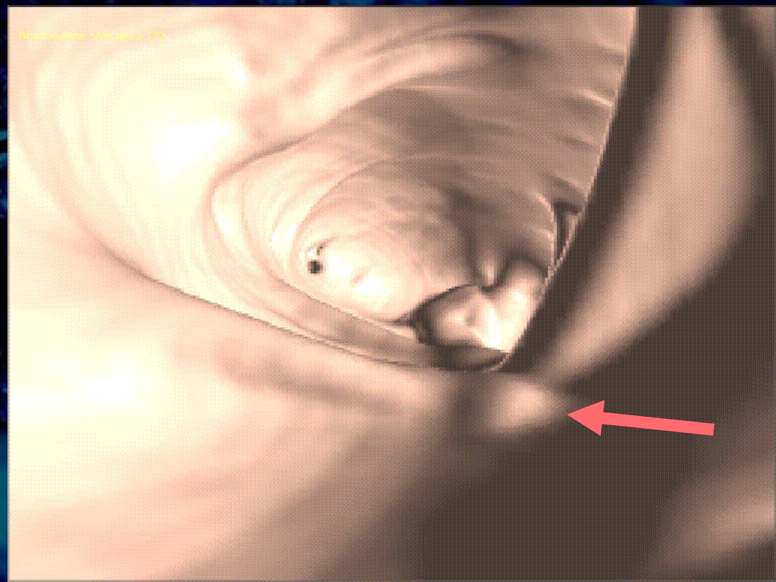




Filename:	image.691
Table Position:	-506.09
Size(Trans, Cor, Sag):	12.9 * 15 * 11.4
Protrusion(Trans, Sag, Cor):	13.8 * 13.8 * 11.2

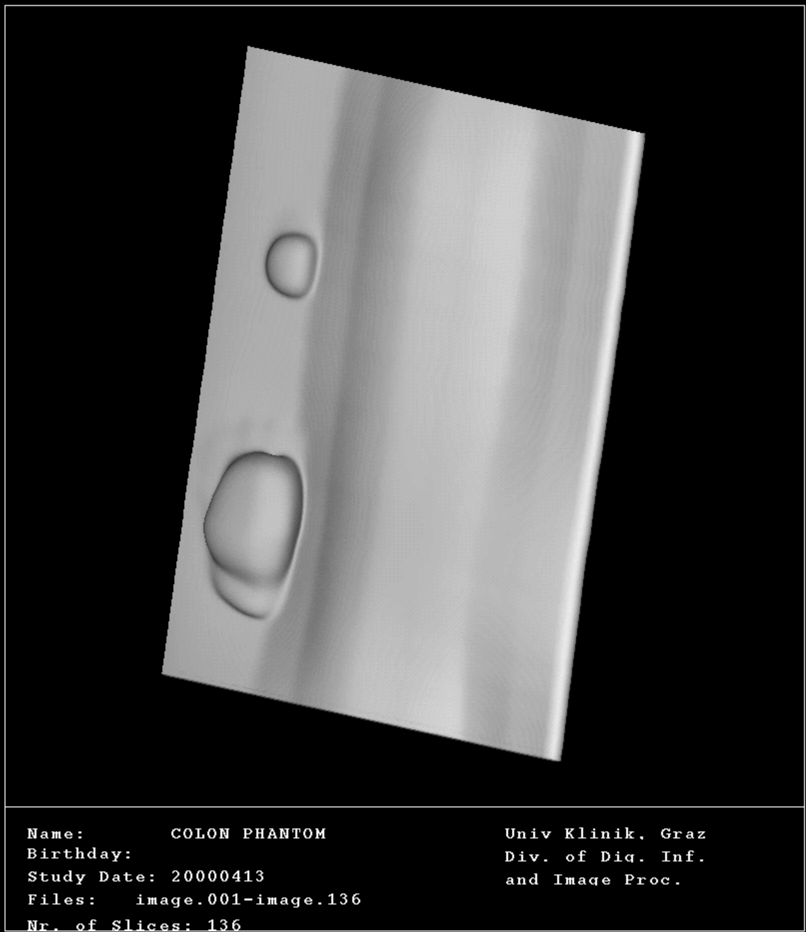
Phantoms - Cadaveric Artific. Polyps (n=13)

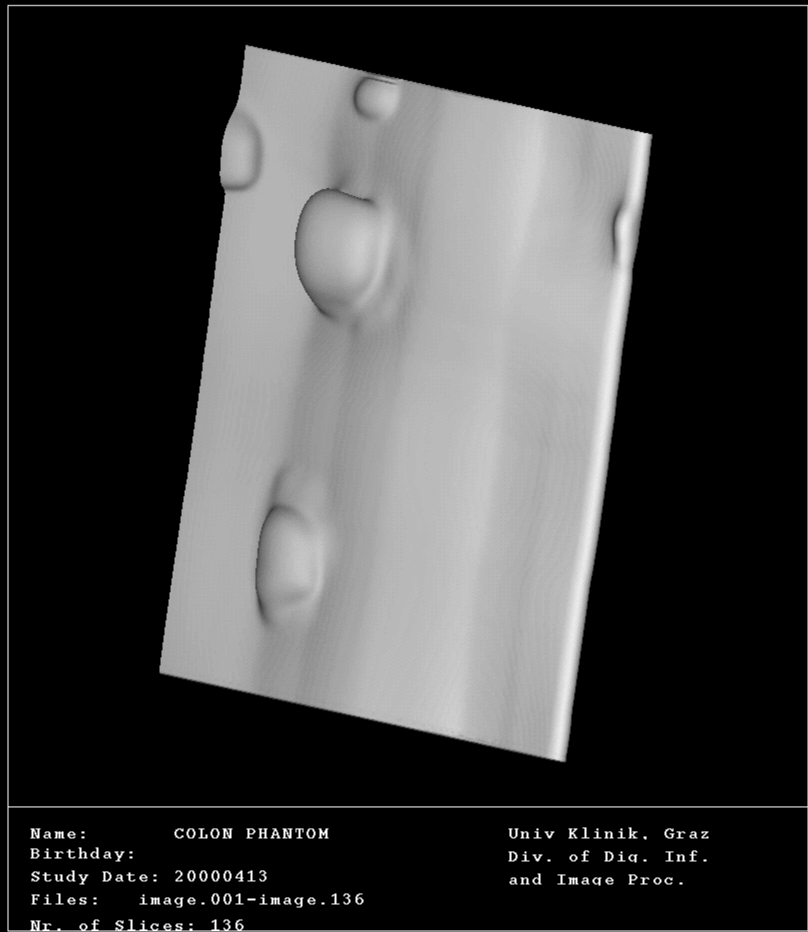




Filename:	image.580
Table Position:	-450.09
Size(Trans, Cor, Sag):	6.8 * 4.8 * 3.6
Protrusion(Trans, Sag, Cor):	2.6 * 1.6 * 0

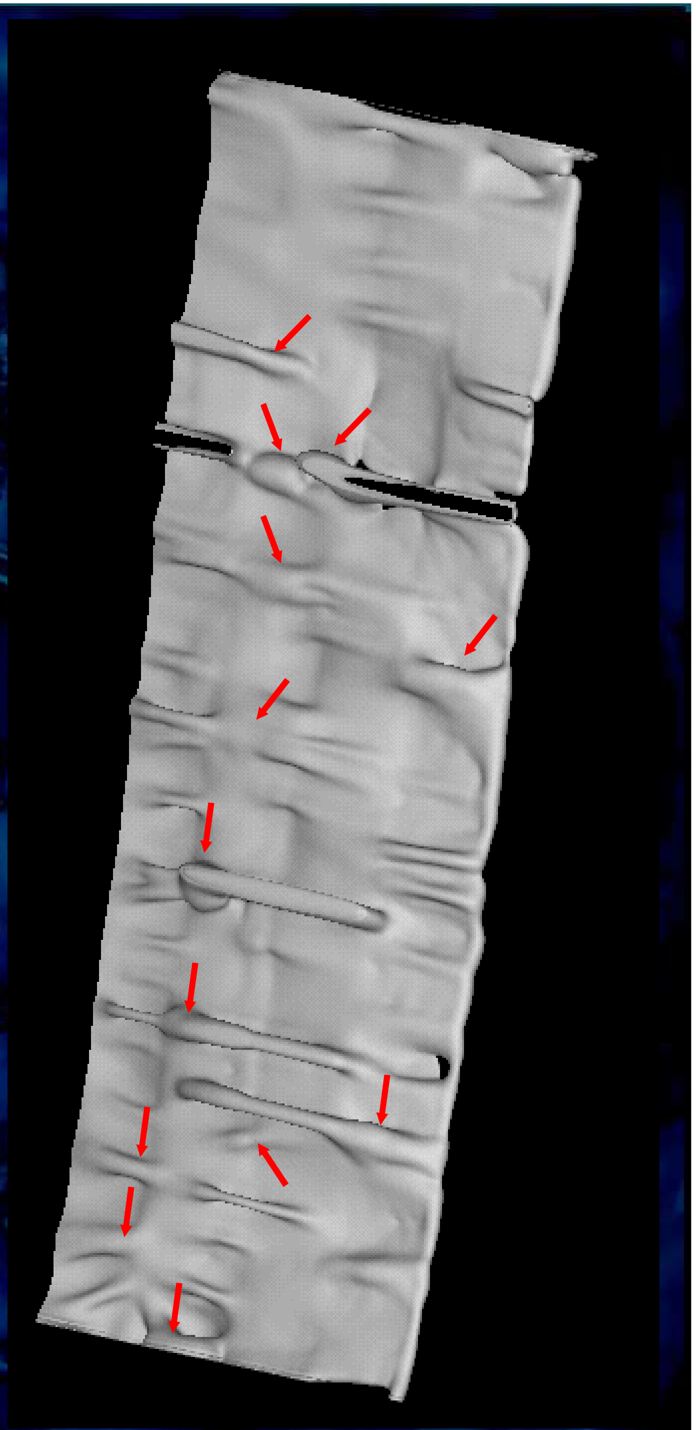
Results - Techn. Phantom





Results - Cadaveric Phantom

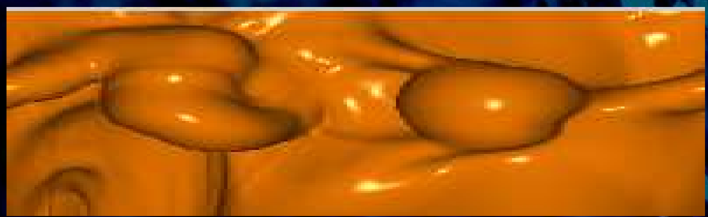
Name: COLON VIRTUELL
Birthday: 20000406
Study Date: 20000406
Files: image.002-image.740
Nr. of Slices: 370



Results - Cadaveric Phantom

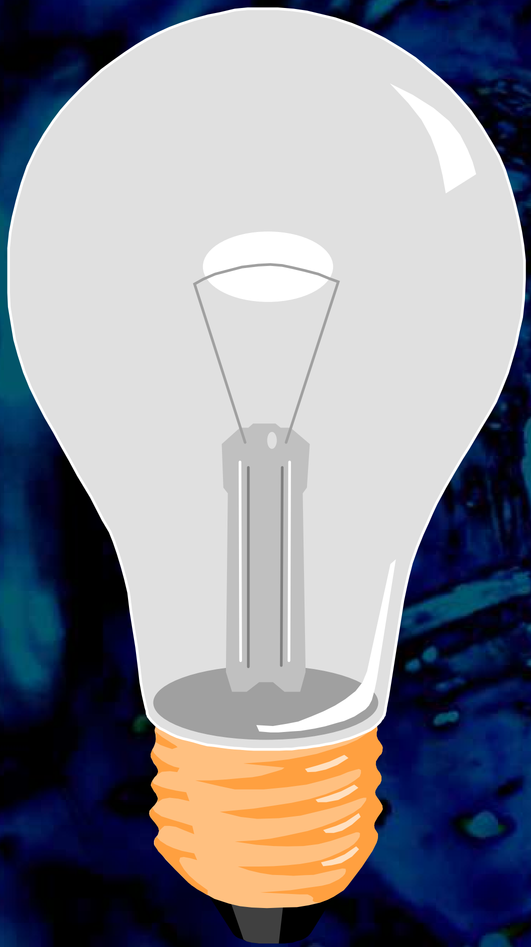
Results - Cadaveric Phantom

Constant Angle Sampling



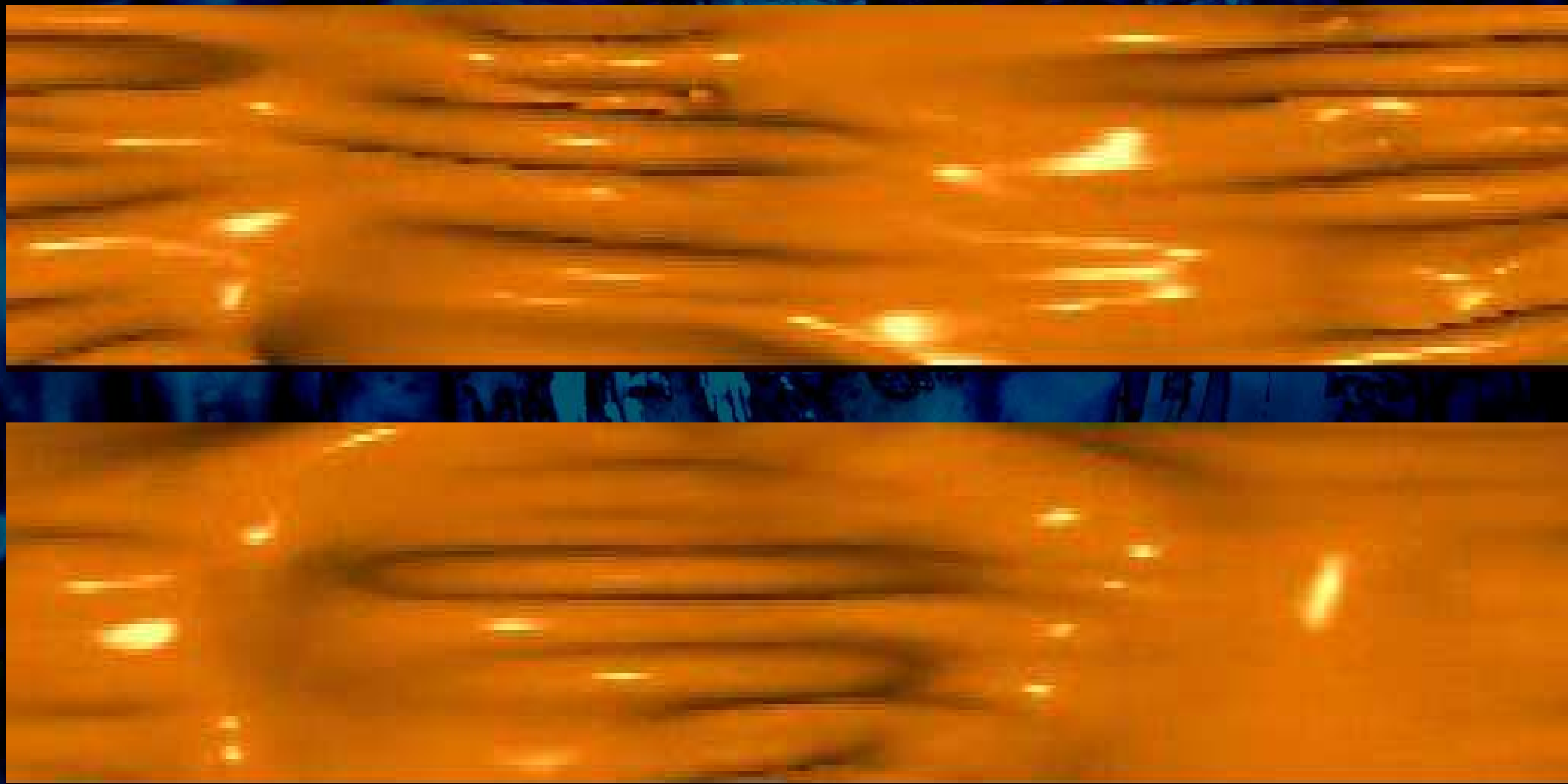
Perimeter Sampling

Results - Cadaveric Phantom



- ☑ **Polyps appear**
  - as bumps
  - as asymmetric broadening of folds
- ☑ **Time:**
  - Operator 10min
  - Total time: 2h

Results - Diverticulitis



Results - Medical Evaluation

- ☑ **2 Observer, 13 Polyps:**
  - Sensitivity: 12/13 = 92.3%
  - Interob. Agreement: 11/13 = 84.6%
  - Pos.pred.Value: 75-80%
- ☑ **Each Observer overlooked 1 Polyp:**
  - 3.9 * 5.0mm
  - 3.5 * 2.5mm

Conclusion VirtDiss

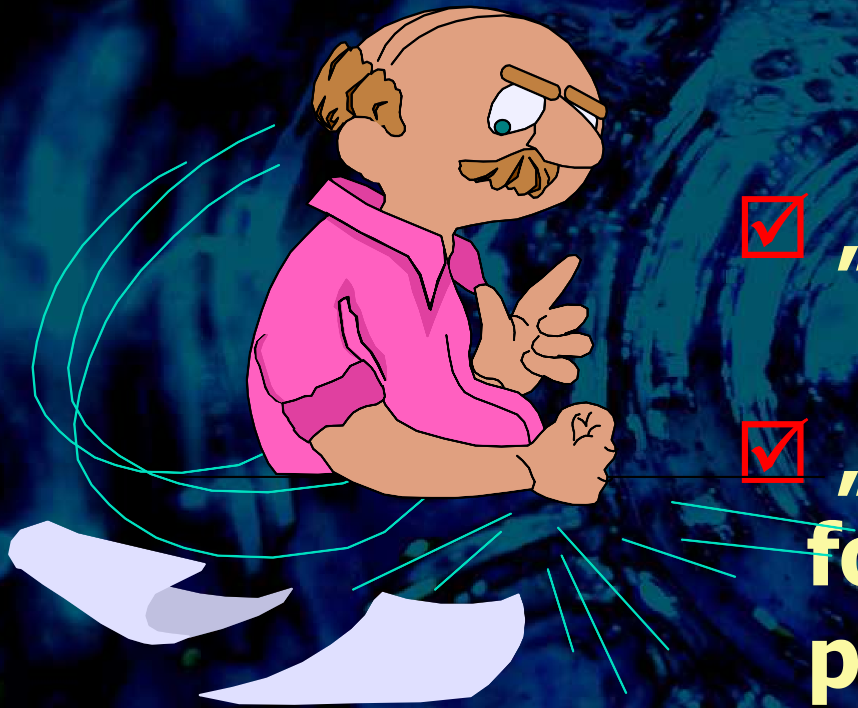
- ☑ Virt. Dissection of the Colon seems to be possible within a reasonable timeframe
- ☑ Operator interaction minimal (<10min), total time about 2h
- ☑ Graz enviroment plattform independent
- ☑ Easy to report, performance excellent
- ☑ Clinical experience until now limited

Outlook

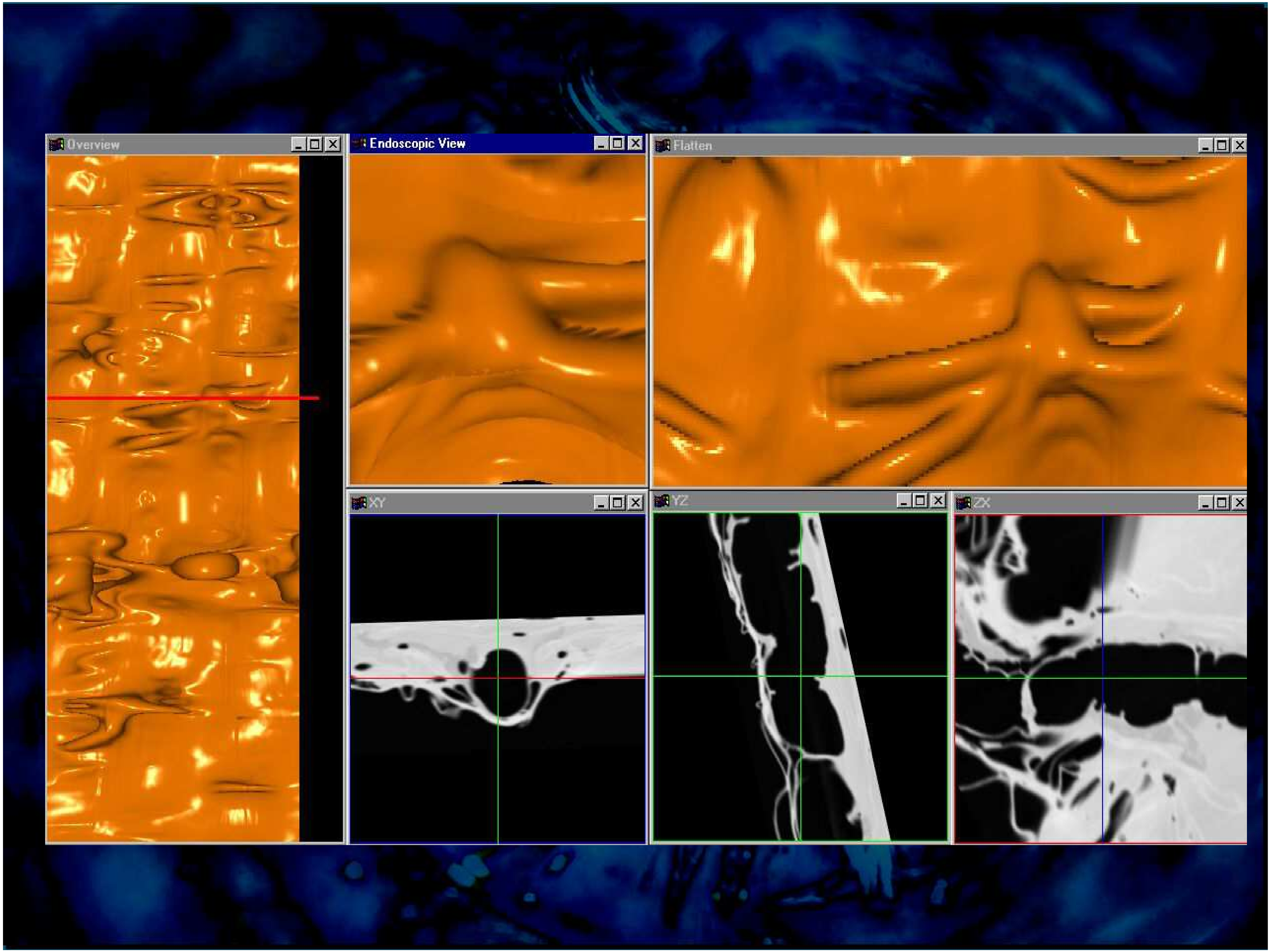
Using the depth map enhance the image using image processing.

