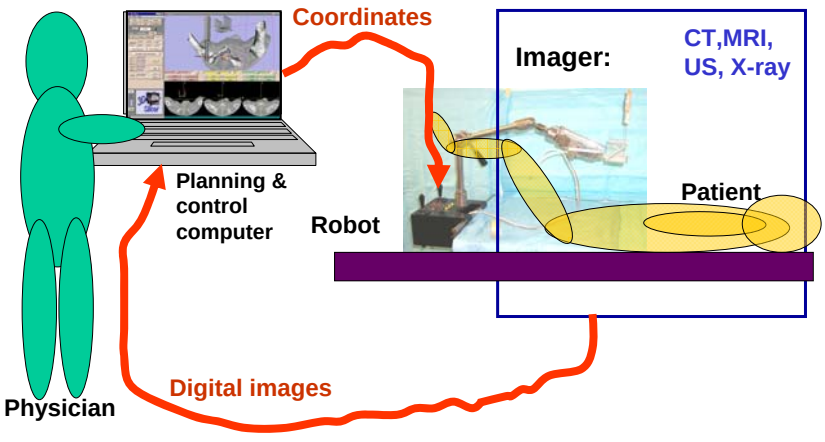
# Needle Placement Robots




## 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

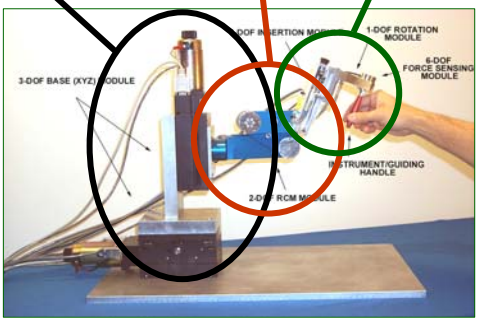
1. **3D translation "move needle to entry"**
2. **2D Rotation "orient needle"**
3. **0D/1D/2D Insertion "drive needle"**

**Pros:**

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

**Cons:**

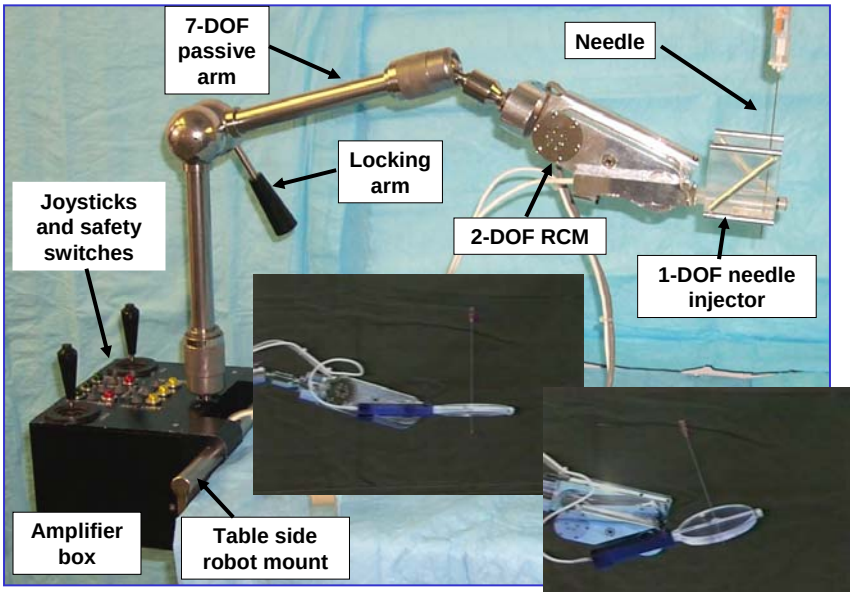
- **Limited types of motions**
- **Limited trajectory**
- **Ragged motion**




