Lecture 1: Introduction to medical robotics

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About this class

• Teaching staff
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  TA: Sean Sketch

• Who are you?

• Review course logistics
  Web page
  Syllabus
To do by Friday

• Fill out the survey (handout)
• Sign up on piazza:
  https://piazza.com/stanford/spring2015/me328/home
• Enter your availability on this when2meet poll:
  http://www.when2meet.com/?2899756-xMjW0
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

~10 cm

~1 cm
Potential Impact of Medical Robotics

**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.

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Graph:  
- **X-axis:** Number of patients treated
- **Y-axis:** Level of challenge
Preoperative computer-assisted planning

patient-specific modeling

CAD

Intraoperative update model

update plan

cam

real-time computer assistance

Postoperative computer-assisted assessment

TQM

patient database
apluss
Surgical robotics:

Giving the surgeon superhuman capabilities
Level of Human Input Varies

Oral

Manual

Cooperative manipulation

Teleoperation

Autonomous

AESOP

JHU

JHU

JHU

Dario et al.

da Vinci

Sensei

CyberKnife
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)
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

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

stiffness differences are difficult to feel through a rigid contact

stiffness graphical overlay
Preoperative
computer-assisted
planning
... also for training
patient-specific
modeling

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)
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
  - Symmetric
  - Bevel
  - Pre-bent

Insertion
Steering Performance

deformation

teleoperation

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

- 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

- 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.

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)
Optimizing Movement Therapy

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

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...