- Contour detection.
- Curvature detection.

Outlook



- ☑ „Troubelshhooting Tool"
- ☑ „Fecal Tagging" – for easier patient preparation

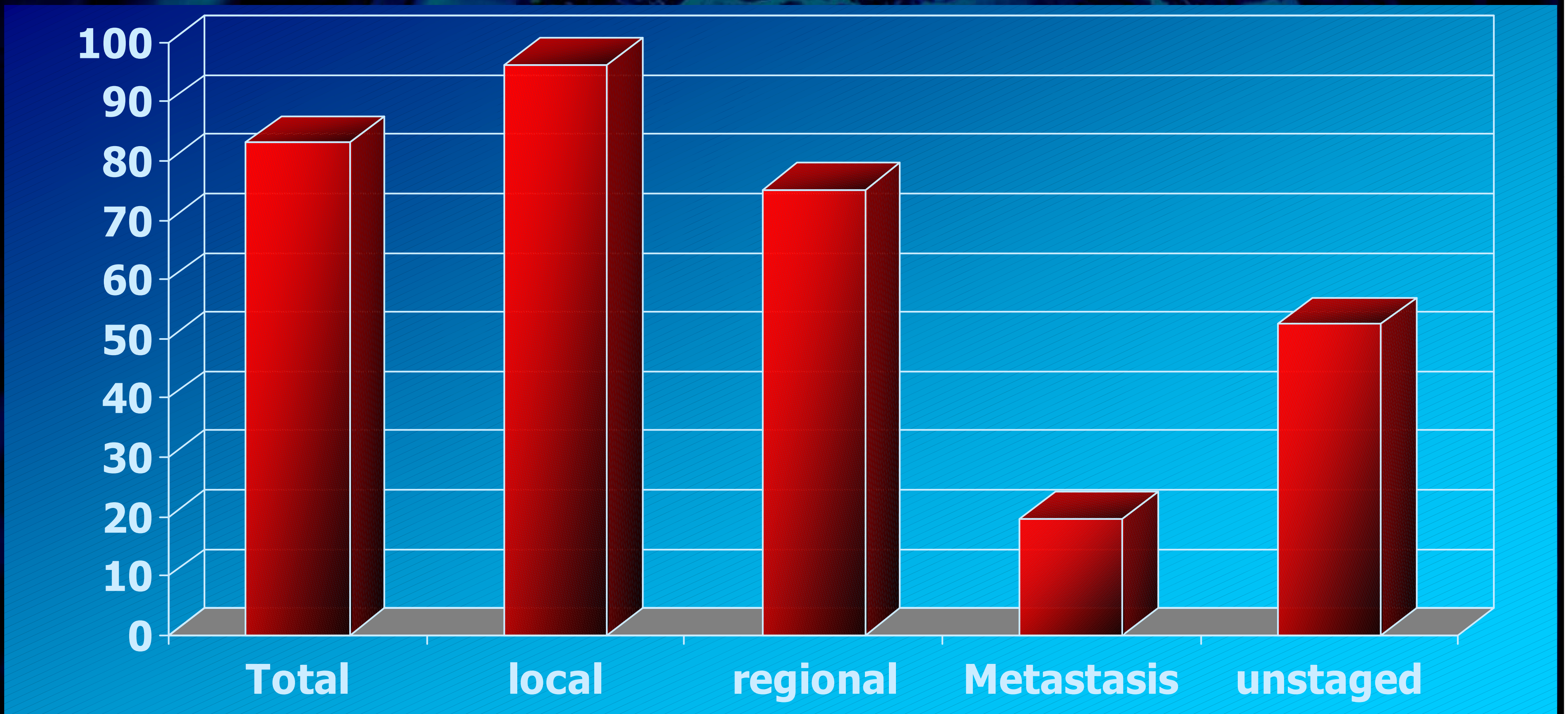

Overview
Endoscopic View
Flatten
XY
YZ
ZX

Breast Cancer - FACTS:

- ☑ Breast carcinoma leading cause of cancer death in womean
- ☑ Every 8-10th woman affected during lifetime
- ☑ About 4000 new cases/a in Austria
- ☑ Clustered mircrocalcificat one of early sign`s

Breast Cancer - FACTS:

SURVIVAL vs TUMORSPREAD

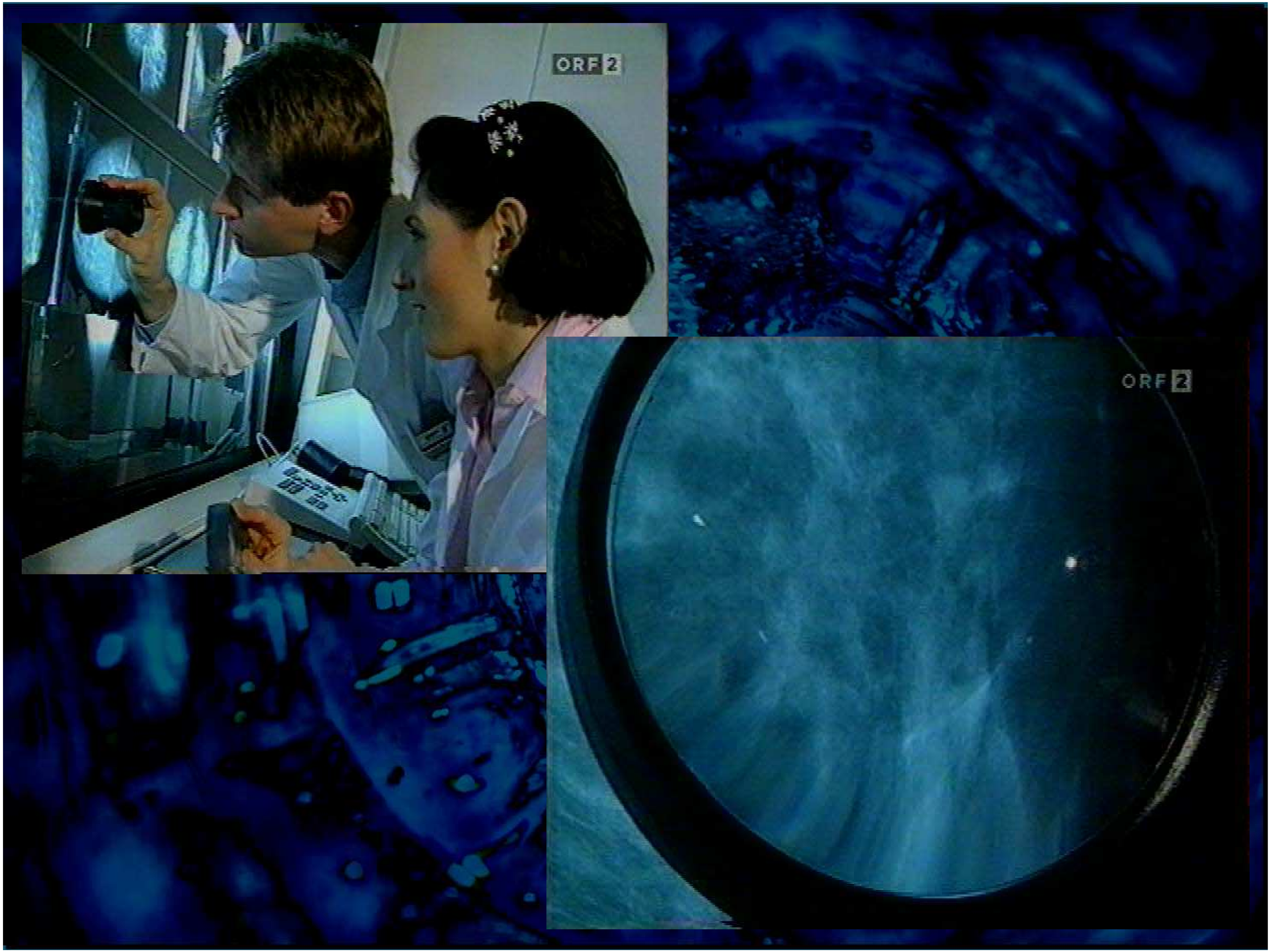


Mammography - TECHNIQUE:

Mammography - REPORTING:

☑ **Clsutered Microcalcifications are early sign´s ofbreast cancer (bright spot´s)**

- Size: 0.2-0.5 mm - search with a magnifying glass
- Difficult perception in low contrast areas
- Differentiate: cancerous vs non cancerous


ORF 2
ORF 2

Mammography - DILEMMA:

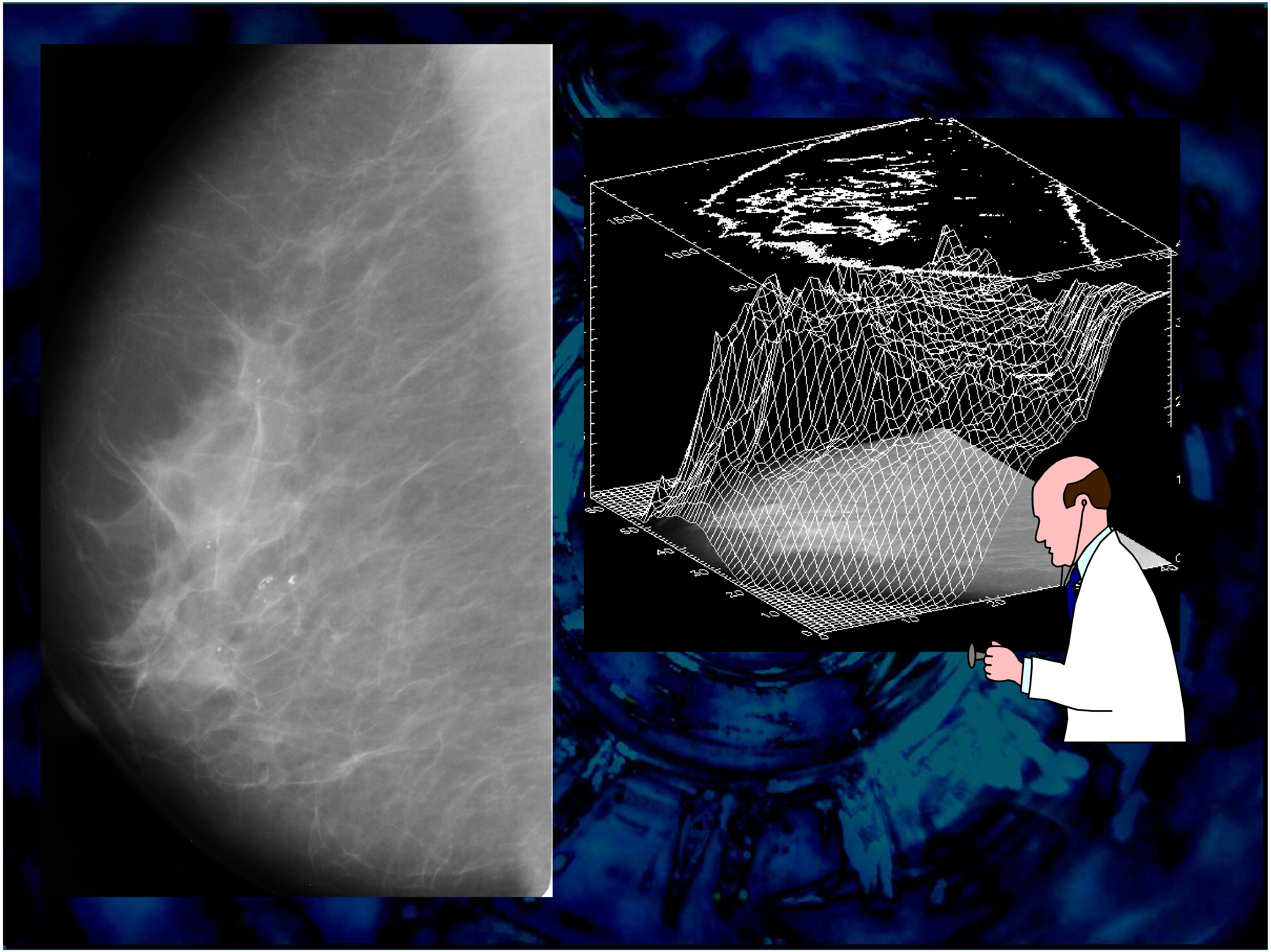
- ☑ Special training of radiologists necessary
- ☑ Positive predictive value of radiologists: 20%
- ☑ „Double Reading“ (independet reporting by 2 radiologists): improves accuracy by 5 - 15%

Artificial Intelligence in Mammography - HYPOTHESIS:

- ☑ Clustered microcalcifications be found reliably found by a computer application
- ☑ and a discrimination between cancerous and non cancerous microcalcifications be done using neuronal nets

Mammography - VISION

☑ **CAD System (Computer Aided Diagnosis) can act as “never tired, second reader”**

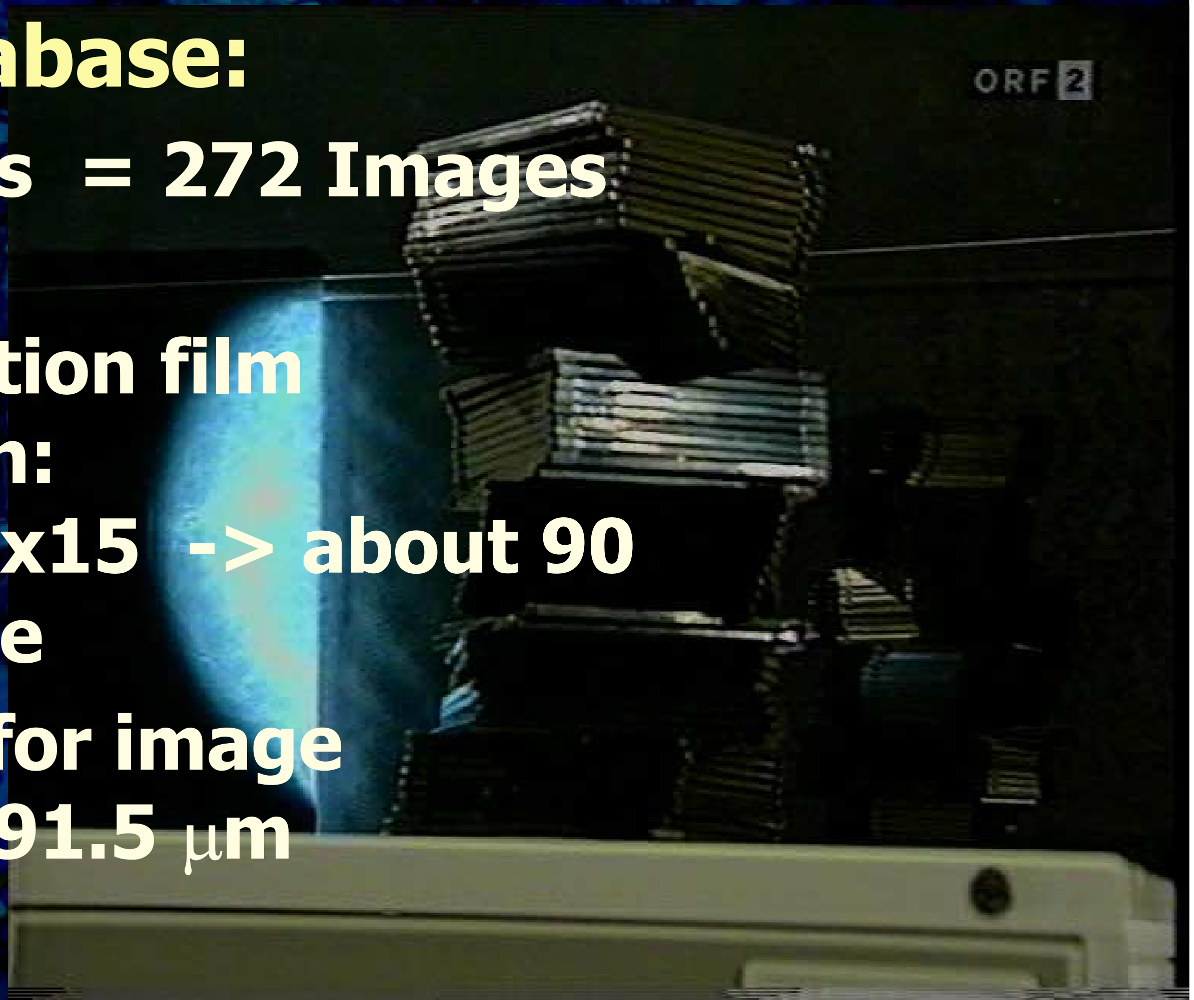


Variance of female FEATURES

ANN & Mammography - PATIENTS:

☑ **Patient Database:**

- **100 patients = 272 Images with Mc´s**
- **High resolution film digitalization: 8000x6000x15 -> about 90 Mbyte/image**
- **Resolution for image processing: 91.5 μm**



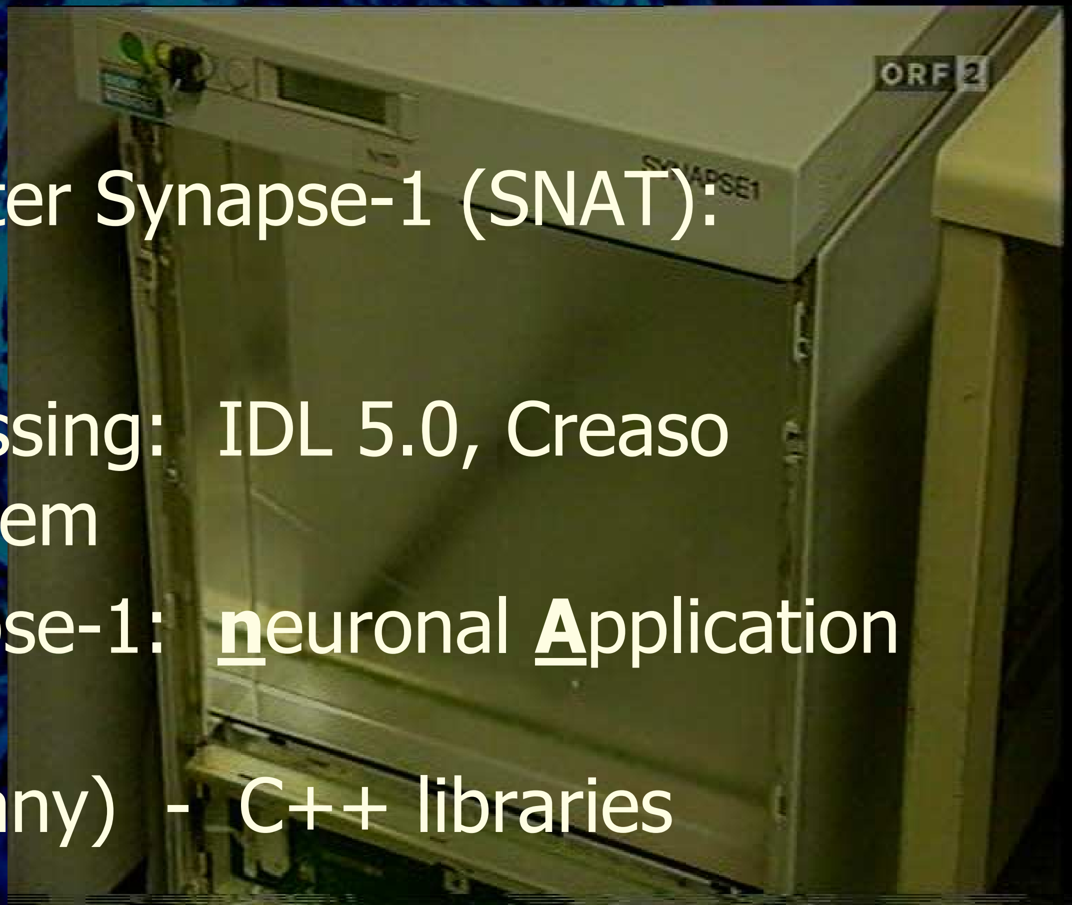
ANN & Mammography - GROUNDTRUTH:

