Course Introduction

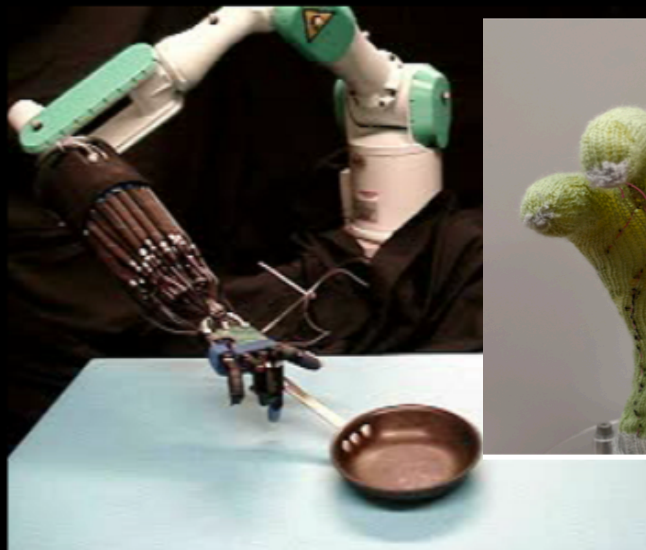
16-848 Hands: Design and Control for Dexterous Manipulation

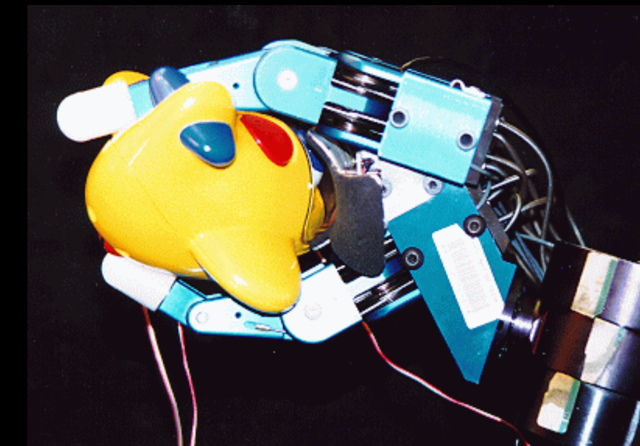
Spring 2020

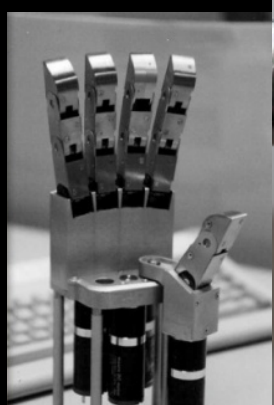
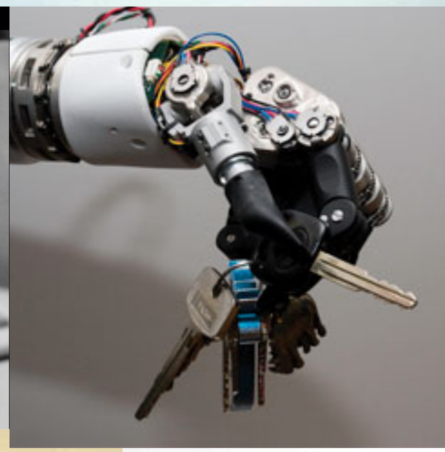
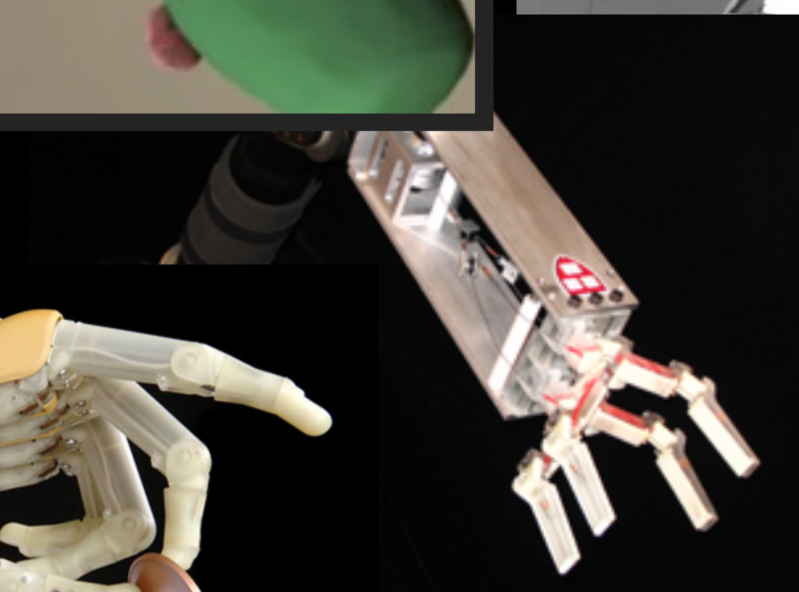
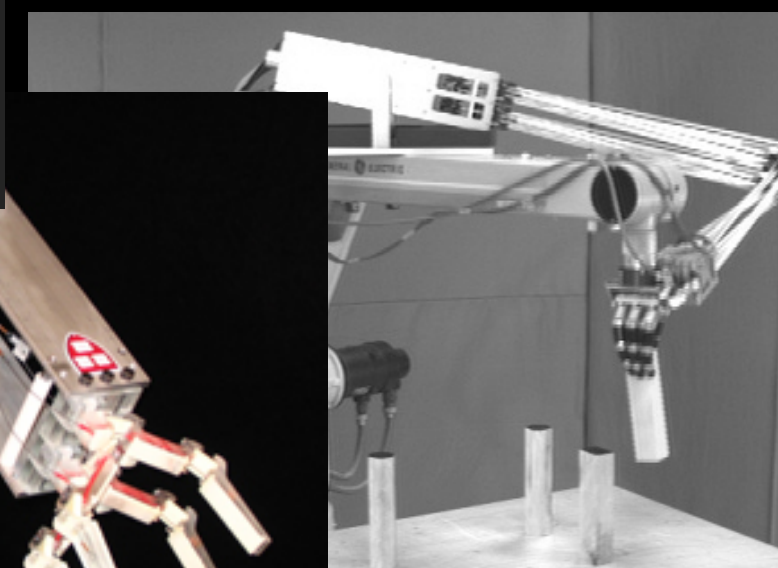
Opening thoughts on robot hands

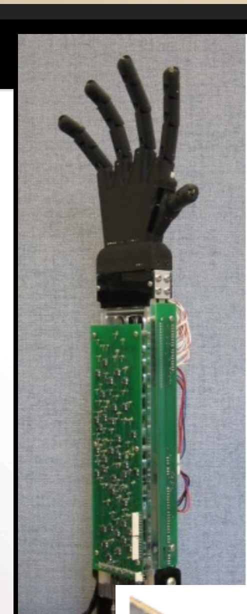
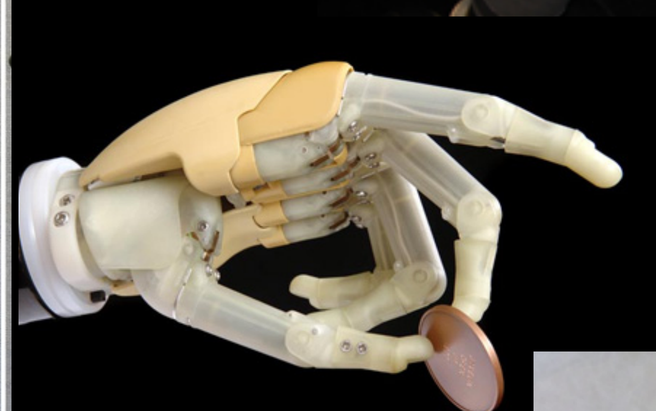
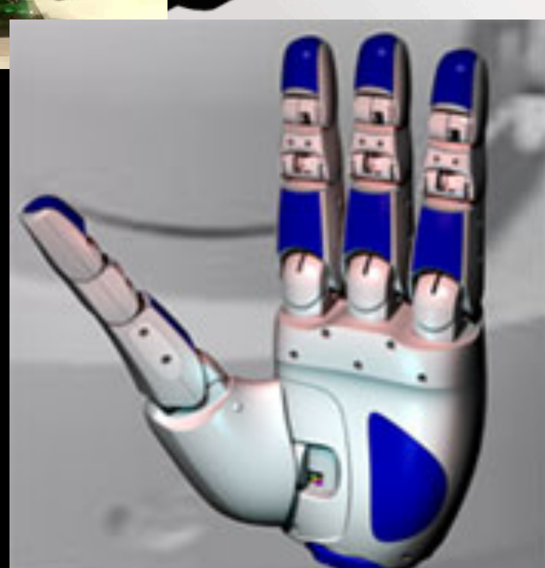
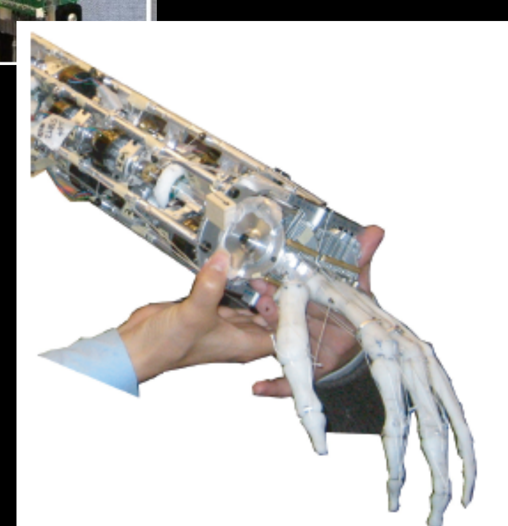
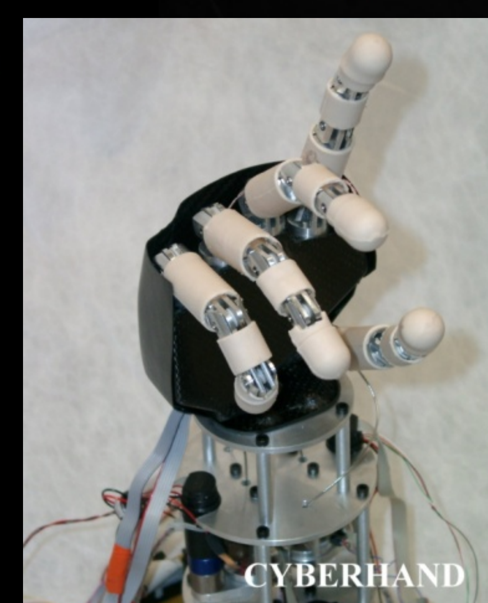
- We have had high degree of freedom robot hands in humanlike form since the 80's
- There have been many exciting new ideas about hand design throughout the past decades
- Yet we still do not have highly dexterous robots
- Why is this the case?
- What are the gaps?
- How can we close them?

