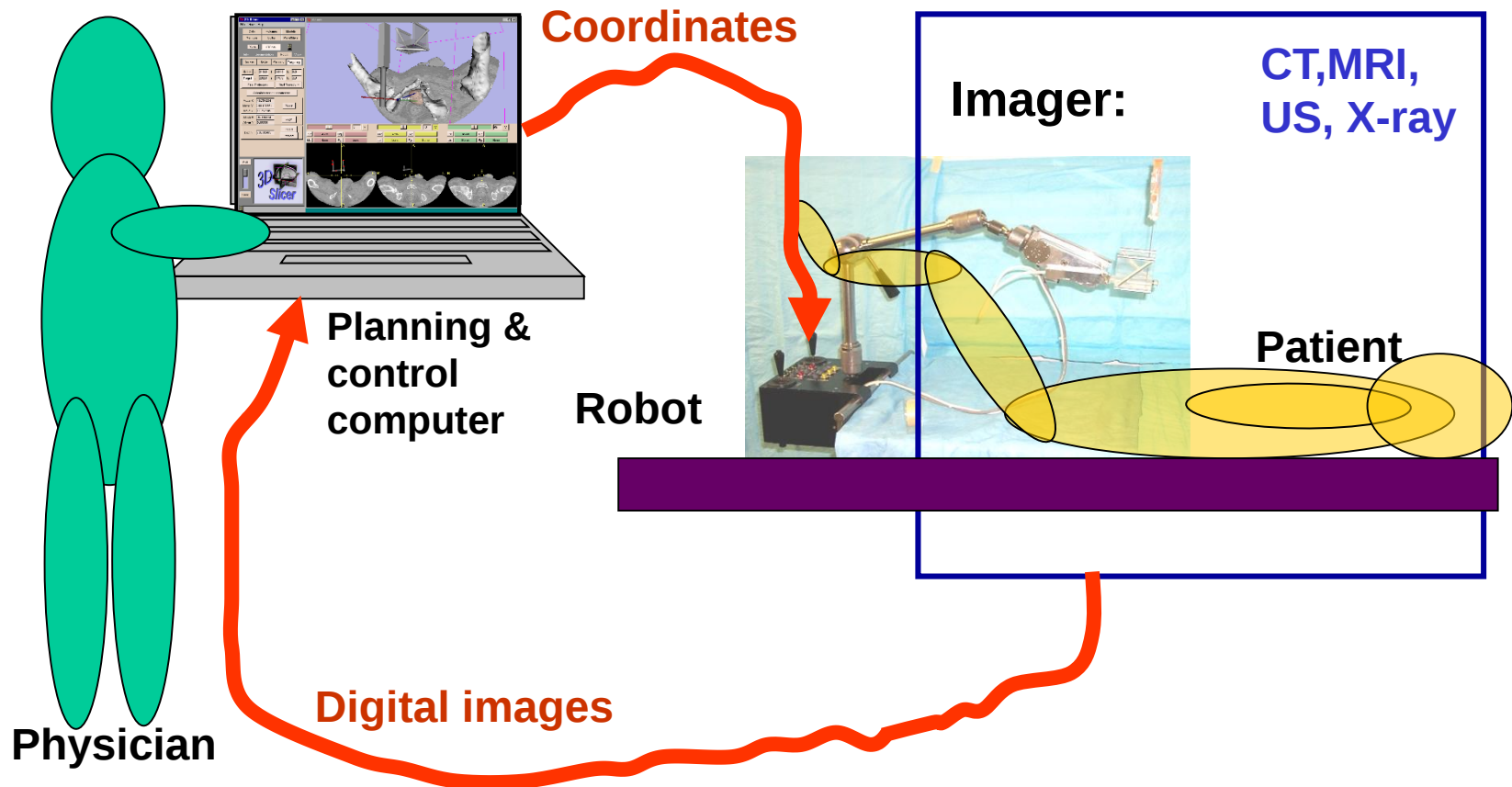


# Needle Placement Robots



# In-Scanner Robotic Interventions

When robot and patient meet in an imaging scanner in an intervention



# Serial Linkages

Where all joints move in synch

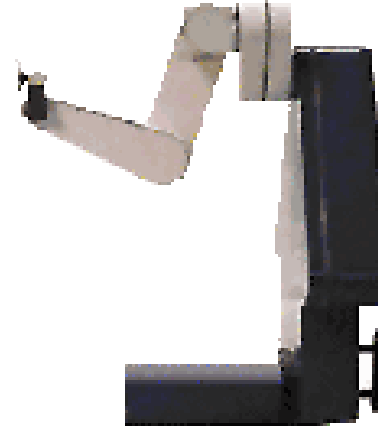
## Pros:

- Can move virtually anywhere
- Lots of different motions
- Smooth motion

## Cons:

- Hard to constrain
- Safety concerns
- Complex control
- Ugly math
- Aggregating errors
- **“Must do everything to do anything”**

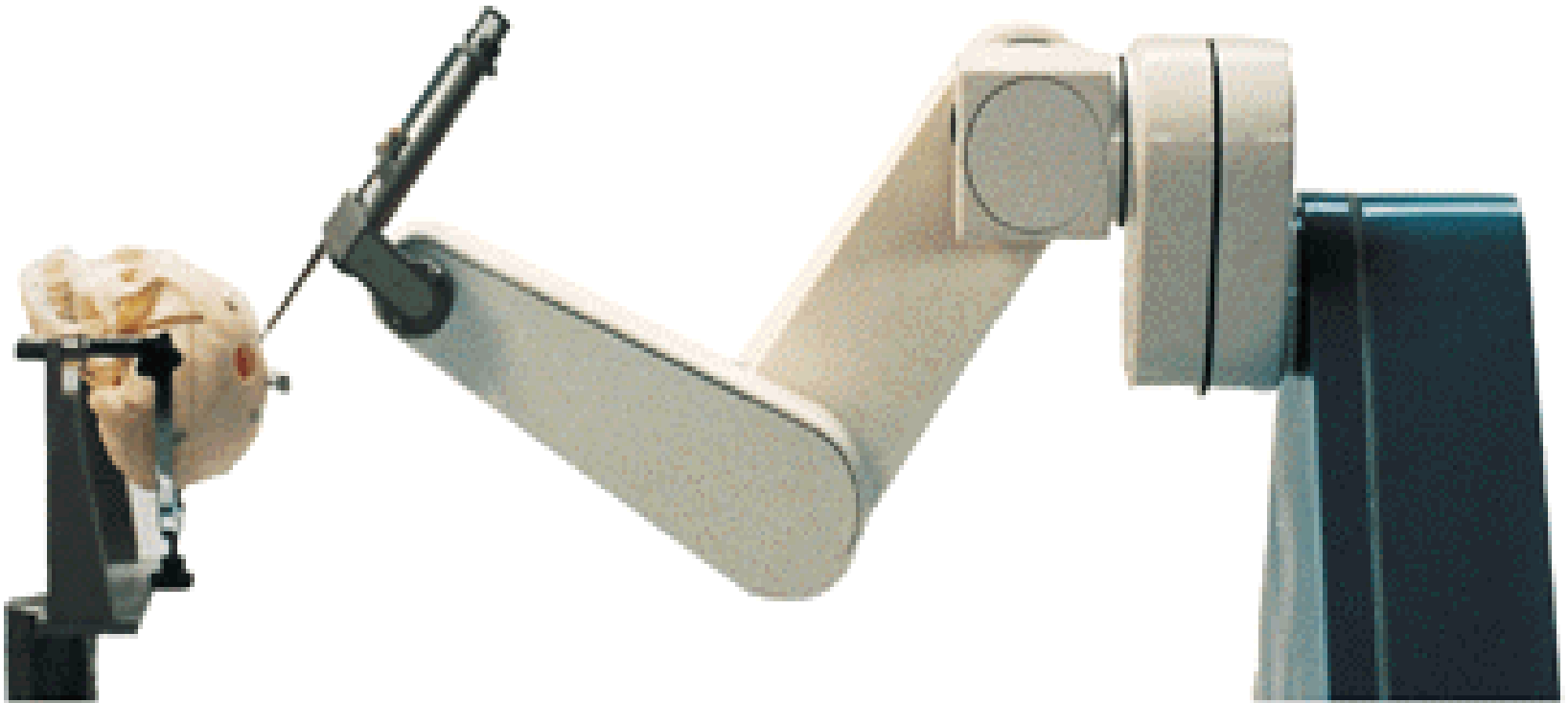
custom-developed (Neuromate)



Industry robots and derivatives (PUMA SCARA, etc...)



