MEAM 520

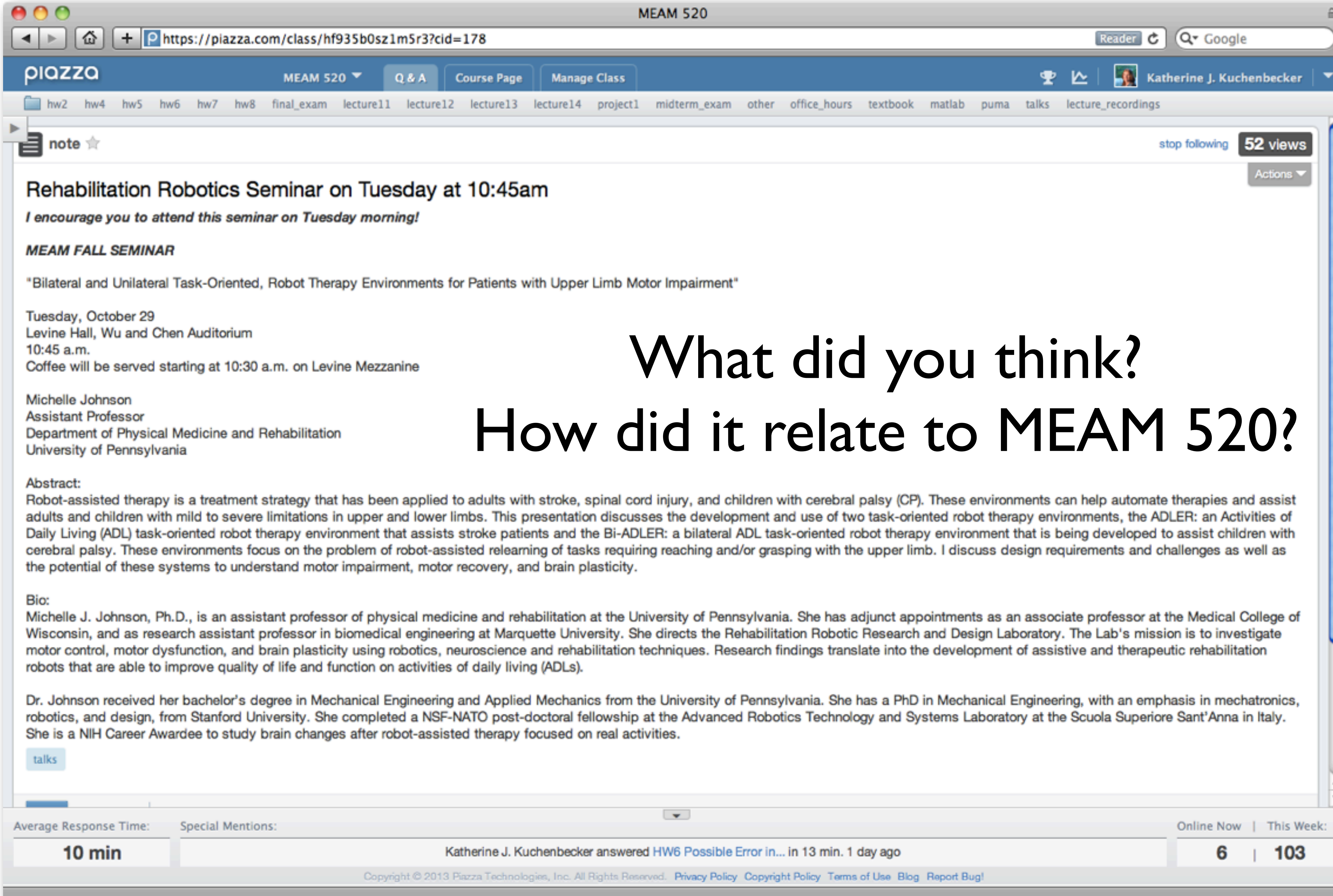
Robot Hardware

Katherine J. Kuchenbecker, Ph.D.
General Robotics, Automation, Sensing, and Perception Lab (GRASP)
MEAM Department, SEAS, University of Pennsylvania

LEGES SINE MORIBUS VANAE

GRASP
LABORATORY

Lecture 17: October 29, 2013



MEAM 520

https://piazza.com/class/hf935b0sz1m5r3?cid=178

piazza MEAM 520 Q & A Course Page Manage Class Katherine J. Kuchenbecker

hw2 hw4 hw5 hw6 hw7 hw8 final_exam lecture11 lecture12 lecture13 lecture14 project1 midterm_exam other office_hours textbook matlab puma talks lecture_recordings

note

stop following 52 views

Actions

Rehabilitation Robotics Seminar on Tuesday at 10:45am

I encourage you to attend this seminar on Tuesday morning!

MEAM FALL SEMINAR

"Bilateral and Unilateral Task-Oriented, Robot Therapy Environments for Patients with Upper Limb Motor Impairment"

Tuesday, October 29
Levine Hall, Wu and Chen Auditorium
10:45 a.m.
Coffee will be served starting at 10:30 a.m. on Levine Mezzanine

Michelle Johnson
Assistant Professor
Department of Physical Medicine and Rehabilitation
University of Pennsylvania

Abstract:
Robot-assisted therapy is a treatment strategy that has been applied to adults with stroke, spinal cord injury, and children with cerebral palsy (CP). These environments can help automate therapies and assist adults and children with mild to severe limitations in upper and lower limbs. This presentation discusses the development and use of two task-oriented robot therapy environments, the ADLER: an Activities of Daily Living (ADL) task-oriented robot therapy environment that assists stroke patients and the Bi-ADLER: a bilateral ADL task-oriented robot therapy environment that is being developed to assist children with cerebral palsy. These environments focus on the problem of robot-assisted relearning of tasks requiring reaching and/or grasping with the upper limb. I discuss design requirements and challenges as well as the potential of these systems to understand motor impairment, motor recovery, and brain plasticity.

Bio:
Michelle J. Johnson, Ph.D., is an assistant professor of physical medicine and rehabilitation at the University of Pennsylvania. She has adjunct appointments as an associate professor at the Medical College of Wisconsin, and as research assistant professor in biomedical engineering at Marquette University. She directs the Rehabilitation Robotic Research and Design Laboratory. The Lab's mission is to investigate motor control, motor dysfunction, and brain plasticity using robotics, neuroscience and rehabilitation techniques. Research findings translate into the development of assistive and therapeutic rehabilitation robots that are able to improve quality of life and function on activities of daily living (ADLs).

Dr. Johnson received her bachelor's degree in Mechanical Engineering and Applied Mechanics from the University of Pennsylvania. She has a PhD in Mechanical Engineering, with an emphasis in mechatronics, robotics, and design, from Stanford University. She completed a NSF-NATO post-doctoral fellowship at the Advanced Robotics Technology and Systems Laboratory at the Scuola Superiore Sant'Anna in Italy. She is a NIH Career Awardee to study brain changes after robot-assisted therapy focused on real activities.