Four Decades of Robot Hands



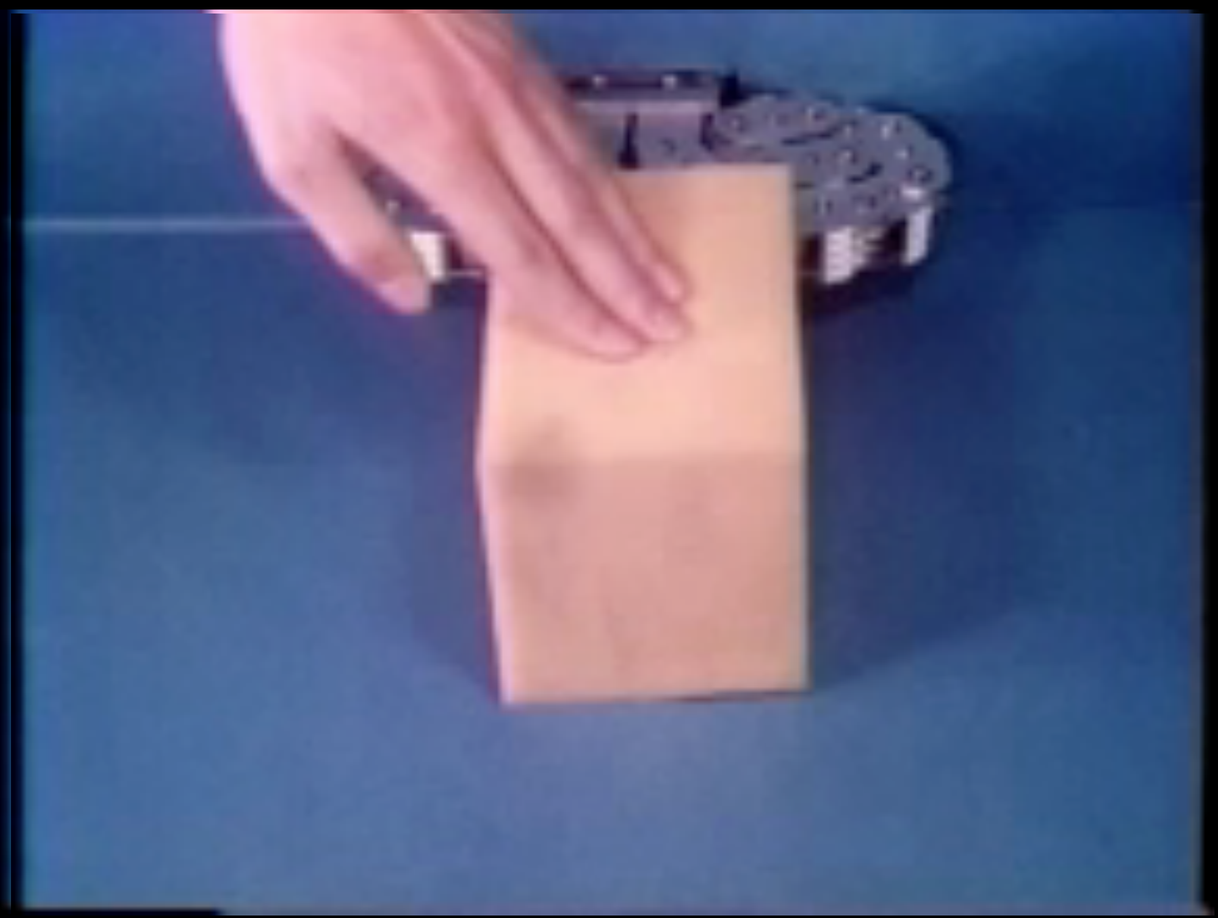


Hands of the 80’s

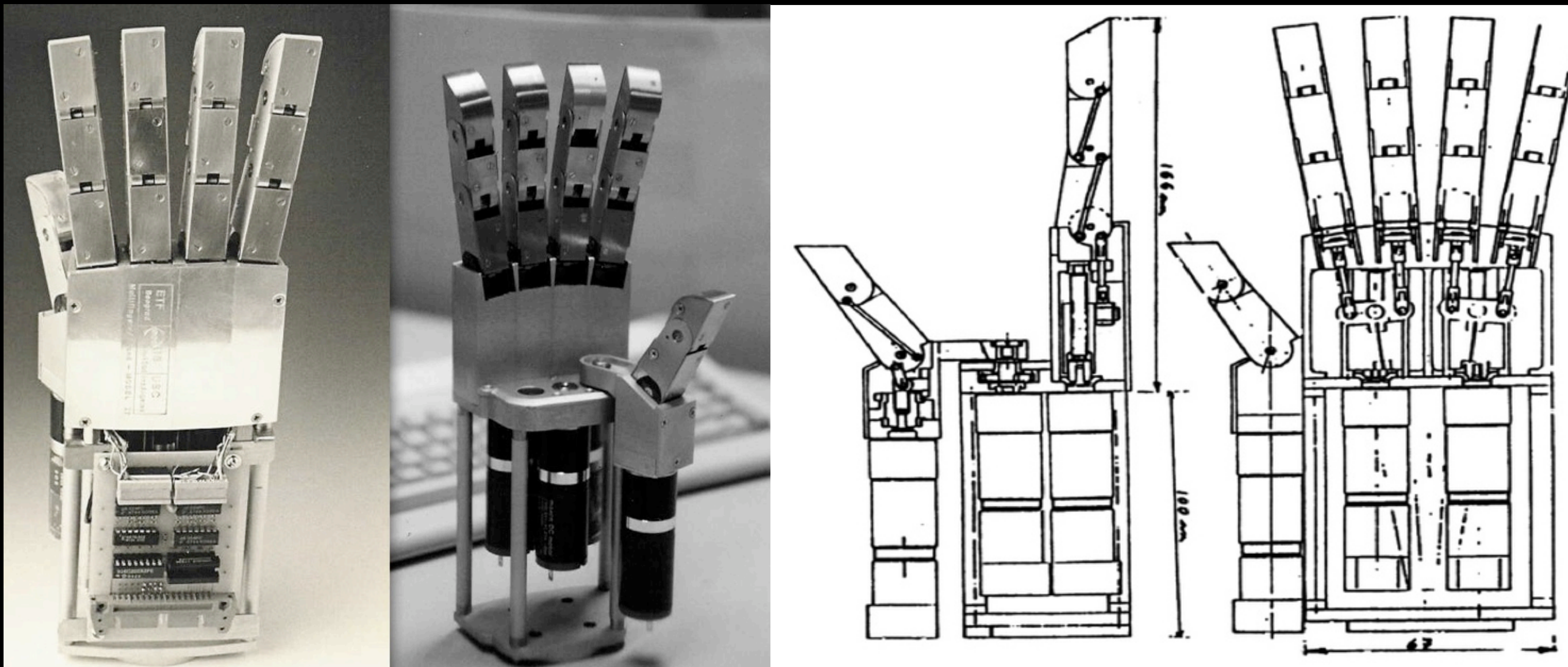
Hirose Soft Gripper (Shigeo Hirose, Tokyo Inst. Technology)



Soft gripper development began in the 70’s
1 DoF
Graduated pulleys at joints create evenly distributed forces

Hands of the 80's

Belgrade / USC hand (Rajko Tomovic and George Bekey)



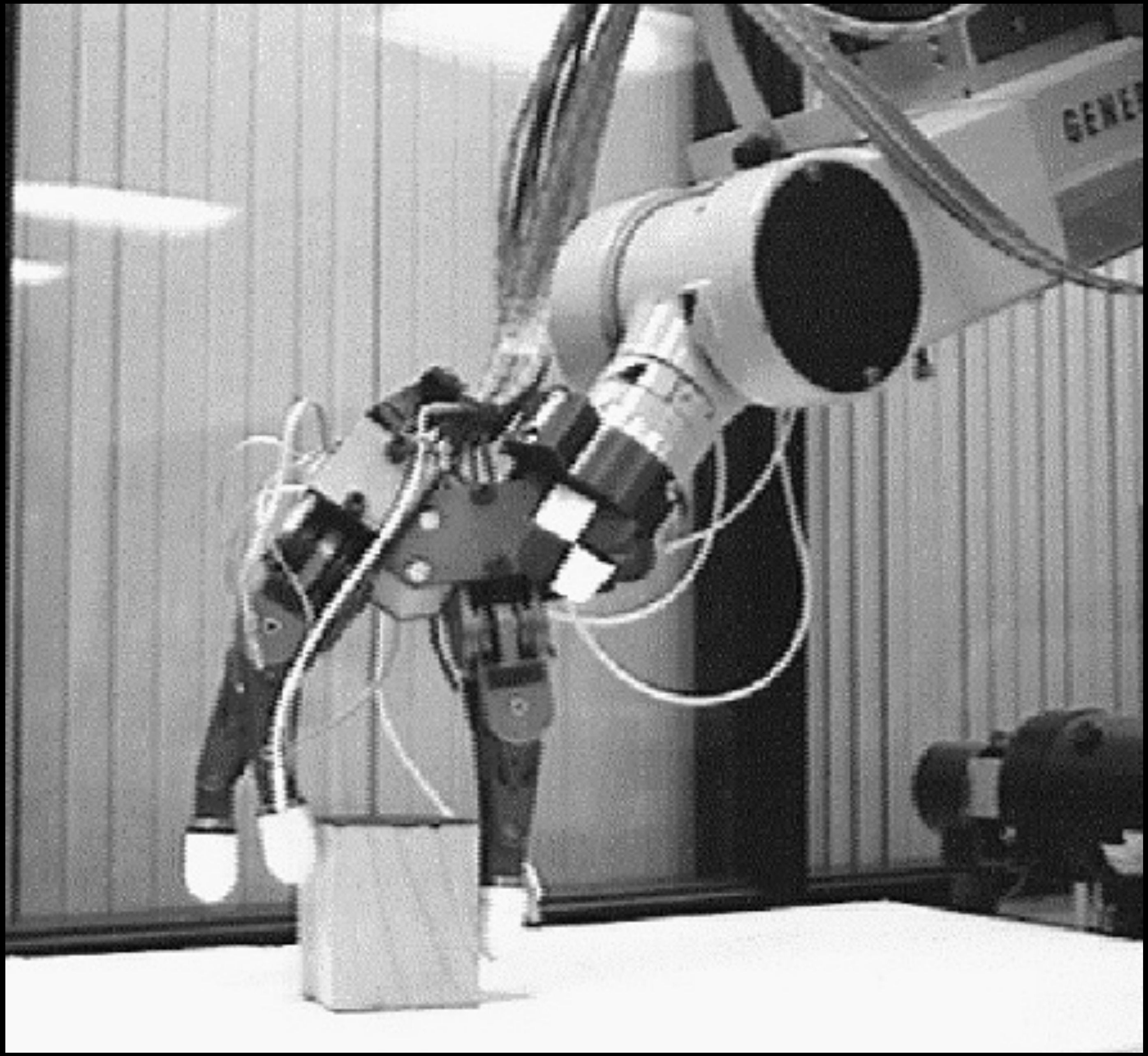
Pioneering effort – development of first prototypes after WWII

