ME 23N: Soft Robots for Humanity
Autumn 2019

Week 4:
Air powered robots and pneumatic artificial muscles

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Particle Jamming Example: Hands-on Haptic Medical Simulation

Medical Simulation

Laerdal's SimMan

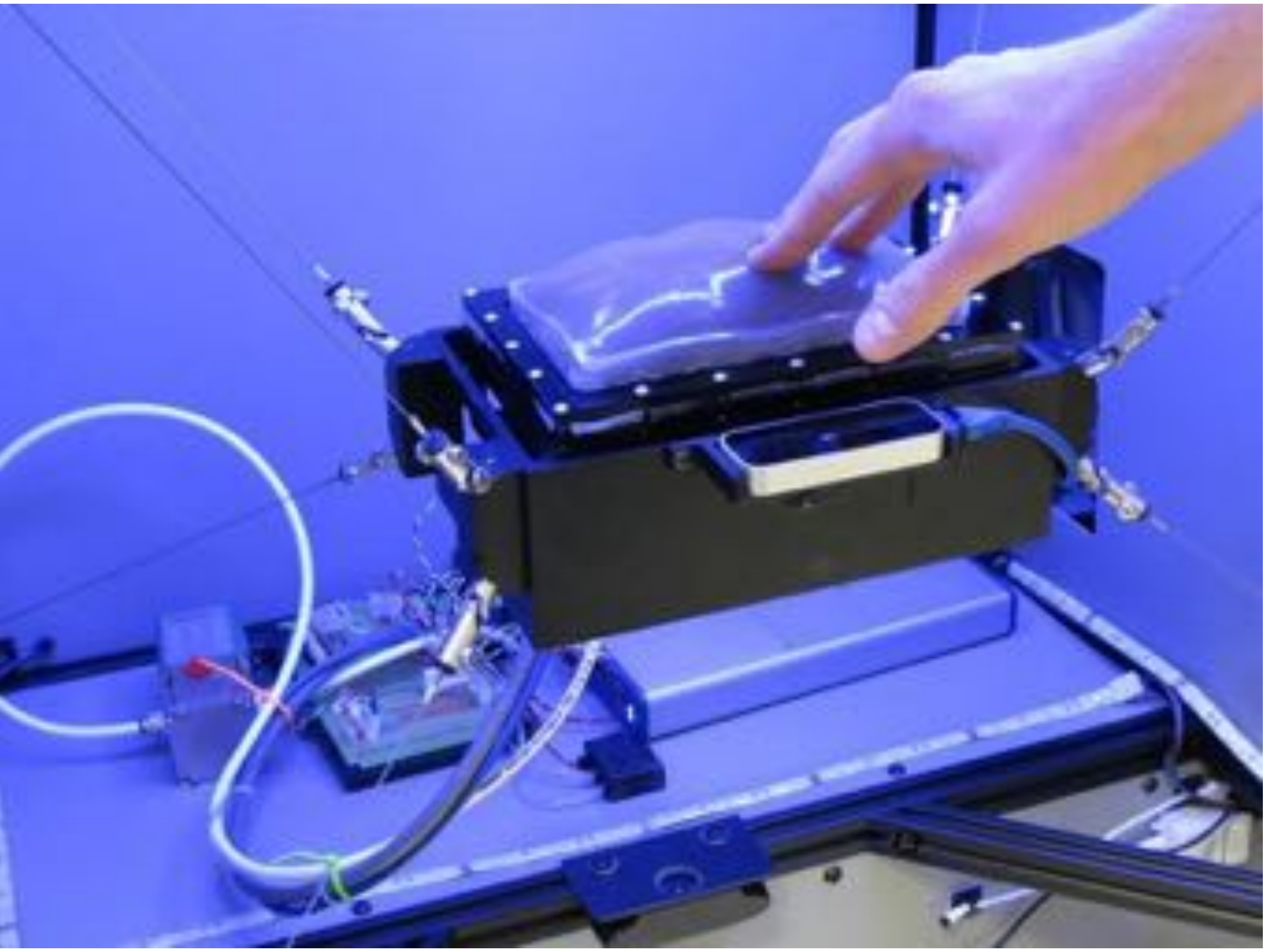
Phantom Desktop

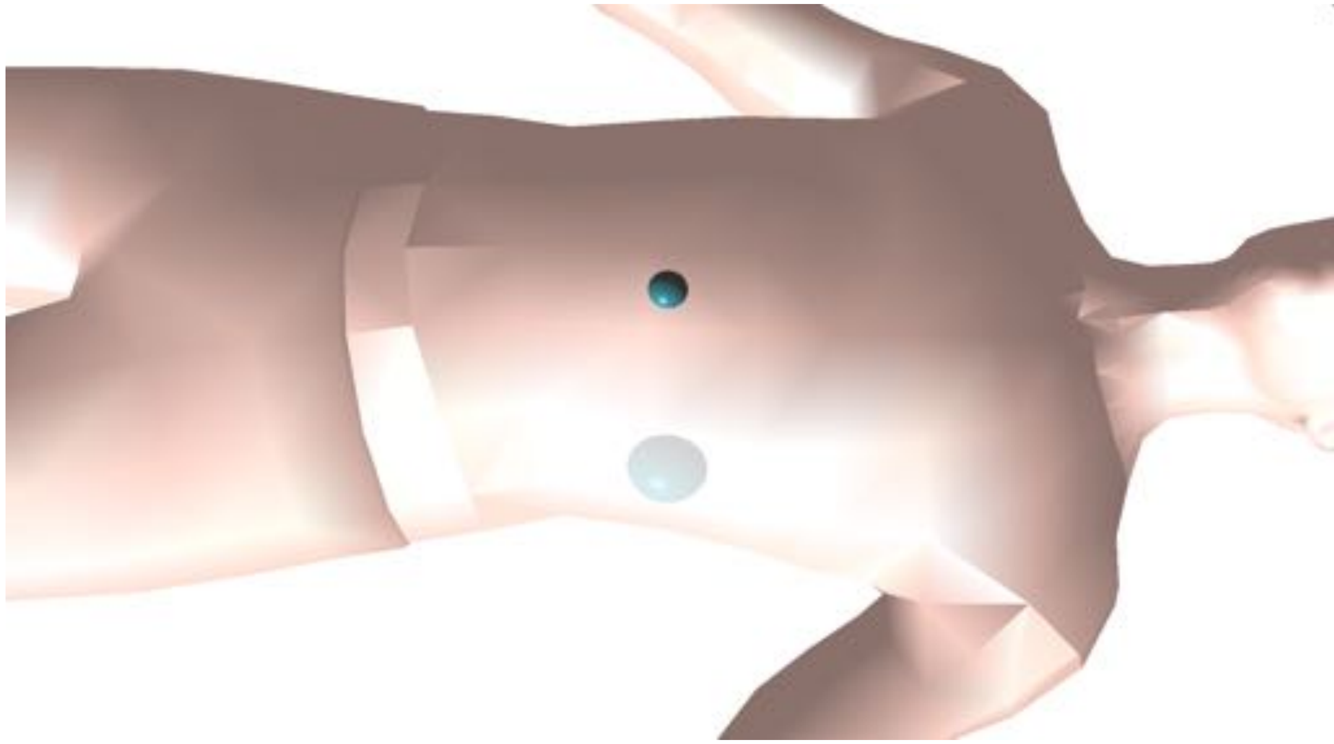
Mannequins:
mostly passive,
tactile, multi-contact

Tool-based
interaction: active,
programmable forces

Can we have the best of both worlds?

