



# Panel Discussion: Clinical Feasibility of AR - Requirements, Developments, Evaluation, and Clinical Integration

moderated by Wolfgang Birkfellner (*Medical University Vienna, Austria*)

organized by Joerg Traub (*CAMP, TU Munich, Germany*)

- Ali Khamene  
(*Siemens Corporate Research*)
- Philip Edwards  
(*Imperial College, London, UK*)
- Pierre Jannin  
(*INSERM, Visages/U746 INSERM, INRIA, CNRS Université de Rennes 1 France*)
- Kensaku Mori  
(*Nagoya University, Japan*)
- Terry Peters  
(*Robarts Research Institute, University of Western Ontario, Canada*)



9th. MICCAI Conference  
- Copenhagen, Denmark



AMI-ARCS 2006

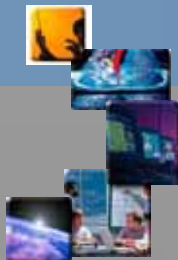
International Workshop on Augmented environments  
for Medical Imaging and Computer-aided Surgery

# Wolfgang Birkfellner

Medical University Vienna, Austria

October 06, 2006

AMI-ARCS Panel Discussion



AMI-ARC Copenhagen 2006

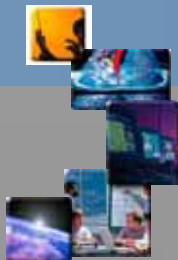
# Ramp at SCR



Ali Khamene, PhD

Project Manager @ Interventional Imaging

SIEMENS CORPORATE RESEARCH



# (RAMP)

## Reality Augmentation for Medical Procedures

SIEMENS CORPORATE RESEARCH



→ Head mounted camera triplet – two optical-one IR

→ Head mounted display

→ Retro-reflective marker

SCR

Interventional  
Imaging

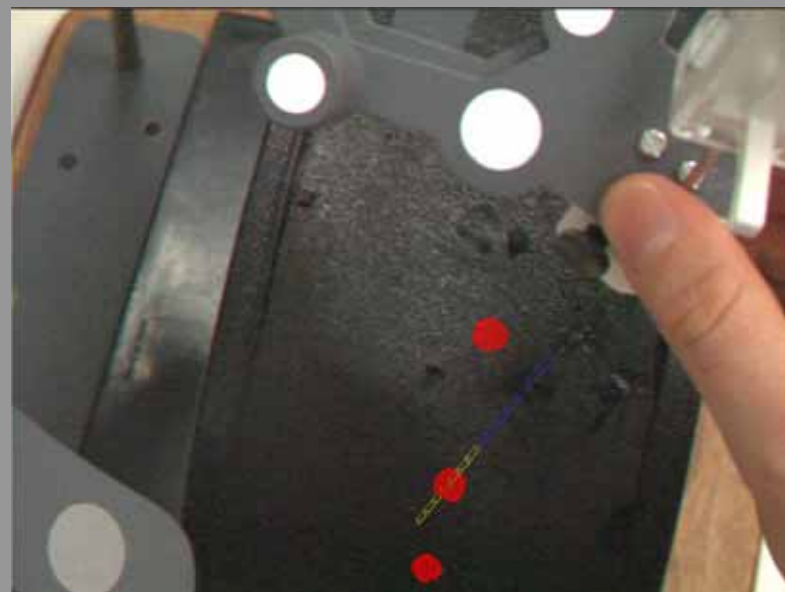
# Clinical Applications



Neurosurgical iMRI-OR  
*UCLA*

# Clinical Applications

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Interventional CT  
*Brigham & Woman's*

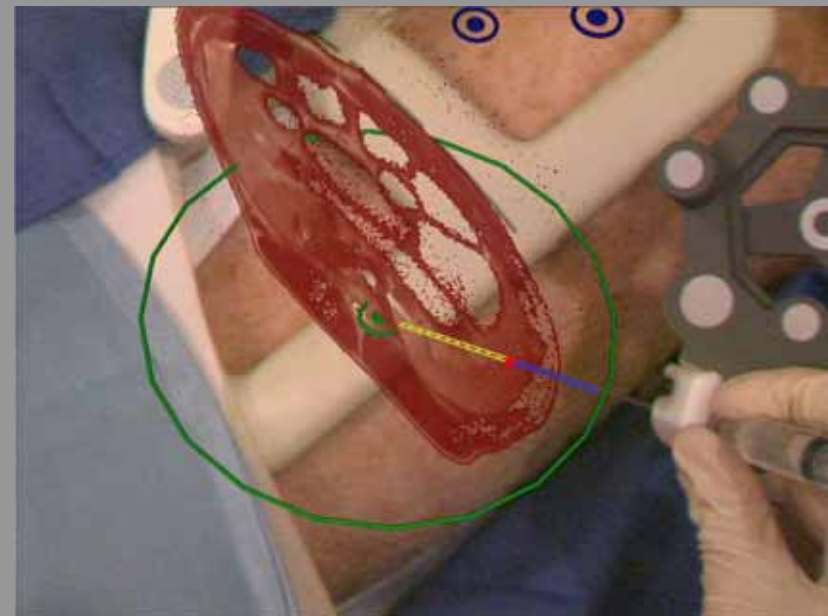
Extensive phantom studies with three  
interventional radiologists

SCR

Interventional  
Imaging



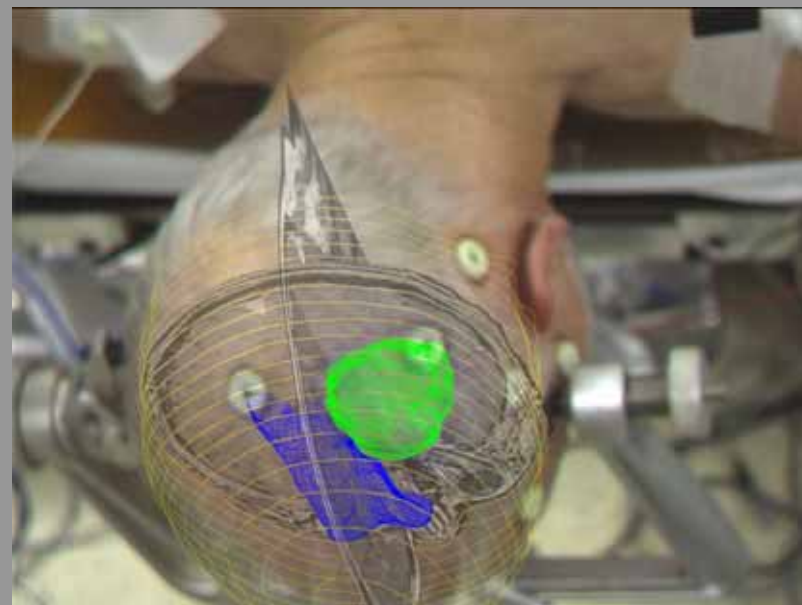
# Clinical Applications



Interventional MR  
*Cleveland UH*

- Extensive phantom studies
- 2 pigs with 6 targets, up to 13 cm deep, needle localization below 1 cm error

# Clinical Applications



Craniotomy Planning

*Univ. of Penn.*

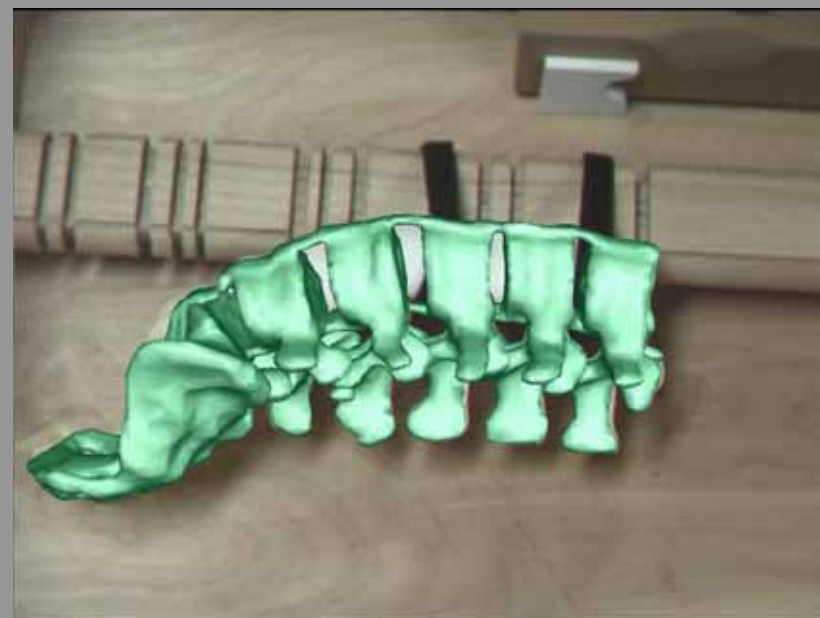


# Clinical Applications



Interventional (3D) US  
*SCR*

# Clinical Applications



Orthopedics  
*LMU Munich*



# Visibility

SIEMENS CORPORATE RESEARCH



- 3 Exhibitions
- >10 Conf. Publications
- 3 Journal Publications

**Augmented Reality Visualization for CT-guided Interventions: System Description, Feasibility, and Initial Evaluation in an Abdominal Phantom<sup>1</sup>**

**Walter Dier, MD**  
**Peter Dier, PhD**  
 U. Jansen (Ulmer) MD  
 M. Ottermann, PhD  
 Sebastian Vogt, MD  
 Peter Schöler, PhD  
 Burkhard Meier  
 EuroScreening, AG  
 Sharp, Stiermer, AG

**Abstract**

The purpose of this study was to evaluate the feasibility and performance of an augmented reality (AR) visualization prototype for virtual computed tomography (CT)-guided interventional procedures in a non-invasive abdominal phantom. With the aid of AR glasses, three radiologists performed 20 attempts at targeting simulated liver lesions of different sizes (range, 10–33 mm) with a biopsy needle. The position of the needle tip relative to the lesions was recorded by using fluoroscopy and CT. With AR, all positions located were successfully targeted with the first needle pass in all cases. In the course of these results, AR visualization for CT-guided interventional approaches for the liver and other lesions and various lesions targeting in a phantom.