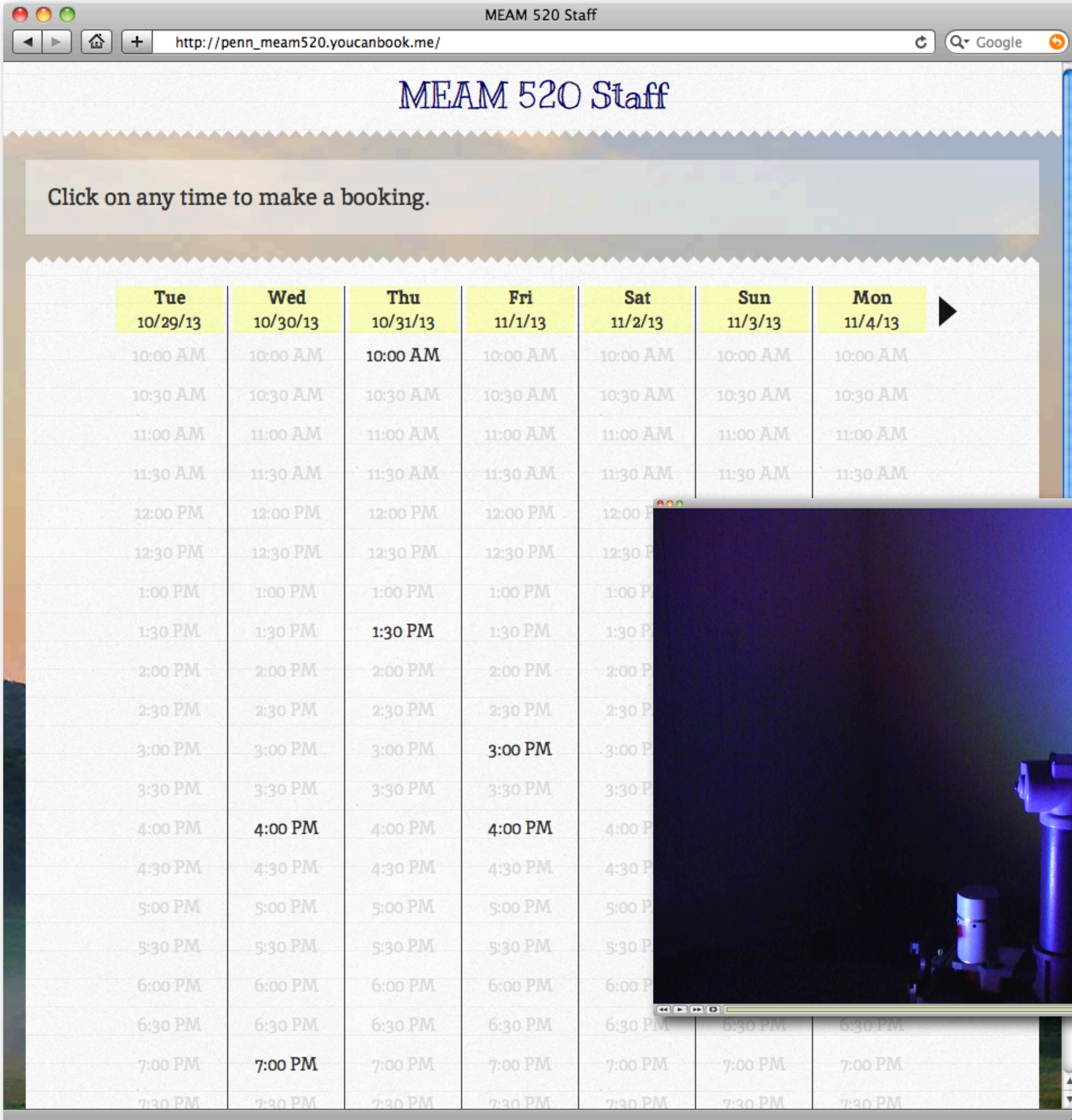
talks

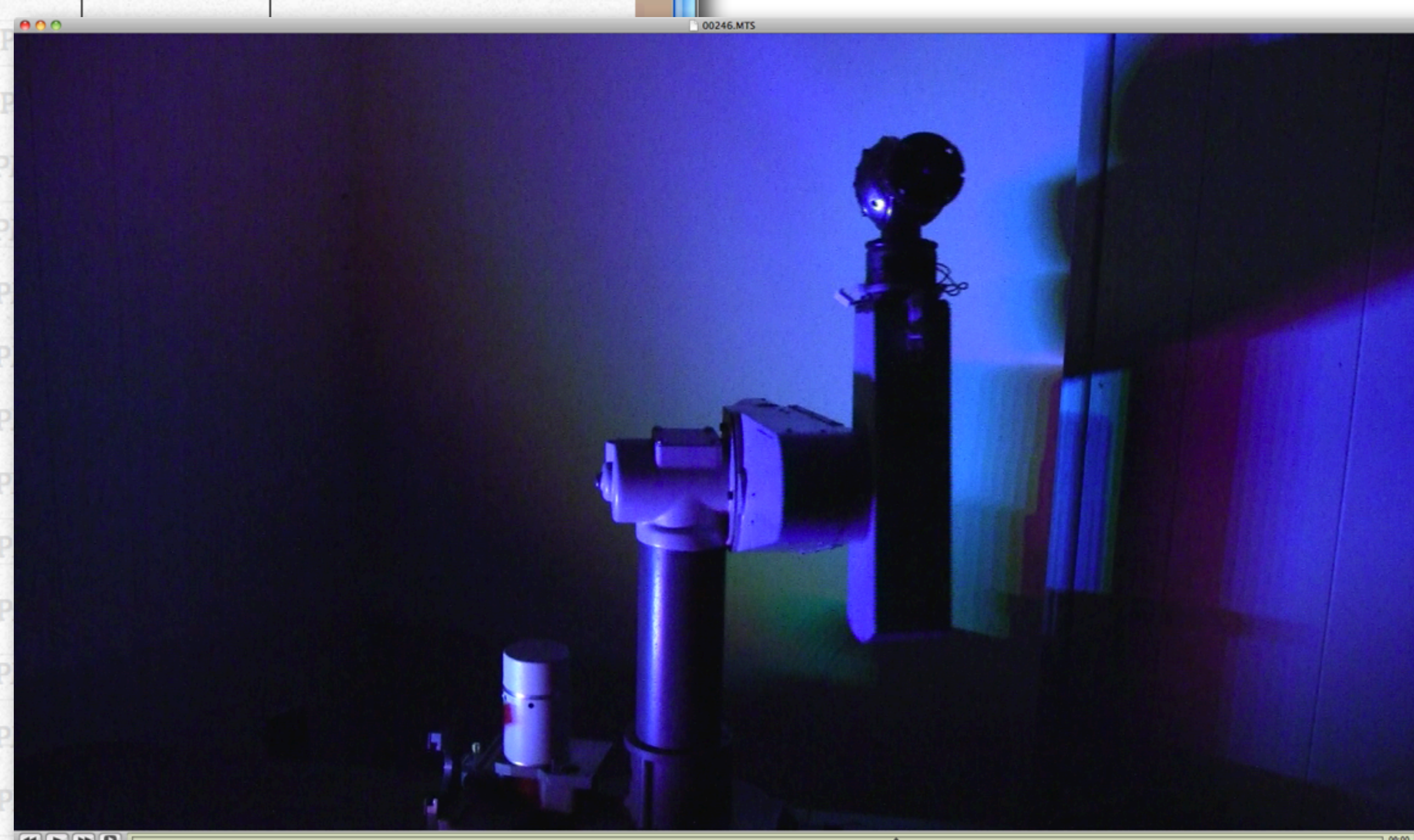
Average Response Time: 10 min

Special Mentions: Katherine J. Kuchenbecker answered HW6 Possible Error in... in 13 min. 1 day ago

Online Now | This Week: 6 | 103

What did you think?
How did it relate to MEAM 520?





Please sign up for a slot to film your PUMA dance.

MEAM 520 Calendar

Ongoing – Film PUMA Dance

Sunday 10/27 – Homework 6 Due

Tuesday 10/29 – Robot Hardware
Thursday 10/31 – More Robot Hardware,
Midterm Review
Sunday 11/3 – Extra Office Hours (TBA)
Sunday 11/3 – Homework 7 Due

Monday 11/4 – Extra Office Hours (TBA)
Tuesday 11/5 – Midterm Exam
Thursday 11/7 – Start Chapter 3.3 (IK)

Homework 7:
PUMA 260 Singularities and Manipulability

MEAM 520, University of Pennsylvania
Katherine J. Kuchenbecker, Ph.D.

October 24, 2013

This assignment is due on **Sunday, November 3, by midnight (11:59:59 p.m.)** Your code should be submitted via email according to the instructions at the end of this document. Late submissions will be accepted until Wednesday, November 6, by midnight (11:59:59 p.m.), but they will be penalized by 10% for each partial or full day late, up to 30%. After the late deadline, no further assignments may be submitted.

You may talk with other students about this assignment, ask the teaching team questions, use a calculator and other tools, and consult outside sources such as the Internet. To help you actually learn the material, what you write down must be your own work, not copied from any other individual or team. Any submissions suspected of violating Penn's Code of Academic Integrity will be reported to the Office of Student Conduct. If you get stuck, post a question on Piazza or go to office hours!

Individual vs. Pair Programming

You may do this assignment either individually or with a partner. If you do this homework with a partner, you may work with ***anyone except your partner from Project 1***. We want everyone in this class to gain experience working with a variety of partners. Consider using the "Search for Teammates!" tool on Piazza.

If you are in a pair, you should work closely with your partner throughout this assignment, following the paradigm of pair programming. You will turn in one MATLAB script for which you are both jointly responsible, and you will both receive the same grade. Please follow these pair programming guidelines, which were adapted from "All I really need to know about pair programming I learned in kindergarten," by Williams and Kessler, *Communications of the ACM*, May 2000:

- Start with a good attitude, setting aside any skepticism and expecting to jell with your partner.
- Don't start writing code alone. Arrange a meeting with your partner as soon as you can.
- Use just one computer, and sit side by side; a desktop computer with a large monitor is better for this than a laptop. Make sure both partners can see the screen.
- At each instant, one partner should be driving (using the mouse and keyboard or recording design ideas) while the other is continuously reviewing the work (thinking and making suggestions).
- Change driving/reviewing roles at least every thirty minutes, *even if one partner is much more experienced than the other.* You may want to set a timer to help you remember to switch.
- If you notice a bug in the code your partner is typing, wait until they finish the line to correct them.
- Stay focused and on-task the whole time you are working together.
- Recognize that pair programming usually takes more effort than programming alone, but it produces better code, deeper learning, and a more positive experience for the participants.
- Take a break periodically to refresh your perspective.
- Share responsibility for your project; avoid blaming either partner for challenges you run into.

1

Homework 7

MATLAB Assignment on PUMA 260 Singularities and Manipulability

Done individually or with a partner *(not project 1 partner)*

Due Sunday 11/3

Extra copies available

Questions?

Name ____________________

Midterm Exam

MEAM 520, Introduction to Robotics
University of Pennsylvania
Katherine J. Kuchenbecker, Ph.D.

November 8, 2012

You must take this exam independently, without assistance from anyone else. You may bring in a calculator and two 8.5"×11" sheets of notes for reference. Aside from these two pages of notes, you may not consult any outside references, such as the textbook or the Internet. Any suspected violations of Penn's Code of Academic Integrity will be reported to the Office of Student Conduct for investigation.

This exam consists of several problems. We recommend you look at all of the problems before starting to work. If you need clarification on any question, please ask a member of the teaching team. When you work out each problem, please show all steps and box your answer. On problems involving actual numbers, please keep your solution symbolic for as long as possible; this will make your work easier to follow and easier to grade. The exam is worth a total of 100 points, and partial credit will be awarded for the correct approach even when you do not arrive at the correct answer.

	Points	Score
Problem 1	20	
Problem 2	20	
Problem 3	15	
Problem 4	20	
Problem 5	25	
Total	100	

I agree to abide by the University of Pennsylvania Code of Academic Integrity during this exam. I pledge that all work is my own and has been completed without the use of unauthorized aid or materials.

Signature ____________________

Date ____________________

1

Unavoidable conflict? There is a make-up exam time.

Midterm is closed book.