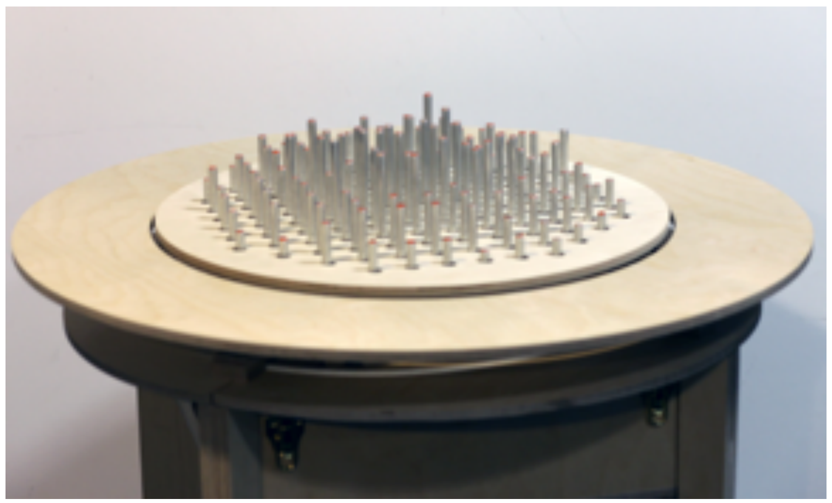
Encountered-Type Medical Simulator



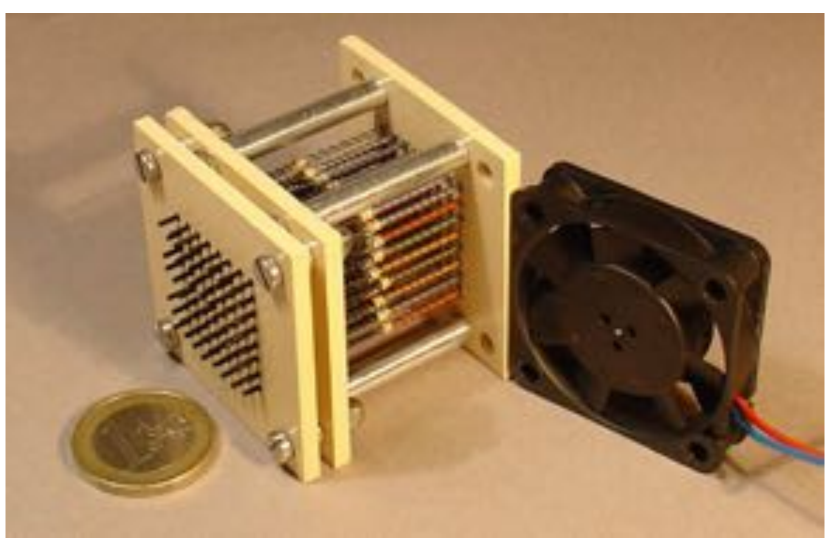


Stanley & Okamura Eurohaptics 2014

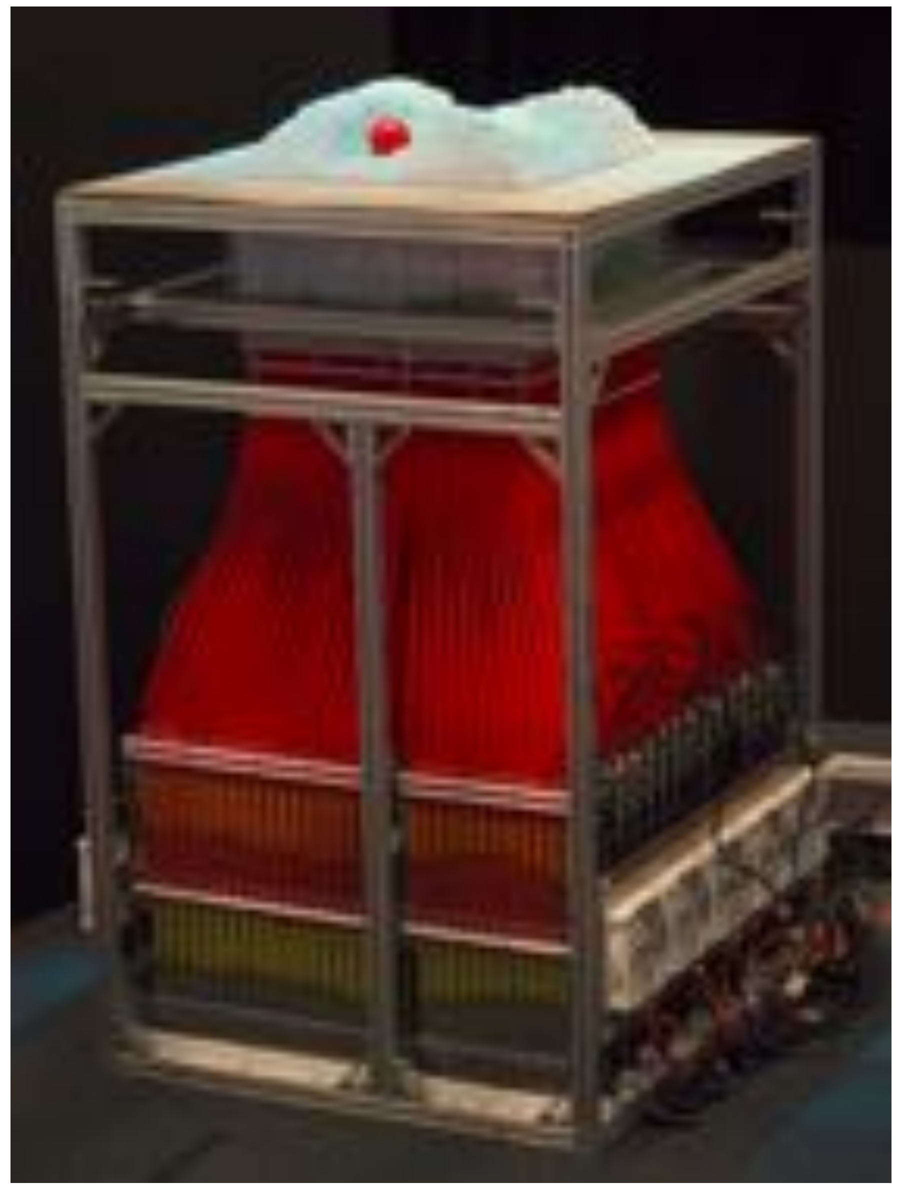
Pin Arrays and Crusts



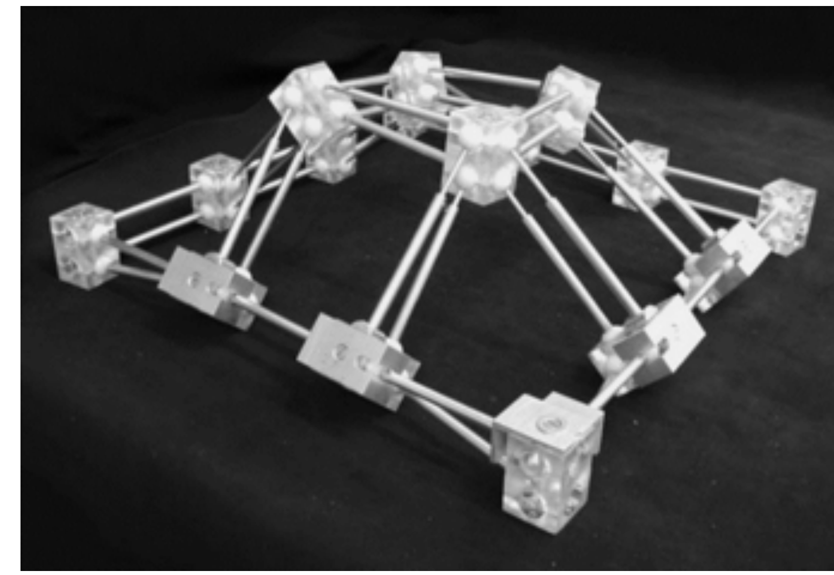
Leithinger et al. 2010



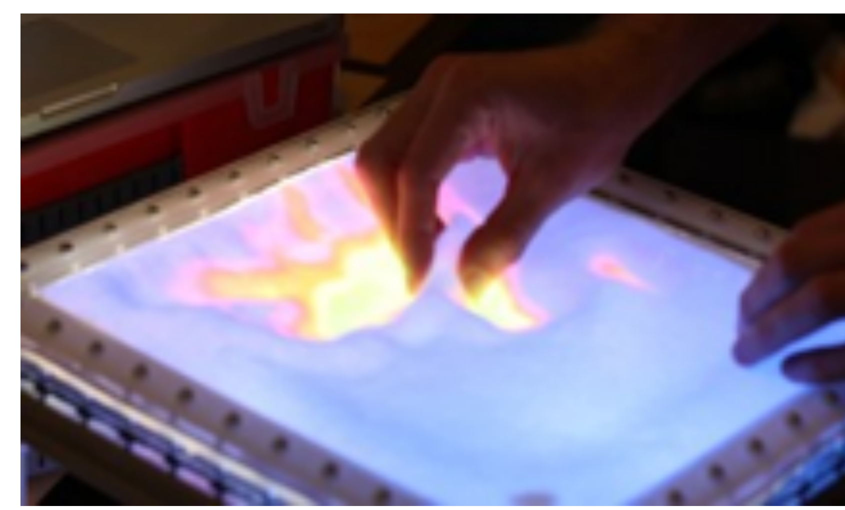
