ME 23N: Soft Robots for Humanity
Autumn 2019

Week 3:
Particle jamming
and creating stiffness change

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Lab 1 recap: Localized compliance and bending, shape memory alloys

Jumper

1. Describe/speculate on how the SMA jumper works
2. What would improve the jump height?
3. What else could you use SMA for in a similar fashion? What are the downsides?

Crawler

4. What is the function of the feet on the crawler?
5. What else could you use SMA actuation like seen in the crawling robot for? What are the downsides?
6. Contrast the function of the SMA and rubber band in the jumper and the crawler.

…for Humanity?

8. What are the **implications** of SMA actuation?

   you can make devices that are small, lightweight, and slow

   What are the possible **benefits to society** that could be achieved using SMAs?

   assistive devices
   mechanisms for surgery
   devices for spying?

   What are the **downsides** of SMAs, ethical or environmental?

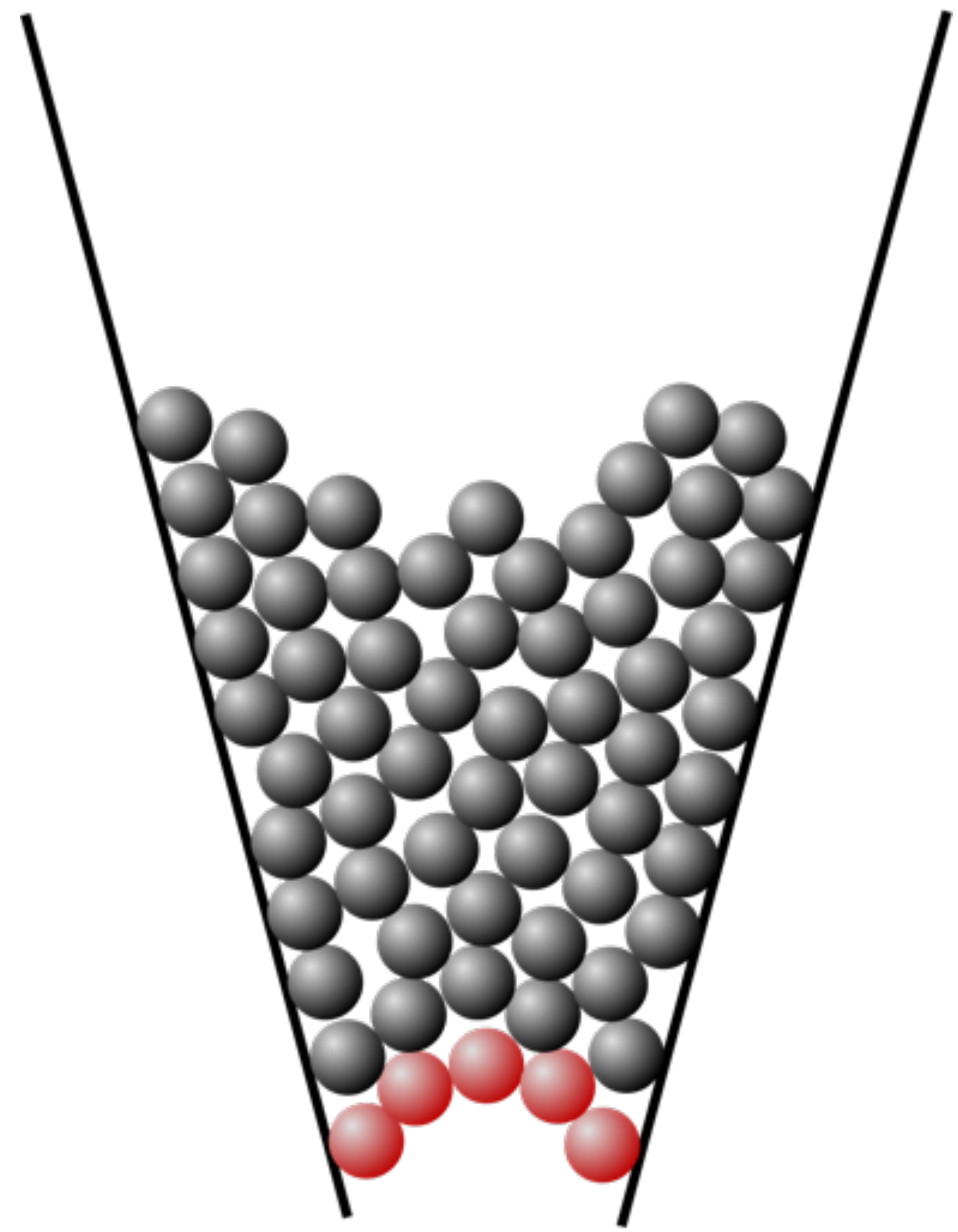
   energy efficiency poor
   manufacturing waste?
   do we consider history?

