



# 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*)

- ú Ali Khamene  
(*Siemens Corporate Research*)
- ú Philip Edwards  
(*Imperial College, London, UK*)
- ú Pierre Jannin  
(*INSERM, Visages/U746 INSERM, INRIA, CNRS Université de Rennes 1 France*)
- ú Kensaku Mori  
(*Nagoya University, Japan*)
- ú 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

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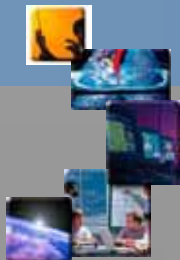
AMI-ARC Copenhagen 2006

# Ramp at SCR



Ali Khamene, PhD

Project Manager @ Interventional Imaging



# (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

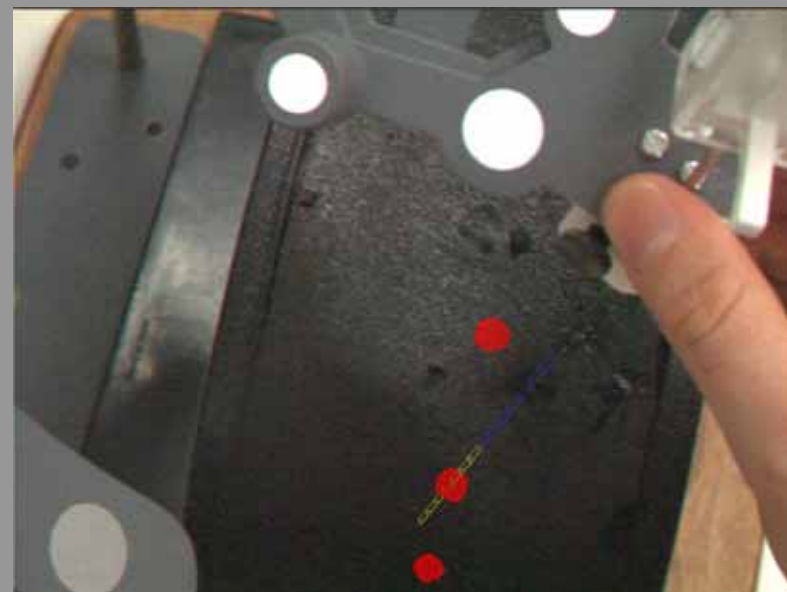
# Clinical Applications



Neurosurgical iMRI-OR  
*UCLA*

# Clinical Applications

SIEMENS CORPORATE RESEARCH



Interventional CT  
*Brigham & Woman's*

Extensive phantom studies with three  
interventional radiologists

SCR

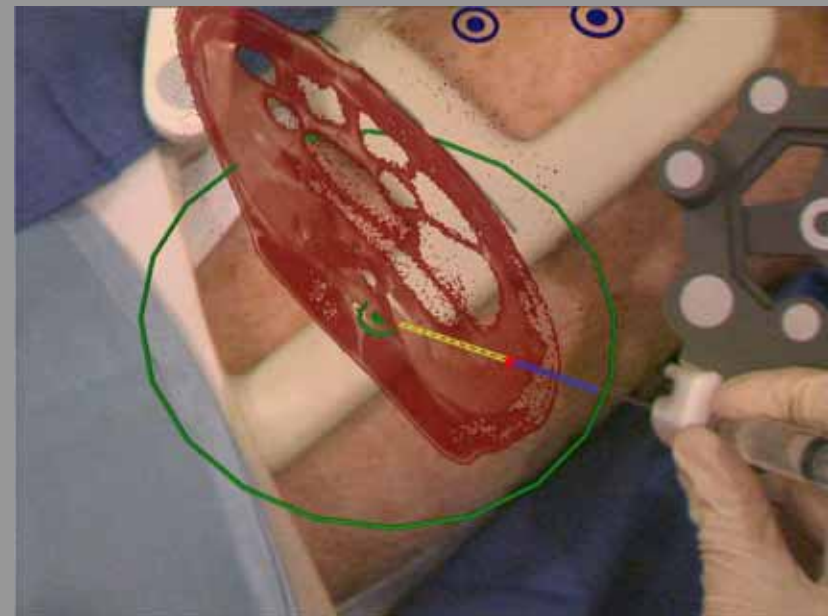
Interventional  
Imaging

# Clinical Applications

SIEMENS CORPORATE RESEARCH

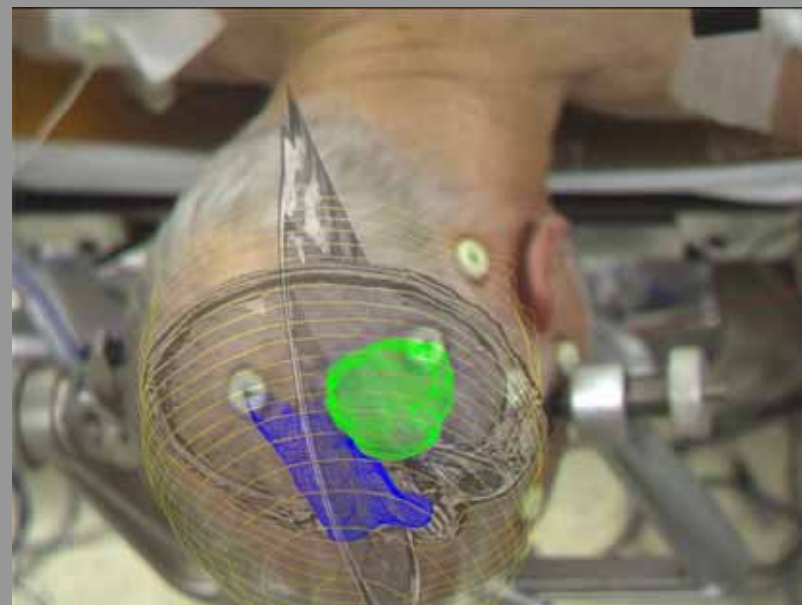


Interventional MR  
*Cleveland UH*



- Ø Extensive phantom studies
- Ø 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*

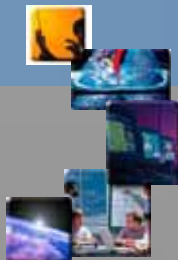


# A Challenge in AR : Respiratory Motion



∅ respiration

targets in abdomen/thorax shift





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# AR Experiences and Expectations

Eddie Edwards, Imperial College, London, UK

October 06, 2006

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# AR Experiences and Expectations

