Augmented Reality with Haptics for Medical Applications

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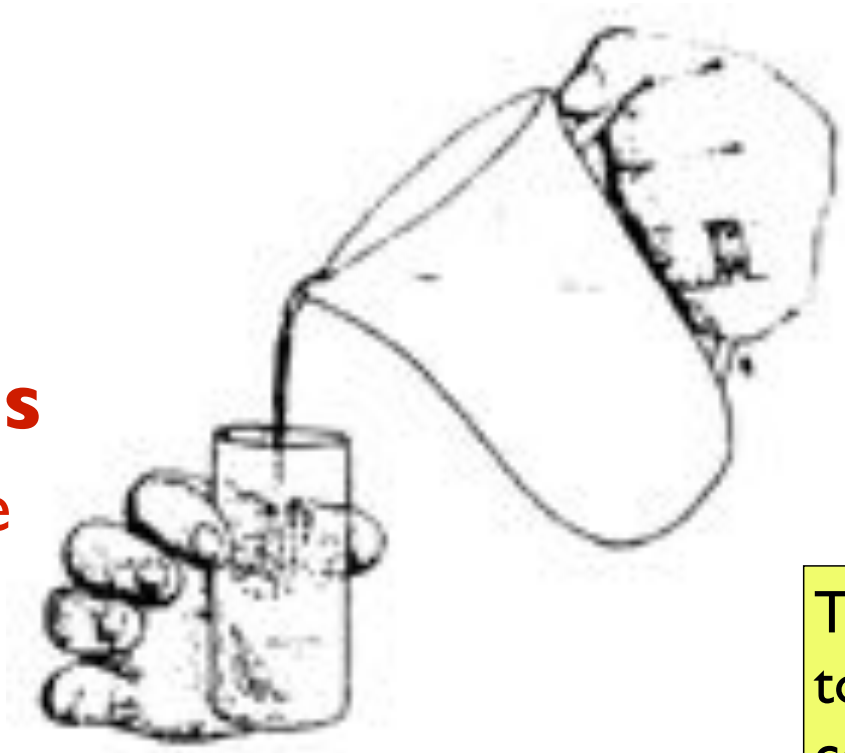
hap·tic ('hap-tik)

adj. Of or relating to the sense of touch.

[Greek *haptikos*, from *haptesthai*, to grasp, touch. (1890)]

Kinesthesia

Location/configuration
Motion
Force
Compliance



R. Johansson

Cutaneous

Temperature
Texture
Slip
Vibration
Force

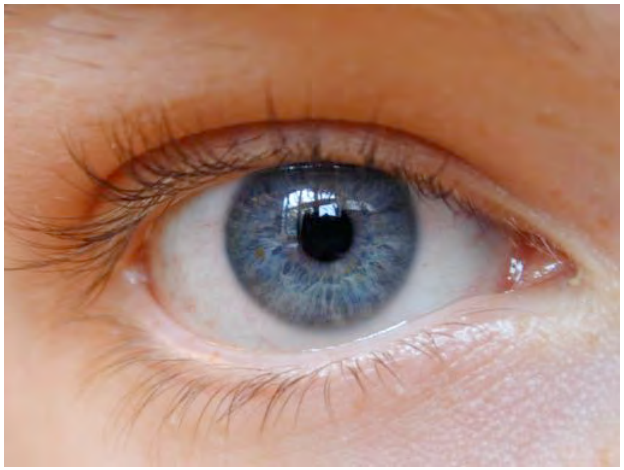
The haptic senses work together with the motor control system to:

- Coordinate movement
- Enable perception

Slide courtesy Ed Colgate

sight

centralized
broad
passive
cognitive

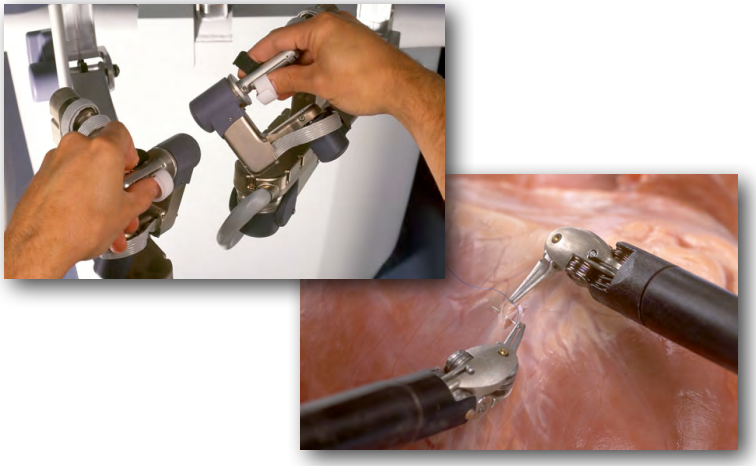


touch

distributed
narrow
active
physical

Slide courtesy Katherine Kuchenbecker

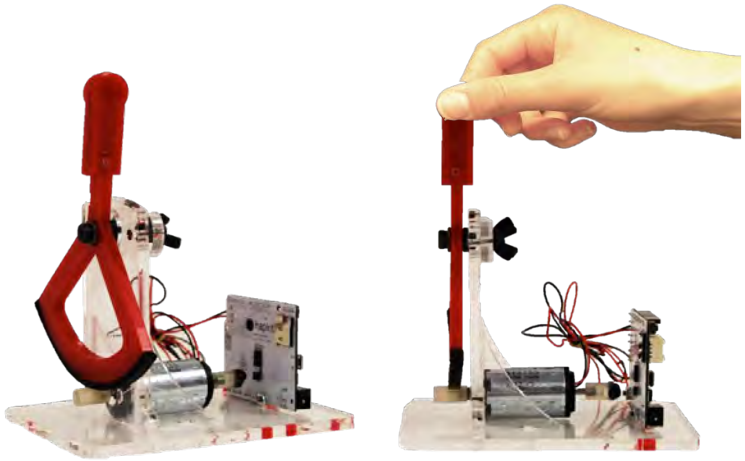
AR with Haptics for Robot-Assisted Surgery