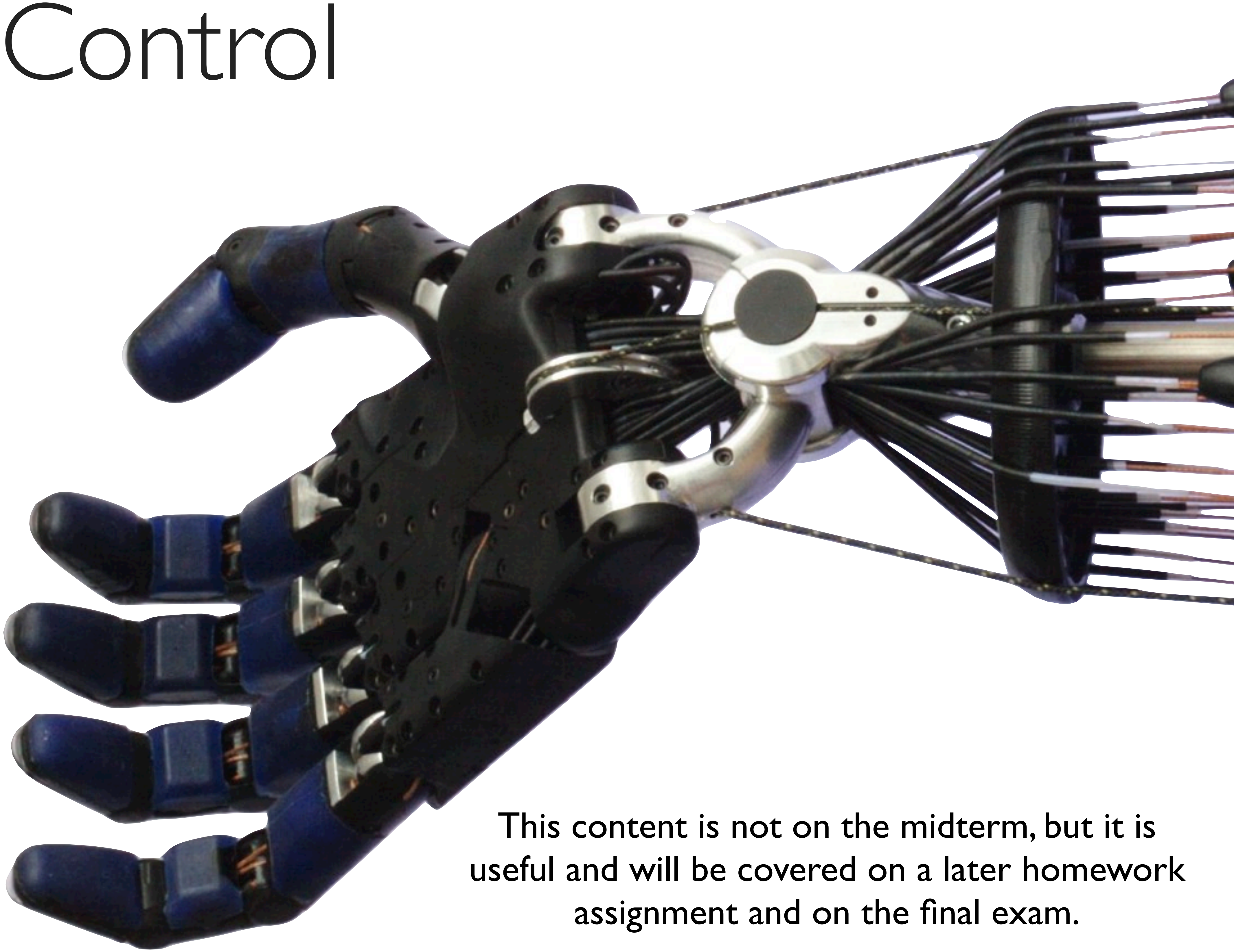
You may bring two pages of notes and a calculator.

A practice midterm and its solutions are posted on Piazza. Look at them.

The practice midterm is a modified version of the exam from last year.

Questions?

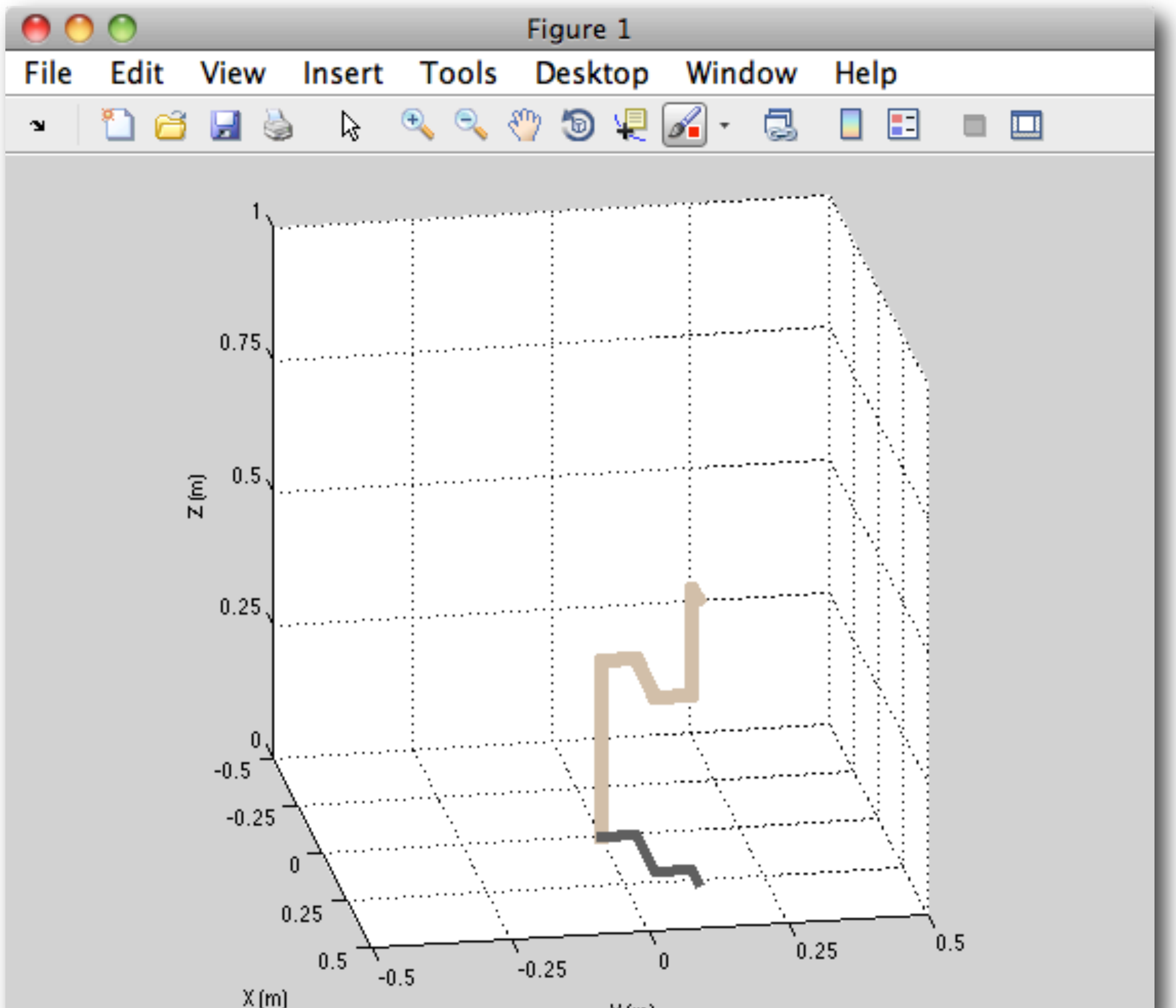
Manipulator Hardware and Control



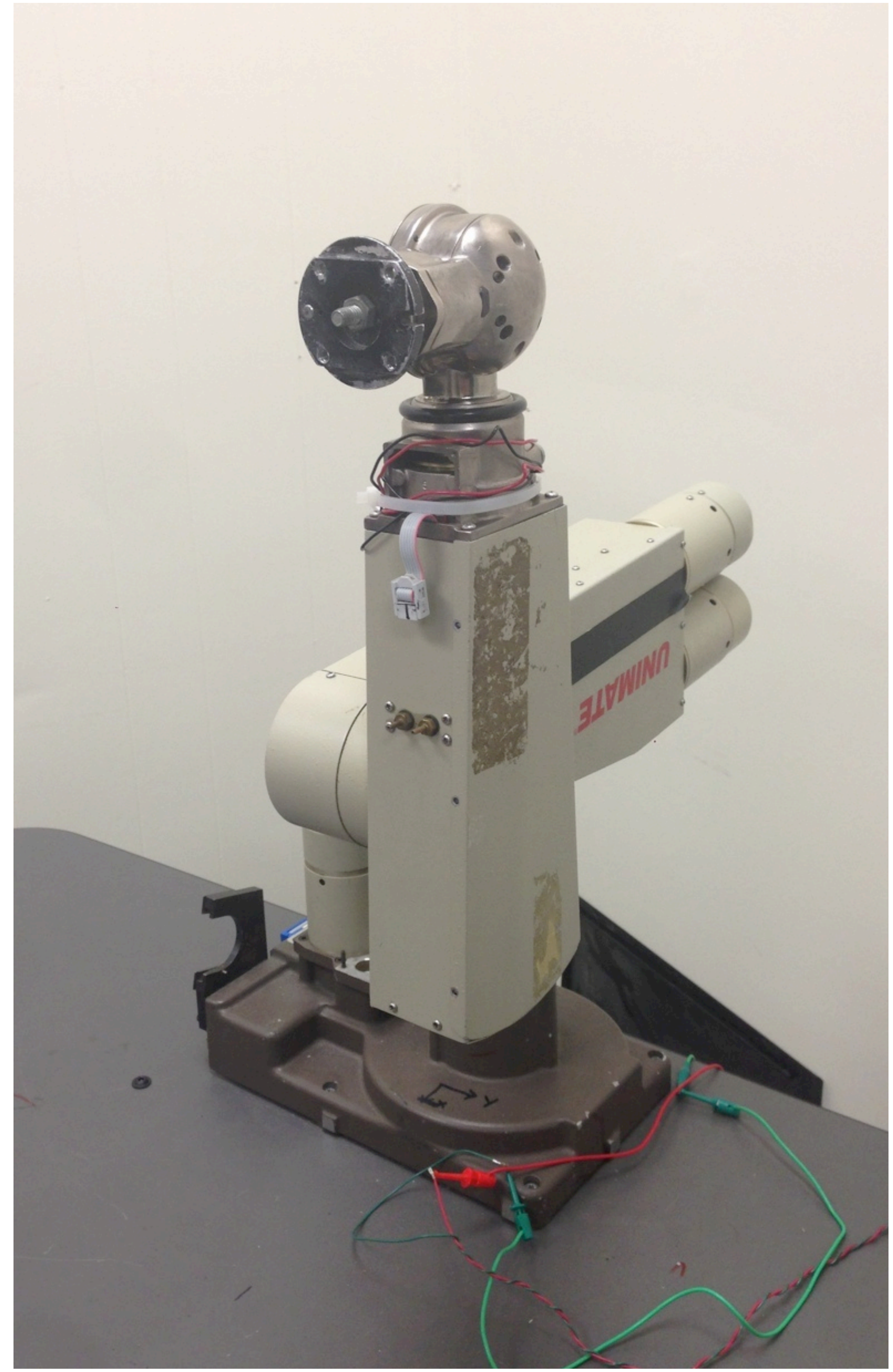
This content is not on the midterm, but it is useful and will be covered on a later homework assignment and on the final exam.