Velazquez et al. 2005



Follmer et al. 2013

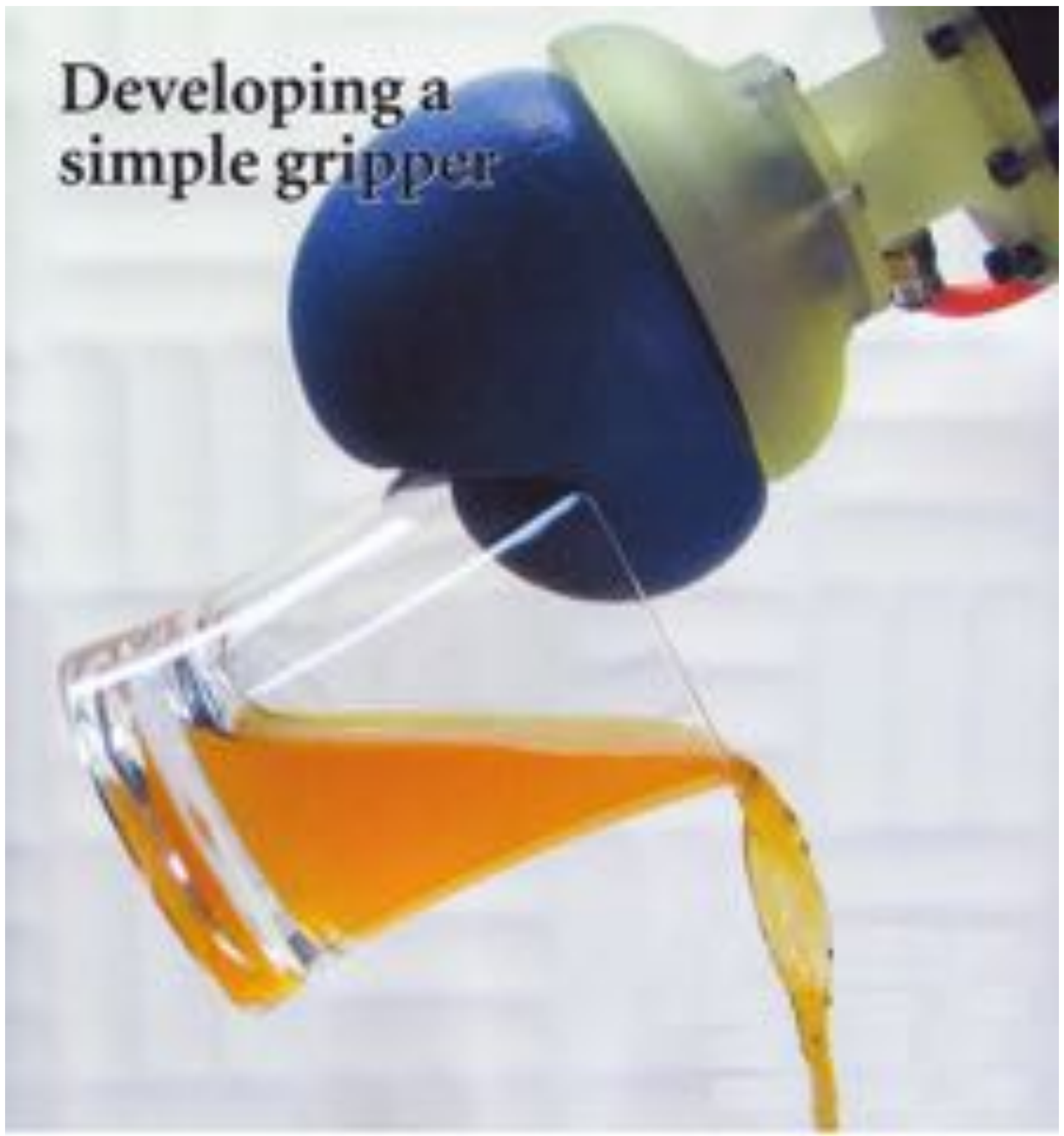


Mazzone et al. 2003



Follmer et al. 2012

Particle Jamming

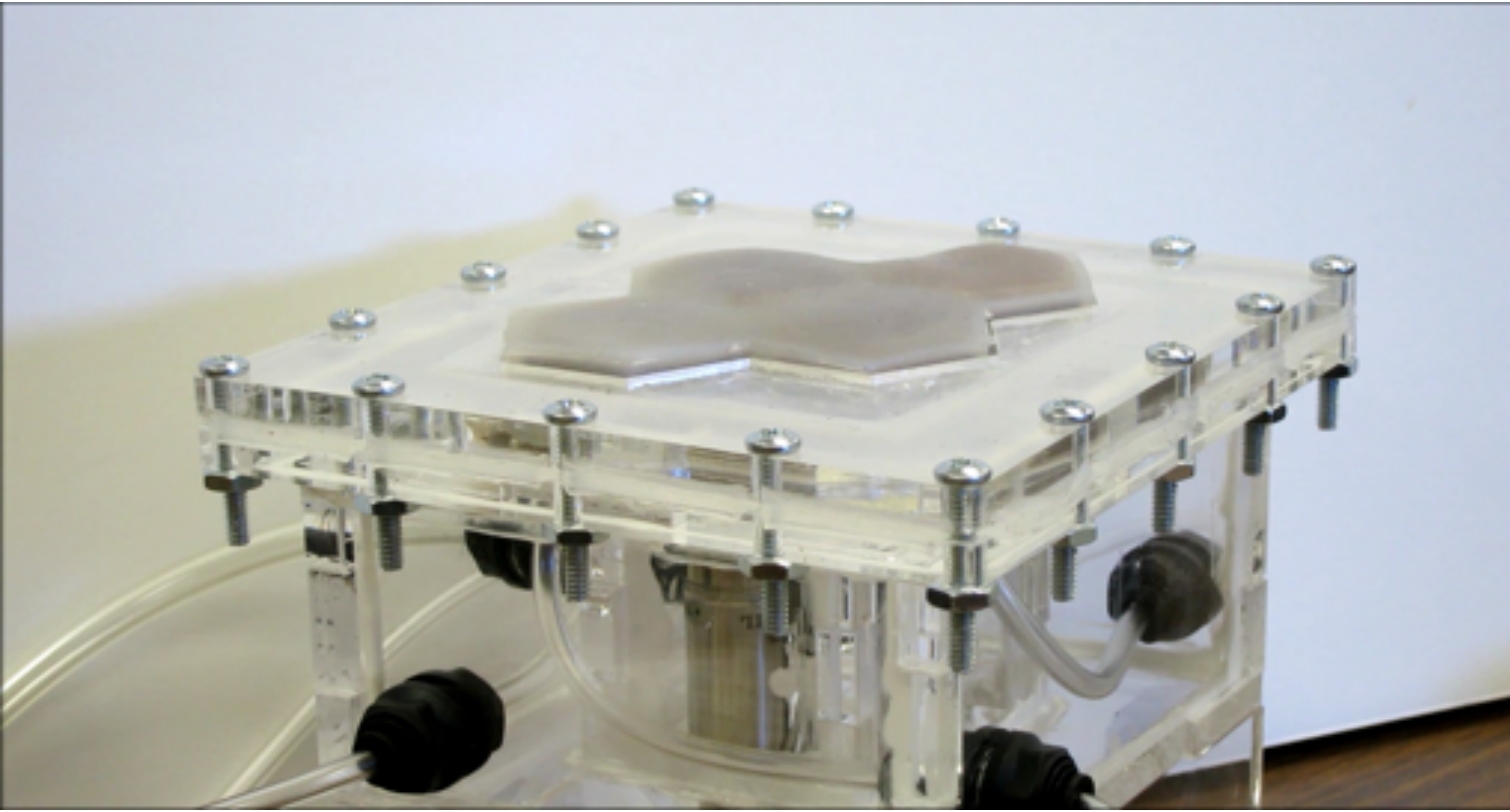


Brown et al. 2010

Cheng et al. 2012

Steltz et al. 2009

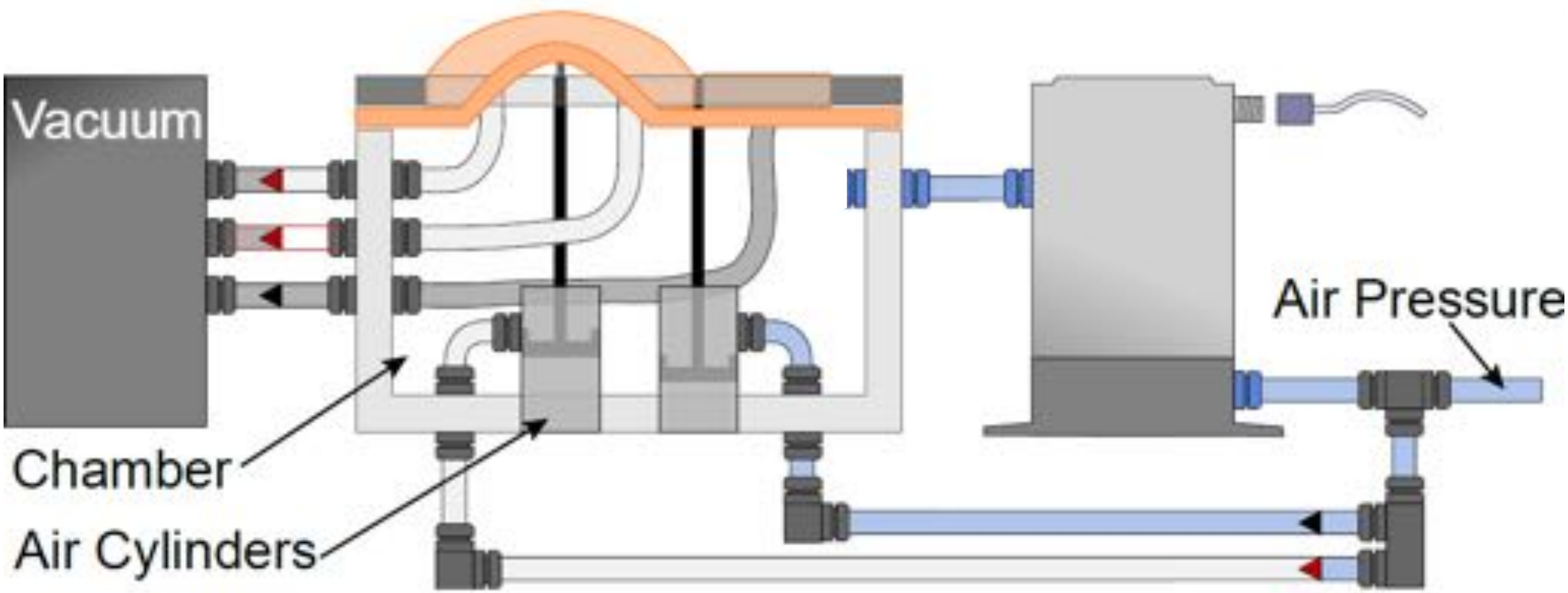