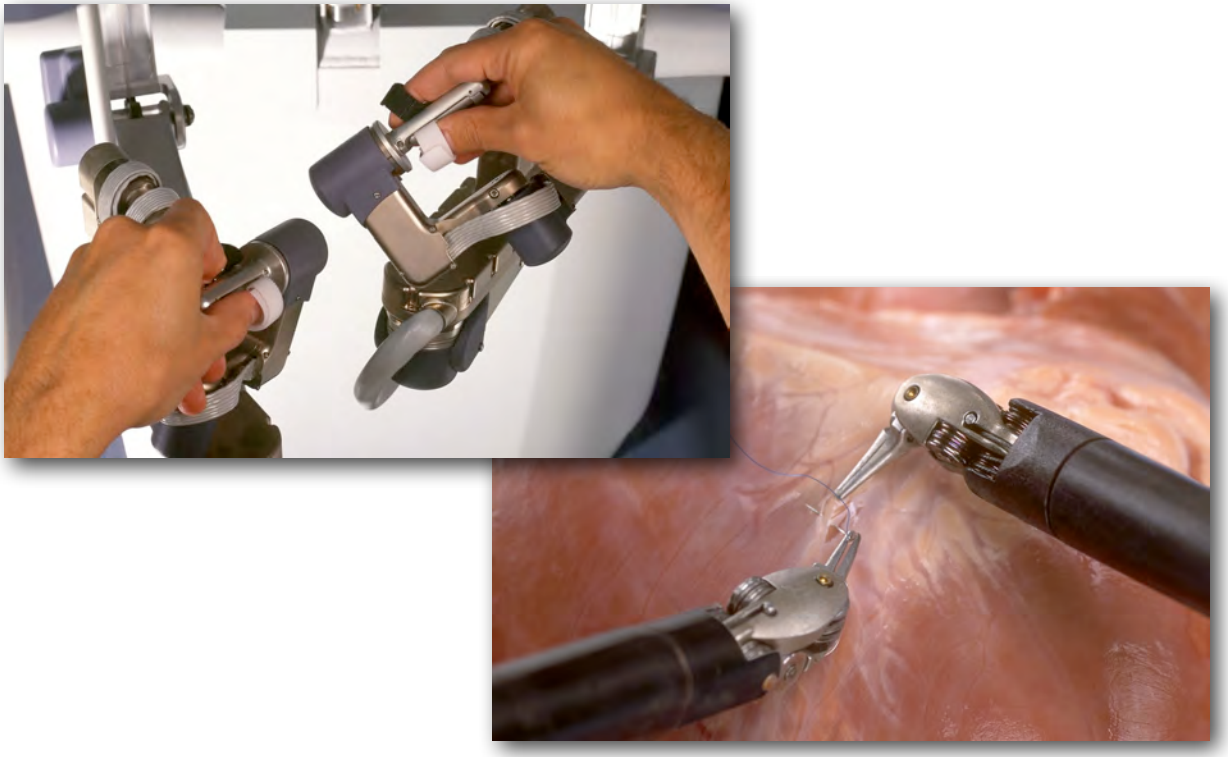
AR with Haptics for Medical Simulation

AR with Haptics for Behavioral Neuroscience

AR with Haptics for Education



AR with Haptics for Robot-Assisted Surgery



Open Surgery

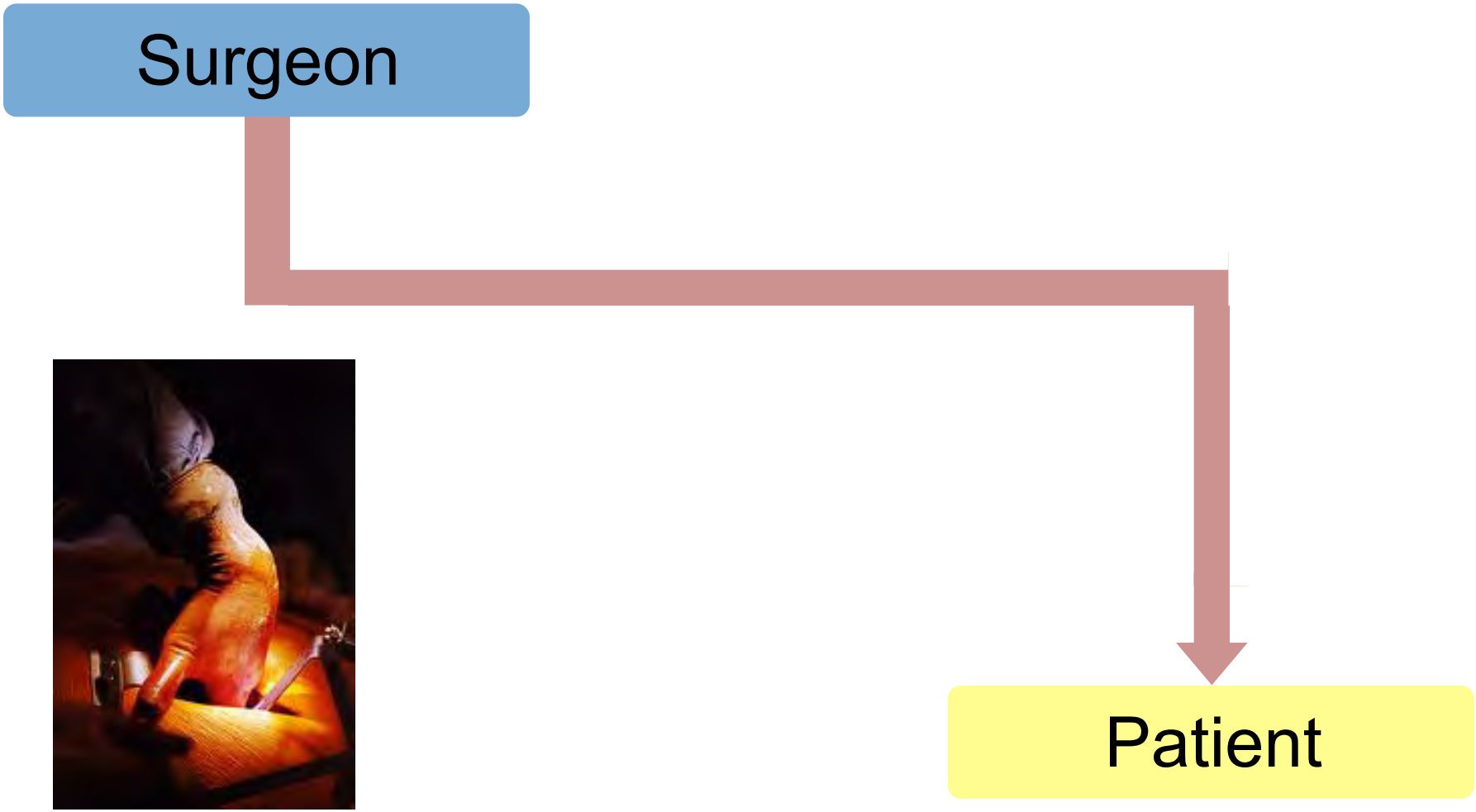


Image source: www.physicianphotos.com

Minimally Invasive Surgery

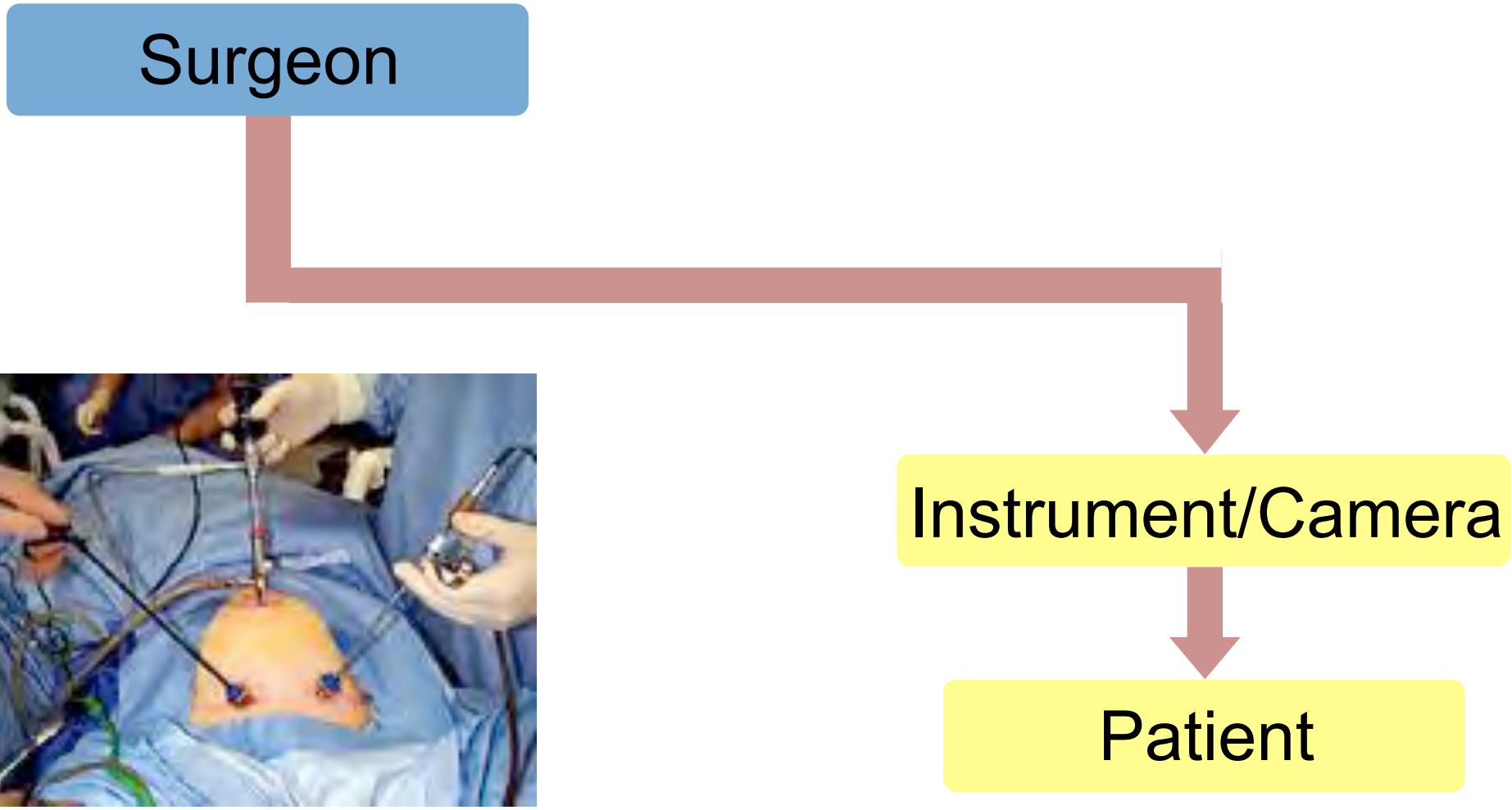
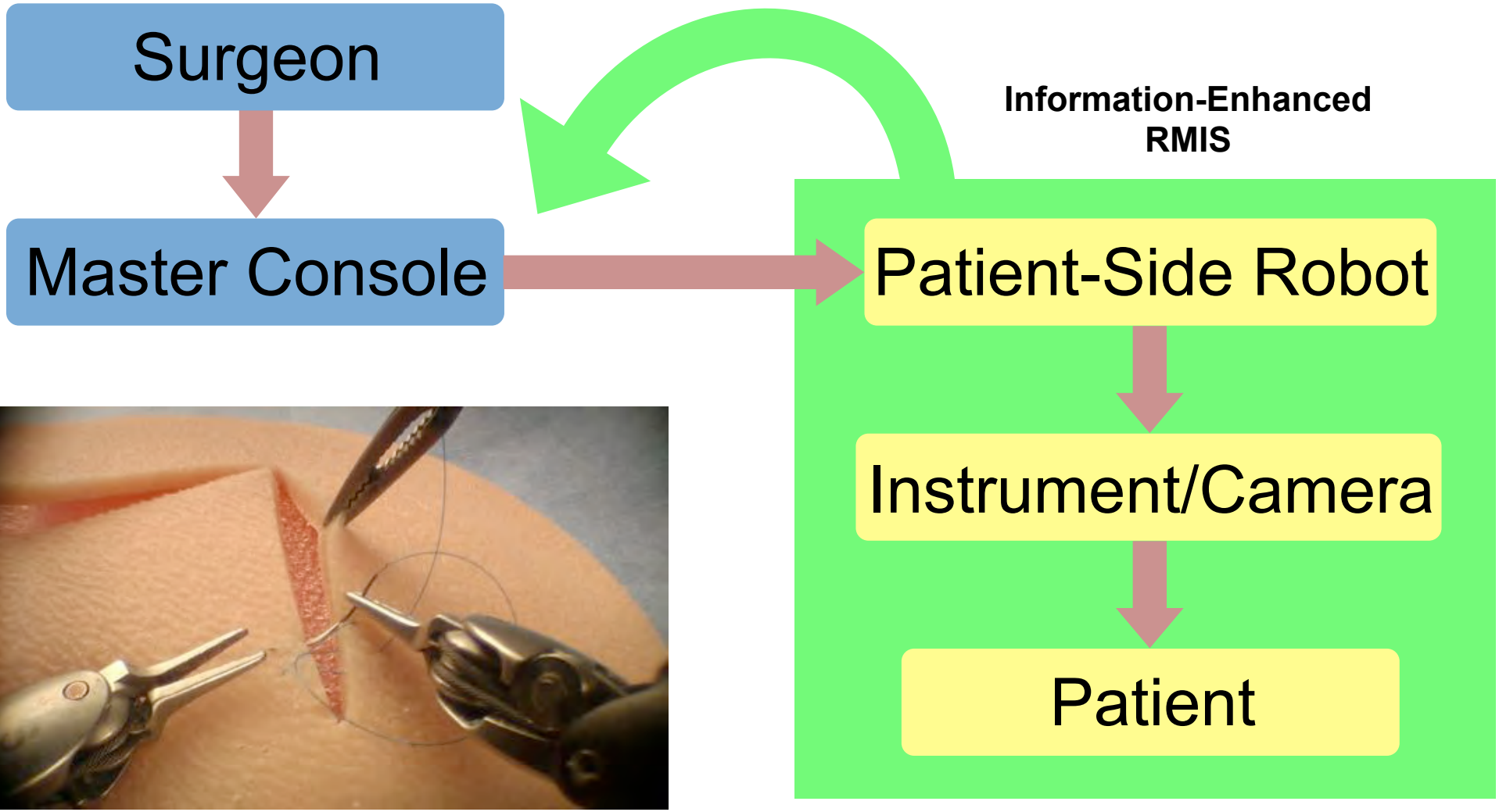
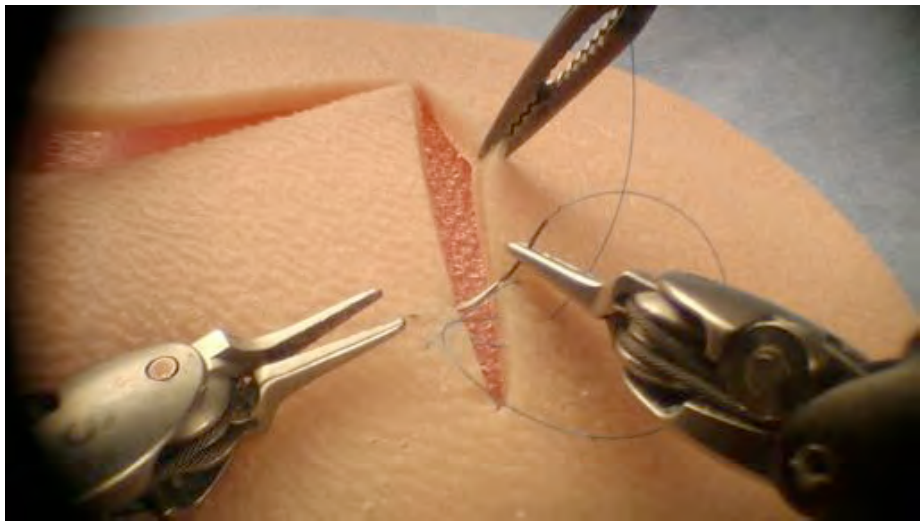


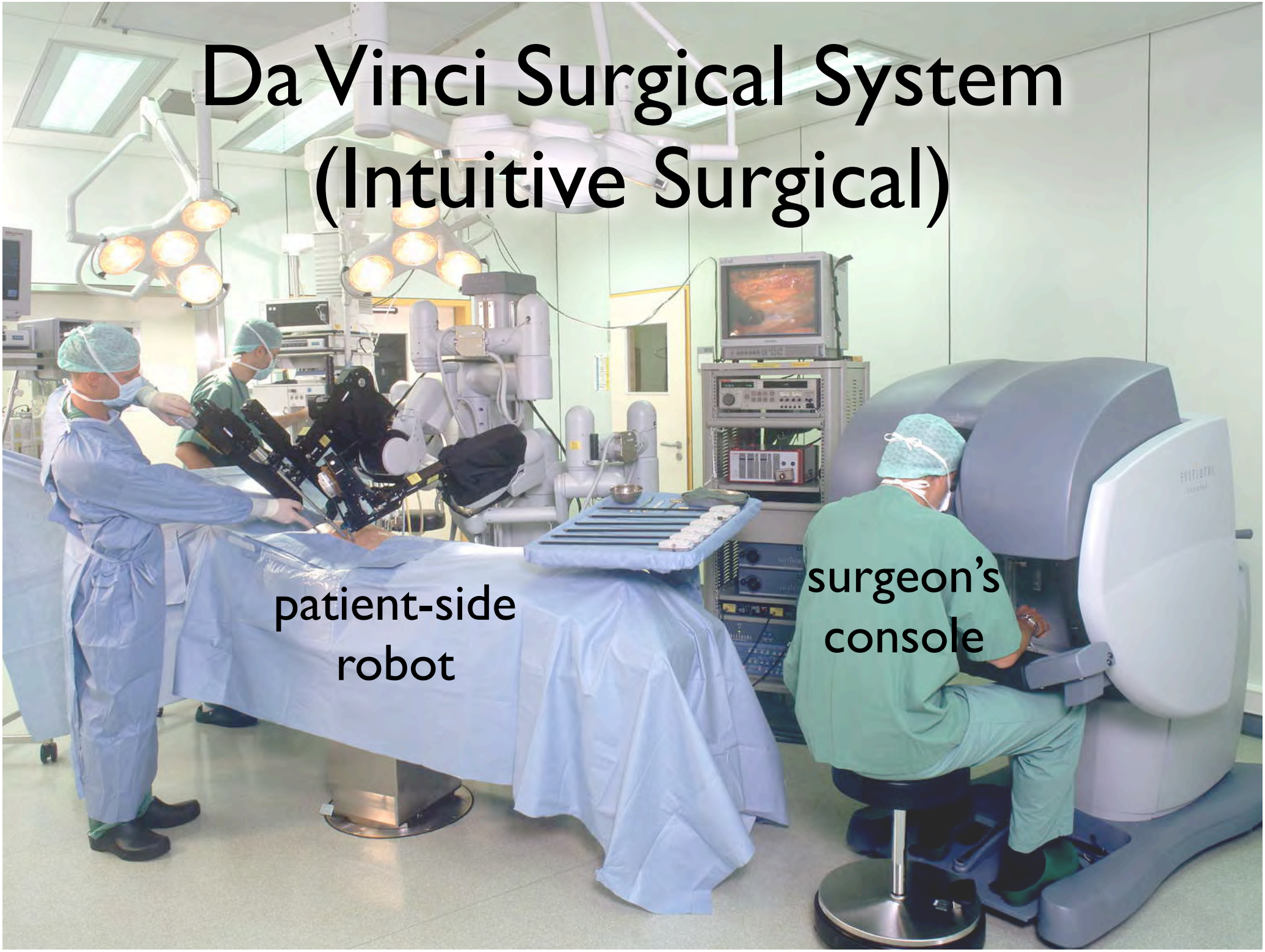
Image source: www.womenssurgerygroup.com

