Haptic Interface for Surgical Manipulator System

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Spring 2012
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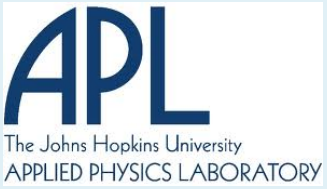
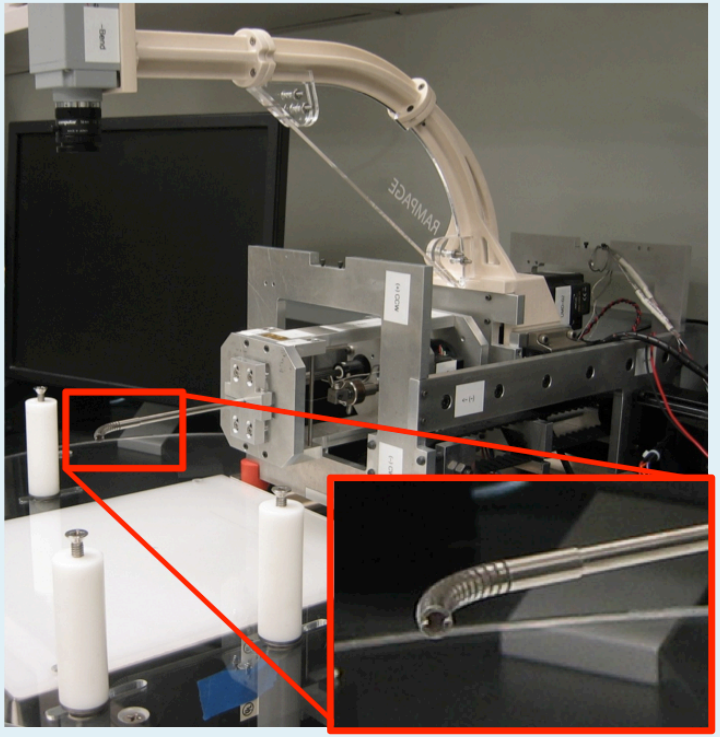


Goal: Create intuitive haptic interface for dexterous surgical manipulator



Dexterous manipulator

PHANTOM Premium haptic device

Michael Kutzer, JHU APL

Sensable Technologies, Inc.

Paper selection

- "**Methods for haptic feedback in teleoperated robot-assisted surgery**," Allison M. Okamura, Industrial Robot: An International Journal
  Volume 31 · Number 6 · 2004 · pp. 499–508
- Why?
  - Teleoperation using force feedback (FF) for medical applications
  - Characterize forces observed during dexterous surgical task
  - Improve user performance using:
    - Haptic feedback
    - Sensory substitution
- → Why haptics?

What is haptics?

- Force + tactile feedback

www.eng.uwaterloo.ca/~fhaque/img/sensable-haptics_lg.jpg

www.funnypuppysite.com/pictures/tickle_tickle.jpg

Bilateral telemanipulation

Master

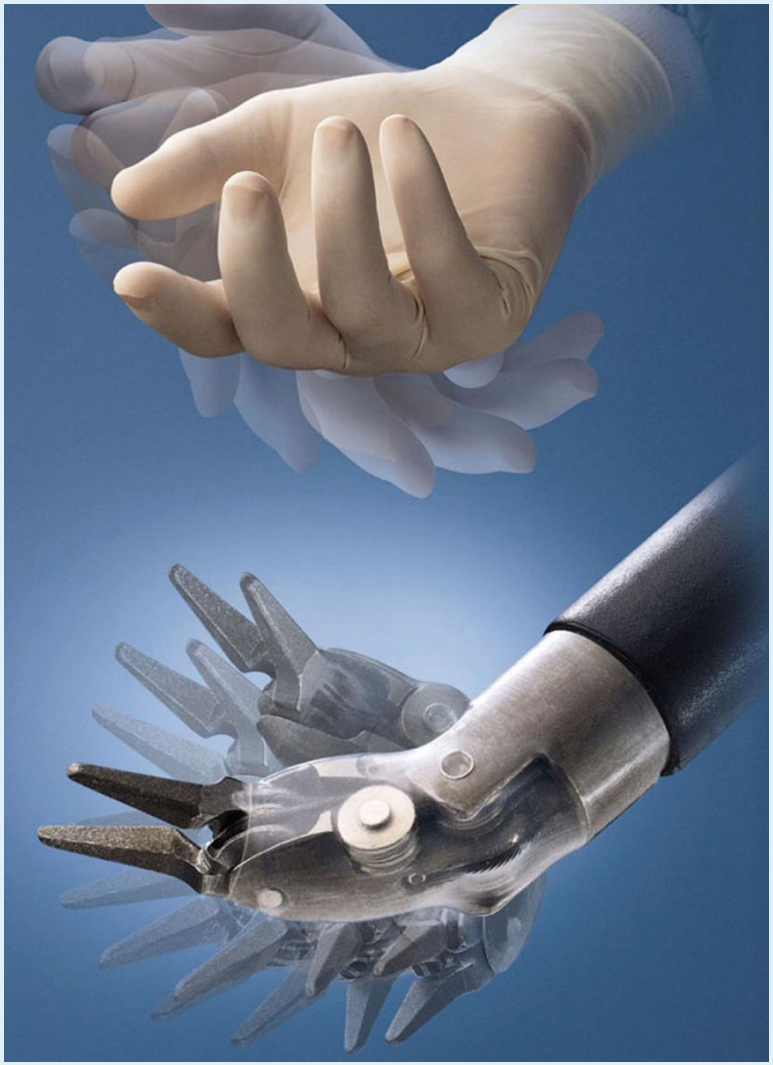
Intuitive Surgical, Inc.