Taylor et al, IEEE TRA, 2001

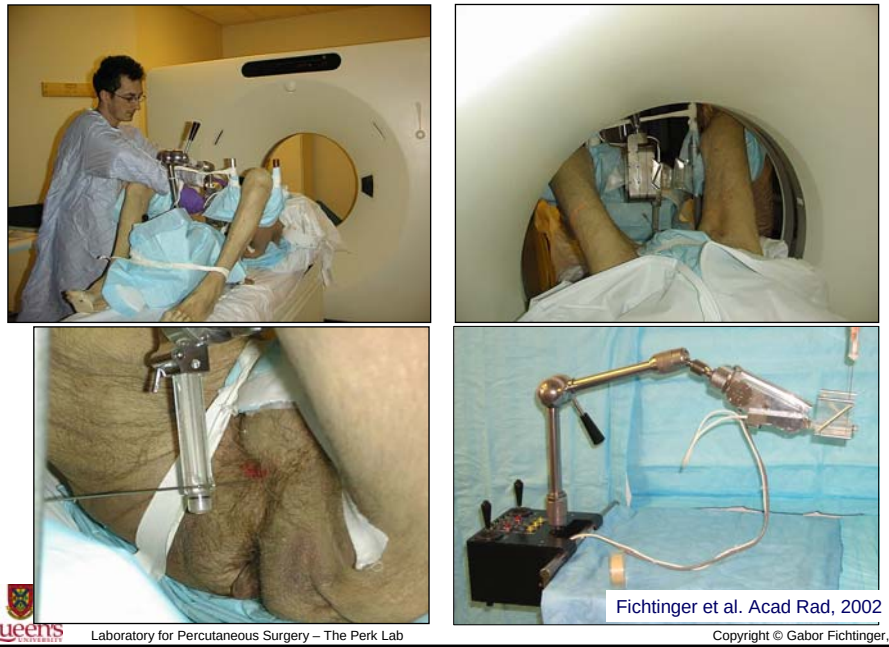



# Example: 3DOF RCM-PAKY




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

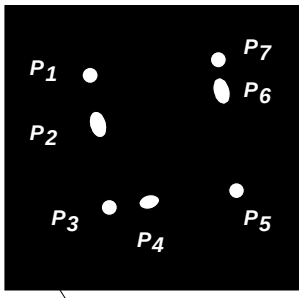
# CT-Guided Prostate Biopsy

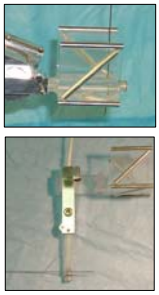


Fichtinger et al. Acad Rad, 2002

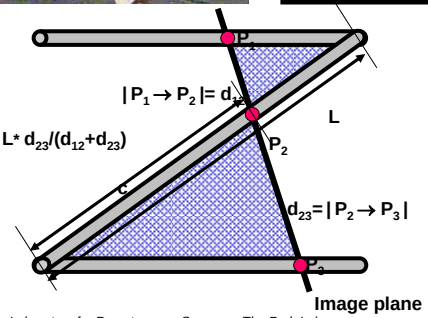



# Single-slice Registration to CT

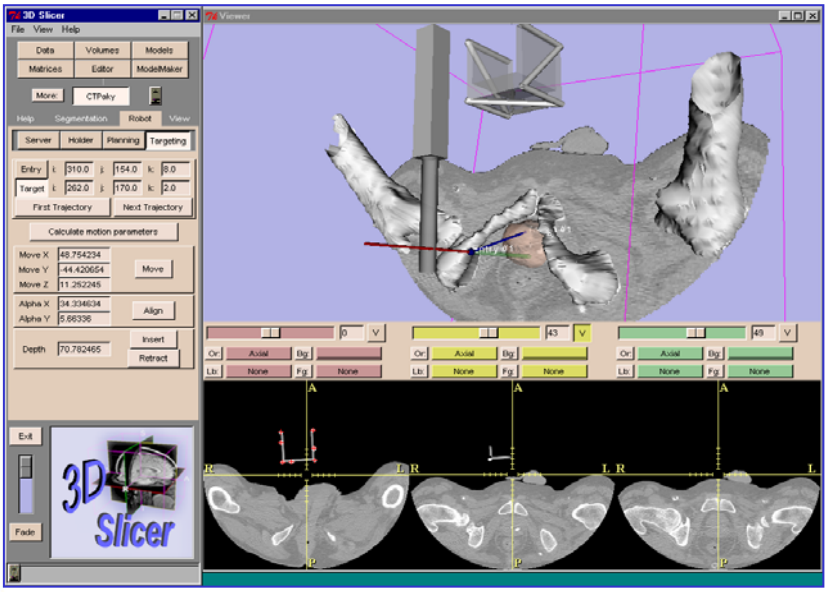





**Closed form: fast and computationally robust**

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