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



# Microscope-assisted Guided Interventions (MAGI)





# Microscope-assisted Guided Interventions (MAGI)

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



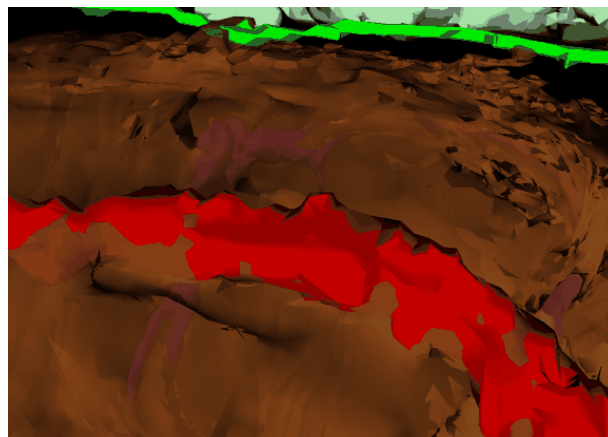
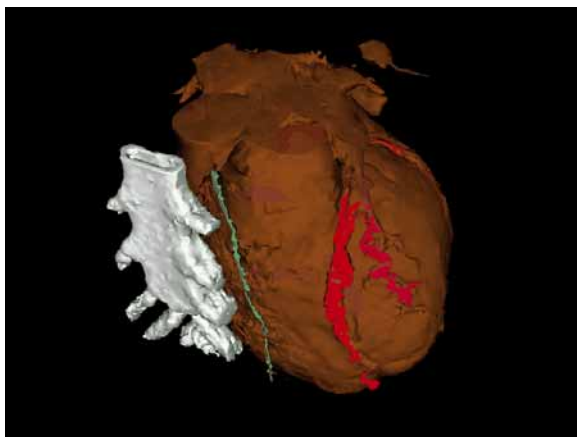
## Summary of Clinical Evaluation

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



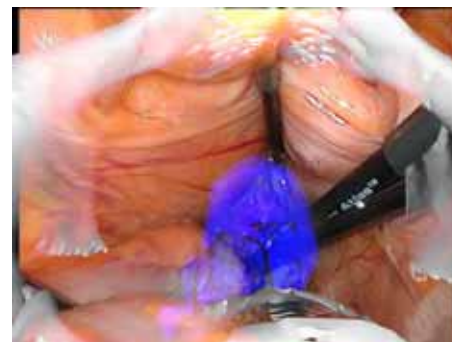
## Image-guided TECAB

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

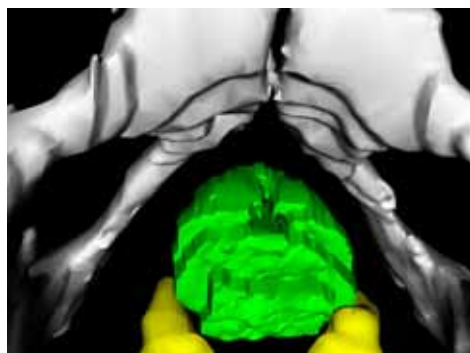




## Future Projects – da Vinci



Rectal cancer surgery



Prostate cancer surgery



## Common Features

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



## Important Questions for Clinical AR Systems

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



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# Patient Models and Surgical Models for Computer assisted Neurosurgery

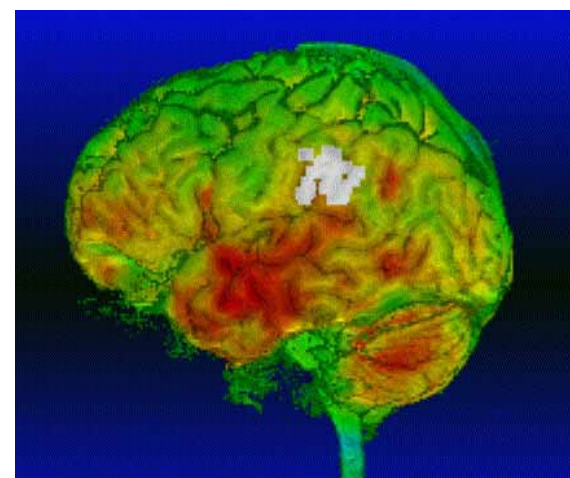
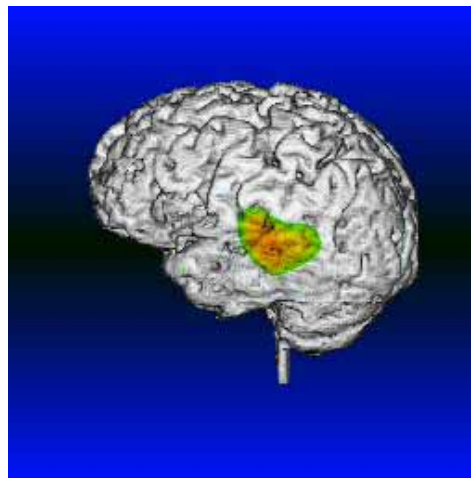
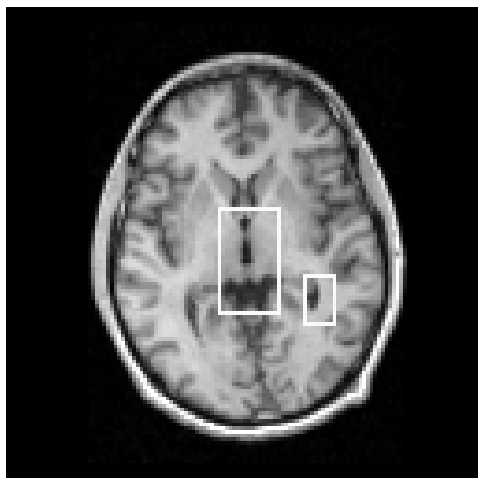
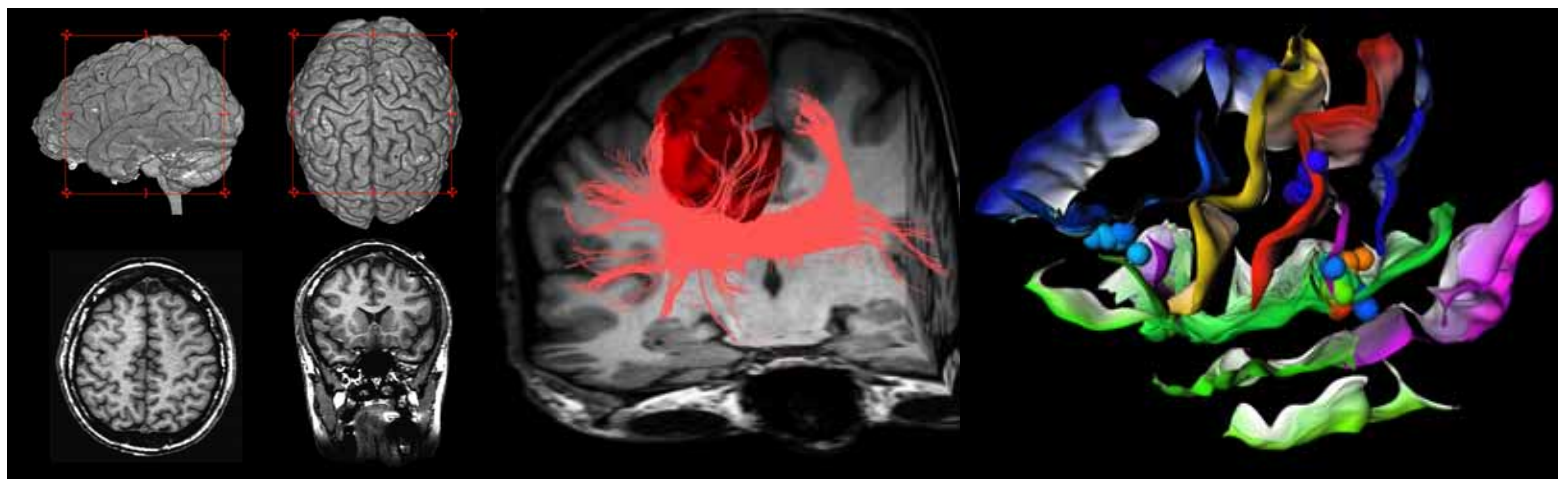
Pierre Jannin, INSERM, Visages/U746 INSERM, INRIA, CNRS  
Université de Rennes 1 France