Haptic Jamming: Four-Cell Surface



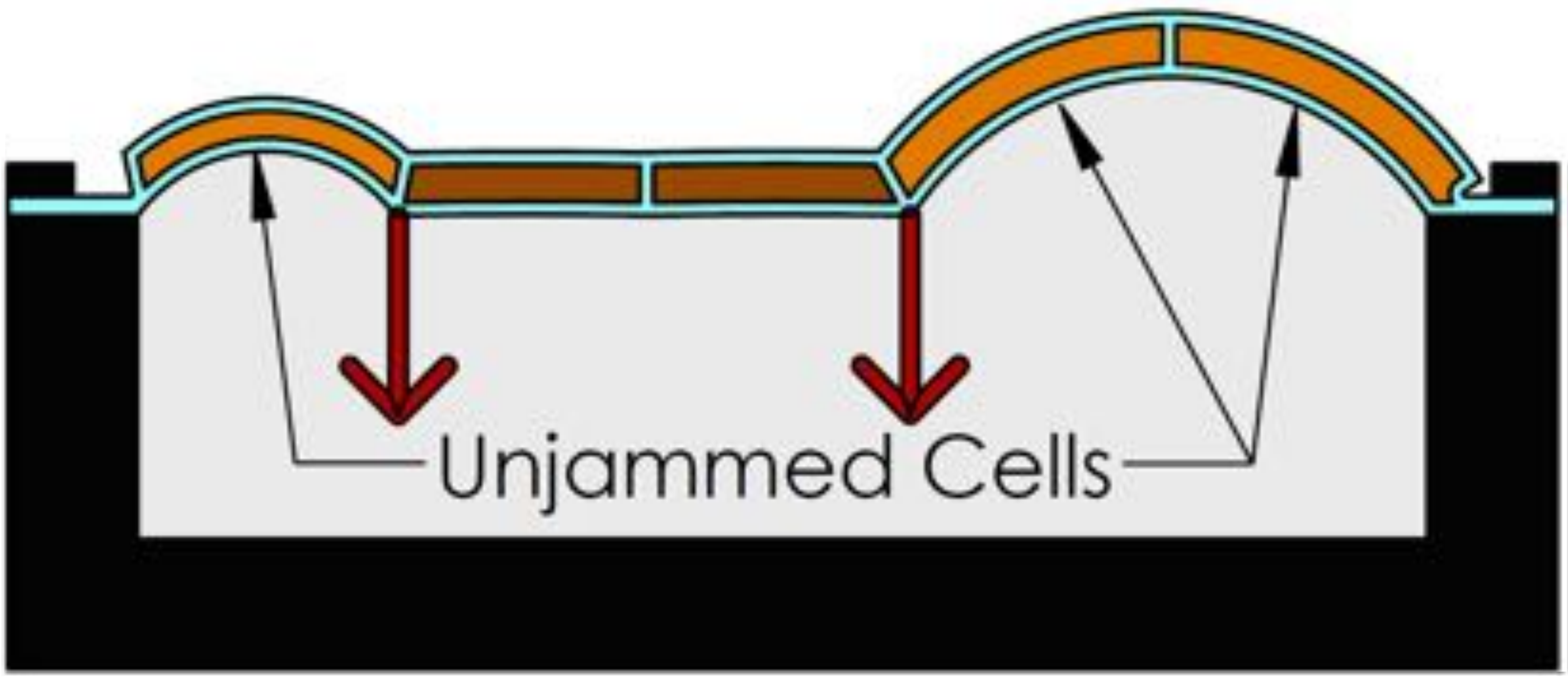
Video is real time

Stanley et al. MMVR 2013

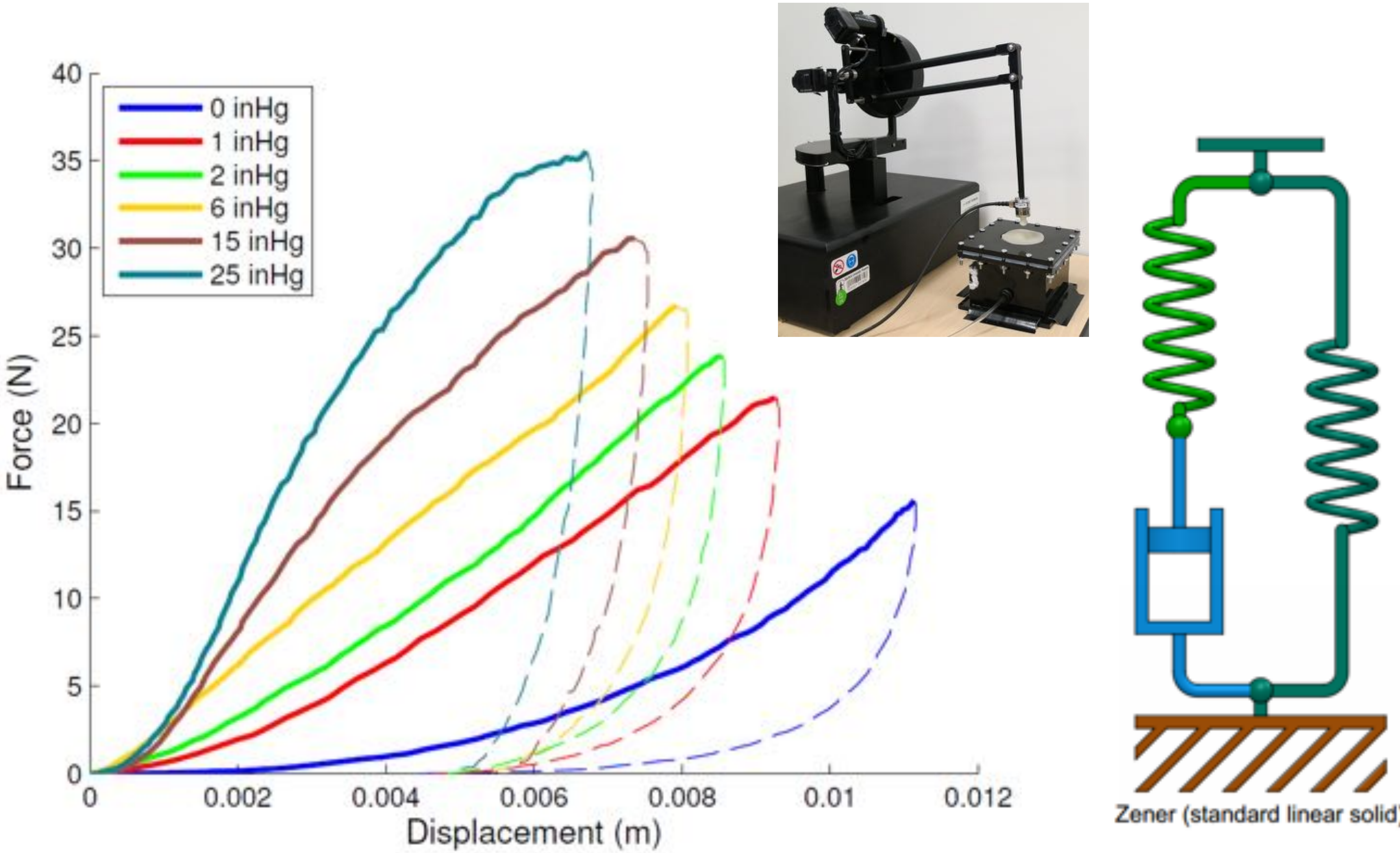
Haptic Jamming Actuation



Haptic Jamming Actuation

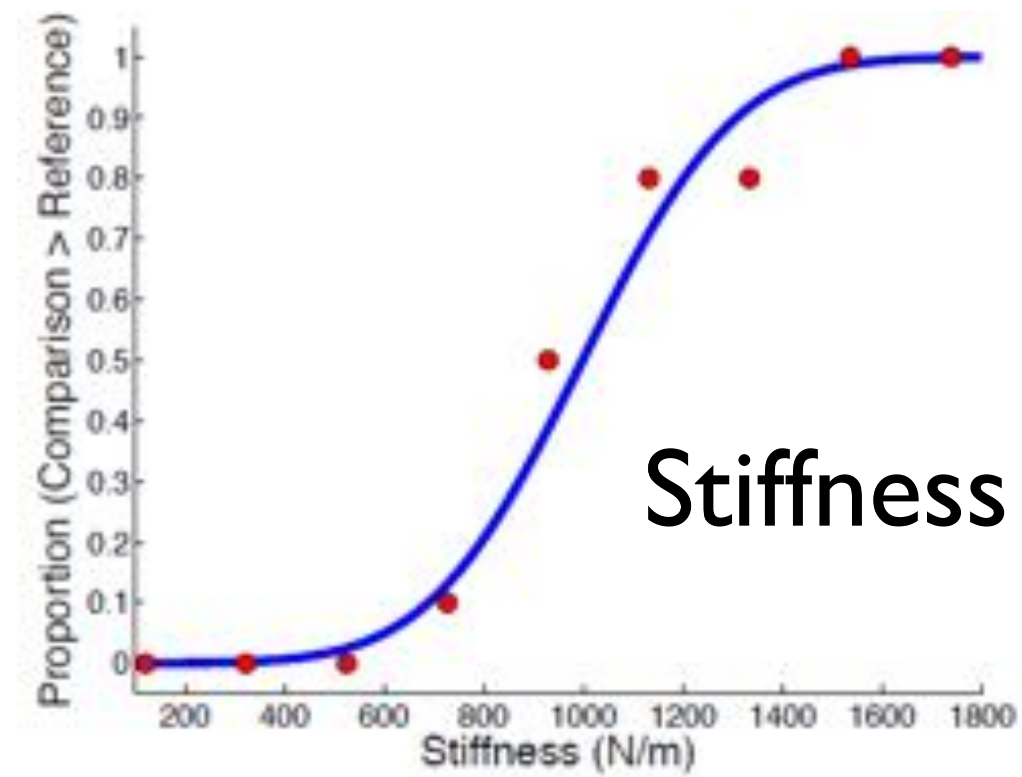


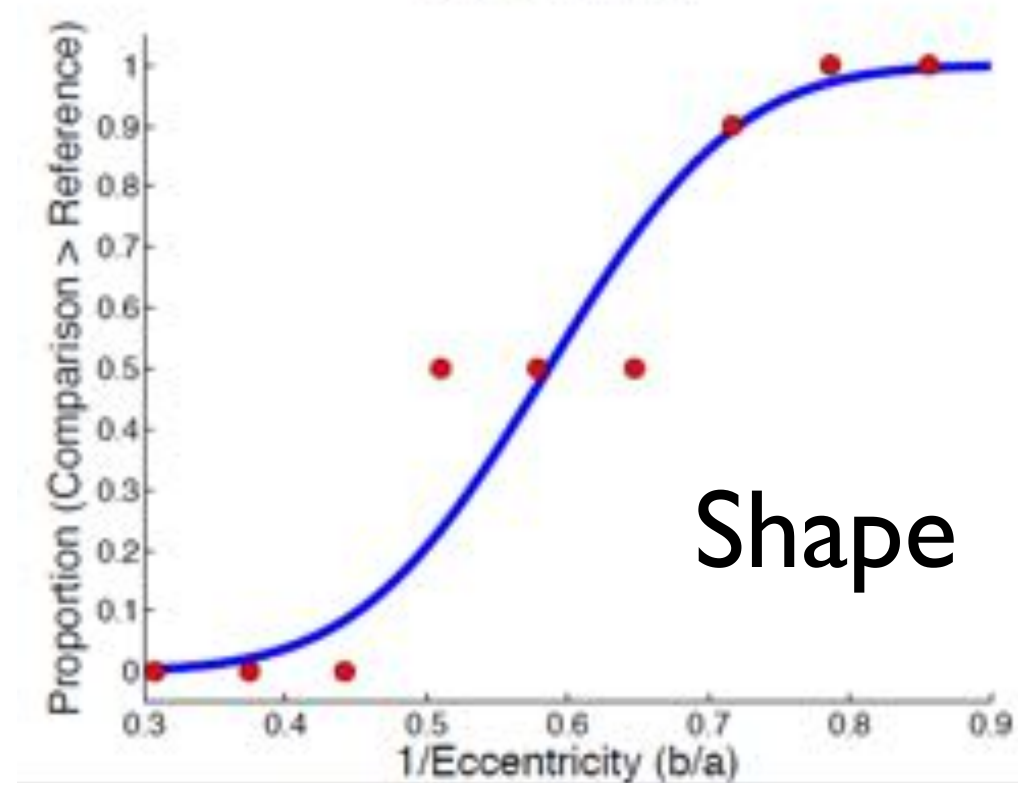
Mechanical Properties