9. Any other thoughts?

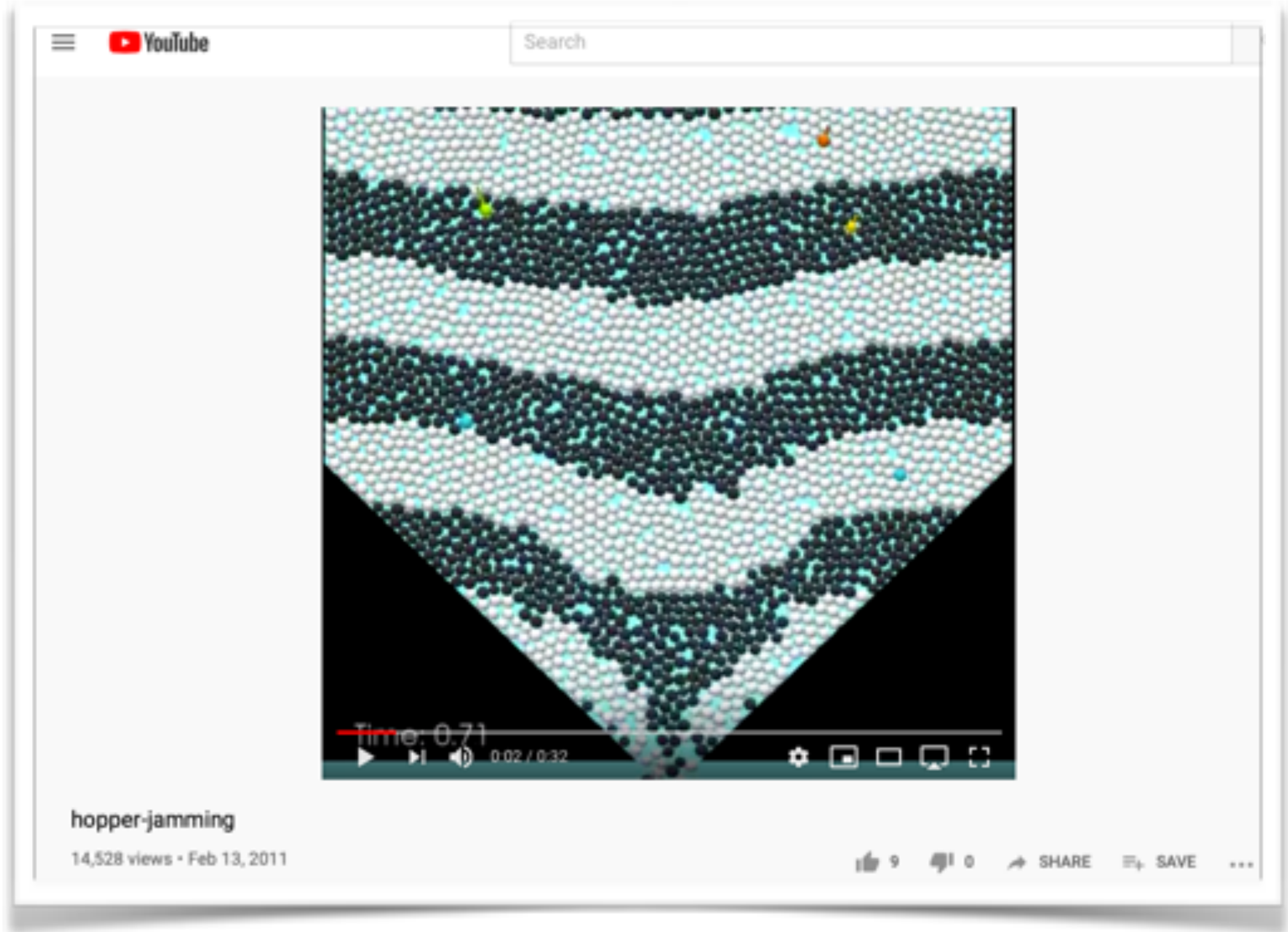
Particle Jamming

Jamming is the physical process by which the **viscosity** of some **mesoscopic** materials, such as granular materials, glasses, foams, polymers, emulsions, and other complex fluids, increases with increasing particle density.