# Floor-mounted NeuroMate™ system

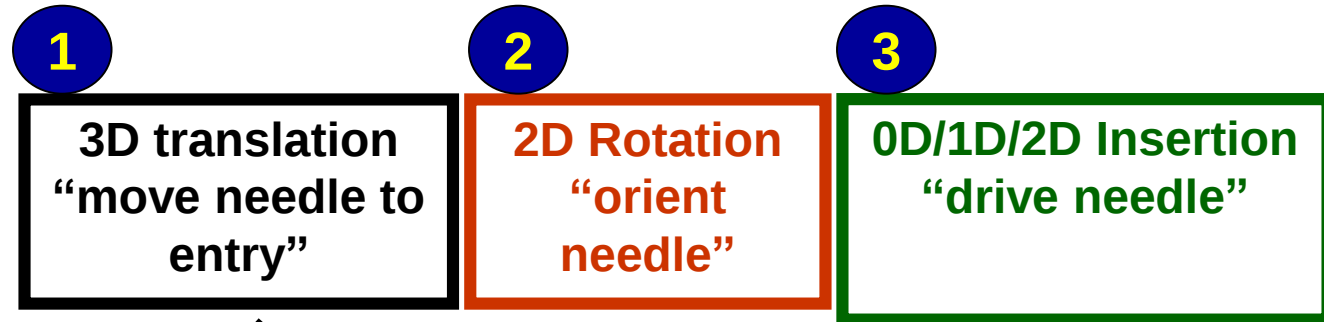


*System used for brain biopsies*  
*Contact-based registration with fiducials*



# Decoupled Linkages

Where joints can move selectively

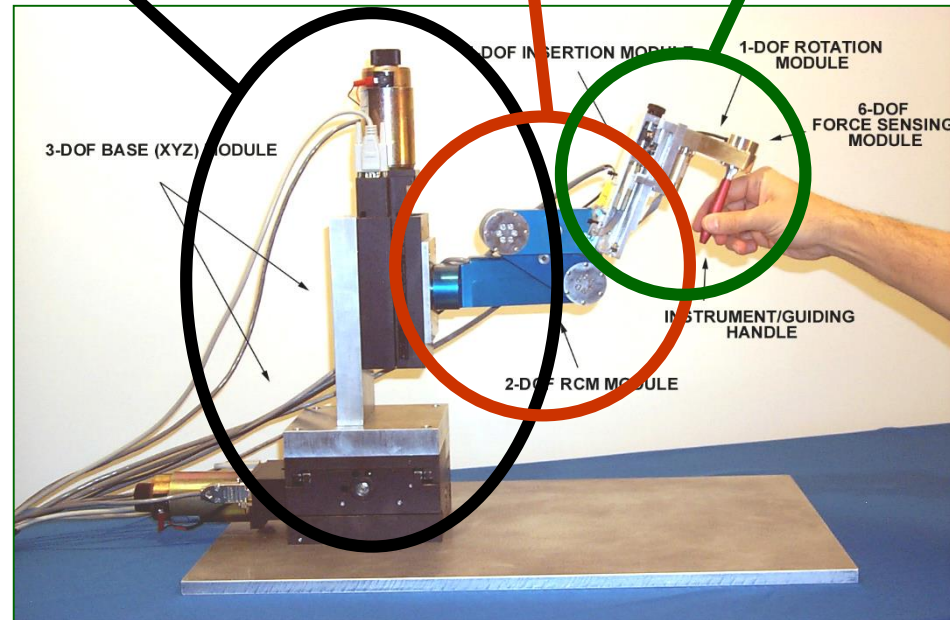


## Pros:

- **CAN BE INHERENTLY SAFE**
- Separates steps of surgery
- Easy to constrain
- Simpler control
- Simpler Math
- Curbed error aggregation

## Cons:

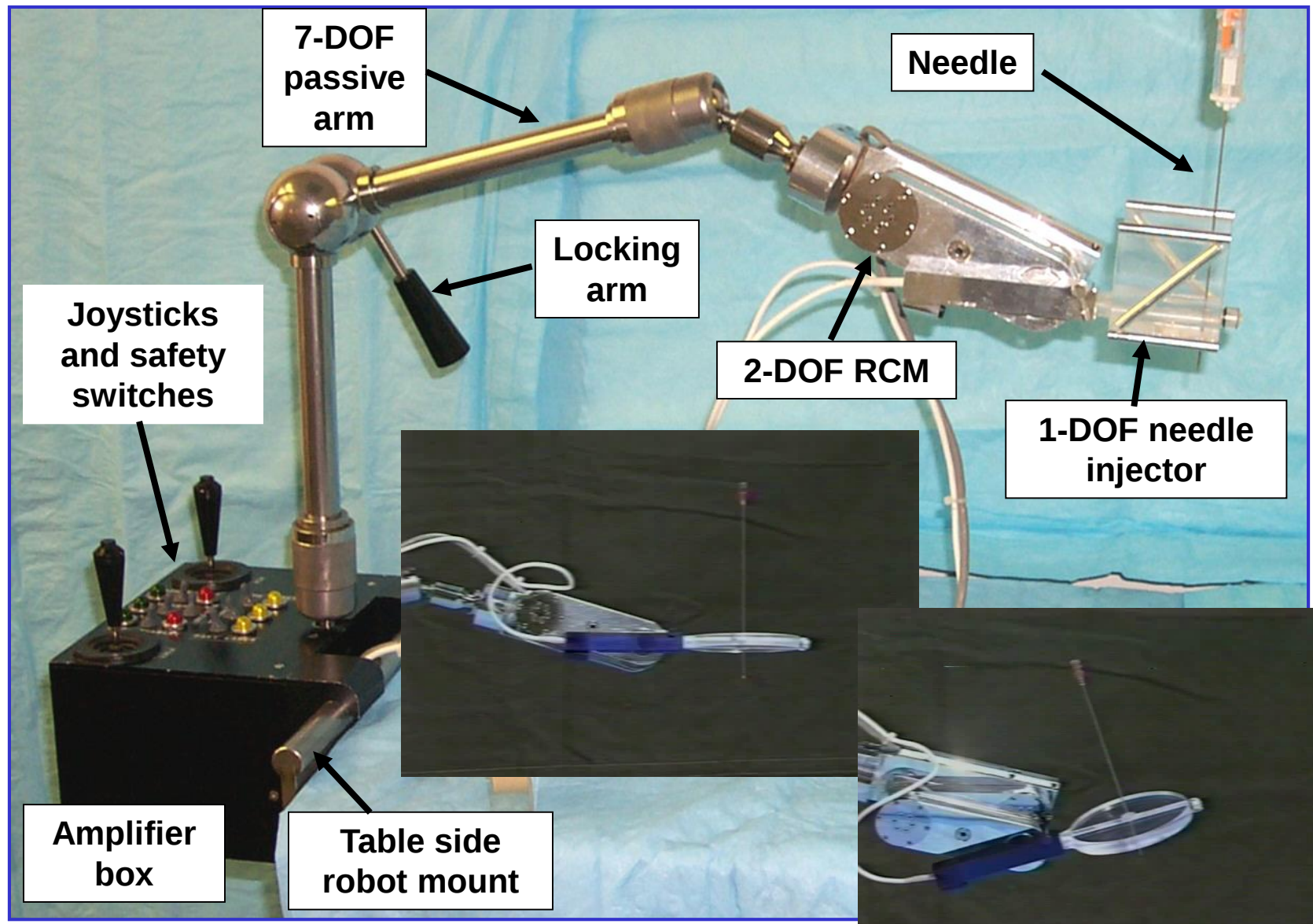
- Limited types of motions
- Limited trajectory
- Ragged motion



