ME 328: Medical Robotics
Winter 2019

# Lecture 1: Introduction to medical robotics

Allison Okamura
Stanford University

# About this class

- Teaching staff

Instructor: Allison Okamura
Co-instructor for seminars: Federico Barbagli
CAs: Lisa Yamada, Cole Simpson

- Who are you?
- Review course logistics

Web page
Syllabus

# To do

- Fill out the survey (handout)
- Sign up on piazza today:

  https://piazza.com/stanford/winter2018/me328

- Enter your availability on this when2meet poll by tomorrow at 3 pm:

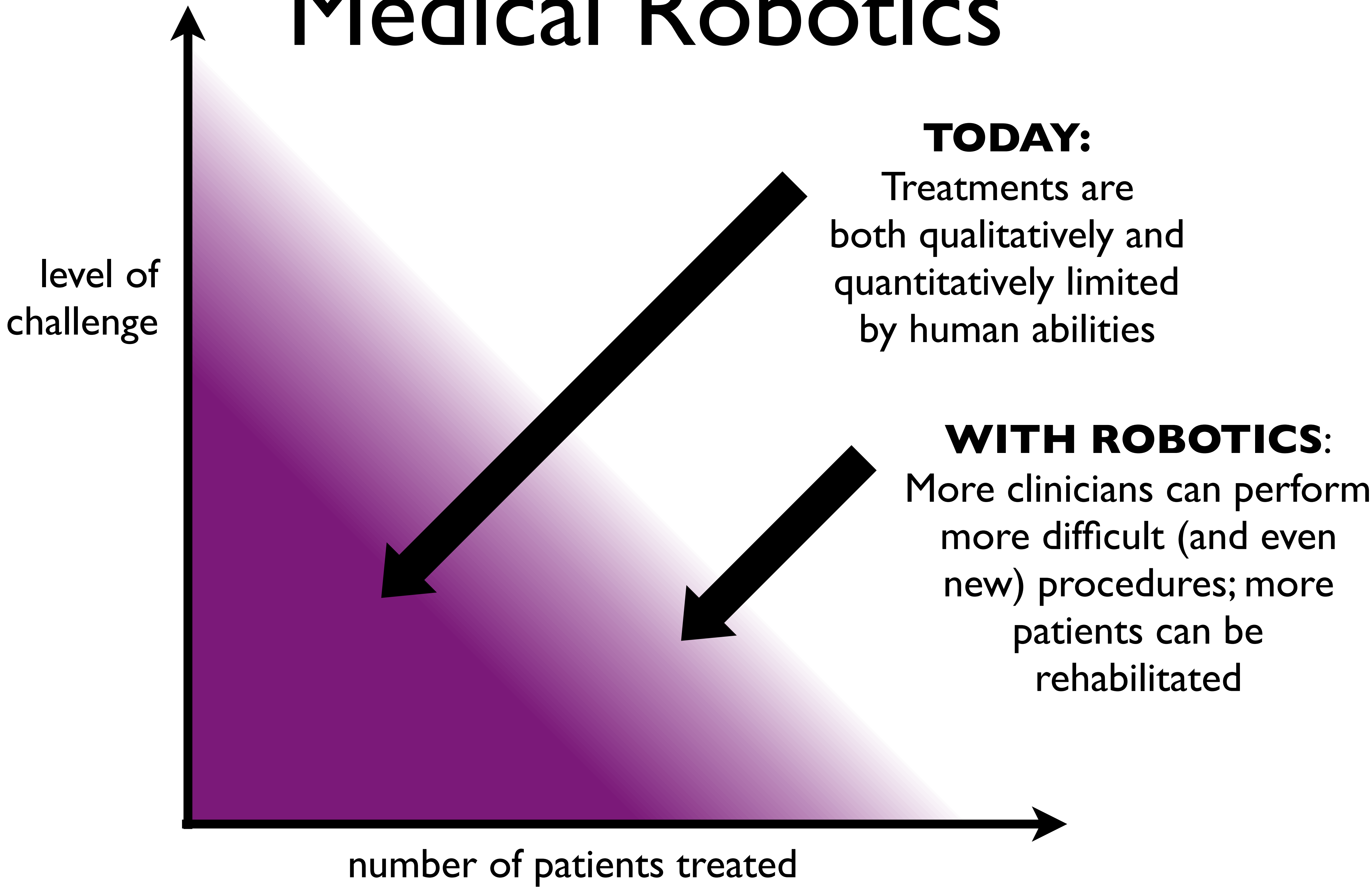
  https://www.when2meet.com/?7393949-lDcQJ

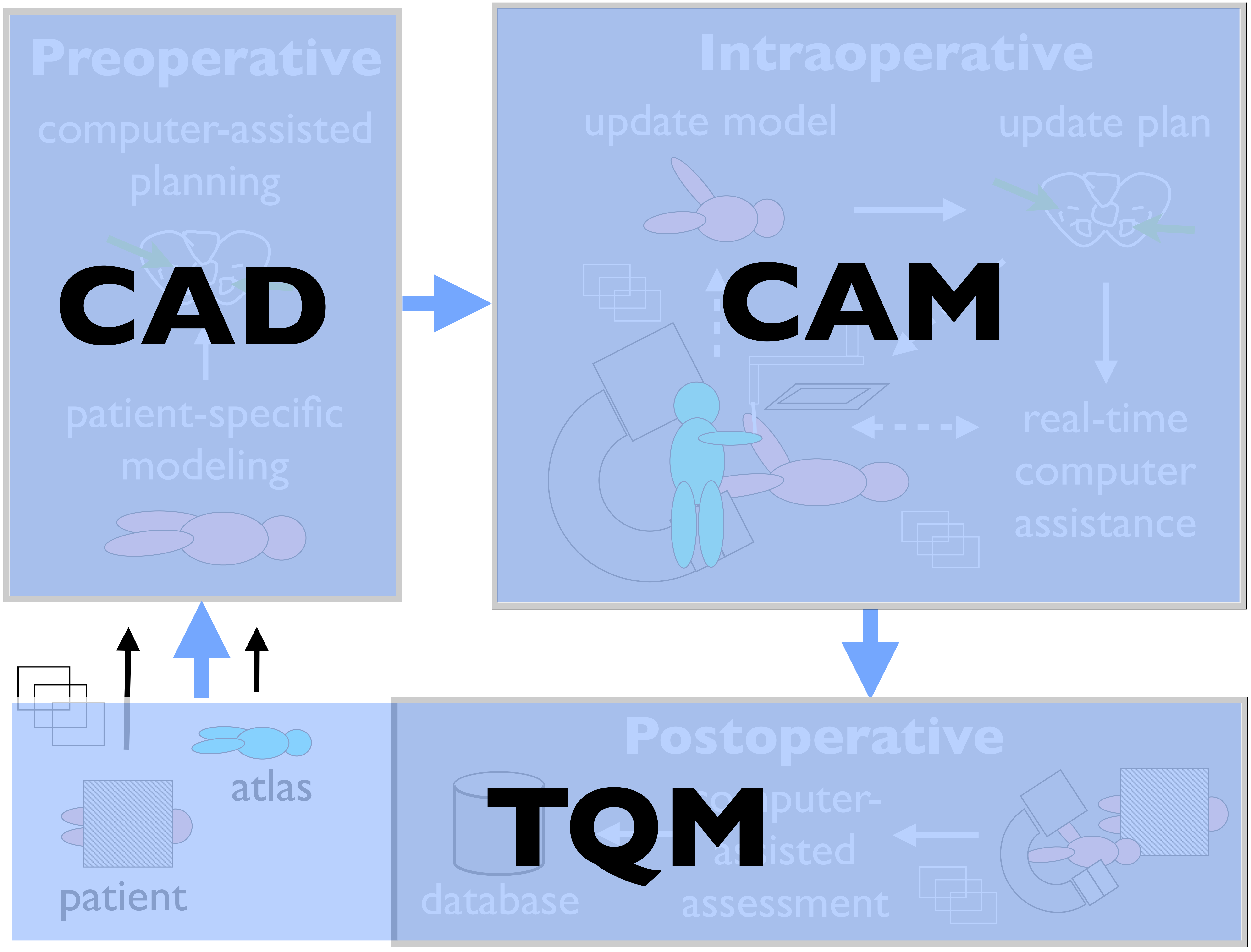
# Robots are...