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## Patient Model Creation



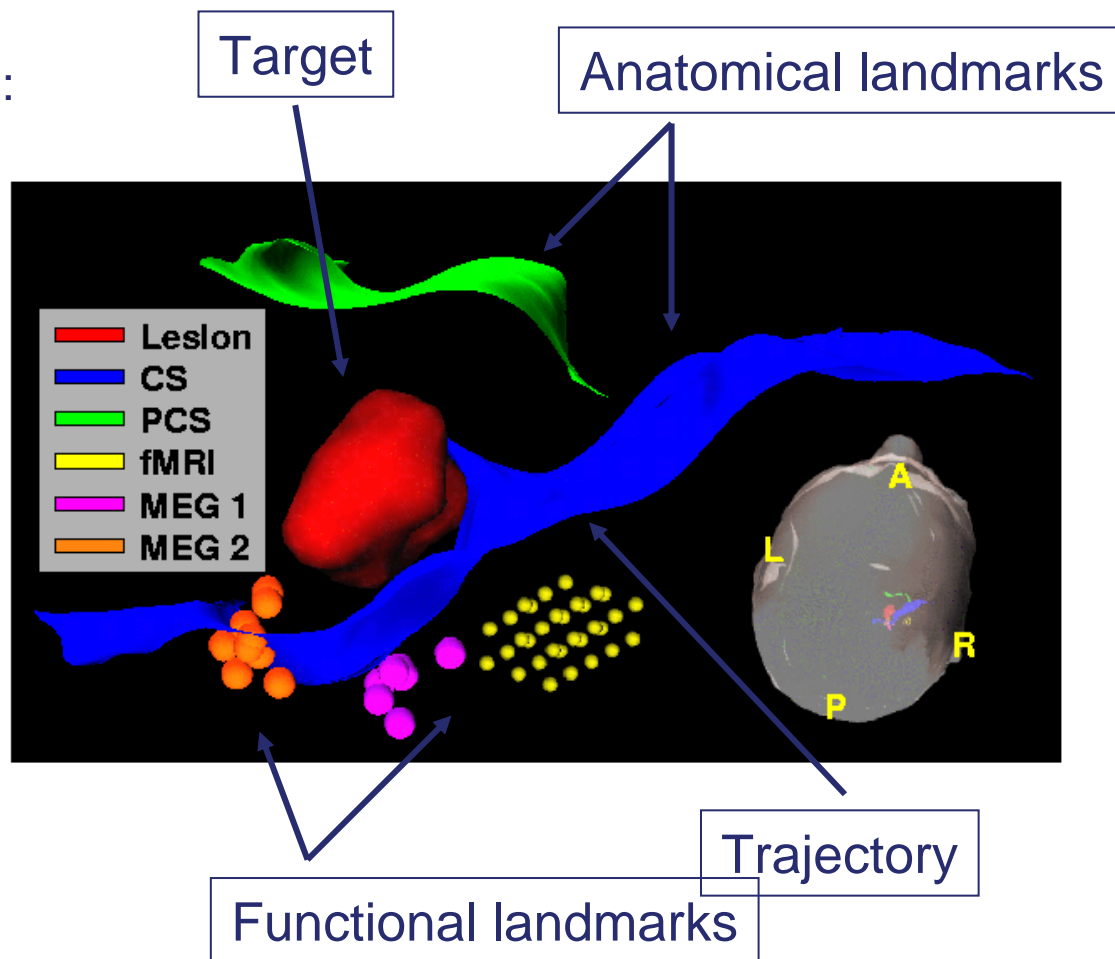
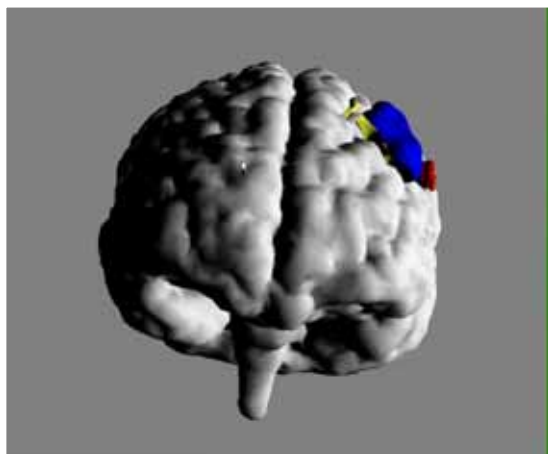


## Patient Model for Surgical Planning

To define the 3D surgical scene :

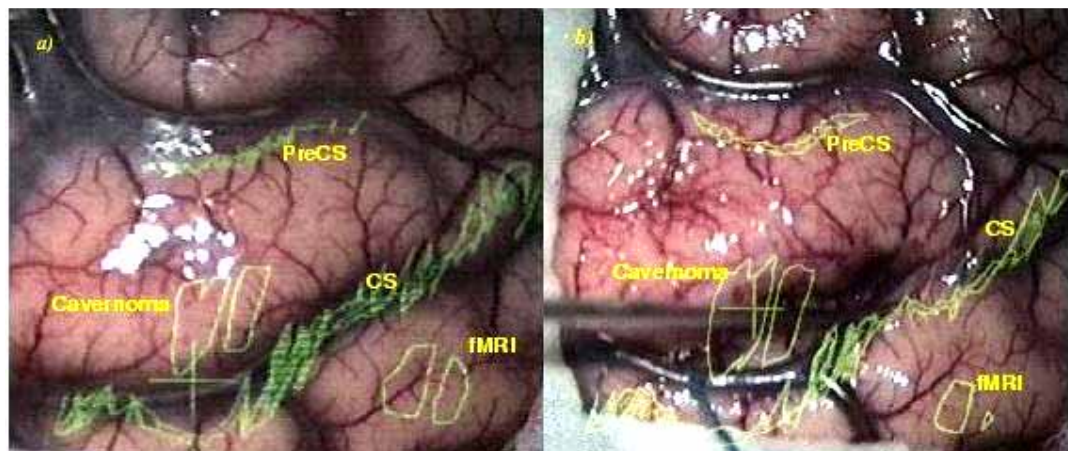
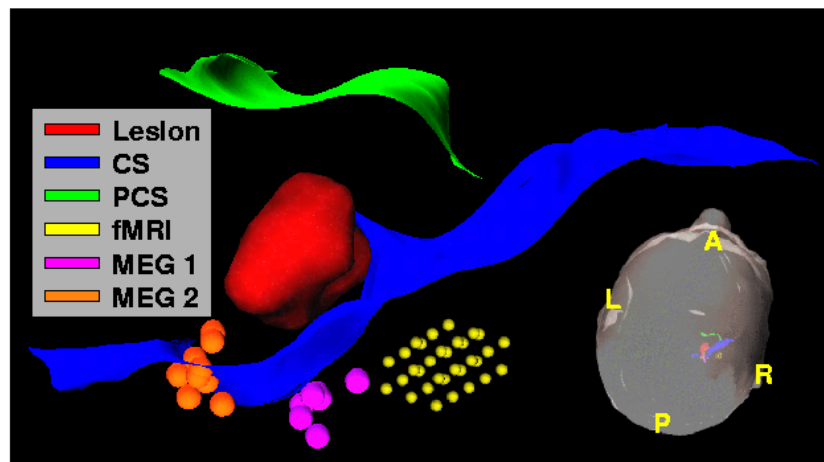
- Target (s),
- Areas to be avoided,
- Reference areas,
- Trajectories