Taylor et al, IEEE TRA, 2001



# Example: 3DOF RCM-PAKY



Stoianovici et al, MICCAI-1997, MICCAI-1998, MICCAI-1998



# CT-Guided Prostate Biopsy

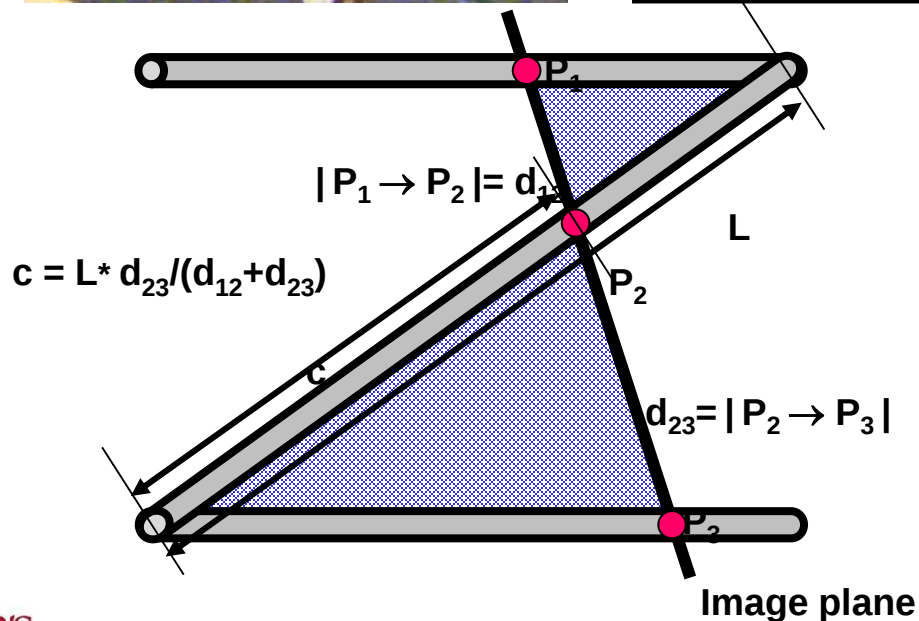
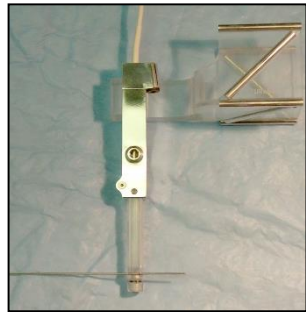
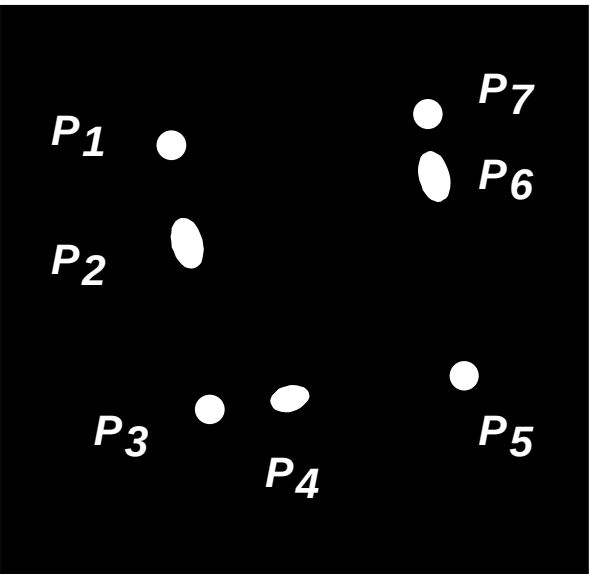