Based on slides created by Jonathan Fiene

How does the real PUMA differ from the simulated PUMA?



The simulator moves instantly, but the real robot has imperfect sensors, actuators, and controllers.



A Biological Inspiration

Mechanical Structure

Bones	Frame / Links
Joints	Joints

Actuators

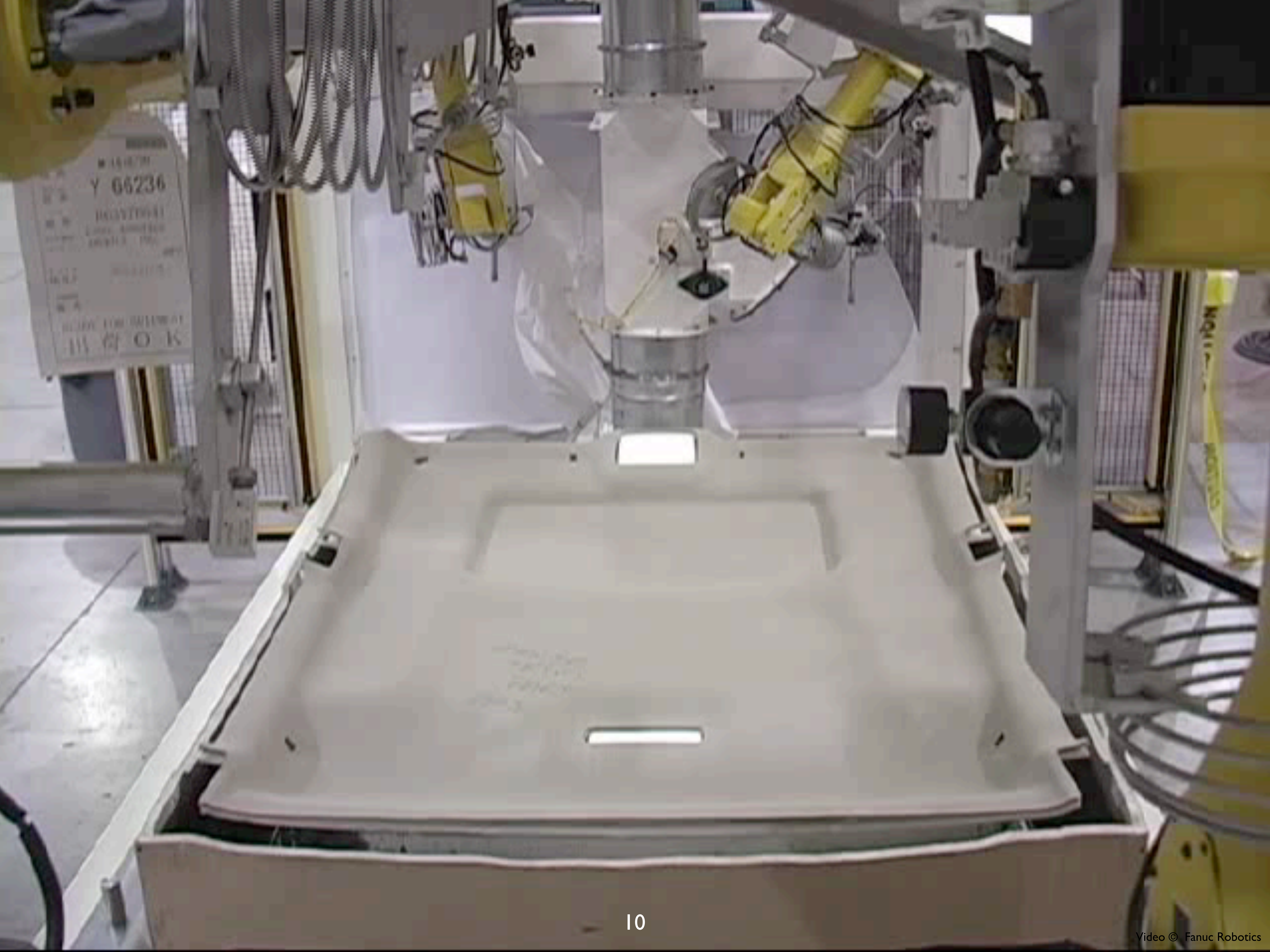
Muscles	Electric Motors
	Hydraulics
	Pneumatics
	SMA, etc.

