Lecture 1:
Introduction to medical robotics

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About this class

• Teaching staff

Instructor: Allison Okamura
Co-instructor for ME/CS 571: Federico Barbagli
CAs: Robert Carrera, Margaret Koehler

• Who are you?

• Review course logistics

Web page
Syllabus
To do by Wednesday

• Fill out the survey (handout)
• Sign up on piazza:
  https://piazza.com/stanford/fall2016/me328
• Enter your availability on this when2meet poll:
  http://www.when2meet.com/?5587086-8EXrd
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
TODAY:
Treatments are both qualitatively and quantitatively limited by human abilities.

WITH ROBOTICS:
More clinicians can perform more difficult (and even new) procedures; more patients can be rehabilitated.

Potential Impact of Medical Robotics

- Level of challenge vs. number of patients treated

Graph showing the potential impact of medical robotics on treatments and patient rehabilitation.
Preoperative
computer-assisted
planning

Intraoperative
update model
update plan

Postoperative
real-time
computer
assistance

CAD
patient-specific
modeling

CAM

TQM
computer-
assisted
assessment
Surgical robotics:

Giving the surgeon superhuman capabilities
Level of Human Input Varies

Oral

Manual

Cooperative manipulation

Teleoperation

Autonomous

AESOP

JHU

JHU

da Vinci

Sensei

Dario et al.

CyberKnife
Open Surgery

Surgeon

Patient

Image source: www.physicianphotos.com
Minimally Invasive Surgery

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
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.

In collaboration with D.Yuh (JHMI Cardiac Surgery) and Li-Ming Su (JHMI Urology)
Preoperative
computer-assisted planning
...also for training
patient-specific modeling

Intraoperative
update model
update plan
real-time computer assistance

Postoperative
database
computer-assisted assessment

... also for training
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

Effects of material properties, boundary constraints, and geometry

In collaboration with K. Macura (JHMI Radiology and Radiological Sciences)
Modeling enables needle steering

- Rotation
- Use tip asymmetry
- Insertion
- Symmetric
- Bevel
- Pre-bent
Steering Performance

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

- Regaining function & retaining independence
- Caretaking for staying at home/aging-in-place
- Individualized learning and training for special needs

- 1 in 5 children is overweight
- 1M Parkinson’s patients, 50,000 new/year
- 750,000 strokes/year in US alone
- Vets with PTSD, TBI, amputations, etc.
- Millions suffer from isolation and depression
- 6.6M special ed students
- 3.5M children with ADHD
- 6.2 to 7.5M people with mental retardation
- A surging need for caregivers in-home and in-institution

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

Mental Model of Arm
Vision
Socket Forces and Torques
Artificial Proprioception and Tactile Sensation
Efferent Commands

K. J. Kuchenbecker

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.

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...