Fichtinger et al. Acad Rad, 2002





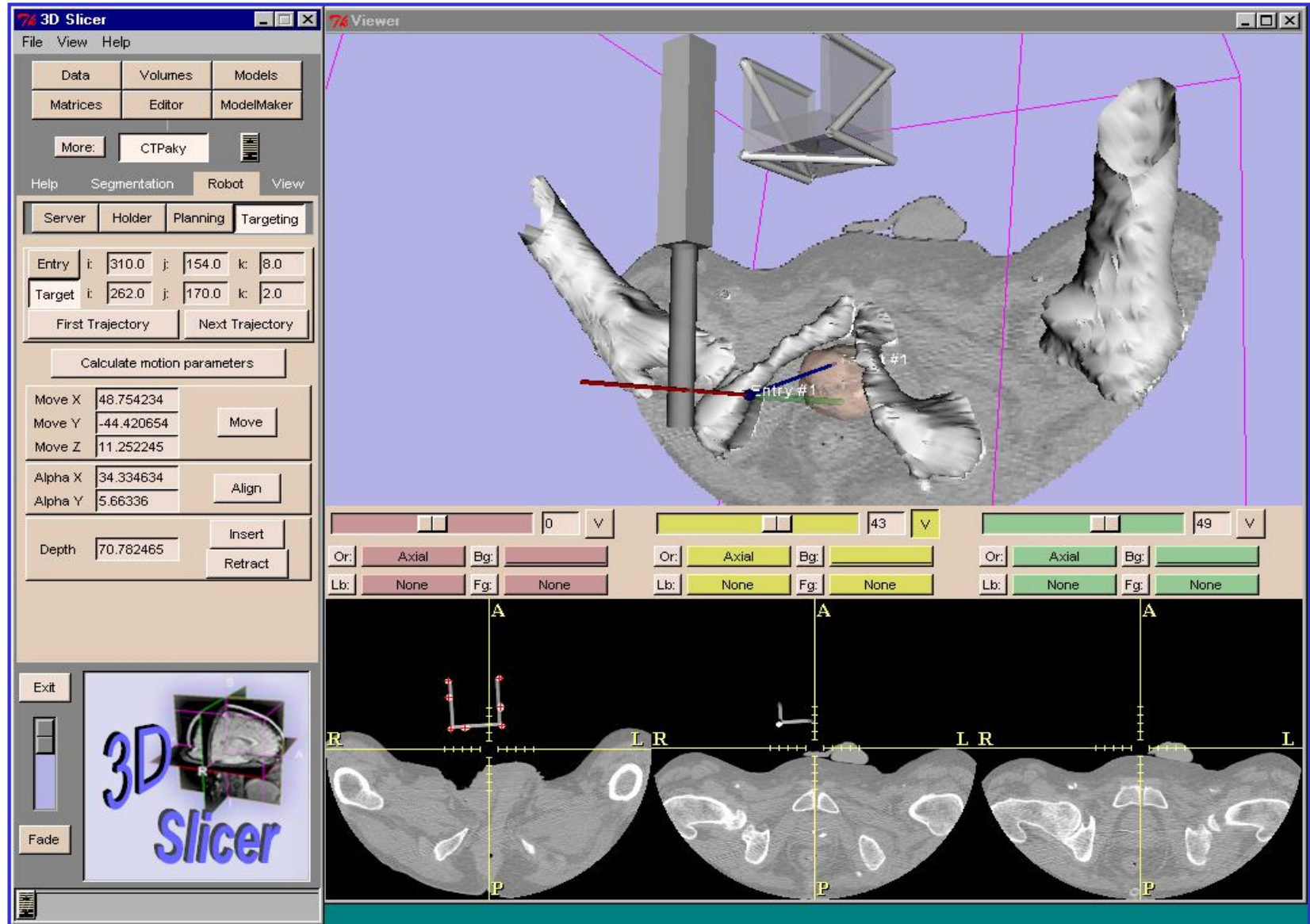
Queen's  
UNIVERSITY



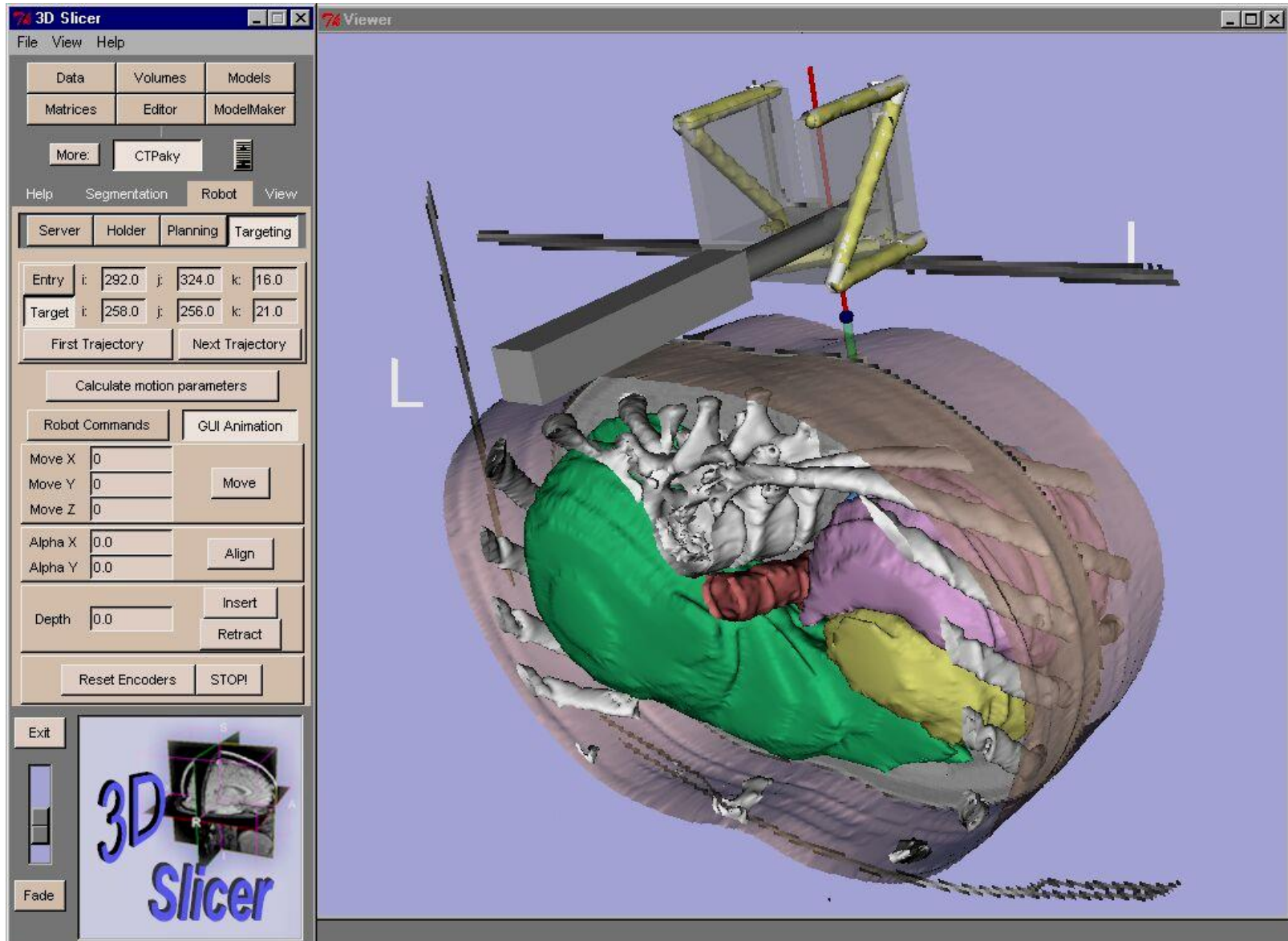
**Closed form: fast and computationally robust**

Susil et al. MICCAI 1999  
Masamune et al. JCAS 2001  
Lee et al. J. MedPhys 2002

# Slicer-based Treatment Planning



# Slicer-based Treatment Planning



Credit: A. Tanacs

# CT-Guided Kidney Biopsy

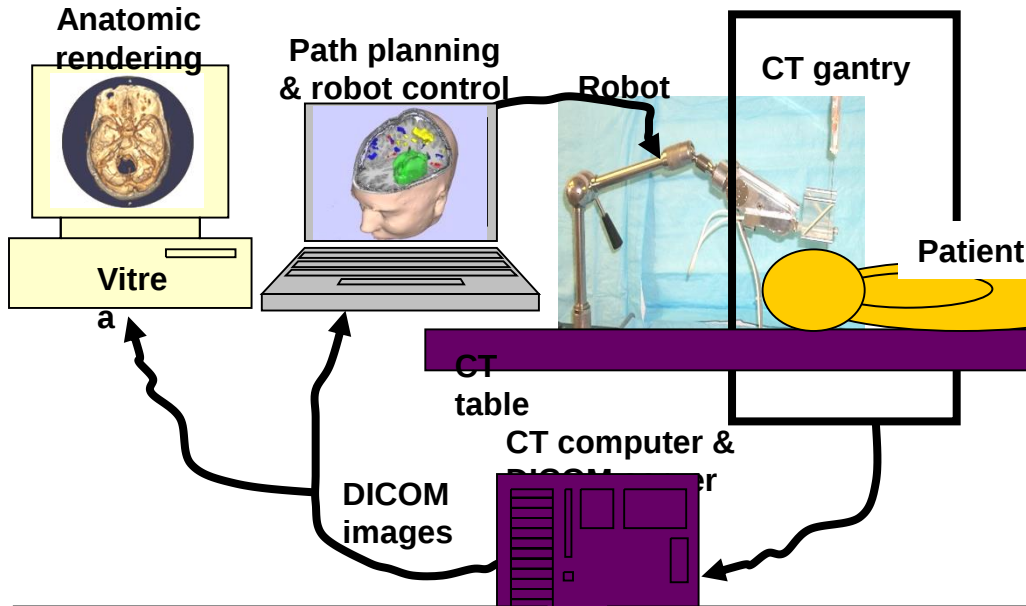
Robot registered to CT from a single image using stereotactic frame on the end-effector



[PLAY VIDEO](#)

Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon (JHU Bayview)

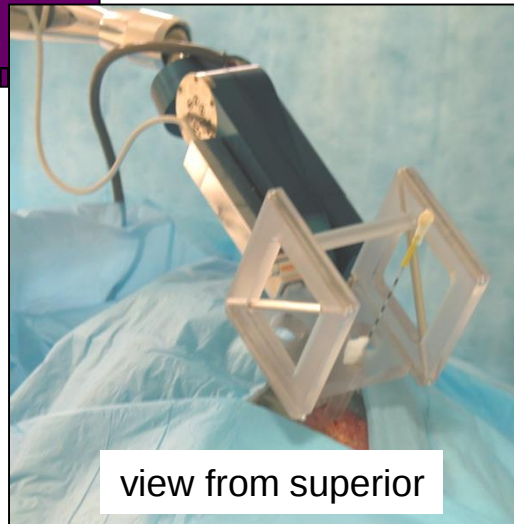
# Intra-Cranial Hemorrhage Removal



Blind spots  
Collision  
3DOF insufficient



view from inferior



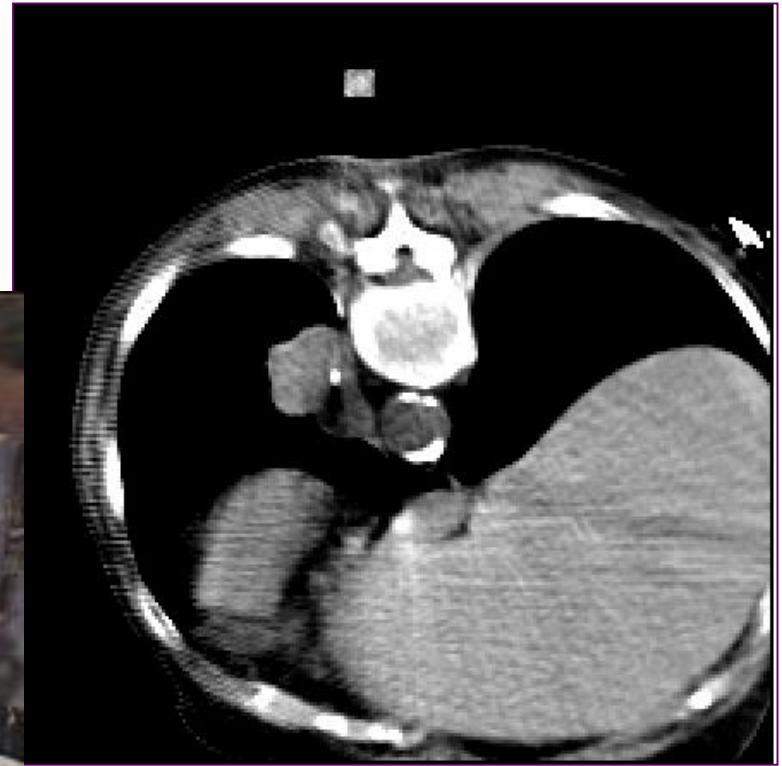
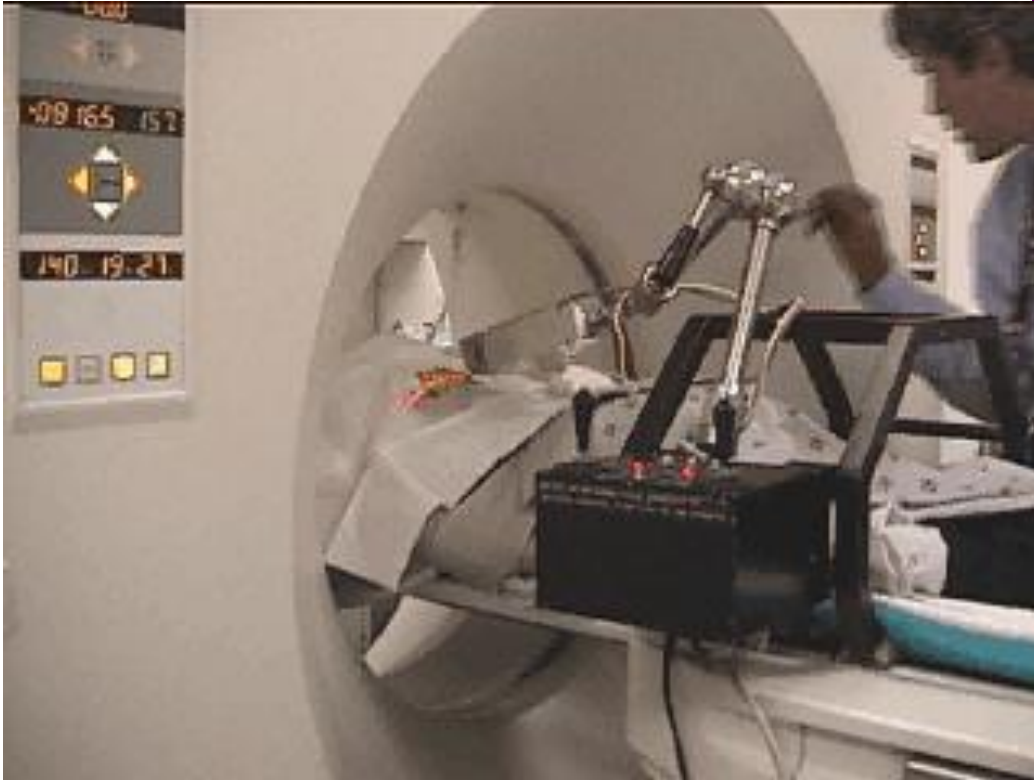
view from superior

**Credit: Ellis, Fichtinger, et al.**



# CT-Guided Lung Biopsy

Robot registered to CT using  
the scanner's alignment laser

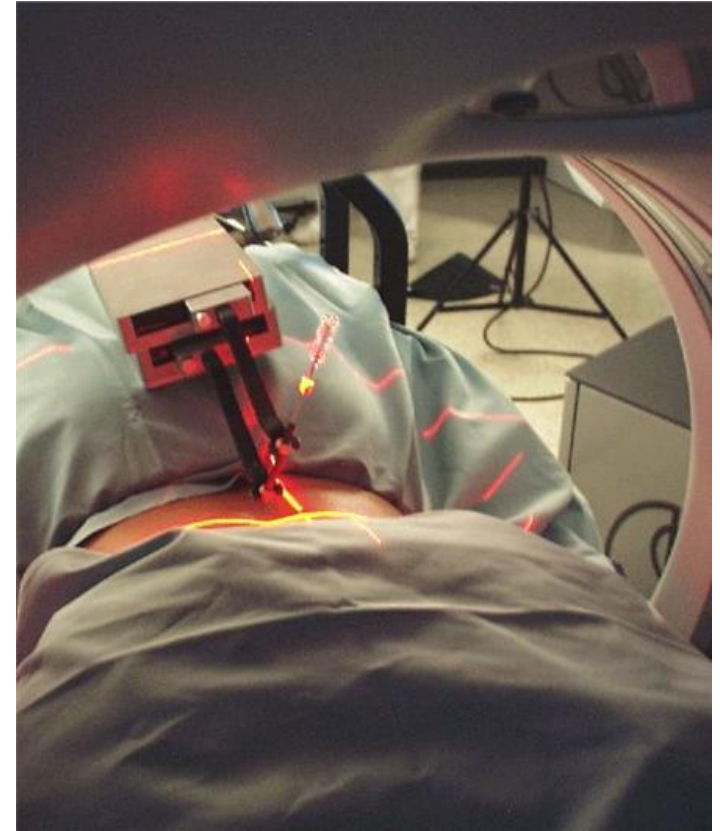


[PLAY VIDEO](#)