Sensors

Kinesthetic	Encoders
Tactile	Load Cells
Vision	Vision
Vestibular	Accelerometers

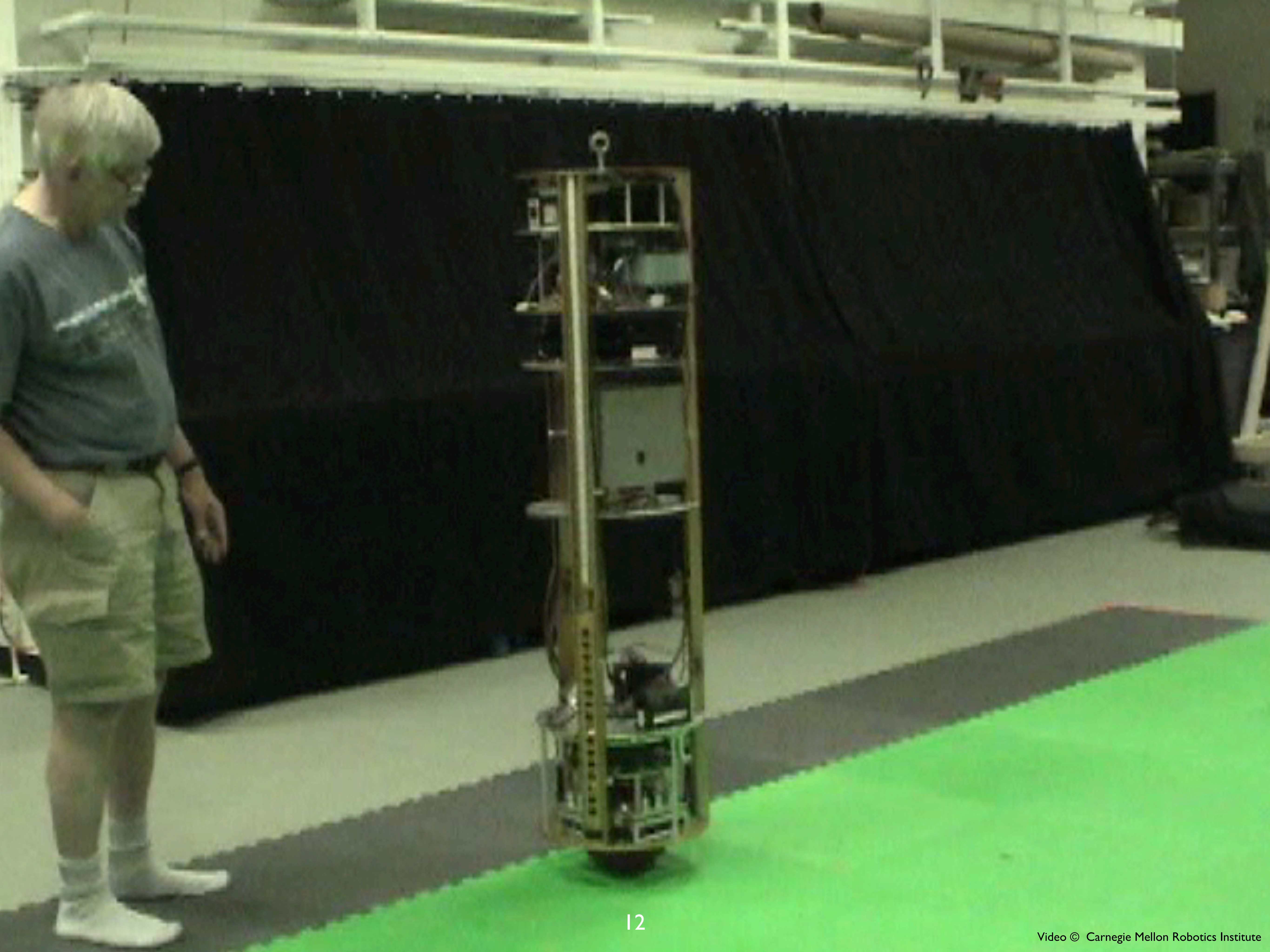
Controller

Brain	Computer
Spinal Cord Reflex	Local feedback

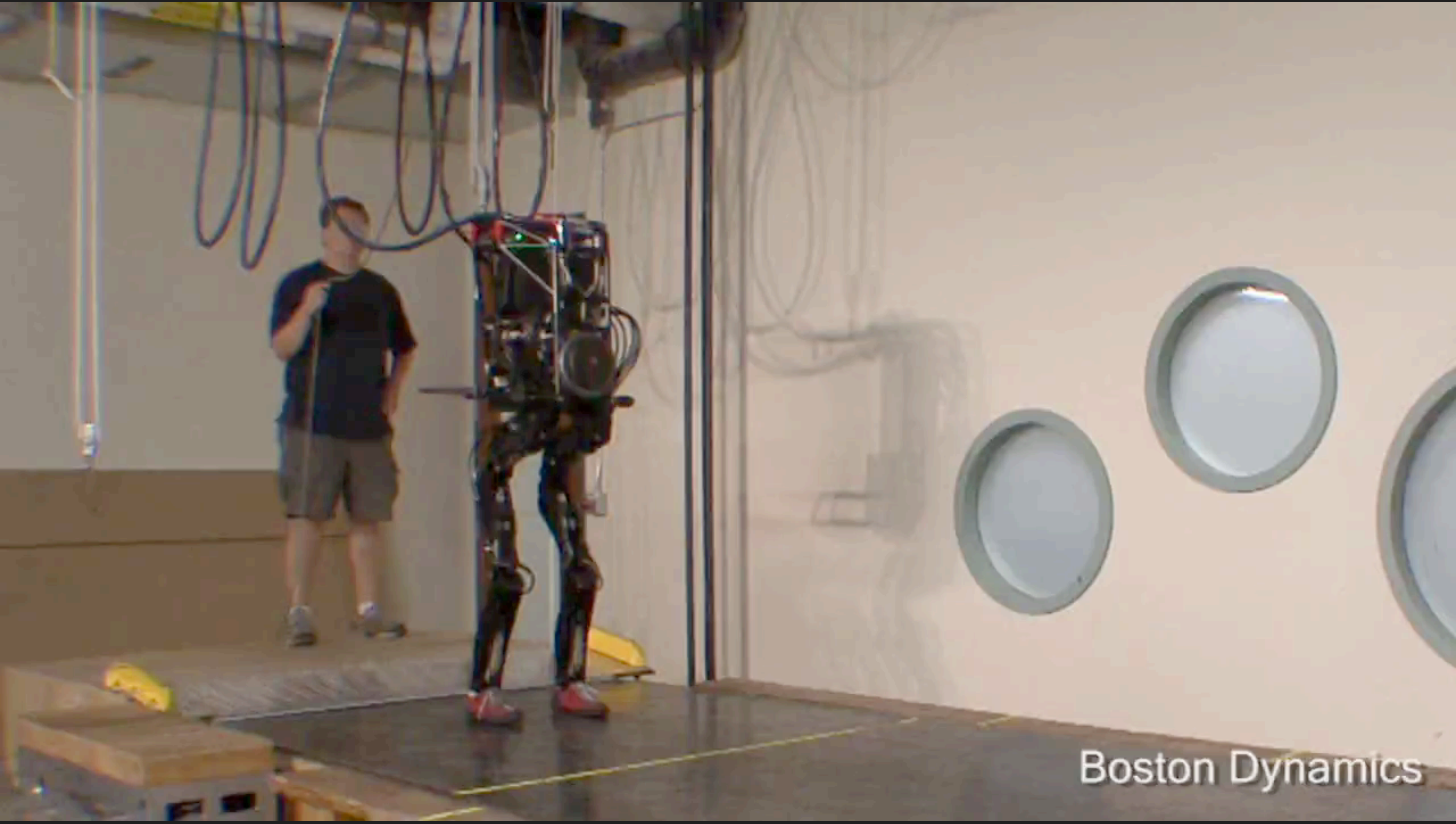


Video ©. Fanuc Robotics

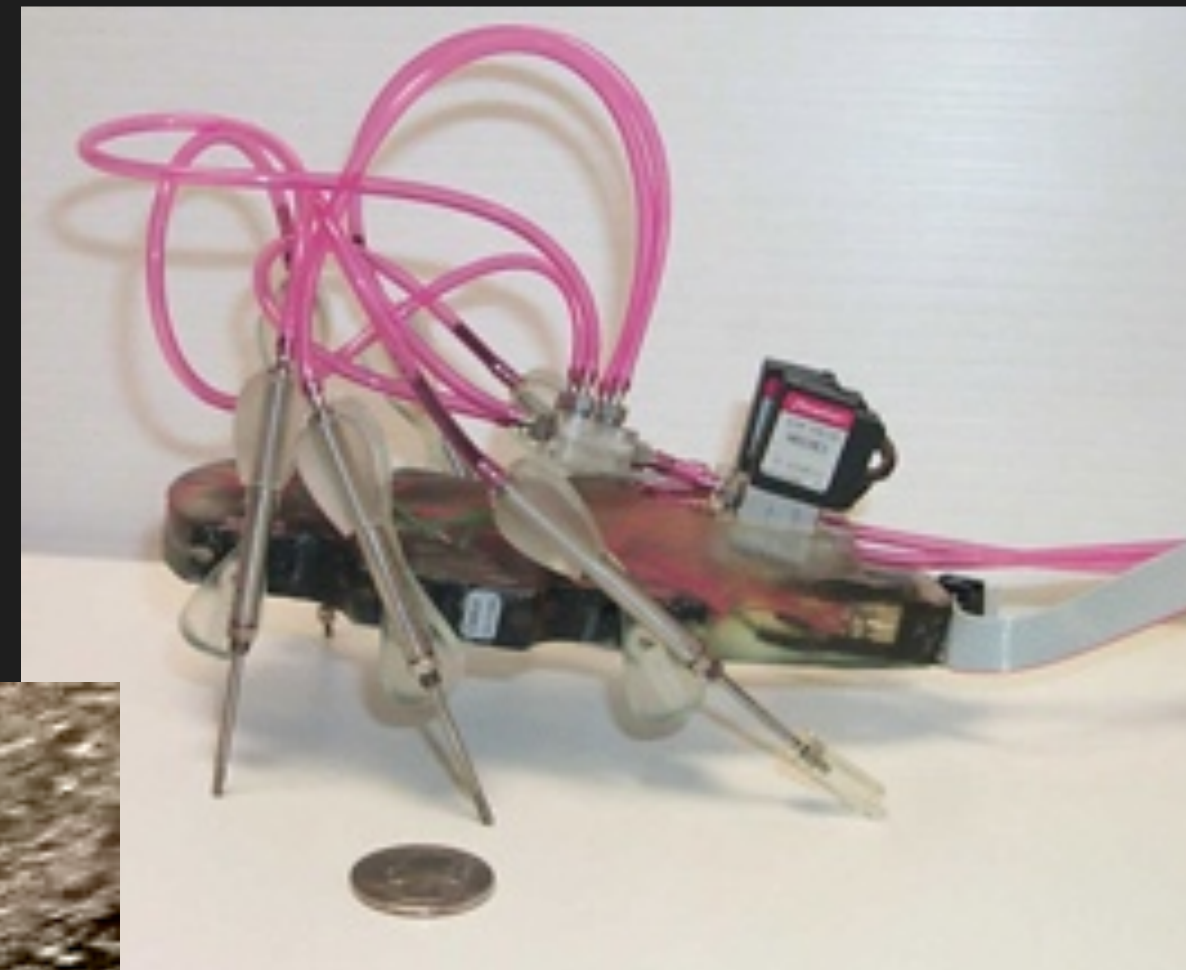
Video © Fanuc Robotics

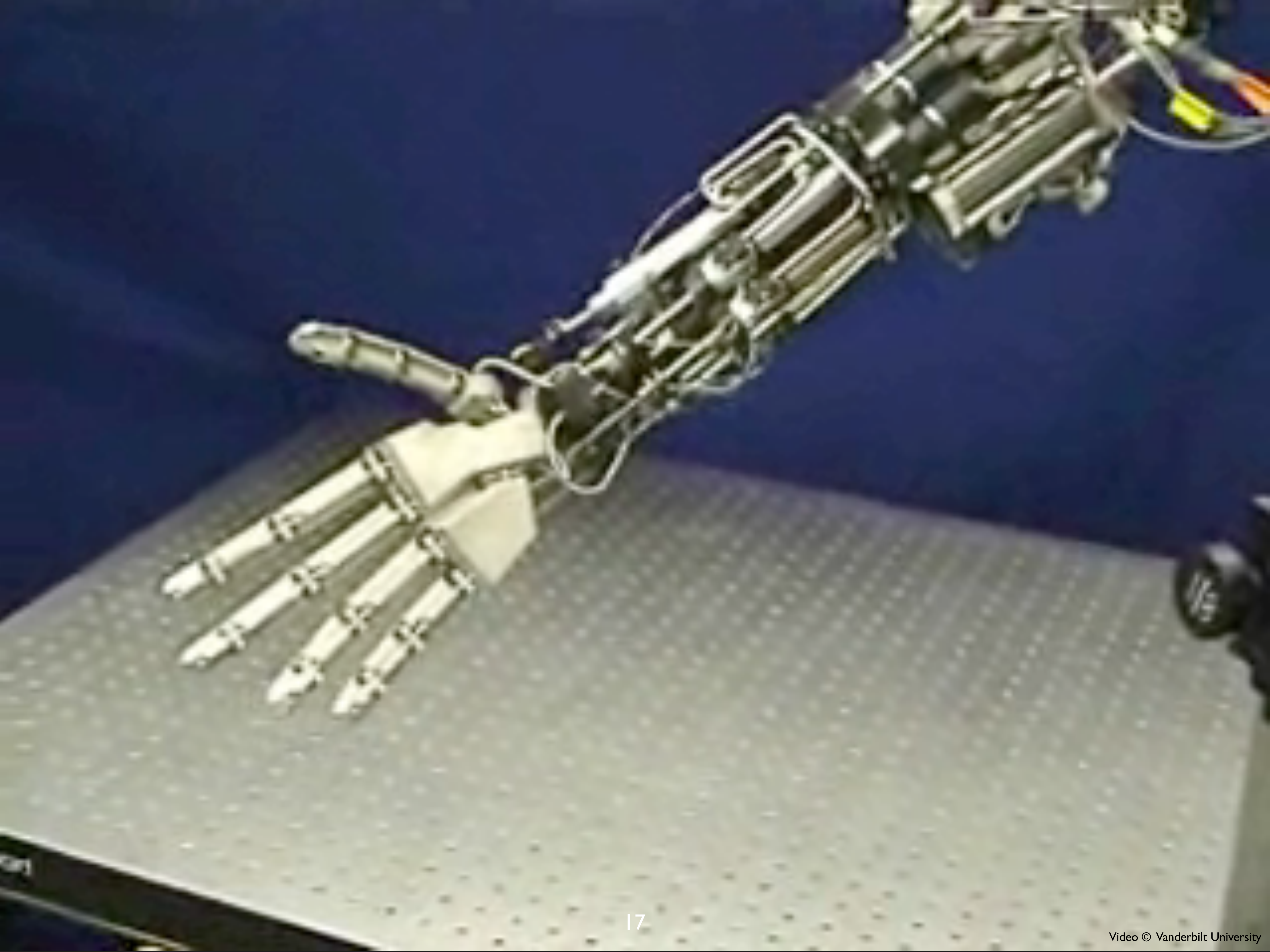



Boston Dynamics

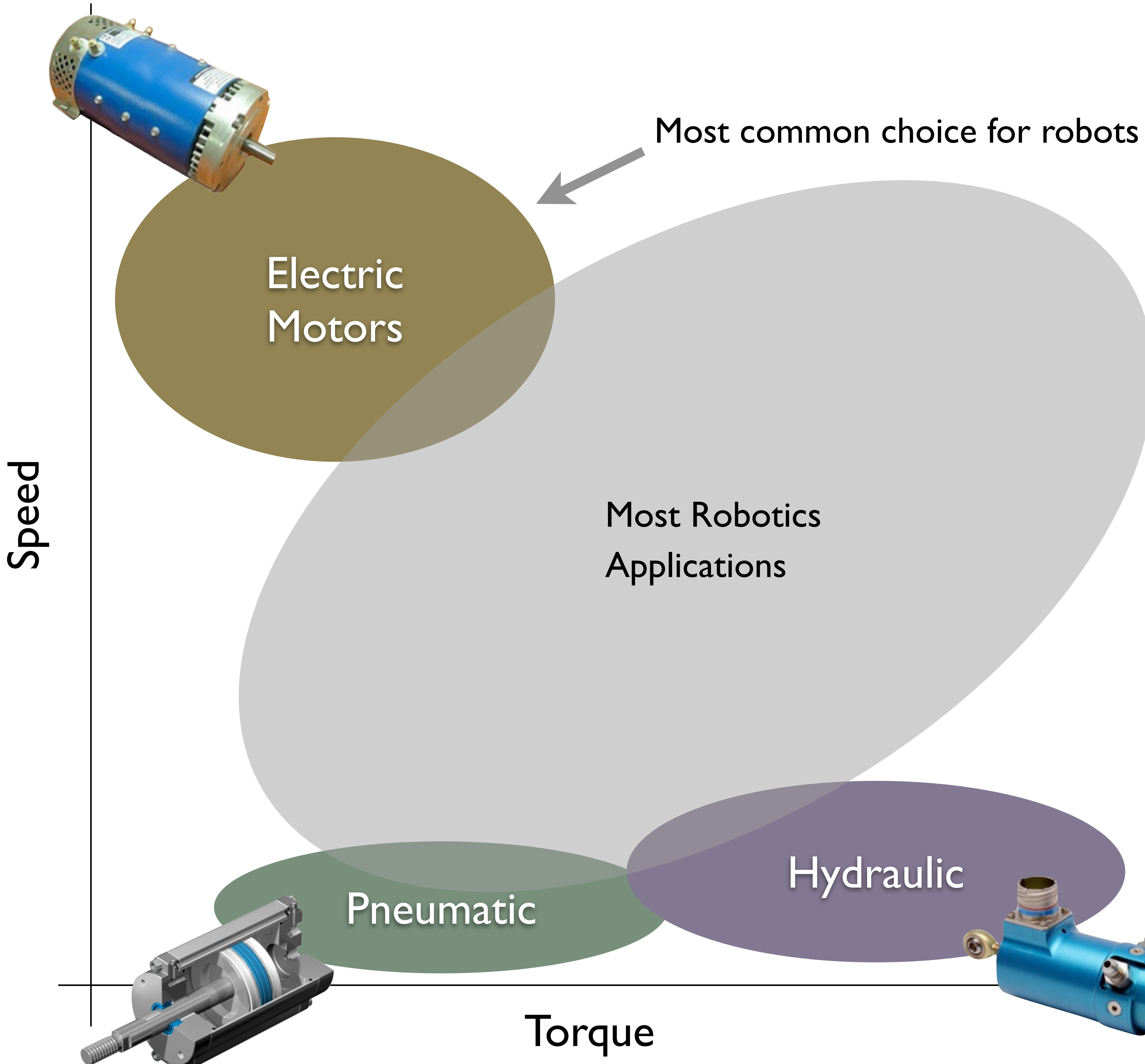