Bilateral telemanipulation

Surgeon console

Intuitive Surgical, Inc.

Advantages of robot-assisted surgery



- Reduced tremor
- Increased accuracy
- Higher degree of freedom (DOF) and dexterity
- Magnified, 3D visual feedback
- → safer, more effective

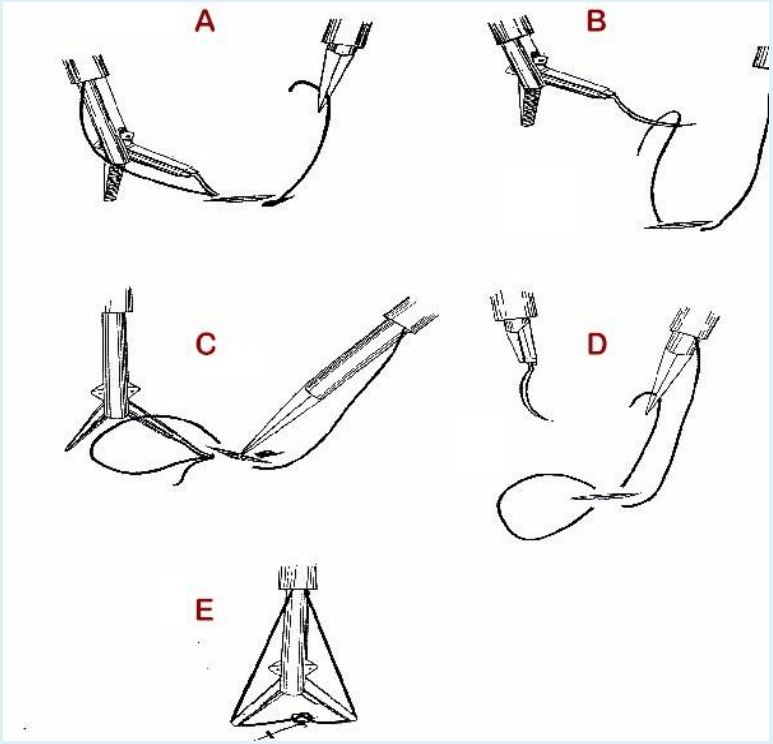
Intuitive Surgical, Inc.

Problems with robot-assisted surgery

- Loss of force feedback
- Longer, more technically challenging procedures
- Steep learning curve

Suture manipulation for cardiac surgery

- Challenging environment
- Dexterous
- Force control critical
- Measurable functional outcomes