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**Keywords:** augmented reality, visualization, CT-guided interventional procedures

**Introduction**

CT-guided interventional procedures are a common and effective method for the diagnosis and treatment of various abdominal diseases. However, the procedure is often associated with a high degree of radiation exposure and a high degree of patient discomfort. In addition, the procedure is often associated with a high degree of radiation exposure and a high degree of patient discomfort. In addition, the procedure is often associated with a high degree of radiation exposure and a high degree of patient discomfort.

**Conclusion**

AR visualization for CT-guided interventional procedures is a promising approach for the diagnosis and treatment of various abdominal diseases. However, the procedure is often associated with a high degree of radiation exposure and a high degree of patient discomfort. In addition, the procedure is often associated with a high degree of radiation exposure and a high degree of patient discomfort.

**References**

1. Dier W, Dier P, Jansen U, et al. Augmented Reality Visualization for CT-guided Interventions: System Description, Feasibility, and Initial Evaluation in an Abdominal Phantom. *Journal of Medical Imaging and Biomedical Engineering*. 2014;4(1):1-8.

**An Augmented Reality System for MR Image-guided Needle Biopsy: Initial Results in a Swine Model<sup>1</sup>**

**Robert H. Weiser, MD**  
 Sebastian Vogt, MD  
 M. Ottermann, PhD  
 Peter Schöler, PhD  
 David S. Taylor, PhD  
 Frank Dier, PhD  
 Sebastian Vogt, MD  
 Burkhard Meier  
 EuroScreening, AG  
 Sharp, Stiermer, AG

**Abstract**

The purpose of this study was to evaluate the feasibility and performance of an augmented reality (AR) system in combination with a 3.0 T closed-bore magnetic resonance (MR) scanner as a navigation tool for needle biopsy.

**Methods and Results**

The experimental protocol had institutional medical ethics and was conducted retrospectively. Simulated lesions were performed in phantoms by using MR image targets, needle with a diameter of 2 mm, and 20 virtual lesions. The position of the needle tip in MR and MR image space was registered to multiple imaging planes, and virtual and real needle tip localization system were evaluated. Two AR-guided biopsies were performed in three pigs, and the duration of each procedure was determined. After successful procedure, the distance to the target was measured on MR images. The workflow from the selected in-plane location and the final location was calculated. A registered anatomical analysis of lesions was used to determine whether the placement error in a particular dimension (x, y, or z) differed from the others.

**Results**

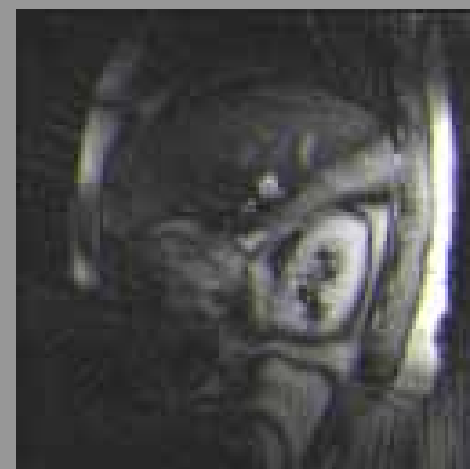
For the 20 virtual targets, a mean error of 3.3 mm ± 0.5 (standard deviation) was calculated. A registered anatomical analysis of lesions indicated no statistically significant differences (P > .05) in the errors in any particular dimension. For the real targets, all positions were made the 5 mm diameter tube in the transverse plane. The needle depth was within the target plane in 11 biopsy procedures; the mean distance to the center of the target was 3.22 cm (95% confidence interval: 1.77 mm, 5.34 mm). For nine biopsy procedures, the needle tip was inside the target plane, with a mean distance to the edge of the target plane of 1.14 cm (range, 0.57–2.81 mm). In the virtual space, the placement was successful in all 20 cases, with a mean registration distance of 0.6 mm ± 0.36. The average procedure time was 19 minutes per patient.

**Conclusion**

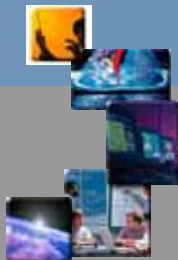
Biopsy procedures performed with a combination of a closed-bore MR scanner and an AR system are feasible and accurate.

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# A Challenge in AR : Respiratory Motion



- **respiration**  
targets in abdomen/thorax shift





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# AR Experiences and Expectations

Eddie Edwards, Imperial College, London, UK

October 06, 2006

AMI-ARCS Panel Discussion





## AR Experiences and Expectations

- Historical projects – MAGI & MARS
- Current project – AR for TECAB
- Embryonic projects
  - Robotic AR for the lower abdomen
  - See-through AR and navigation
- Common features of these projects
- Important questions for clinical AR



# Microscope-assisted Guided Interventions (MAGI)





## Microscope-assisted Guided Interventions (MAGI)

- ENT and Neurosurgery application
- Was in clinical use for 7 years
  - See-through AR only adds information
  - This enabled early evaluation in the OR
  - Initial functional model tested very early
  - Project development with continual clinical feedback
- Developed significantly over that time
  - Entire system rewritten twice
  - Simulation for accuracy analysis
- Promising clinical evaluation

# MAGI Clinical Evaluation

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Patient ID	Pathology	- Copenhagen, Denmark Accuracy (mm)	International Workshop on Augmented environments for Medical Imaging and Computer-aided Surgery Clinical Effect	Comments
A	epidermoid cyst	3-5	None	Anatomical registration
B	glomus jugulare	>10 (fail)	None	Radiotherapy mask
C	ethmoid carcinoma	2 (initial)	None	Initial LADS design
D	carotid lesion	2-3	None	LADS Mk II
E	petrous apex cyst	1	Increased confidence	Current LADS design
F	superficial AVM	3-4	Craniotomy navigation	Brain shift
G	facial nerve angioma	<1	None	Highly accurate LADS
H	clivus meningioma	1-2	None	Uncomfortable bone pin
I	vestibular Schwannoma	2	None	Good 3D perception
J	parietal meningioma	~3-10	Craniotomy navigation	Poor LADS fit (few teeth)
K	vestibular Schwannoma NF2	1-2	Improved outcome	Aided in long procedure
L	subfrontal meningioma	1-2	None	3D perception of vessel
M	olfactory neuroblastoma	<1	None	LADS repositioning good
N	subfrontal meningioma	fail	None	Inappropriate draping
O	recurrent ethmoid carcinoma	1	Full extraction	Pointer only + LADS
P	ethmoid carcinoma	1-2	Improved confidence	Imaging 1 week earlier
Q	adenocarcinoma	1	Improved confidence	Bone surface registration



## Summary of Clinical Evaluation

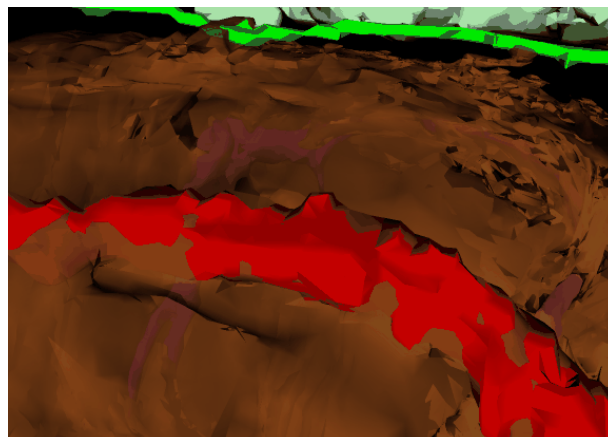
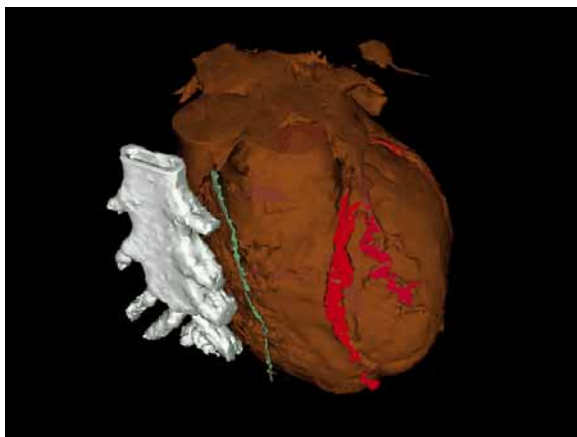
	Number of operations
Improved outcome	2
Improved craniotomy	2
Improved confidence	3
No difference	10
Impaired	0





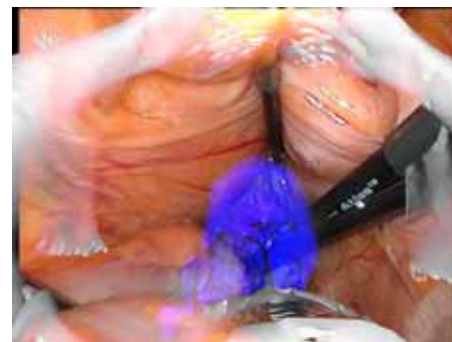
## Image-guided TECAB

- Uses da Vinci robot
- Requires registration of a 4-D model to stereo video + soft tissue deformation

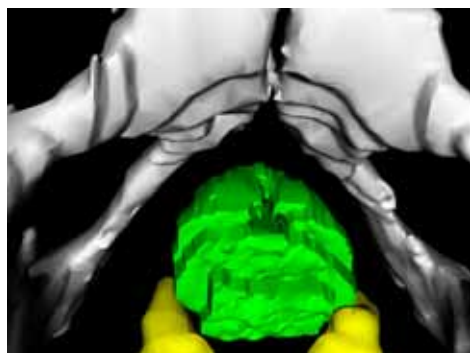




## Future Projects – da Vinci



Rectal cancer surgery



Prostate cancer surgery



## Common Features

- Minimisation of impact on surgical workflow
  - Incorporation into devices that are already present
  - See-through AR for MAGI
  - External video mixer for da Vinci (real view has no lag)
- Little or rare movement of the device, so little lag issue
- Stereo visualisation
- Concentration on accuracy



## Important Questions for Clinical AR Systems

- Is there a real justification for using AR?
  - Could the task be better performed another way?
    - Robotically
    - Entirely virtually (do we really need to see the real scene?)
  - Surgery with display of critical structures is a good example
- How can the system be easily and ergonomically incorporated into the OR?
- Perception is a major issue (see MICCAI paper by Tobias Sielhorst)
  - What is the right mix of real and virtual?
  - What is the optimal display paradigm?