Boston Dynamics


RHex





Video © Vanderbilt University



Other concerns?

Cost

Availability

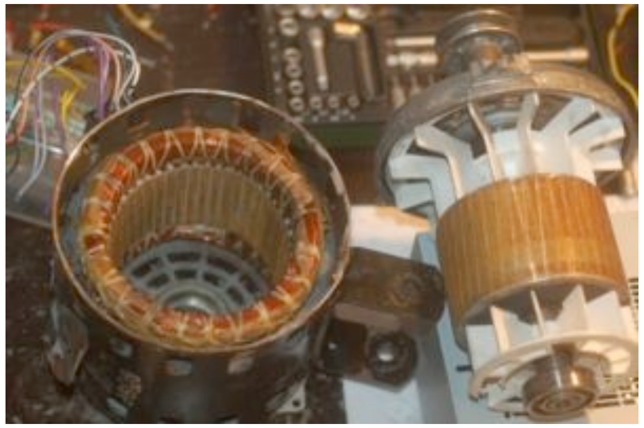
Size

Power to Weight

Stiffness

Ease of Integration

Support Systems

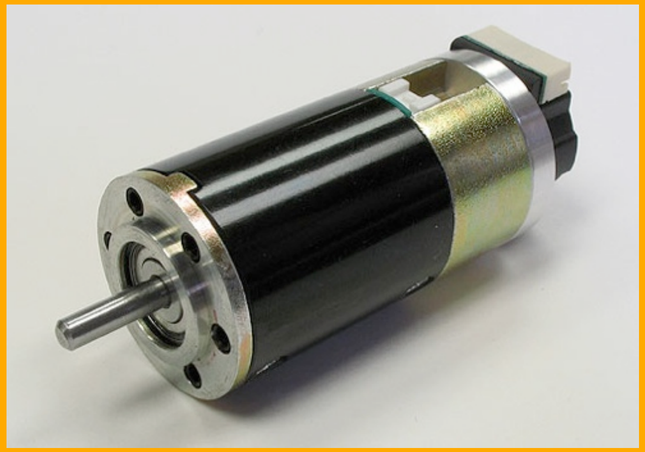


AC

Magnetic Rotor

Coil Stator

Output speed is a sub-multiple of voltage supply frequency



DC Brushed

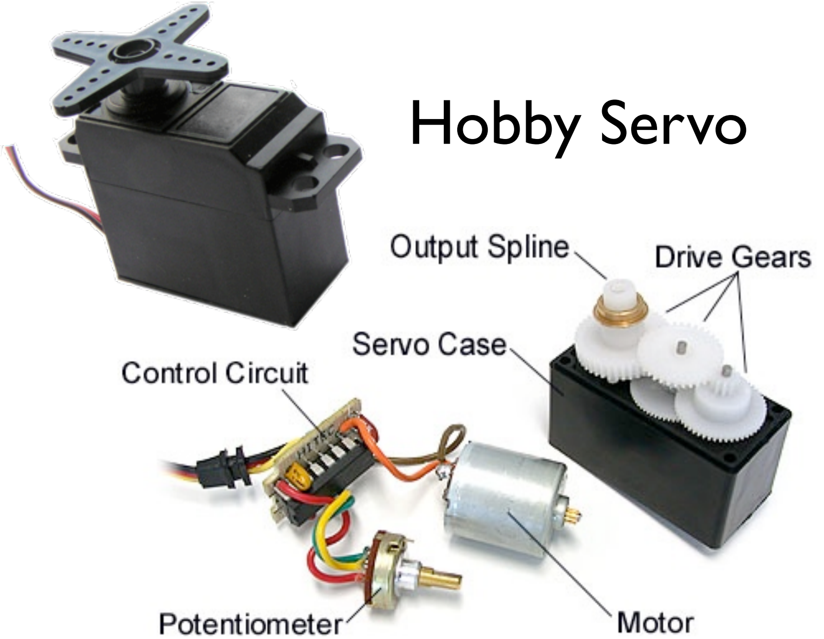
Most common!