Teleoperated Robot-Assisted Minimally Invasive Surgery

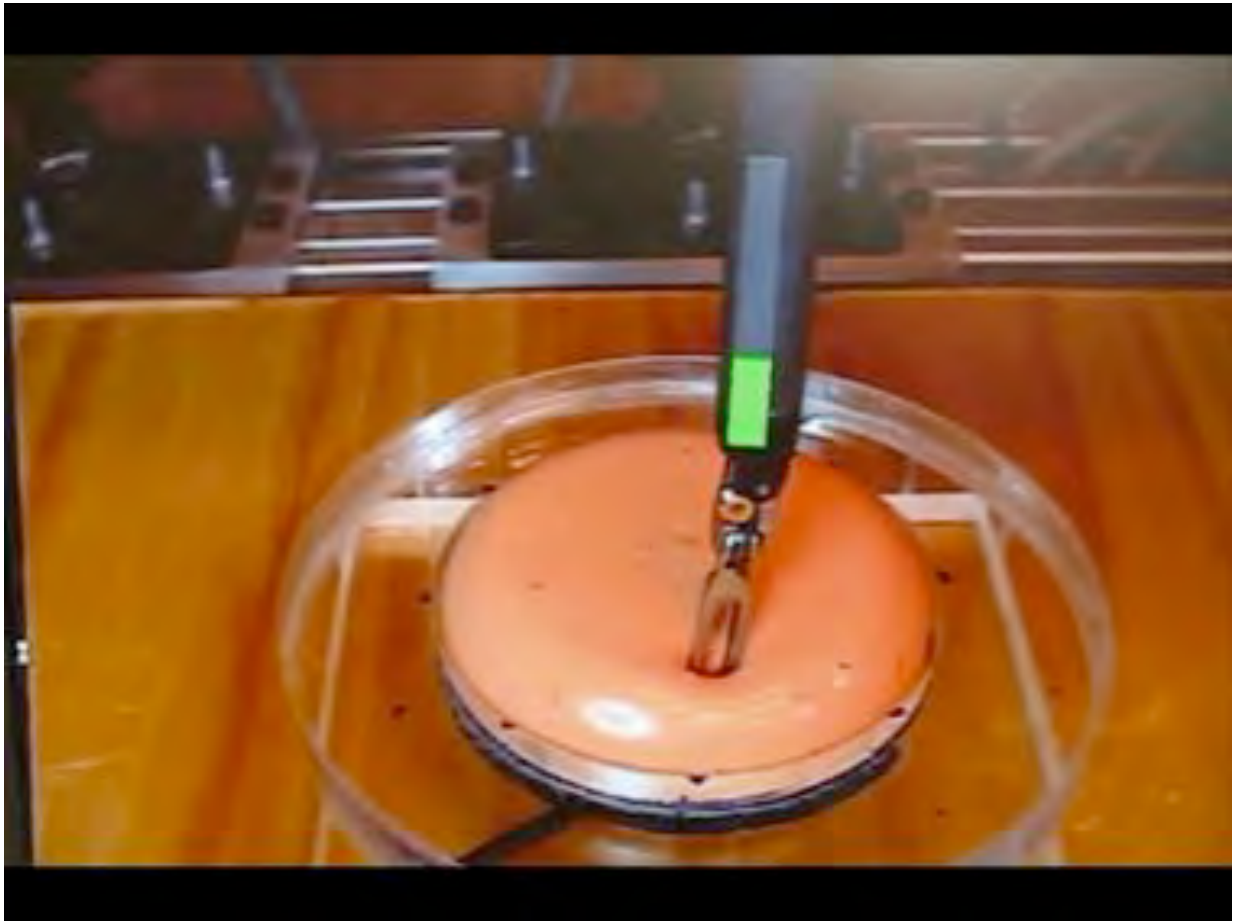


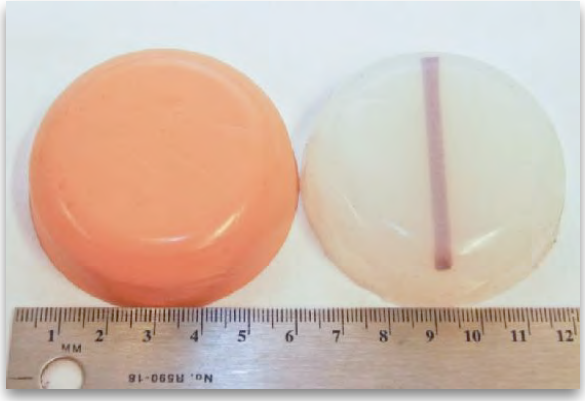


Da Vinci Surgical System (Intuitive Surgical)



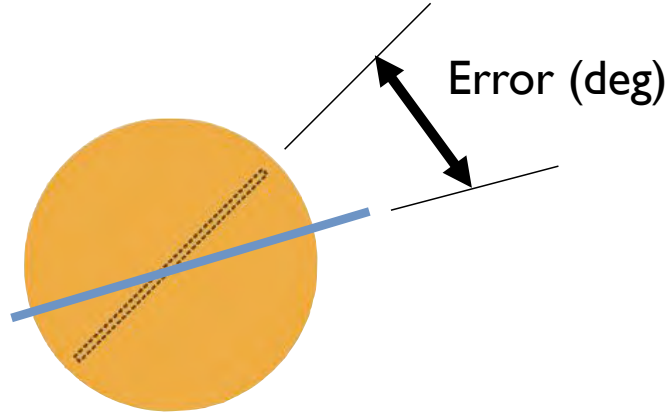
Force feedback: haptics and graphics

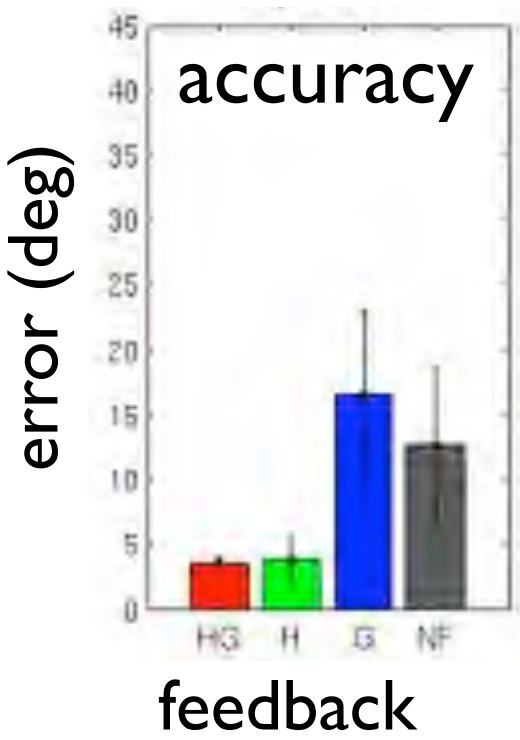


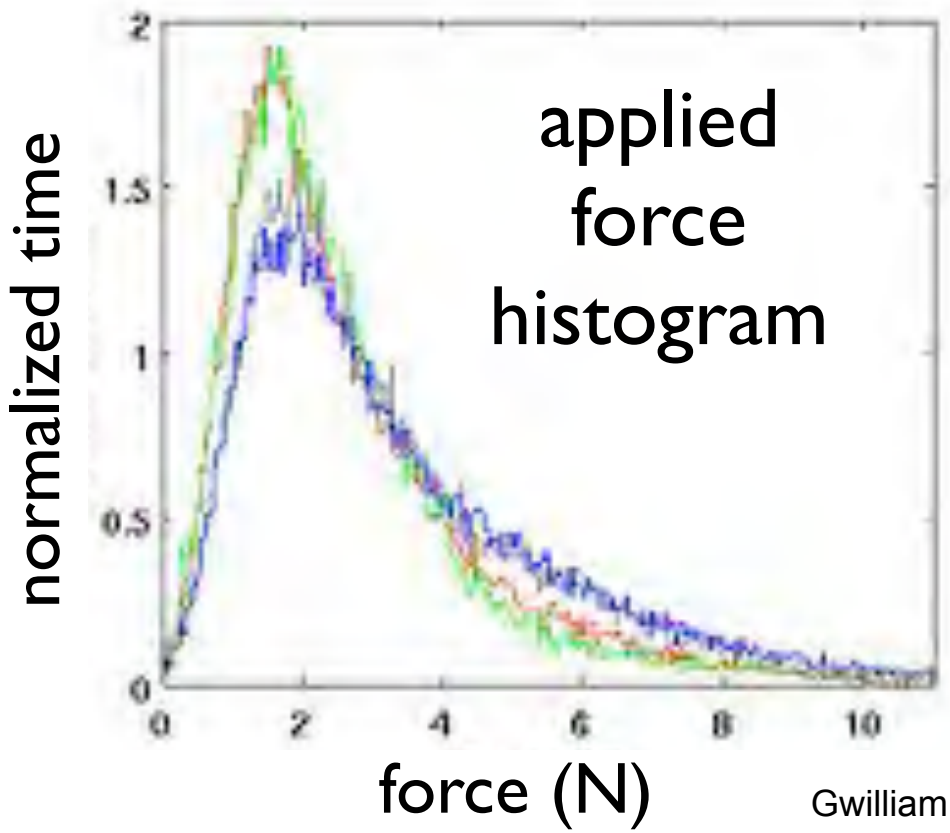


Effects of force feedback

1. Haptic + Graphical
2. Haptic Only
3. Graphical Only
4. No Force Feedback







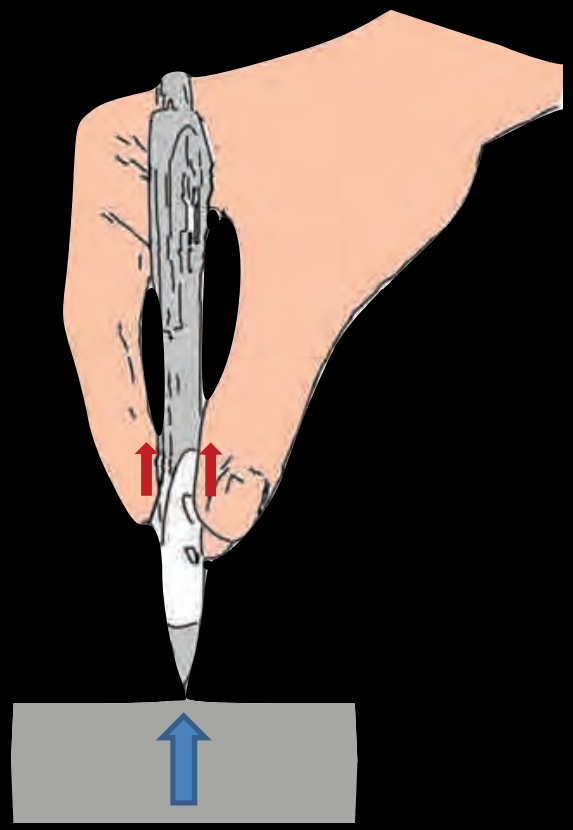
Gwilliam et al. (2010)

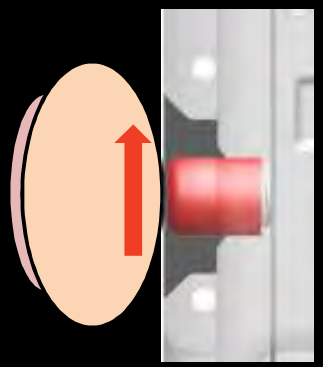
What about manipulation?

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

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

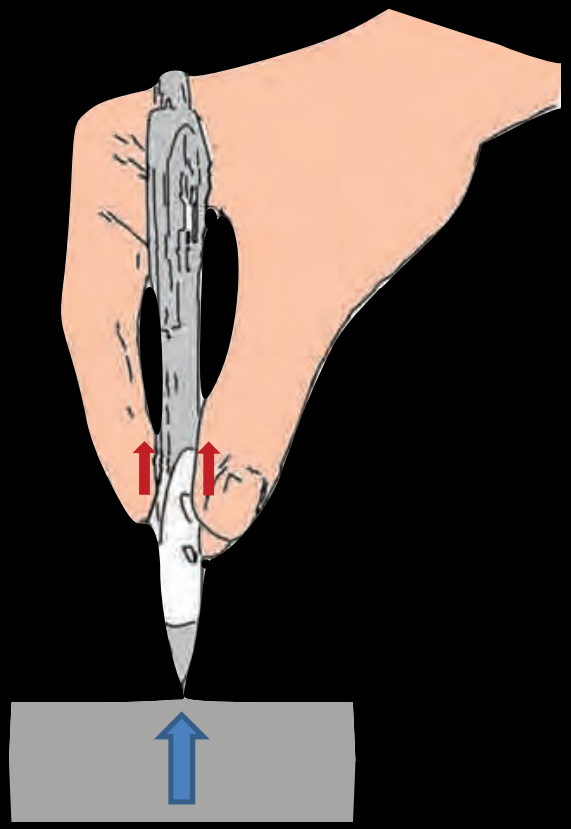
Skin stretch haptic device

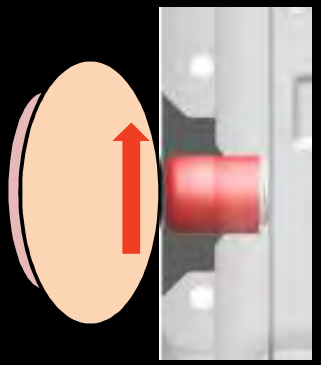


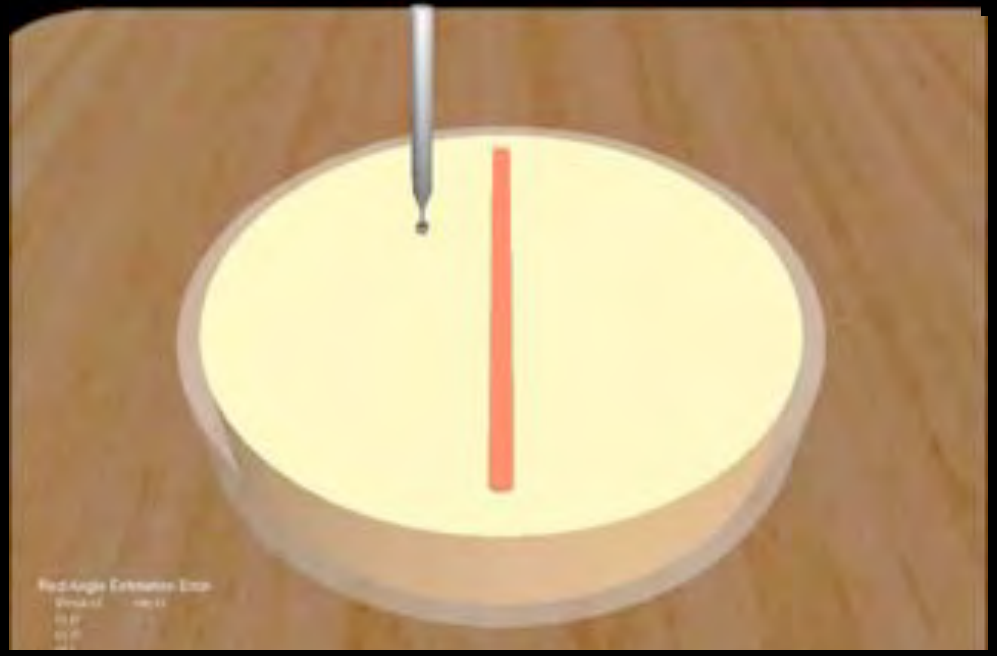


Quek et al. (2013)