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# Patient Models and Surgical Models for Computer assisted Neurosurgery

Pierre Jannin, INSERM, Visages/U746 INSERM, INRIA, CNRS  
Université de Rennes 1 France

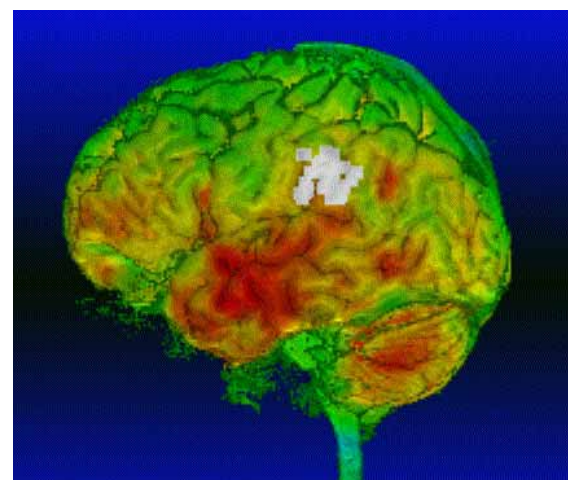
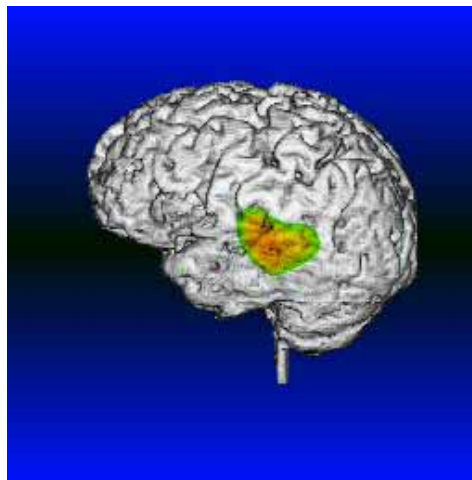
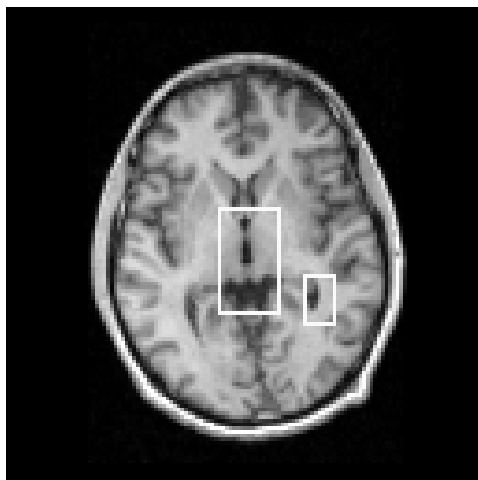
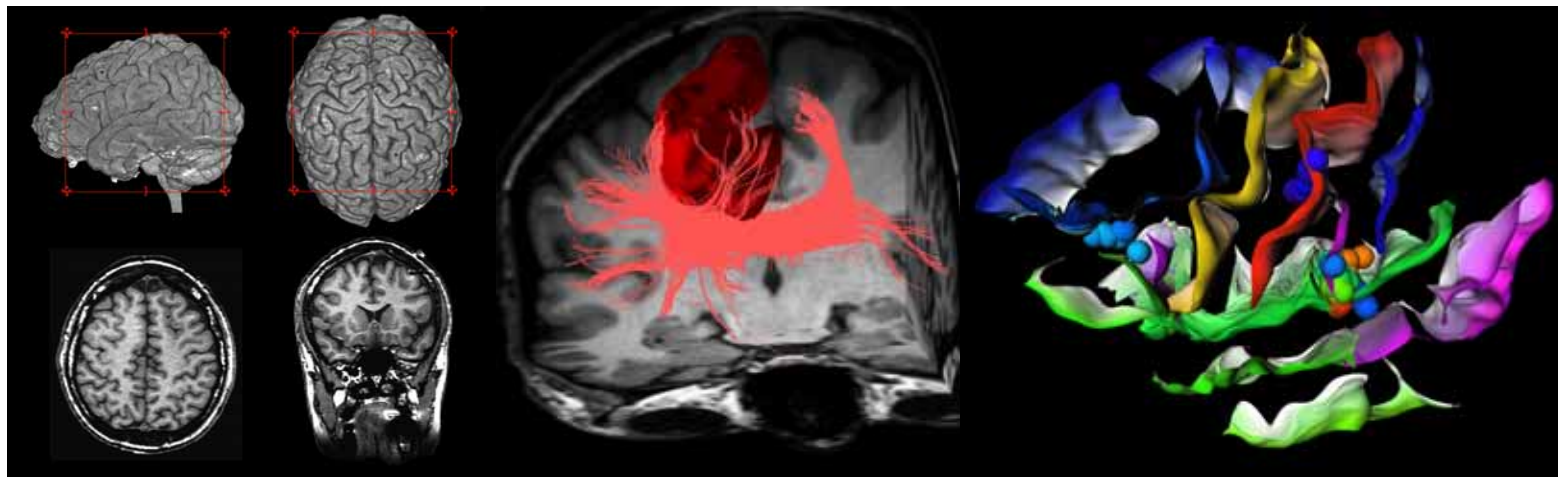
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## Patient Model Creation



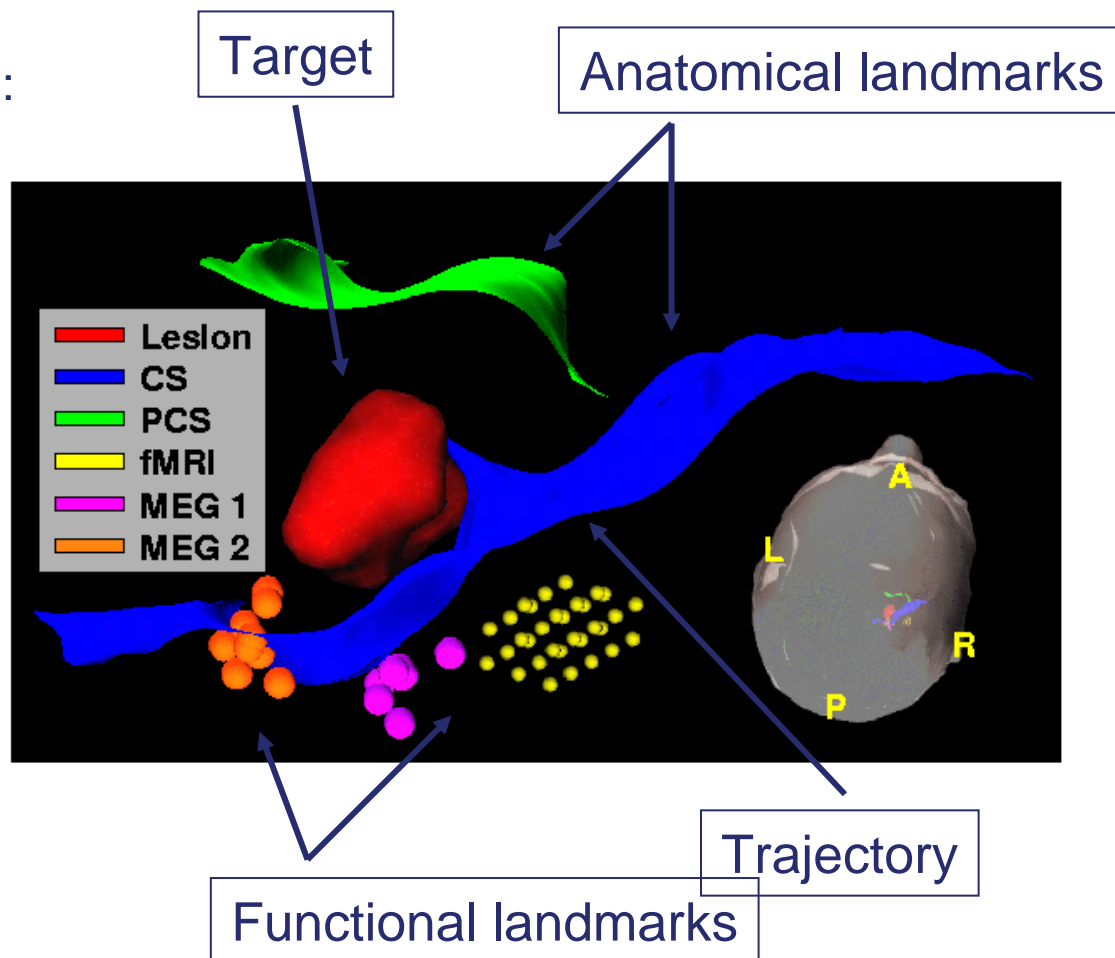
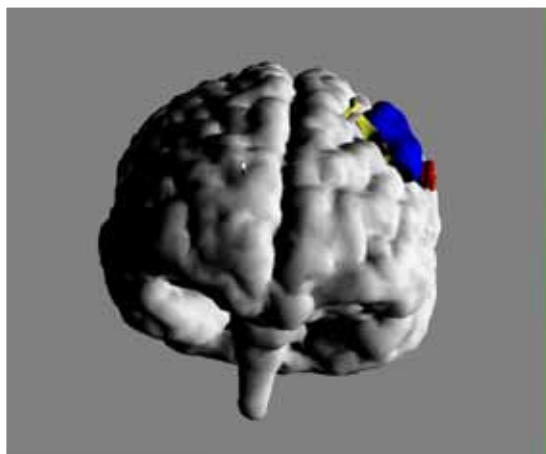