Coil Rotor

Magnetic Stator

Brushes carry current to the rotor

Hobby Servo



DC brushed motor with integrated sensor and controller

DC Brushless

Magnetic Rotor

Coil Stator

Similar in construction to AC, but electrically commutated

Requires a position sensor (commonly built in)

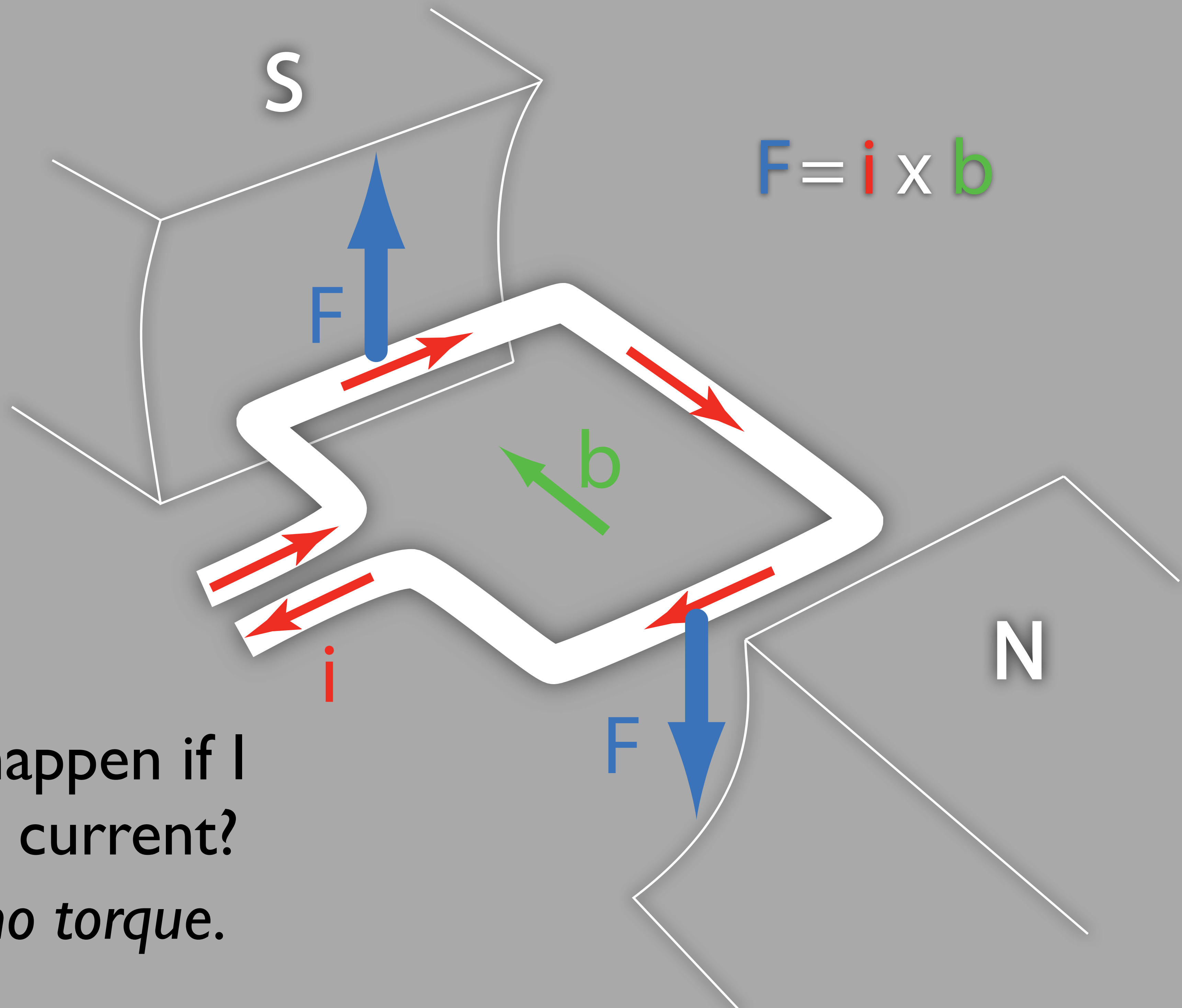
Stepper

Toothed Magnetic Rotor

Multi-Coil Stator

Capable of open-loop positioning

Requires a controller



What would happen if I turned off the current?

No forces, so no torque.

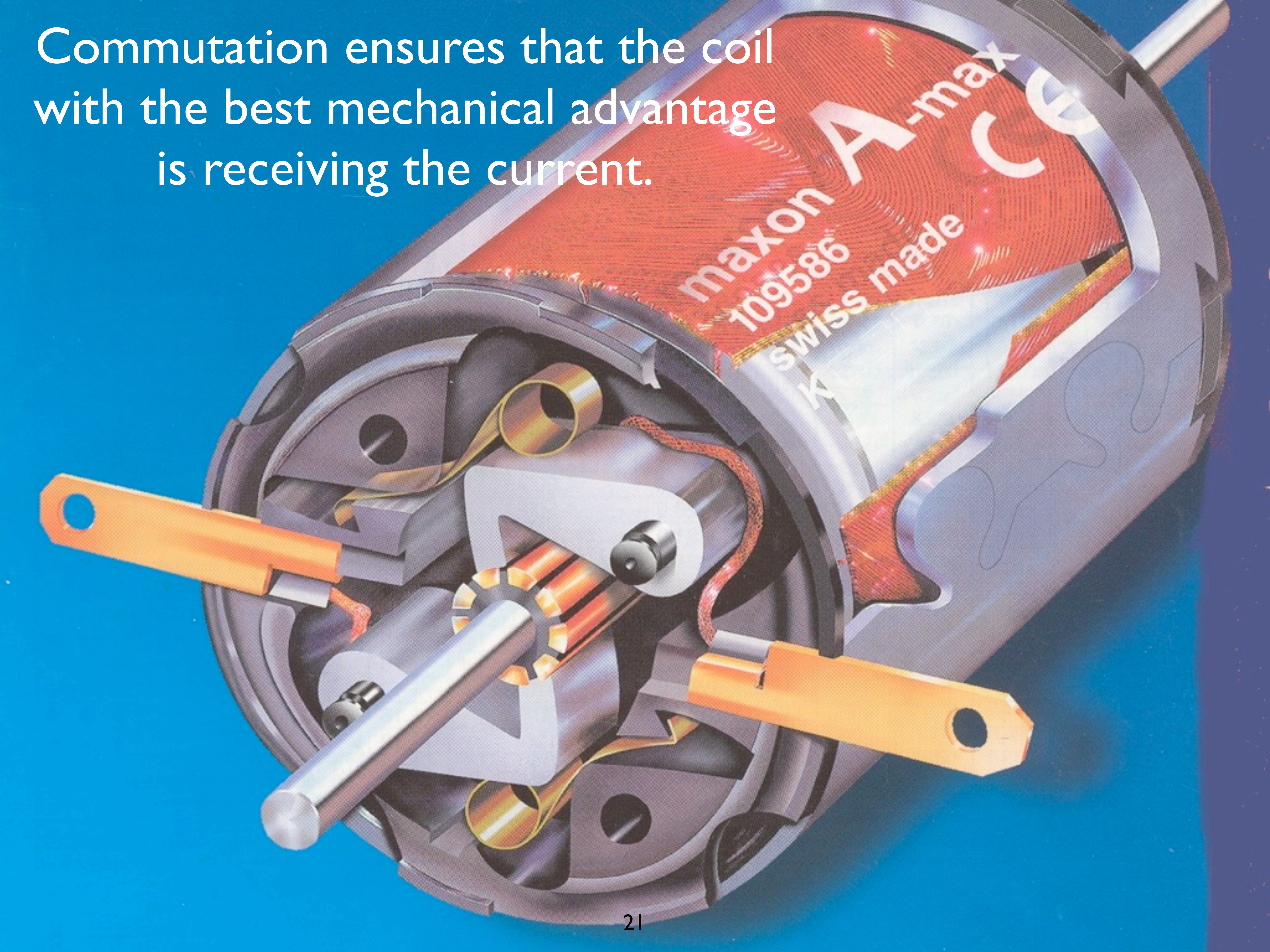
What would happen if I flipped the sign of the current?

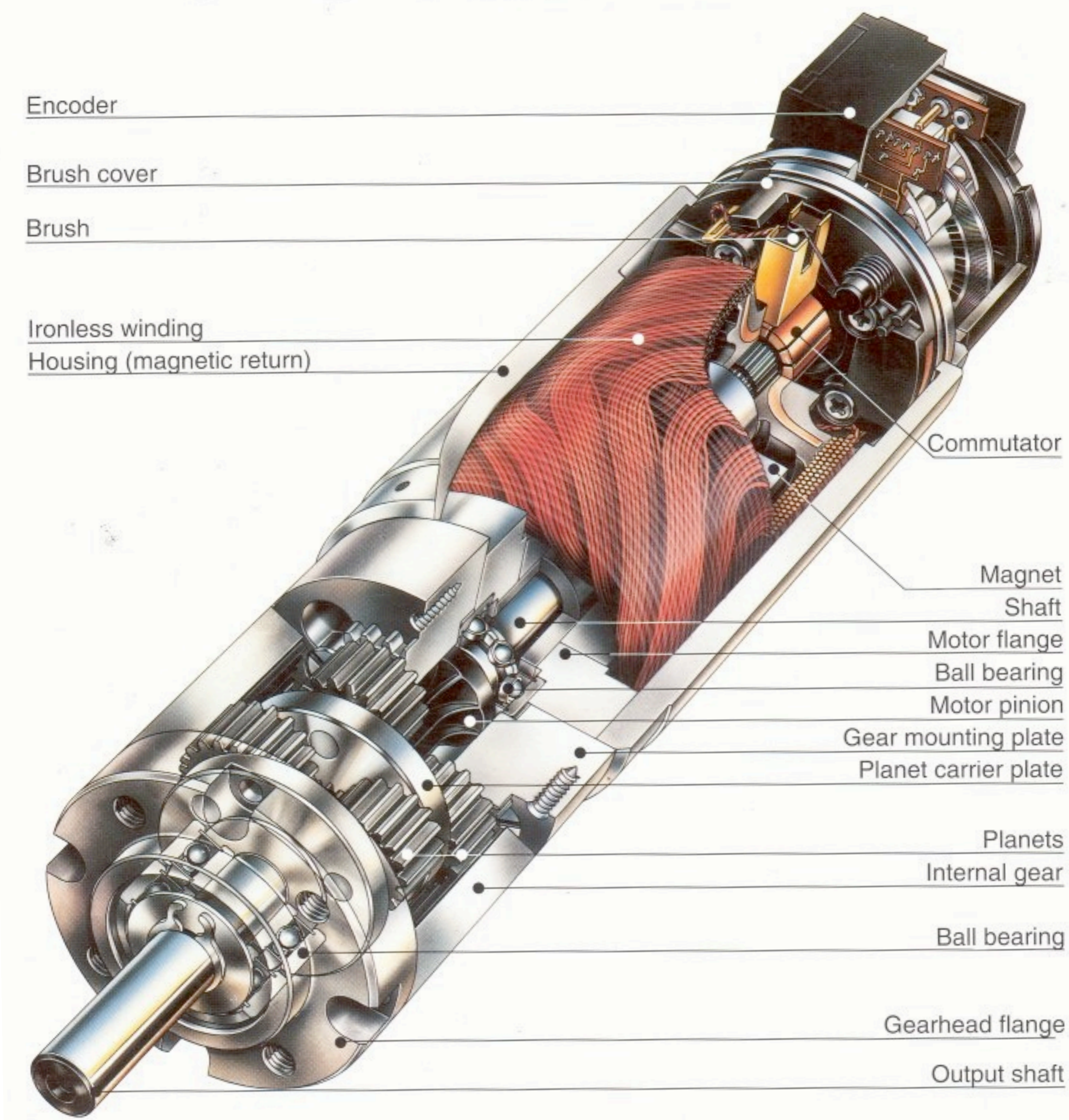
Opposite forces, so opposite torque.