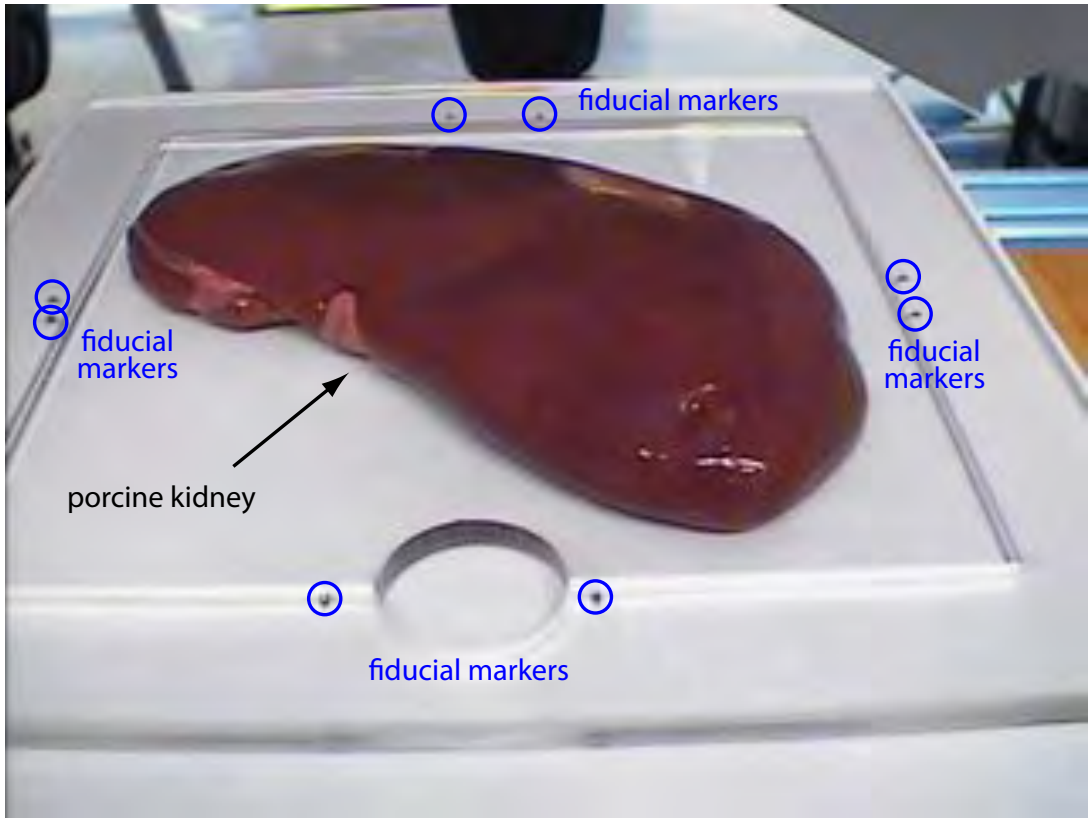
Skin stretch haptic device



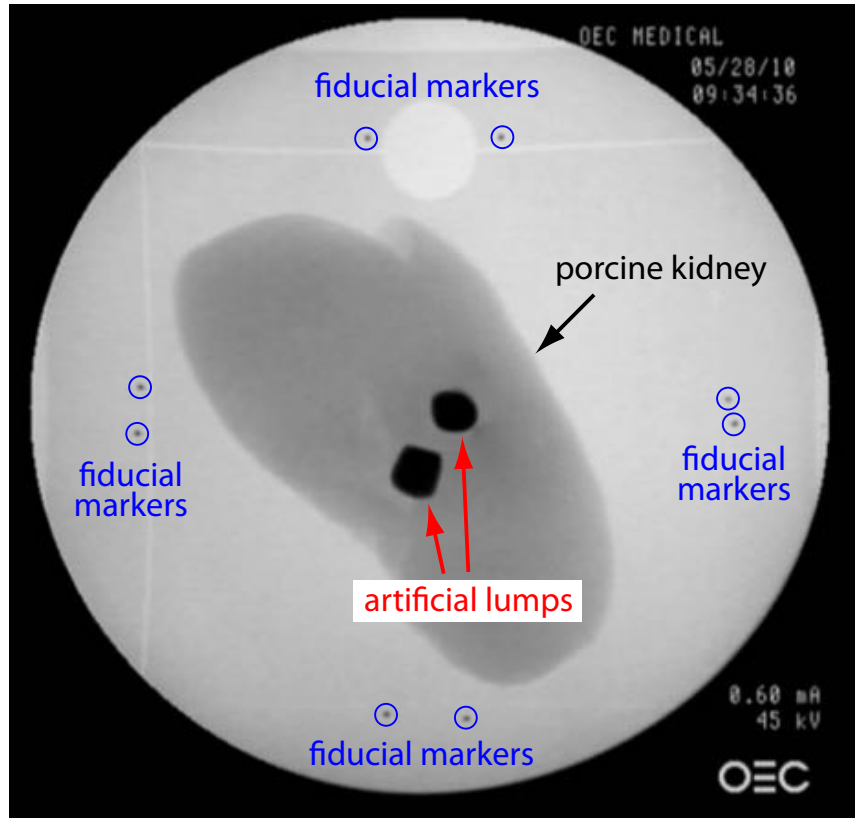




Lump detection task

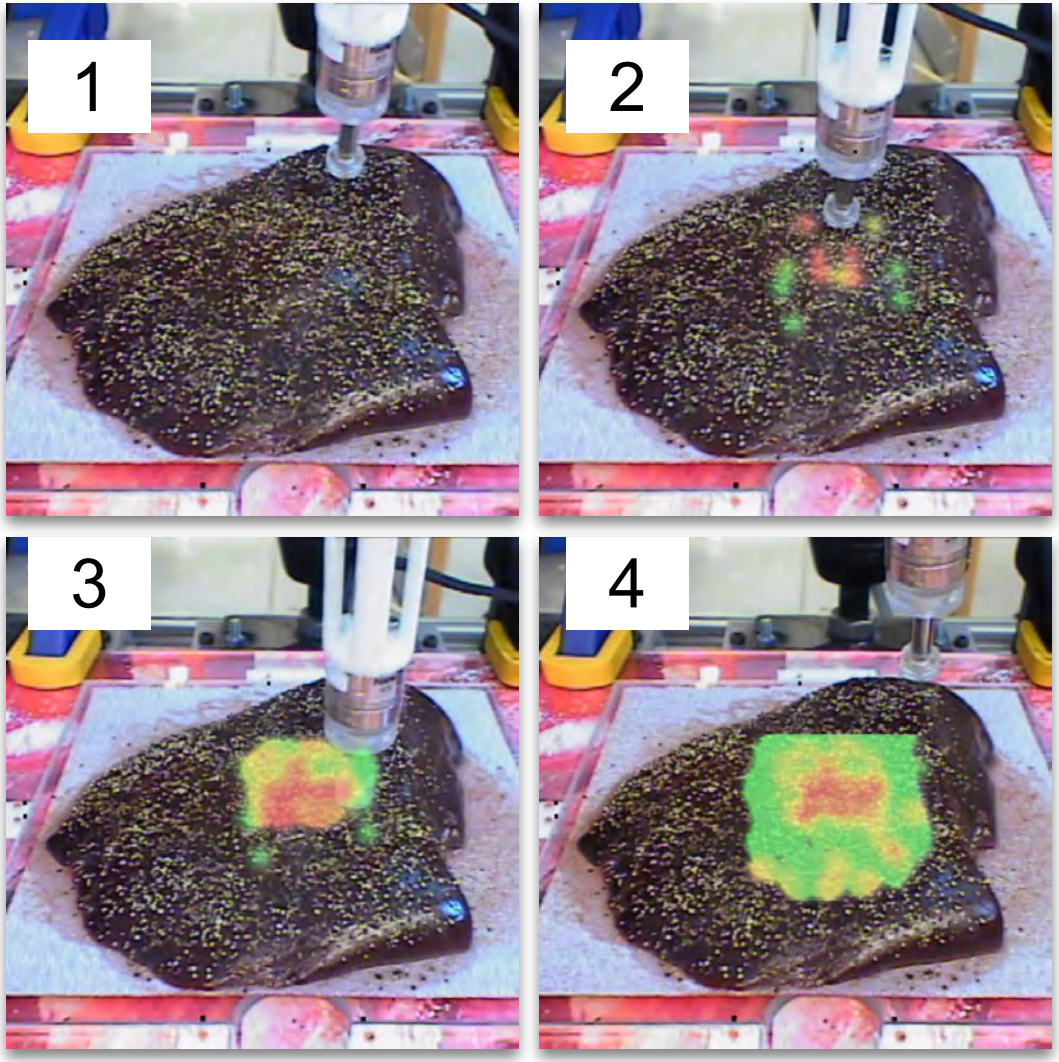


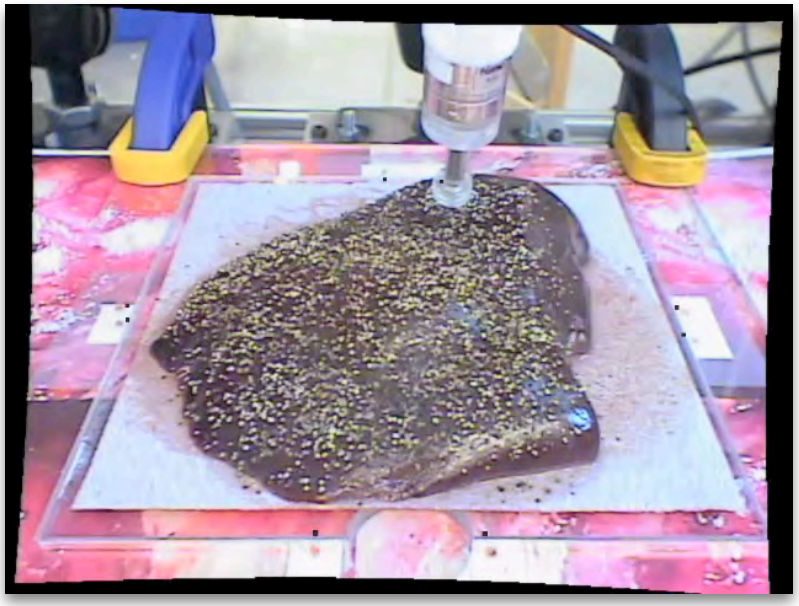
Camera image



X-ray image

Experimental Results





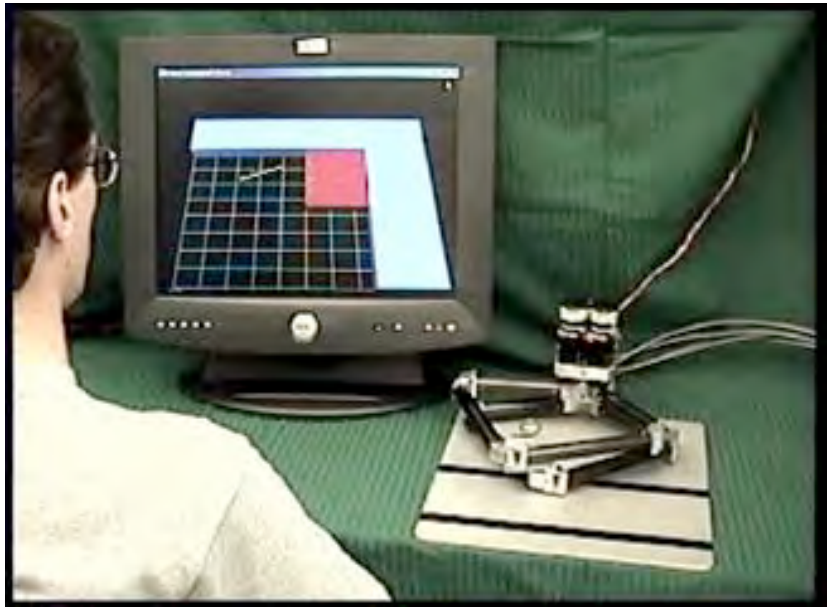
AR with Haptics for Medical Simulation

In medical simulation today, haptic feedback is typically restricted to that provided by:

artificial materials
(e.g., mannequins)