## Patient Model for Surgical Planning

To define the 3D surgical scene :

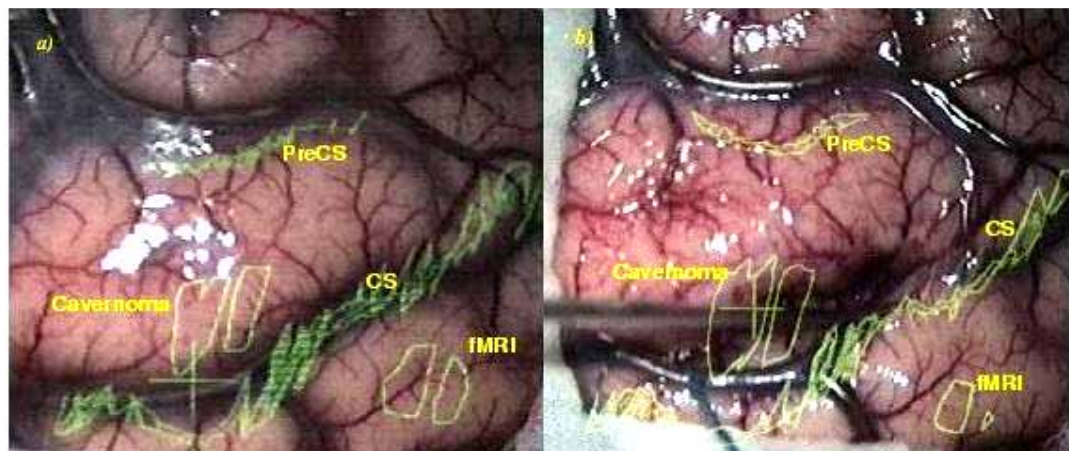
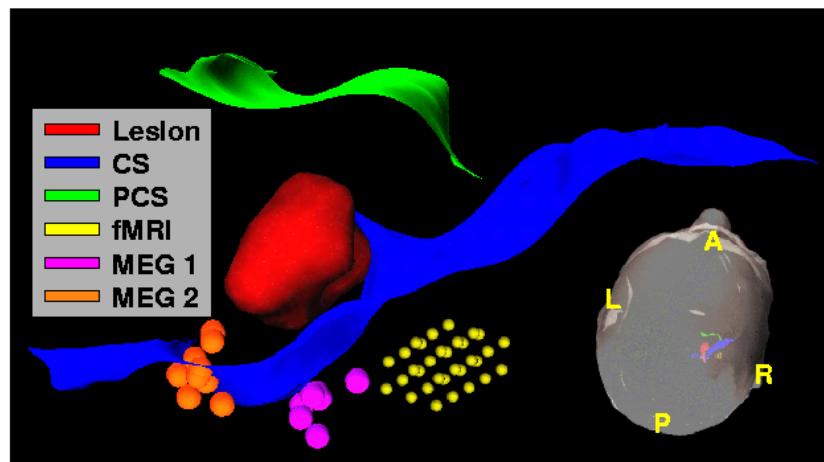
- Target (s),
- Areas to be avoided,
- Reference areas,
- Trajectories

from multimodal images





## Patient Model in the OR : Augmented Reality

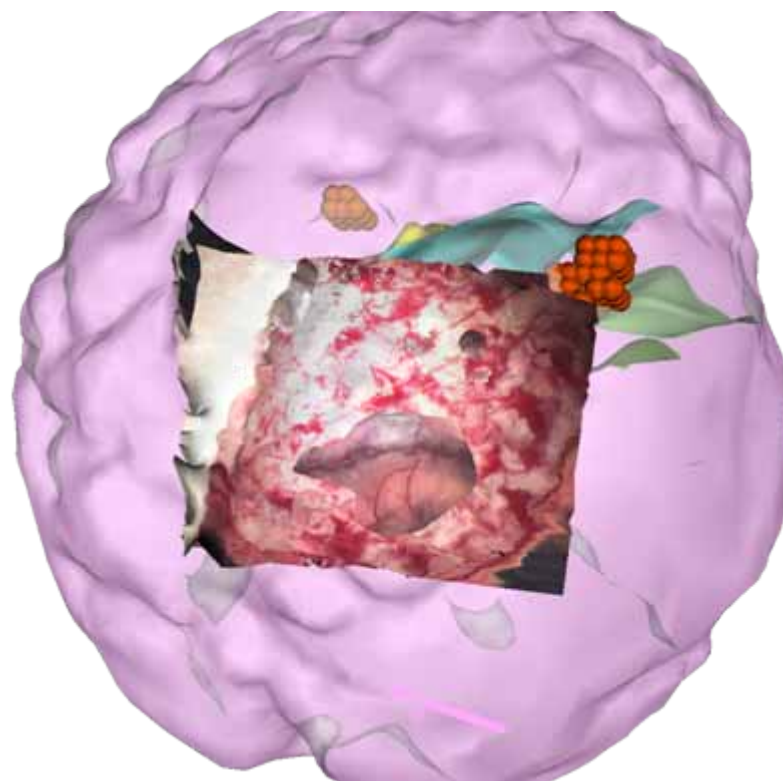
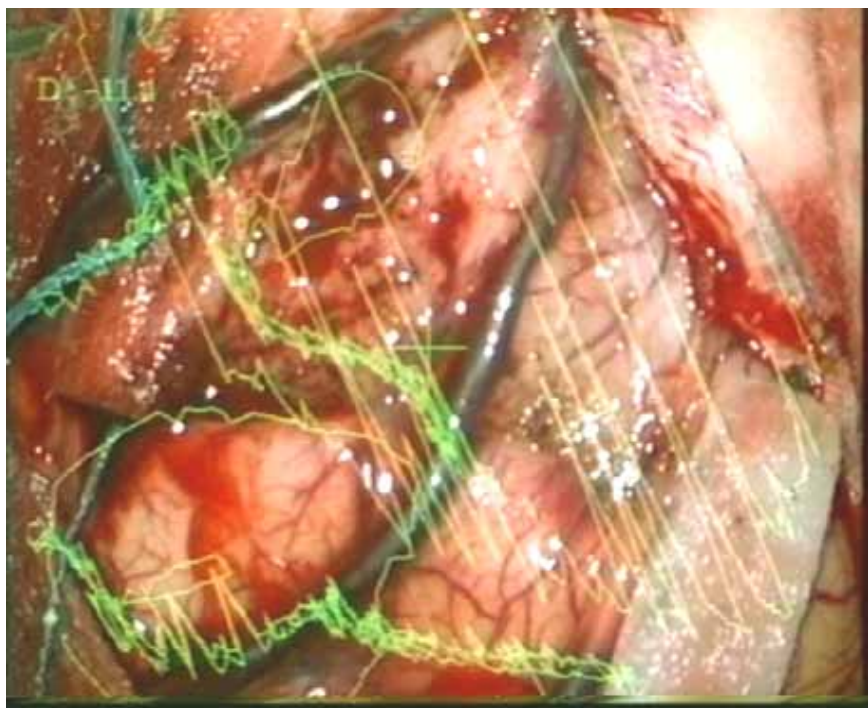