- Accurate and precise; Untiring
- Smaller or larger than people (as needed)
- Remotely operated (as needed)
- Connected to computers, which gives them access to **information**
- Not always able to operate autonomously in highly complex, uncertain environments

→ **Need for human interaction**

# Potential Impact of Medical Robotics





Preoperative
computer-assisted planning
CAD
patient-specific modeling
Intraoperative
update model
update plan
CAM
real-time computer assistance
Postoperative
TQM
computer-assisted assessment
database
atlas
patient

Surgical robotics:

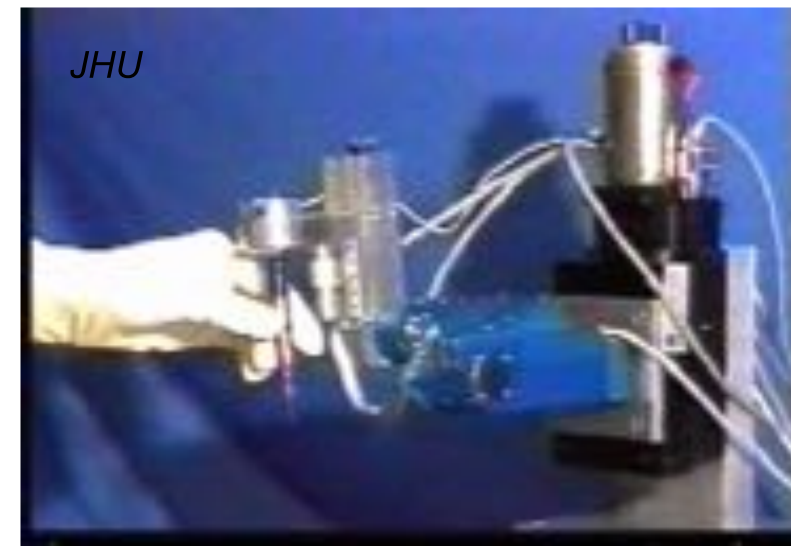
Giving the surgeon superhuman capabilities

# Level of Human Input Varies

## Oral


## Manual


## Cooperative manipulation




## Teleoperation



## Autonomous

Dario et al.

CyberKnife

# STOPPED HERE

# Open Surgery

Surgeon

Patient

Image source: www.physicianphotos.com

# Minimally Invasive Surgery

Surgeon

Instrument/Camera

Patient

Image source: www.womenssurgerygroup.com

# Teleoperated Robot-Assisted Minimally Invasive Surgery

Surgeon

Master Console

Information-Enhanced RMIS

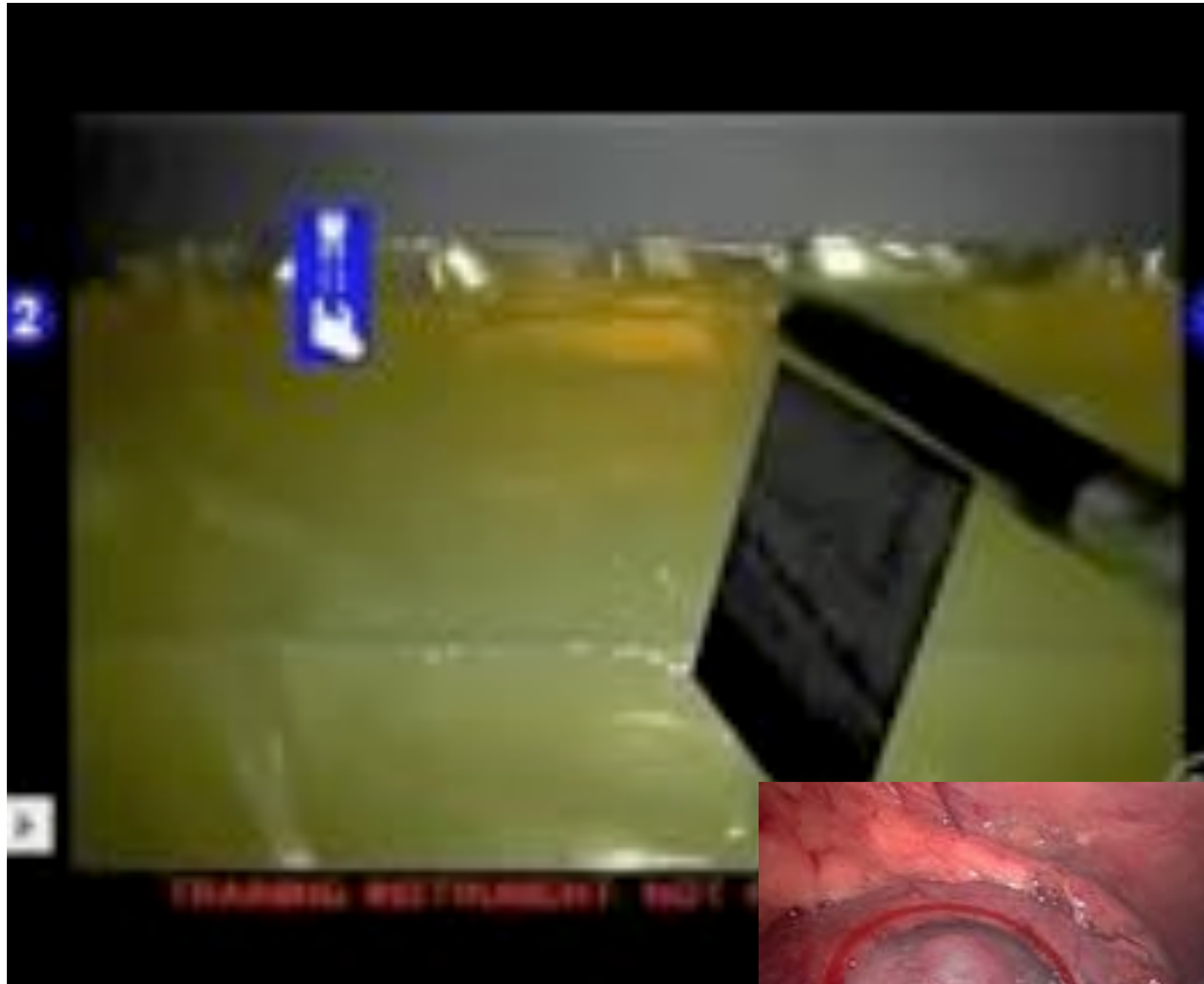
Patient-Side Robot

Instrument/Camera

Patient

# Integrating Images

Laparoscopic ultrasound integrated with the da Vinci surgical system



Russell Taylor and Gregory Hager (JHU)