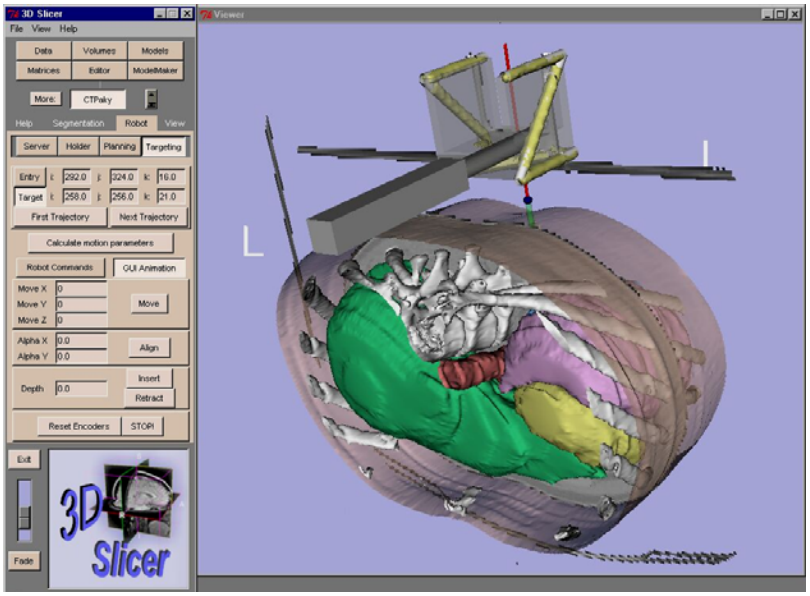
# Slicer-based Treatment Planning




**Credit: A. Tanacs**



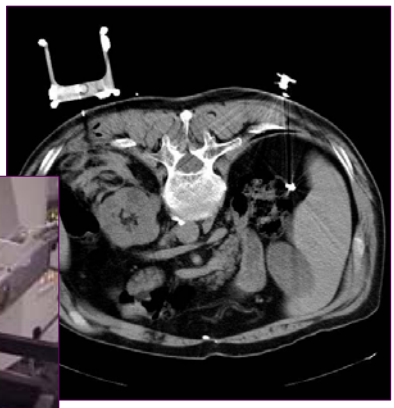

# Slicer-based Treatment Planning




**Credit: A. Tanacs**

# CT-Guided Kidney Biopsy

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

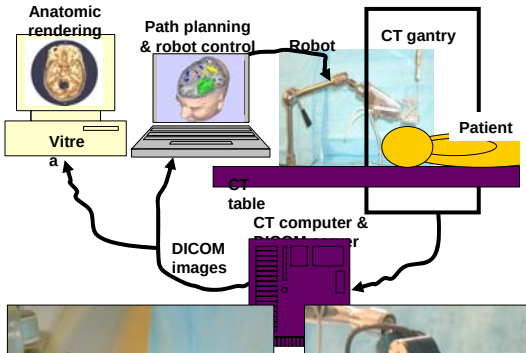


PLAY VIDEO

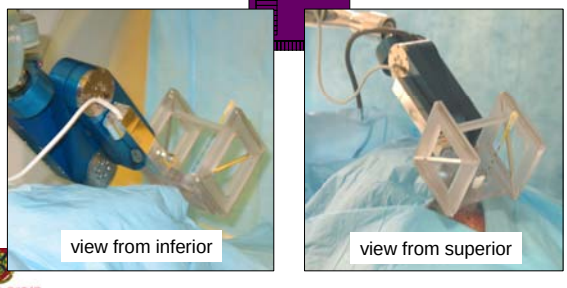
**Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon (JHU Bayview)**




