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)]

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**Cutaneous**
- Temperature
- Texture
- Slip
- Vibration
- Force

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**Kinesthesia**
- Location/configuration
- Motion
- Force
- Compliance

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The haptic senses work together with the motor control system to:
- Coordinate movement
- Enable perception

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R. Johansson

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
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
Da Vinci Surgical System
(Intuitive Surgical)

patient-side robot

surgeon’s console
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)

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

Laerdal's SimMan

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
Haptic Jamming Display
Haptic Jamming Display
Personalized Robot Design and Use
Visualize patient-specific anatomy
Visualize concentric tube robot
Integration of hand tracking
Acknowledgments

**Collaborators**
Amy Bastian (KKI/JHU Neurosci.)
Michael Choti (JHU Surgery)
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Intuitive Surgical, Inc.

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Kamran Shamaei+
Sean Sketch
Andrew Stanley
Julie Walker
… and many talented undergraduate researchers!

**Support**
NSF
NIH
DoD
Intuitive Surgical
Oculus/Facebook
Extra slides
(not presented)
AR with Haptics for Behavioral Neuroscience
User guidance with wearable haptics
Motion Incoordination: Cerebellar Ataxia

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.

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Before | After | Before | After
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Individuals | Group | Individuals | Group
AR with Haptics for Education
Sequoia High School
Redwood City, CA

Warm Springs Elementary School
Fremont, CA
\[
K = \begin{bmatrix}
  k_{11} & k_{12} & \cdots & k_{1n} \\
  k_{21} & k_{22} & \cdots & k_{2n} \\
  \vdots  & \vdots  & \ddots & \vdots \\
  k_{n1} & k_{n2} & \cdots & k_{nn}
\end{bmatrix}
\]

\[
d\frac{d}{dt} \left( \frac{\partial L}{\partial \dot{q}_j} \right) - \frac{\partial L}{\partial q_j} = Q_j
\]