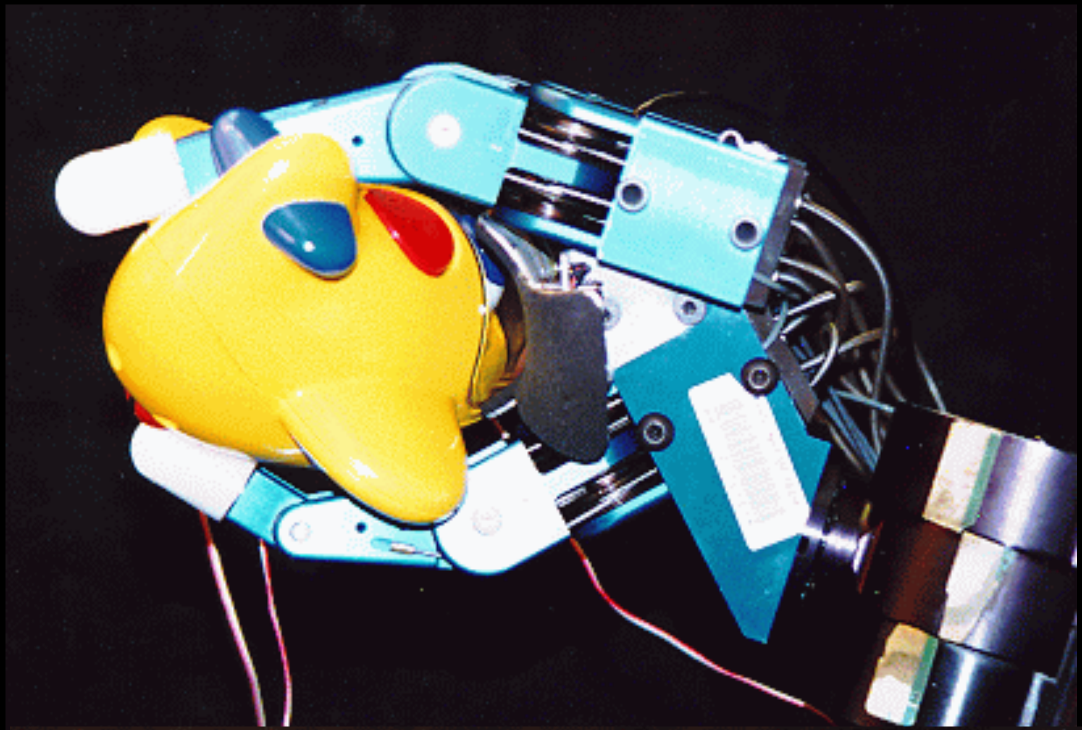
4DoF (1 for each pair of fingers, 2 for thumb)

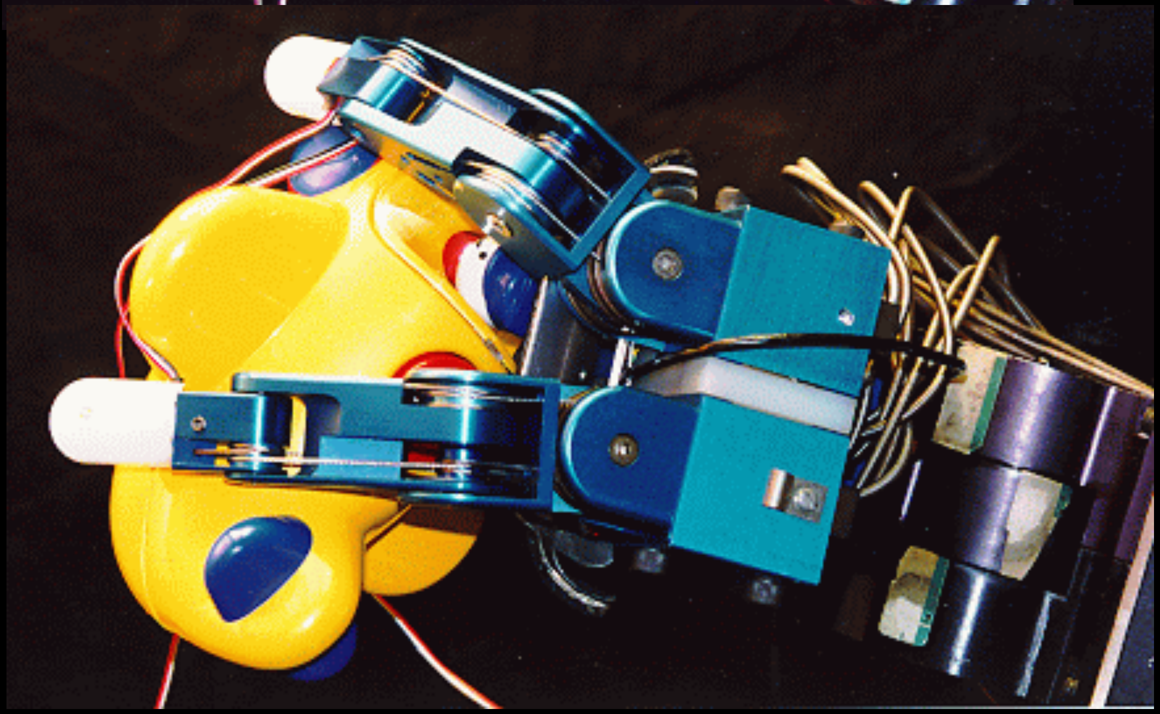
Some adaptability (e.g., flex one finger in a pair if other stalls)

Hands of the 80's

Stanford / JPL hand







9 DoF, 4 tendons/finger, designed for fingertip manipulation

Strain gauge fingertip sensors

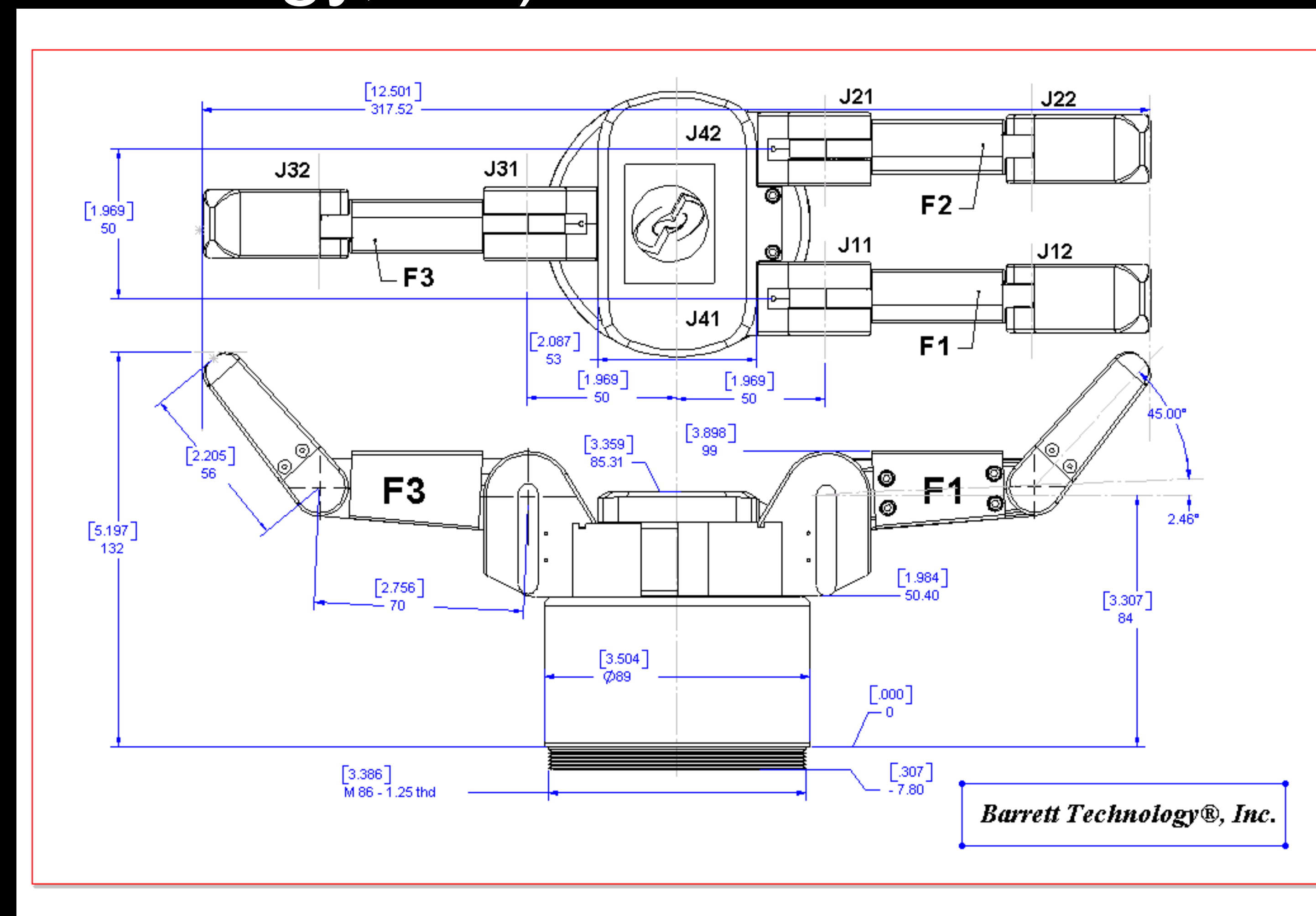
Hands of the 80's

Utah / MIT hand

16 DoF, 32 tendons
position and tendon tension sensing (Hall effect)
7lb fingertip force (human level)
Complex tendon mounting scheme

Commercial Hands

Barrett hand (Barrett Technology, Inc)



~$30K
4 motors: 1 per finger plus palm spread
breakaway clutch allows fingers to adapt to object geometry
optical encoder position sensing
3.3lb fingertip force
1.18kg weight