from multimodal images





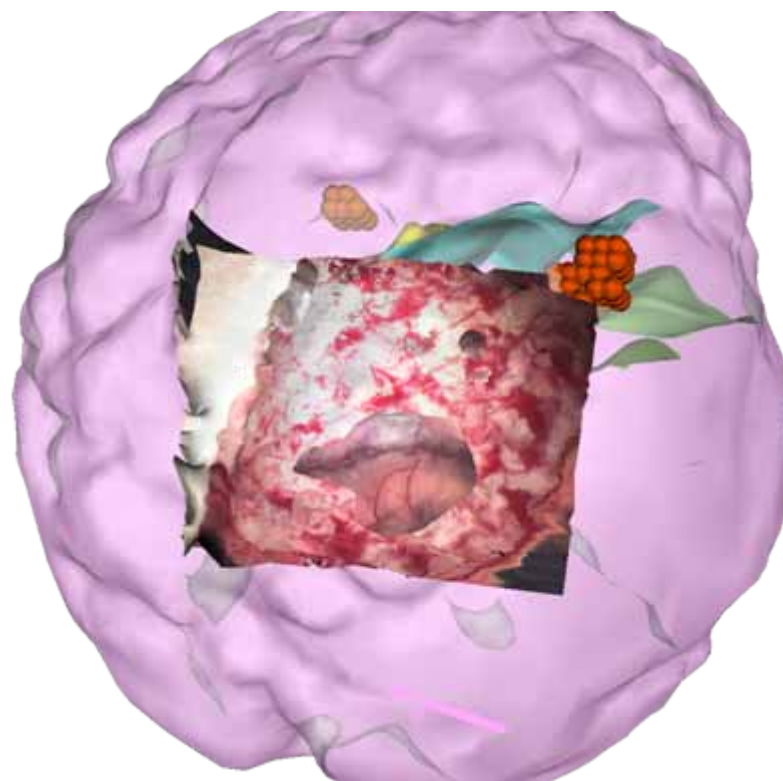
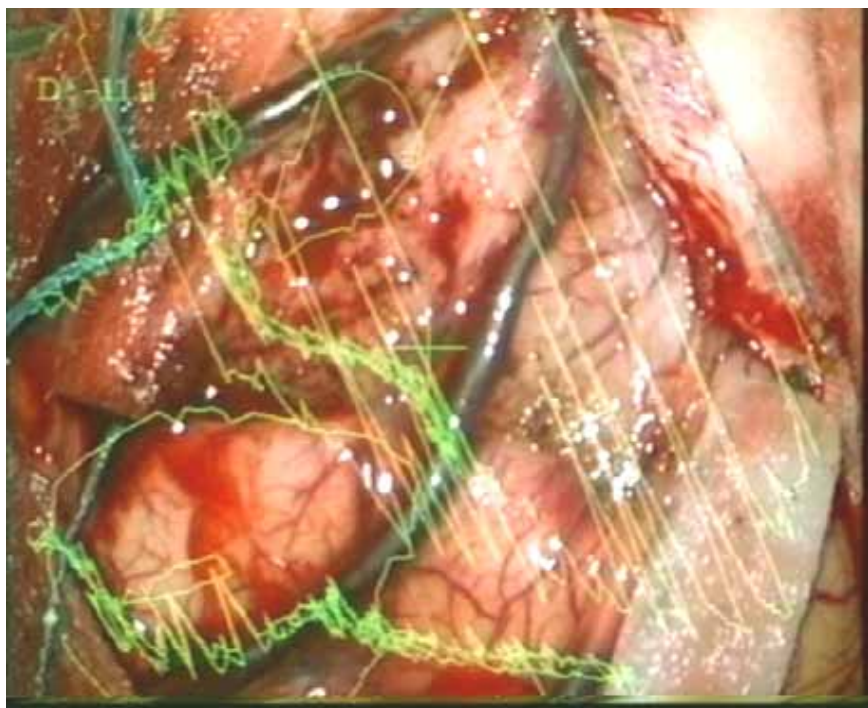
## Patient Model in the OR : Augmented Reality