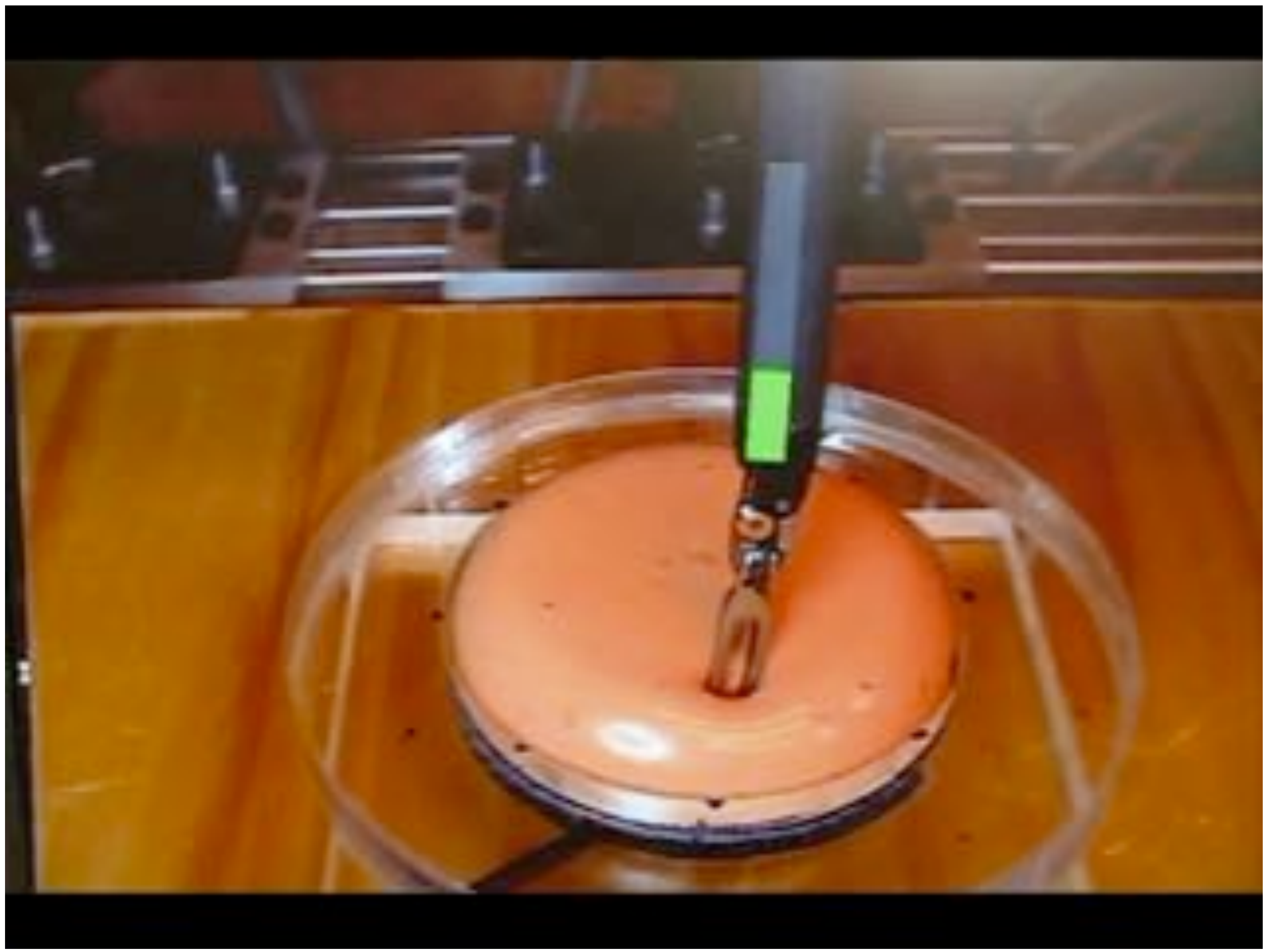
# Force Feedback for Manipulation



Graphical force feedback results in **lower peak forces**, **lower variability of forces**, and **fewer broken sutures** for untrained robot-assisted surgeons

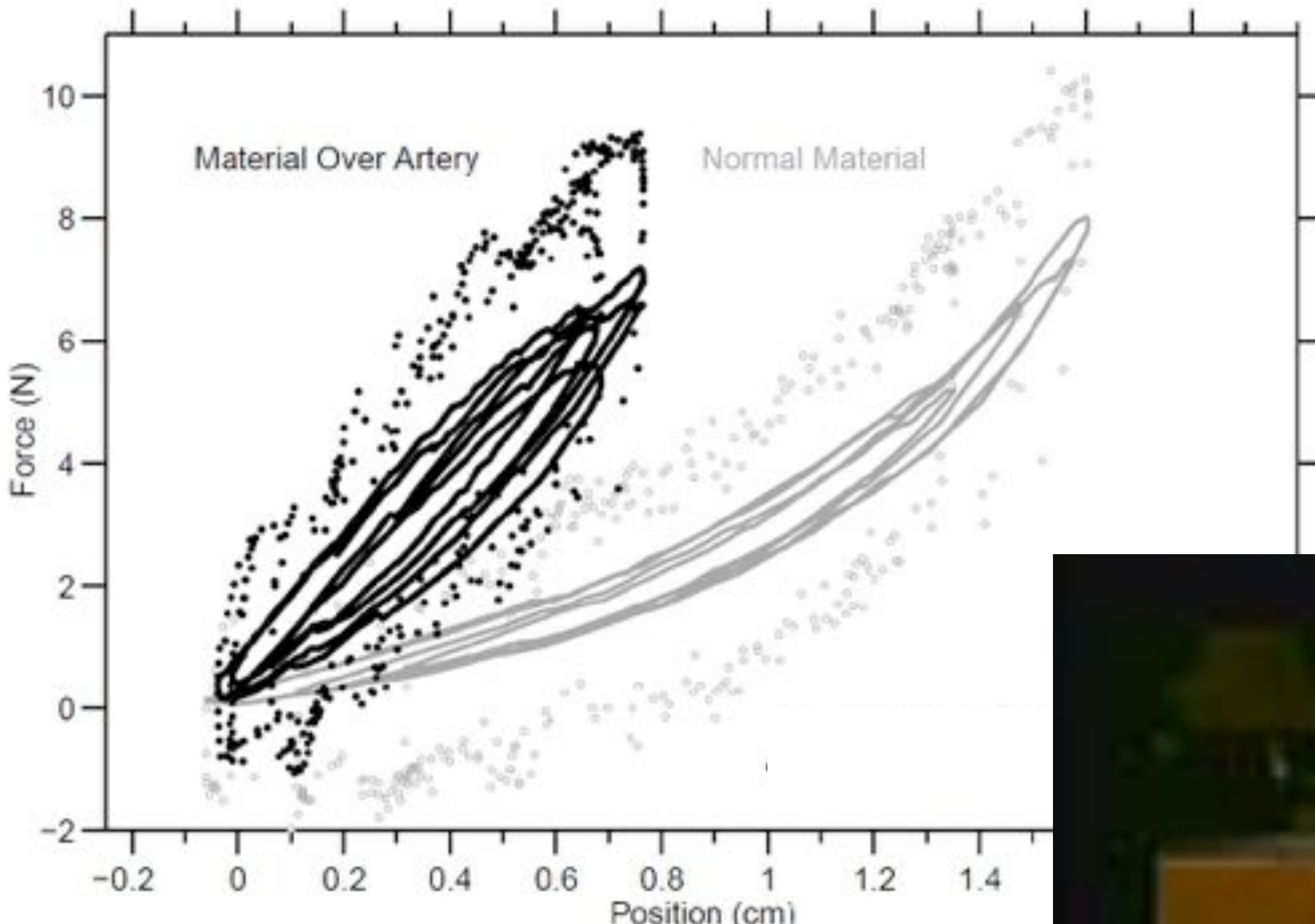
In collaboration with D. D. Yuh of JHMI Cardiac Surgery