One way to increase the density is by applying a **vacuum.**

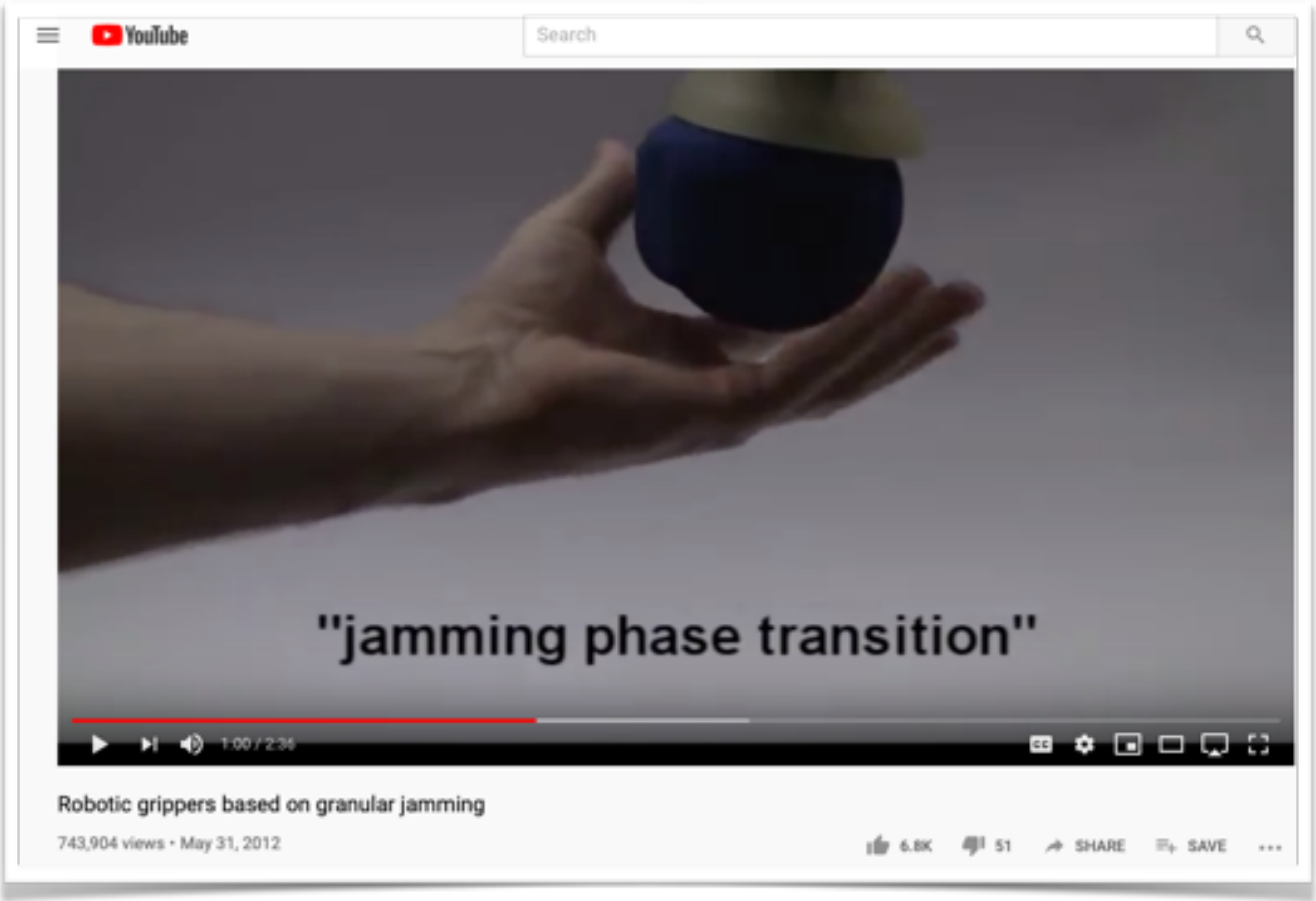


Example: Jamming in a Hopper



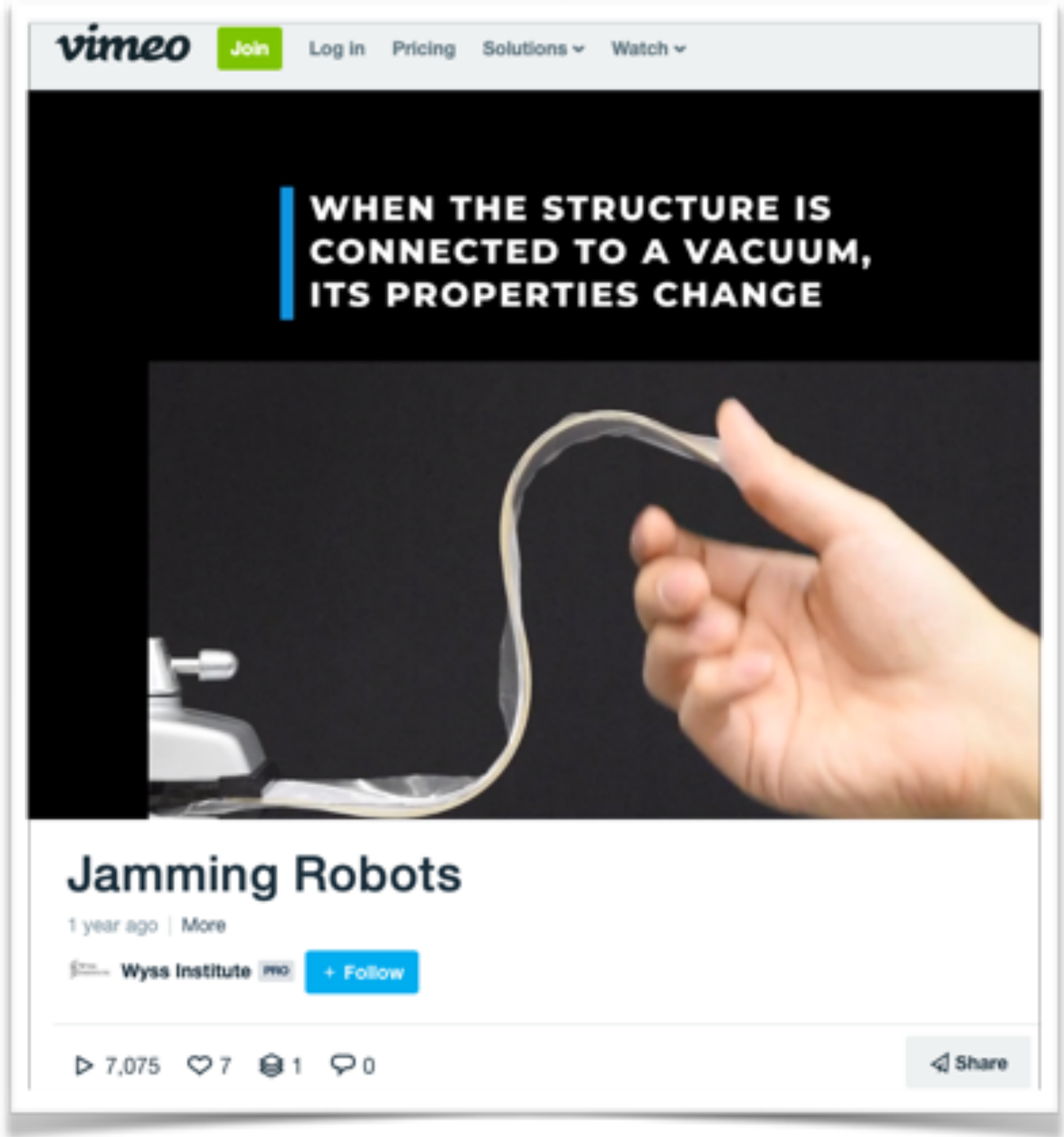
https://youtu.be/lWSJwZhqoQw
https://youtu.be/fPpdBKhx84o