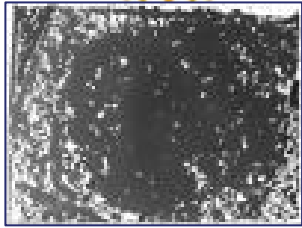




## Pb: 2D, Monochrome, and Too Much Info

→ Augmented virtuality





$T_d \rightarrow$

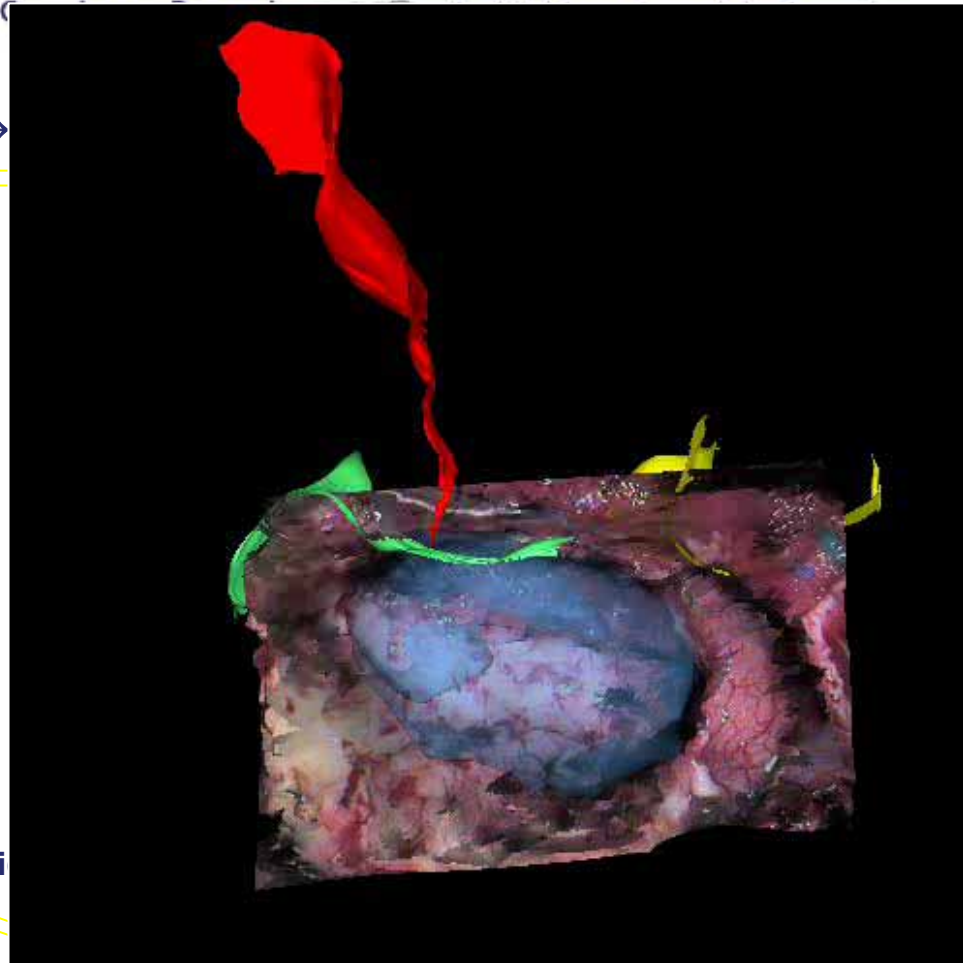
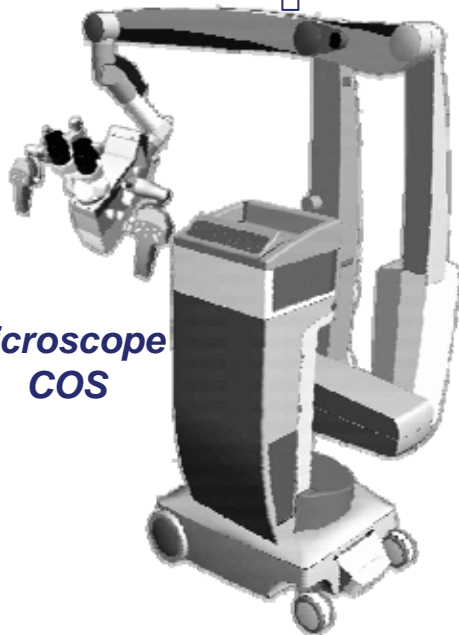
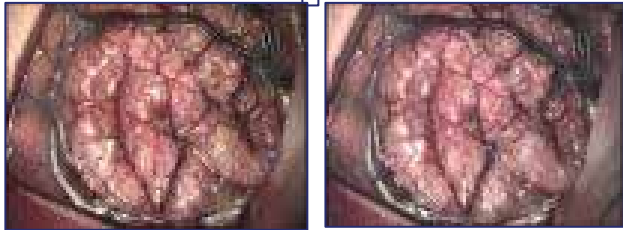
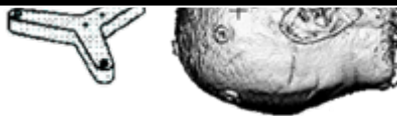


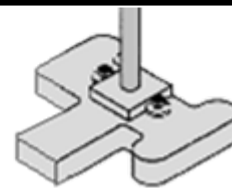
Image COS

$T_{mi}$

$\rightarrow pat$



Patient COS

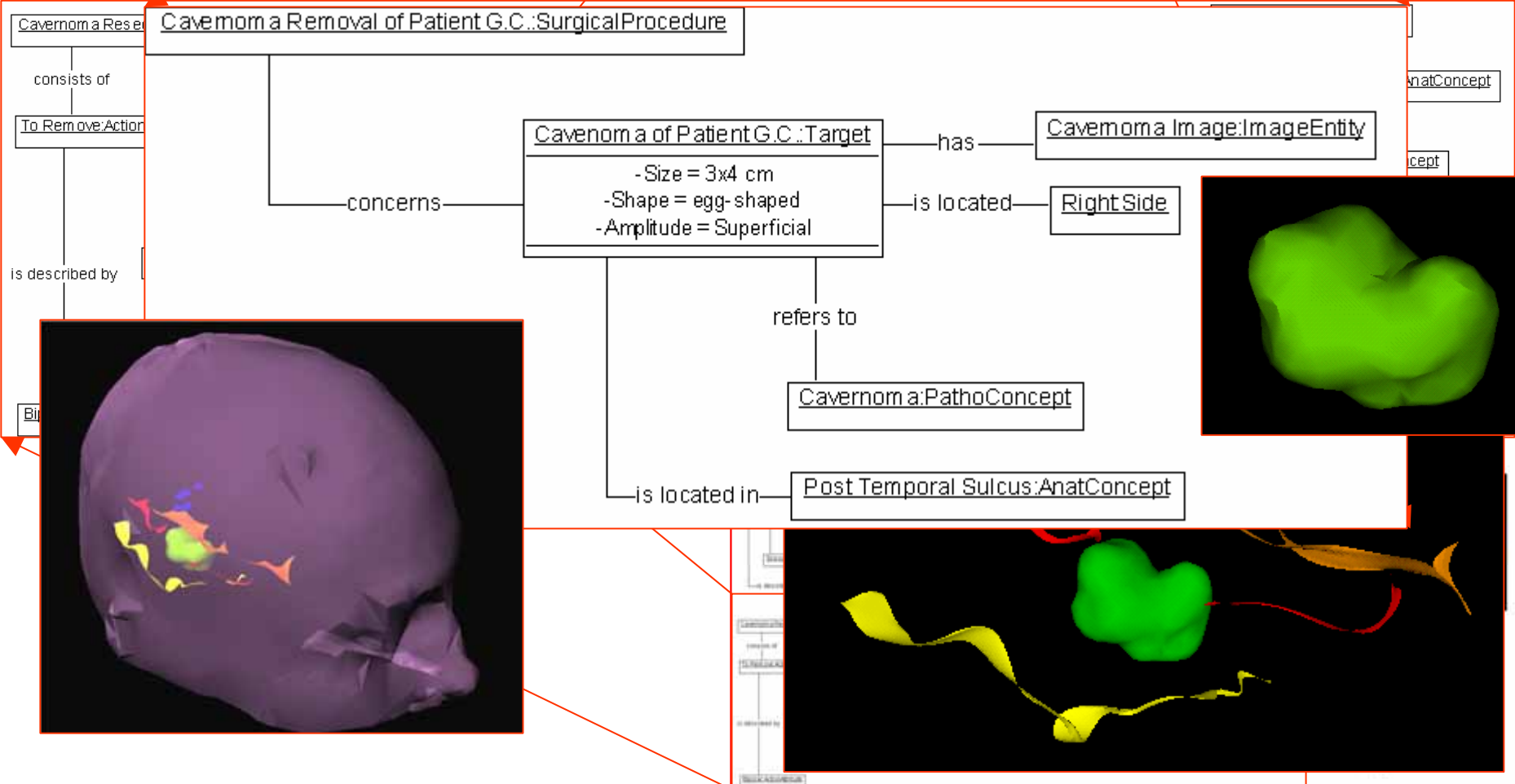


[Paul, Fleig, Jannin, IEEE TMI, 24(11) 2005]