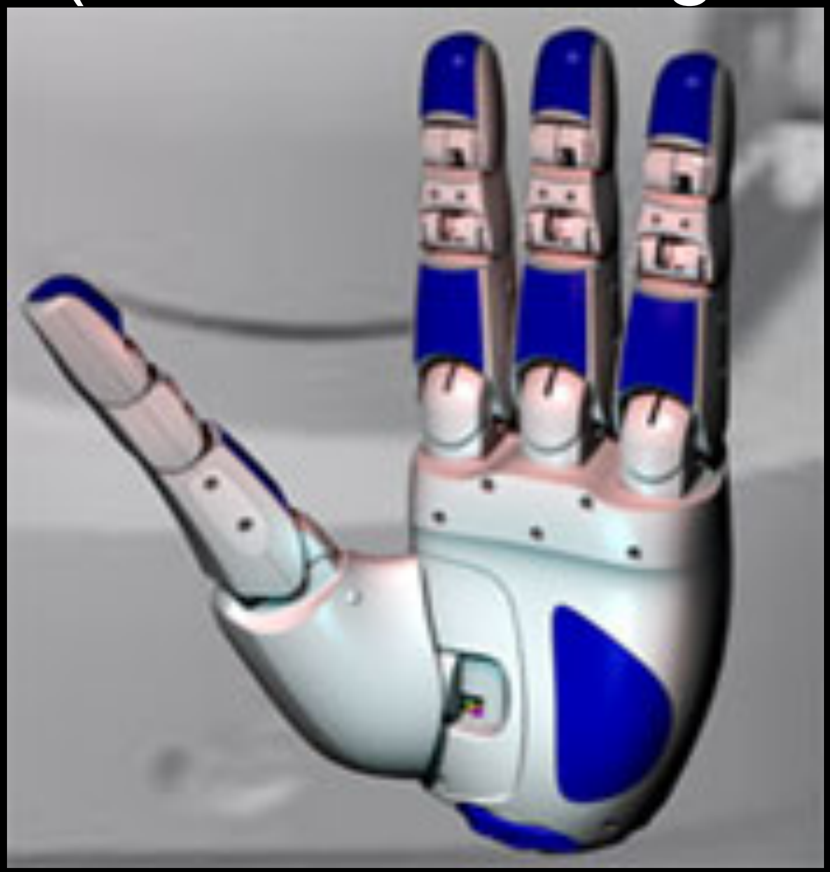
Commercial Hands

Gifu Hand (Kawasaki and Mouri, Gifu Univ. / sold by Dainichi)

~$50K
16 controlled DoF (last two joints coupled except thumb)
pressure sensing, but no accurate position sensing
0.6 lb fingertip force
1.4kg weight
larger than human size

Commercial Hands

DLR / HIT hand (Gerhard Hirzinger, DLR / sold by Schunk)



~$60K
13 controlled DoF (last two joints of each finger are coupled)
hall effect position sensors
1.5lb fingertip force
2.2kg weight
larger than human size

Commercial Hands

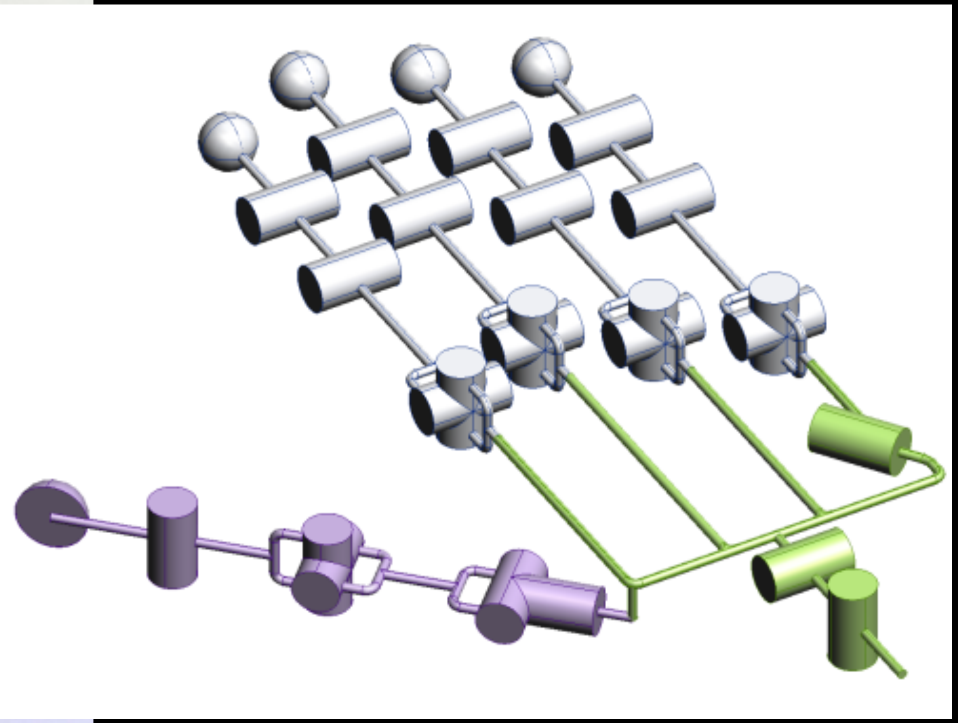
SVH Hand (Schunk)

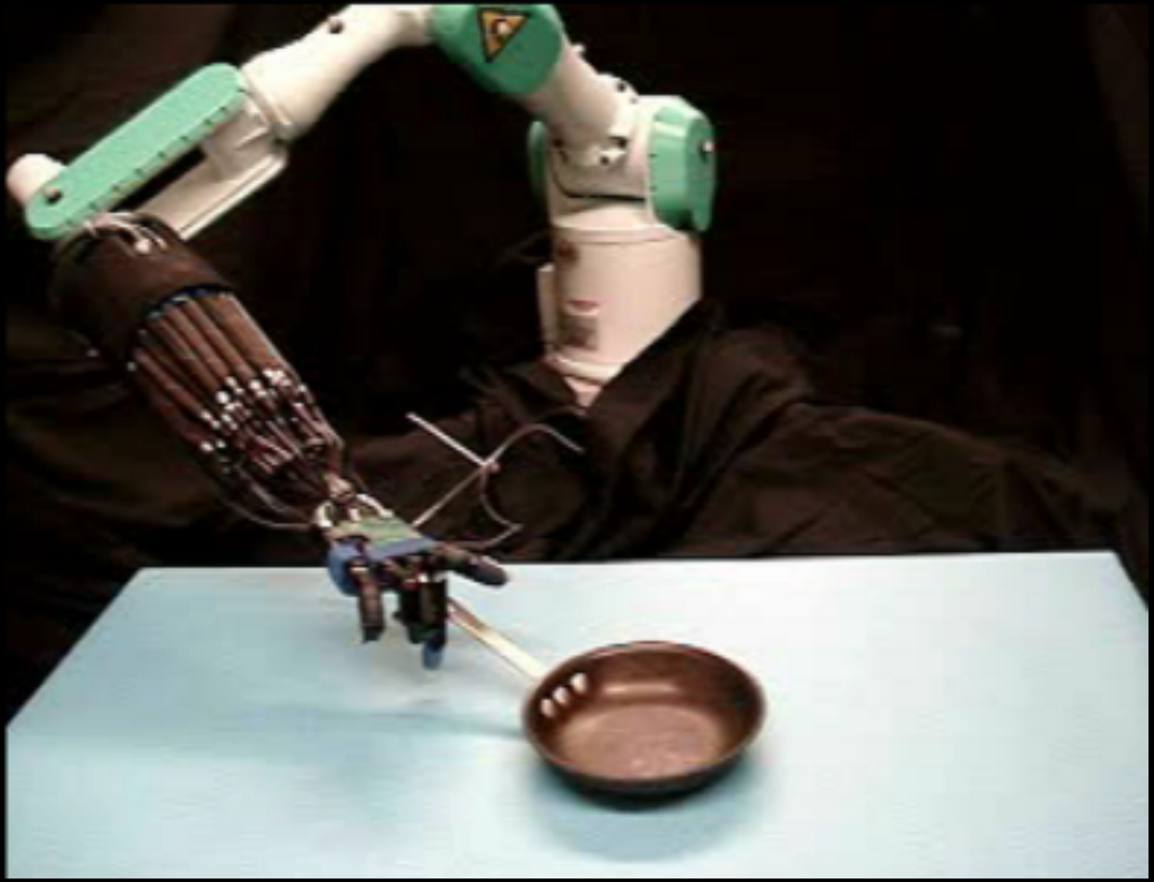
9DOF

(2 thumb, 2 index, 2 middle, 1 ring, 1 pinky, 1 spread)

Commercial Hands

Shadow hand (Shadow Robot Company)



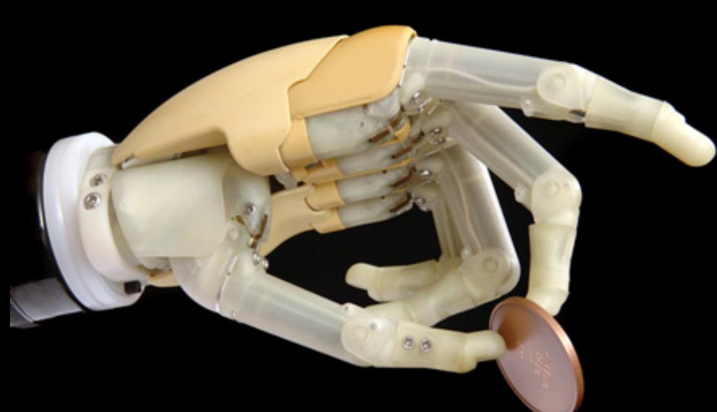


working on highly backdrivable, low inertia electric motors (electric artificial muscle)

picked up by British MoD for research into bomb disposal (e.g., for cutting wires)

Prosthetic Hands

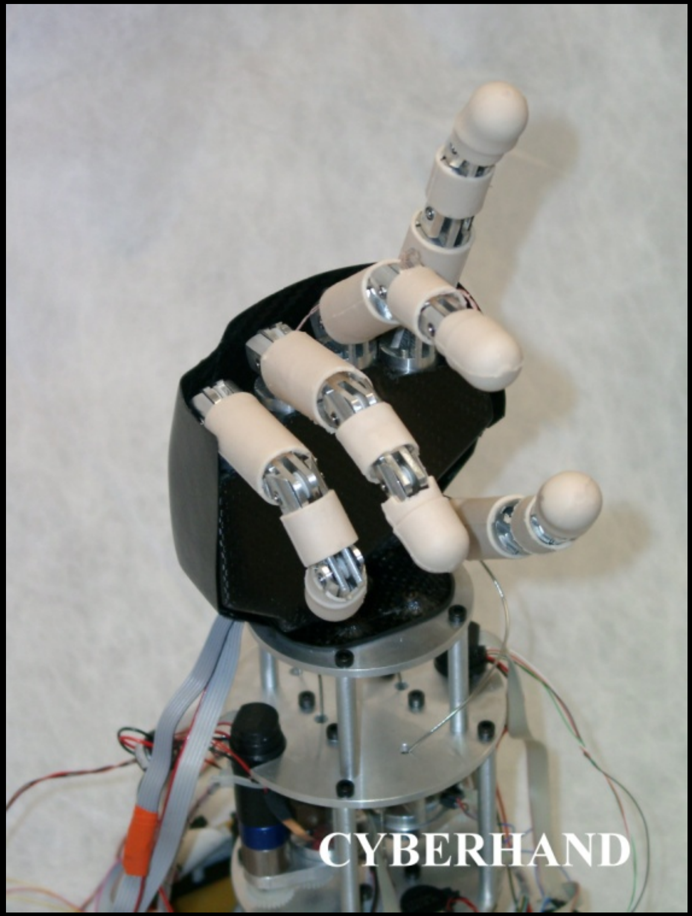
iLimb (Touch Bionics)