Example: Vacuum Jamming



https://www.youtube.com/watch?v=ZKOI_IVDPpw

Alternative: Layer Jamming

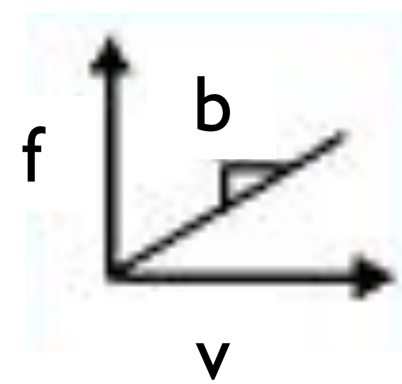


https://vimeo.com/267446388

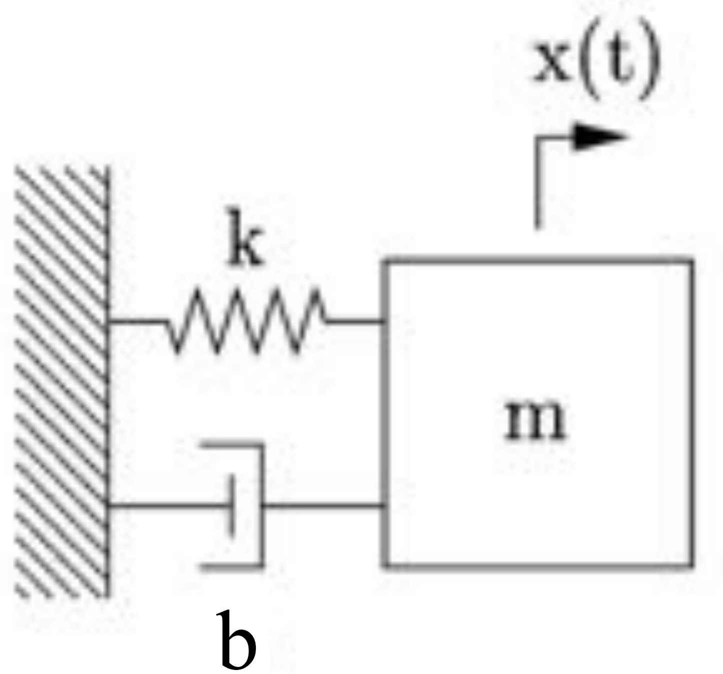
Viscosity and Friction

Viscosity = Damping = Linear Friction

$$f = bv$$



(compare to stiffness: $f=kx$)



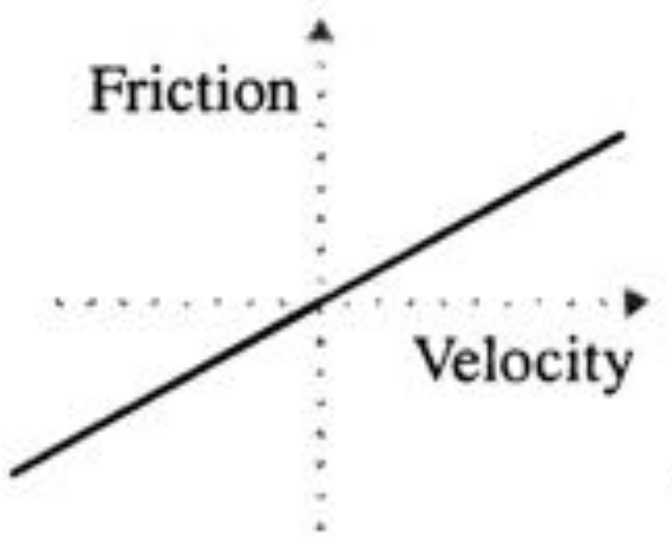
f is the force

b is the viscosity/damping/linear friction

v is the velocity of the material ($v = dx/dt$)

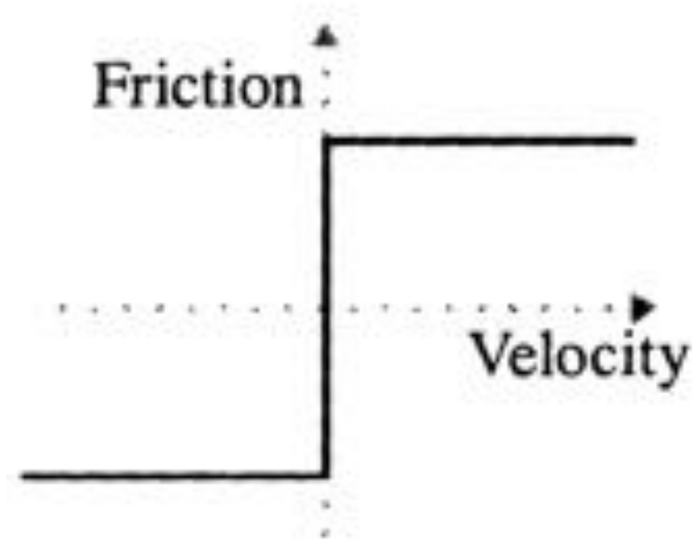
Coulomb (non-linear) Friction

Linear friction



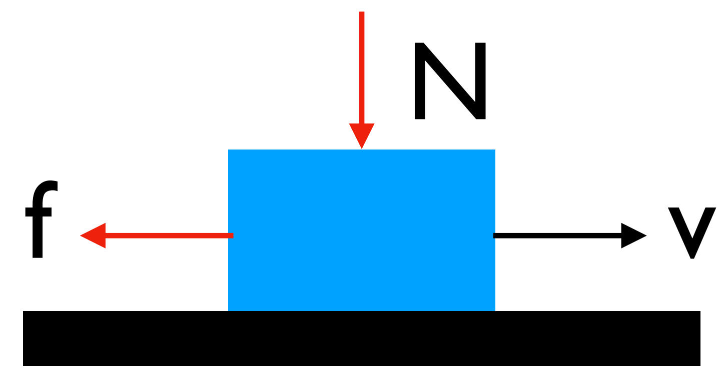
$$f = bv$$

Coulomb friction



$f = \mu * N$ for $v>0$

$f = -\mu * N$ for $v<0$



Static vs. Dynamic Friction

In some cases the friction is higher until movement occurs, then it drops to a lower value.