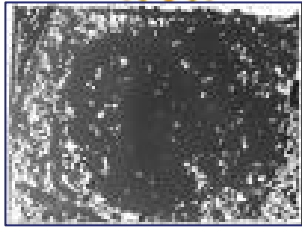




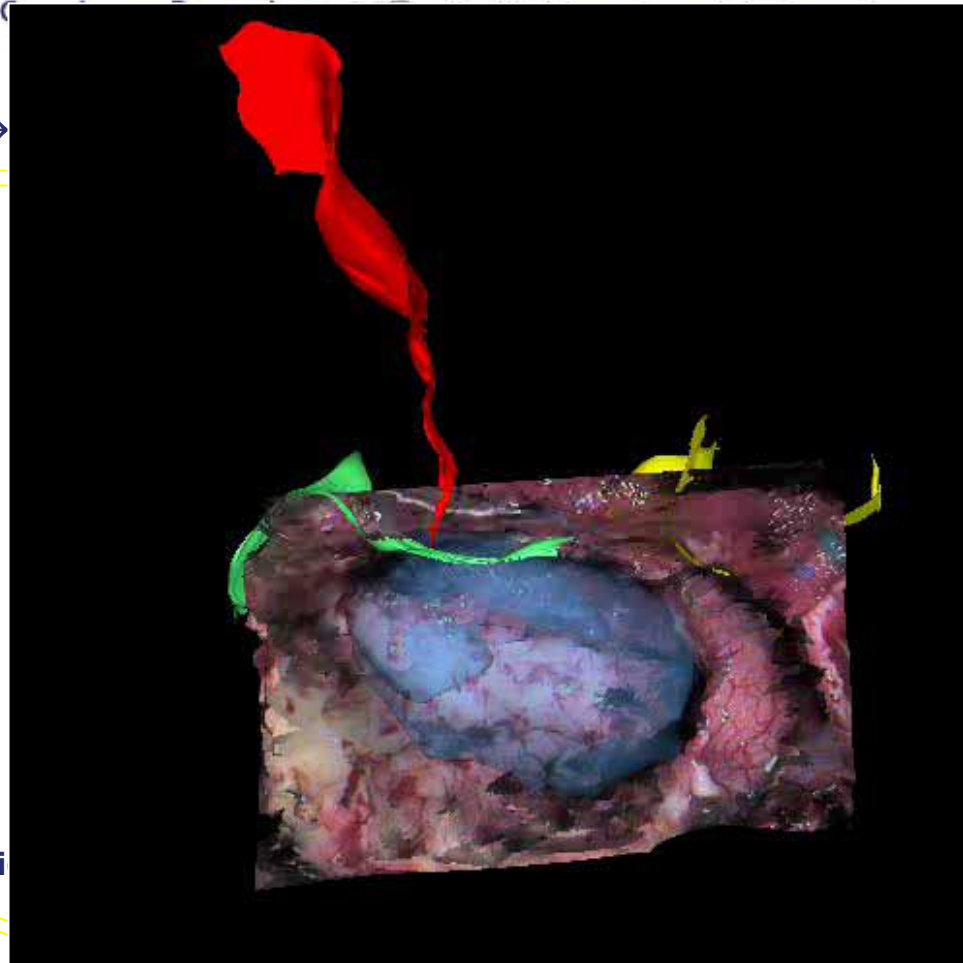
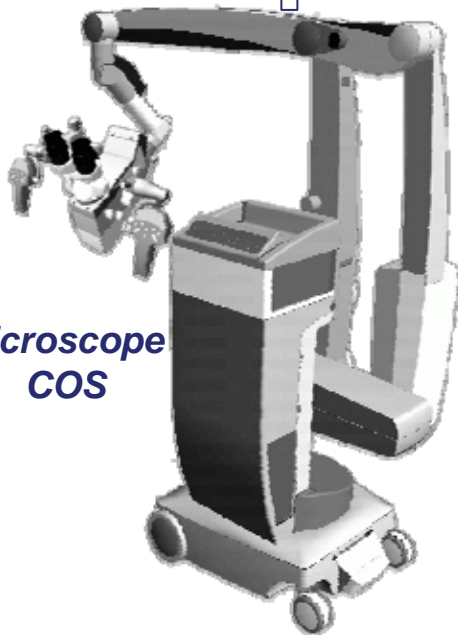
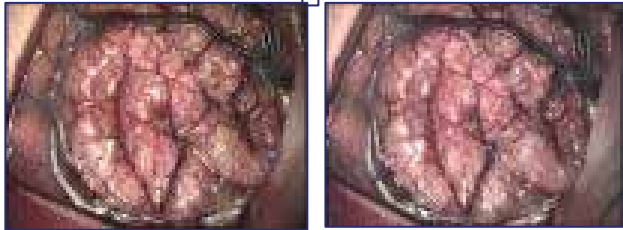
## Pb: 2D, Monochrome, and Too Much Info

→ Augmented virtuality

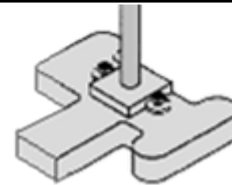
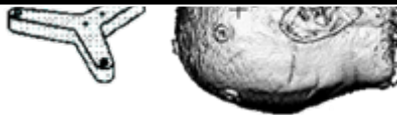




$T_d \rightarrow$



$T_{mi}$



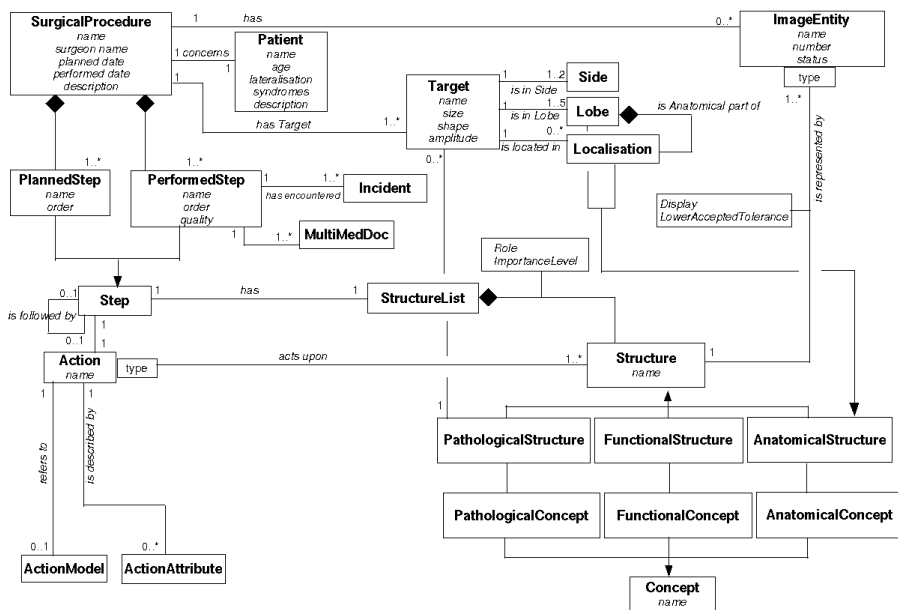
[Paul, Fleig, Jannin, IEEE TMI, 24(11) 2005]



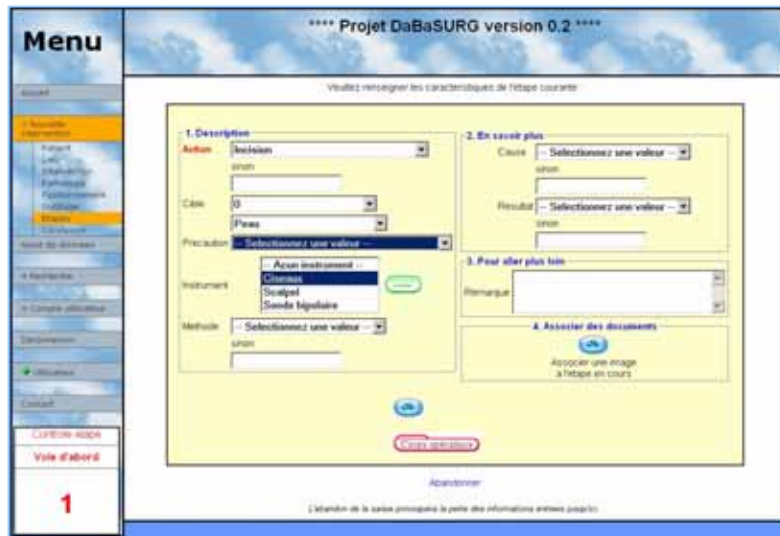


# Surgical Models

- Explicit knowledge-description of surgery



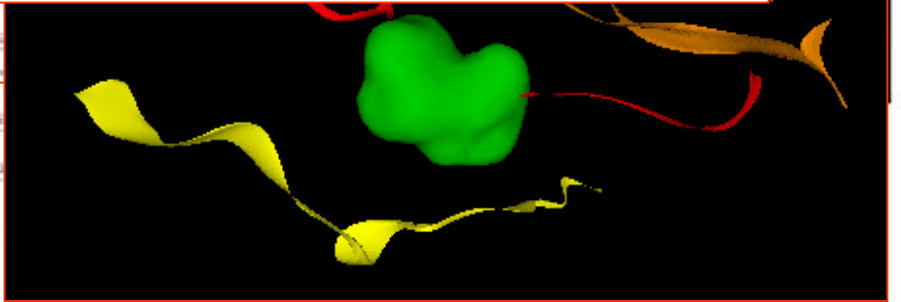
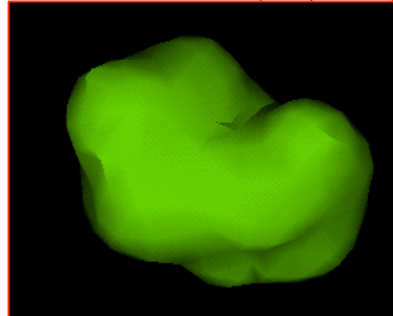
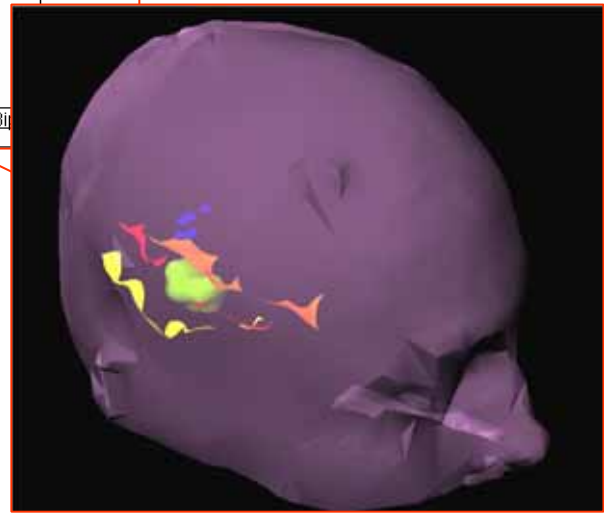
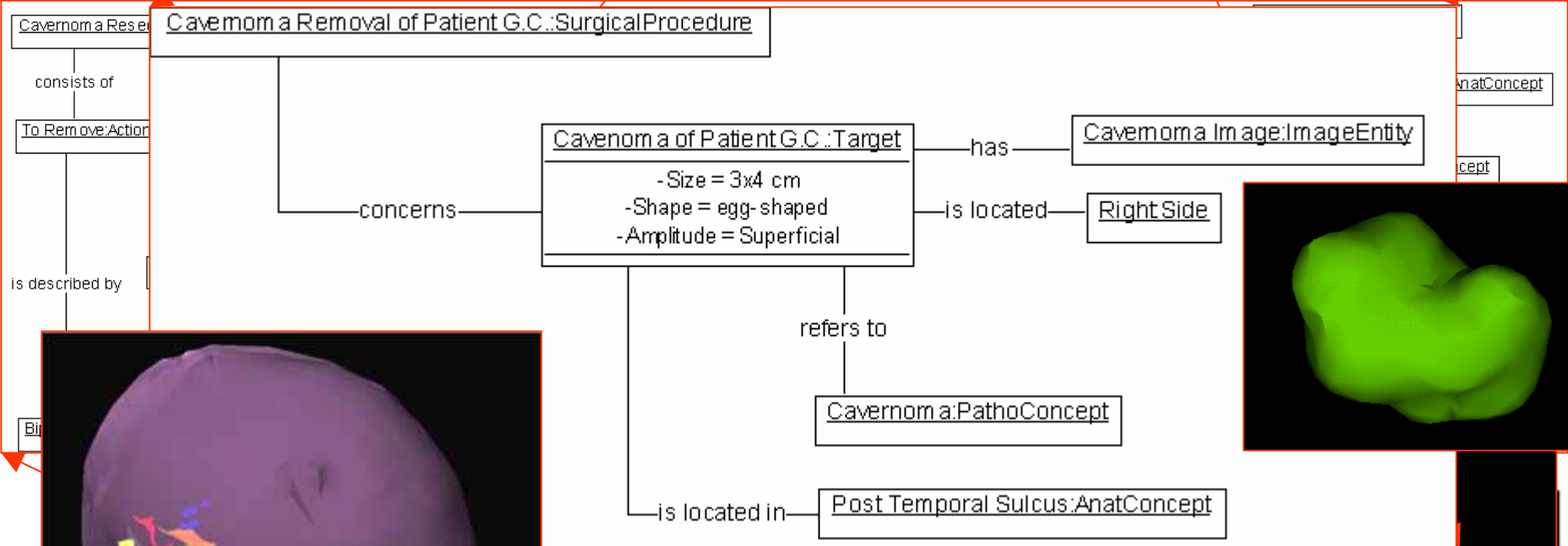
Surgical Ontology