# Description before surgery





# Surgical Knowledge Extraction



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



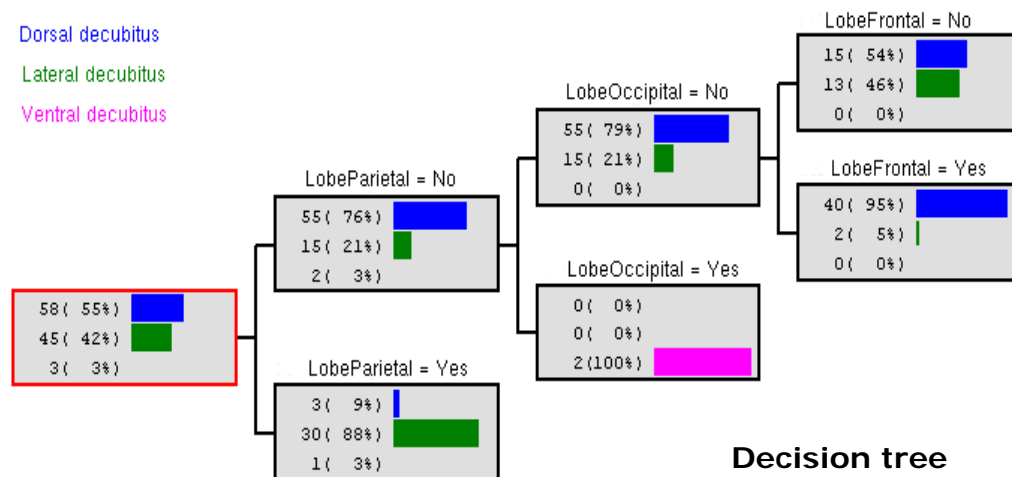
Dorsal decubitus

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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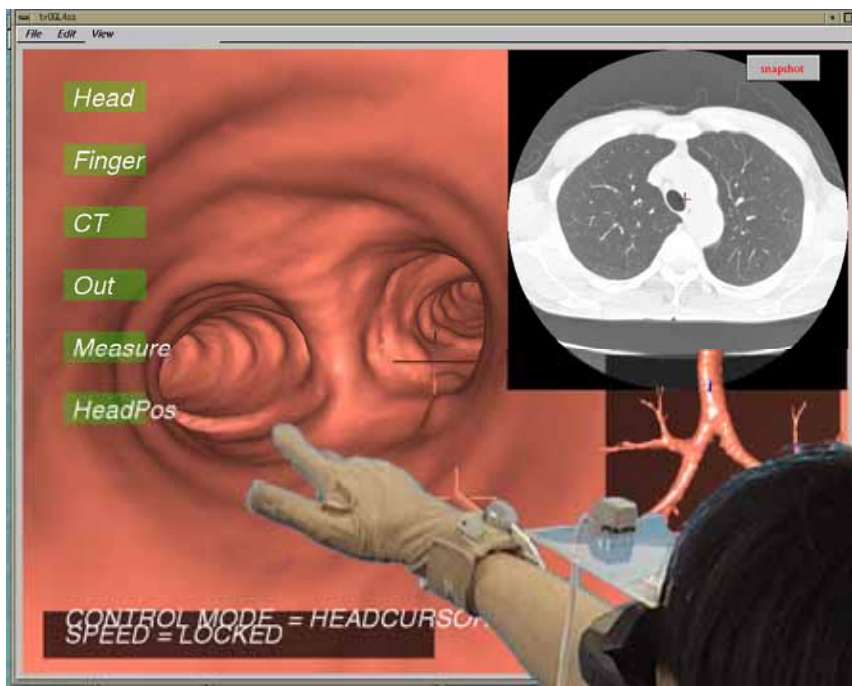


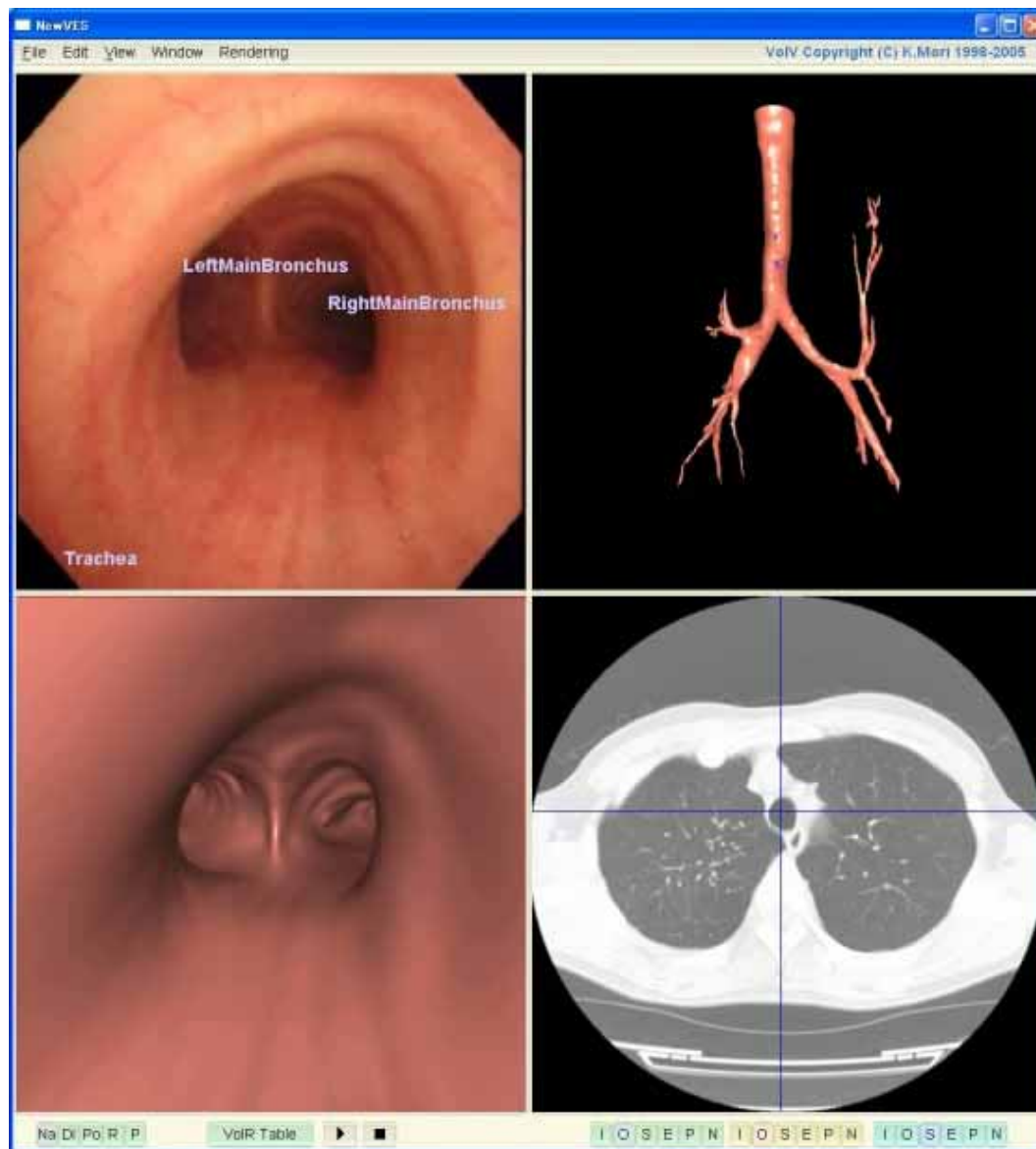
## My background and experience in medical AR