- ☑ **All patients operated and biopsy reports availabale:**
  - 54 malignant, 46 benign
- ☑ **All patients rated to be**
  - benign, indeterminate, malignant
- ☑ **Manual marking of**
  - 828 indiv. microcalcifications
  - 735 artifacts

ANN & Mammography - HARD & SOFT:

☑ **Hardware:**

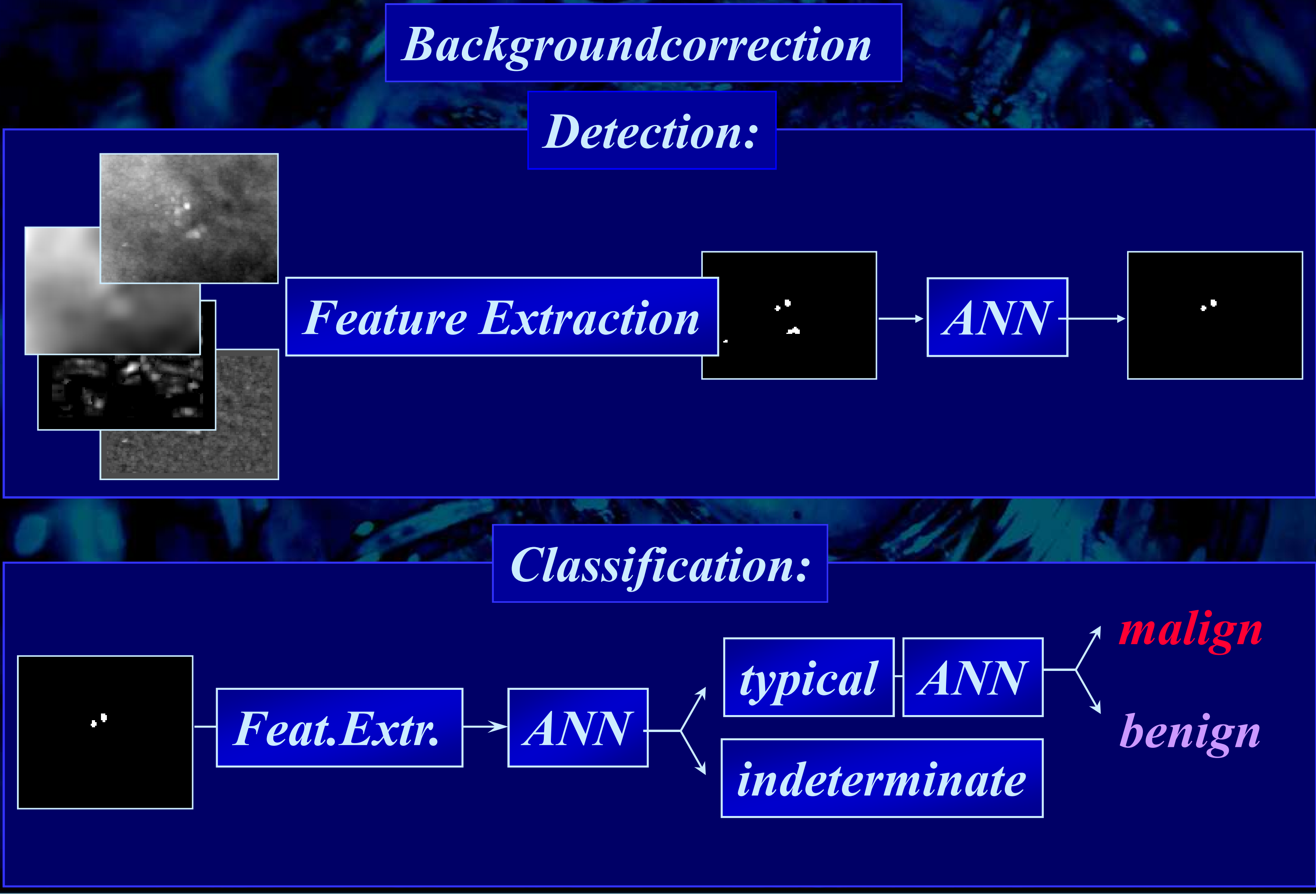
- SunSparc20
- Neurocomputer Synapse-1 (SNAT):



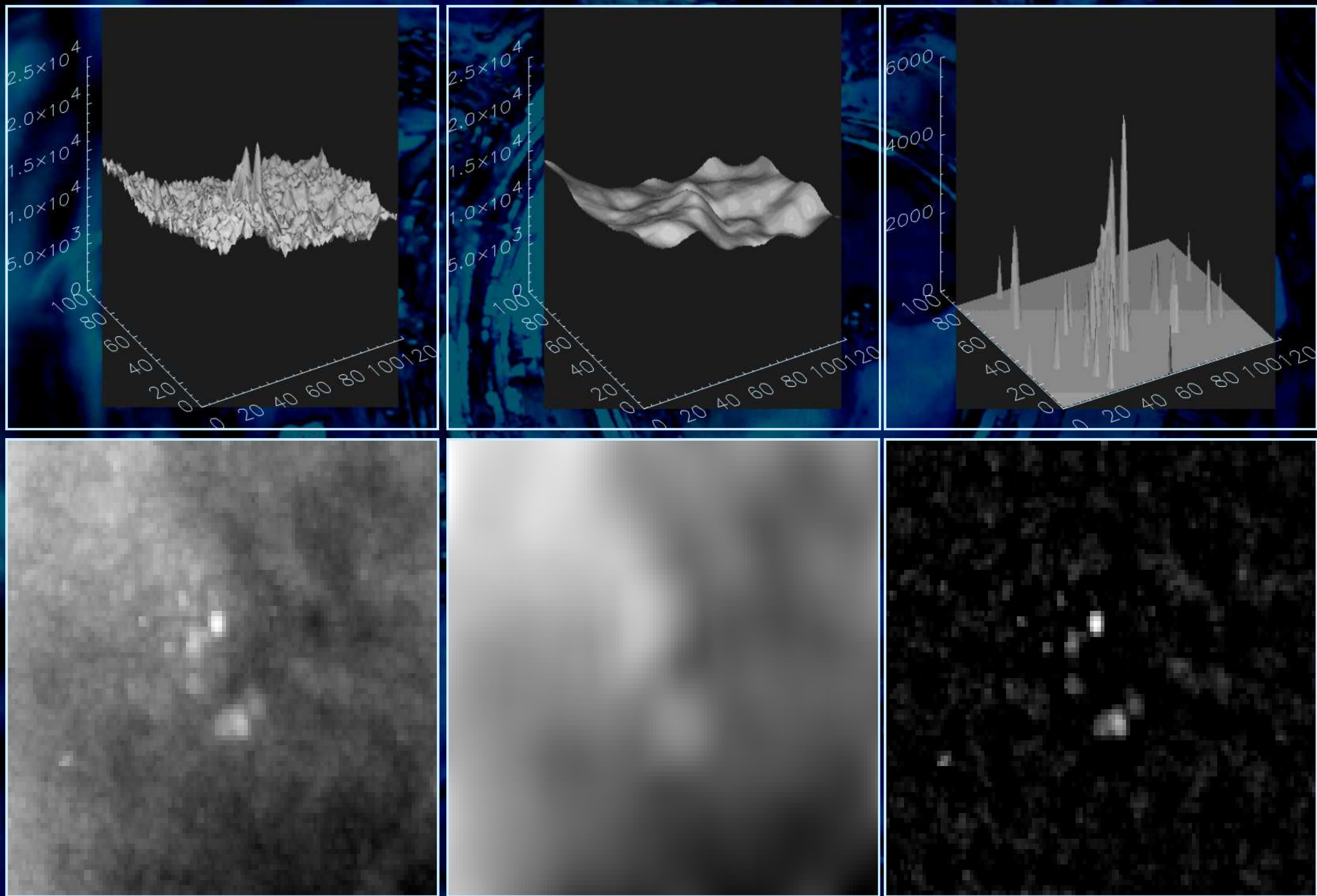
☑ **Software:**

- Image Processing: IDL 5.0, Creaso Research System
- ANN - Synapse-1: **n**euronal **A**pplication **L**anguage (SNAT, Germany) - C++ libraries

ANN & Mammo - WORKFLOW

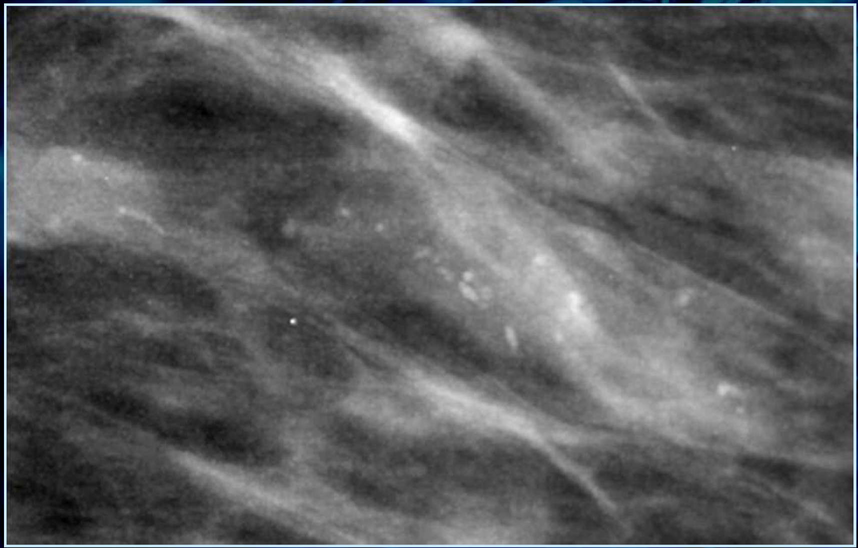


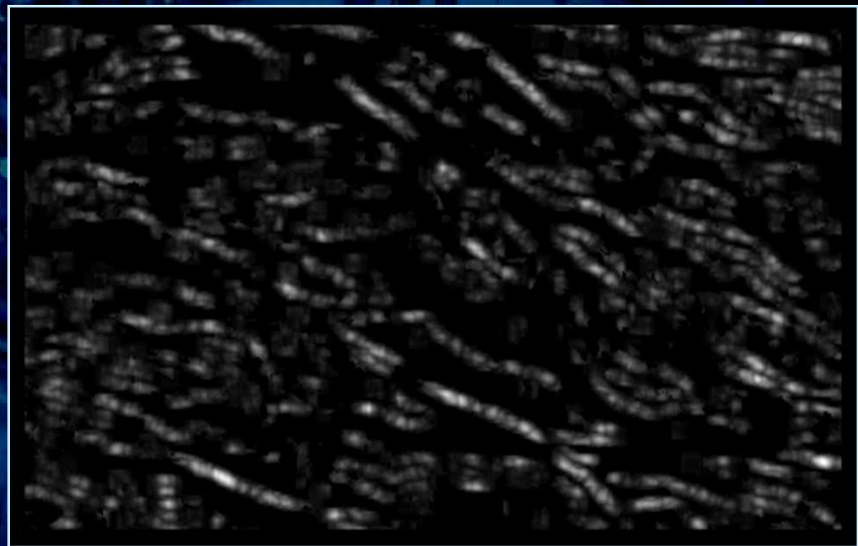
ANN & Mammography - BACKGROUNDKORRECTION



ANN & Mammography - FEATURES FOR DETECTION:

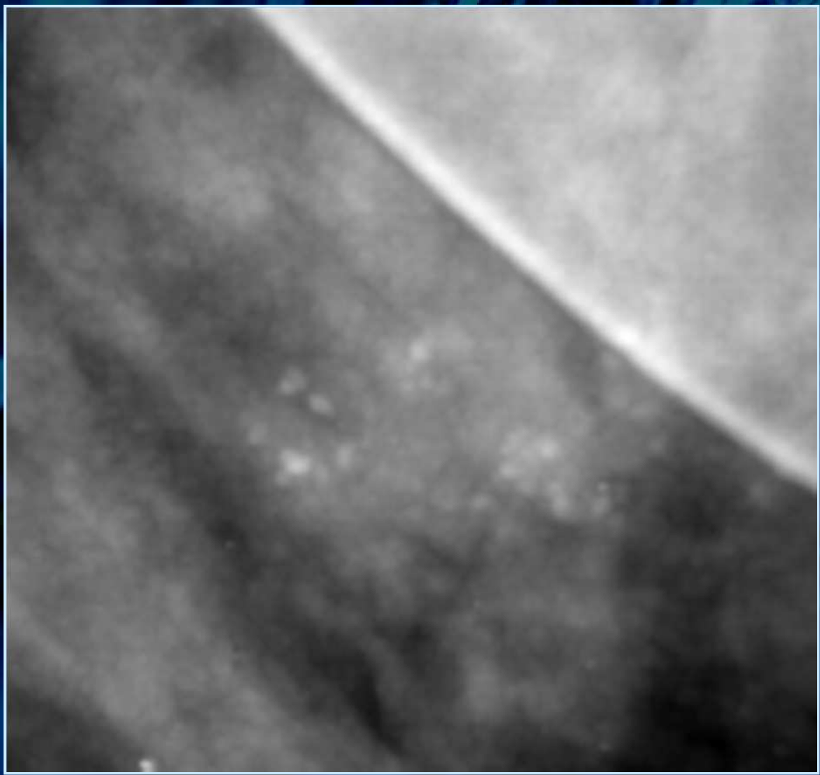
☑ **Linefeatures:**

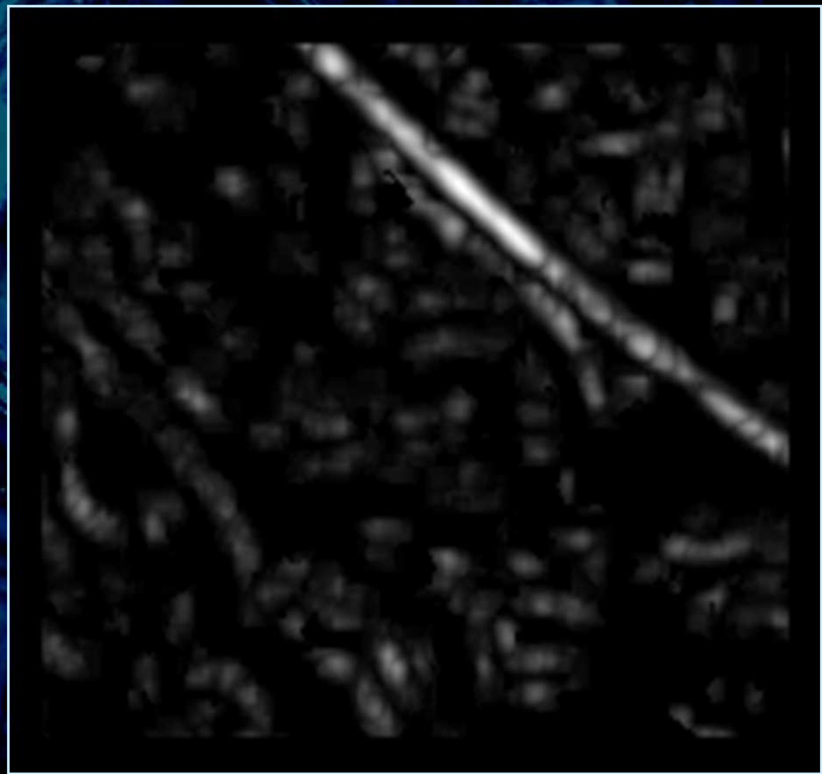




ANN & Mammography - FEATURES FOR DETECTION:

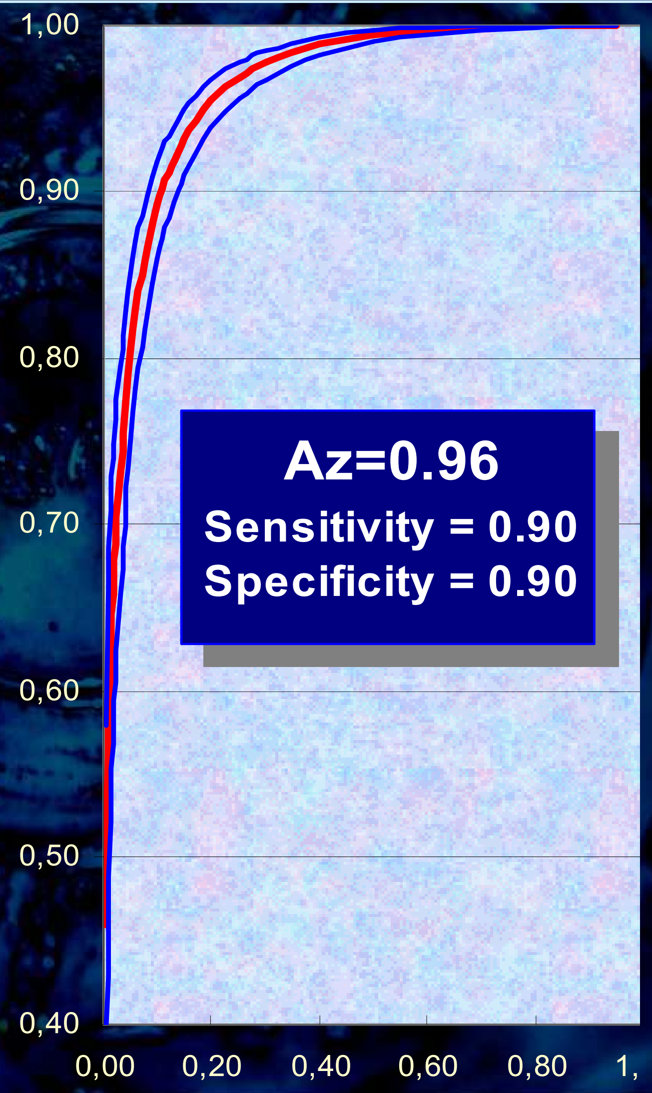
☑ **Linefeatures:**

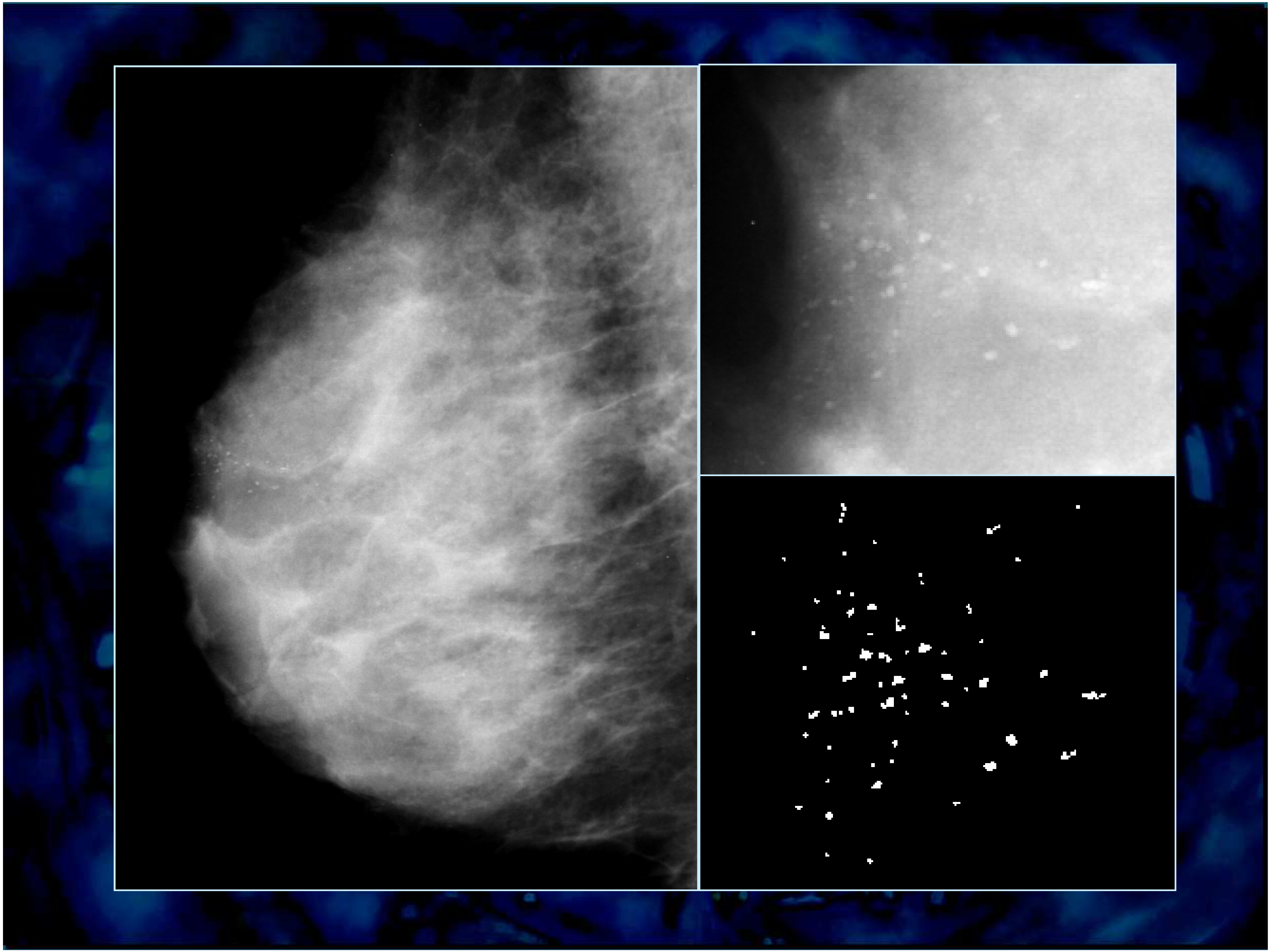




ANN & Mammography - RESULTS DETECTION:

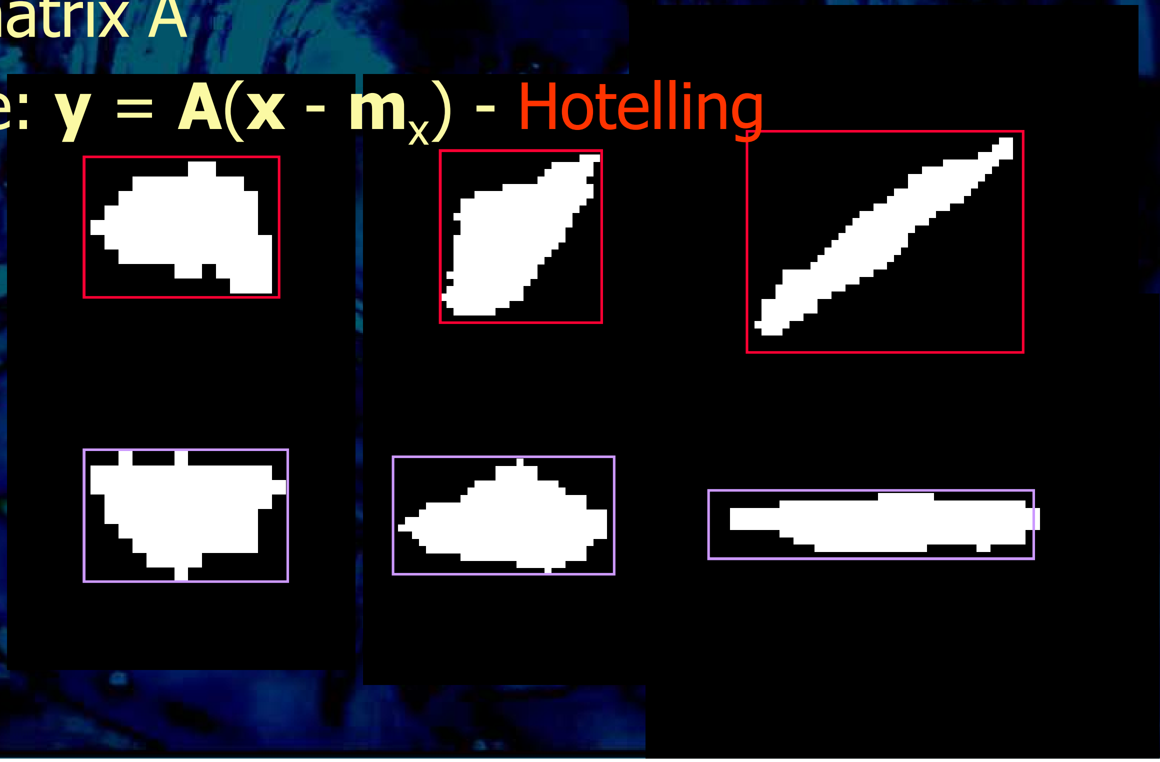
FEATURE		Az
graylevel	min	0.769
	max	0.836
	mean	0.808
	var	0.875
edge gradients	min	0.817
	max	0.895
	mean	0.920
	var	0.755
line feature	min	0.651
	max	0.608
	mean	0.636
	var	0.557
local contrast (object)		0.930





ANN & Mammography - FEATURES FOR CLASSIFICATION

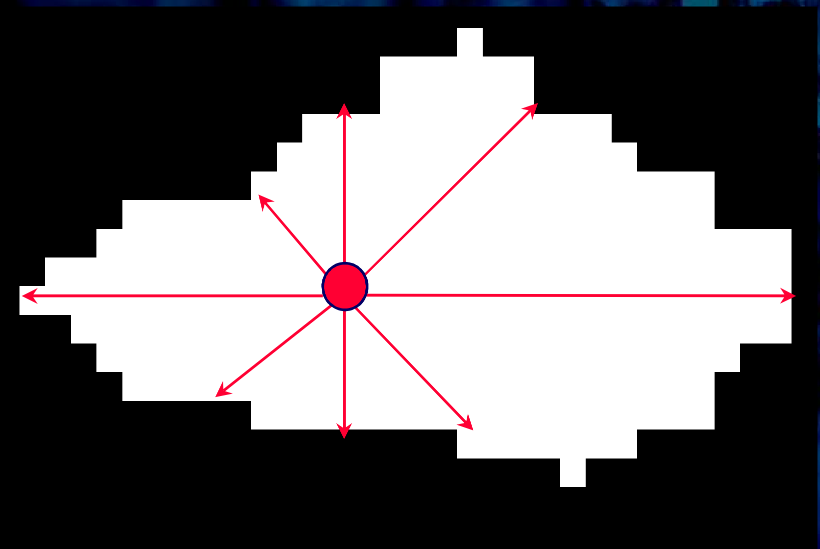
- ☑ Mean vector of population: $\mathbf{m}_x = E\{\mathbf{x}\}$
- ☑ Covariance matrix: $\mathbf{C}_x = E\{(\mathbf{x} - \mathbf{m}_x)(\mathbf{x} - \mathbf{m}_x)^T\}$
- ☑ Calculate eigenvectors of $\mathbf{C}_x$, and transformationmatrix A
- ☑ Transform image: $\mathbf{y} = \mathbf{A}(\mathbf{x} - \mathbf{m}_x)$ - Hotelling Transformation

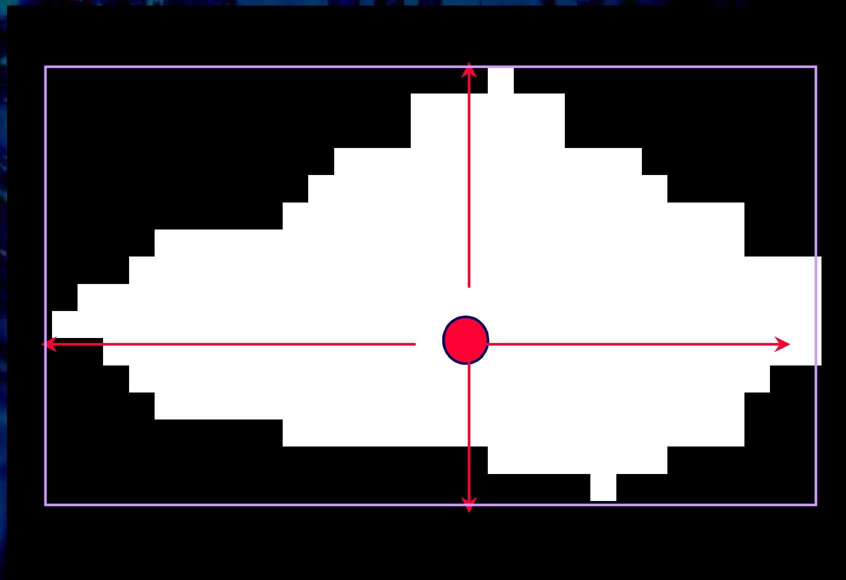


ANN & Mammography - FEATURES FOR CLASSIFICATIONS

- ☑ **Extension in 8 directions**
- ☑ **„Minimum Enclosing Rectangle“:**
  - Center of gravity, excentricity, aspect-ratio

  ....





ANN & Mammography - FEATURES FOR CLASSIFICATIONS

☑ Features of individual microcalcifications:

- Meanvalue of greylevels of pixels within one mc
- Local contrast of one mc
- Border gradients
- Area, perimeter and compactness (P^2/A)

ANN & Mammography - FEATURES FOR CLASSIFICATIONS

- ☑ **Clustering - recursive algorithm**
- ☑ **Area of the cluster - Convex Hull Procedure**

ANN & Mammography - FEATURES FOR CLASSIFICATIONS

☑ Features from „Convex Hull“:

- Number of mc’s
- Area, perimeter and compactness of cluster
- Density (number of mc’s/A)
- Inter mc - distances
- descriptive statistics of individual mc features

ANN & Mammography - FEATURES FOR CLASSIFICATIONS

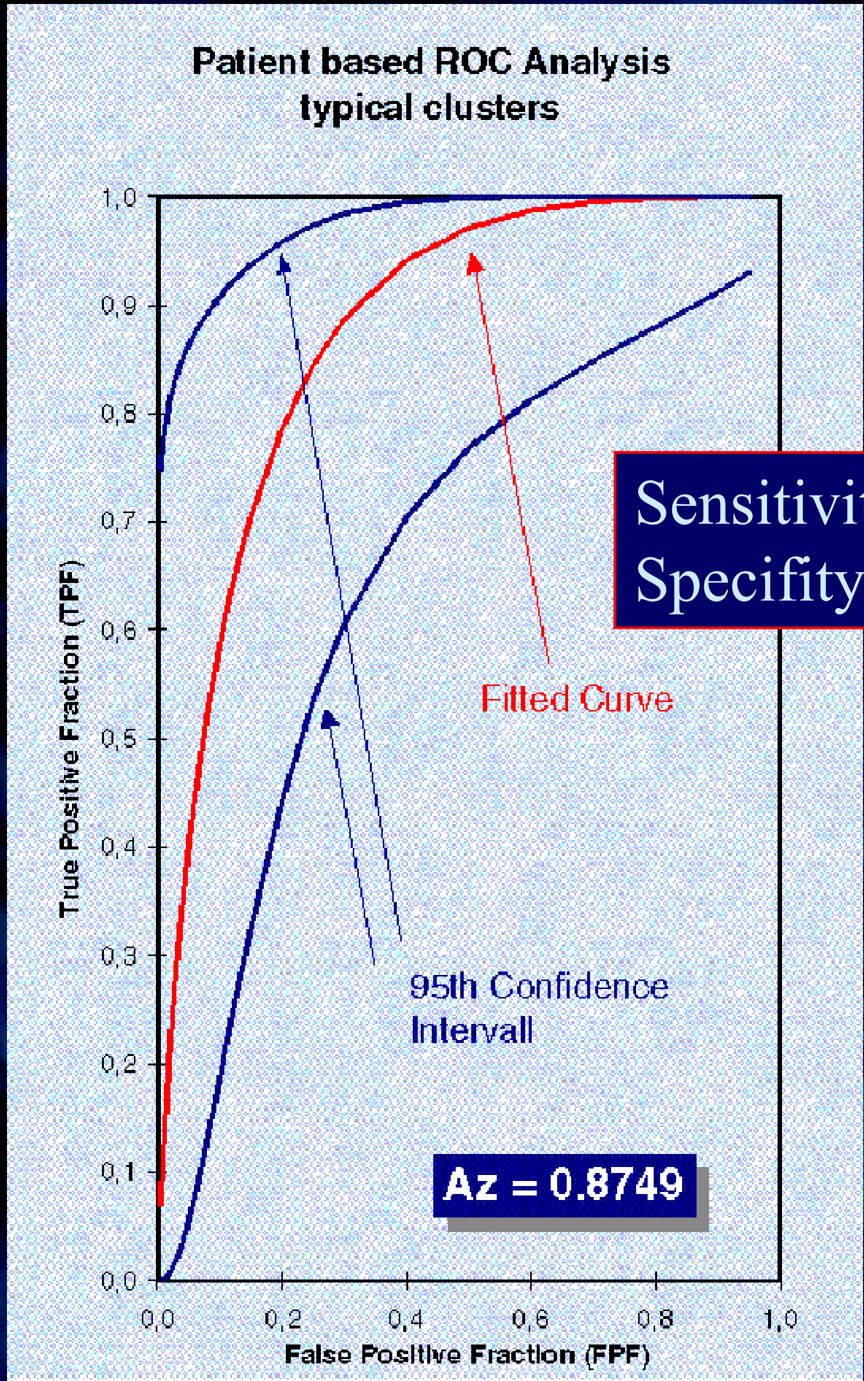
- ☑ **Total features: n=73**
- ☑ **Automatic selectionsprocess: patient based**

  „ Leave-o

  every featu

10 suited for differentiation typical - indeterminate

12 suited for differentiation benign - malignant



Sensitivity : 98%

Specifity : 47%

Background

- ☑ **Imaging modalities (eg CT, MRI):**
  - Data acquisition ↑
- ☑ **Computers:**
  - Speed ↑
  - Graphics display ↑
  - Availability from open operating systems

L I N U X *(http://www.linux.org)*

challenging new applications

Question?

☑ Can we (as radiologists) exploit these emerging technologies for improving patient care?

Image Guided Therapy…
Robotics….

☑ **Image guided therapy:**

- almost everything
  - ✓ Segmentation
  - ✓ Registration - Fusion
  - ✓ Quantification
  - ✓ Navigation
  - ✓ Virtual / Augmented Reality

☑ **Robotics:**

- Interventions, CAS, Rehabilitation……

Image Guided Therapy…
Robotics….

- ☑ **Image guided therapy:**
  - almost everything
    - ✓ Segmentation
    - ✓ Registration - Fusion
    - ✓ Quantification
    - ✓ Navigation
    - ✓ Virtual / Augmented Reality
- ☑ **Robotics:**
  - Interventions, CAS, Rehabilitation…..

Outline

- ☑ **Registration**
- ☑ **What is Augmented Reality (AR)?**
  - „Ingredients" of AR - Systems
  - Applications and first results
- ☑ **Robotics**
  - Defniton
  - Types
  - Applications

Registration (Image Matching)

- ☑ **Several images of the same object are taken:**
  - using different imaging modalities
  - at different time instants
- ☑ **It is necessary to compare two objects**
  - Reality and Virtuality
- ☑ **It is desired to match an image to a model (e.g. digital atlas)**

Registration – Problem:

- ☑ **To determine:**
  - an unknown geometric transformation:
  - that maps one image into another (to a certain degree of accuracy)
- ☑ **If registration problem is solved we know:**
  - for each pixel in the first image we know the corresponding pixel in the second image
- ☑ **This assumes that the images are:**
  - similar in the sense that both images contain the same (or similar) object, which may be rotated, translated, or elastically deformed

Registration - Classification

- ☑ **Dimensionality:**
  - of images that are registered (2-D, 3-D, 4-D methods)
- ☑ **Image features being matched:**
  - (extrinsic and intrinsic methods)
- ☑ **Mechanism of interaction with the user**
- ☑ **Type of geometric transformation used for registration**
  - rigid, affine, perspektive, elastic

Registration – Algorithms

- ☑ **Using corresponding points identified in images**
- ☑ **Using corresponding surfaces**
- ☑ **Using voxel intensity values**

  - M. Sonka, J. M. Fitzpatrick, Eds., Handbook of Medical Imaging, Volume 2. Medical Image Processing and Analysis, SPIE, 2000
  - J. V. Hajnal, D. L. G. Hill, D. J. Hawkes, Eds.,Medical Image Registration, CRC Press, 2001

Registration - Trackers

☑ C

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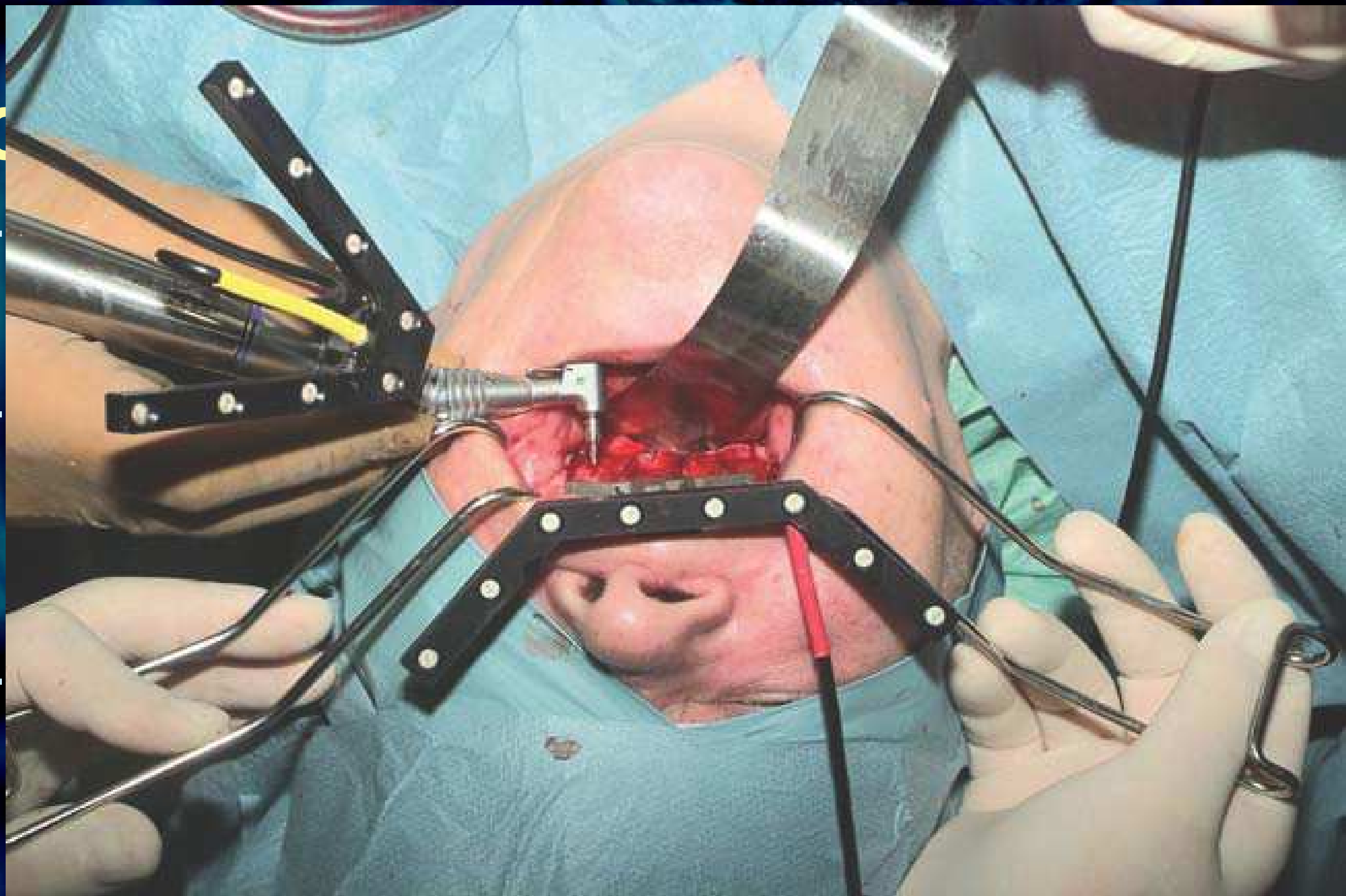
d light



–

What is Augmented Reality (AR)?