www.clarkescope.com/techniques.html

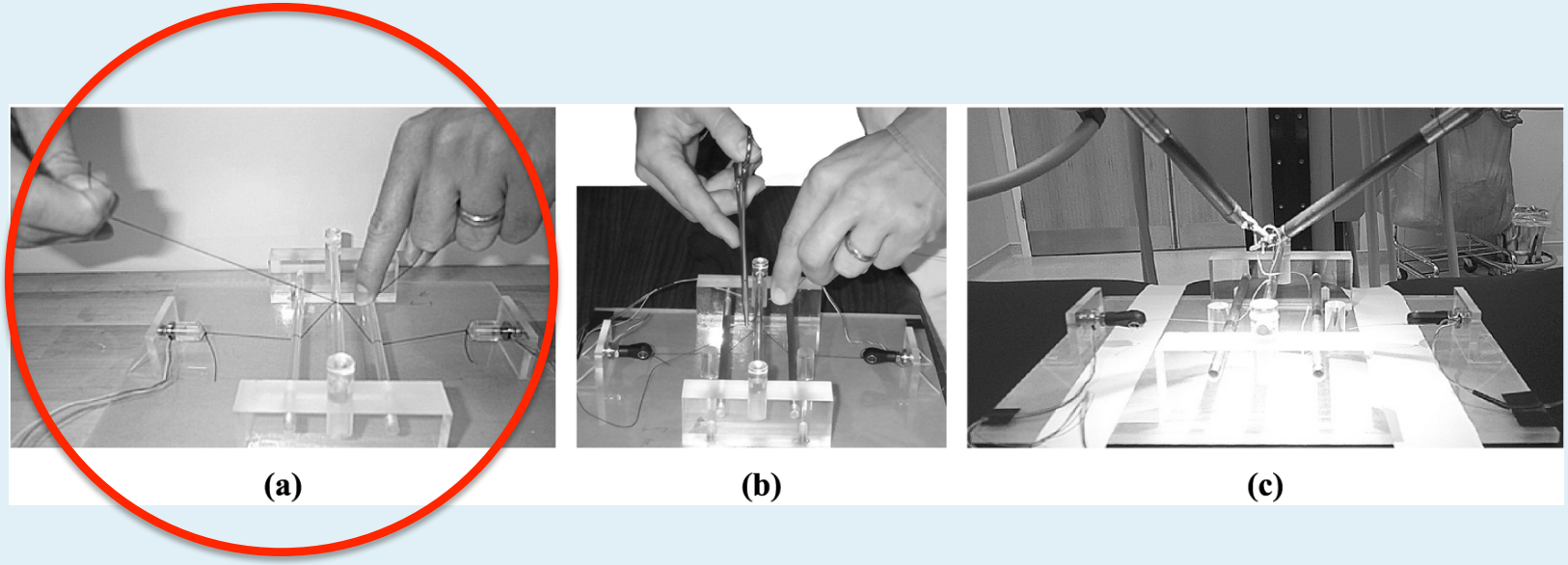
Significance

- Increase sense of telepresence
- Intelligent assistance (ex. virtual fixtures)
- In vivo tissue modeling

Experiment

- Different levels of force feedback
  - Manual

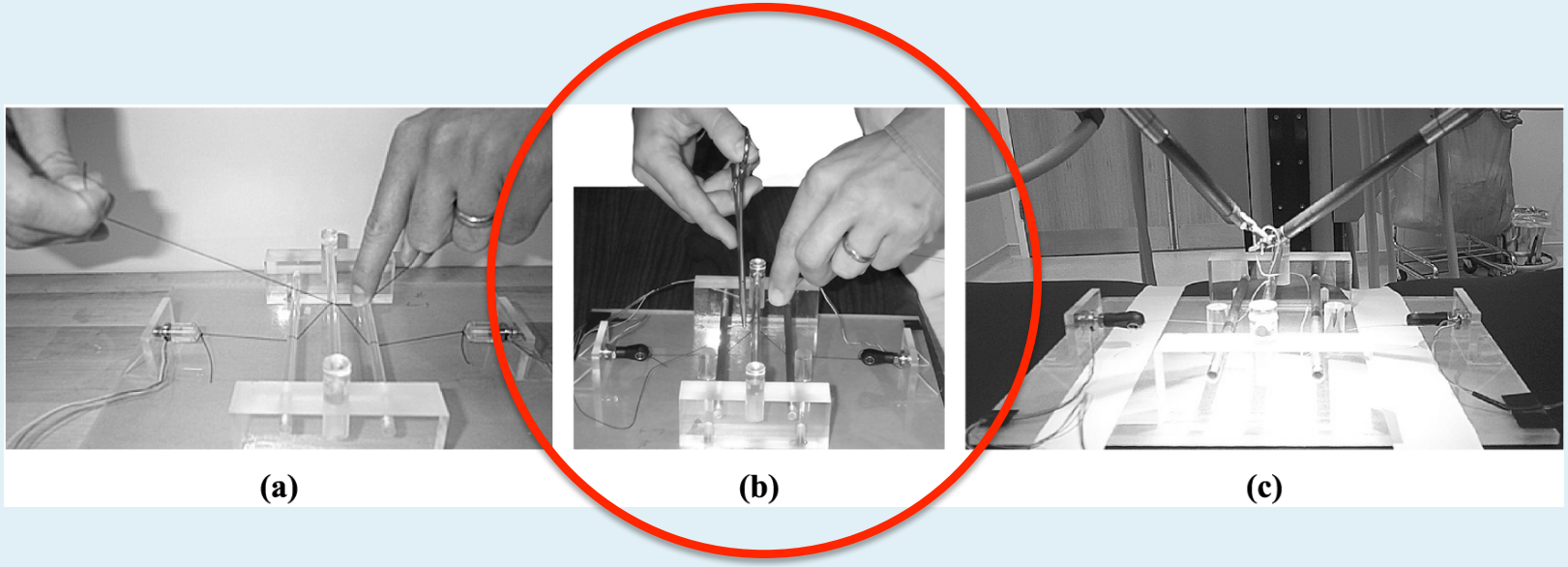
Ideal forces!