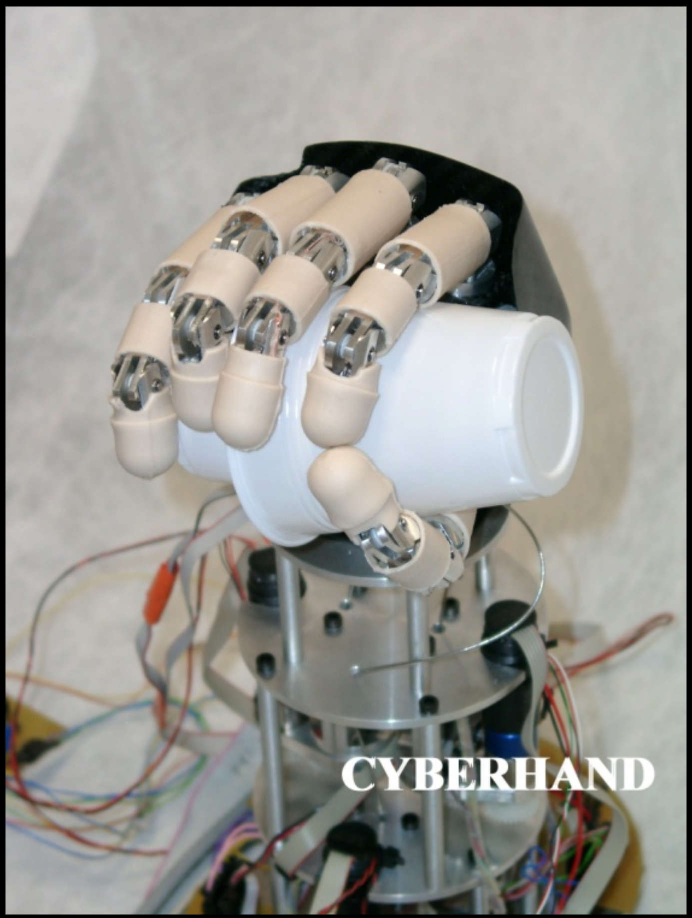


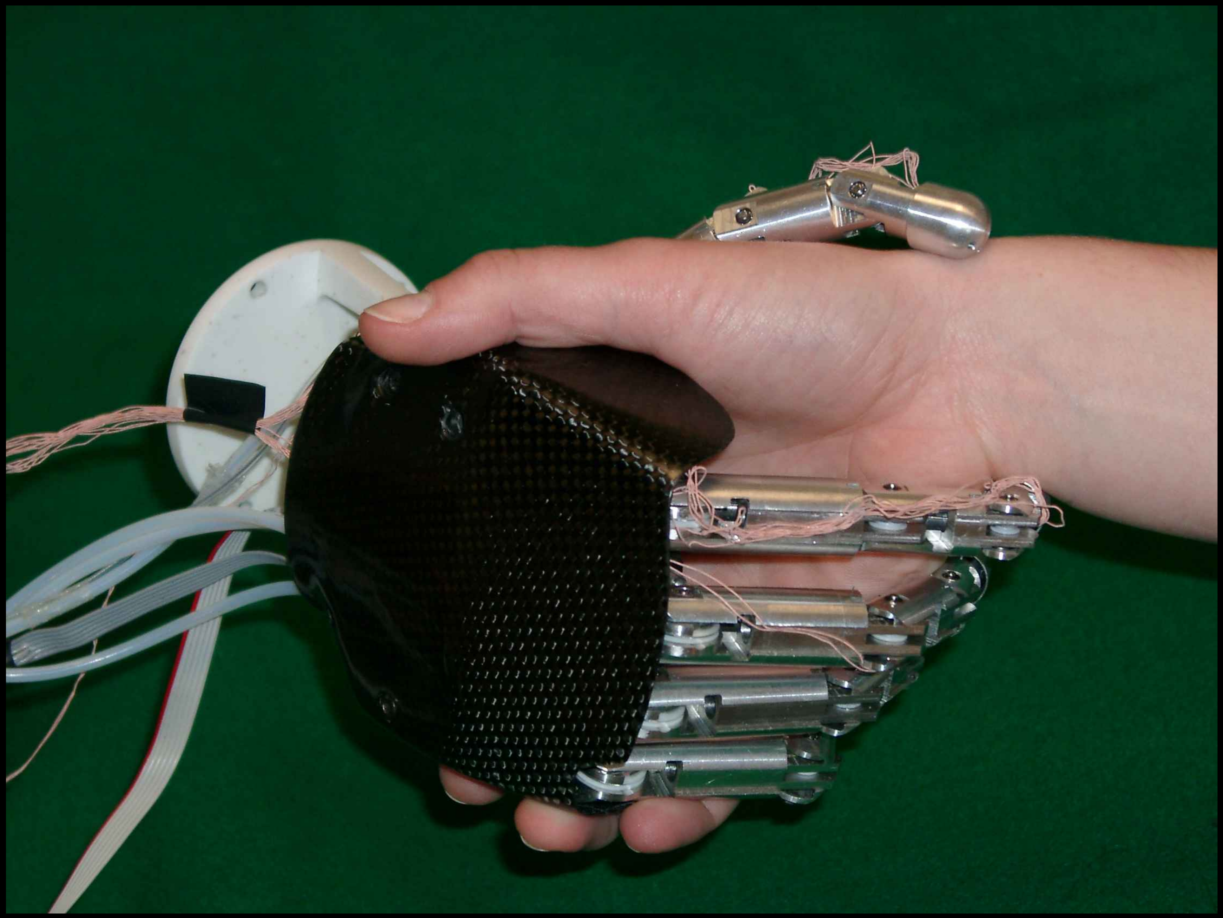
~$18K
5 motors driven from single muscle signal
thumb preshape for power, precision, key grip
motors stall individually for adaptive pose
in use by >250 people

Prosthetic Hands

Cyberhand (Maria Carrozza, Scuola Superiore Sant'Anna)







6 motors control 16 joints, cable driven
designed for prosthetic applications; preshape/close to force
sensors: position, cable force, fingertip force, tactile array
3.3 lb fingertip force, closes in 3 seconds
0.45Kg weight (not including forearm motors)

Prosthetic Hands

DEKA (Dean Kamen)

DARPA Revolutionizing Prosthetics Program

others under development (JHU/APL, RIC, Otto Bock)

http://www.cnn.com/video/data/2.0/video/tech/2009/07/31/eod.artificial.arm.cnn.html