Before movement, it is **static friction** (also called **stiction**)

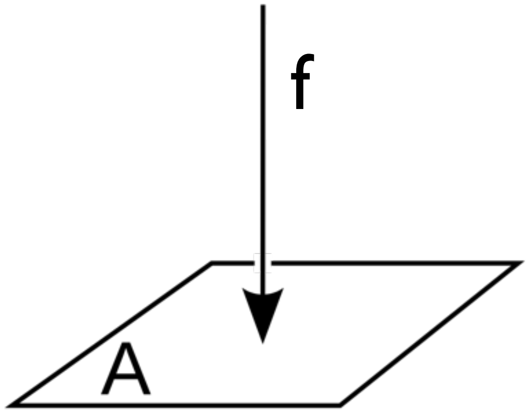
During movement, it is **dynamic friction**

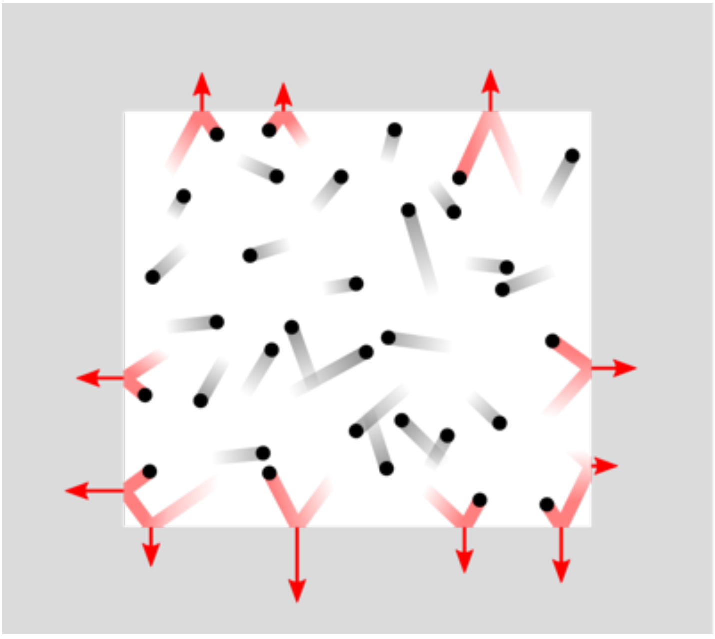
Vacuum

Pressure

Pressure is the force applied perpendicular to the surface of an object per unit area over which that force is distributed.

$$p = f/A$$





The SI unit for pressure is the pascal (Pa), equal to one newton per square metre (N/m^2, or $kg \cdot m^{-1} \cdot s^{-2}$)

Gauge pressure (or gage pressure) is the pressure relative to the ambient pressure.

Vacuum is space devoid of matter

An approximation to such vacuum is a region with a gaseous pressure much less than atmospheric pressure.

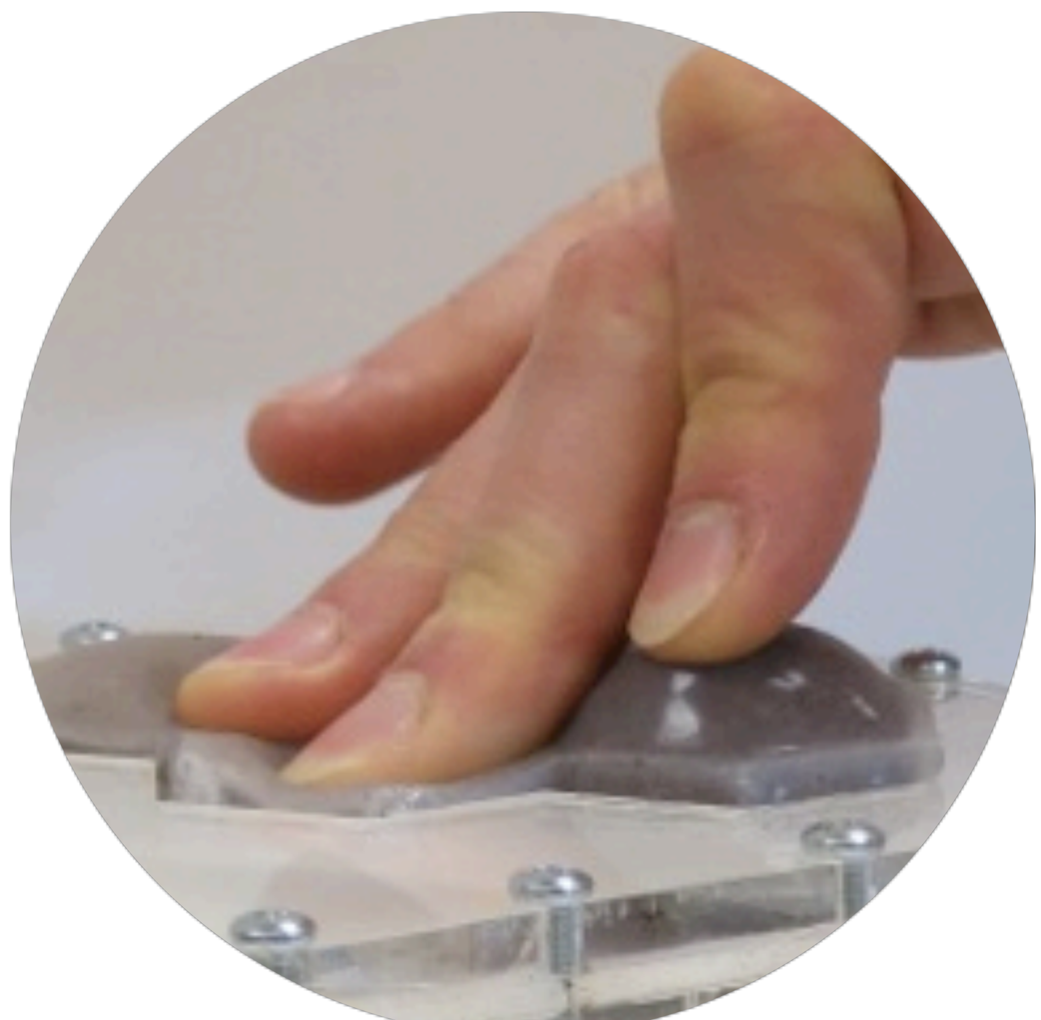
We will use a tool to apply a vacuum to a small enclosed volume with air and particle inside. (We only suck out the air, not the particles!)