Methods for haptic feedback in teleoperated robot-assisted surgery

Experiment

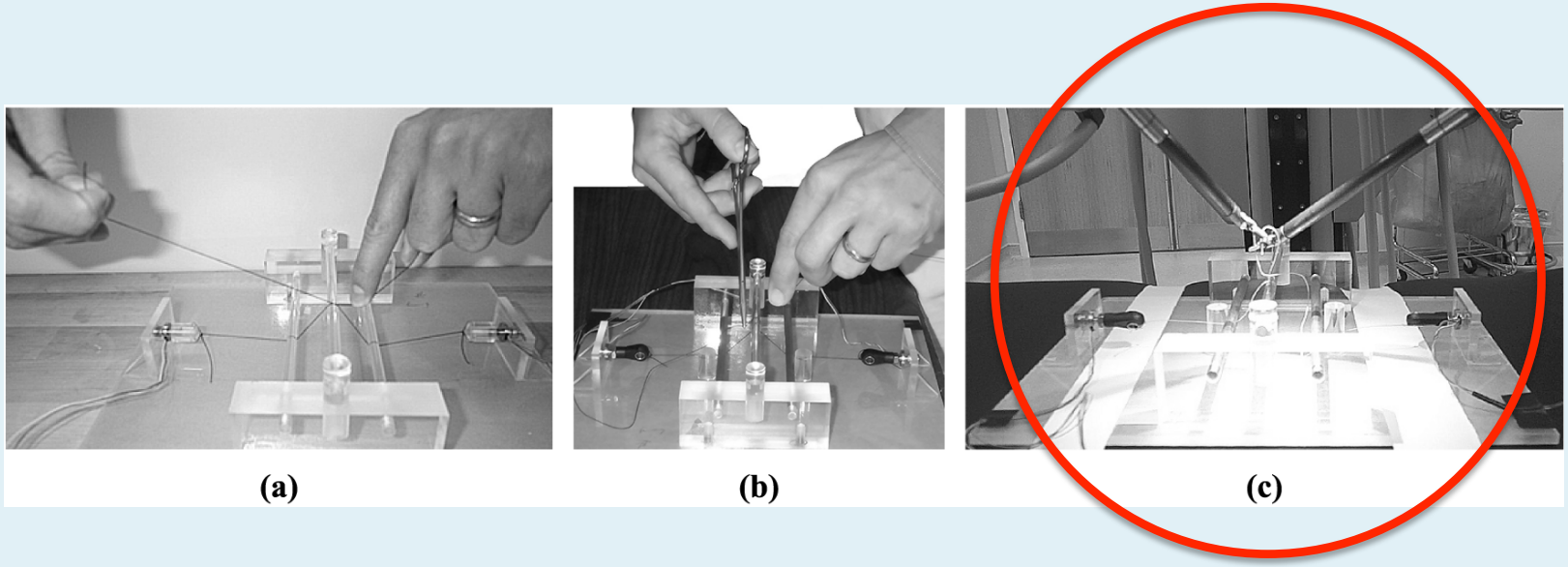
- Different levels of force feedback
  - Manual
  - Instrument (with or without force feedback)



Methods for haptic feedback in teleoperated robot-assisted surgery

Experiment

- Different levels of force feedback
  - Manual
  - Instrument (with or without force feedback)
  - Robotic



Methods for haptic feedback in teleoperated robot-assisted surgery

Hypotheses

- Forces could be applied more accurately with resolved force feedback than without