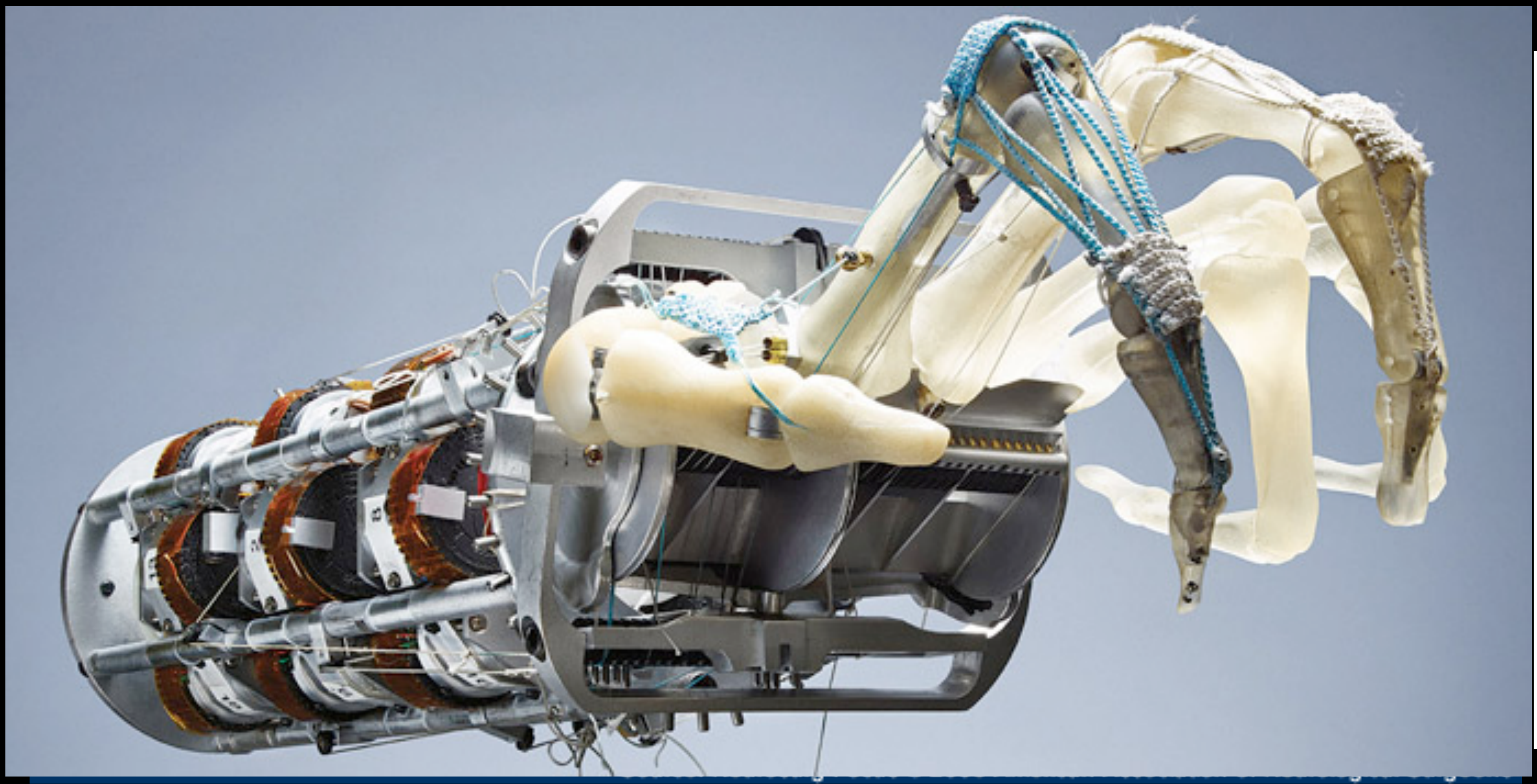
Research Hands

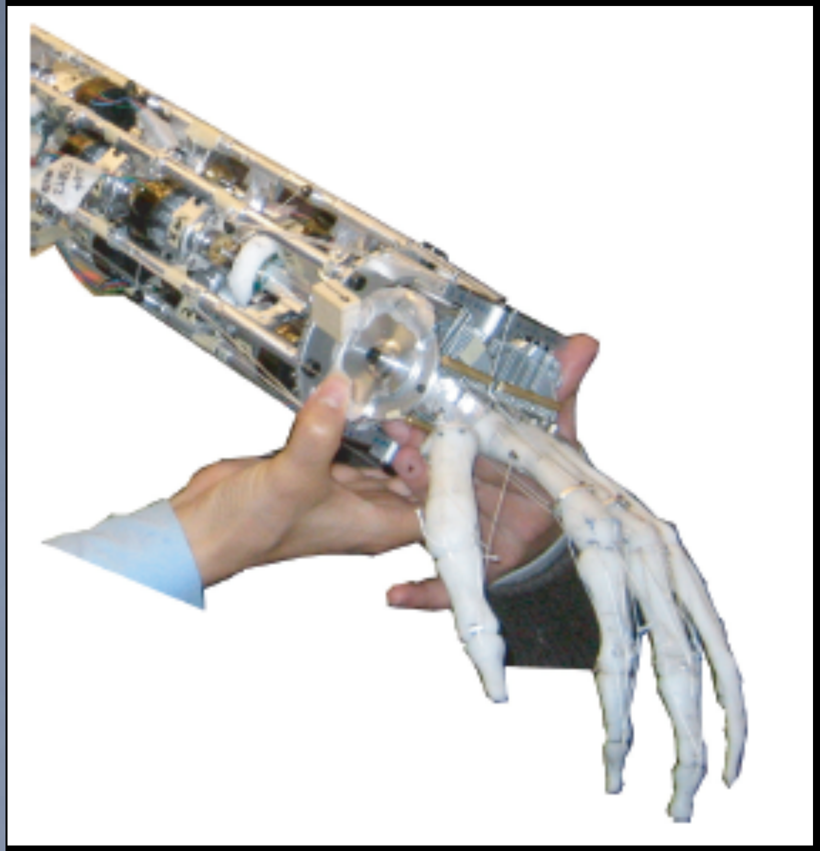
Robonaut hand (Robert Ambrose and colleagues, NASA)

14 controlled DoF (including wrist)
motors in forearm
tactile sensing glove designs with FSR and QTC elements
last two fingers mount at an angle and rotate at CMC joint
successful teleoperation of many complex manipulation tasks

Research Hands

ACT Hand (Yoky Matsuoka, University of Washington)



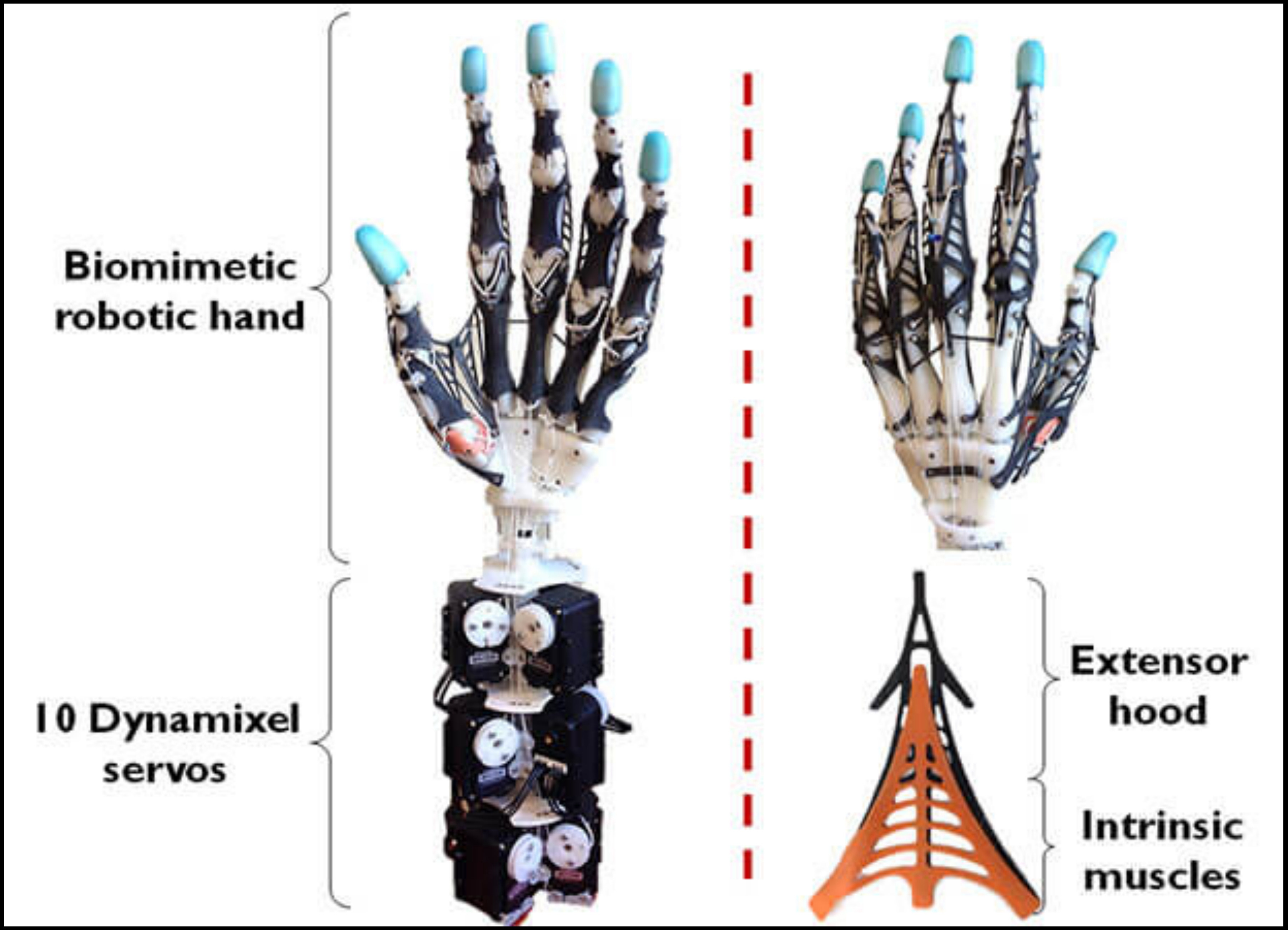


3 fully actuated fingers with human musculoskeletal structure (redundant actuation)

passive and active dynamics consistent with human hand

goal: study human control of hand movements

Research Hands



Xu and Todorov Hand

Research Hands

Deimel and Brock Hand

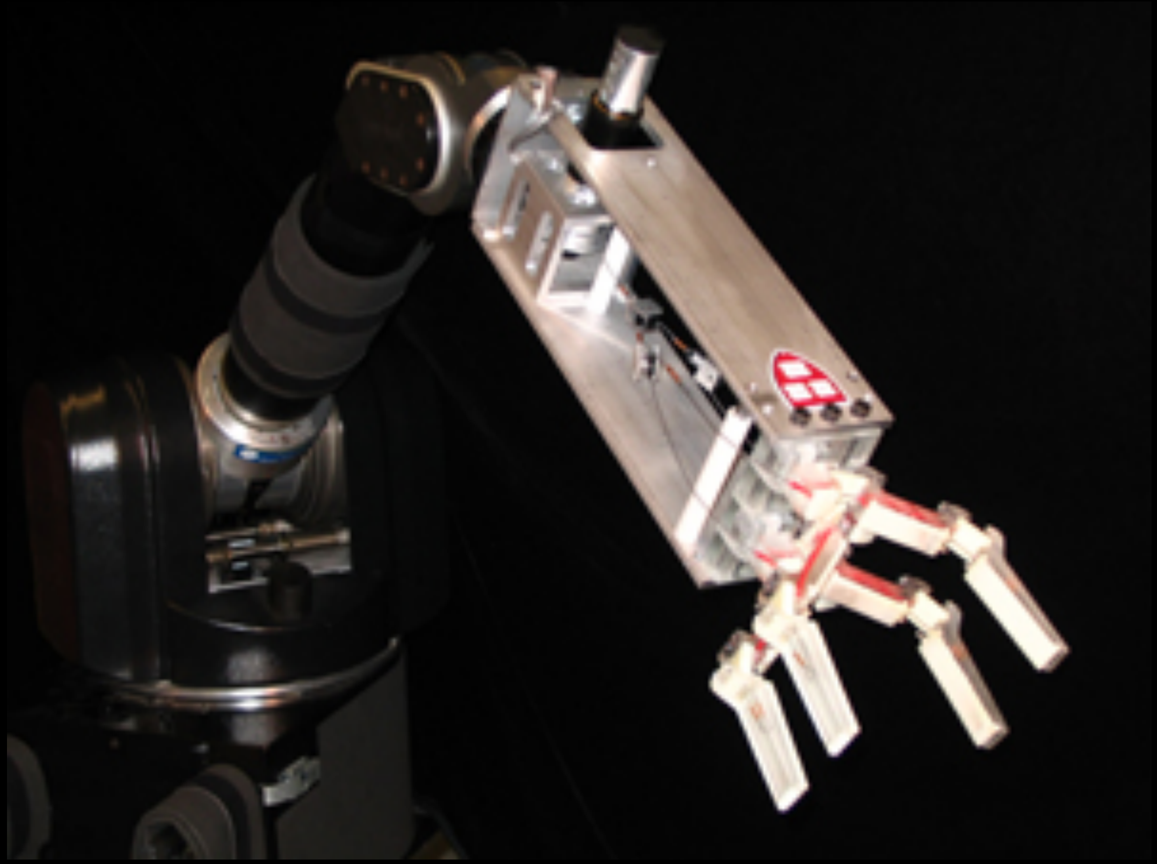
Raphael Deimel and Oliver Brock. A Novel Type of Compliant and Underactuated Robotic Hand for Dexterous Grasping. International Journal of Robotics Research 2015.