# Force Feedback for Exploration

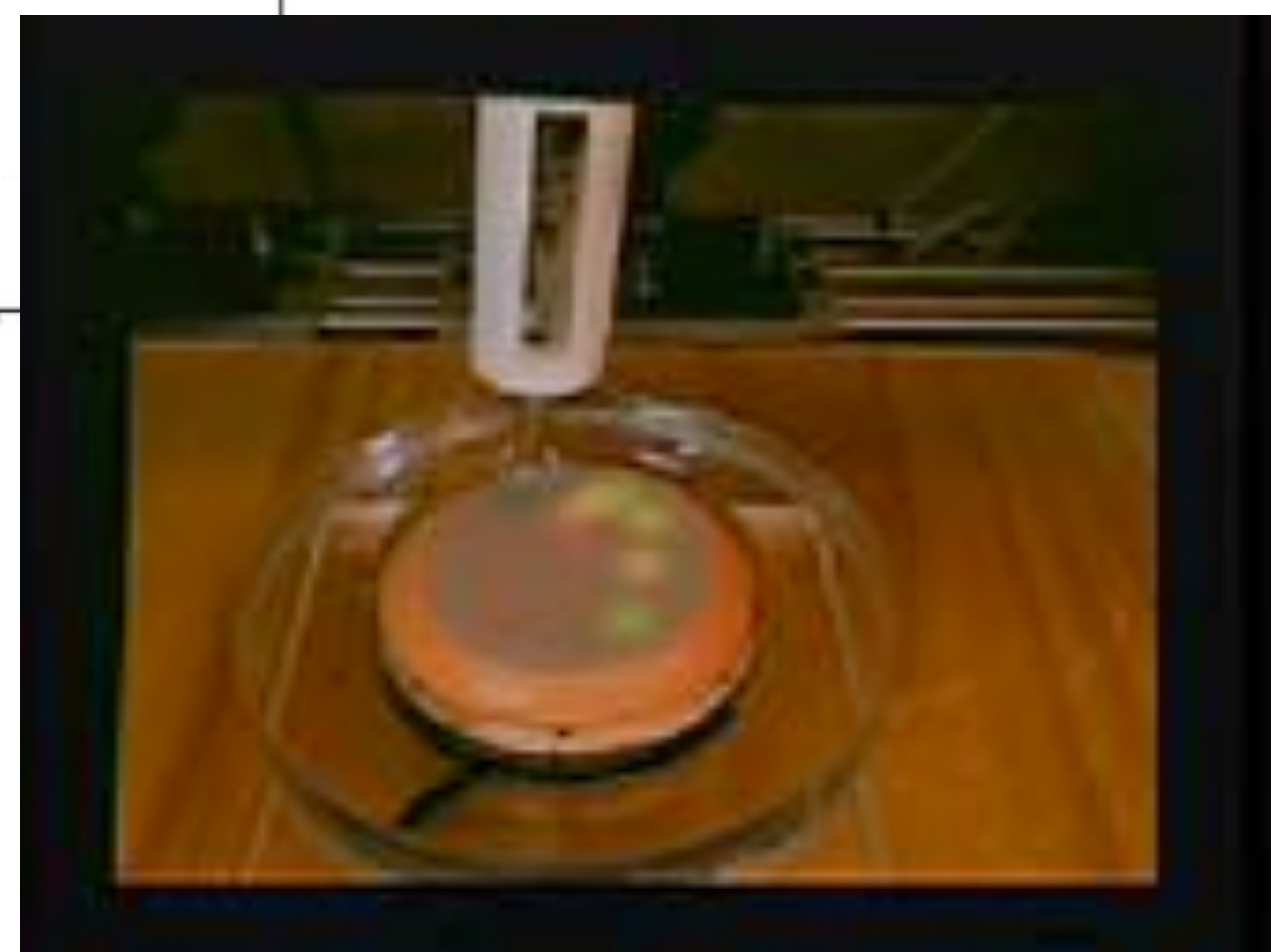


In collaboration with D. D. Yuh of JHMI Cardiac Surgery and Li-Ming Su of JHMI Urology

# The Sensing Challenge

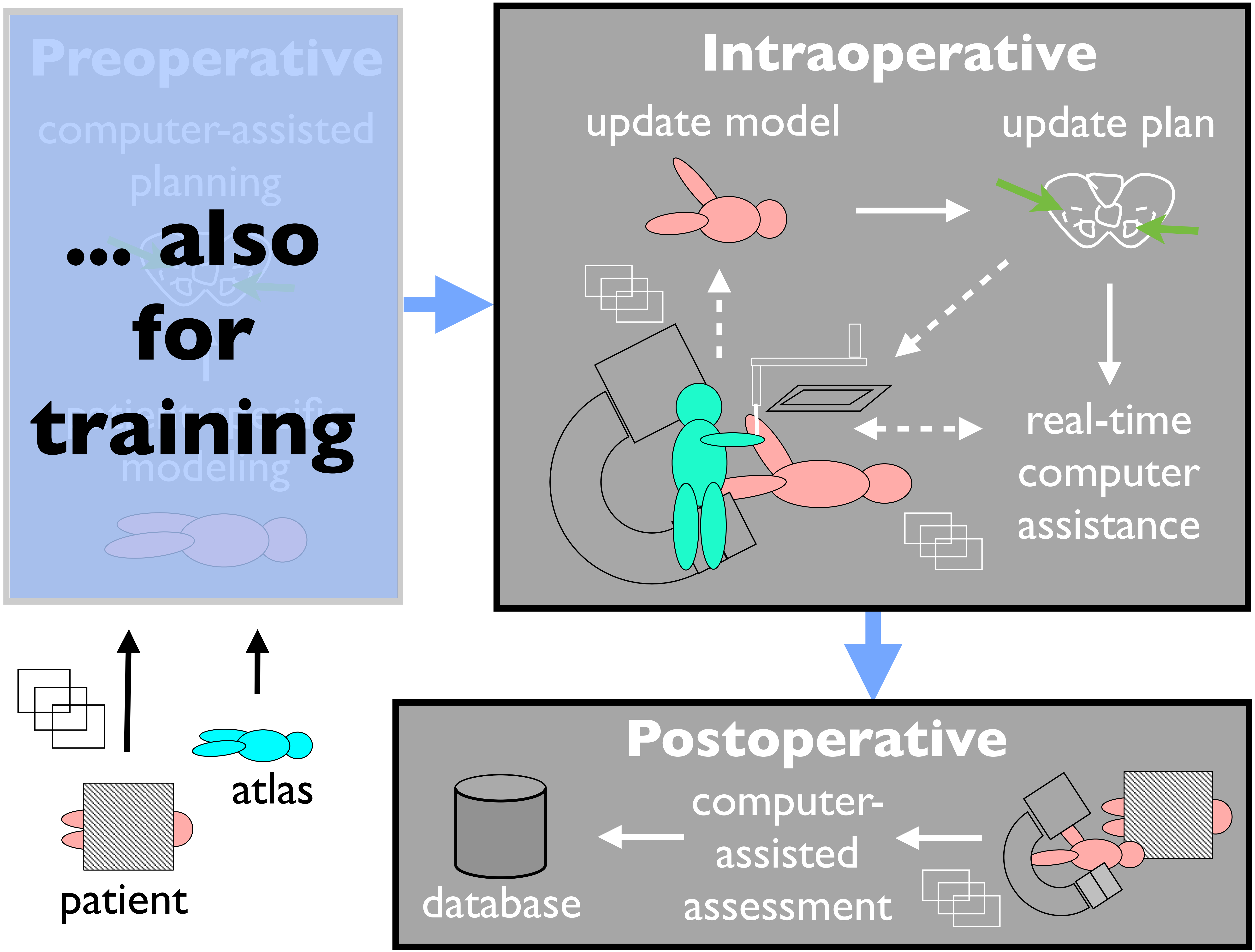



stiffness differences are difficult to feel through a rigid contact



stiffness graphical overlay

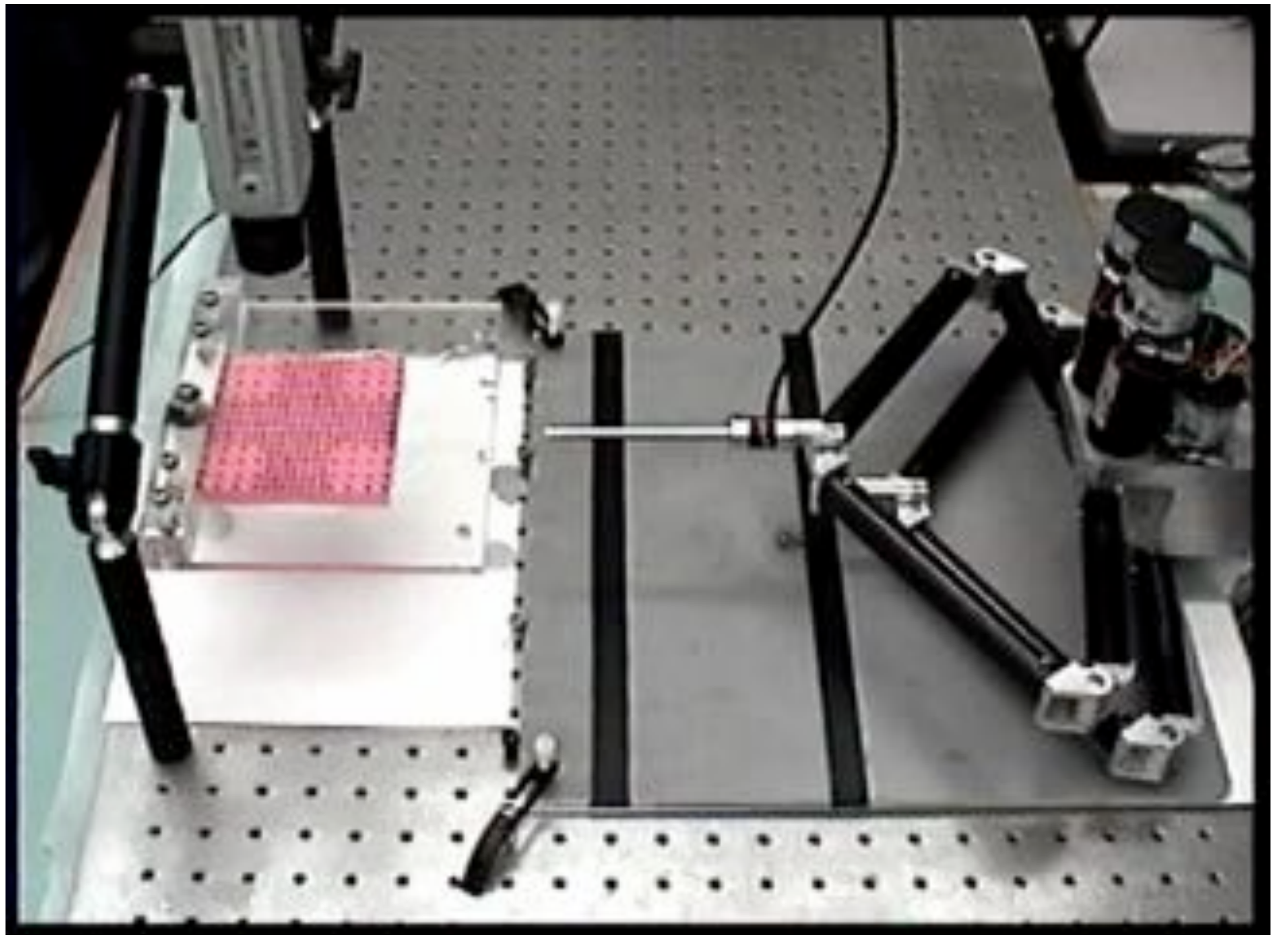
In collaboration with D. Yuh (JHMI Cardiac Surgery) and Li-Ming Su (JHMI Urology)