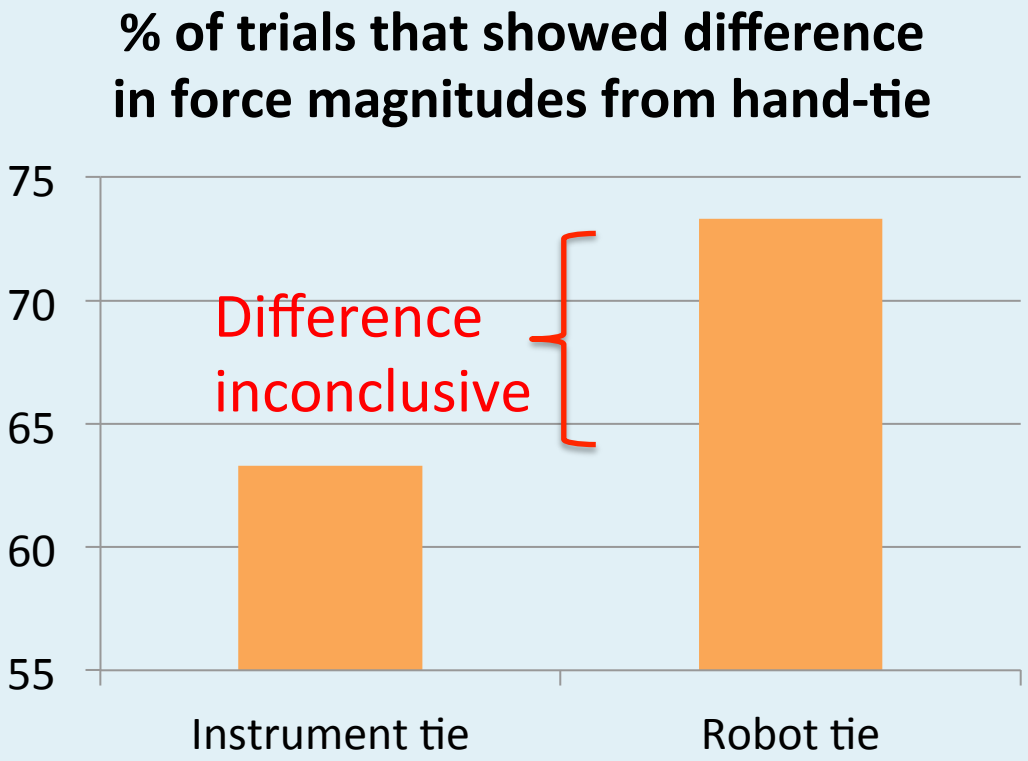
Hypotheses

- Forces could be applied more accurately with resolved force feedback than without

Measured:
suture tension

Hypotheses

- Forces could be applied more accurately with resolved force feedback than without



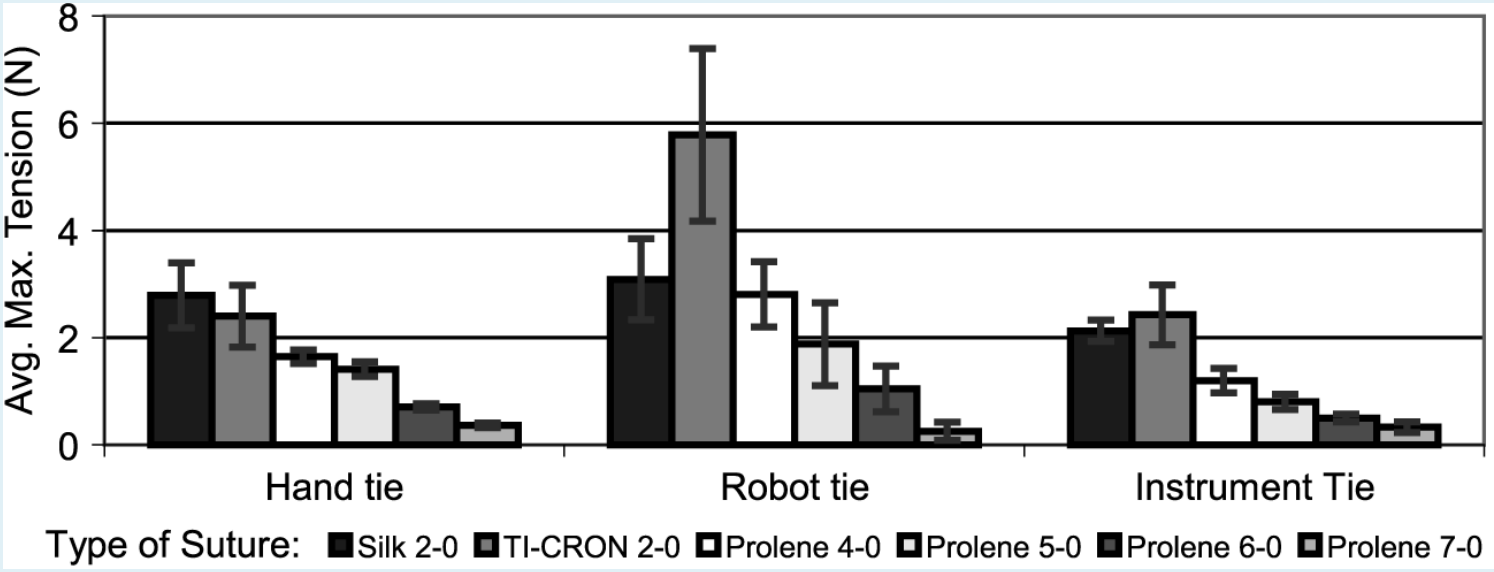
Hypotheses

- Precision improved with inclusion of resolved force feedback in robot-assisted system