Stanley & Okamura ToH 2014

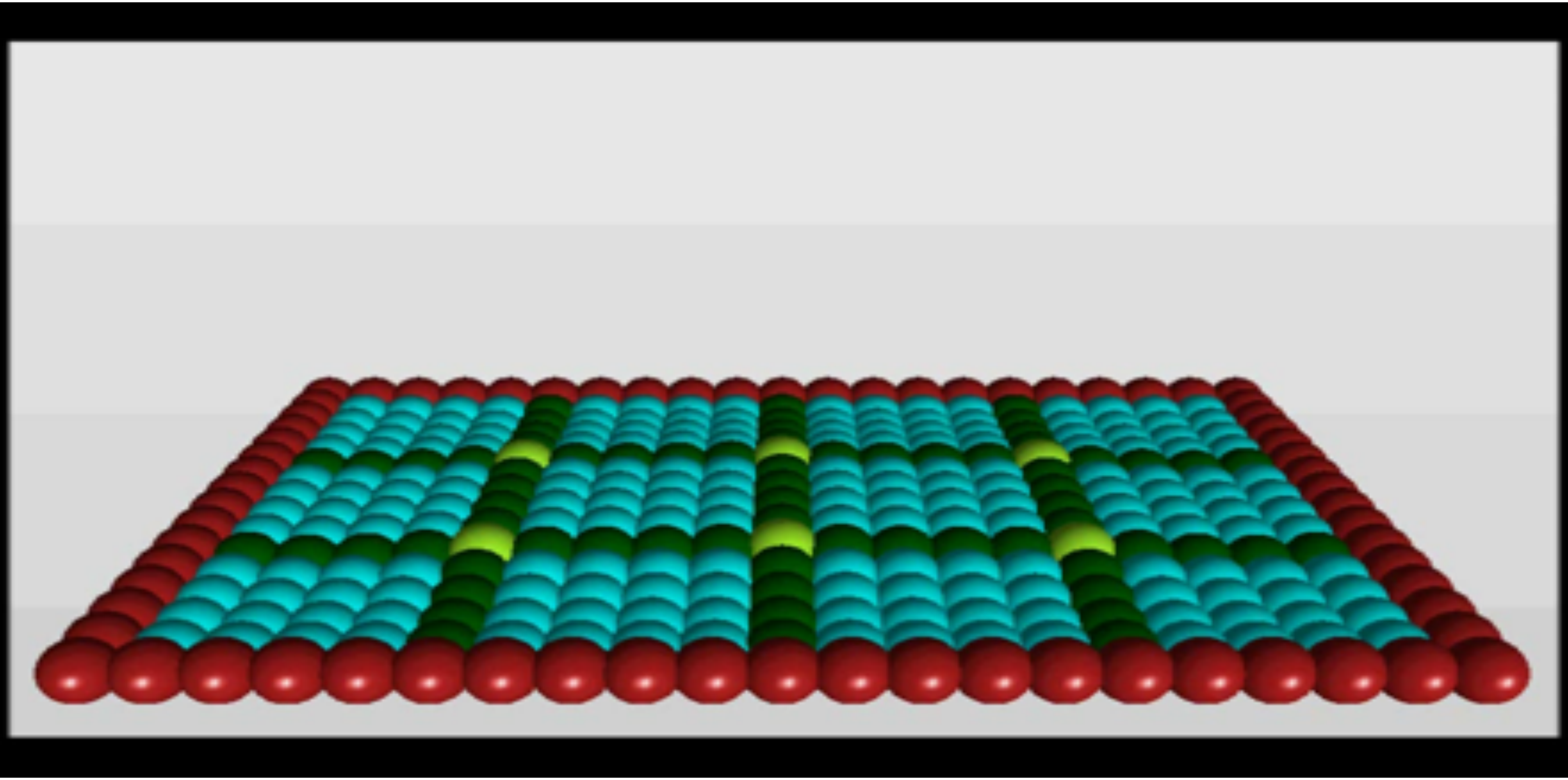
Perception





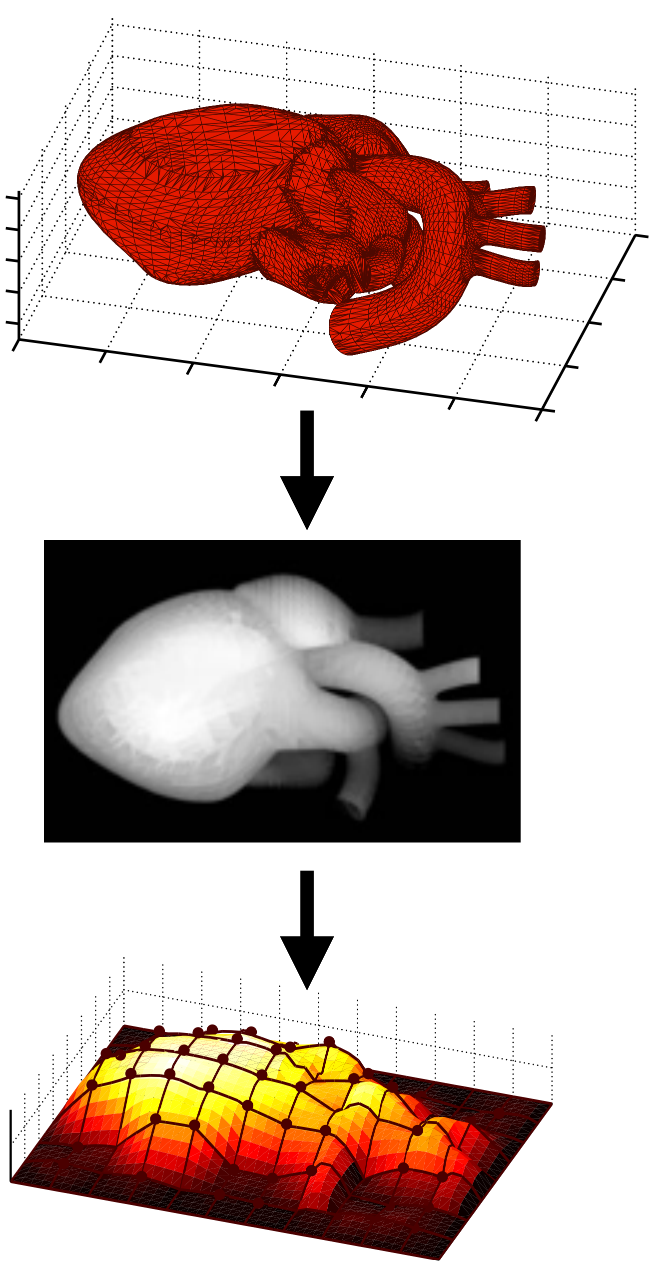
Genecov et al. Haptics Symp 2014

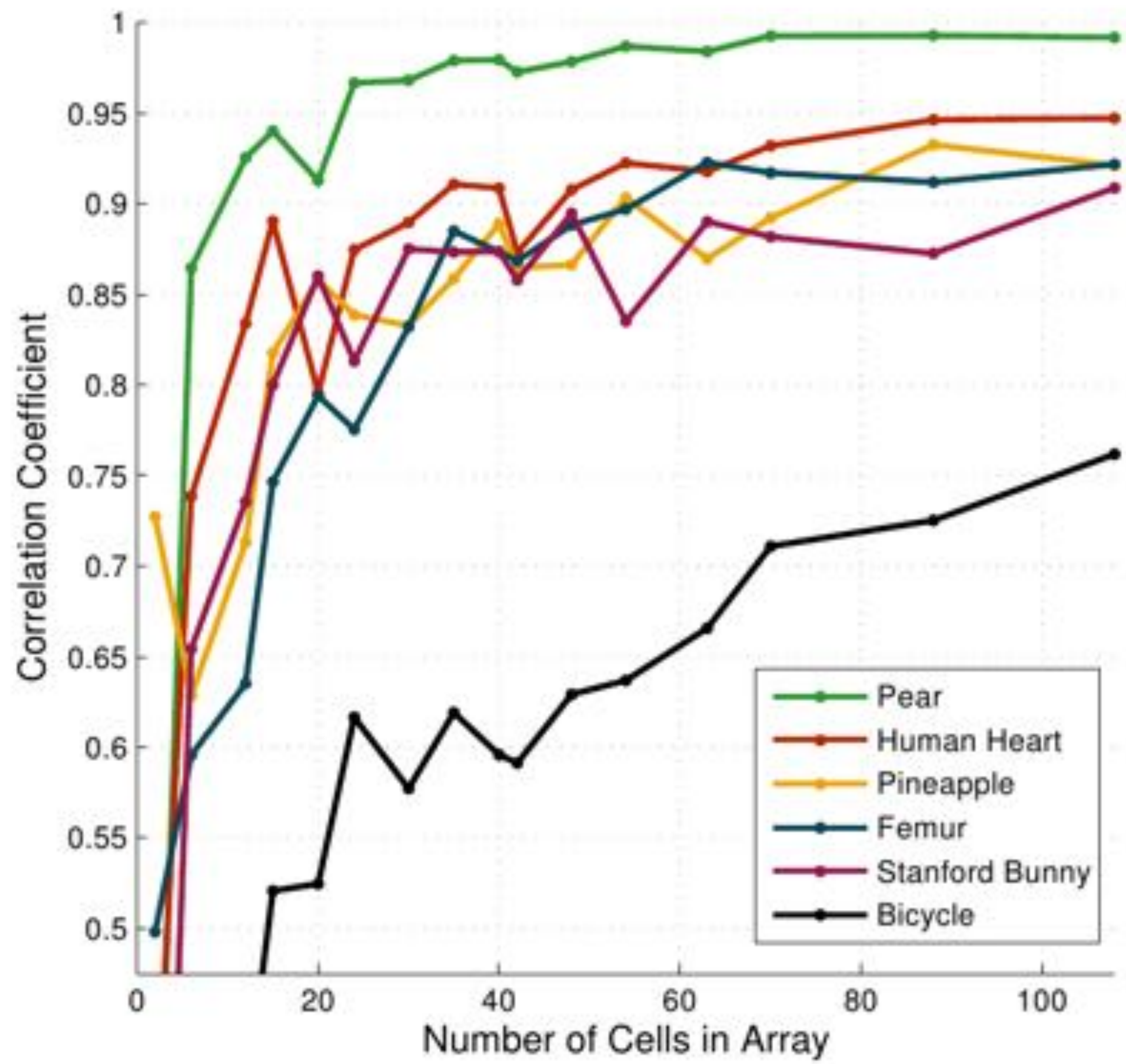
Shape Simulation



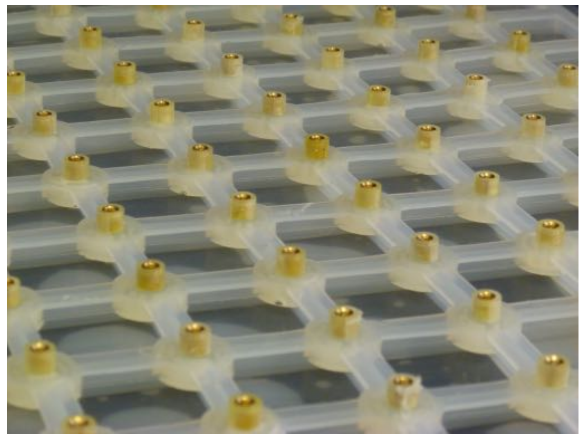
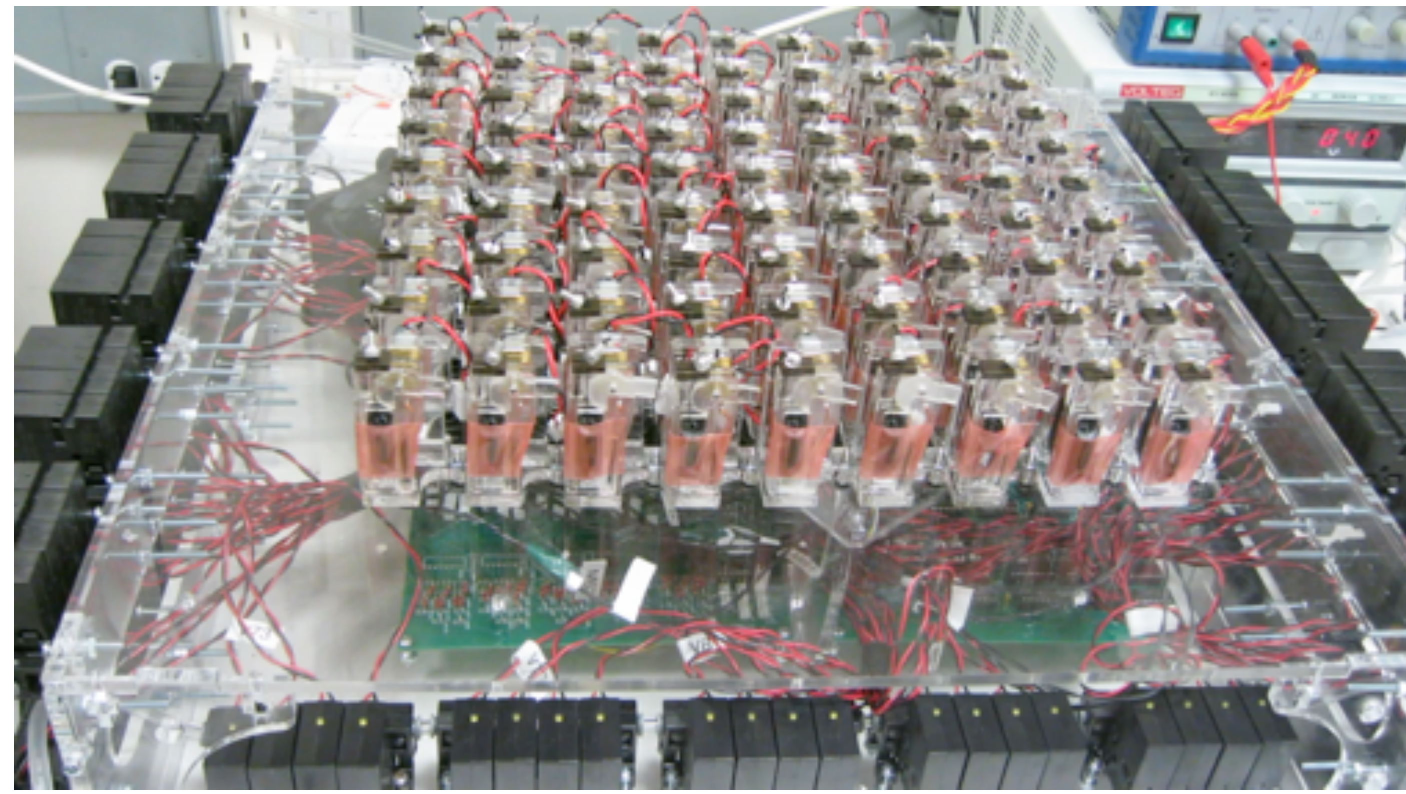
Shape Simulation