Web-based software for description



# Description before surgery





# Surgical Knowledge Extraction



$$= f ( \text{Brain Lobes} )$$



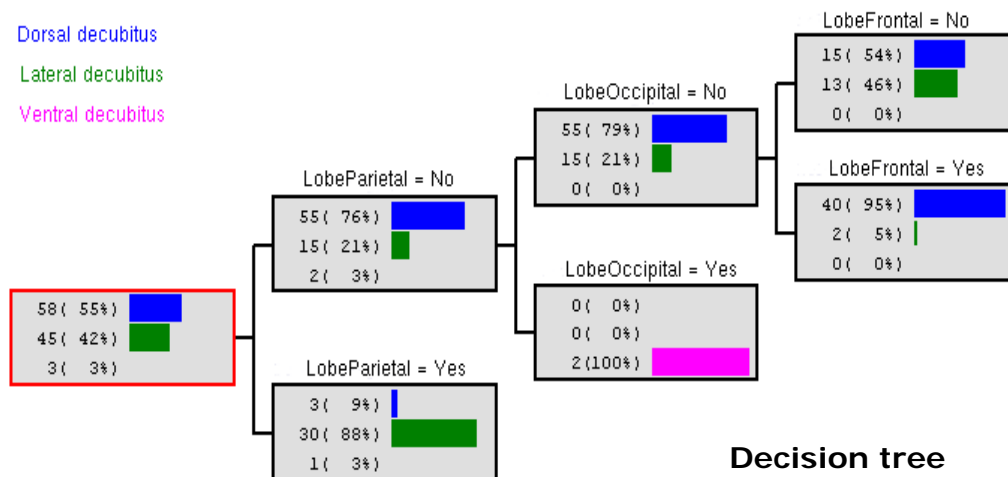
Dorsal decubitus

Lateral decubitus

Ventral decubitus

Prediction : CART  
and C 4.5

[Raimbault, Morandi, Jannin,  
SPIE Medical Imaging, 2005]



Decision tree



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# Medical AR at Nagoya University

Kensaku Mori, Nagoya University

October 06, 2006

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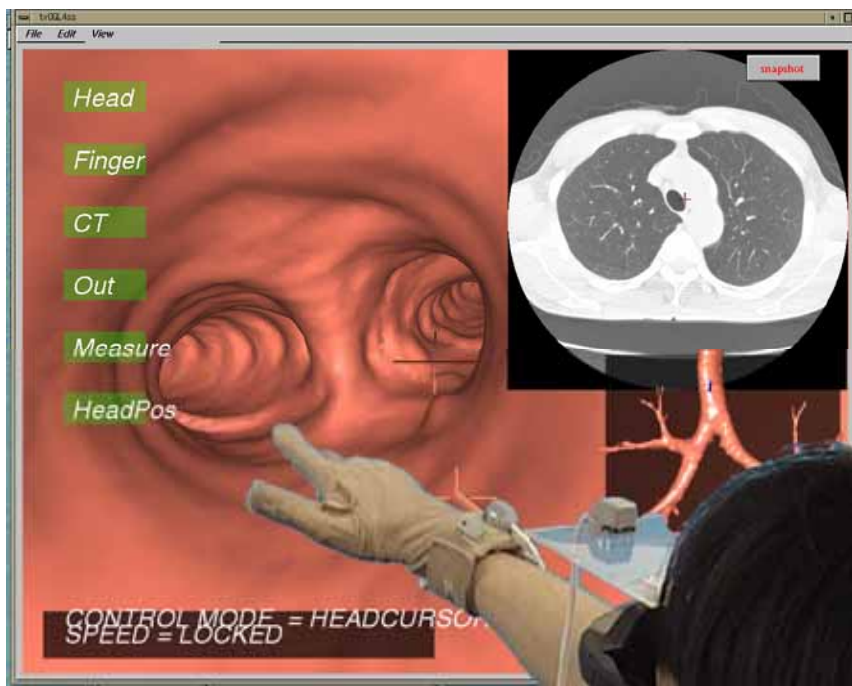
## My background and experience in medical AR

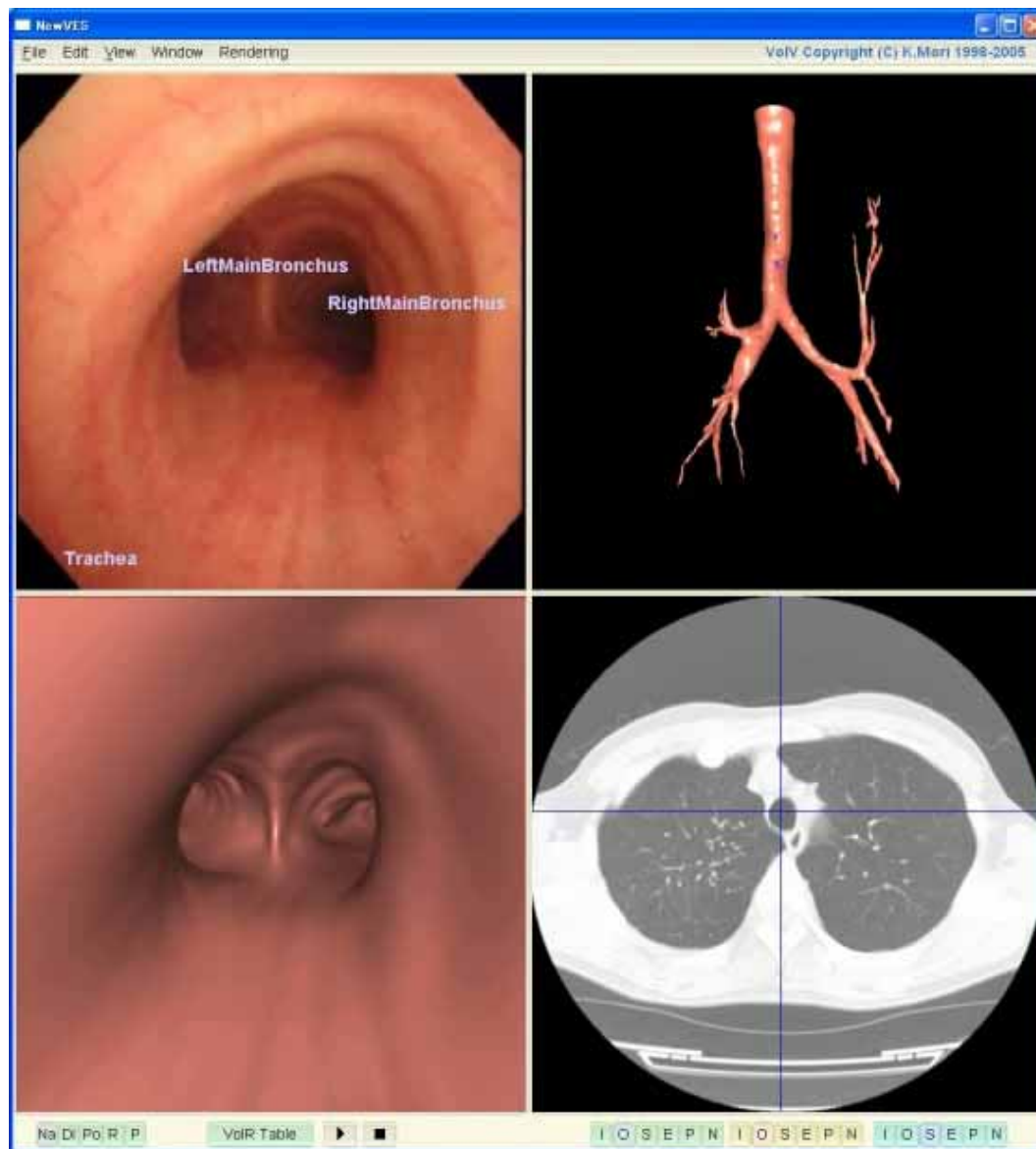
- Started from computer aided diagnosis of chest CT images
  - CAD – Lung nodule detection from 3D CT in 1992
- Worked on virtual endoscopy over 12 years
  - Developed as an aid for diagnostic process of CT images
  - Bronchoscopy and Colonoscopy
- Strong request to augmenting bronchoscopy from medical side
  - Fusion of REAL and VIRTUAL endoscopy
- Bronchoscopy navigation
  - Bronchoscope tracking based on image registration (IR) or combination of IR and EM tracker