- ☑ **Overlay of artificial„target information“ over real-worldview**
- ☑ **Virtual scenery adopts itself to the position of the viewer Technology:**
  - Visualization devices such as head-mounted displays(HMD)
  - Position tracking or pose estimation
  - Interfacing to 3D-visualization systems

Visualization Devices

☑ **Features to consider:**

- Optics
- Focal problems, display quality, parallax error, calibration
- Appropriate visualization, tracking, latency, weight
- Acceptance
- Appropriateness for given applications, acceptance of end users

Graz Approach

☑ **Features:**

- Now fixed on operator's head
- 2 Monitors: 800x600 px (for every eye)
- infinitely variable Reality ←→ Virtuality

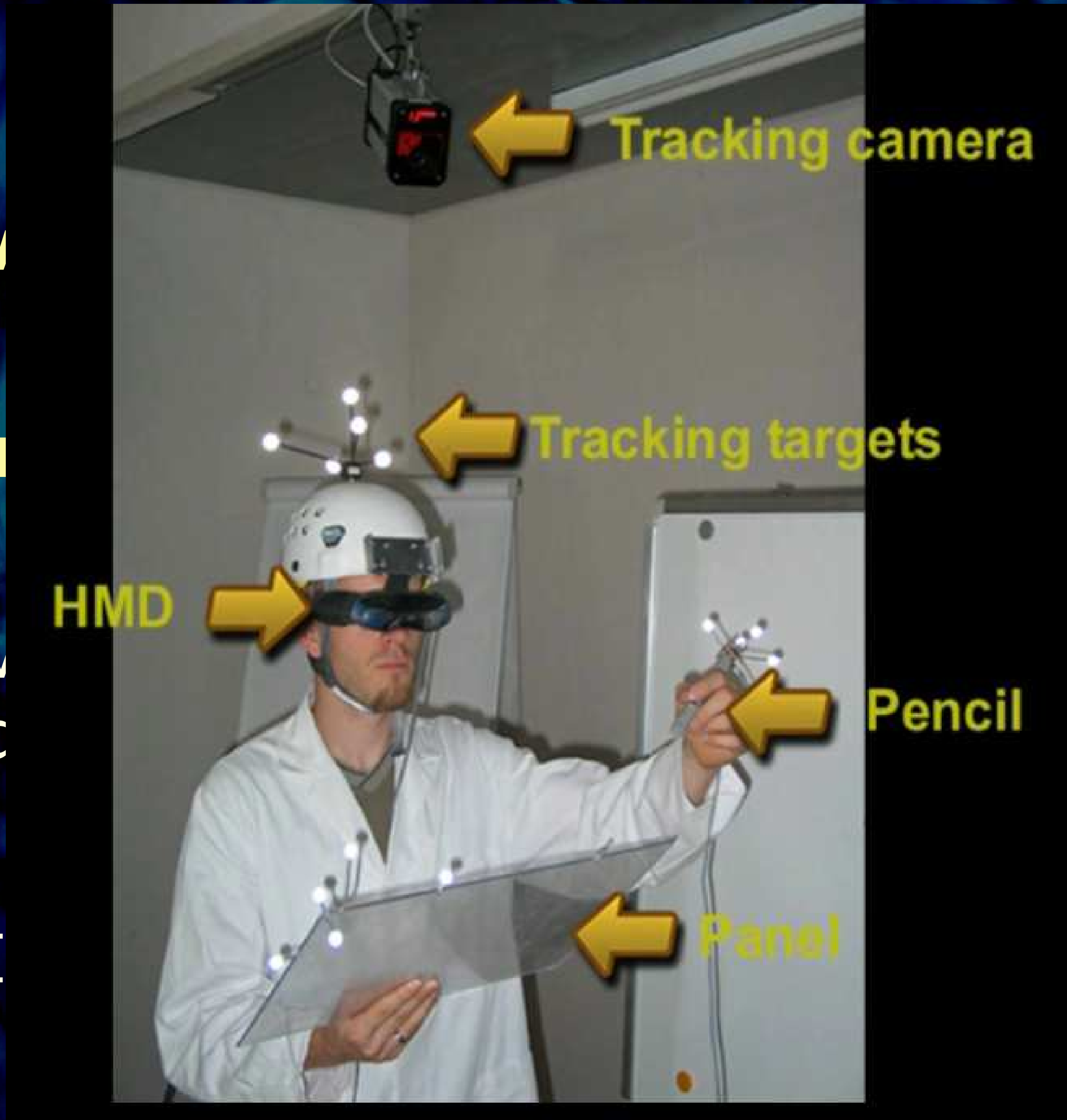
Question?

- ☑ Can we (as radiologists) exploit these emerging technologies for improving patient care?

Attack….

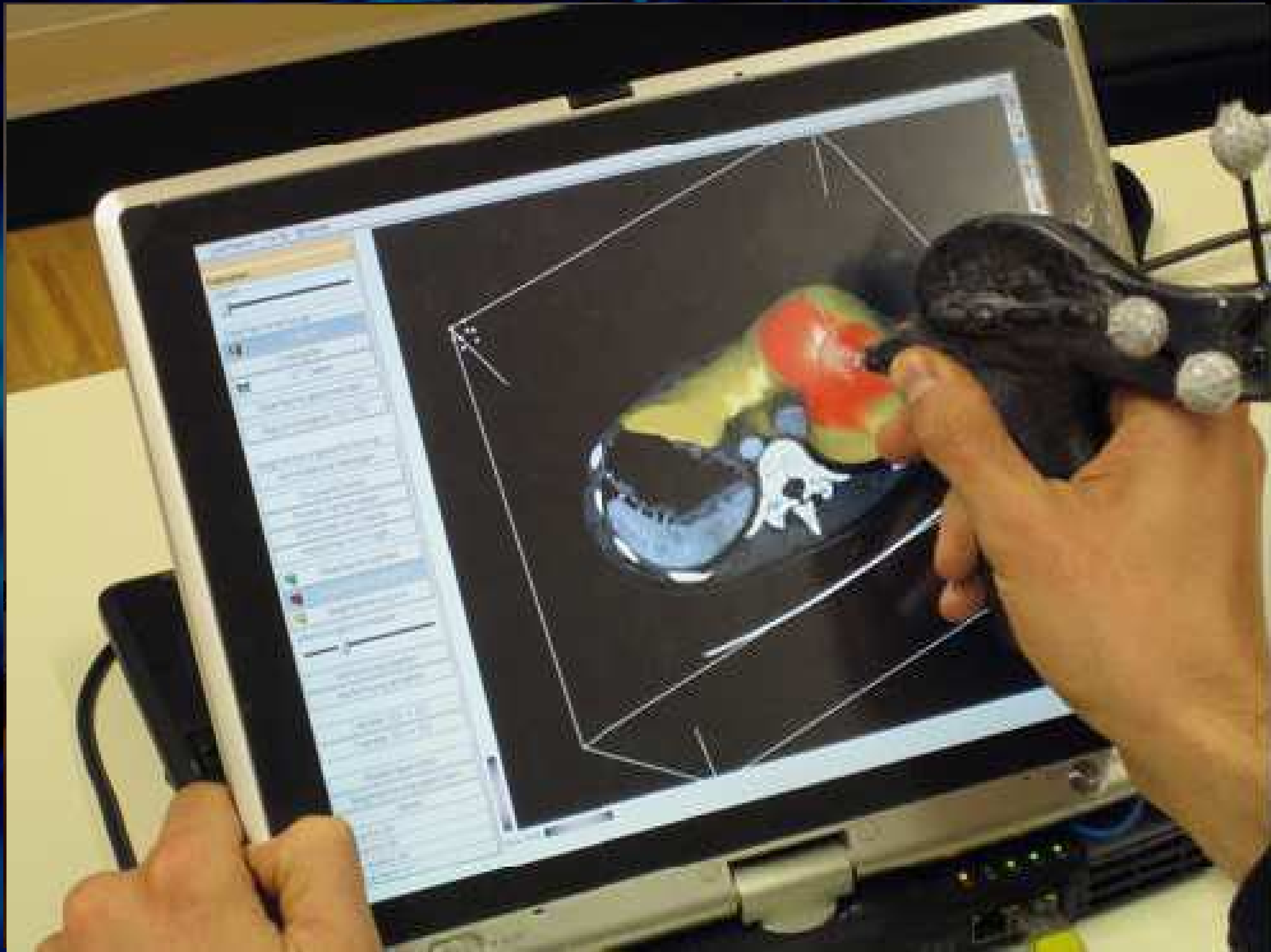
- ☑ **Computer-Assisted Tumor Ablation**
  - Usuage of an Augmented Reality System (AR) for:
    - ✓ Visualisation
    - ✓ Planing
    - ✓ Navigation
    - ✓ Success Control
- ☑ **Multidisciplinary Team**
  - Radiologists
  - Surgeons
  - Informatics / Telematics
  - Biomedical Engineering / Image Procesing

Augmented Reality System



- ☑ **Ov** … **mation“**
- ☑ **Vi** … **the** … **ology:**
  - V … ounted c
  -
  - I … ns

Augmented Reality (AR)



Graz Experience – „Virtual Liver Surgery"

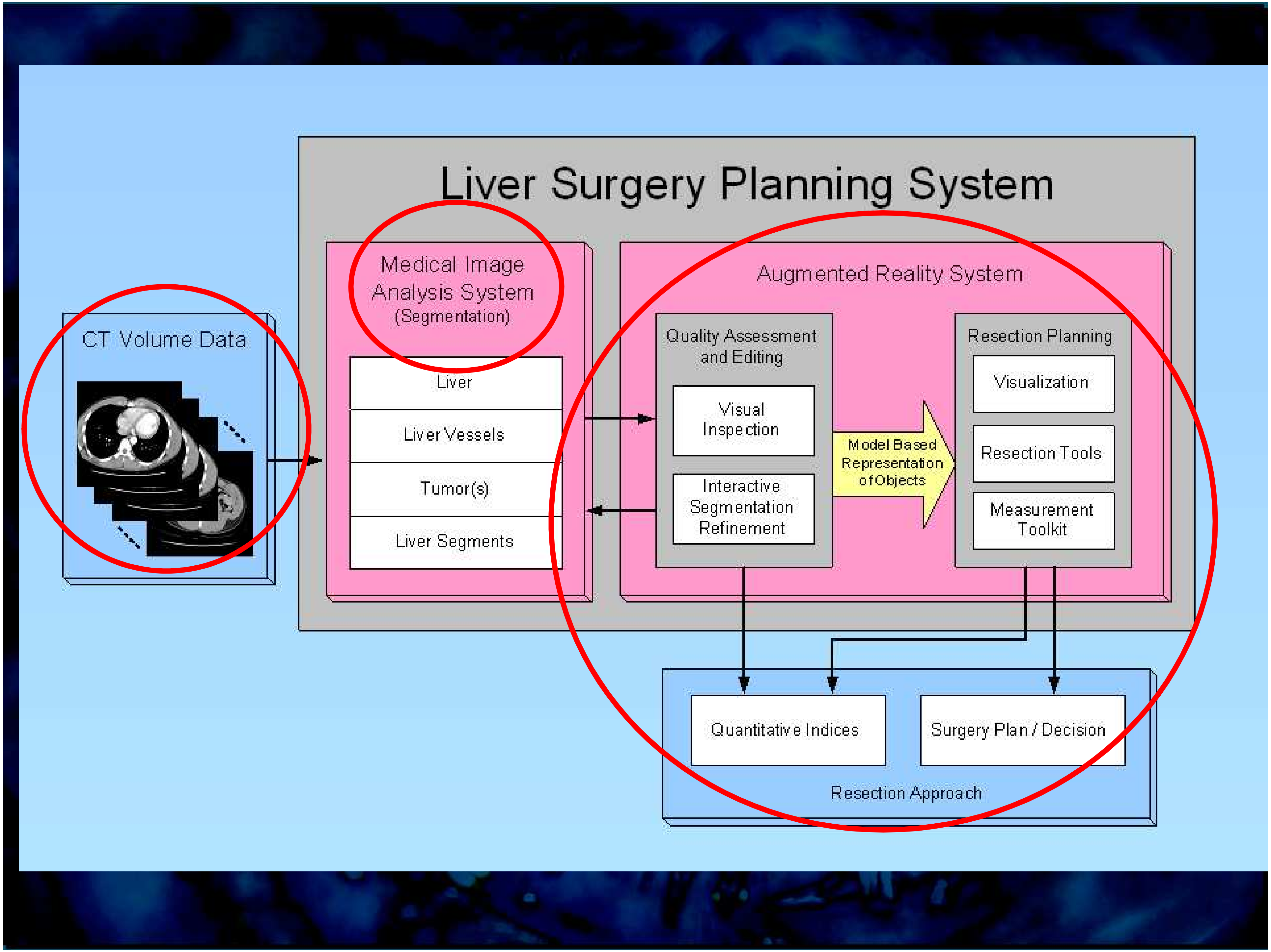
- ☑ **Multidisciplinary team:**
  - Radiology, Surgery, Biomedical Engineering
- ☑ **Focus:**
  - Enhanced preoperative visualization
  - Surgery Planning tool
  - Future: functional assessement of postoperative remaining liver tissue