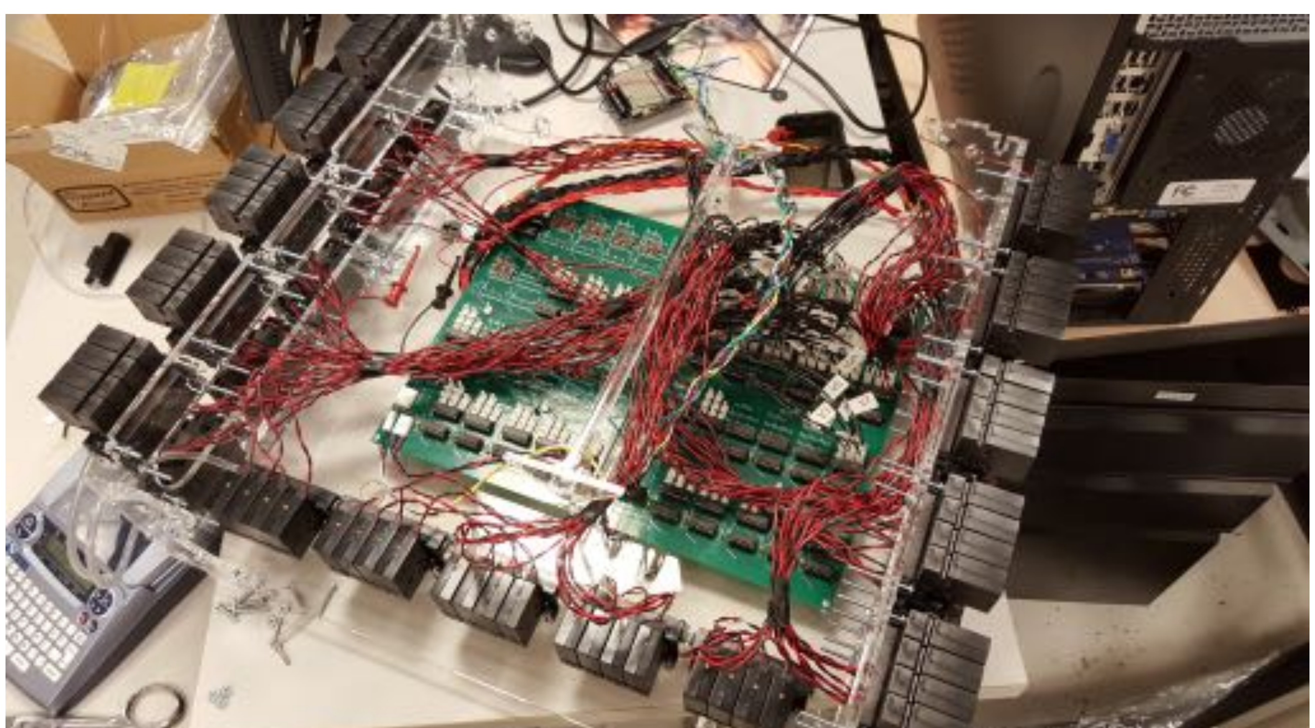
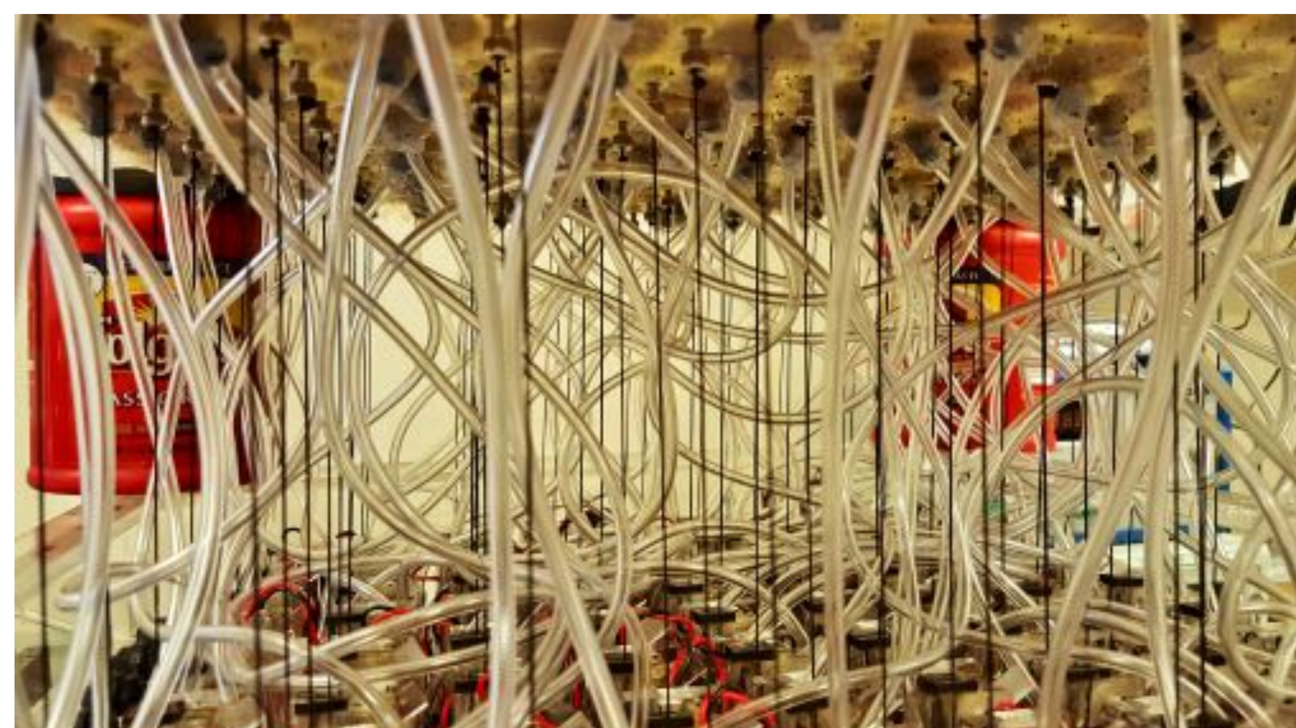
Which shapes will render well?





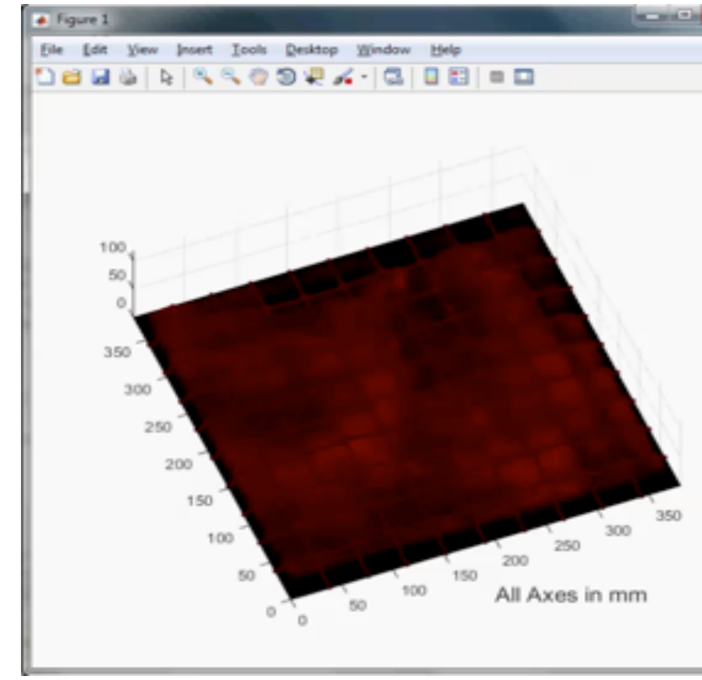
100-Cell Array

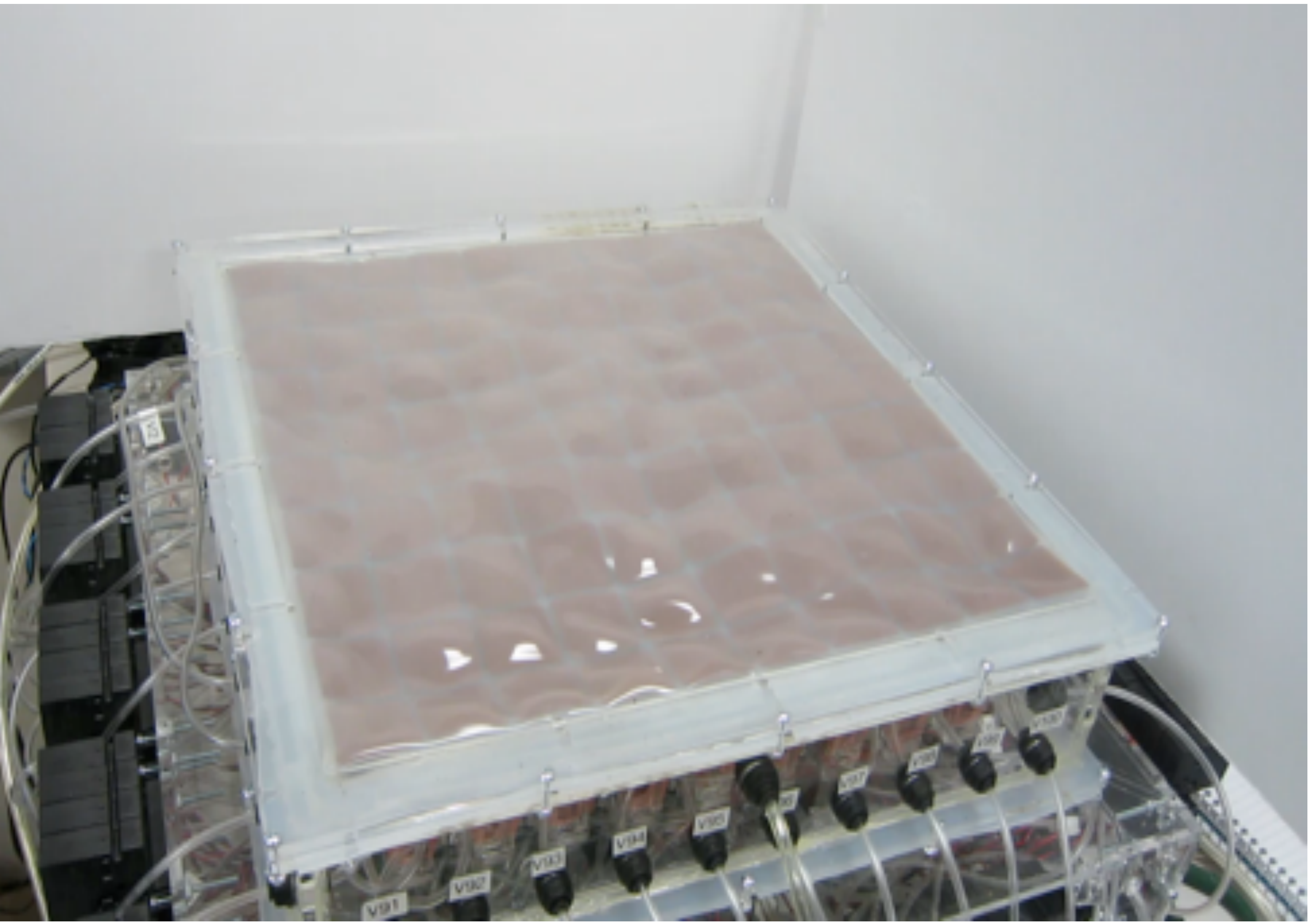




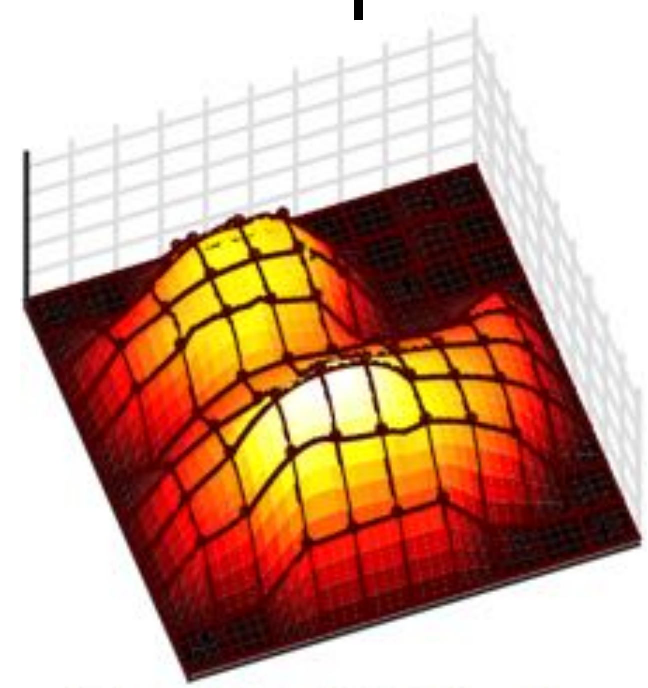
100-Cell Array

Measured Output





Simulated Output



Video is real time

Stanley & Okamura in preparation

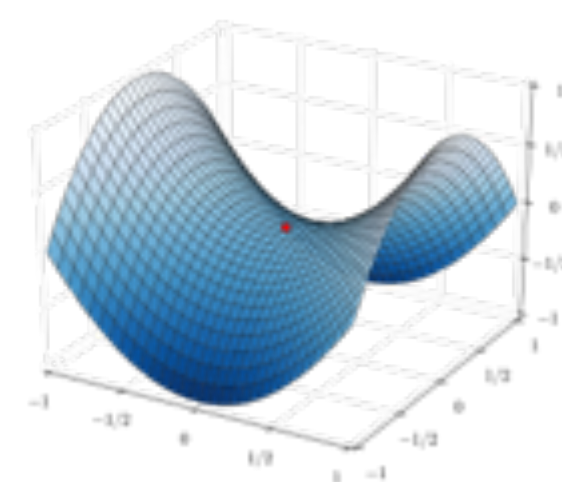
Other Applications

consumer

- Human-computer interaction scenarios

assistive/rehab

- Self-sensing of shape and contact with human
- "Fast refresh" 3D printing
- Changeable Product



education

Continuum Robots

Continuum Robots

- A continuum robot is a continuously bending, infinite-degree-of-freedom robot with an elastic structure
- Continuum robots are related to, but distinct from, hyperredundant robots which consist of (finitely) many short, rigid links.