Patriciu et al, MICCAI 2001



# CT-Guided Biopsy Sandwich Robot (by Kronreif et al.)



**Credit: Gernot Kronreif, Joachim Kettenbach, Martin Fürst, Martin Kornfeld, Wolfgang Ptacek, Michael Voge, ARC Seibersdorf Research GmbH, Austria**

Kettenbach et al. Invest Radiol. 2005 Apr;40(4):219-28.; Kettenbach et al. Eur Radiol. 2005 Apr;15(4):765-71

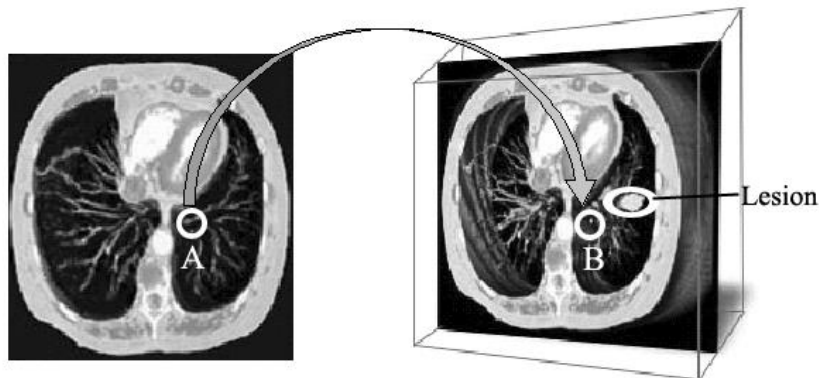
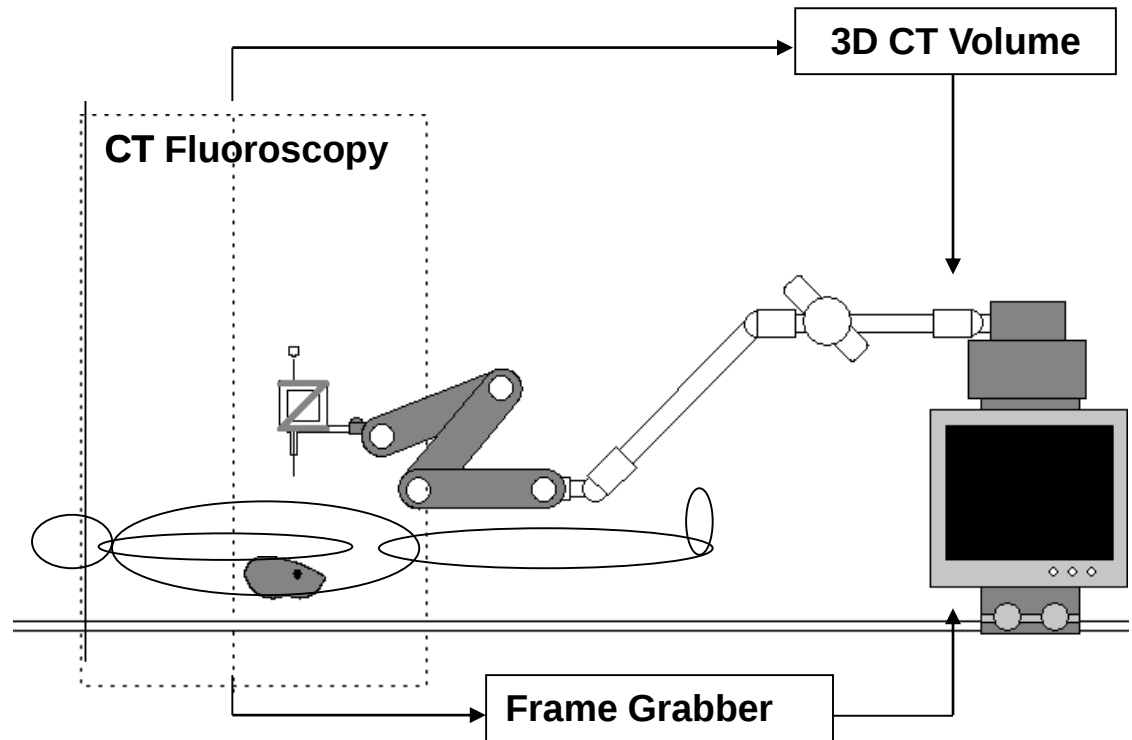
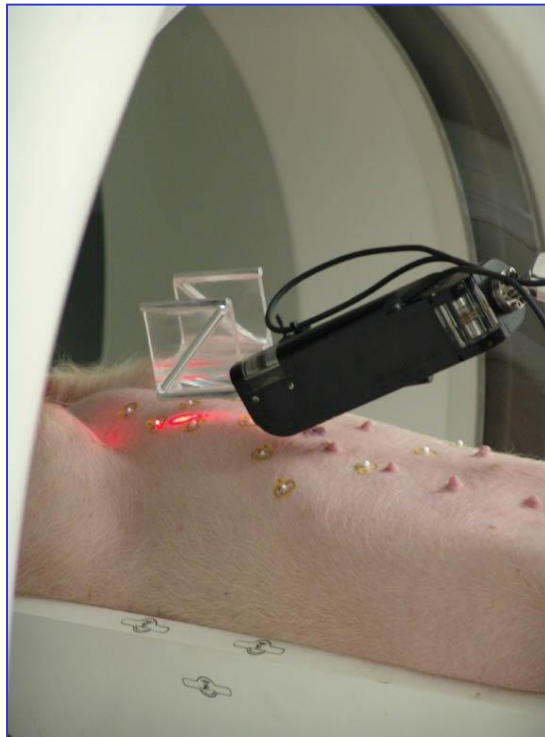
# Accubot