# Intra-Cranial Hemorrhage Removal



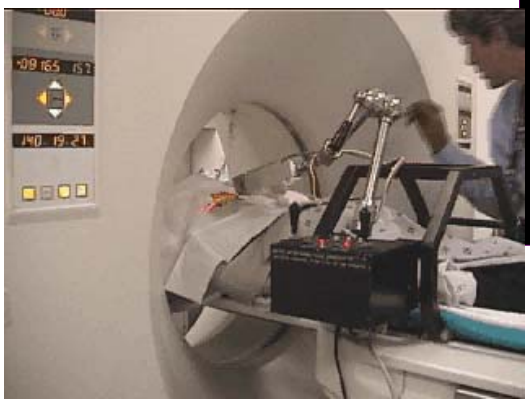

Blind spots
Collision
3DOF insufficient

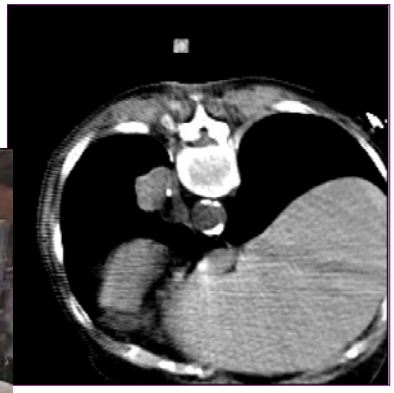



**Credit: Ellis, Fichtinger, et al.**

# CT-Guided Lung Biopsy

Robot registered to CT using the scanner's alignment laser



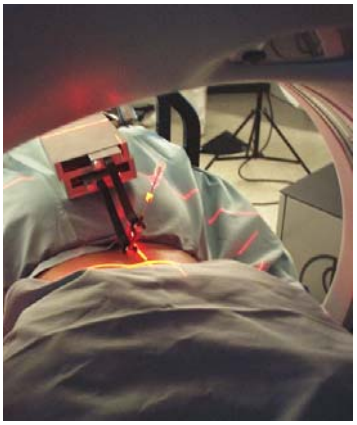


PLAY VIDEO

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 Vogele, ARC Seibersdorf Research GmbH, Austria

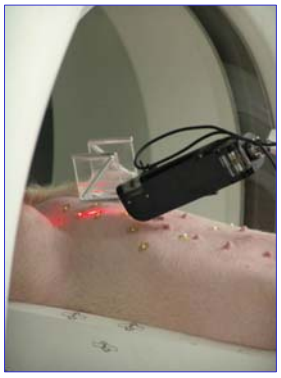
Kettenbach et al. Invest Radiol. 2005 Apr;40(4):219-28.; Kettenbach et al. Eur Radiol. 2005 Apr;15(4):765-71

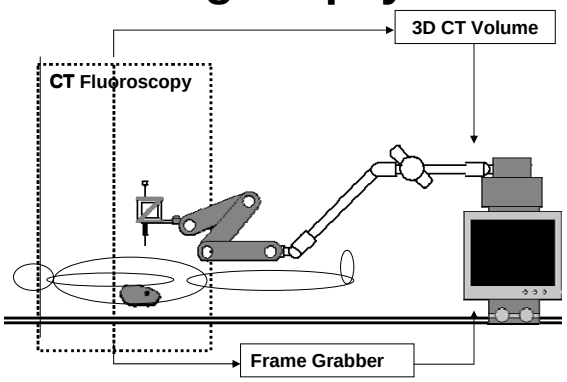
# Accubot

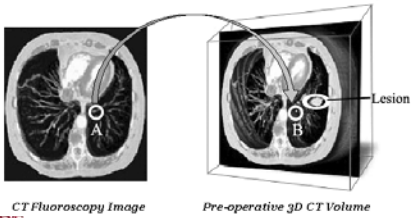
Stoianovici et al, IEEE Transactions on Robotics and Automation. Oct 2003




# CTF-Guided Lung Biopsy





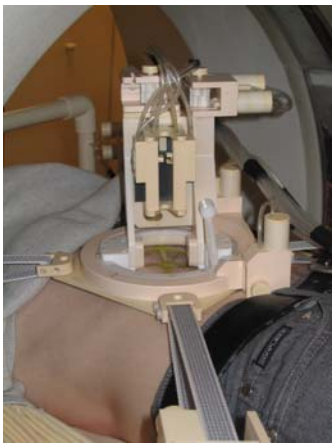

CT Fluoroscopy Image  Pre-operative 3D CT Volume

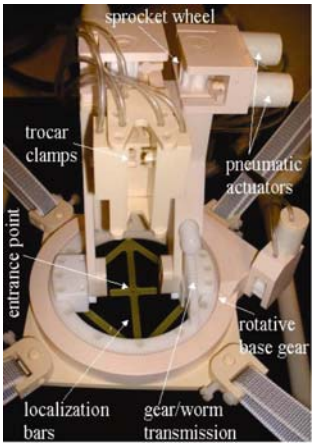
**Register real-time CTF to CT**
**Then compensate with robot**