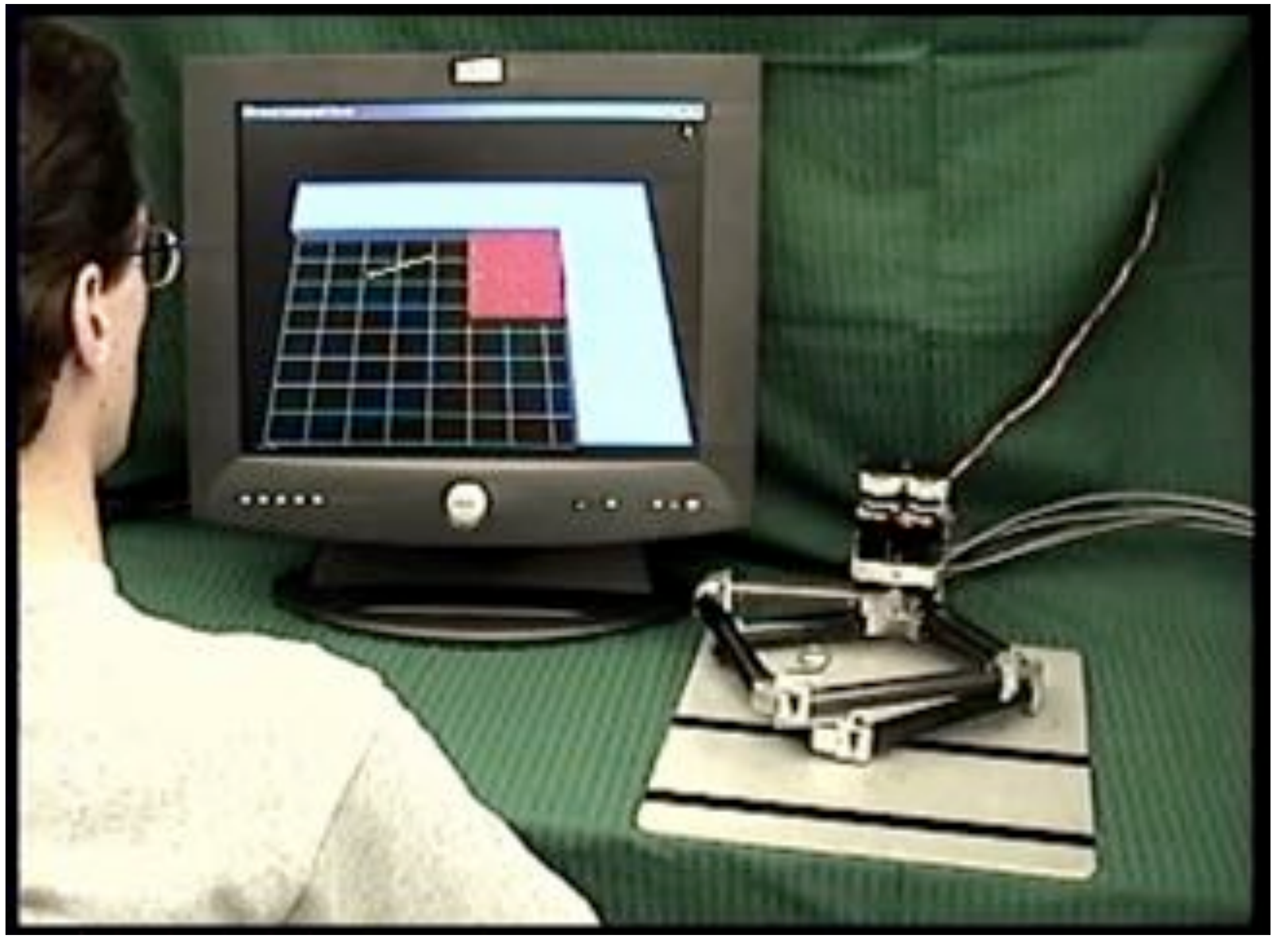

Preoperative
computer-assisted
planning
... also for training
modeling
patient
atlas
Intraoperative
update model
update plan
real-time computer assistance
Postoperative
database
computer-assisted assessment

# Modeling:

Improving training and planning (and paving the way for autonomous robotic procedures)