Units for Vacuum

Vacuum quality	**Torr**	**Pa**	**Atmosphere**
Atmospheric pressure	760	1.013×10^{5}	1
Low vacuum	760 to 25	1×10^{5} to 3×10^{3}	9.87×10^{-1} to 3×10^{-2}
Medium vacuum	25 to 1×10^{-3}	3×10^{3} to 1×10^{-1}	3×10^{-2} to 9.87×10^{-7}
High vacuum	1×10^{-3} to 1×10^{-9}	1×10^{-1} to 1×10^{-7}	9.87×10^{-7} to 9.87×10^{-13}
Ultra high vacuum	1×10^{-9} to 1×10^{-12}	1×10^{-7} to 1×10^{-10}	9.87×10^{-13} to 9.87×10^{-16}
Extremely high vacuum	$< 1\times10^{-12}$	$< 1\times10^{-10}$	$< 9.87\times10^{-16}$
Outer space	1×10^{-6} to $< 1\times10^{-17}$	1×10^{-4} to $< 3\times10^{-15}$	9.87×10^{-10} to $< 2.96\times10^{-20}$
Perfect vacuum	0	0	0

Low vacuum is often measured in millimeters of mercury (mmHg) or pascals (Pa) below standard atmospheric pressure. "Below atmospheric" means that the absolute pressure is equal to the current atmospheric pressure.