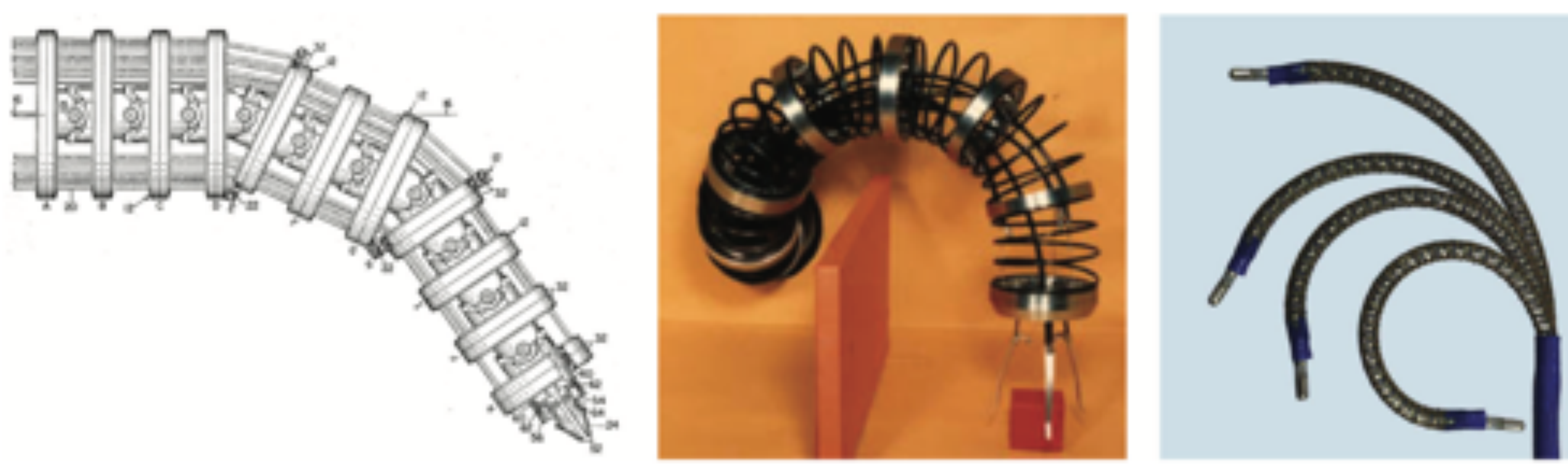
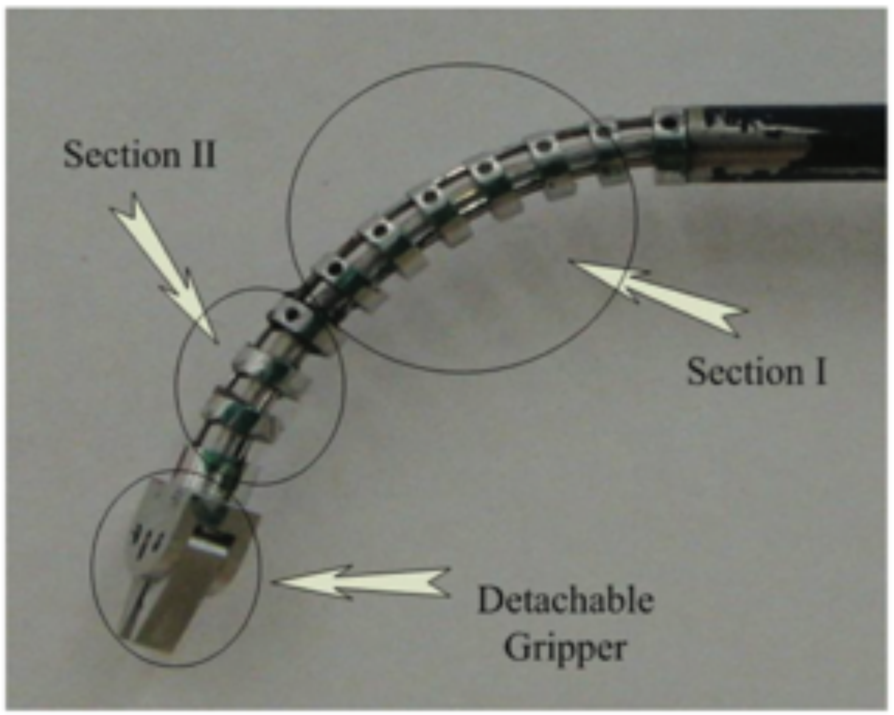


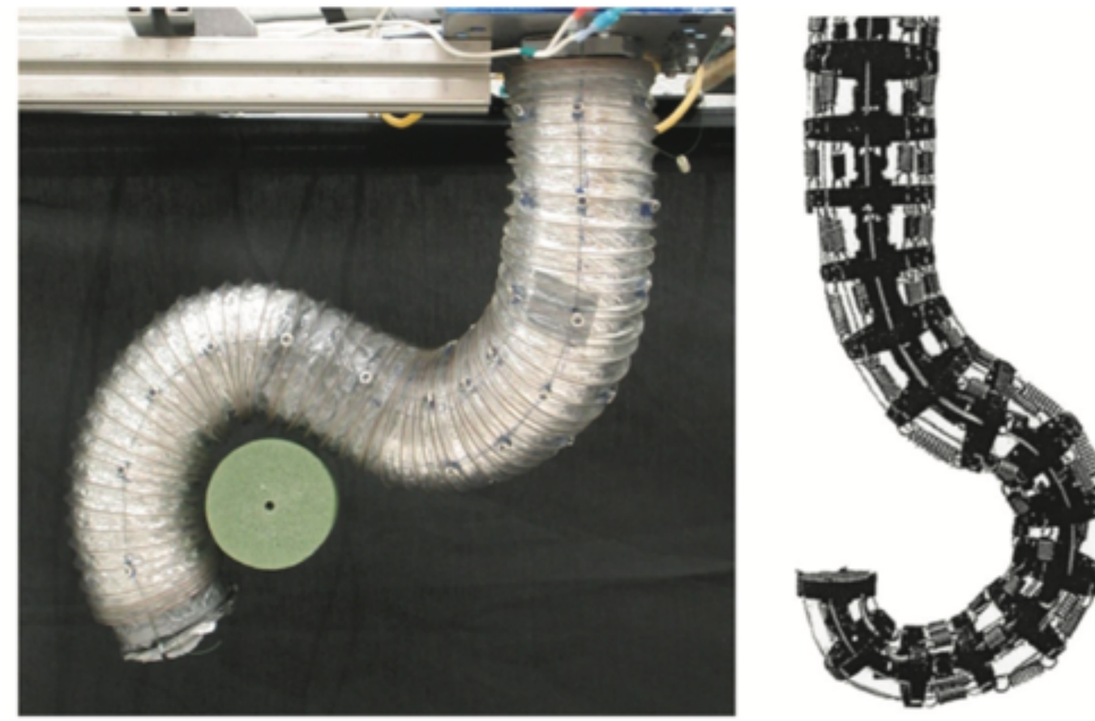
Fig. 1. (Left) The Tensor Arm of Anderson and Horn (1967) is generally regarded to be the first example of a hyperredundant robot. (Center) The subsequent work of Hirose (1993) was the first sustained research program in continuum and hyperredundant robots, beginning in the 1970s (image courtesy of Shigeo Hirose, and used by permission of Oxford University Press). (Right) An example of a modern continuum robot used for medical applications is the Hansen Medical Sensei® system, the kinematics and mechanics of which have been described by Camarillo et al. (2008) (image courtesy of David Camarillo, © 2008 IEEE).

Actuators include cables, flexible push rods, or pneumatic tubes.



push rod

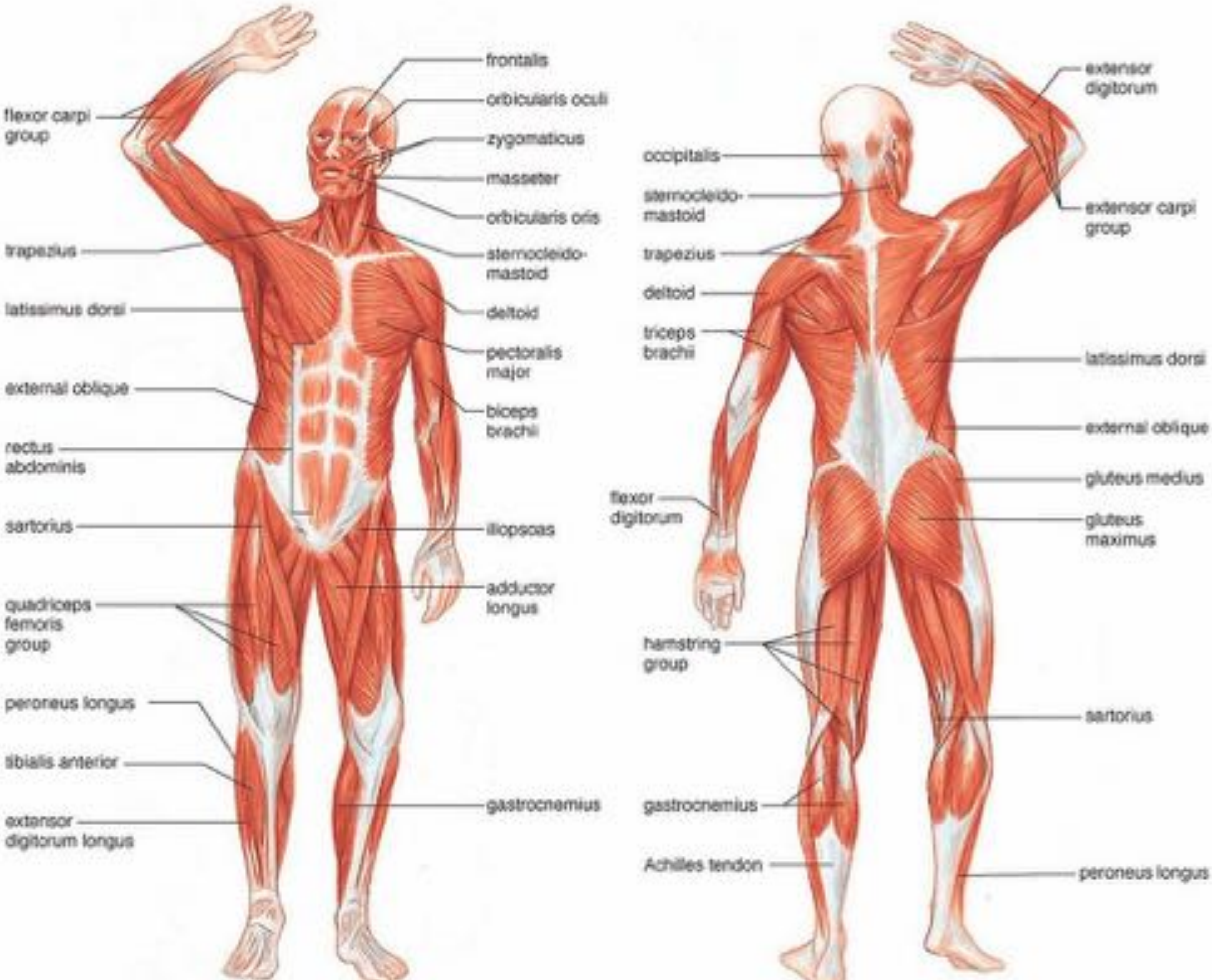
pneumatic



cable-driven

Robert J. Webster, III, Bryan A. Jones. Design and Kinematic Modeling of Constant Curvature Continuum Robots: A Review. International Journal of Robotics Research, 2010.
https://doi.org/10.1177/0278364910368147