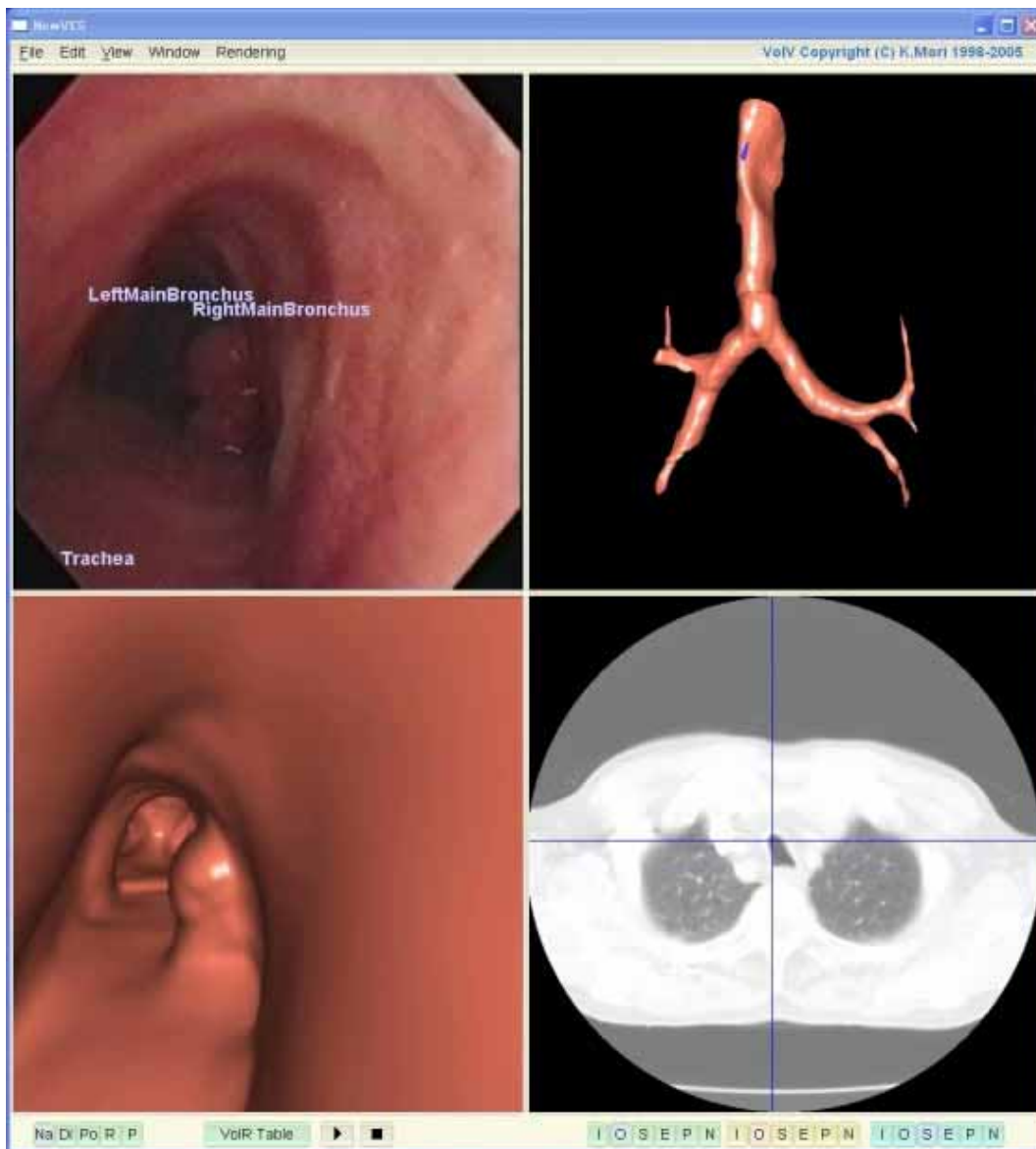




# I started VR (or AR) from ...









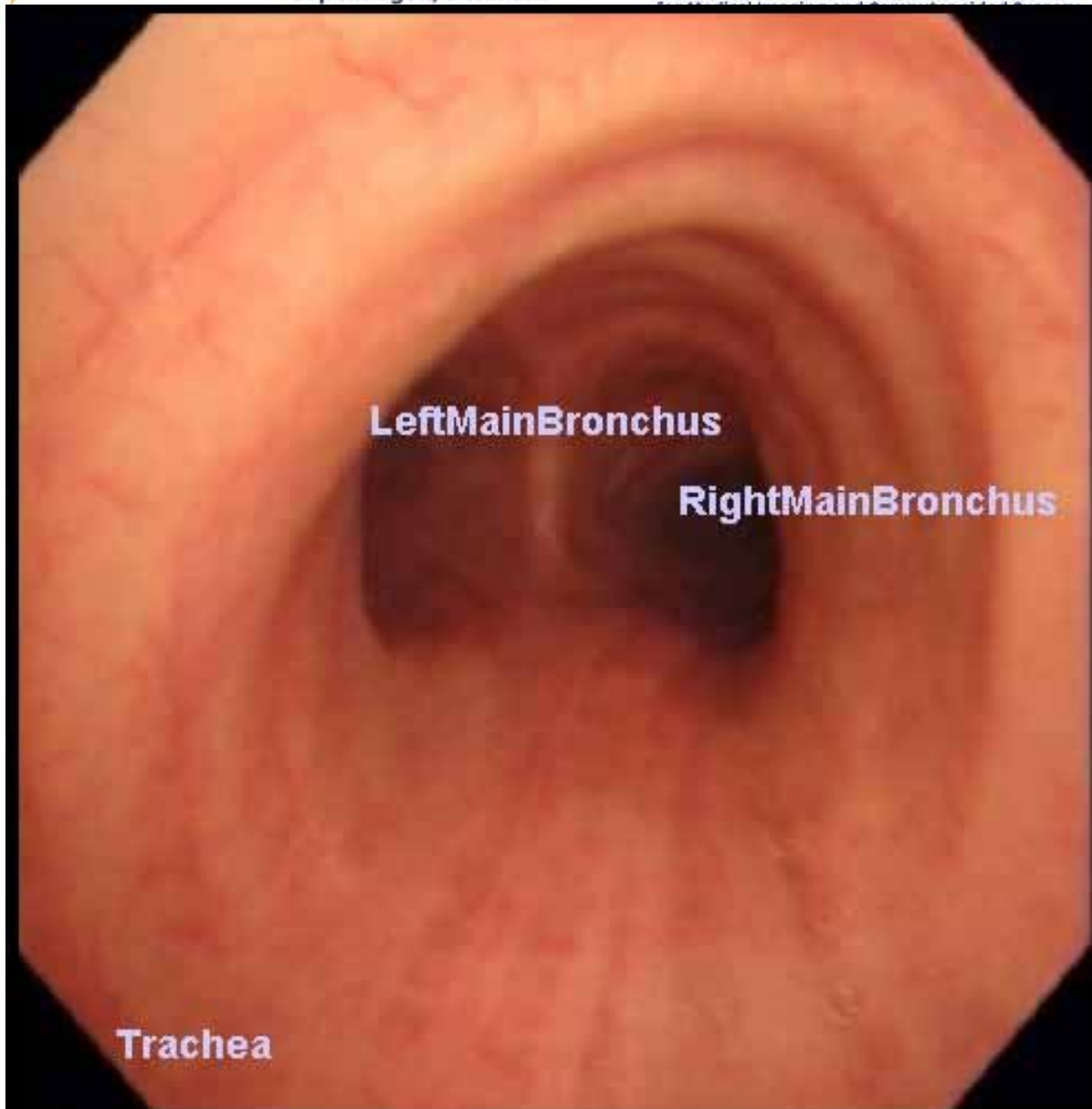
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## My questions

- Position Tracking
  - What is the best tracking device for medical AR?
  - Magnetic tracker is suitable for medical AR? Especially for flexible endoscopic surgery or treatment?
- Organ motion modeling and tracking
  - How can we model organ model?
  - How can we track organ motion in-vivo?
- Display
  - What is the best method for generating AR views?
  - Just overlay underlying anatomical structures?
  - What hardware?
- Evaluation
  - Engineering side
  - Clinical side



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# AR in the VASST lab

Terry Peters, Robarts Research Institute  
University of Western Ontario, Canada

October 06, 2006

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- Robarts Research Institute
- Canada's only private medical Research Institute
- 650 people, 45 Scientists
- Imaging group 220 people, 14 Scientists
  
- Image-guided Surgery Group / VASST\*lab
- 3 Scientists, 55 people
- Projects
  - IGT of
    - Breast
    - Prostate
    - Brain
    - Heart
    - Abdomen
- Main AR focus: Cardiac Intervention



\* Virtual Augmentation and Simulation for Surgery and Therapy



# Neurosurgery Visualization

Neurosurgery Navigator

File View Help

Main Toolbox Planner Atlas fMRI

**Neuro Surgical Planner**

Stereotactic Frame  
Tag Dragger  
Volume Rendering  
Surface Renderings  
Functional Mapping