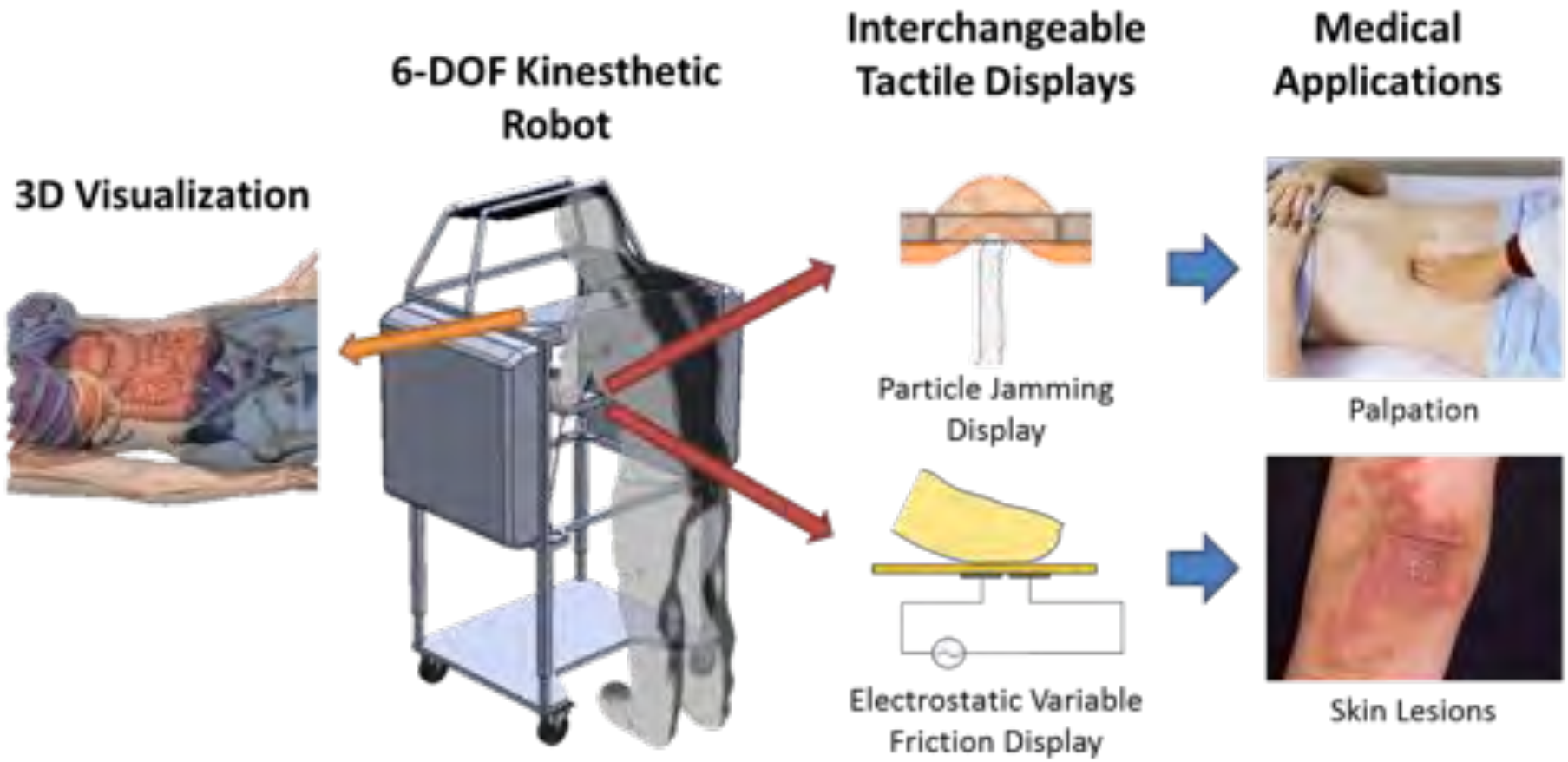
Laerdal's SimMan

resolved forces
(e.g., force feedback haptic interfaces in virtual reality simulators)



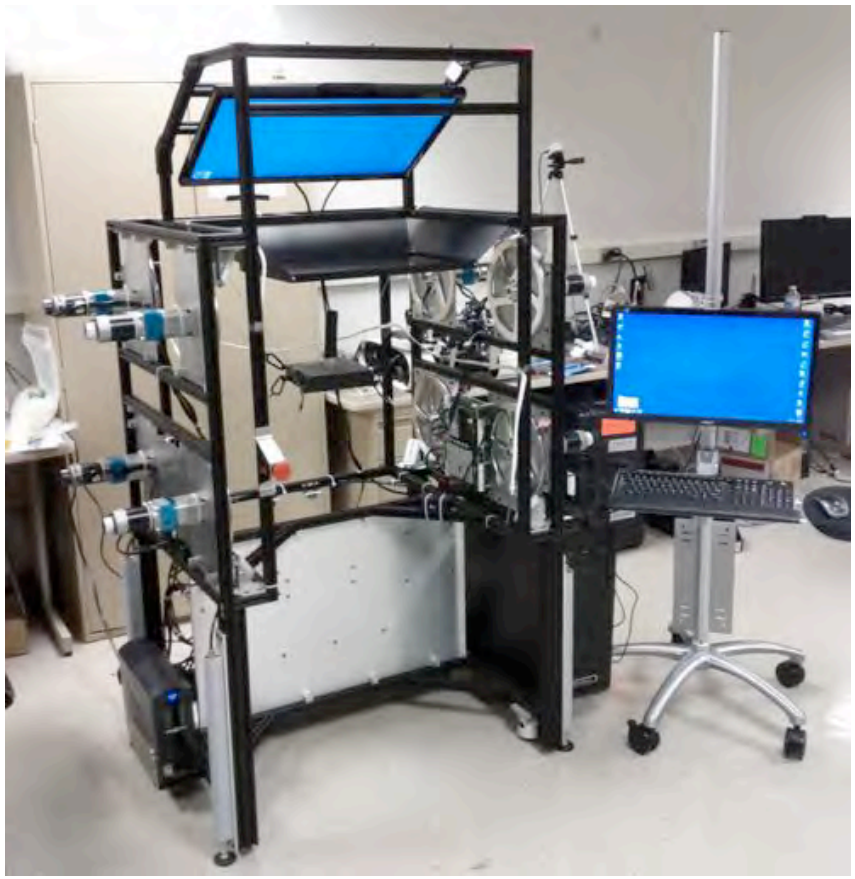
Simon DiMaio, UBC

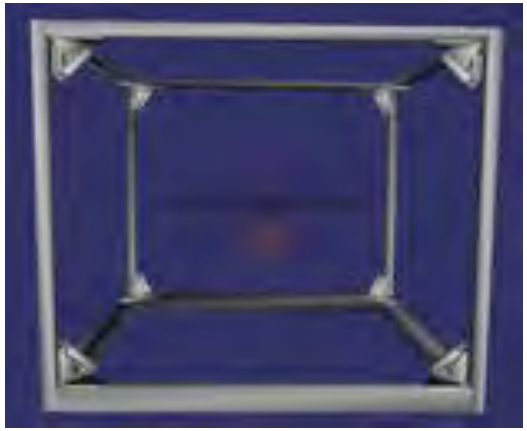
Kinetic System for Medical Simulation (KineSys MedSim)

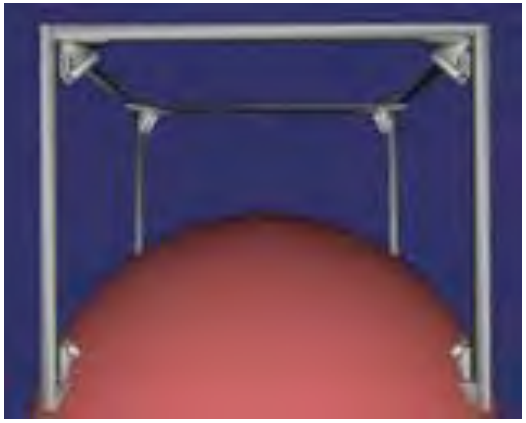


In collaboration with T. Judkins (IAI), J. E. Colgate (Tangible Haptics), D. Gaba (Stanford)

Kinesthetic haptic display

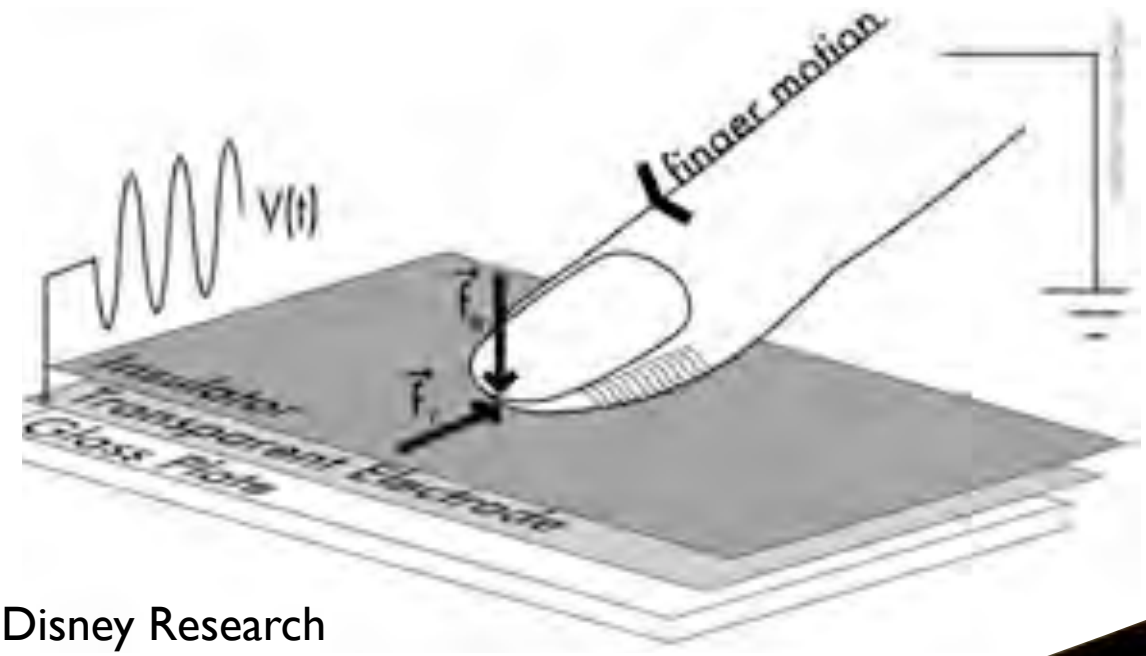






Images courtesy T. Judkins (IAI)

Electrostatic tactile display

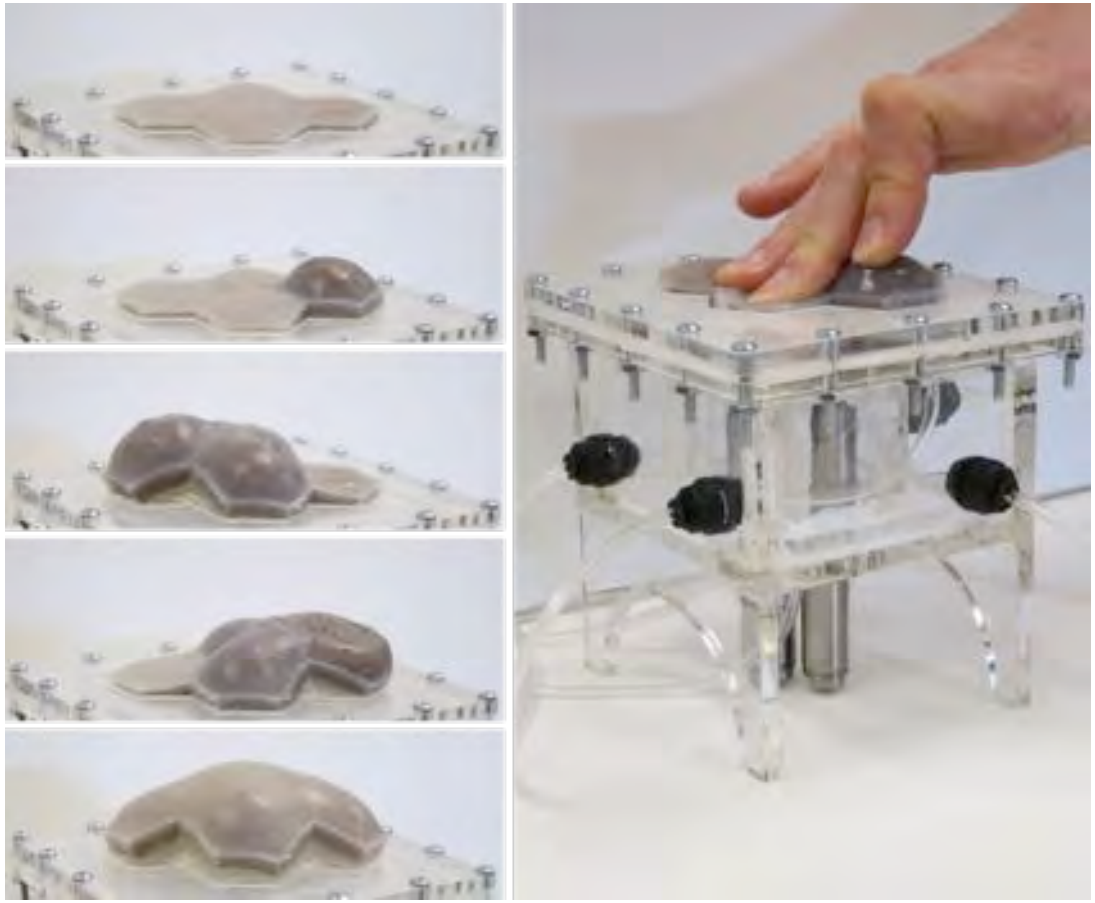


Disney Research

Tangible Haptics

Haptic Jamming: A Deformable Geometry, Variable Stiffness Tactile Display using Pneumatics and Particle Jamming