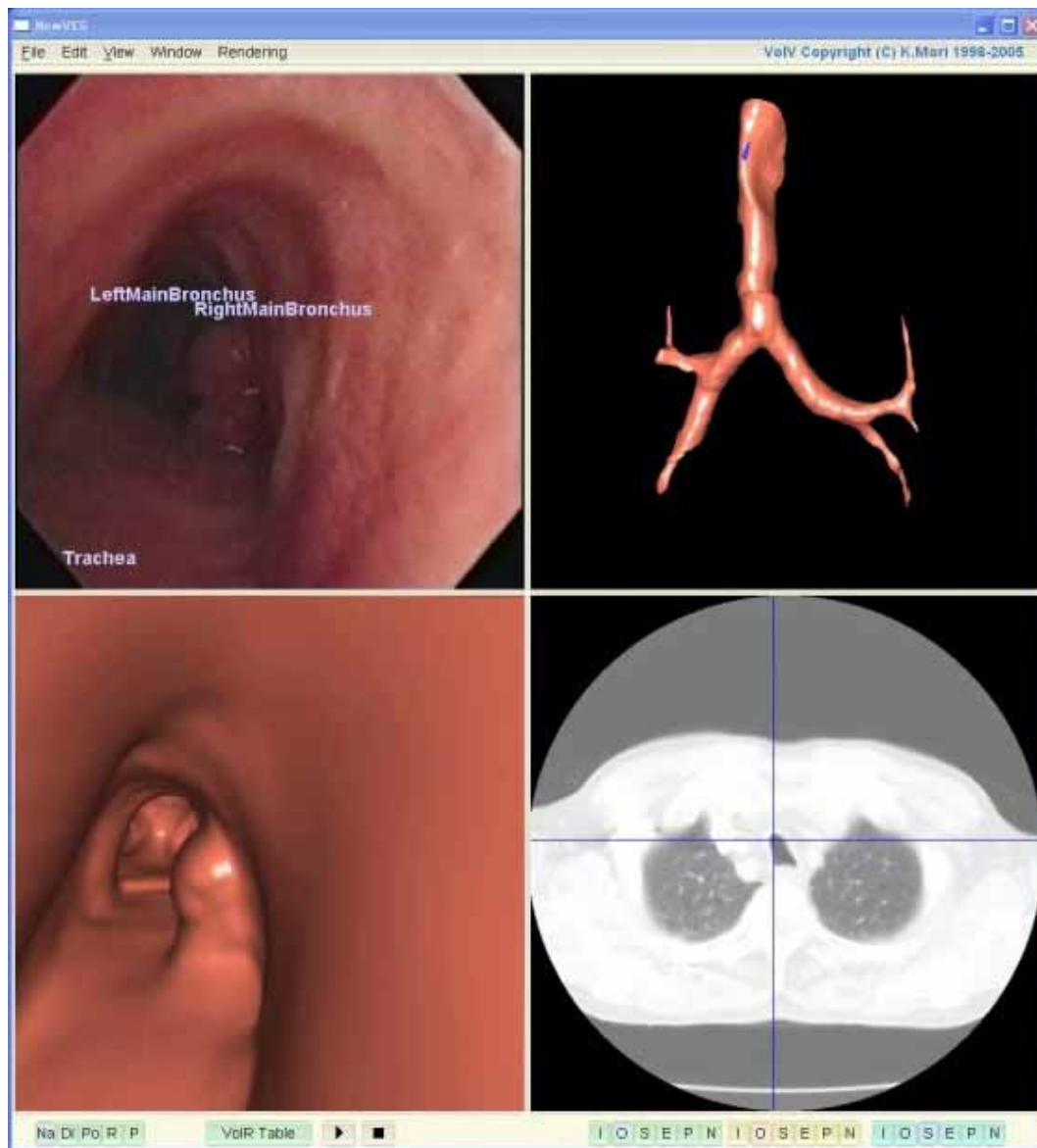
- ú Started from computer aided diagnosis of chest CT images
  - ú CAD – Lung nodule detection from 3D CT in 1992
- ú Worked on virtual endoscopy over 12 years
  - ú Developed as an aid for diagnostic process of CT images
  - ú Bronchoscopy and Colonoscopy
- ú Strong request to augmenting bronchoscopy from medical side
  - ú Fusion of REAL and VIRTUAL endoscopy
- ú Bronchoscopy navigation
  - ú 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