Coefficient of variation (CV) of force for instrument ties indistinguishable from hand ties

Hypotheses

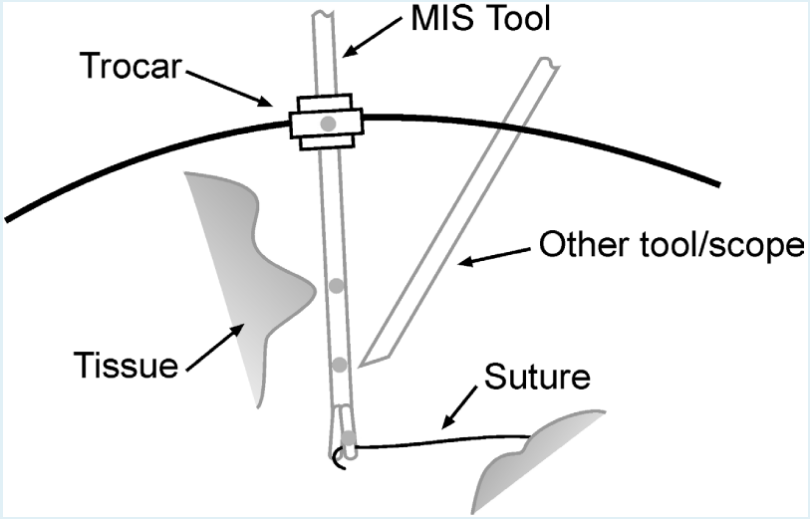
- ☑ Repeatability improved with inclusion of resolved force feedback in robot-assisted system