http://liverplanner.icg.tu-graz.ac.at

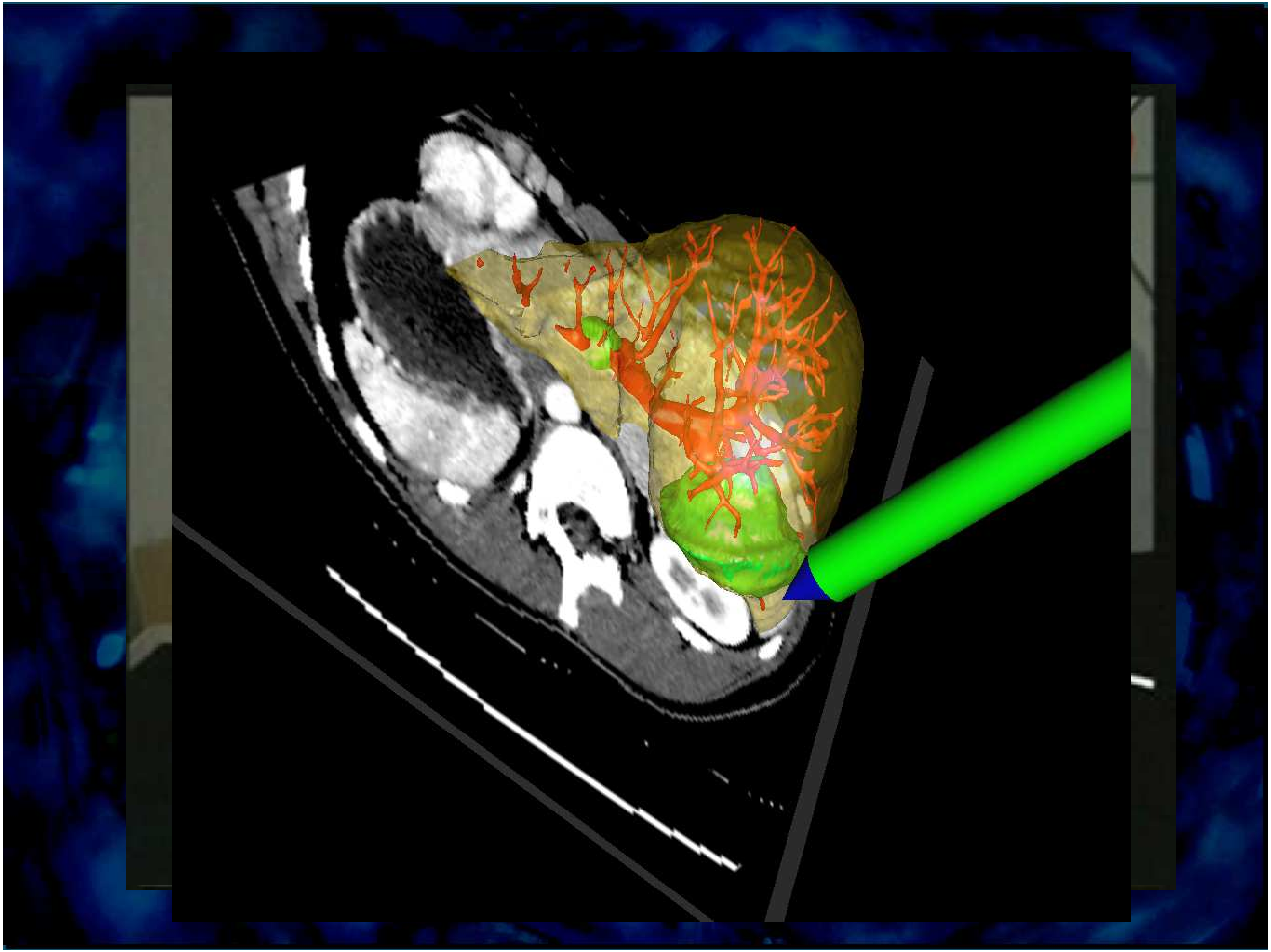
Virtual Planning - Idea

Computer Vision

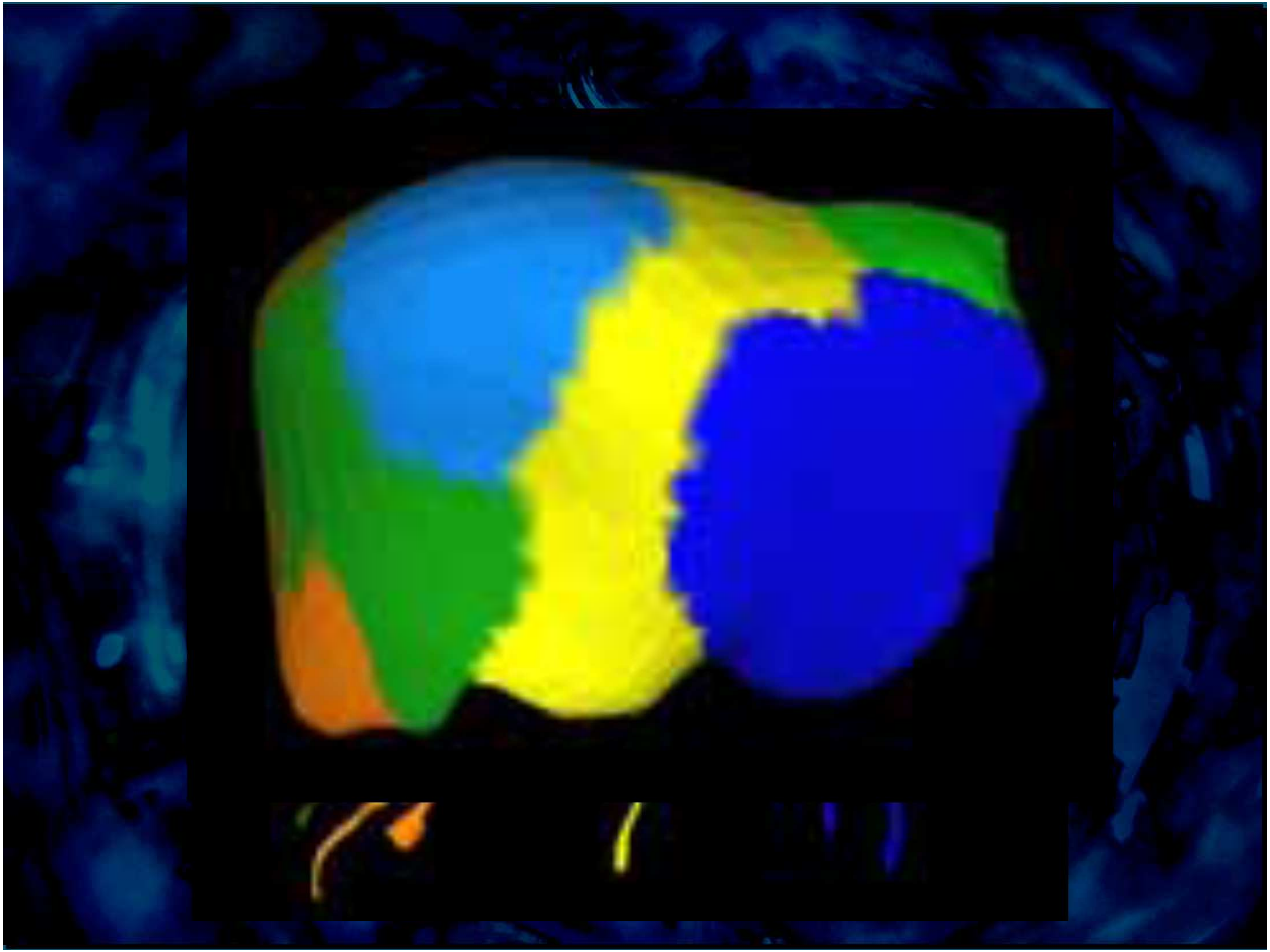
Computer Graphics



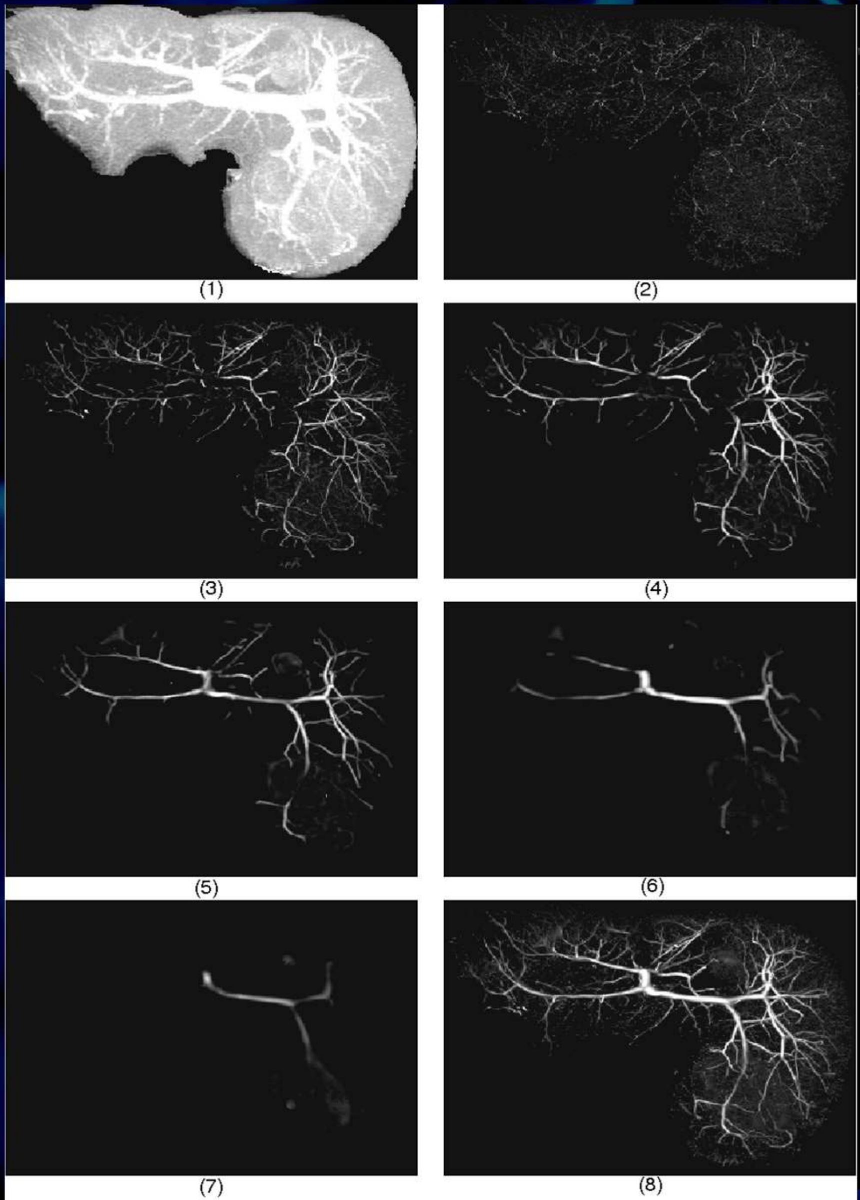
Liver Surgery Planning System
CT Volume Data
Medical Image
Analysis System
(Segmentation)
Liver
Liver Vessels
Tumor(s)
Liver Segments
Augmented Reality System
Quality Assessment
and Editing
Visual
Inspection
Interactive
Segmentation
Refinement
Model Based
Representation
of Objects
Resection Planning
Visualization
Resection Tools
Measurement
Toolkit
Quantitative Indices
Surgery Plan / Decision
Resection Approach

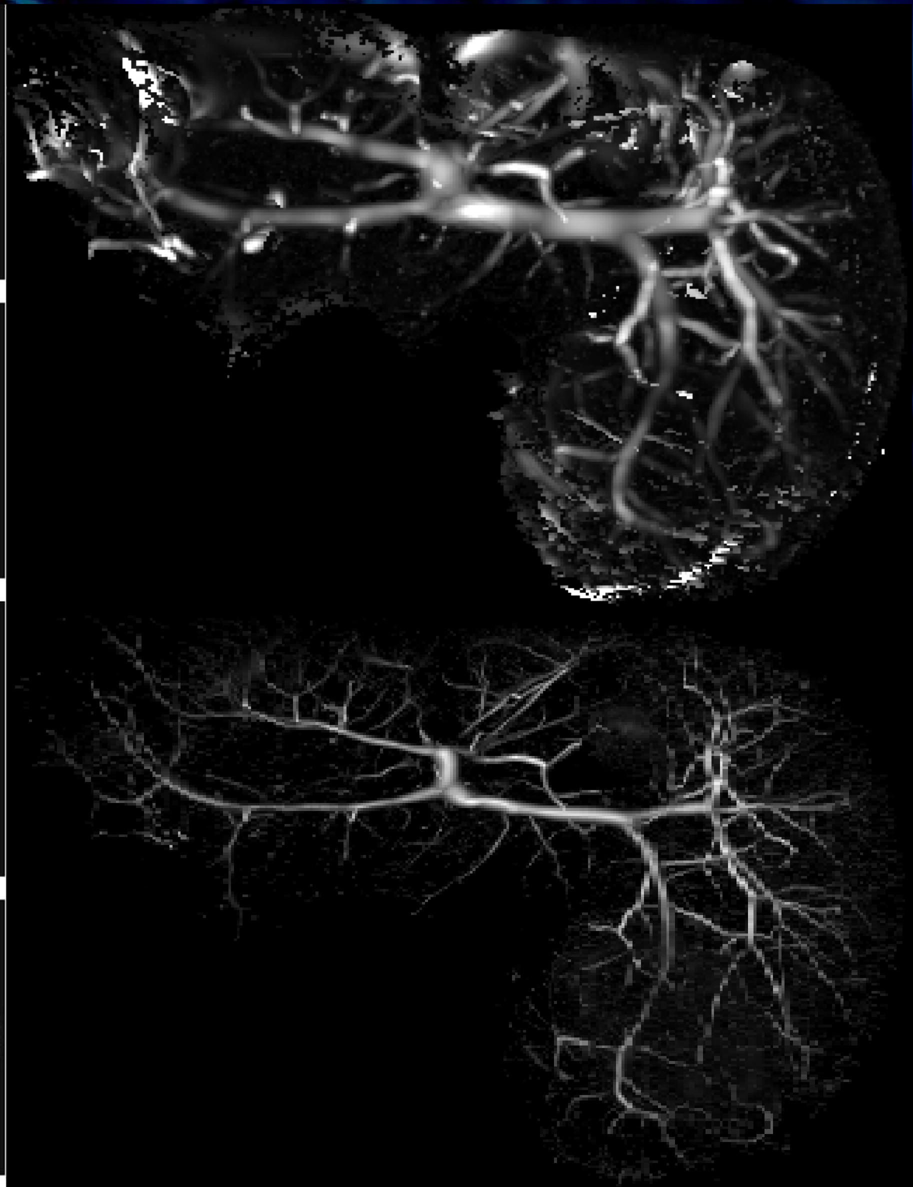



Bereit
00:10

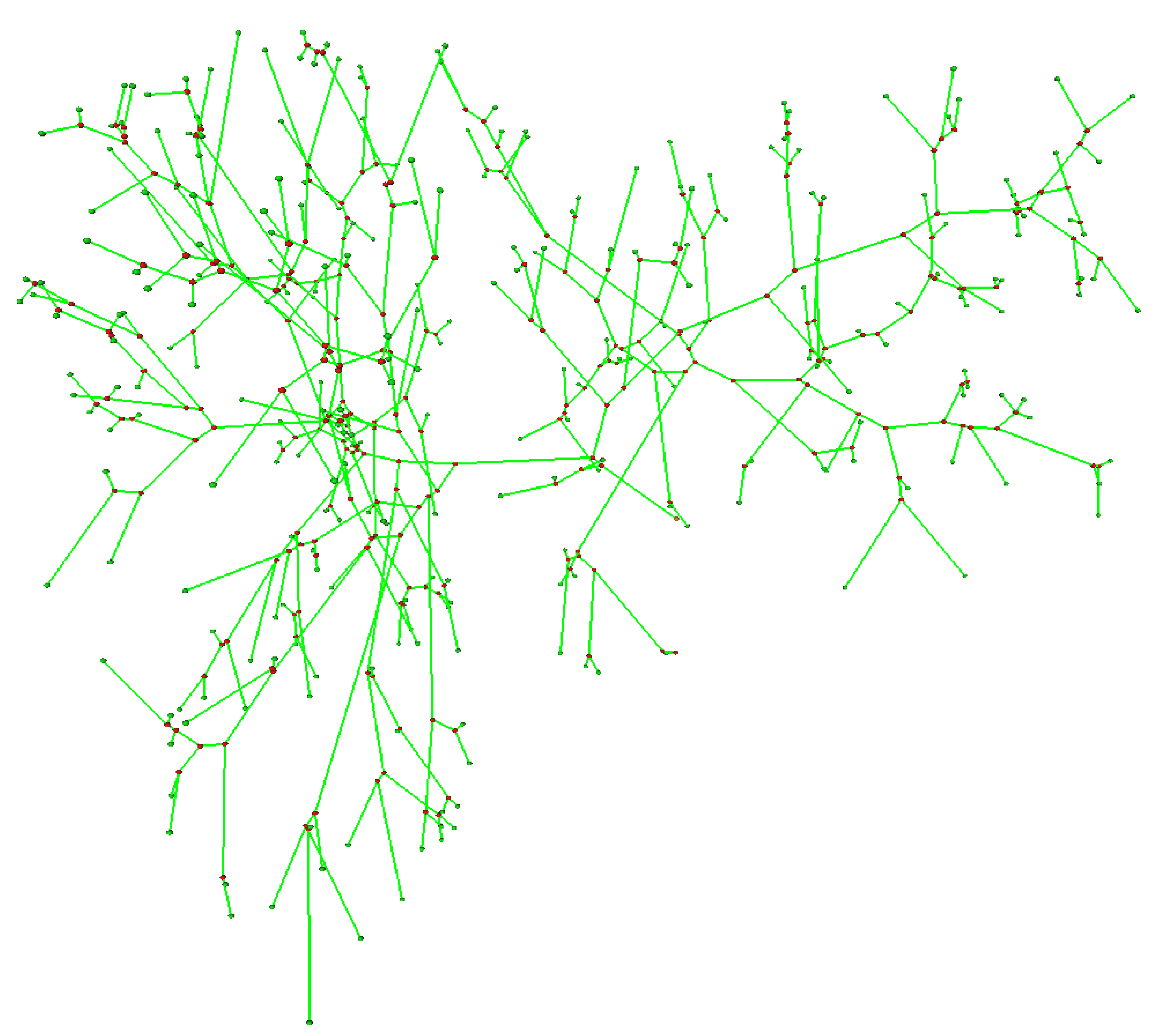


Tube Detection Filter





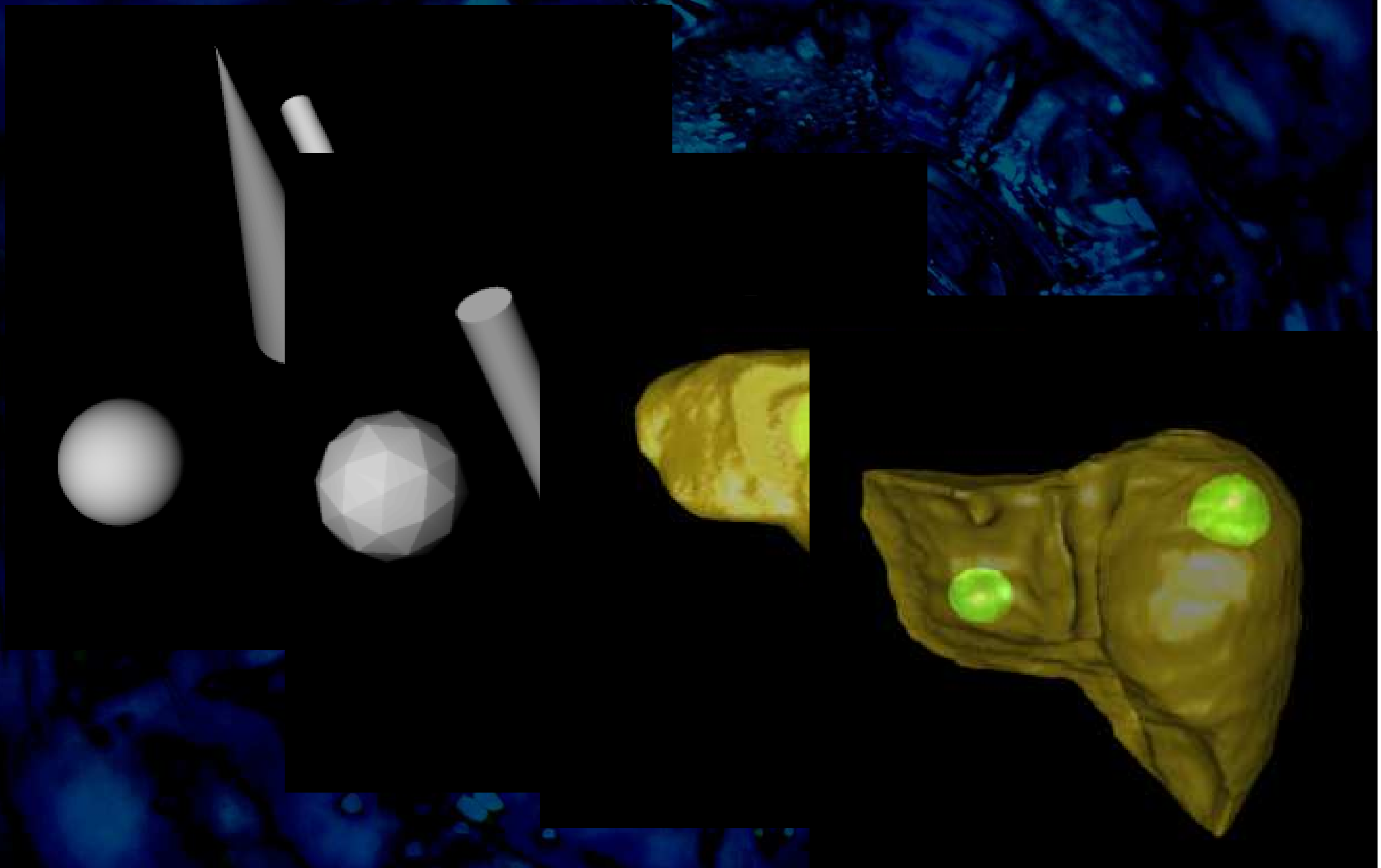
Graph Theory



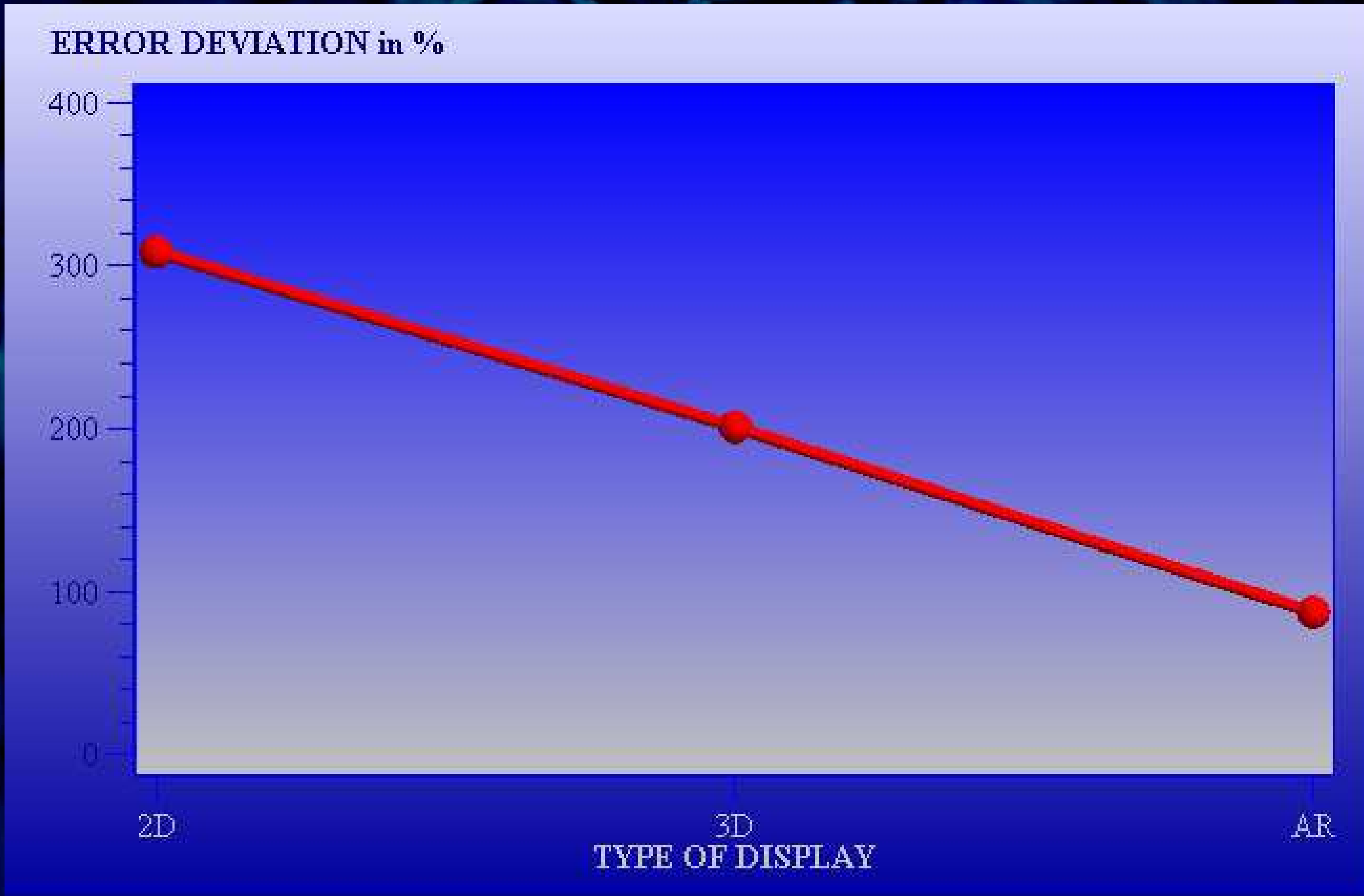
AR – Advantage?