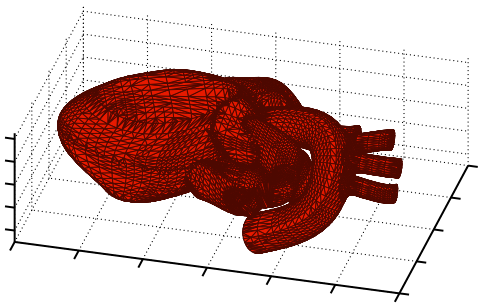
- Simultaneously controllable surface geometry and mechanical properties
- Uses pneumatics and "particle jamming": a cell made from a flexible membrane filled with granular material solidifies when air is vacuumed out

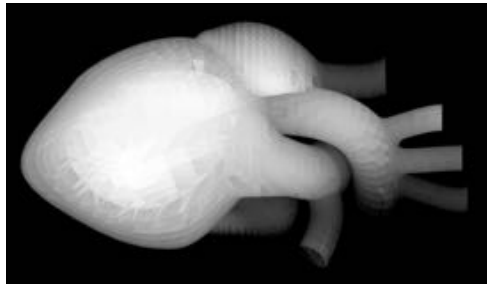


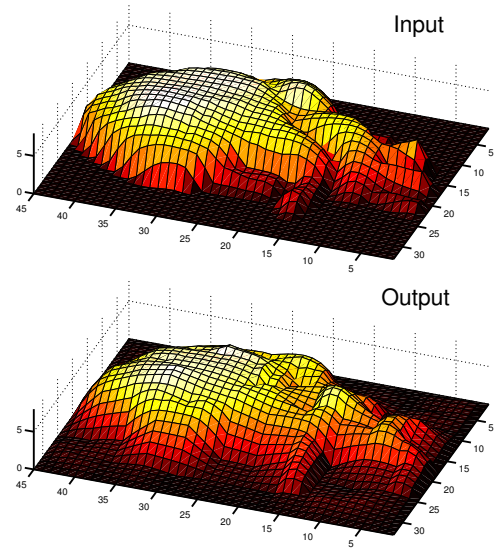
Jim Gwilliam and Andrew Stanley

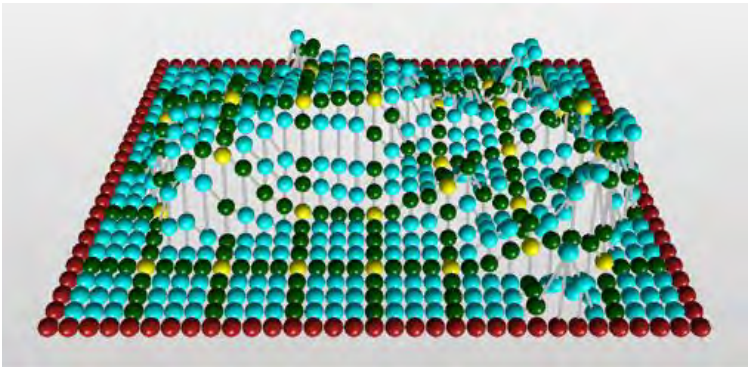
Haptic Jamming Display

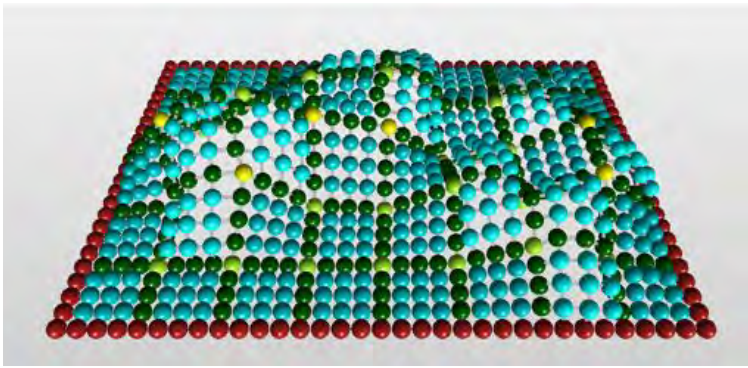
Haptic Jamming Display



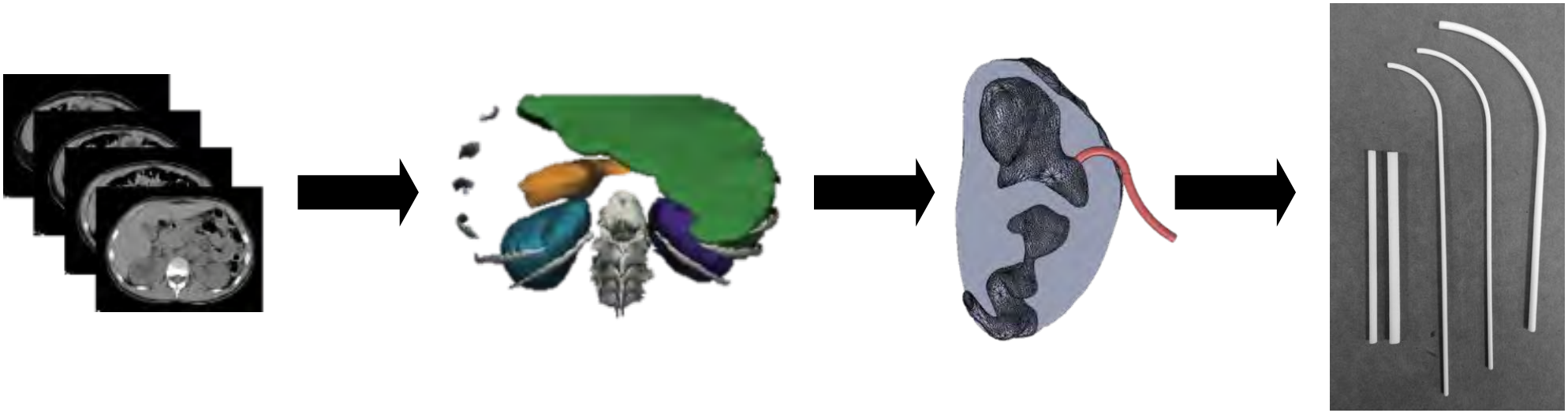


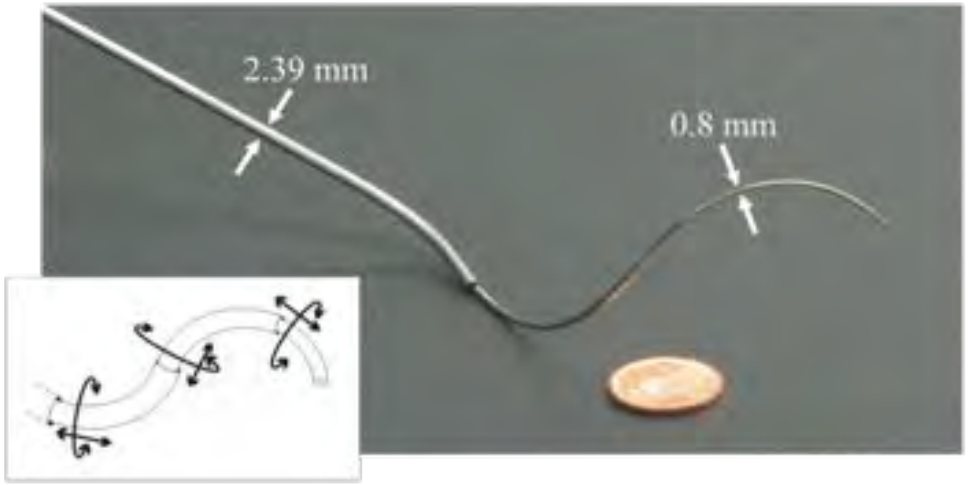






Personalized Robot Design and Use

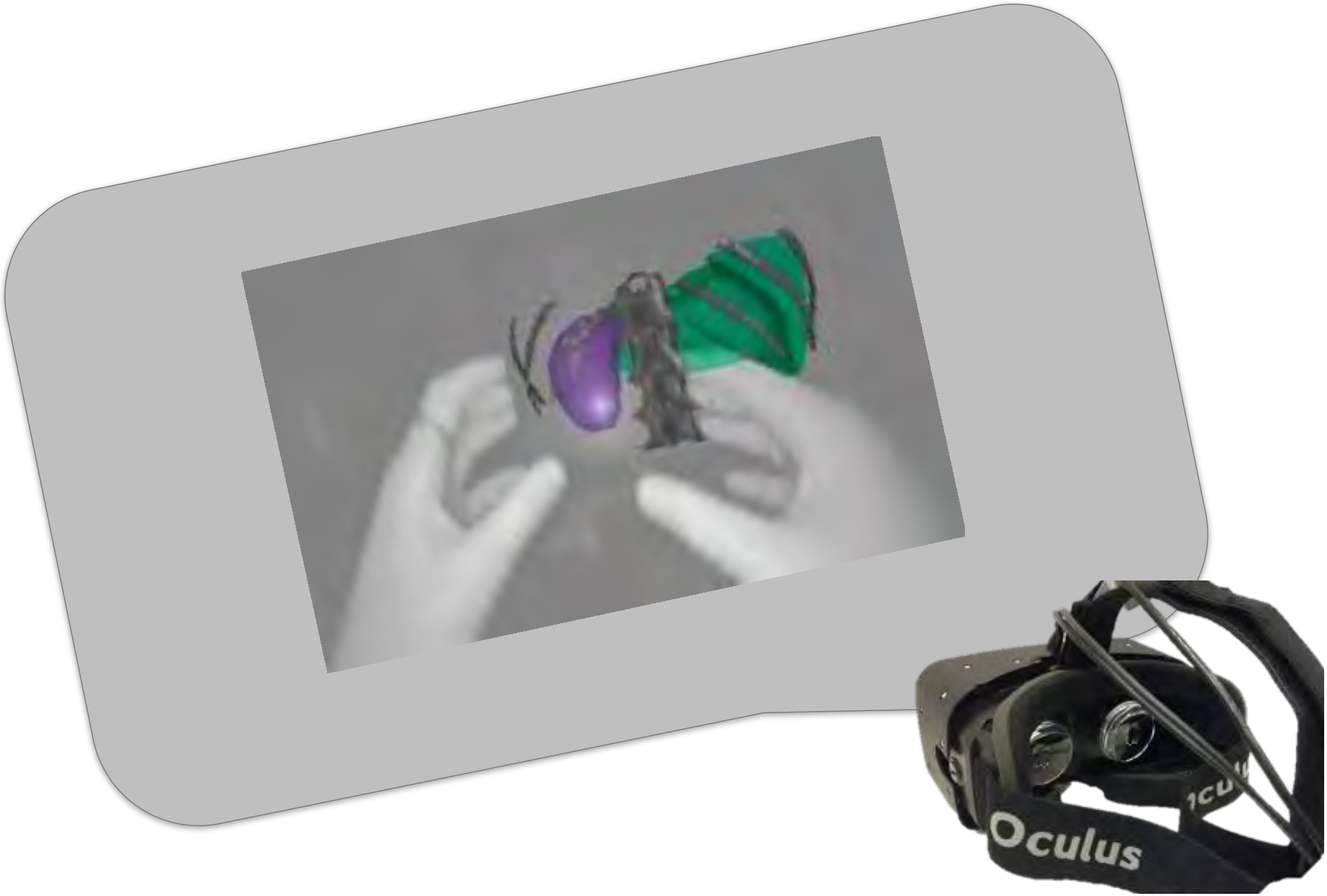




Visualize patient-specific anatomy

Visualize concentric tube robot

Integration of hand tracking




Oculus
ulus

Acknowledgments

Collaborators
Amy Bastian (KKI/JHU Neurosci.)
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Steven Hsiao (JHU Neuroscience)
Michael Hsieh (Stanford Urology)
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KT Ramesh (JHU Mech Eng.)
Danny Song (JHU Radiology)
Russell Taylor (JHU Comp. Sci.)
Louis Whitcomb (JHU Mech. Eng.)
David Yuh (JHU Surgery)
Intuitive Surgical, Inc.