# From Modeling to Simulation





S. DiMaio and S. E. Salcudean (University of British Columbia)

# Example Commercial Simulators

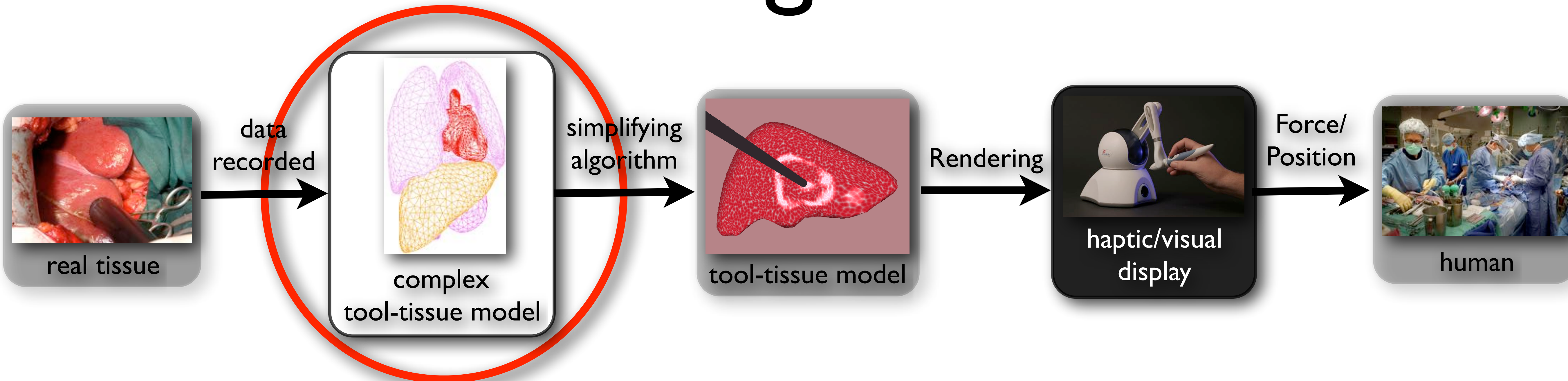
Laparoscopy

Endovascular

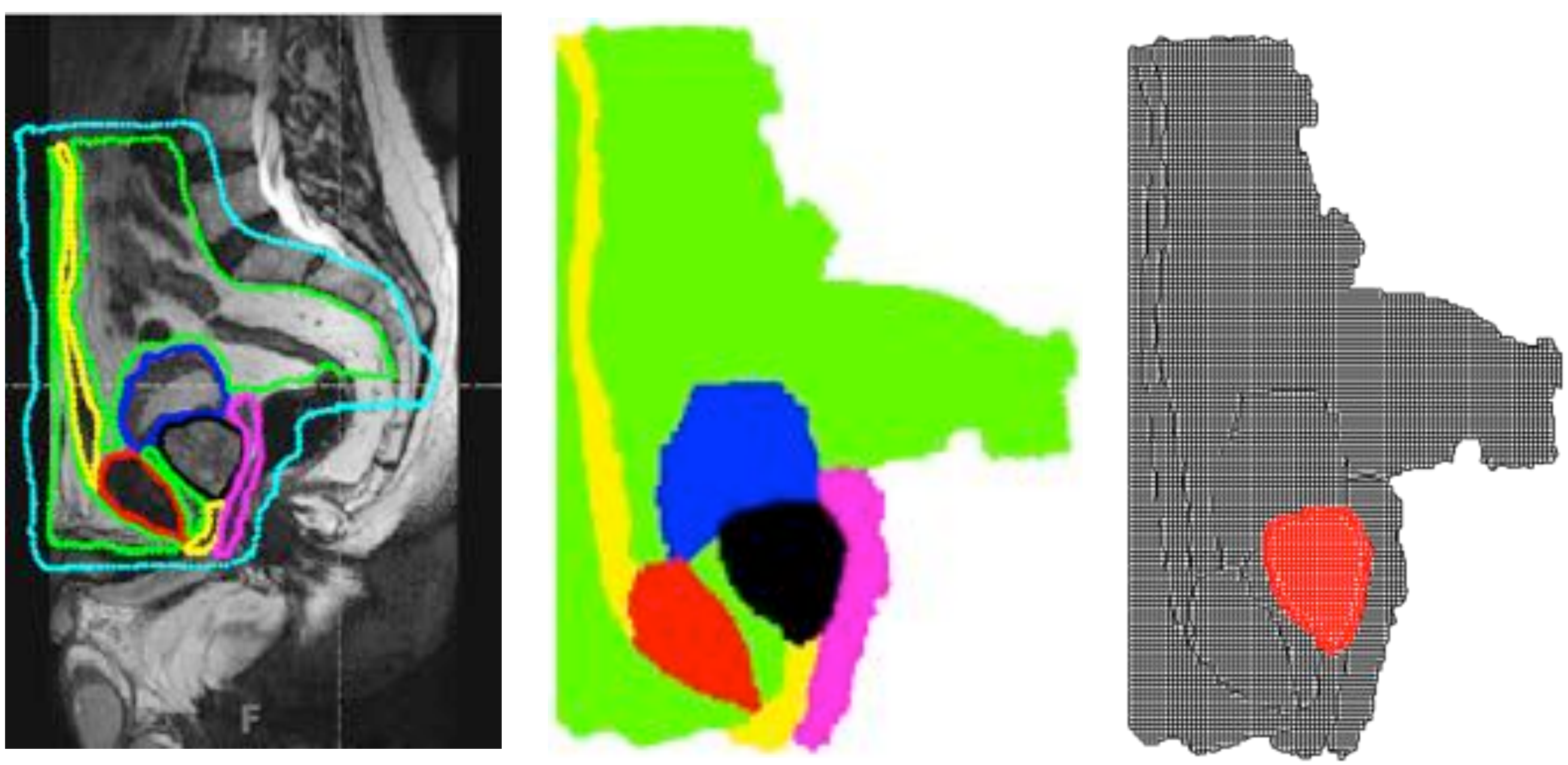
Endoscopy

Immersion Corp.

# Modeling Factors

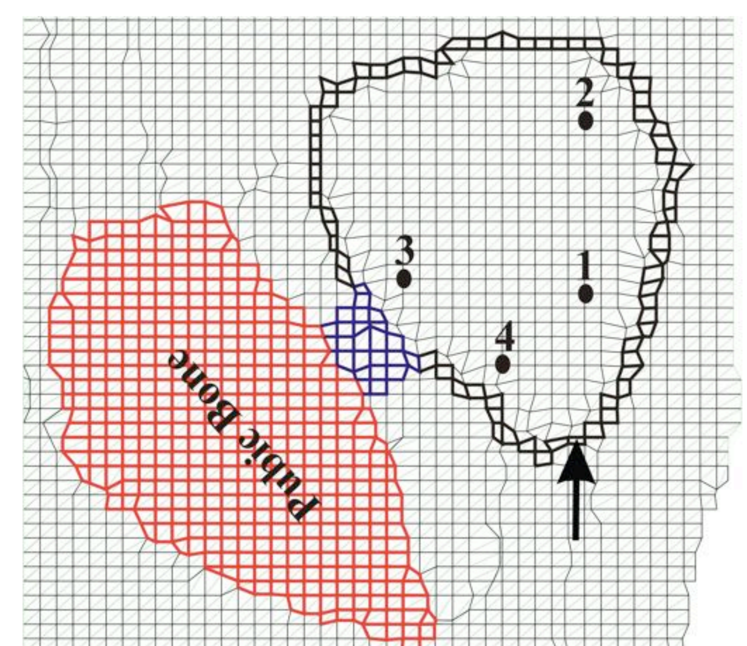



Developing mechanical models from images

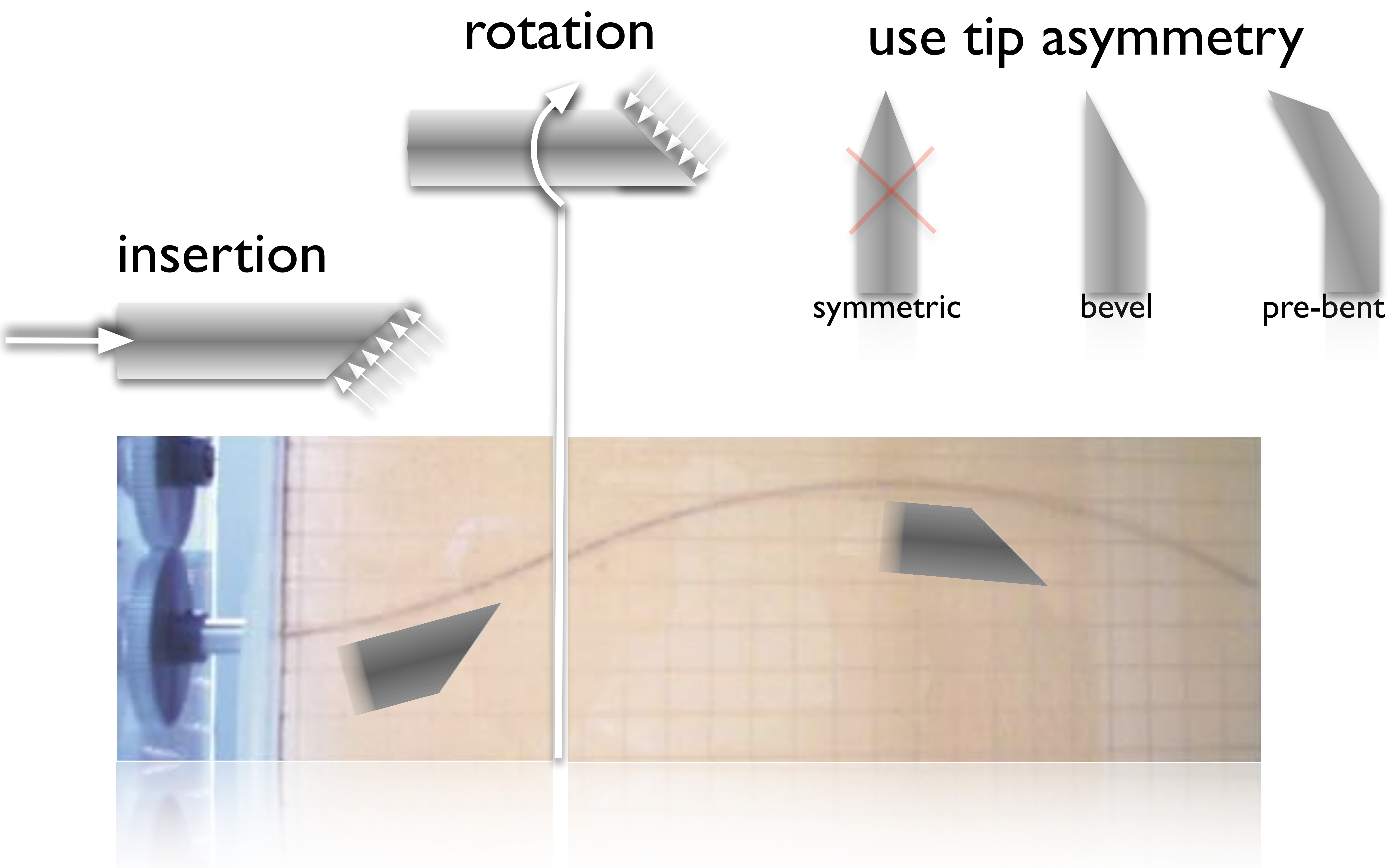


In collaboration with K. Macura
(JHMI Radiology and Radiological Sciences)