- ☑ **14 test cases:**
  - Artificial objects:
    - ✓ Segmented livers, tumors
    - ✓ Portal trees
- ☑ **Tasks:**
  - Volume estimations
  - Volume measurements
  - Distance measurements
  - Evaluation systems
    - ✓ TIANI J-Vision (2D, 3D)
    - ✓ Liverplanner (AR)

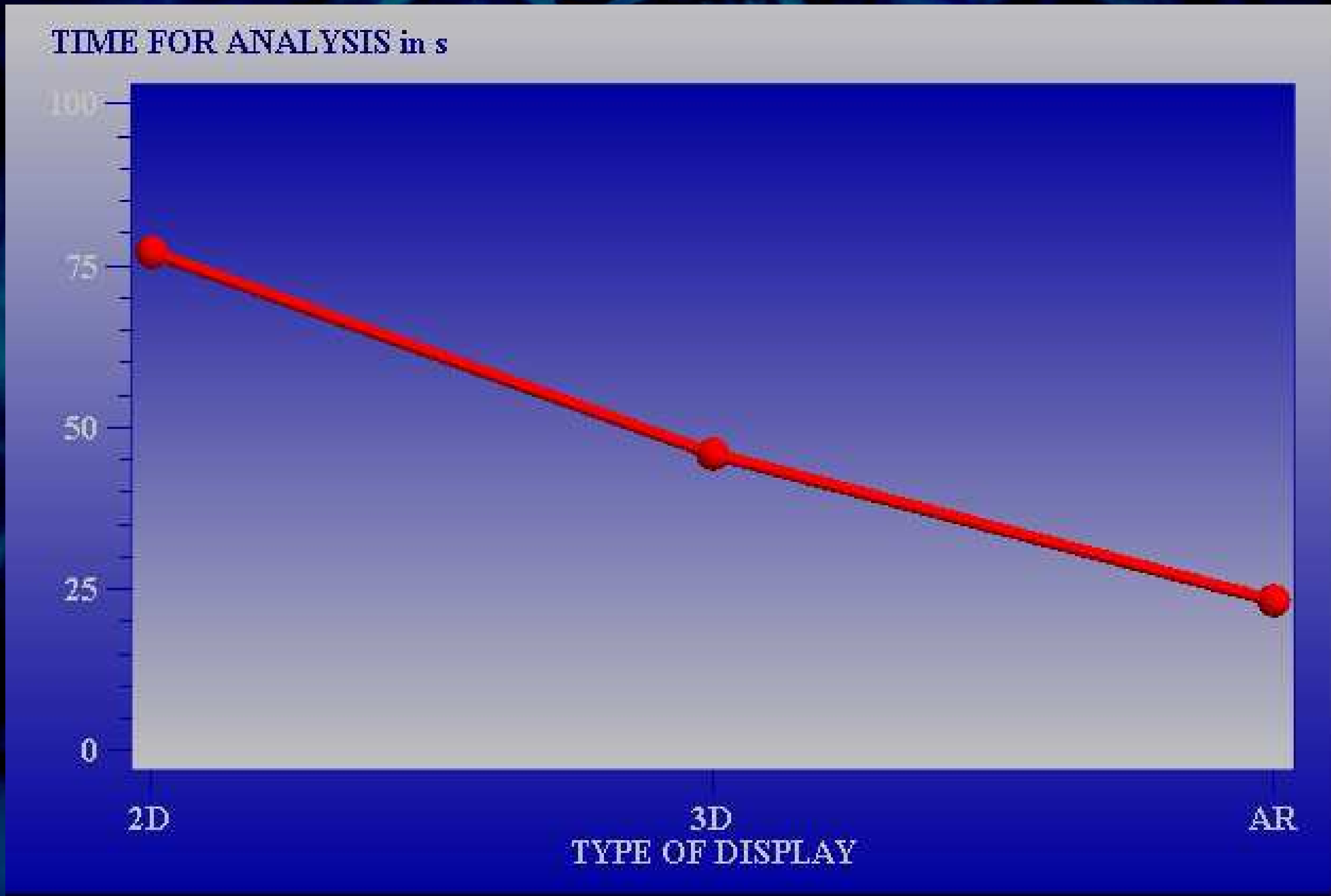
AR - Test Cases



AR – Test →Results

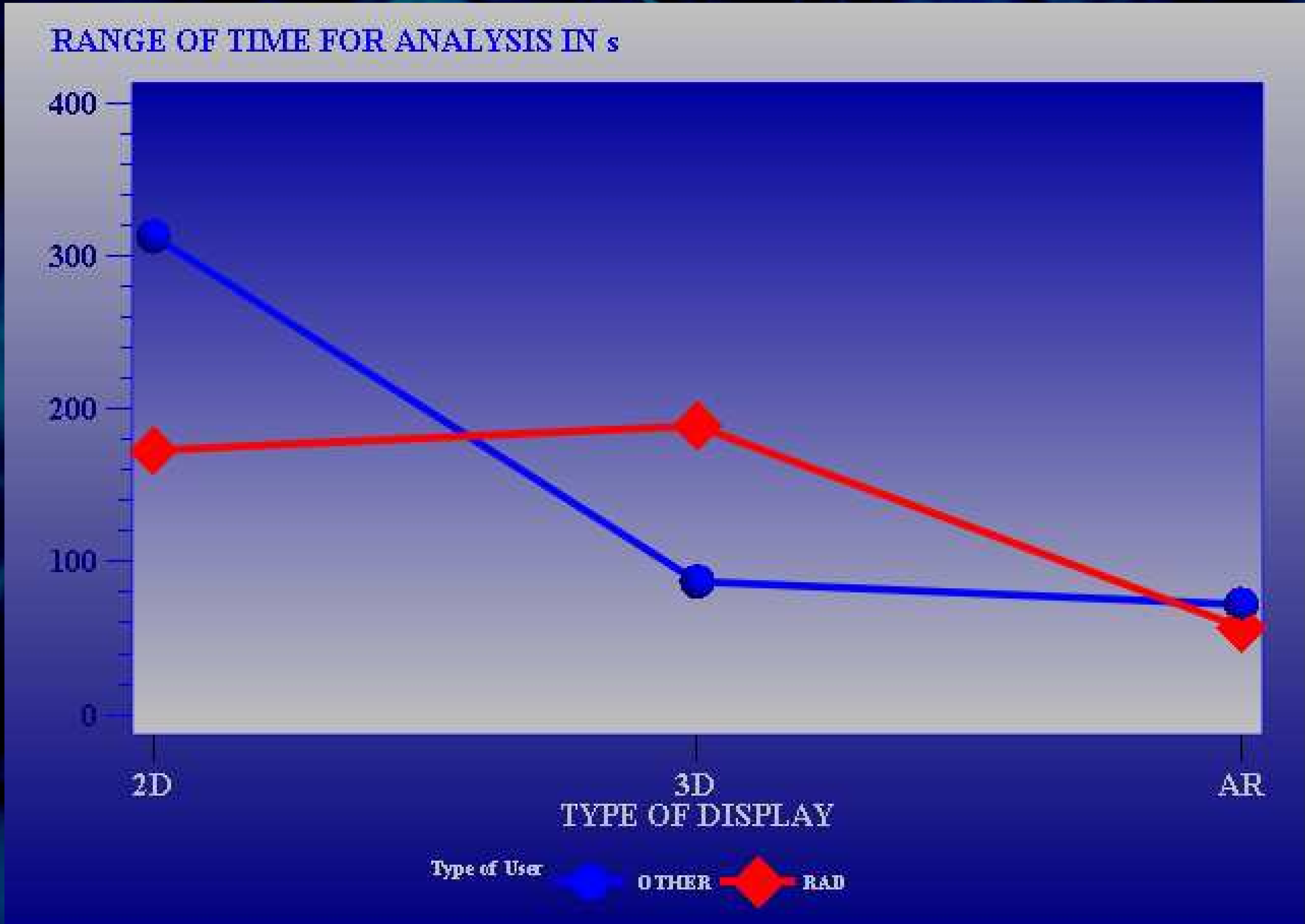


AR – Test → Results

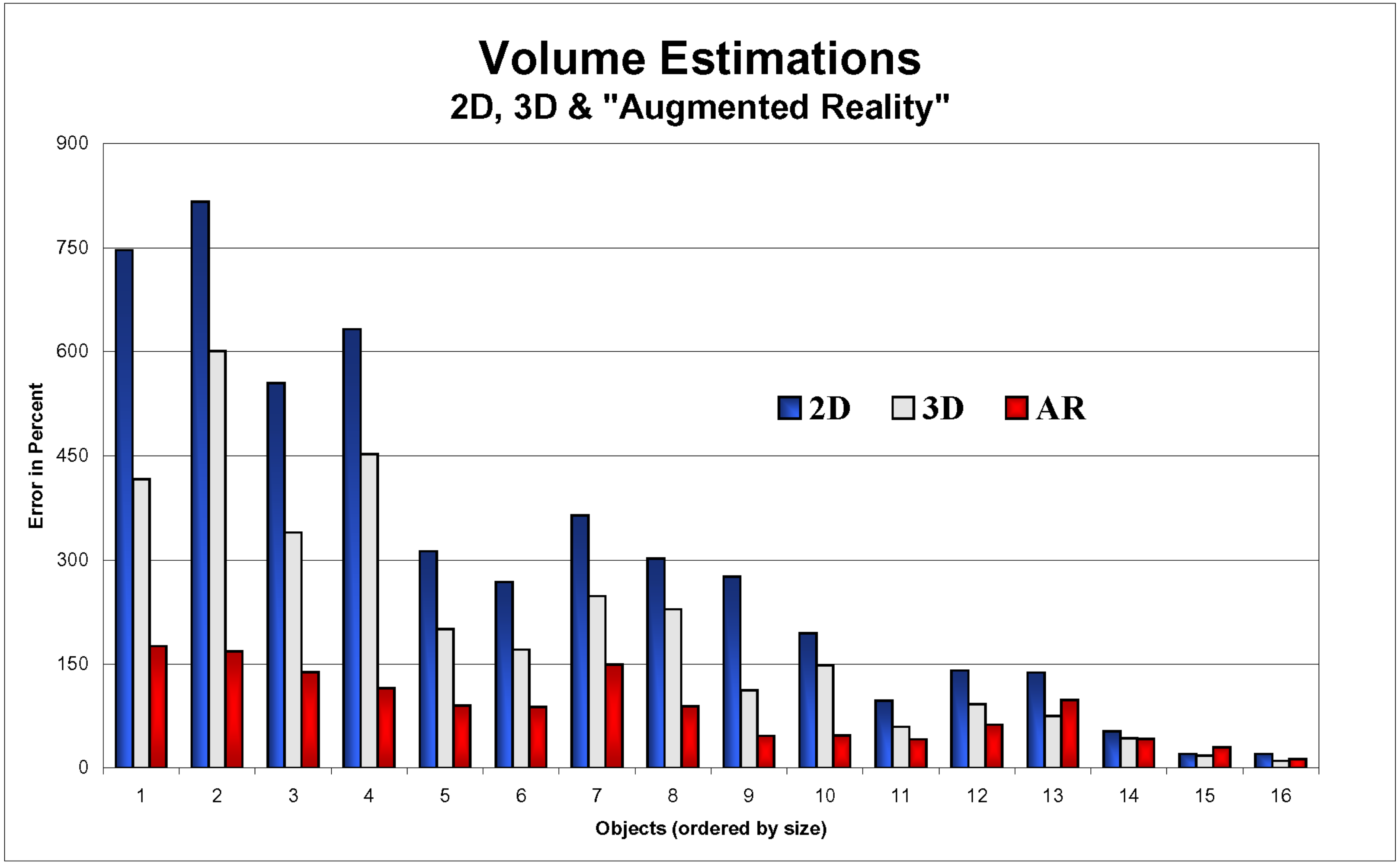


AR – Test → Results

AR – Test → Results



AR – Test → Results



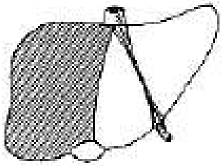
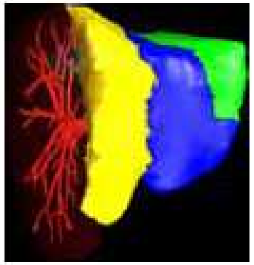
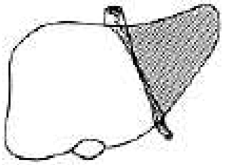
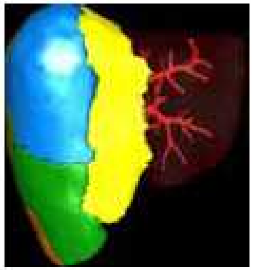
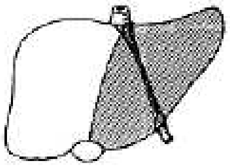
AR – Test → Results
ANOVA – Volume Error

Effect	DF	DF	F-Value	Pr > F
☑ Display	2	456	58.22	<.0001
☑ User	1	456	1.98	0.1596
☑ org. size	1	14	4.82	0.0455
☑ Display*User	2	456	1.57	0.2100
☑ Org. size*Display	2	4	569.13	0.0001
☑ org. size*user	1	456	0.29	0.5881

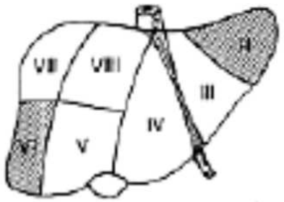
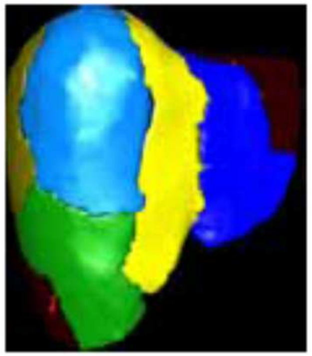
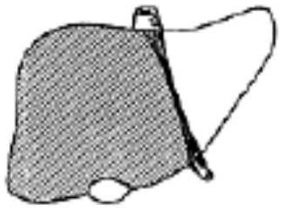
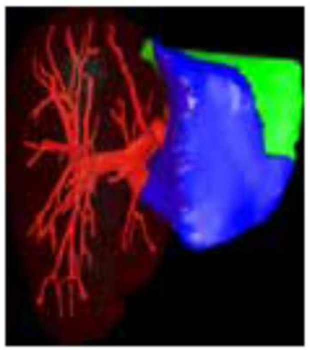
AR – Test → Results
ANOVA – Time

Effect	DF	DF	F	Value	Pr > F
☑ Display		2	352	95.92	<.0001
☑ User	1	352	1.24		0.2663
☑ Display*User	2	352	1.86		0.1579
☑ User*Szene	28	352	1.58		0.0333
☑ Org. size*user	0	.	.	.	

AR: Tools for Interaction

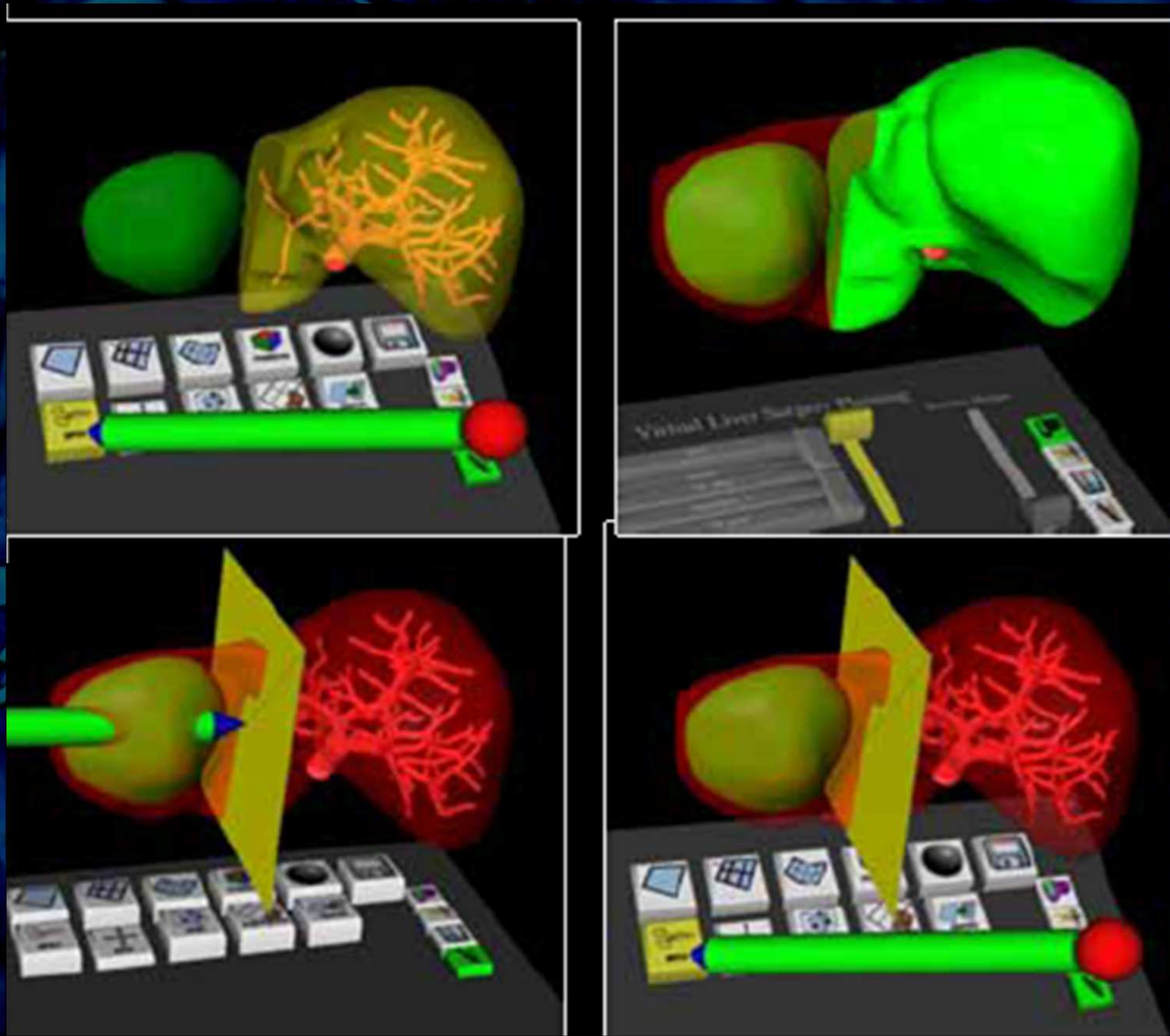
Application	Simulation	Description
 right-sided hemihepatec-tomy		In case of a right-sided hemihepatectomy, segment V, VI, VII, and VIII are removed.
 resection of left liver lobe		In case of the resection of the left liver lobe, only segment II and III are removed.
 left-sided hemi-hepatectomy		In case of a left-sided hemihepatectomy, segment IV is removed in addition to segment II and III.

AR: Tools for Interaction

Application	Simulation	Description
 anatomical resection		If more than one tumor must be resected, specific liver segments are removed. In this particular case, segment II and VI are target for resection.
 extended right-sided hemihepatec-tomy		An extended right-sided hemihepatectomy is required if a larger tumor is located in the right liver lobe, which means that segment IV must also be removed with segment V, VI, VII, and VIII. Only if segment II and III provide enough liver function, this type of resection can be carried out.

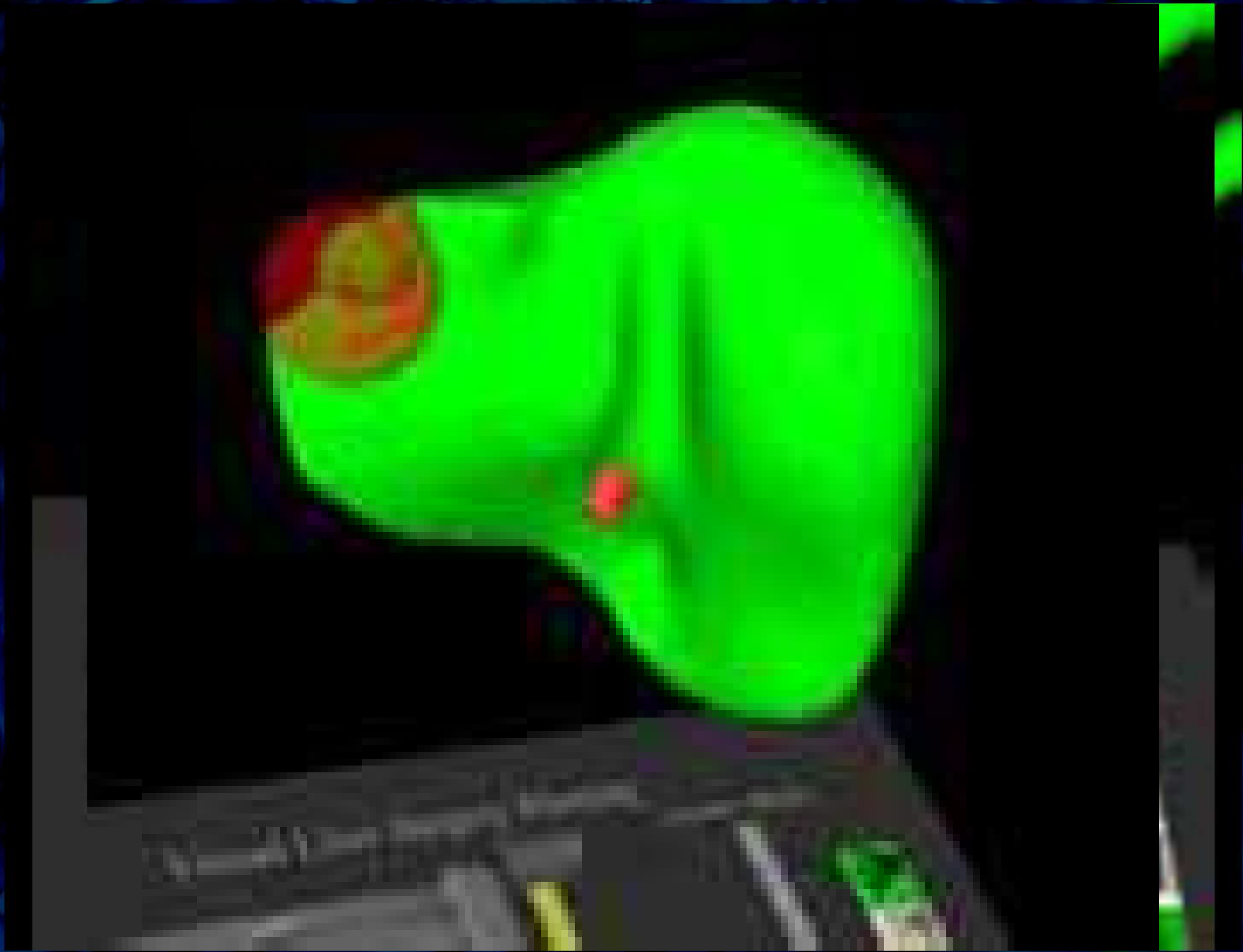
AR: Tools for Interaction

- ☑ **Resektion Tools:**
  - Hemihepat-ectomie



AR: Tools for Interaction

- ☑ **Wedge Resection**



AR: Operation Planning

Information about d048

# of tumors	1
Volume of liver	1,376 ml
Volume of tumor(s)	177 ml
Initial # of tetrehedra	95k
Final # of tetrehedra	115k
Proposal, resected segments	II
Surgical decision, resected segments	atypical
Volume of resected tissue	397 ml (anatomical), 325 ml (atypical)
Volume of remaining tissue	979 ml (anatomical), 1,051 ml (atypical)
Resected tissue (in %)	29 % (anatomical), 23 % (atypical)
Time required for planning	15 min