Particle Jamming Example: Hands-on Haptic Medical Simulation



Medical Simulation

Laerdal's SimMan

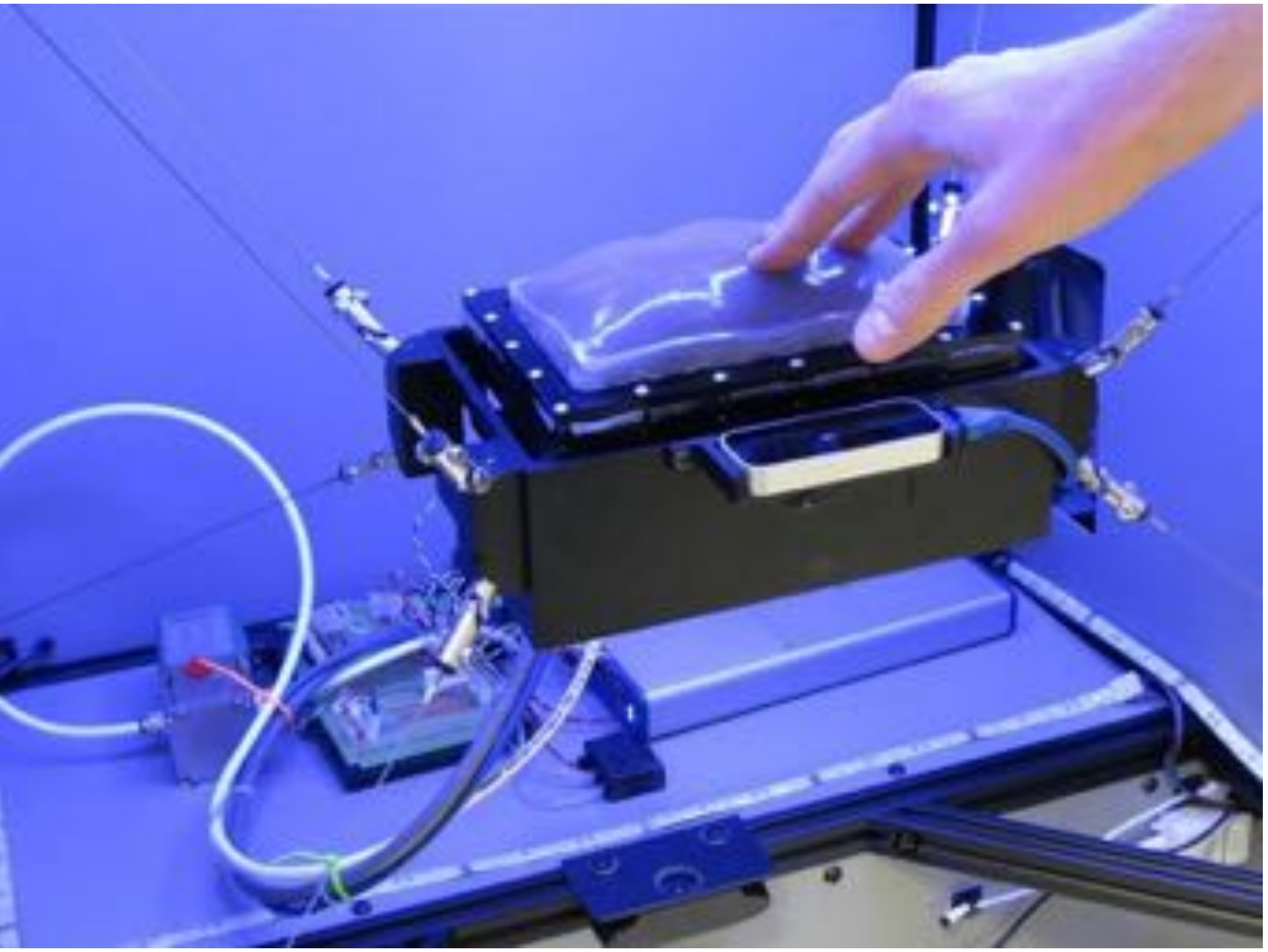
Phantom Desktop

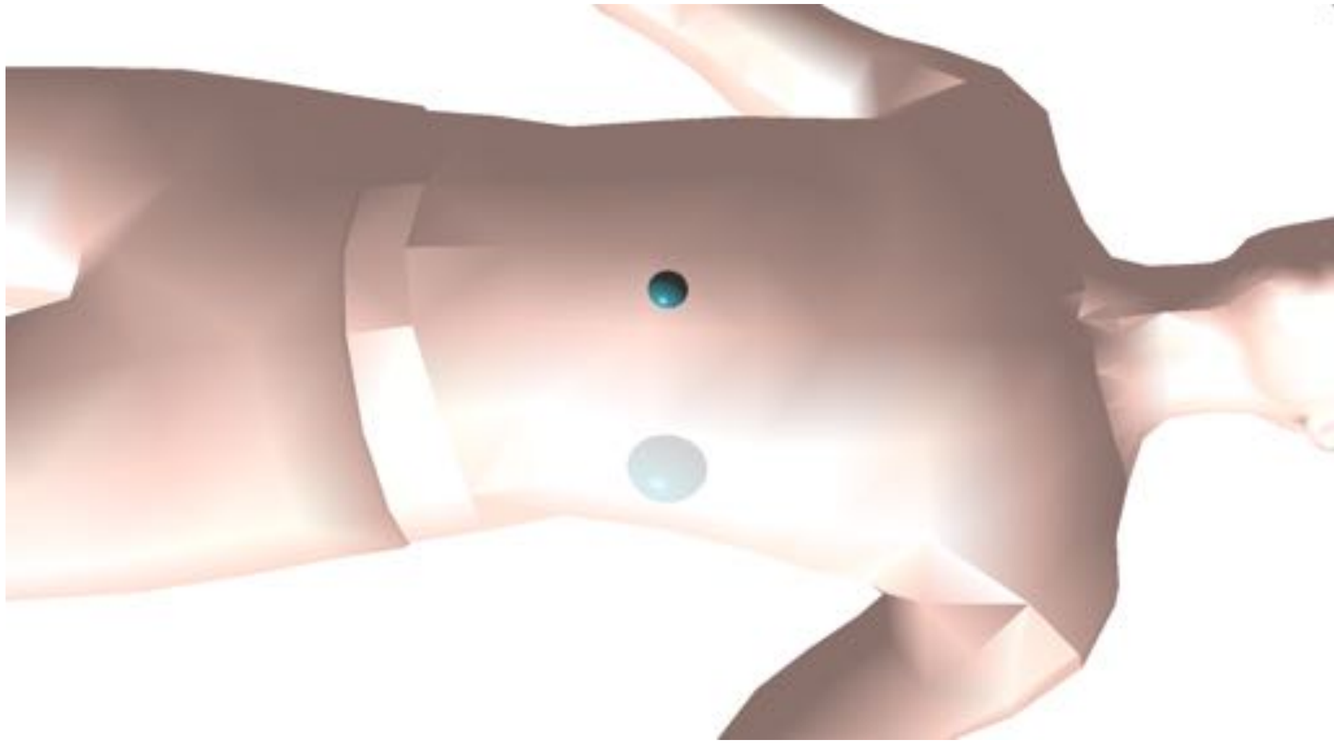
Mannequins:
mostly passive,
tactile, multi-contact

Tool-based
interaction: active,
programmable forces

Can we have the best of both worlds?