Stoianovici et al, IEEE Transactions on Robotics and Automation. Oct 2003



# CTF-Guided Lung Biopsy



**Register real-time CTF to CT  
Then compensate with robot**

**Xu et al. SPIE 2004**



CT Fluoroscopy Image

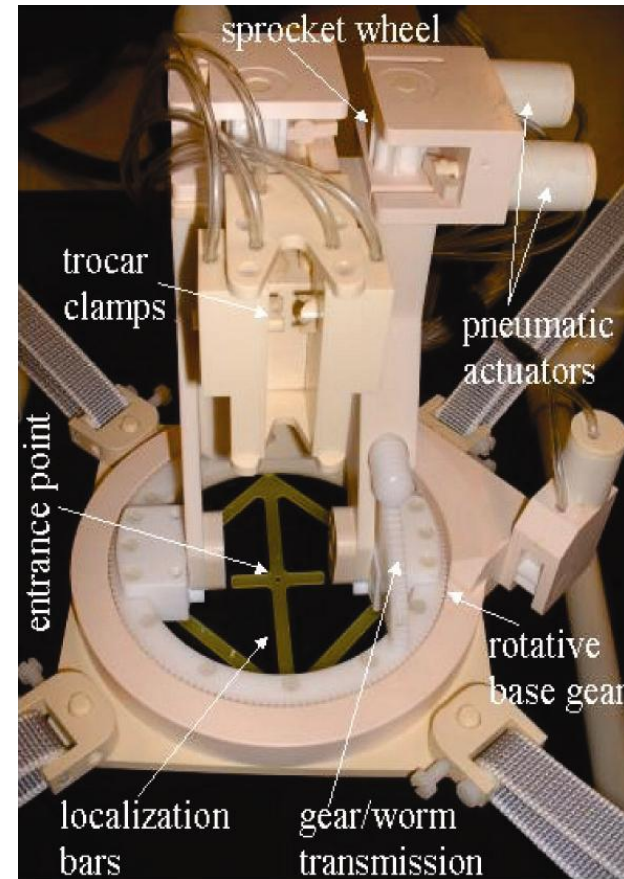
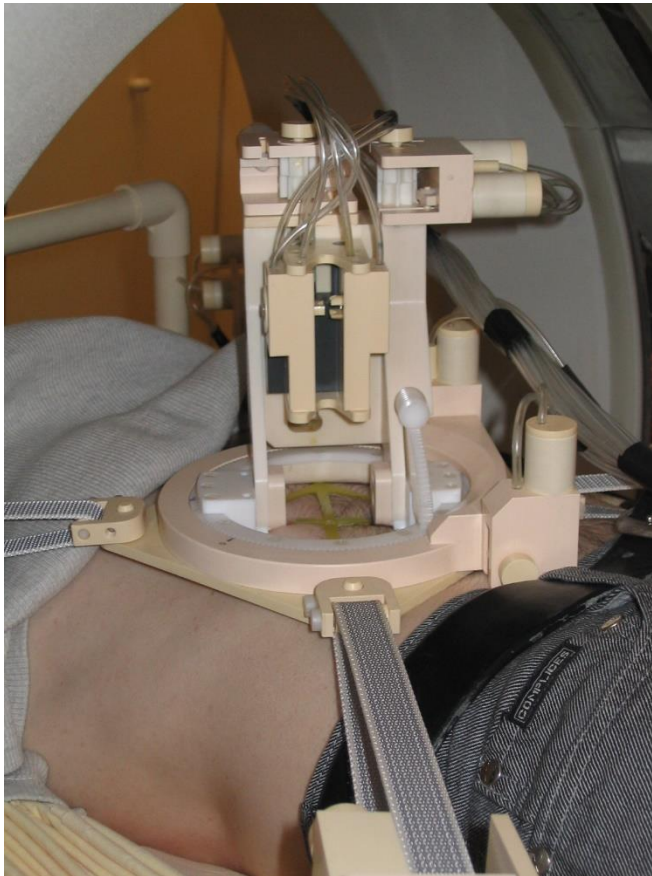
Pre-operative 3D CT Volume

Laboratory for Percutaneous Surgery – The Perk Lab

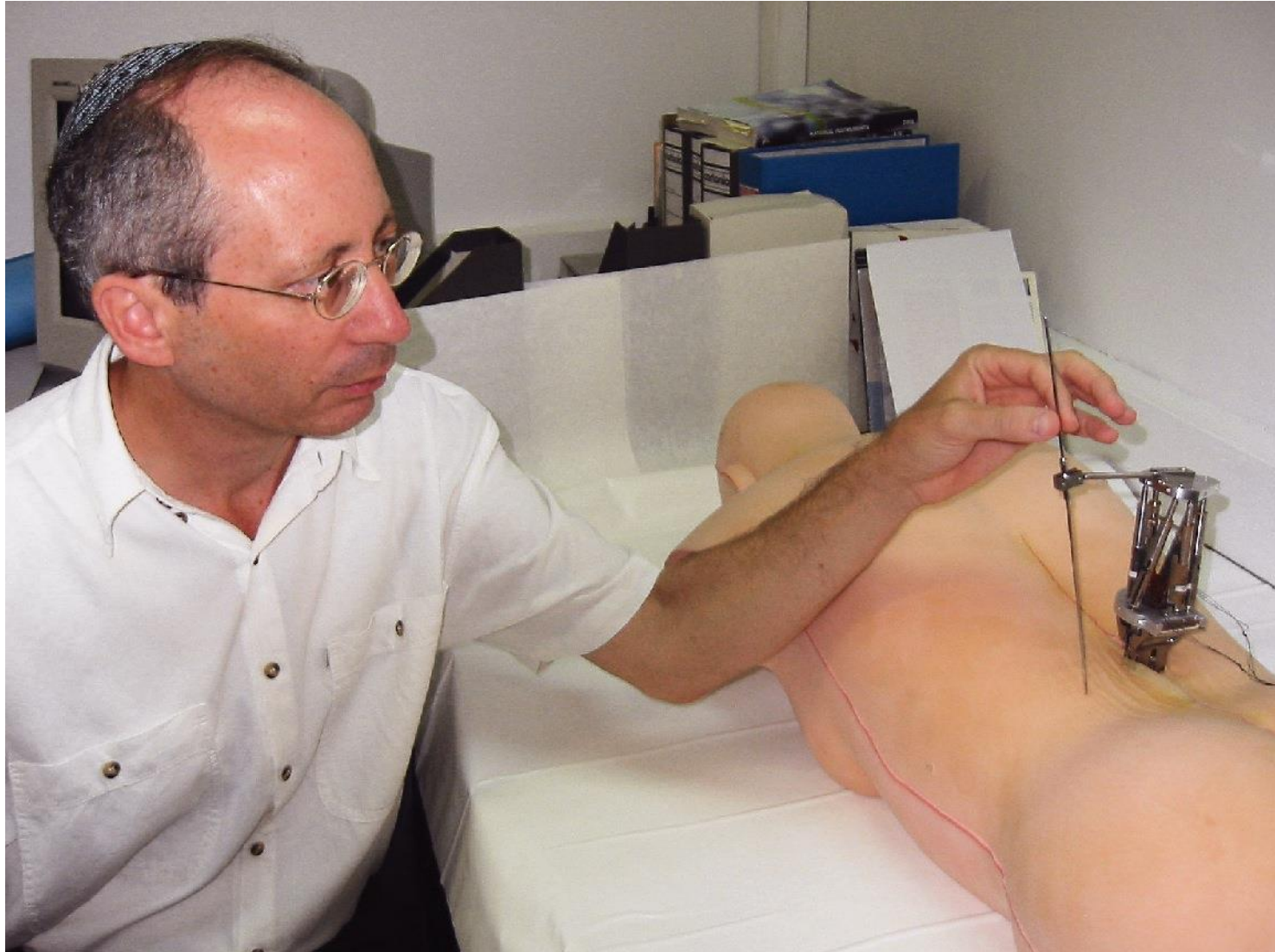
Copyright © Gabor Fichtinger, 2008

# Light Puncturing Robot for biopsies (TIMC, by Troccaz et al.)

- Body mounted
- CT/MR compatible
- No trajectory limitation
- Embedded fiducial localization
- Pneumatic actuation
- Accuracy ~1.5mm