Planning Targets General Surgery

**TARGET COORDINATES**

Inter-electrode Distance: 2

**Central Trajectory:**  
X: 111.28 Y: 94.26 Z: 112.77  
 Trajectory  Electrode

**Anterior Trajectory:**  
X: 111.29 Y: 96.11 Z: 113.54  
 Trajectory  Electrode

**Posterior Trajectory:**  
X: 111.28 Y: 92.42 Z: 111.99  
 Trajectory  Electrode

**Lateral Trajectory:**  
X: 113.13 Y: 93.96 Z: 113.48  
 Trajectory  Electrode

**Medial Trajectory:**  
X: 109.44 Y: 94.57 Z: 112.05  
 Trajectory  Electrode

Save Targets  
Advance/Retrieve 0.00  
New Target Position

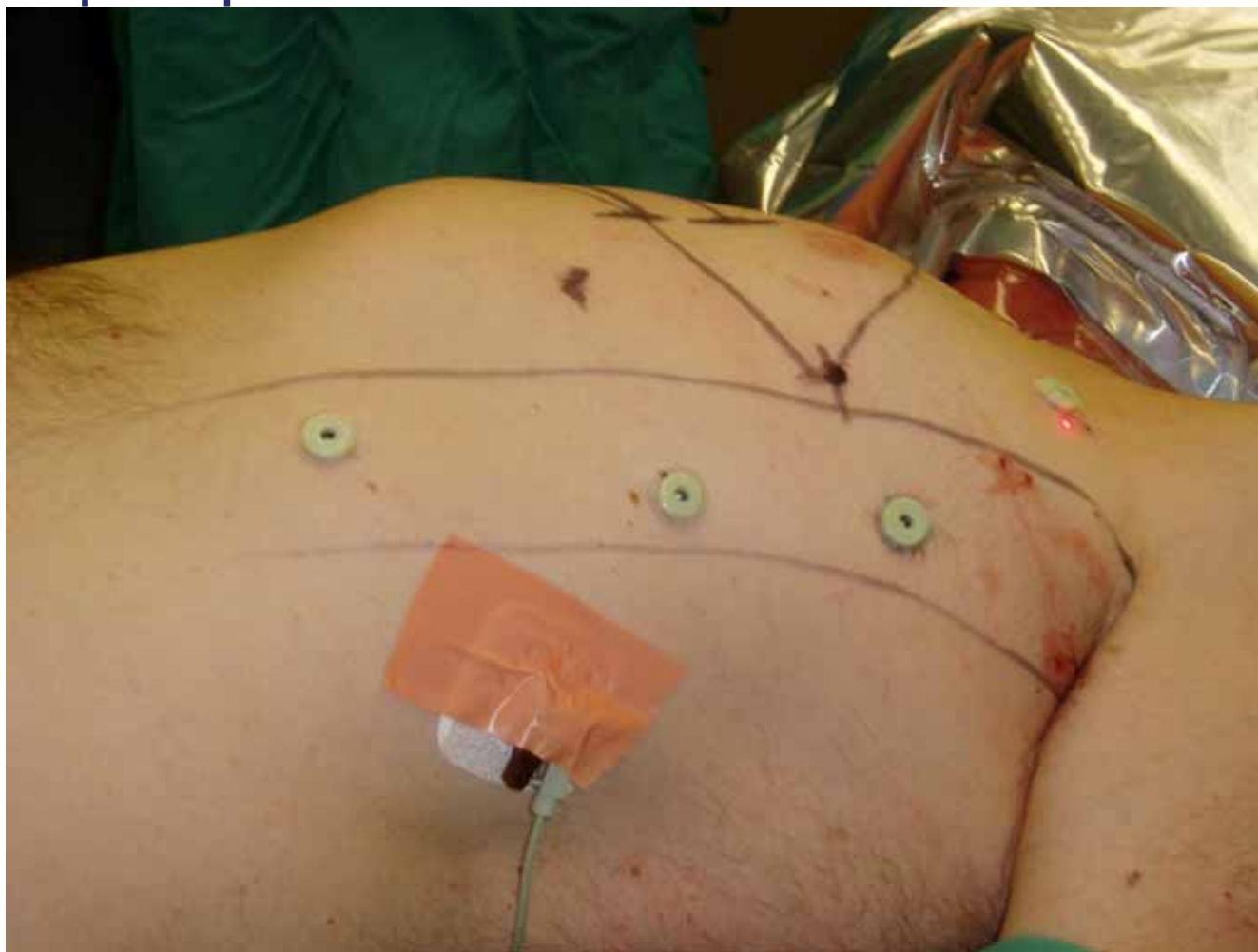
IP Mapping 1 IP Mapping 2

System  
Quit Capture Reset

robarts IMAGING Rotate Zoom Pan Slice Win/Lev 280.0 2.425e+05 91.24R 107.64A 117.63S  
5.62R 24.46A 21.80I



## AR for port placement for Robotic CABG

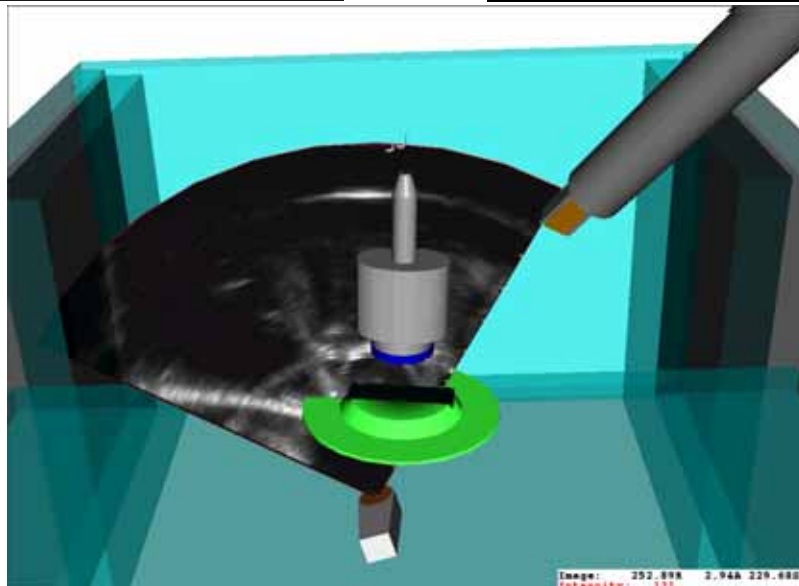
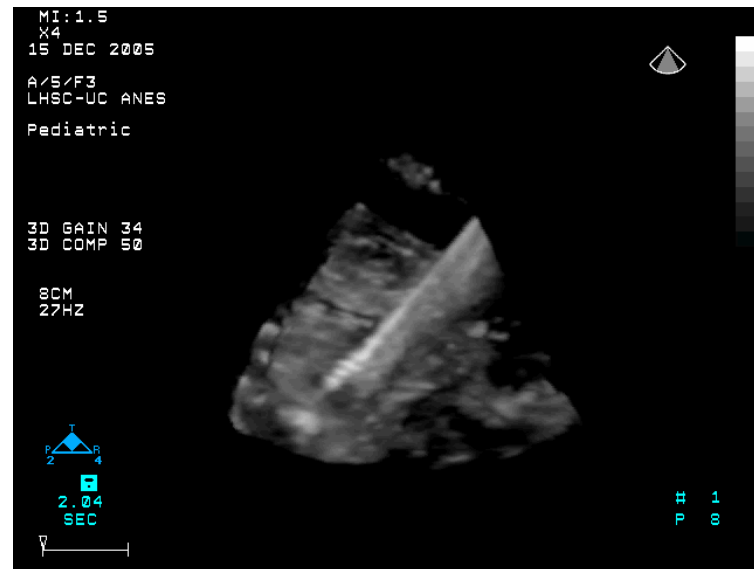
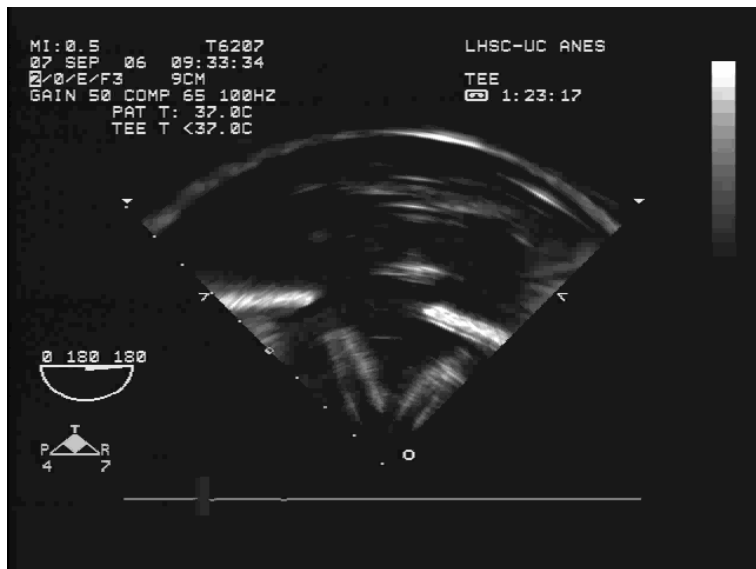






## Addressing limitations of imaging modalities for interventions

- Compromise between resolution, FOV, real-time capability
- Interventional procedures require rapid imaging but often difficult to see target and tools clearly
- Interventional images need context for interpretation
- Positioning of tools difficult to appreciate with interventional images, details of tools impossible to see





## AR in 2020

- VR (AR) complementing high-quality imaging
- Accurate non-rigid registration of patient-specific models to intra-operative imaging modalities
- Tracking technologies that can track ~30-40 targets with at ~30Hz without line-of-sight constraints
- Streamed access to 4D data from iMRI and 3D US
- Miniature pose-tracked HMD
- Complex repair of tissues by purpose-built robotic devices represented in AR environment.