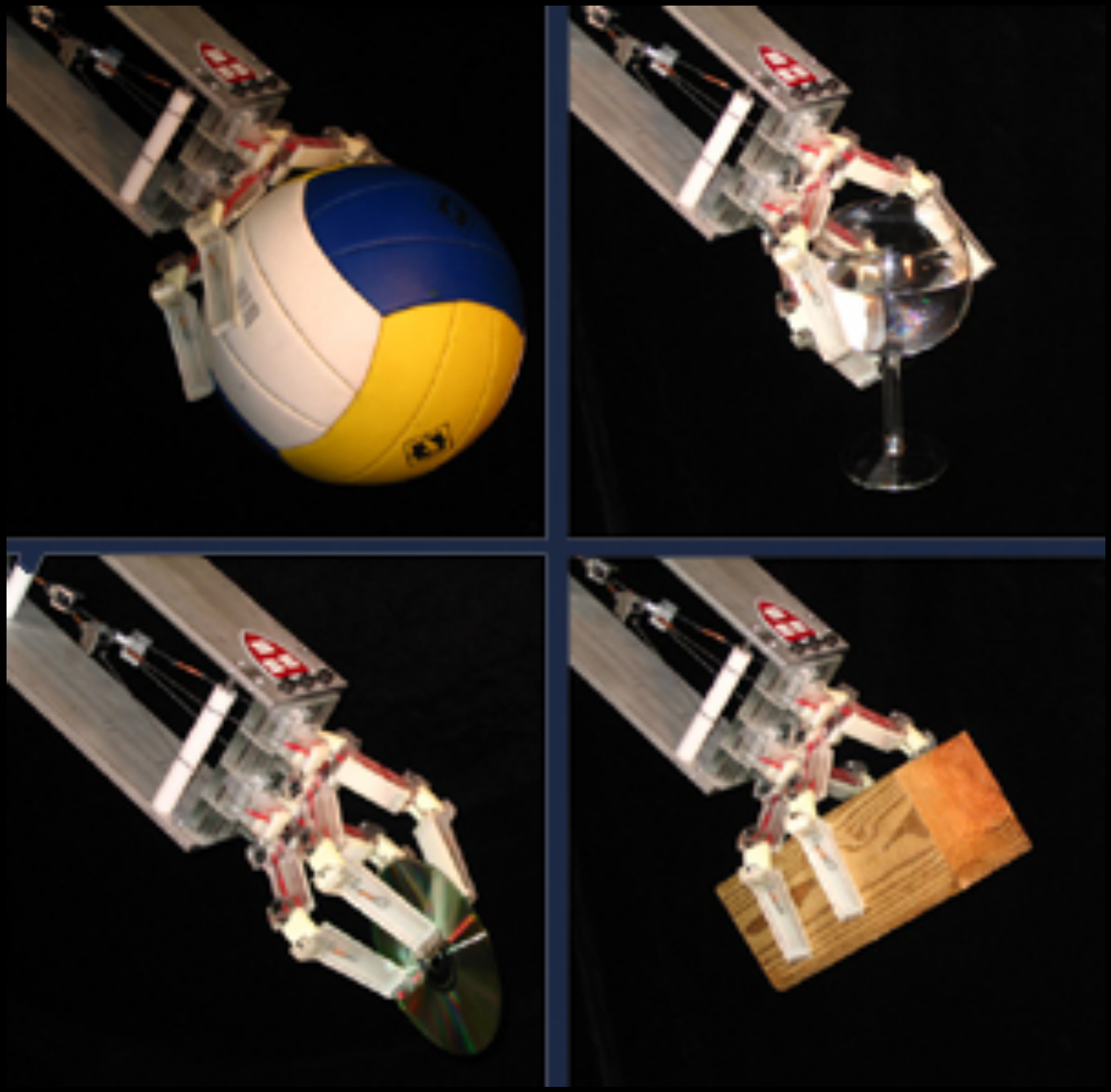
The Maker Movement

- 3D printing
- Soft hand technologies
- Anyone can make a hand?

Early Research

SDM hand (Aaron Dollar and Robert Howe, Harvard)



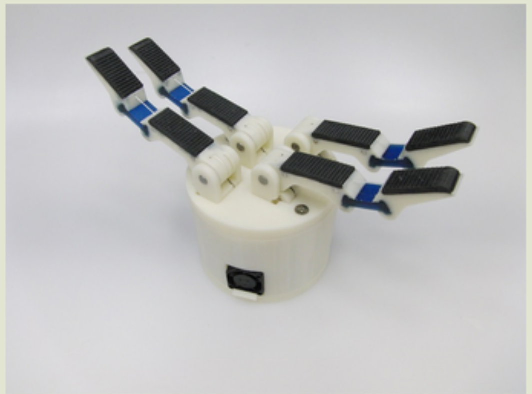


single controlled DoF for 8 joints
compliant joints and fingerpads
shape deposition manufacturing
embedded sensors (hall effect position, optical contact force)
robust, lightweight, inexpensive

Yale OpenHand Project

YALE OPENHAND PROJECT — ABOUT · DESIGN · HANDS · CONTACT

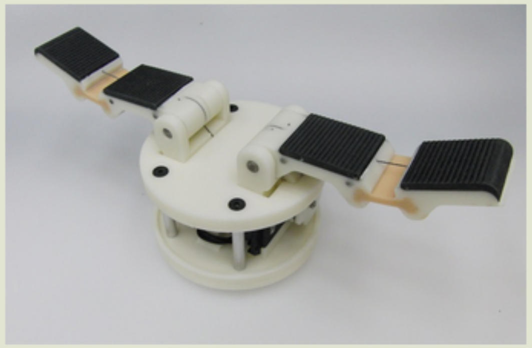
Hand Designs



Model T

About - Performance - Build

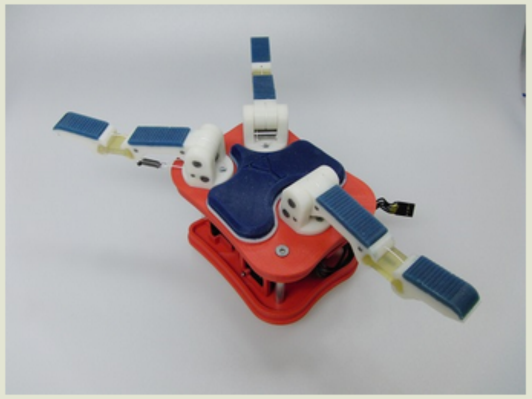
Based on the original SDM Hand, the Model T is the OpenHand Project's first released hand design, initially introduced at ICRA 2013. the four underactuated fingers are differentially coupled through a floating pulley tree, allowing for equal force output on all finger contacts.



Model T42

About - Performance - Build

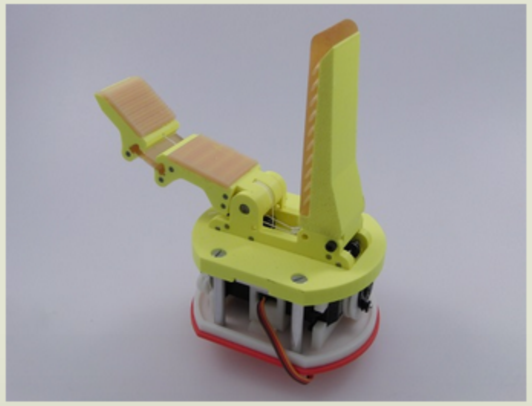
A more dexterous alternative to the Model T, the Model T42 incorporates two underactuated, flexure-based fingers, each driven independently by either a Dynamixel or hobby servo. This type of hand has been shown to be adept at both in-hand manipulation and precision grasping.



Model O

About - Performance - Build

Based on our lab's work with iRobot and Harvard on the iHY hand, which won the DARPA ARM program, the Model O replicates the hand topology common to several commercial hands, including ones from Barrett, Robotiq, and Schunk (among others). A commercial version of this hand is currently for sale by RightHand Robotics.

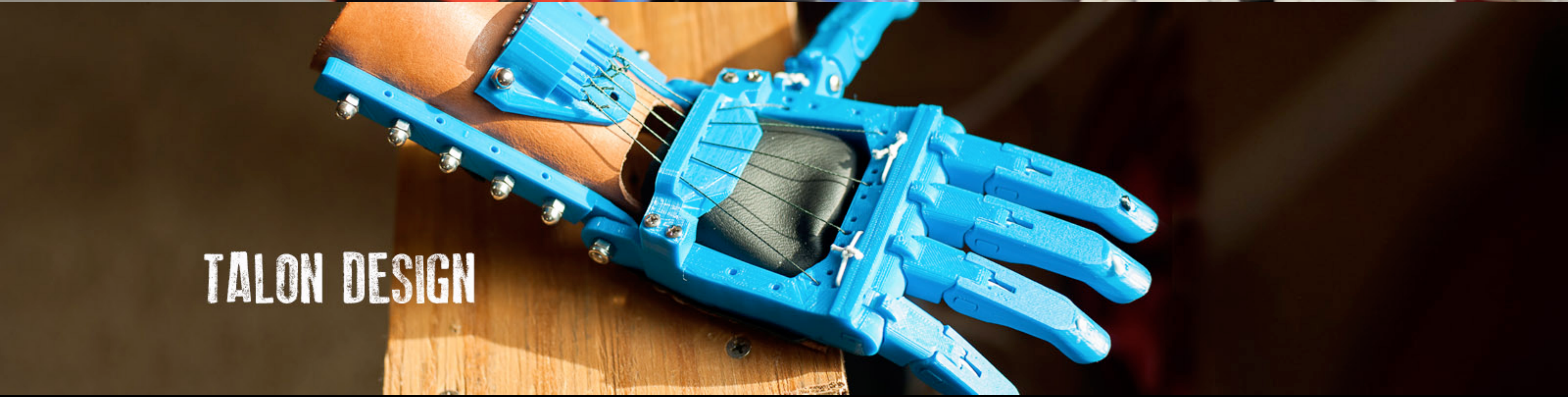


Model M2

About - Performance - Build

The Multi-Modality (M2) gripper employs a single underactuated finger driven by both agonist and antagonist tendons, as well as a modular thumb that can be swapped out for different tasks. The actuated finger may exhibit either underactuated or fully-actuated behaviors, depending on the actuation scheme. A single-actuator version (Model M) is also available as a minimalist design alternative.

enablingthefuture.org



http://enablingthefuture.org/upper-limb-prosthetics/

Concurrent Soft Technology Development

Universal Gripper, University of Chicago

Concurrent Soft Technology Development

Silicone pneumatic technologies

softroboticstoolkit.com/showcase

soft robotics toolkit

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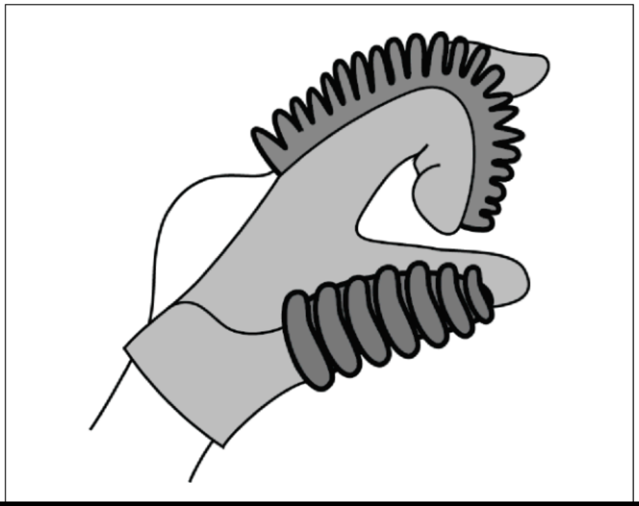
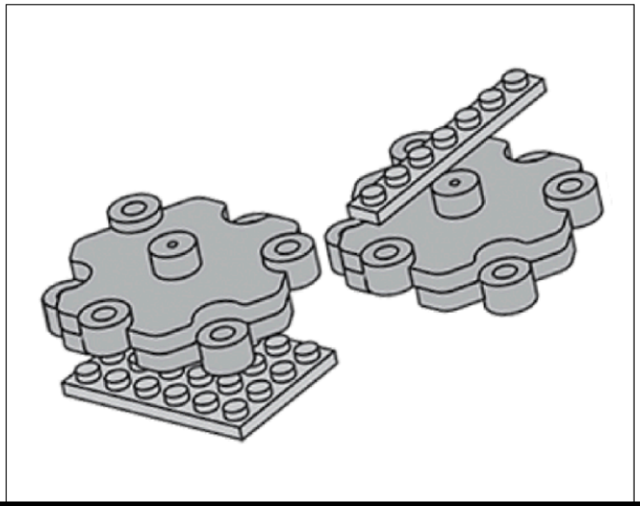
Showcase

Showcase features many of the devices and components that are submitted to the site through the Soft Robotic Design Competition. Students in the undergraduate and high school category, build, document, design and test their devices in order to publish their work to the Toolkit platform.