Biological Muscle



a. Anterior view

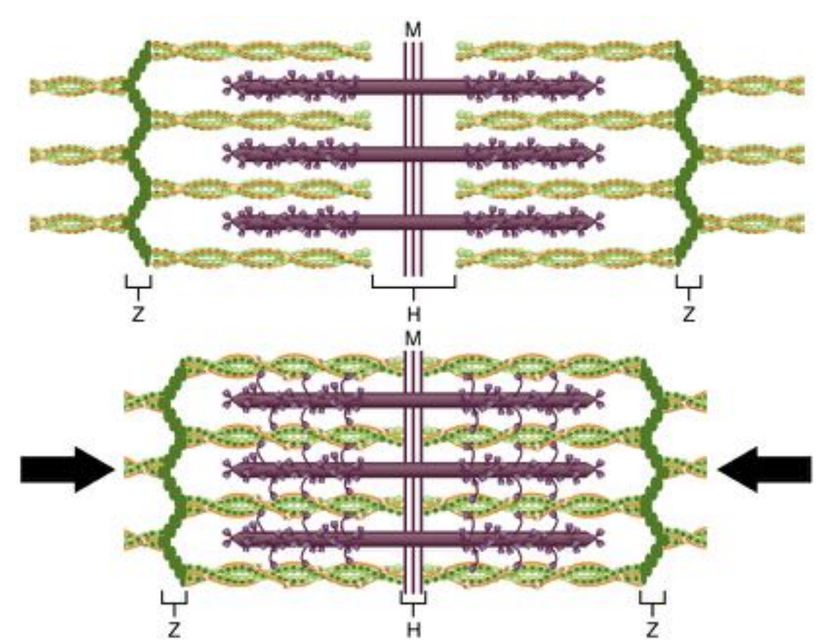
b. Posterior view

Muscle Types

- Muscles function to produce **force** and **motion**
- There are three types of muscle:
  - **skeletal** or striated
  - **cardiac**
  - **smooth**
- Muscle action is either **voluntary** or **involuntary**. Cardiac and smooth muscles contract without conscious thought and are termed involuntary, whereas the skeletal muscles contract upon command.
- Skeletal muscles are divided into **fast twitch** and **slow twitch** fibers.

Muscle contraction

- Muscle cells contain protein filaments of actin and myosin that slide past one another, producing a contraction that changes both the length and the shape of the cell.
- Muscles are predominantly powered by the oxidation of fats and carbohydrates, but anaerobic chemical reactions are also used, particularly by fast twitch fibers. These chemical reactions produce adenosine triphosphate (ATP) molecules that are used to power the movement of the myosin heads.
- The cross-sectional area of a muscle (rather than volume or length) determines the amount of force it can generate by defining the number of "sarcomeres" operating in parallel.



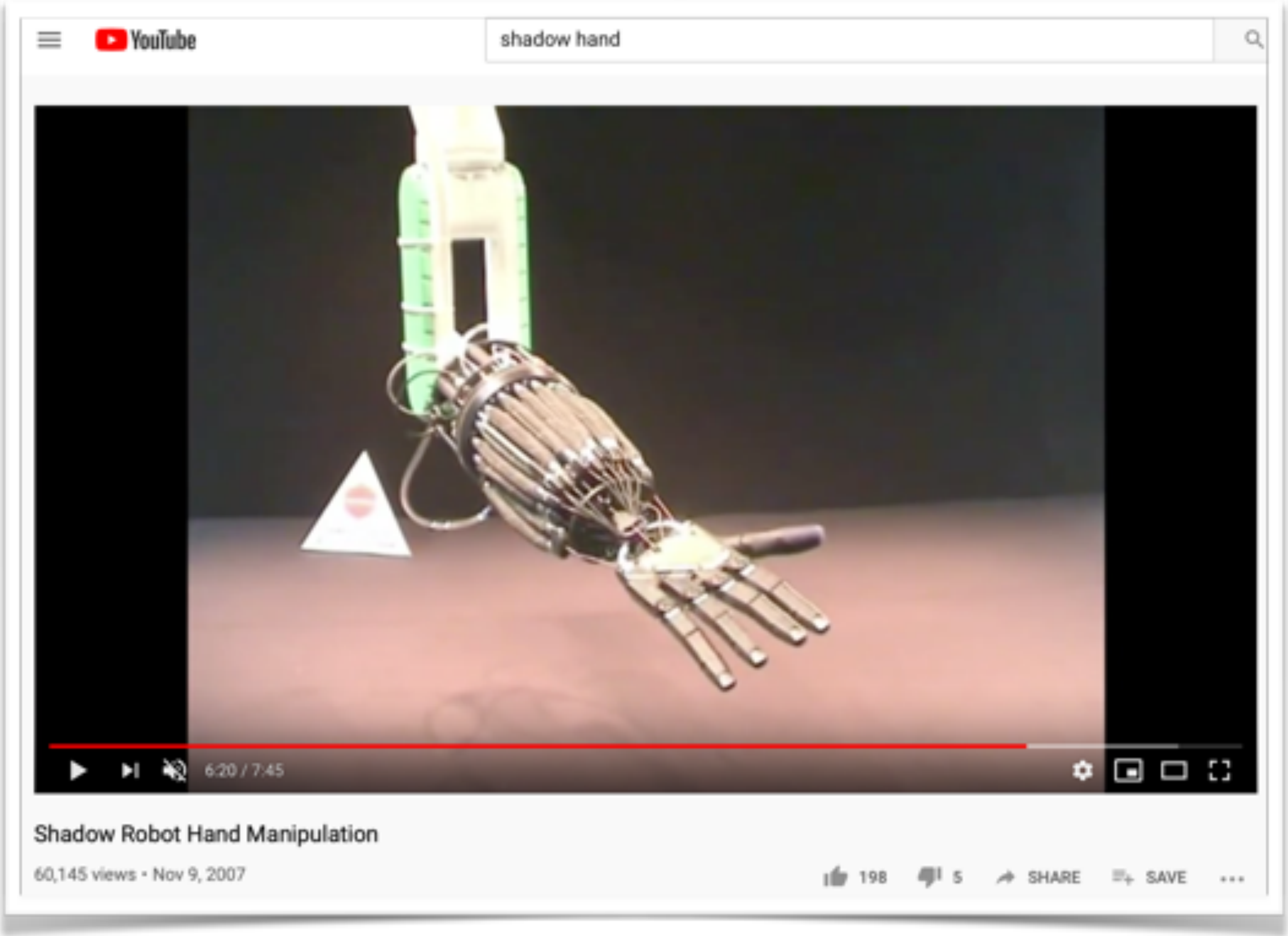
Pneumatic artificial muscles (PAMs)

PAMs

- Also known as McKibben Artificial Muscles (first developed for artificial limbs)
- Lightweight because their main element is a thin membrane
- Can also be hydraulically actuated

https://youtu.be/a6mRhuR_g-E

Shadow Hand

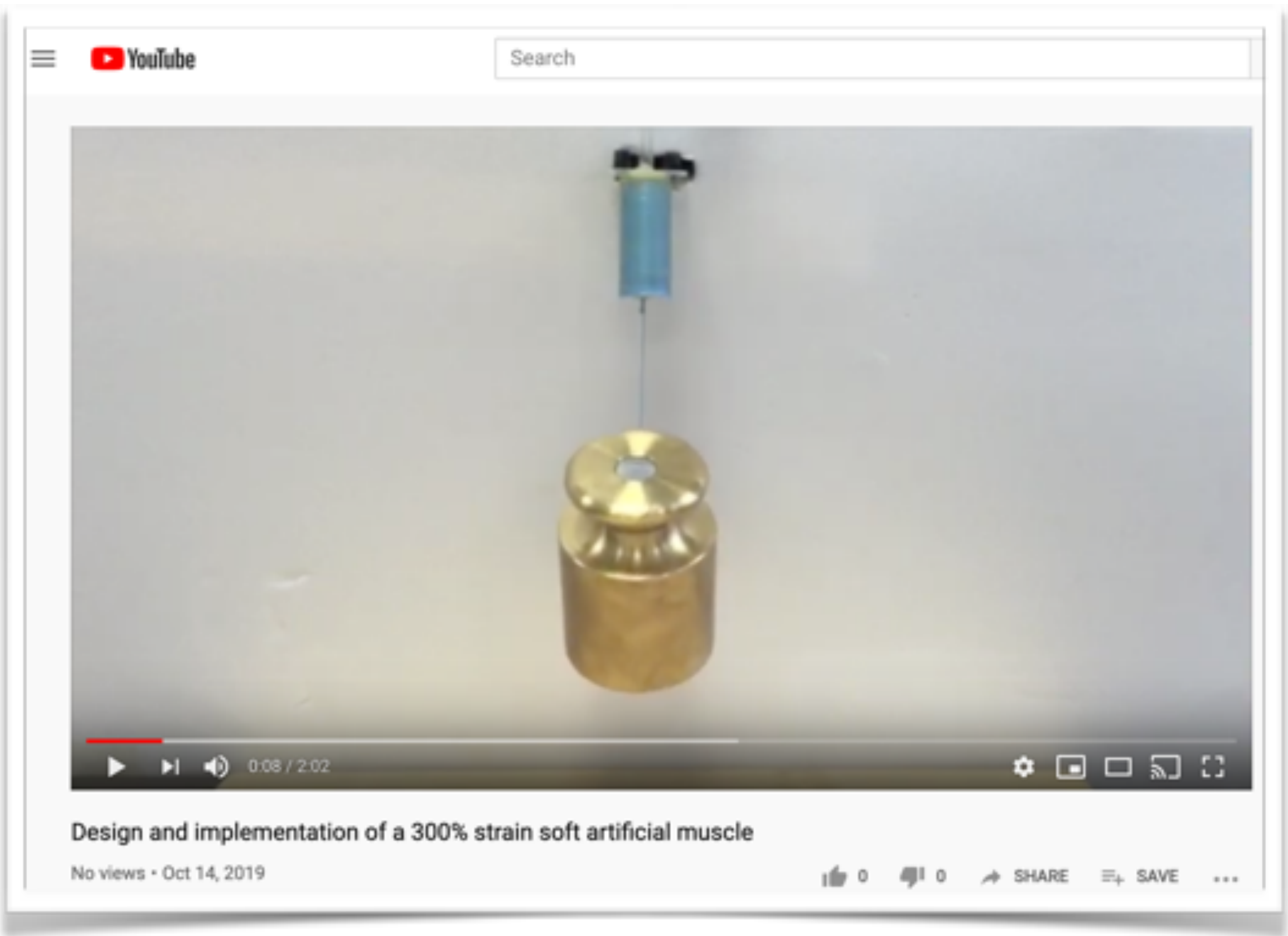


https://youtu.be/3ju4upwhdvM

https://youtu.be/jBgeoJsDWqE

Alternative: IPAMs

Inverse Pneumatic Artificial Muscles



https://youtu.be/Ssfr_HCcz-0

To Do

- Take over a lab bench with your partner (see next slide).

- Read the lab handout first, including the questions!

- Work on the lab for the rest of today and Thursday.

- Answer the questions in your lab notebook (clearly label it with the date and "Lab 3"). Turn in the lab notebook by the end of class on Thursday, or let us know if you need more time/help.

Groups of two for Lab 3

1	Leena	Josue
2	Caroline	Ellie
3	Brian	Nadin
4	Tomas	Youngju
5	Sochima	Angelo
6	Cherié	Alana
7	Nick	Huy
8	Senkai	Emma