Effects of material properties, boundary constraints, and geometry

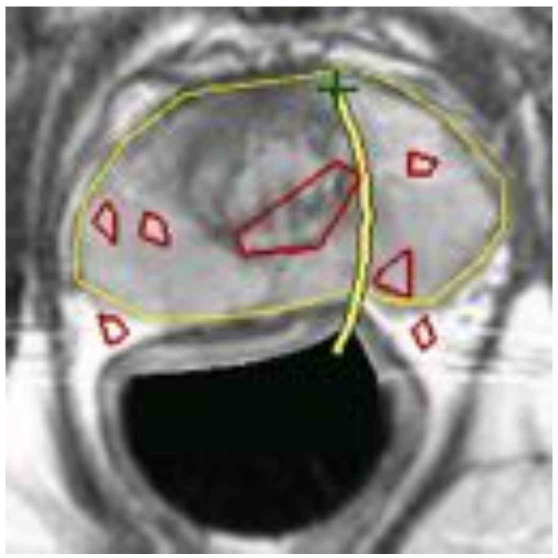


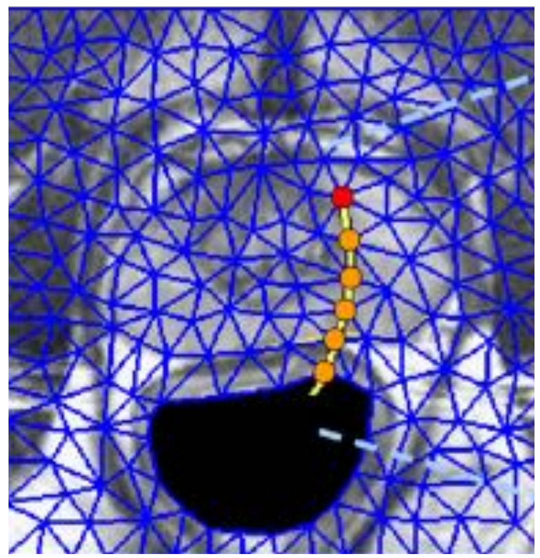
# Modeling enables needle steering



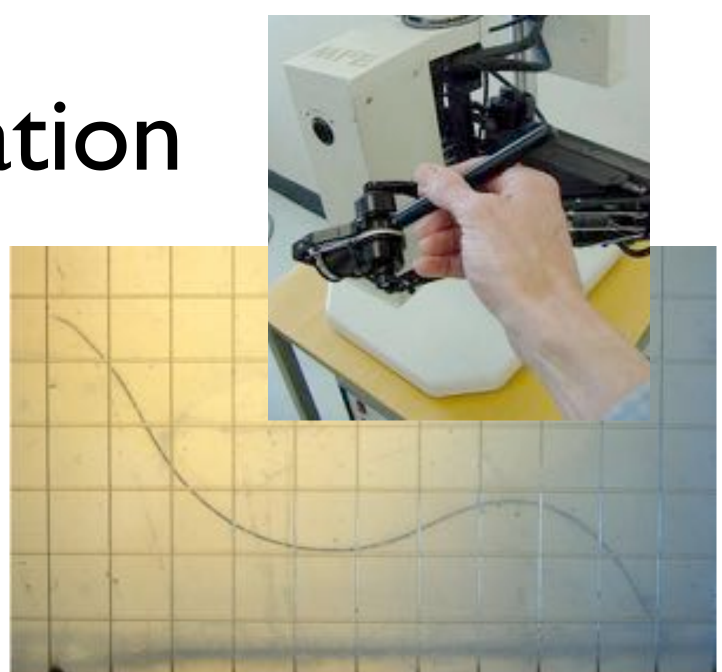
# Steering Performance

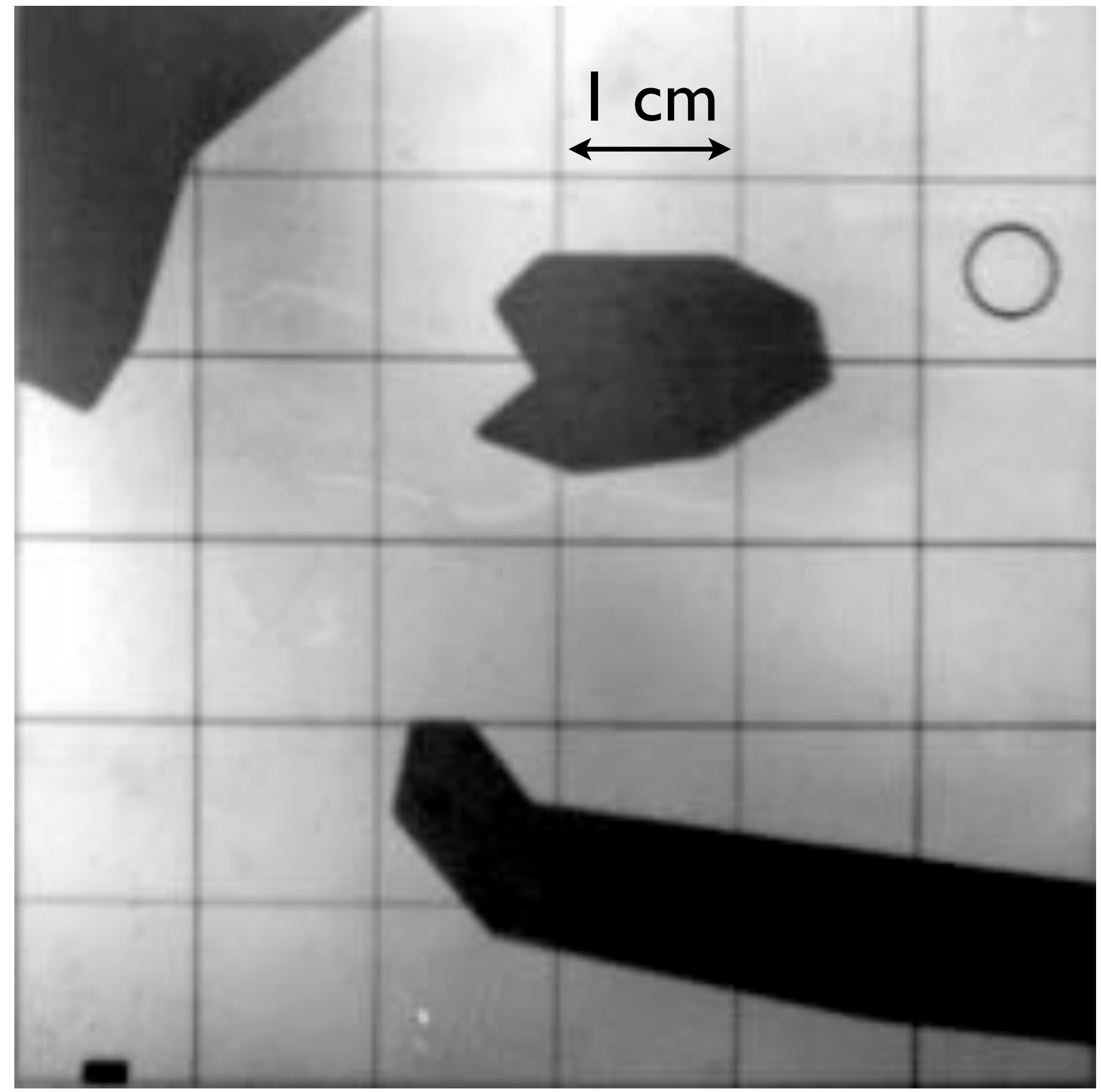
## deformation





## tele-operation






In collaboration with N. Cowan and G. Chirikjian (JHU ME), D. Song (JHMI Radiation Oncology), M. Choti (JHMI Surgery), and K. Goldberg (UC Berkeley)

Rehabilitation Robotics:

Replacing, training, or assisting to improve quality of life

# Growing Healthcare Challenges


Maja Mataric (USC)

# Socially Assistive Robotics

**Problem:** cost/population size and growth trends
**Need:** personalized medium to long-term care
**Part of the solution:** human-centered robotics to improve health outcomes