Experiment

- Different types of telemanipulation **control laws**
  - **Problems!**

Position exchange control vs. Position forward/force feedback control

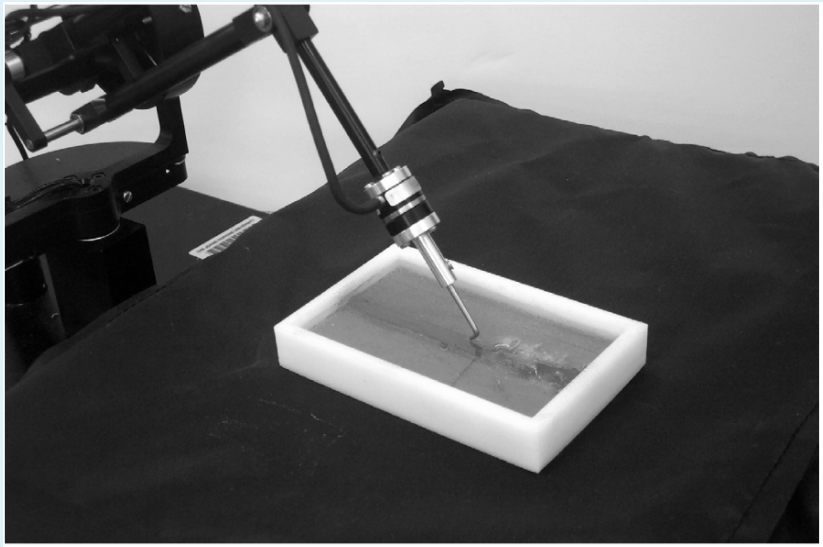


Sensor-actuator asymmetry

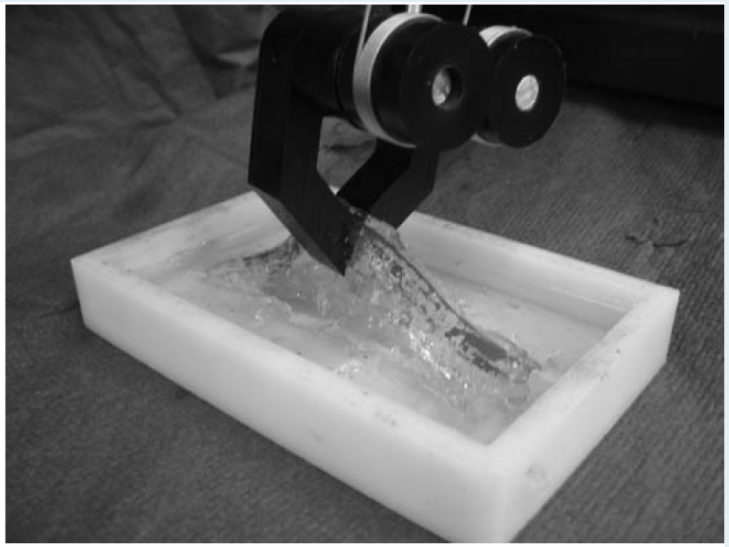
Effect of limiting DOF of force sensing

Bending forces

Grip forces



(a)



(b)

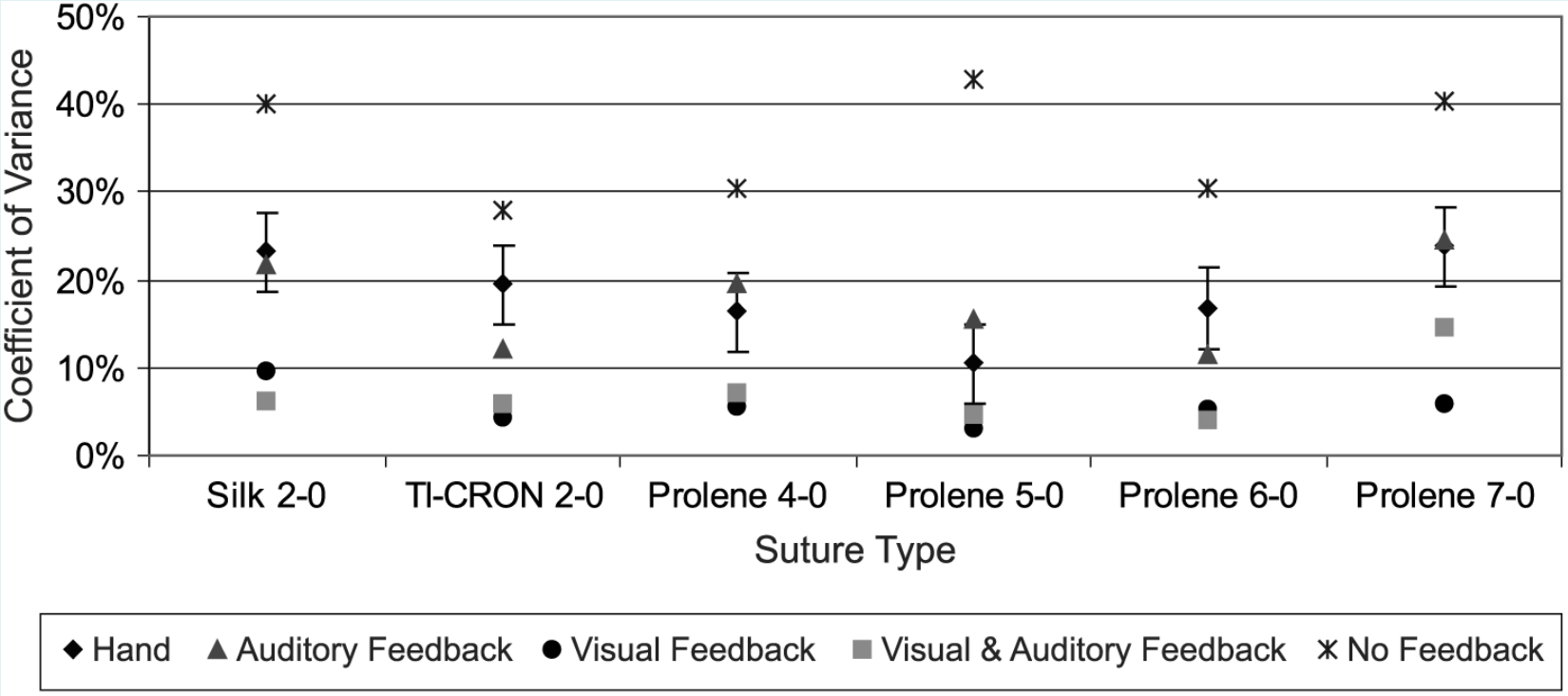
Completely realistic haptic feedback: hard!

Q: How can we overcome limitations of impedance control?