However….

- We still do not have fully dexterous robots
- We cannot teleoperate robots seamlessly with full dexterity
- We cannot even portray completely convincing hands in computer graphics

In this class:

- We will study human, robot, and graphical / virtual hands
- Attempt to understand where there are gaps between the dexterity we have and the dexterity we wish for
- Discuss how can we can close these gaps

What do you notice in this video?

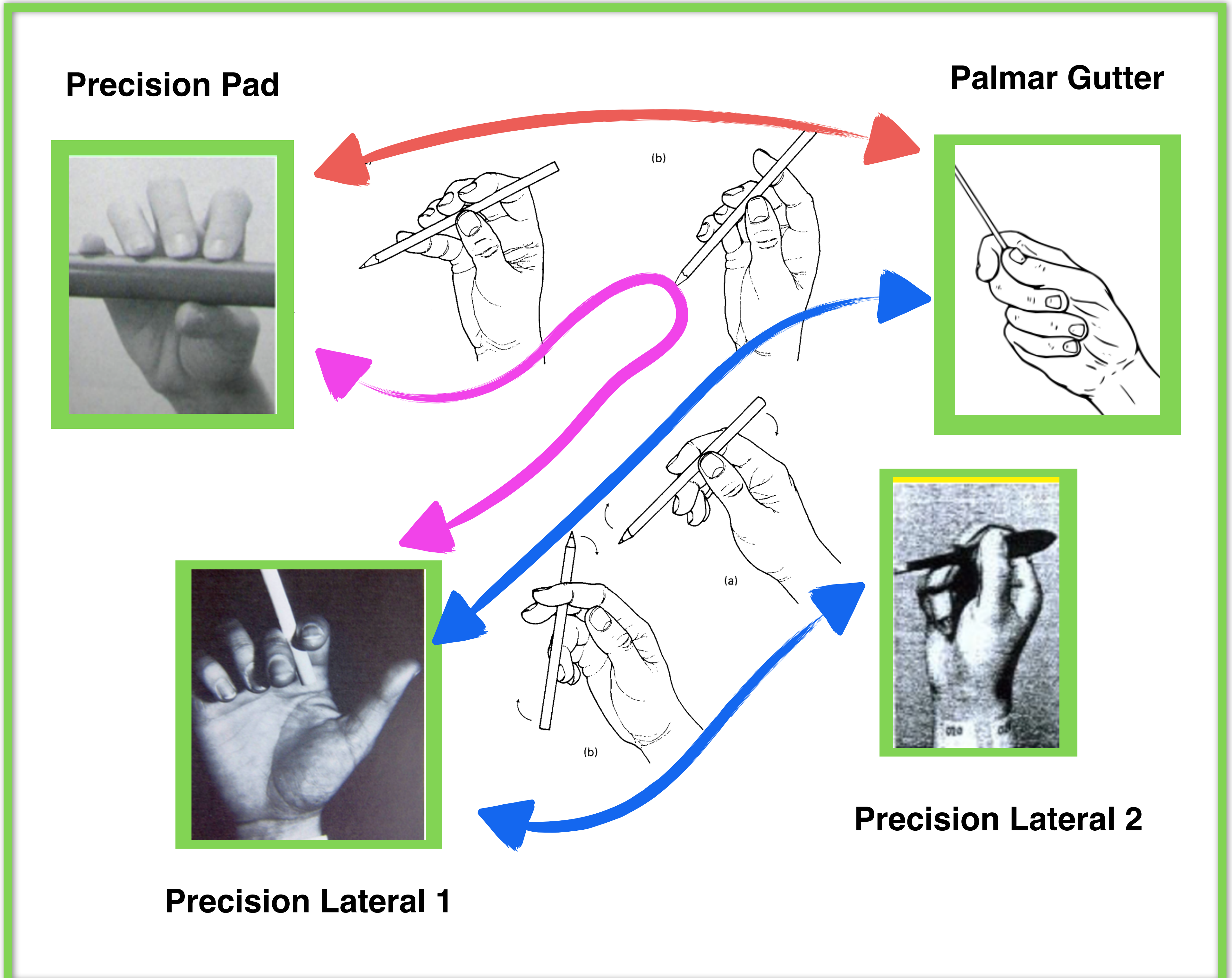
1/4 speed (captured at 120fps)

What is needed?

- Sensing
- Hand shape
- Joint limits
- Compliance
- Control (reflexes?)
- Learning
- Design for specific tasks
- Data!
- New teleoperation interfaces

Some specific questions we are asking

Is there a small family of grasps and manipulation actions that we use for dexterous manipulation?



Applications:

- realistic animation
- dexterous robots
- prosthetics design

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How can we custom design robot hands to perform specific dexterous tasks?

Applications:
- crop picking
- manufacturing
- bin picking
- personal assistants
- prosthetics
- and many more!

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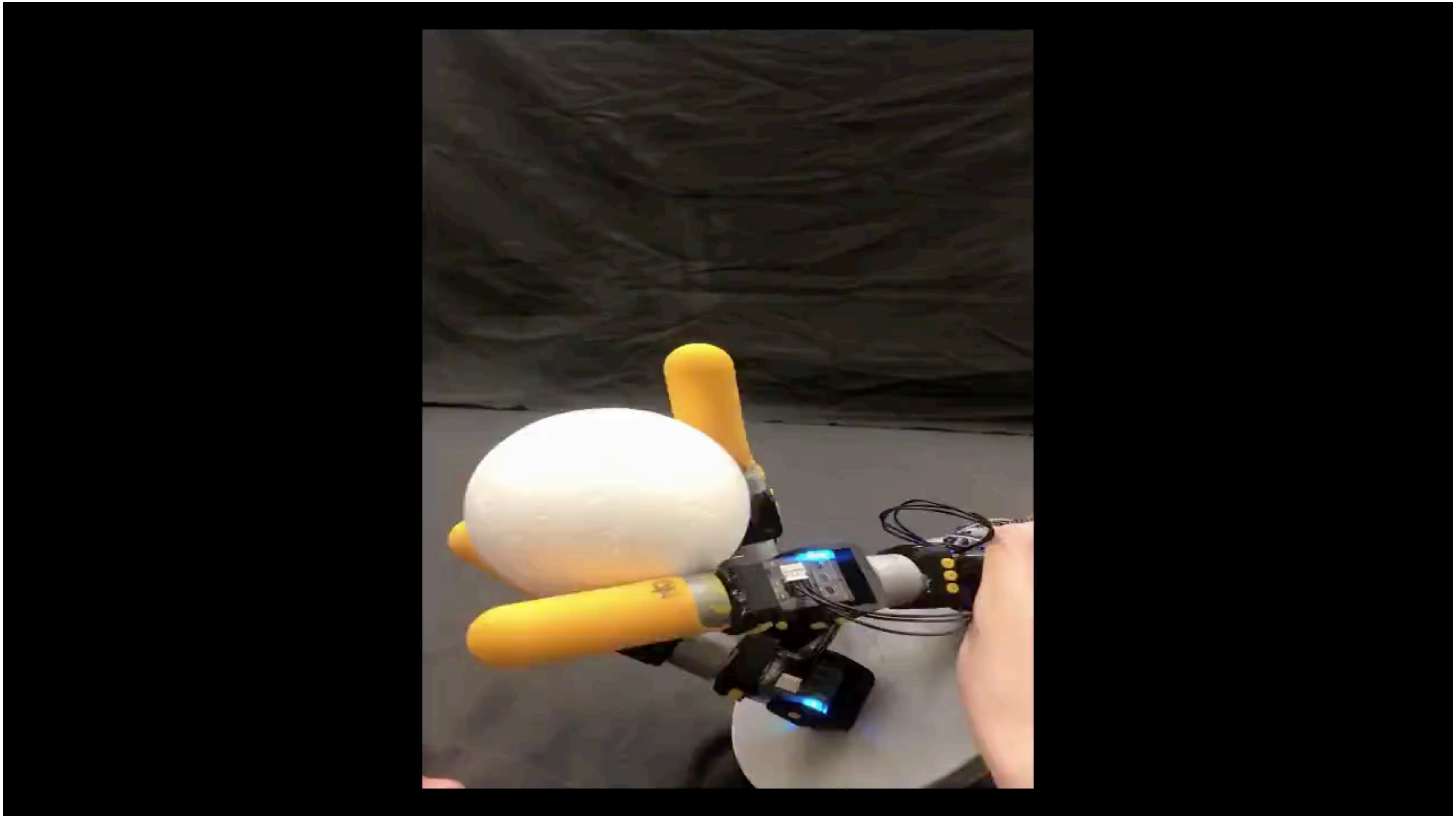
Optimization Example: snap together robot hand designs for specific manipulation tasks



with Chris Hazard, Andre Meixner, and Stelian Coros

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Fabrication Example: fully soft robot hands capable of dexterous manipulation

with Jonathan King, Dominik Bauer, Cornelia Bauer, Daniele Moro, and Stelian Coros

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Expectations for this course

- One hour of prereading or independent research per class
- Active participation in discussions etc.
- Grades:
  - 10% Participation / contributions to class
  - 30% One in-class research presentation
  - 60% Final project

Assignment 0

- 3 topic / paper requests to me by Saturday, Jan18th (earlier is better!)