- Monitoring
- Coaching/training
- Motivation
- Companionship/socialization

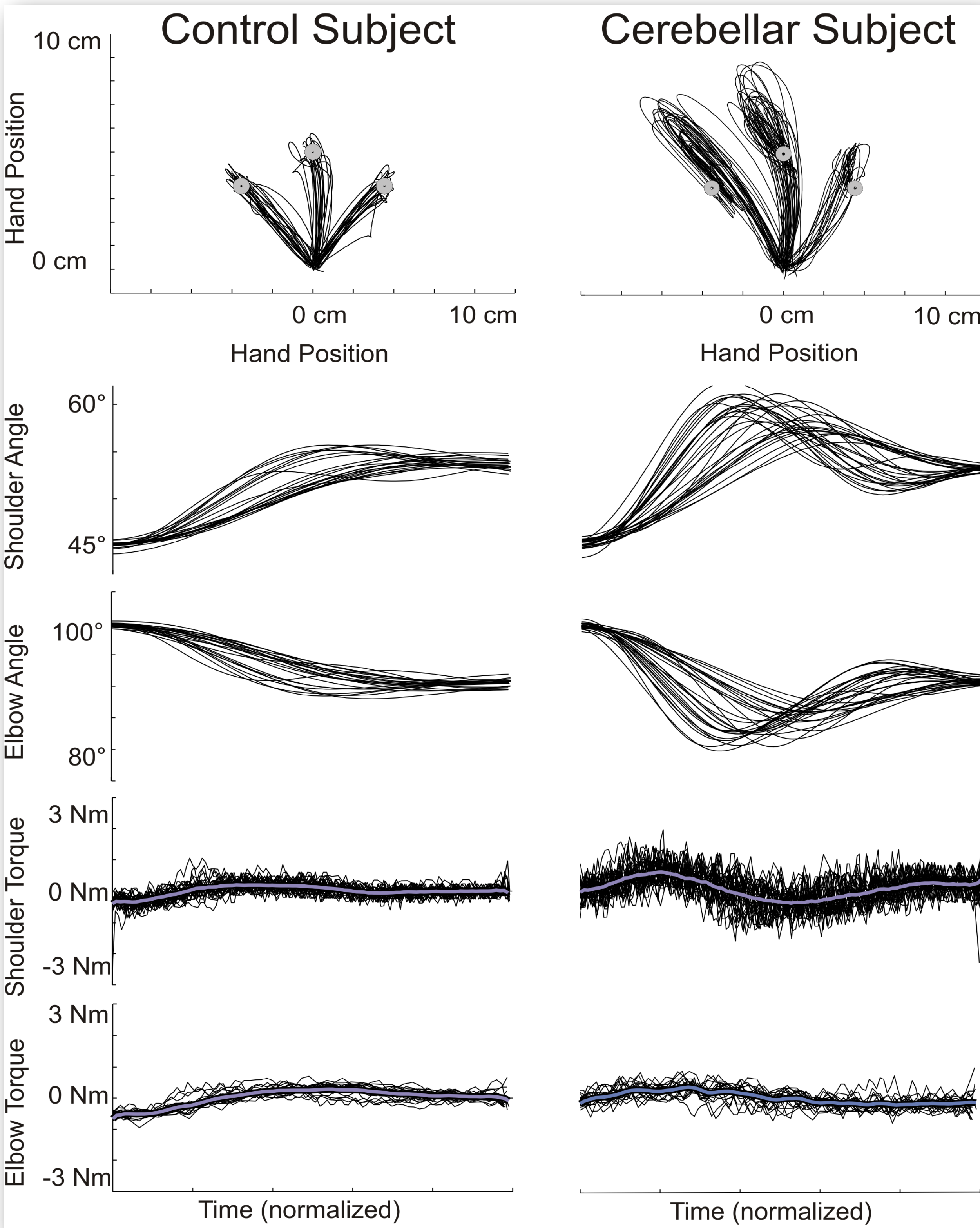
Robots can be a "force multiplier" for caregivers, reducing health care costs and improving quality of life

Maja Mataric (USC)

# Movement Therapy and Assistance

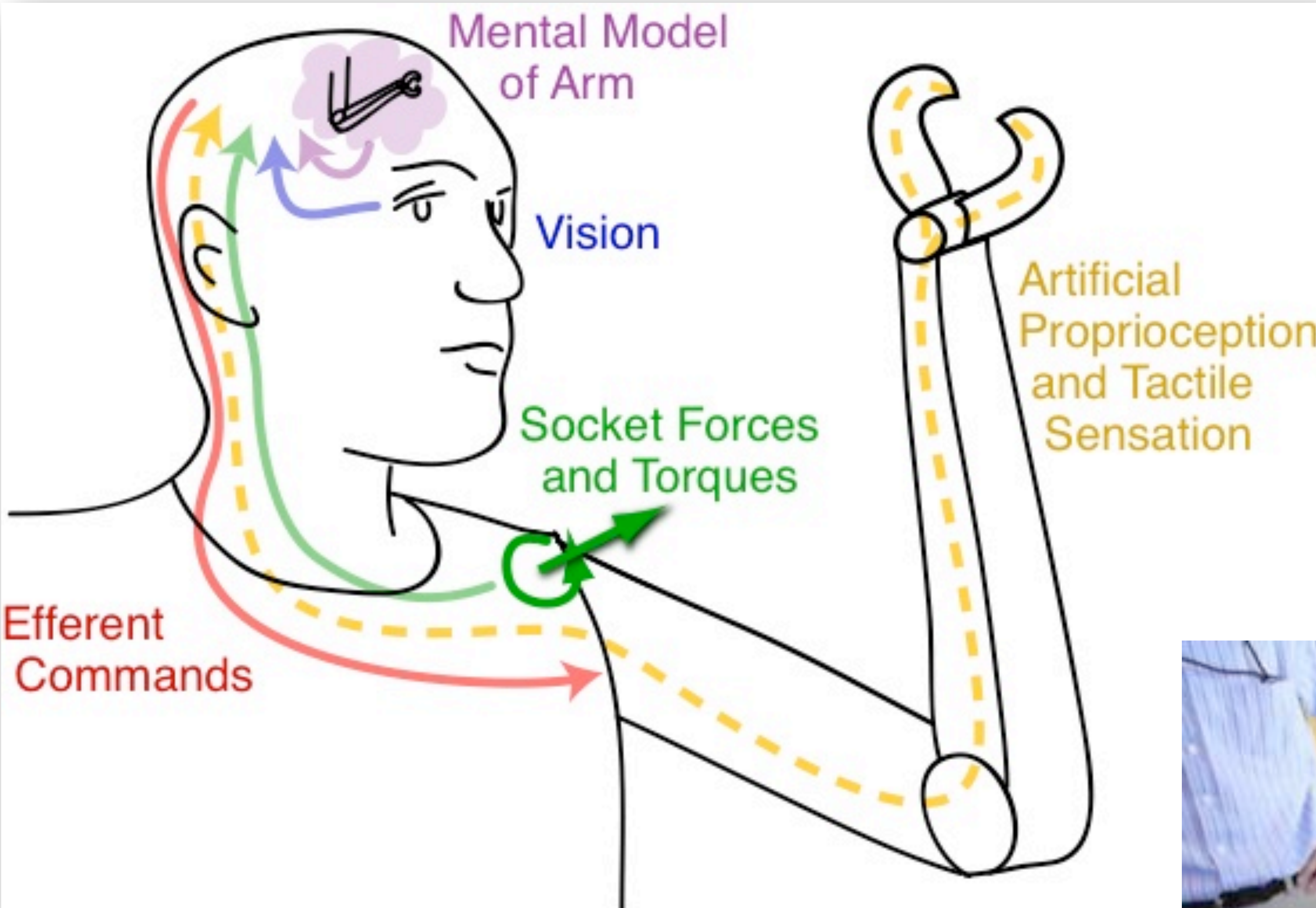
- Over 25% of U.S. population has some functional physical limitation that affects normal living
- 6.5M people in the US have had a stroke (by 2050, cost projected to be $2.2 Trillion)

# Optimizing Movement Therapy




In collaboration with A. Bastian (KKI and JHU Neuroscience)

# Neurally Controlled Prostheses




JHU Applied Physics Laboratory

# Safety

Safety of **industrial robots** is ensured by keeping humans out of the workspace.

**Medical robots** come in contact with both patients and clinicians/caregivers.

*PUMA Industrial Robot*

Approaches include:
- Low force and speed
- Risk analysis (eliminate single points of failure)
- Fault tolerance (hardware and software)
- Fail safe design (system fails to a safe state)
- Redundant sensing

# In an ideal world, medical robotics includes:

- Quantitive descriptions of patient state
- Use of models to plan intervention
- Design of devices, systems, and processes to connect information to action ( = robotics )
- Incorporating human input in a natural way
- Goal: improve health and quality of life

**But these are only the *technical* challenges...**