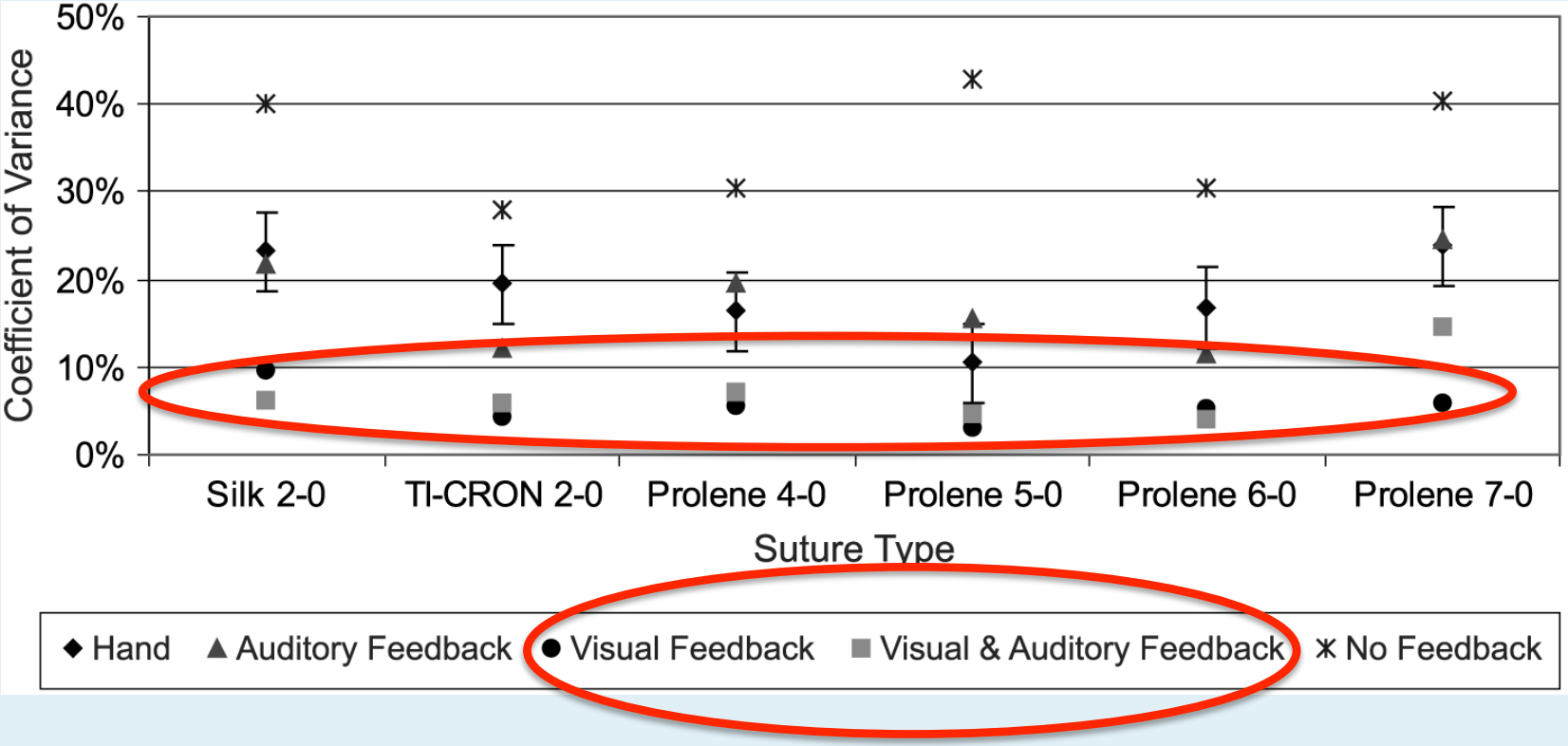
- Adaptive control
- Pseudo-admittance control
- Virtual fixtures

- Sensory substitution

Methods for sensory substitution



Methods for sensory substitution



Importance

- Haptics: justified?

Sensable, Inc

Relevance

- ☑ Dexterous manipulation?
- ☑ Dynamic environment?
- ☐ Accuracy?
- ☐ Precision?
- ☑ Virtual fixtures?

Critique

- Learning curve shortened using haptic feedback?
- User performance throughout course of procedure?
- Quantify effect of indirect view during the robotically executed task?
- Time?

Next steps

- Sensor hardware
- Safety of lack of passivity
- Force **and** tactile feedback
- Virtual fixture geometry
- Tissue modeling

Conclusions

- Force feedback does improve accuracy and precision for complex surgical tasks
- Axial and gripping forces do not greatly affect user performance
- Sensory substitutions a practical option for haptic feedback

Thank you

Questions?