**Xu et al. SPIE 2004**

## 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

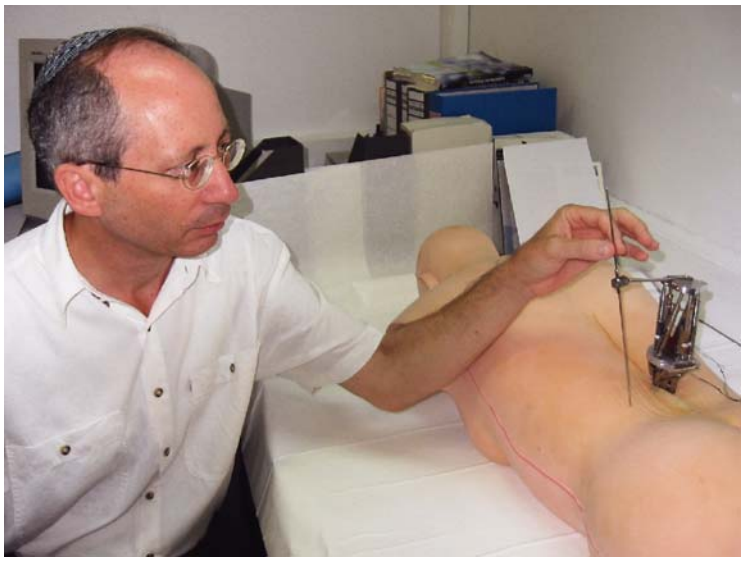






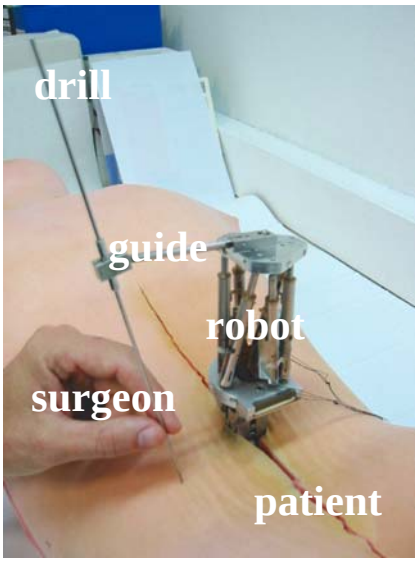


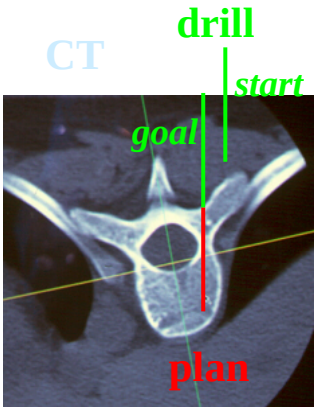
## Bone-mounted MARS system



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

## Robotic positioning: MARS

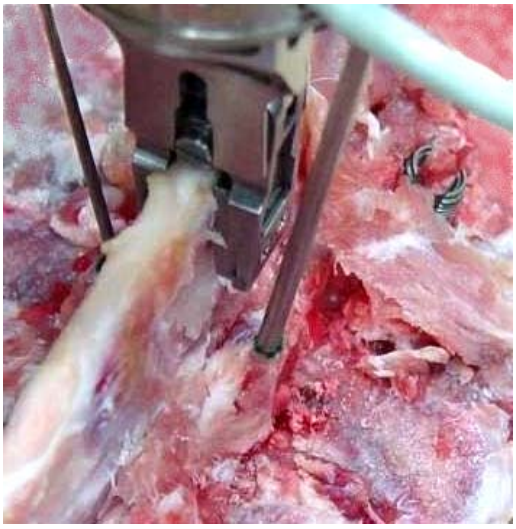






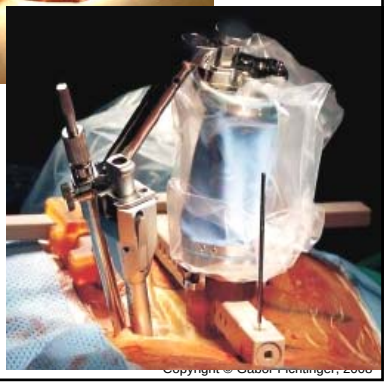
## MARS: pedicle screw insertion



## MARS: Execution




## MARS: Clinical setup



4,000 screw to date