Robotics -Components

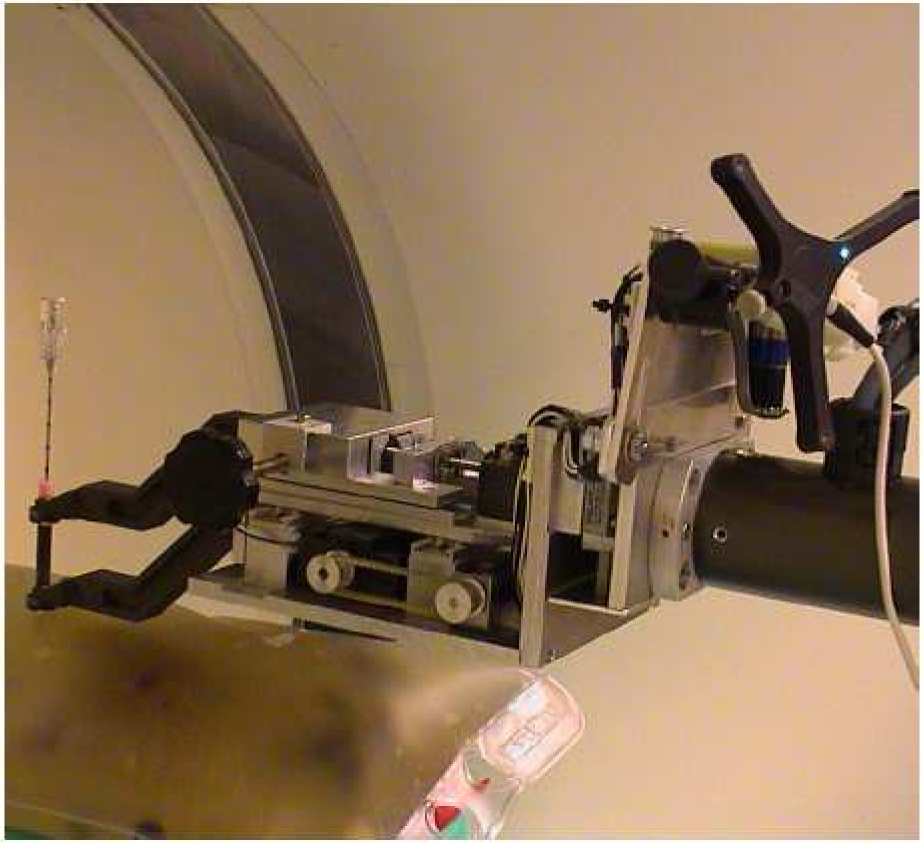
- **Mechanical structure (links, base, etc).**
  Required mass to provide enough structural rigidity to ensure minimum accuracy under varied payloads.
- **Actuators**
  Motors, cylinders, etc. that drive the robot joints. This might also include mechanisms for a transmission, locking, etc.
- **Main Controller**
  This computer interfaces with the user, and in turn controls the robot joints.
- **Effector, "End of Arm Tooling"**
  Designed for specific tasks.
- **Handheld Operation Unit, "Teach pendant"**
  Popular method for programming the robot. Small hand held device that can direct motion of the robot, record points in motion sequences, and begin replay of sequences.

Robots - Safety Regulations IR(EN 775)

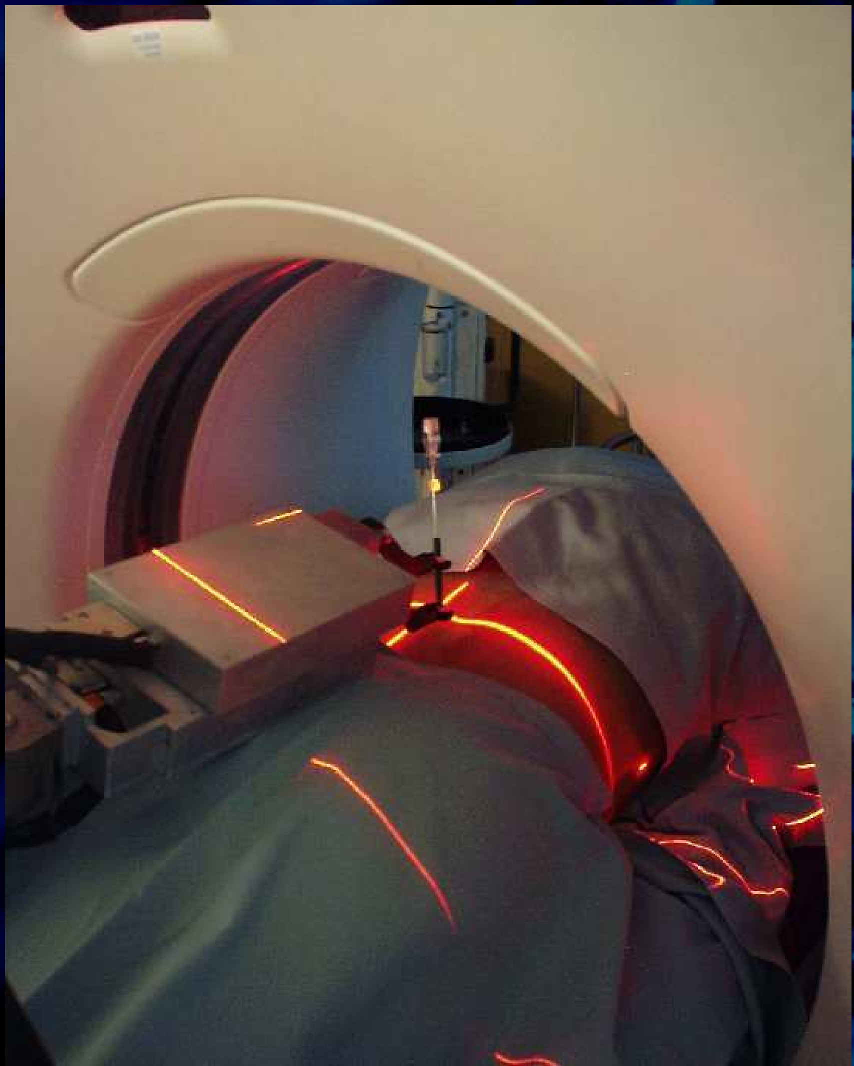
Sa

Industrial robots for medical Applications?

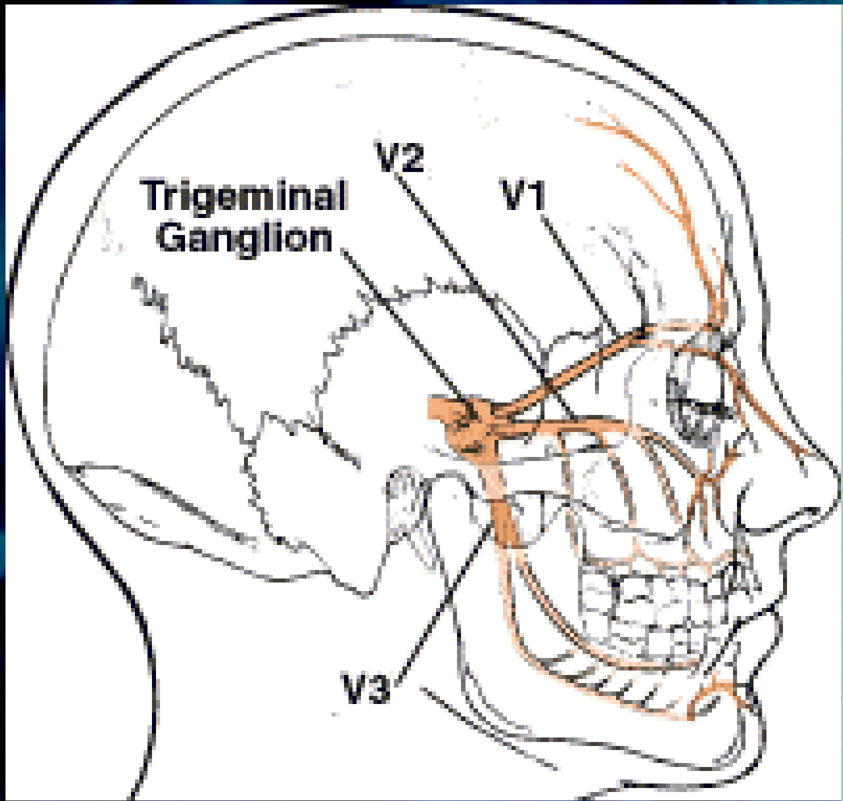
- Major design criteria IR:
  Working envelope ⇧, Velocity ⇧
- SEVERE modifications for system safety
  <u>(not only SW!)</u>
- Application Example:
  Orthopedics, Radiation Therapy

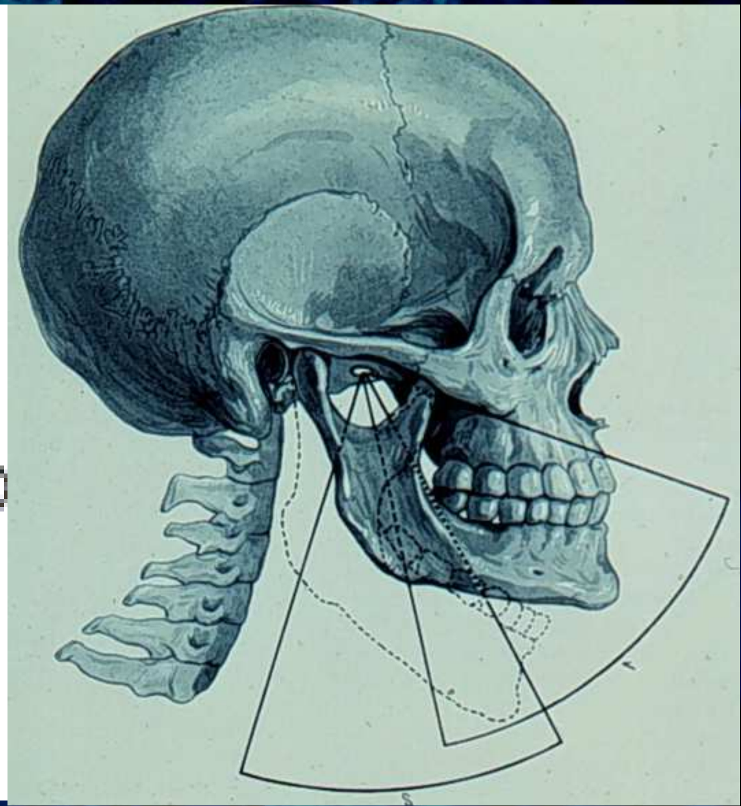


AUSTRIAN RESEARCH CENTERS
SEIBERSDORF



Robots/Navigation: RF Ablation in Trig.Neuralgia





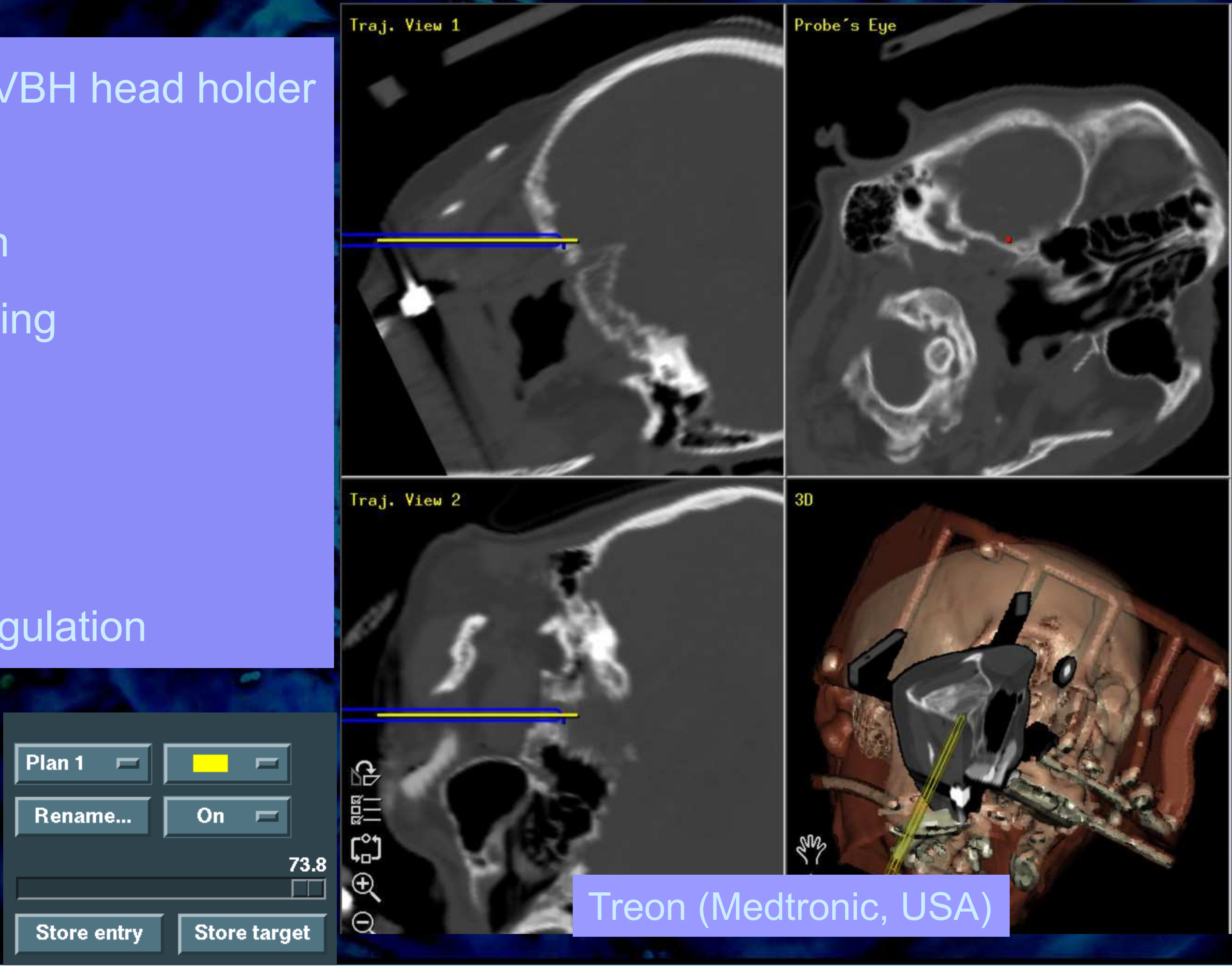
Procedure

1. Imaging in VBH head holder
2. Planning
3. Registration
4. Sterile draping
5. Targeting
6. Puncture
7. Control-CT
8. Thermocoagulation

VBH head holder + SIP-Lab Innsbruck Frame
(Medical Intelligence, Germany)

Procedure

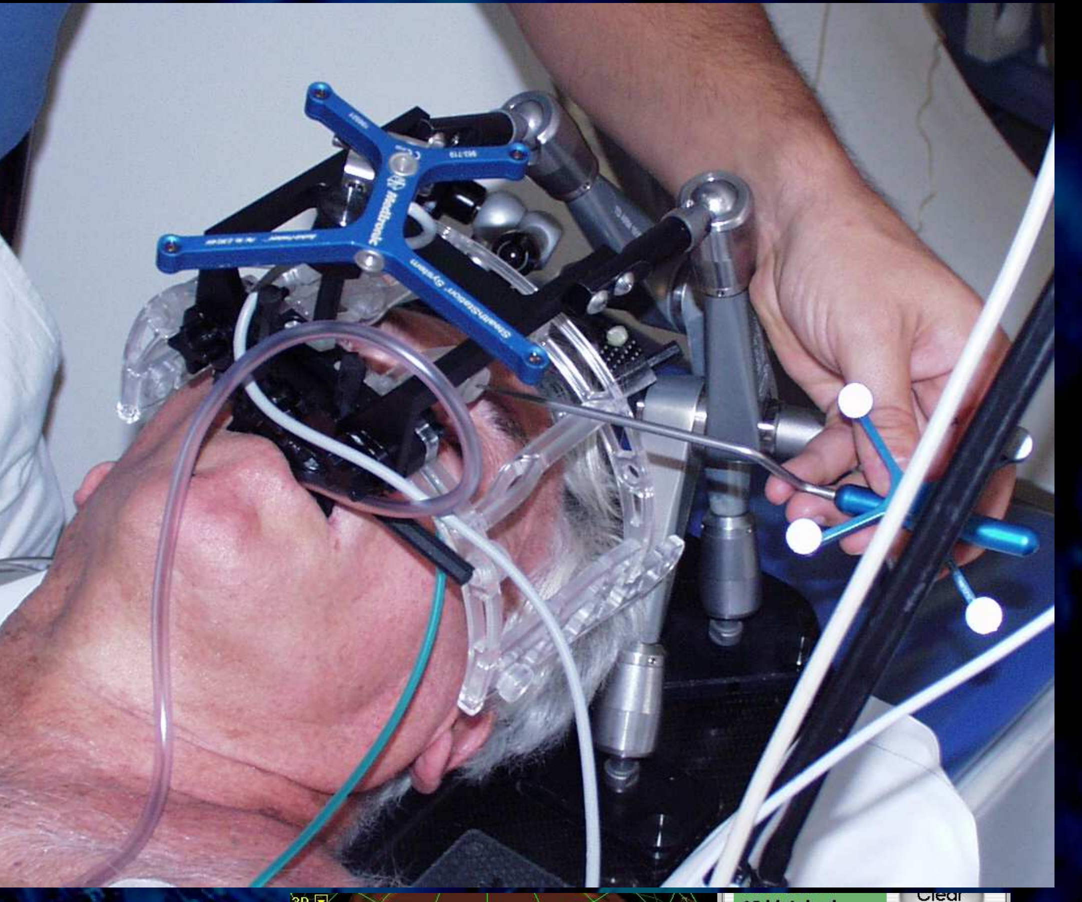
1. Imaging in VBH head holder
2. Planning
3. Registration
4. Sterile draping
5. Targeting
6. Puncture
7. Control-CT
8. Thermocoagulation

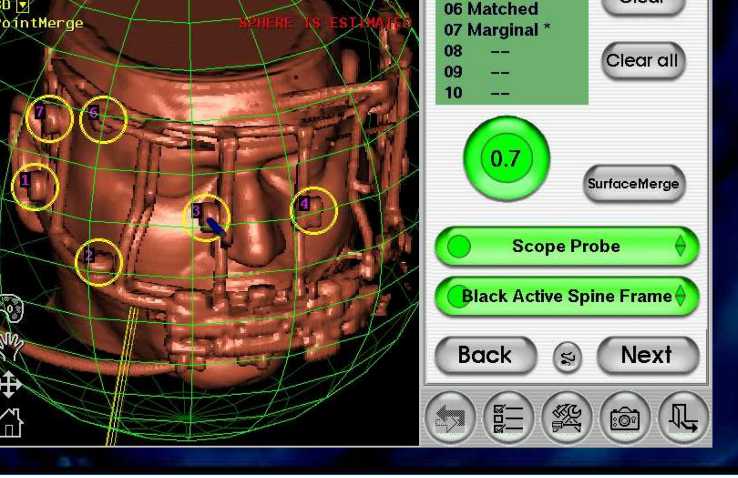


Treon (Medtronic, USA)

Procedure

1. Imaging in VBH head holder
2. Planning
3. Registration
4. Sterile draping
5. Targeting
6. Puncture
7. Control-CT
8. Thermocoagulation





Medical Robotics - Advantages

- ☺ More accurate than manual (esp. complex trajectories and/or exact positioning in 3D)
- ☺ Minimally invasive
- ☺ Robot guides / constrains (safer?)
- ☺ Consistent quality
- ☺ Repetitive motions without tiring
- ☺ History of motions recorded
- ☺ Small movements with small forces (scaling)
- ☺ „Indexing“
- ☺ Sterilisation, resistant against germs/radiation etc.

Conclusion