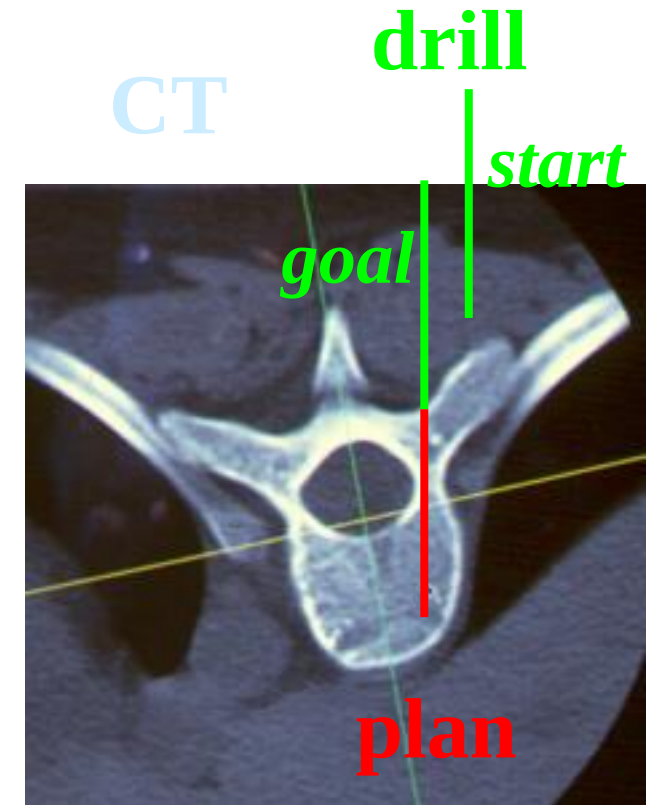
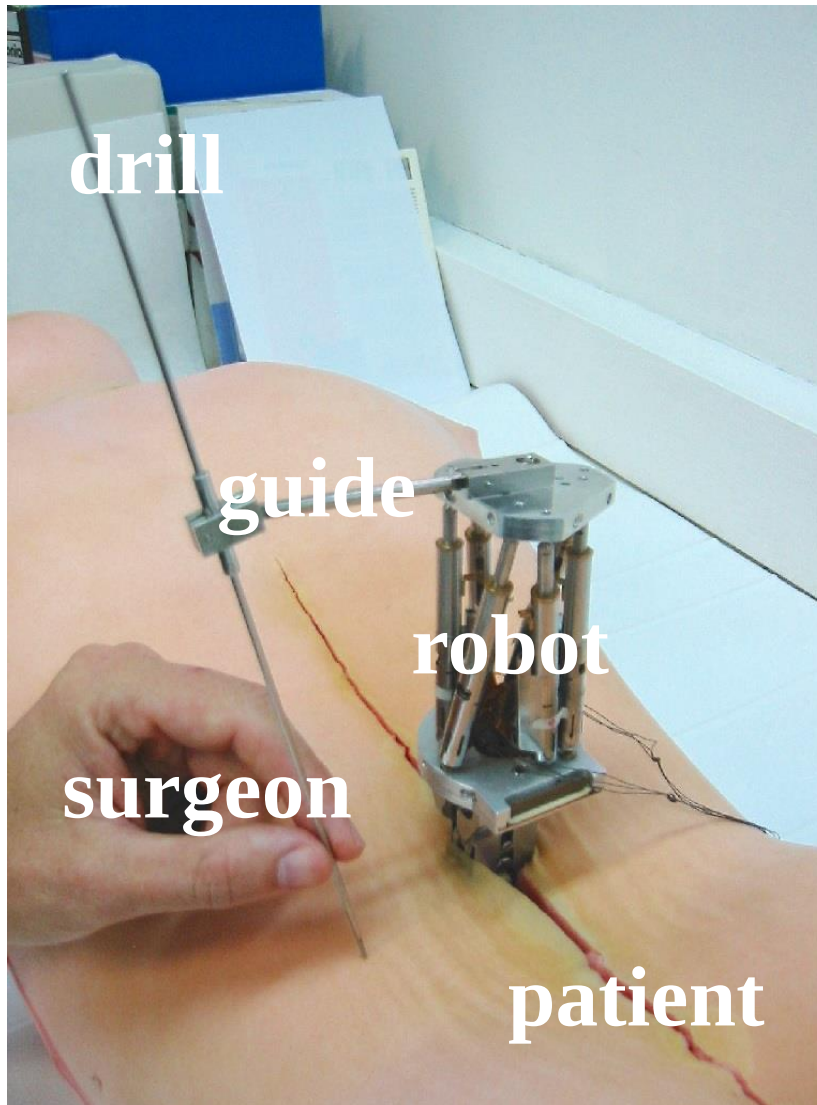


# Bone-mounted MARS system

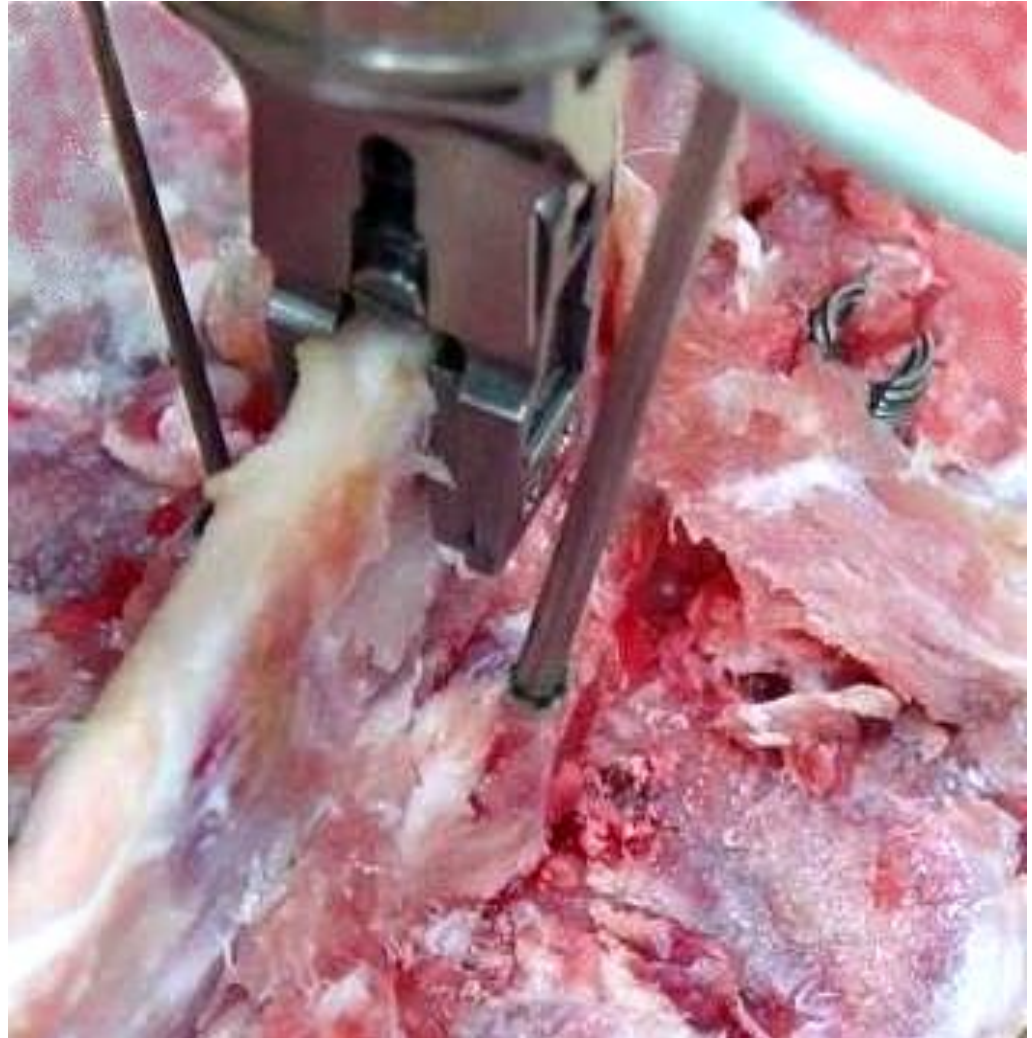


*M. Shoham, Technion and Mazor Surgical Technologies, Israel.*

# Robotic positioning: MARS



# MARS: pedicle screw insertion



# MARS: Execution



# MARS: Clinical setup

