Lecture 4:
Cooperative manipulation

Allison Okamura
Stanford University
What’s Next

• Assignment 1 due today at 4 pm
• Assignment 2 will be posted today (see lab orientation handout also)
• Prof. Nabil Simaan this Friday
• Next week, Allison is in Korea for the IROS conference
  • Mon. 10/10: Dynamics simulation lecture (given by CAs)
  • Wed. 10/12: Prof. Bruce Daniel, MD on interventional radiology
• VOTE on piazza for Intuitive Surgical visit date
Cooperative Manipulation
so-called “steady-hand” robots

Mako’s RIO Robotic Arm Interactive Orthopedic System

JHU Eye Surgery Robot
steady-hand robot behavior

with RCM: http://www.youtube.com/watch?v=qQEJEM7YeXY
MAKO Surgical Robot (makoplasty)

http://www.youtube.com/watch?v=Wun4AJeFZSw
Barrett WAM Arm

The WAM and associated technologies are the basis for the MAKO surgical robot.
Robodoc is a similar system (with much more history)

http://robodoc.com/patient_about_history.html
a more “intelligent” surgical system than pure teleoperation

close integration with information systems

more active user assistance

Manual Surgery  Robotic Surgery
admittance control

the user’s applied force is measured, and the robot is controlled to move proportionally to that force

a typical implementation is:

\[ \dot{x}_d = k_a f \]
\[ f_a = k_p (x_d - x) + k_d (\dot{x}_d - \dot{x}) \]

\( x_d, \dot{x}_d \) desired robot position, velocity
\( f_a \) actuator force
\( k_a \) admittance gain
\( k_p, k_d \) proportional and derivative gains
\( f \) force applied by the user (measured)
\( x, \dot{x} \) robot position, velocity

note: not all cooperative manipulators use admittance control, but many do...
questions

• what happens when $k_a$ is zero?

• how would you create a virtual surface/wall using admittance control?
admittance control

enables very slow, steady motions

is a very good underlying control structure for applying "virtual fixtures" to guide motions.

can be applied to teleoperators as well as cooperative manipulators.

for cooperative manipulation, it is best used on a very accurate, nonbackdrivable robot.
impedance \hspace{4cm} \text{admittance}

\[ F(s) = Z(s)X(s) \quad \quad \quad \quad X(s) = Y(s)F(s) \]

dual concepts, just different causality

with implications for practical implementation on robots
questions

• what are some advantages and disadvantages of cooperative manipulation as compared to teleoperation?

• what are some advantages and disadvantages of admittance control as compared to impedance control?
Assignment 2

Problem 1: Commentary on seminar

Problem 2: Read/skim papers, answer questions

Problem 3: Implement teleoperators and review performance data

Problem 4: Implement admittance control and review performance data

Due Wednesday Oct. 12 at 4 pm
Lab Orientation

• proper handling of the Phantom Omni robot/haptic devices
• use of the programs you need to test the Omni setup
• opening, modifying, and compiling the template program for writing and testing Omni control laws
• the details of the template program you’ll be working with
• how to interpret the experimental data you save