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

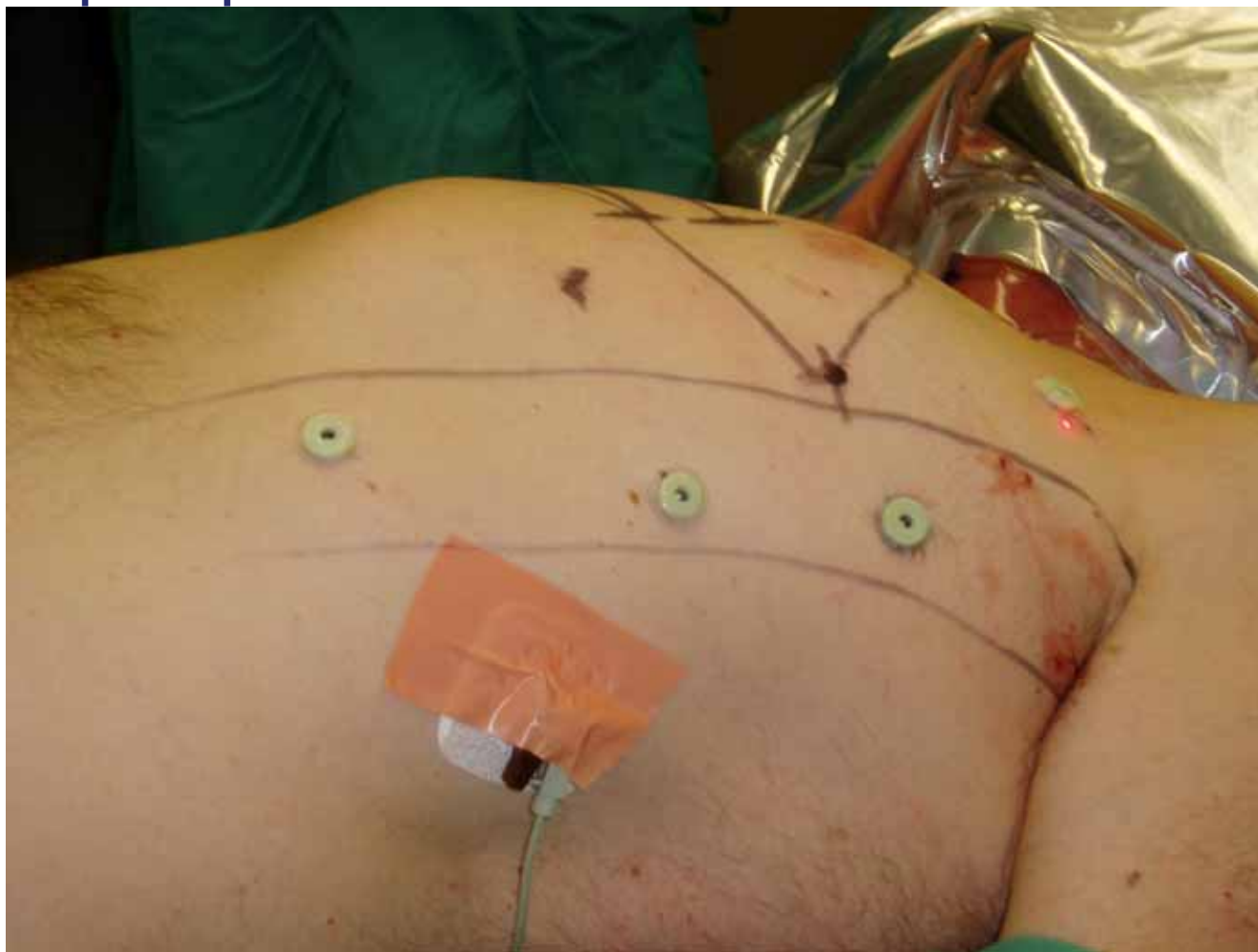
IP Mapping 1 IP Mapping 2

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



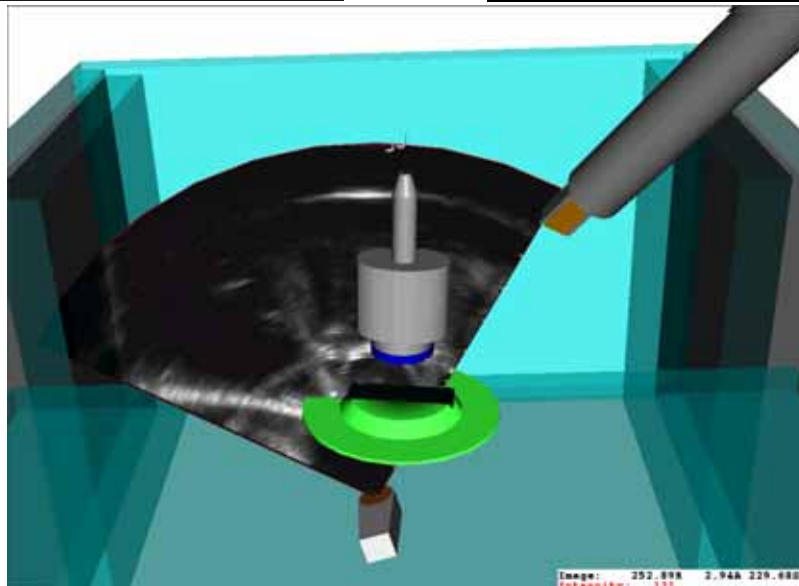
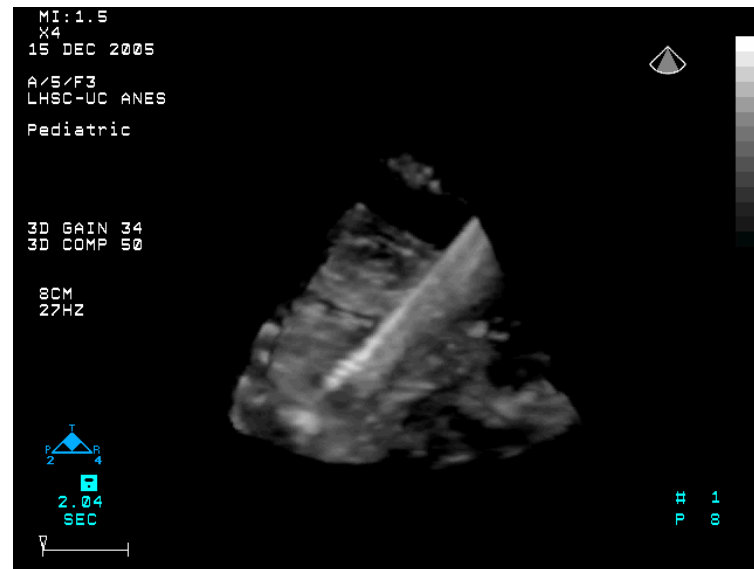
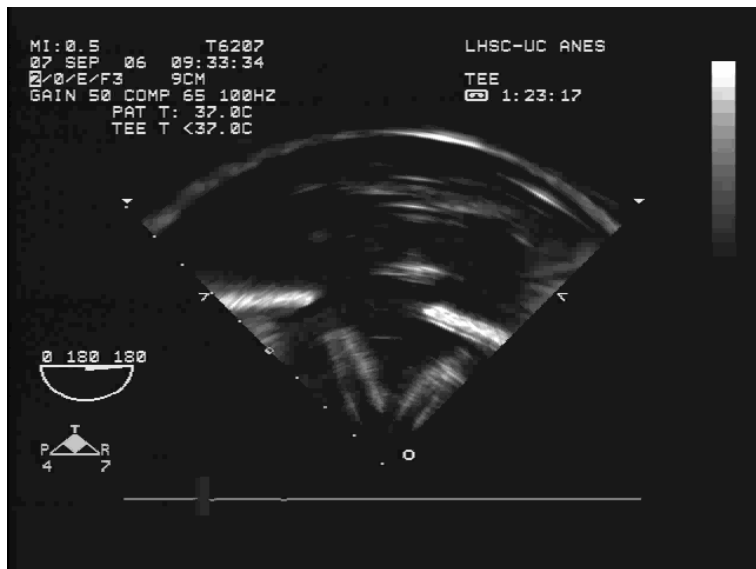
## AR for port placement for Robotic CABG





## Addressing limitations of imaging modalities for interventions

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





## AR in 2020

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