Support
NSF
NIH
DoD
Intuitive Surgical
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Ryder Winck+ (Rose-Hulman)
Tomonori Yamamoto (EndoMaster)
*co-advised, +postdoc

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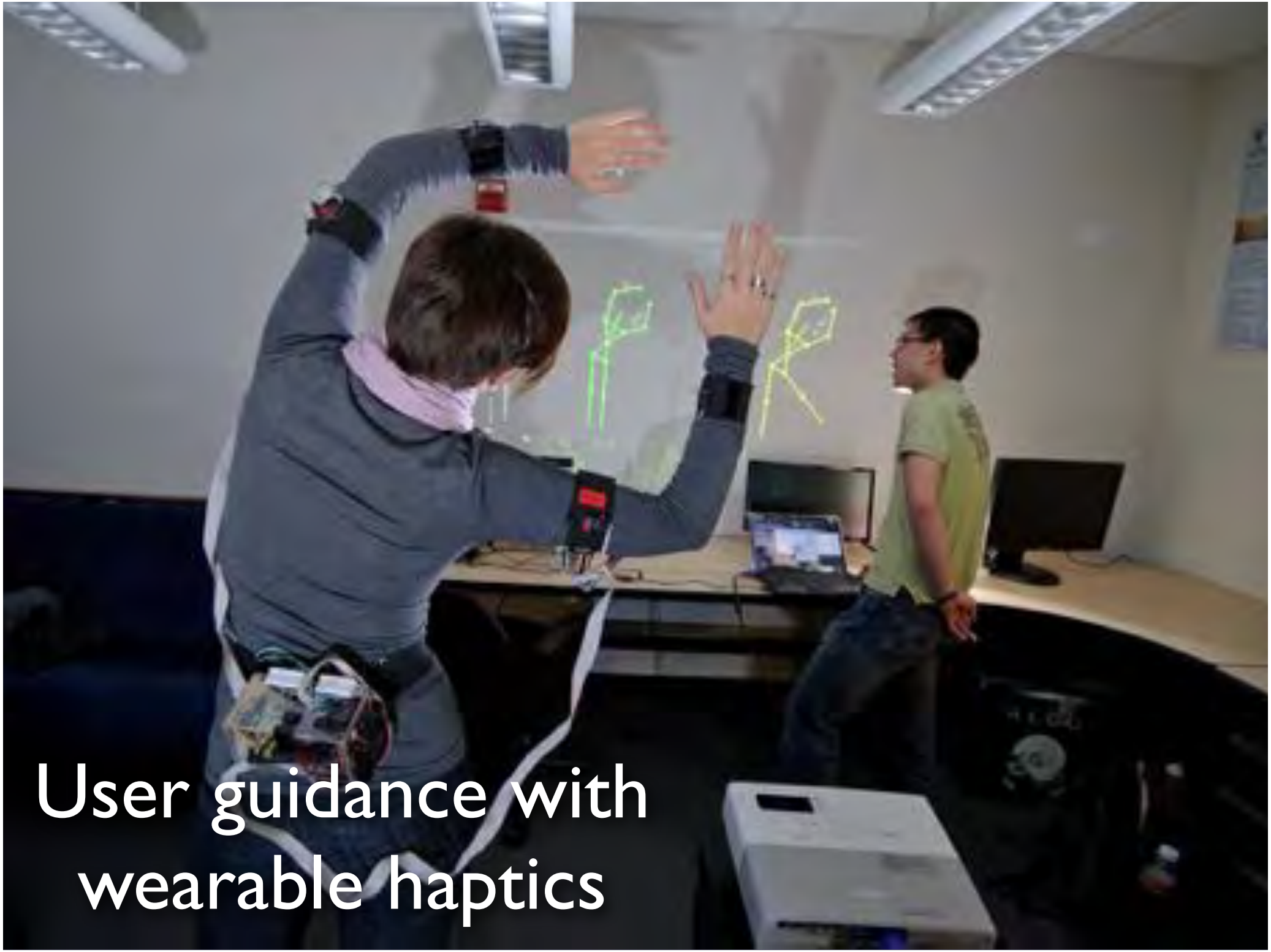
Margaret Koehler
Tania Morimoto
Ann Majewicz
Kirk Nichols
Zhan Fan Quek
Sam Schorr
Kamran Shamaei+
Sean Sketch
Andrew Stanley
Julie Walker
… and many talented undergraduate researchers!

Extra slides
(not presented)

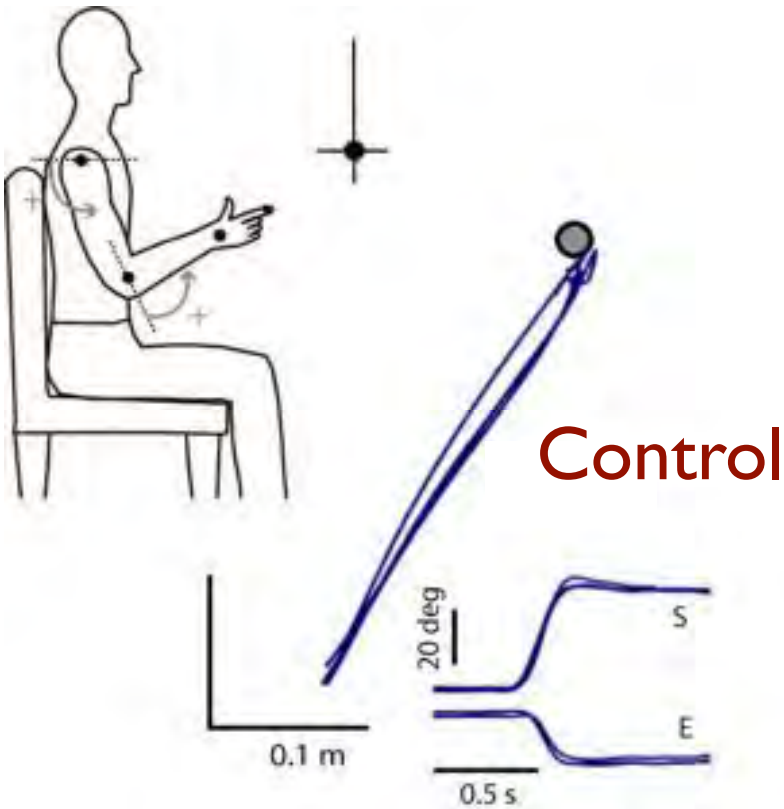
AR with Haptics for Behavioral Neuroscience



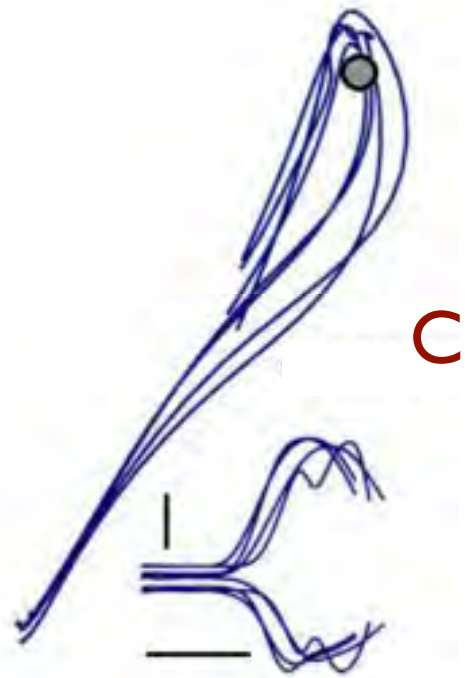
User guidance with wearable haptics

Rehabilitation Institute of Chicago

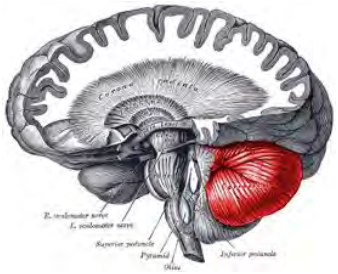
Motion Incoordination: Cerebellar Ataxia



Control



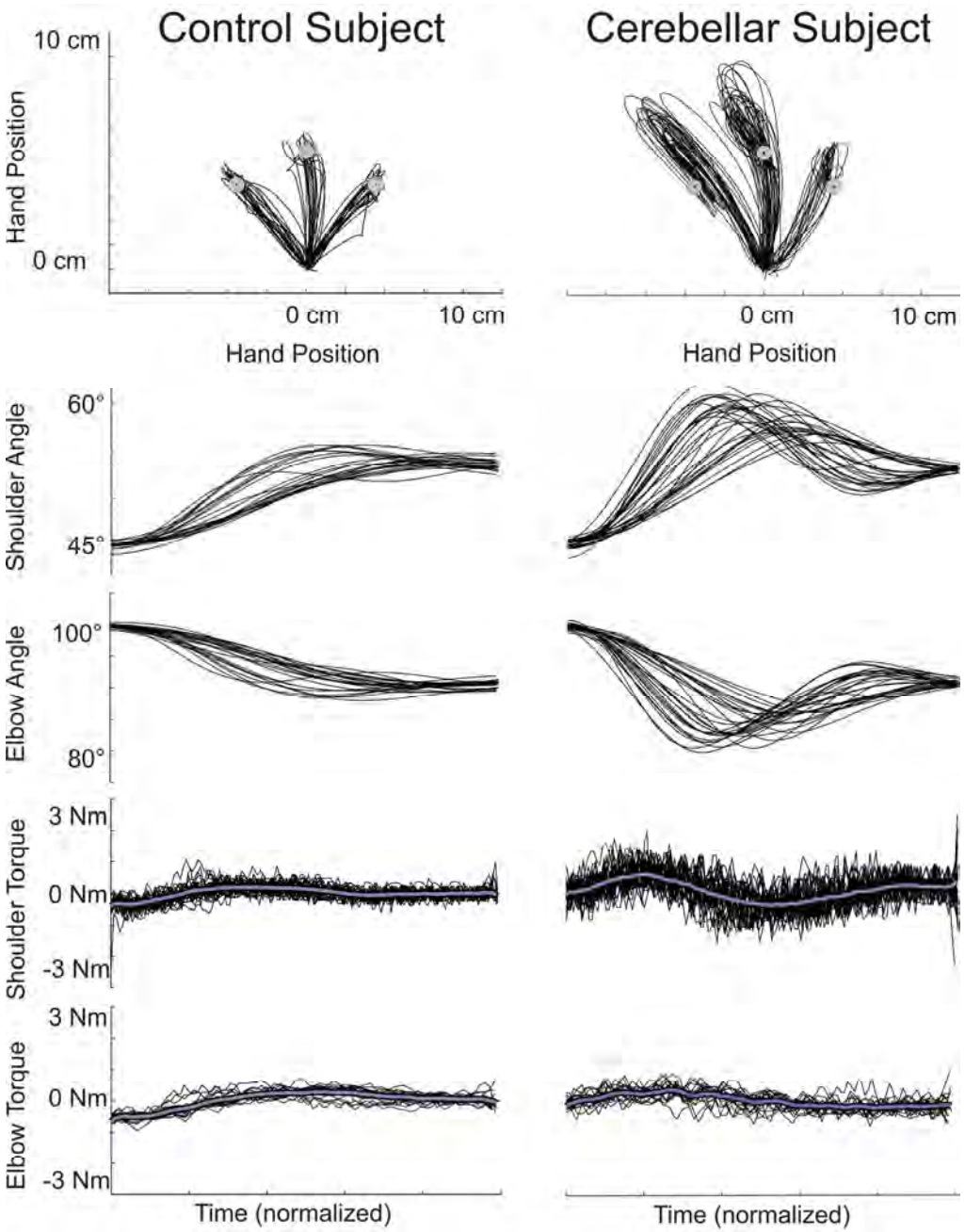
Cerebellar



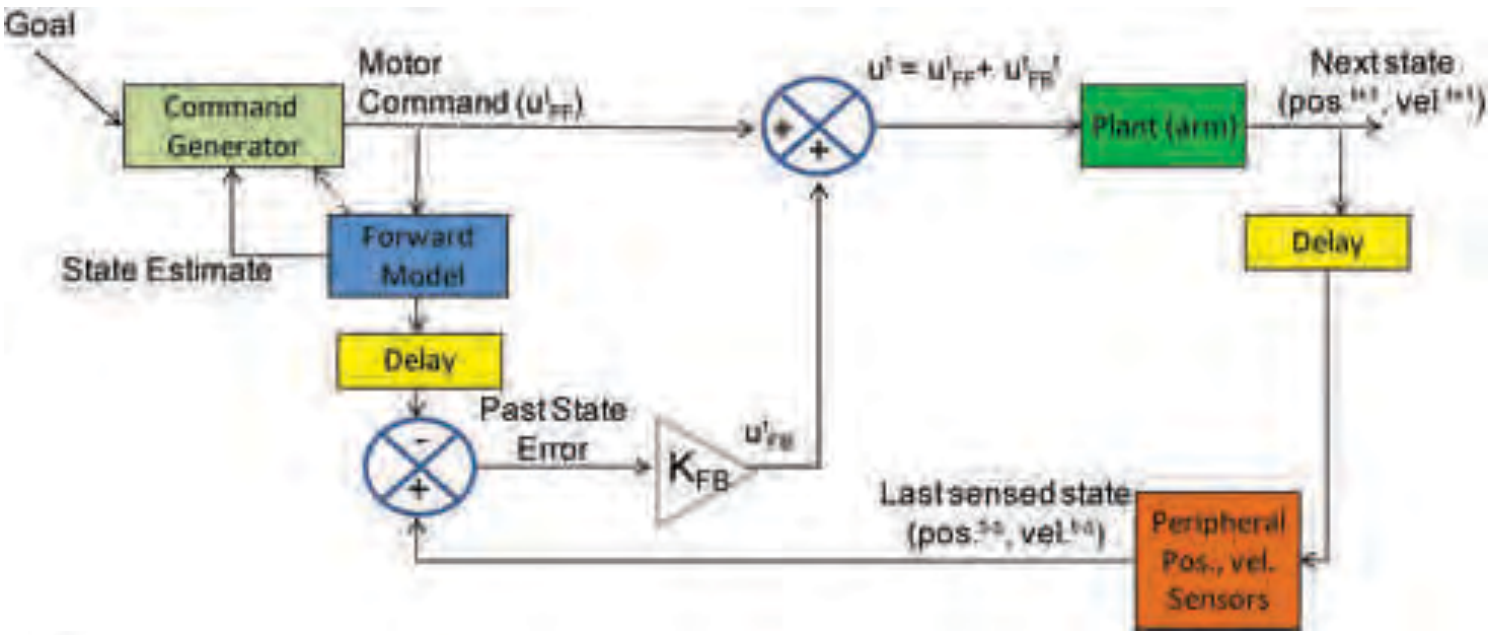
In collaboration with A. Bastian
(Kennedy Krieger Institute and JHU Neuroscience/Neurology)