What if I kept the current but rotated coil to other position?

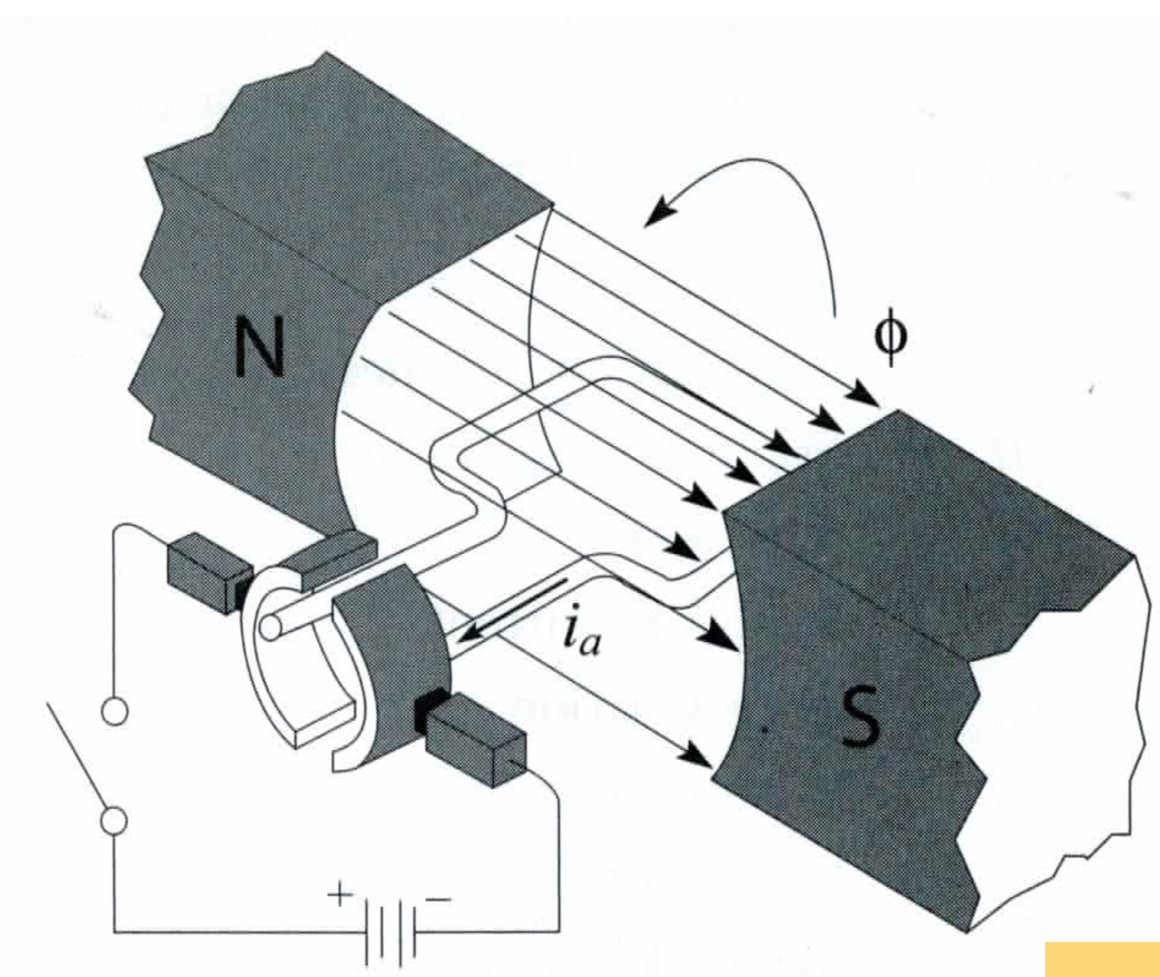
Lower, zero, or opposite torque

Commutation ensures that the coil with the best mechanical advantage is receiving the current.




Encoder
Brush cover
Brush
Ironless winding
Housing (magnetic return)
Commutator
Magnet
Shaft
Motor flange
Ball bearing
Motor pinion
Gear mounting plate
Planet carrier plate
Planets
Internal gear
Ball bearing
Gearhead flange
Output shaft

SHV Section 6.1



magnetic flux (webers)

torque constant (N•m/A)

$$\tau_m = K_1\,\phi\,i_a = k_t\,i_a$$

generated torque (N•m)

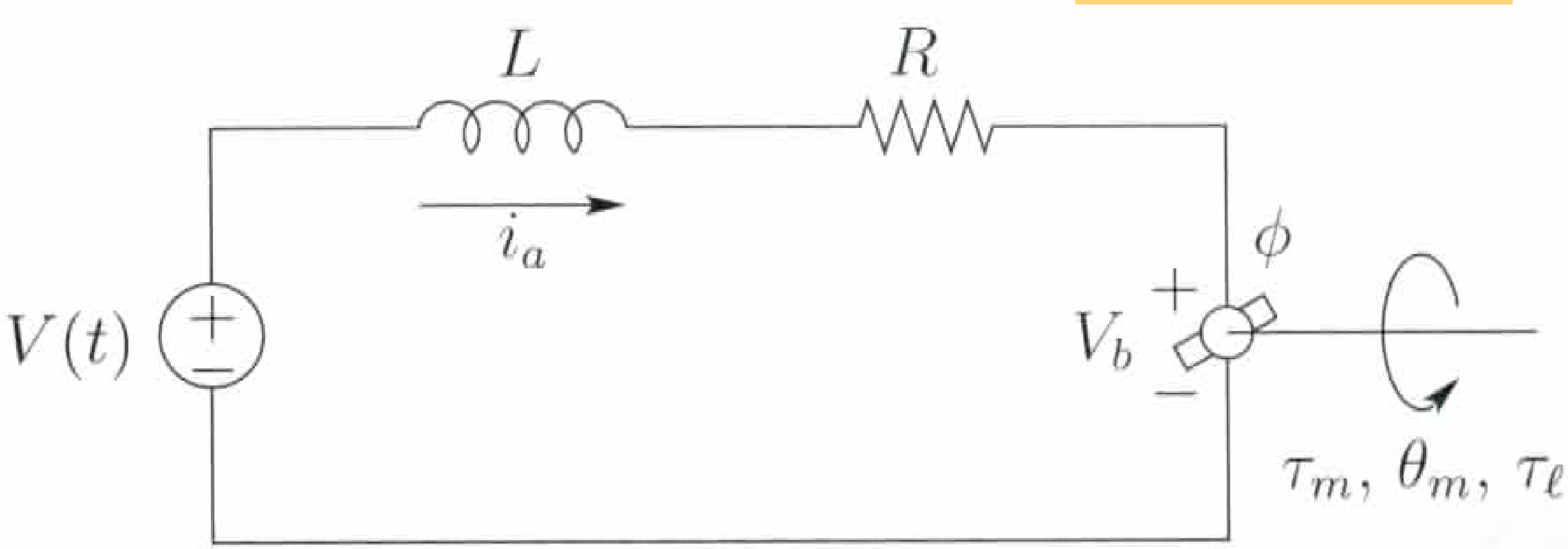
physical constant

armature current (A)

armature current (A)

$$k_t = k_v$$

if using meters, kilograms and seconds



back emf (V)

magnetic flux (webers)

back-emf constant (V•s)

$$V_b = K_2\,\phi\,\omega_m = k_v\,\omega_m$$

physical constant

motor velocity (rad/s)

motor velocity (rad/s)

Motor

The best brushed DC motors are made by Maxon. They are rather expensive, but they work quite well.

- Smooth torque output, independent of motor angle. In other words, very low cogging and torque ripple.
- Low friction, both at low and high speeds, due to high quality bearings and low eddy currents.
- Relatively high stall torque, which is the torque the motor can deliver when it is not rotating.
- Larger motors create higher torques, but they also have higher inertia and higher friction.

Some material adapted from slides by A. Okamura and W. Provancher

Computers and microcontrollers can't output enough power to drive a motor, so use an amplifier.

We usually want to control the motor's torque output, so use a current controller.