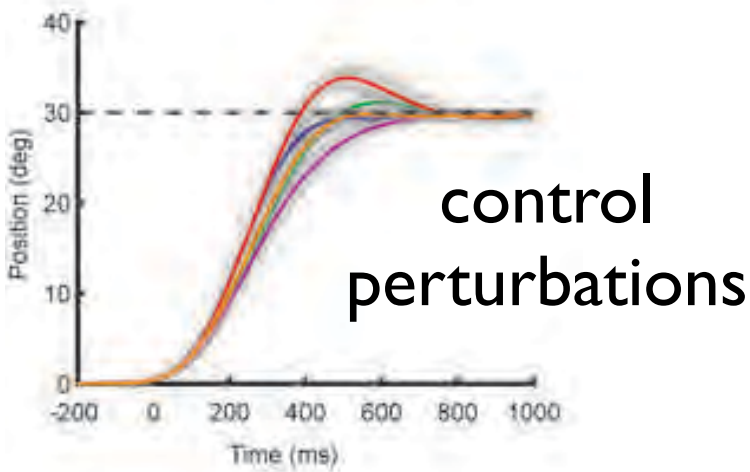
Correcting movement deficits in cerebellar patients

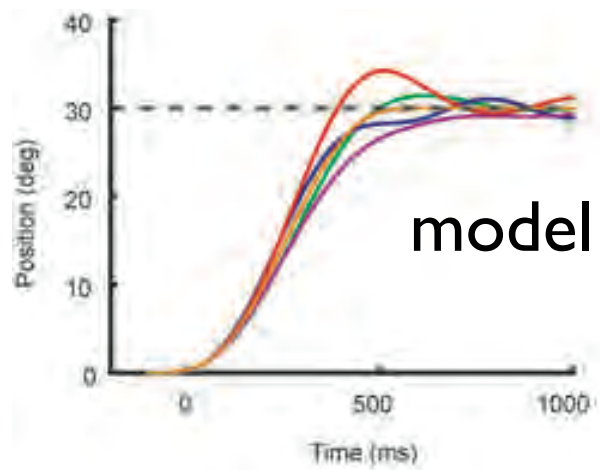
Exoskeleton robot



Correcting movement deficits in cerebellar patients

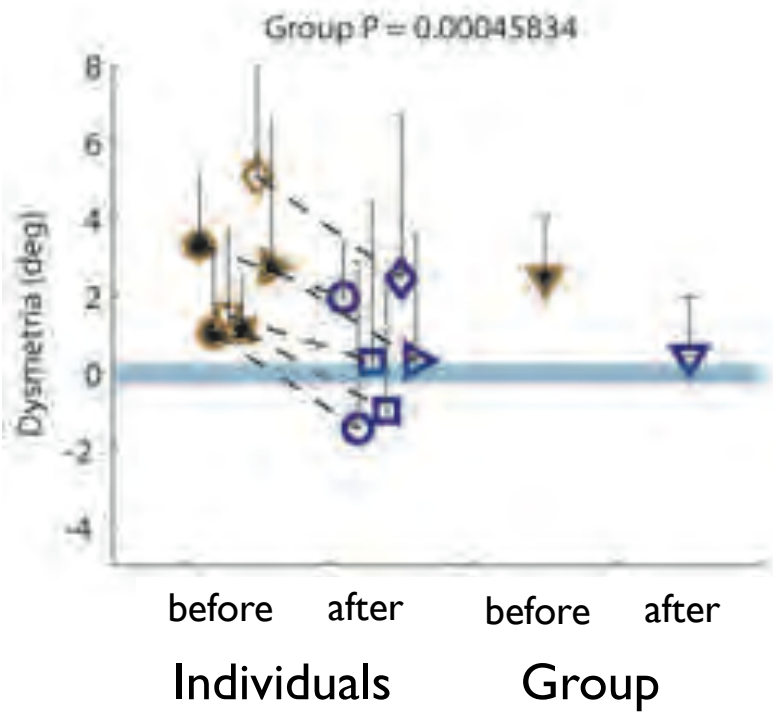




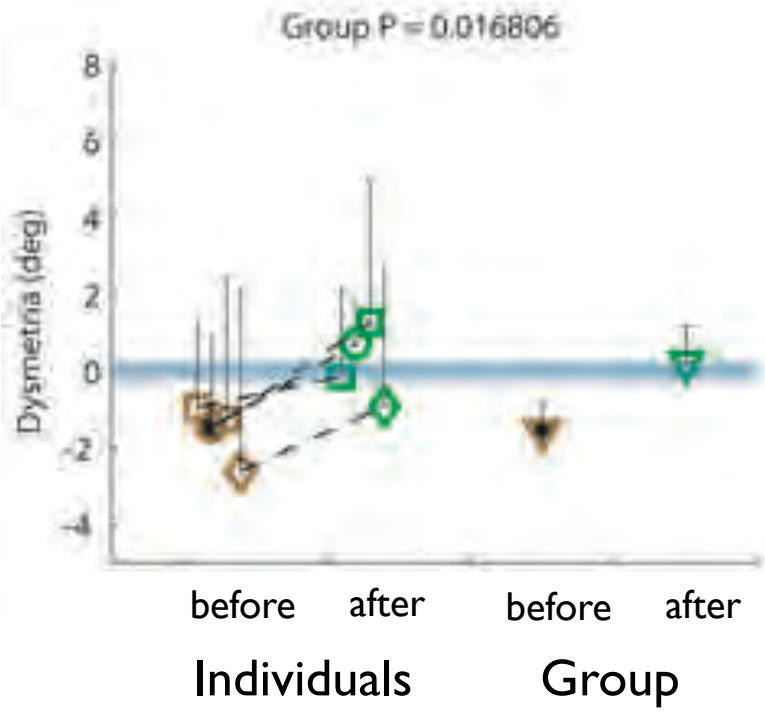


Correcting movement deficits in cerebellar patients

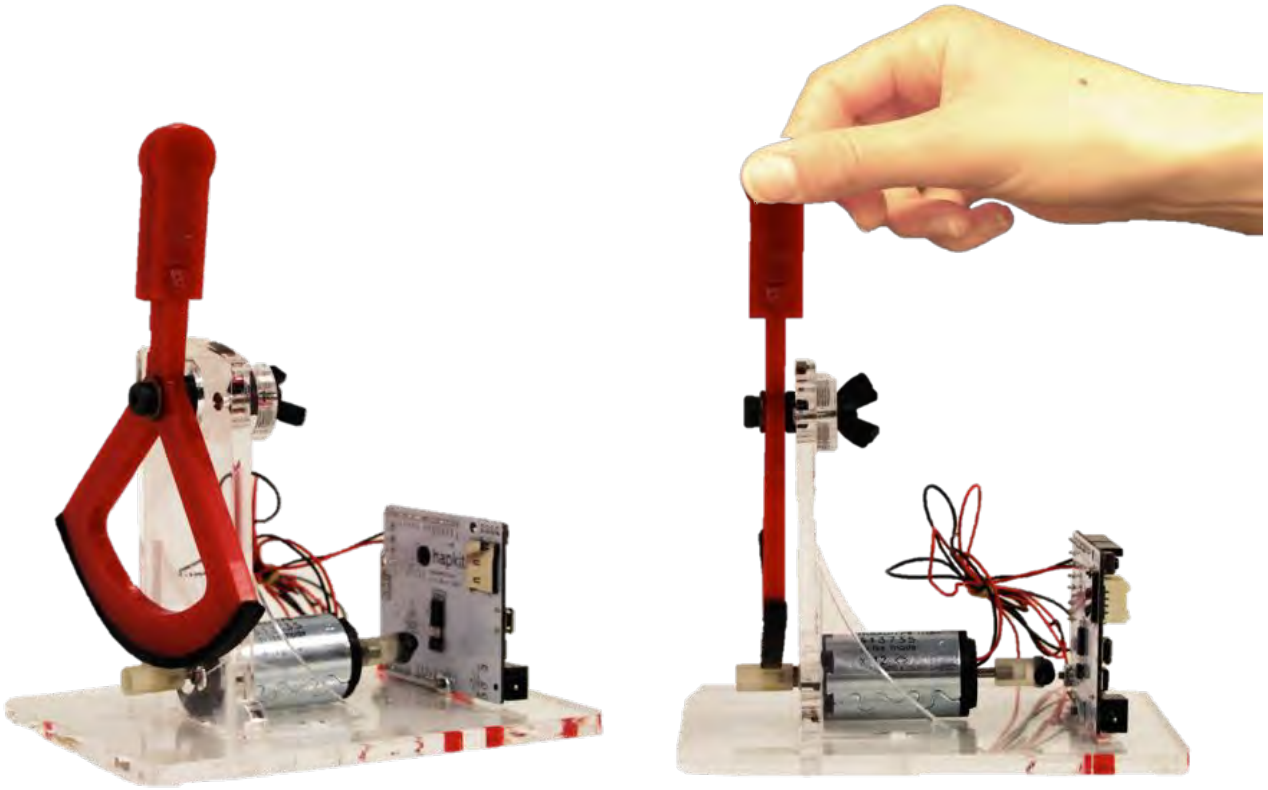
If a patient has **hypermetria**, use the robot to **decrease** their inertia



If a patient has **hypometria**, use the robot to **increase** their inertia

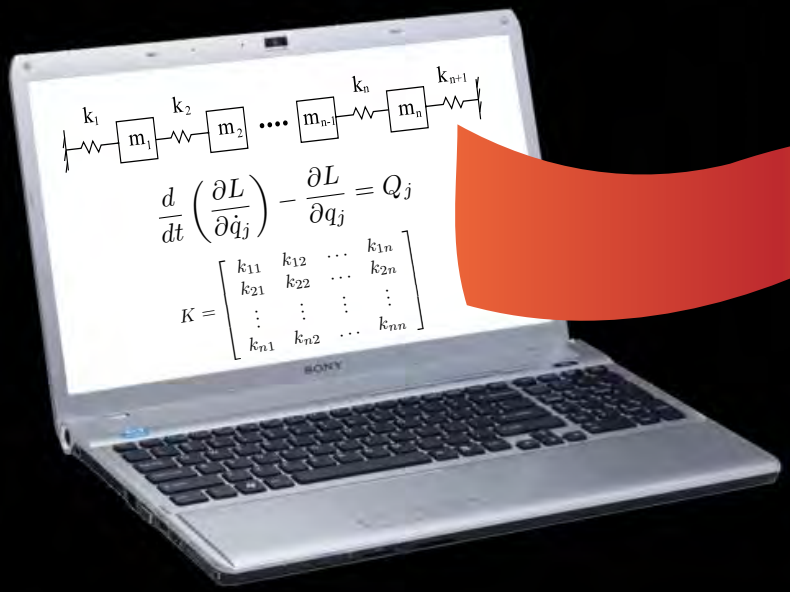


AR with Haptics for Education



Sequoia High School
Redwood City, CA

Warm Springs Elementary School
Fremont, CA


k1
m1
k2
m2
mn-1
kn
mn
kn+1
$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_j}\right) - \frac{\partial L}{\partial q_j} = Q_j$
$K = \begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{21} & k_{22} & \cdots & k_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ k_{n1} & k_{n2} & \cdots & k_{nn} \end{bmatrix}$
SONY

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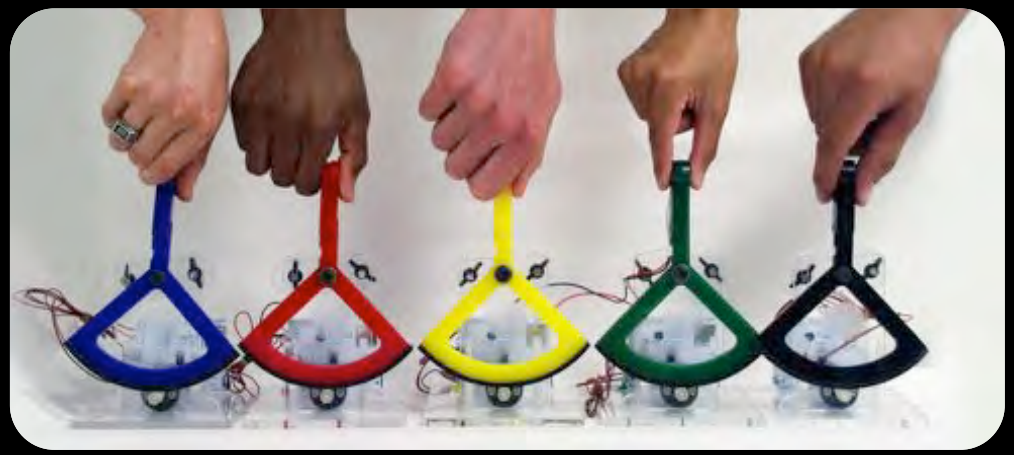

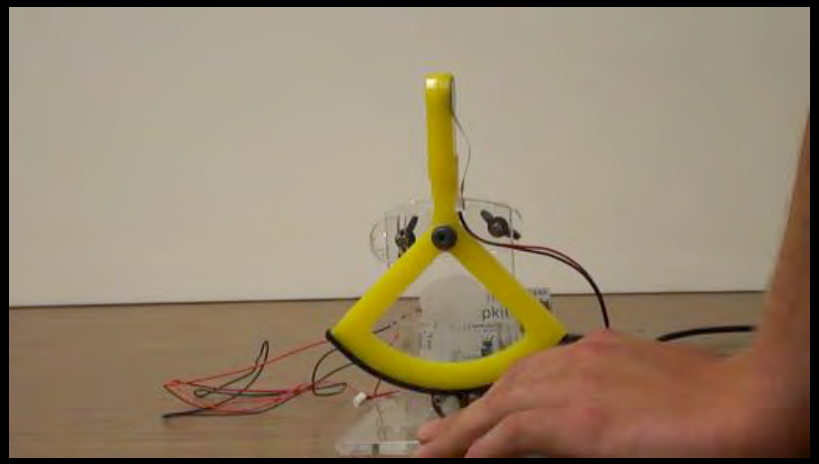

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