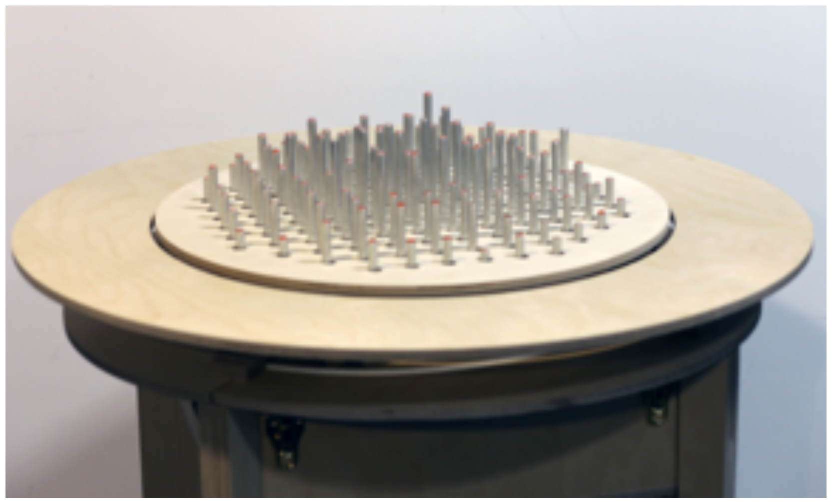
Encountered-Type Medical Simulator

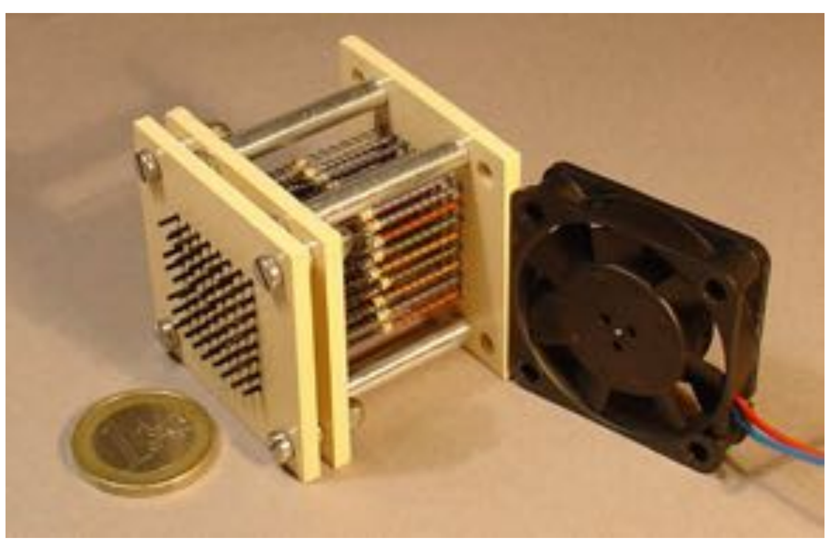


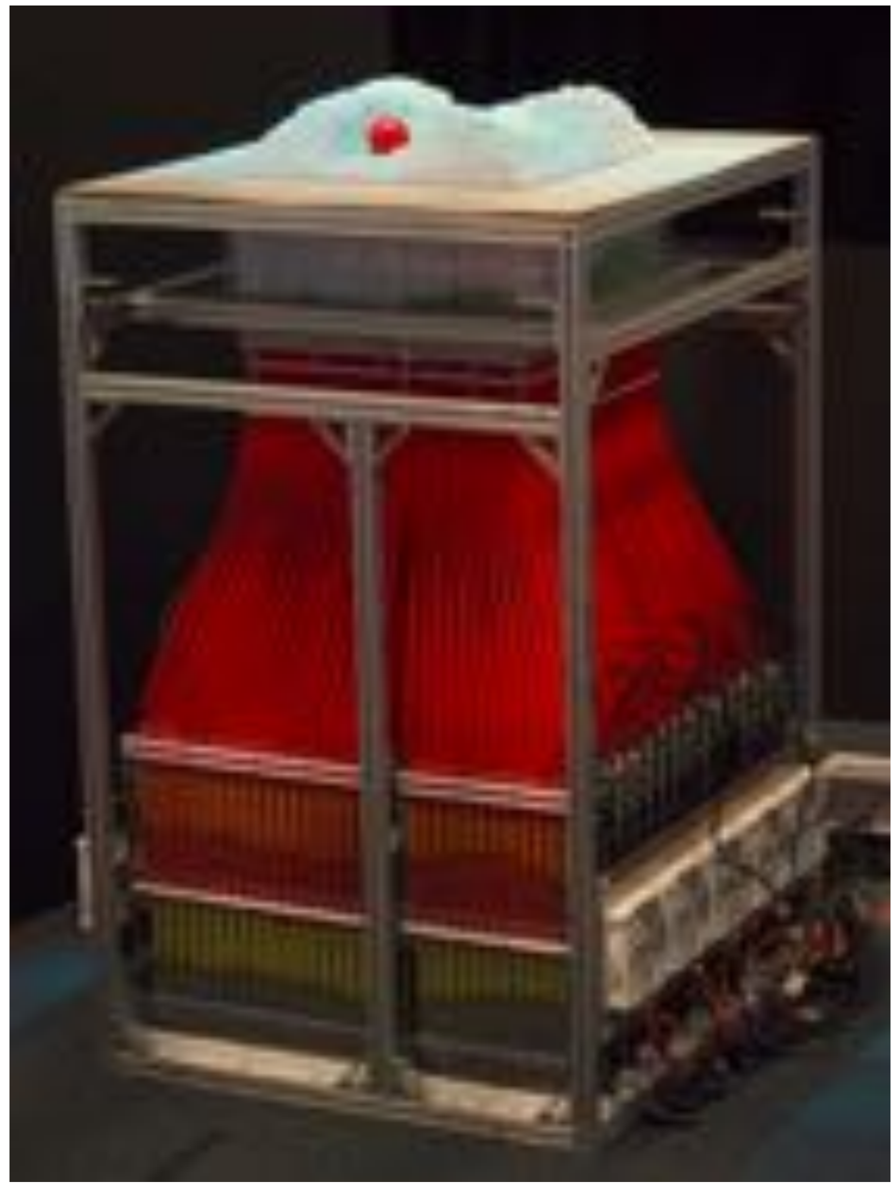


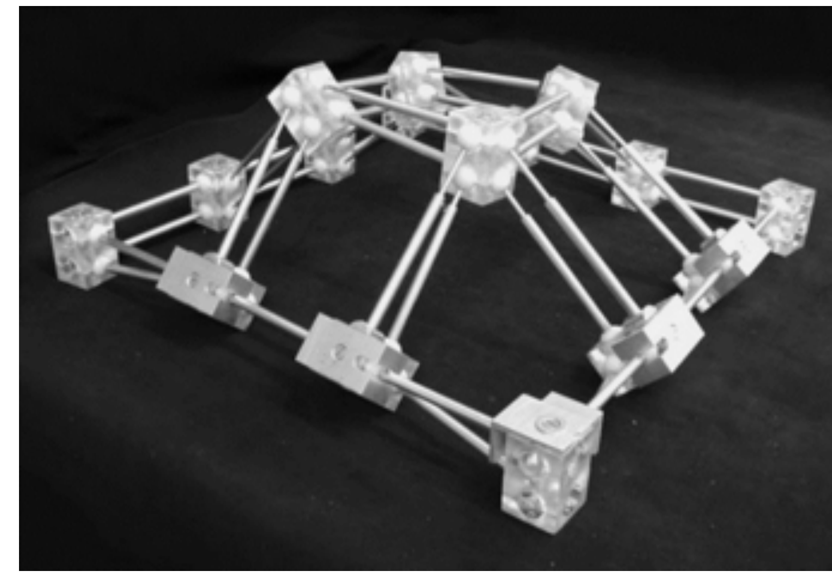
Stanley & Okamura Eurohaptics 2014

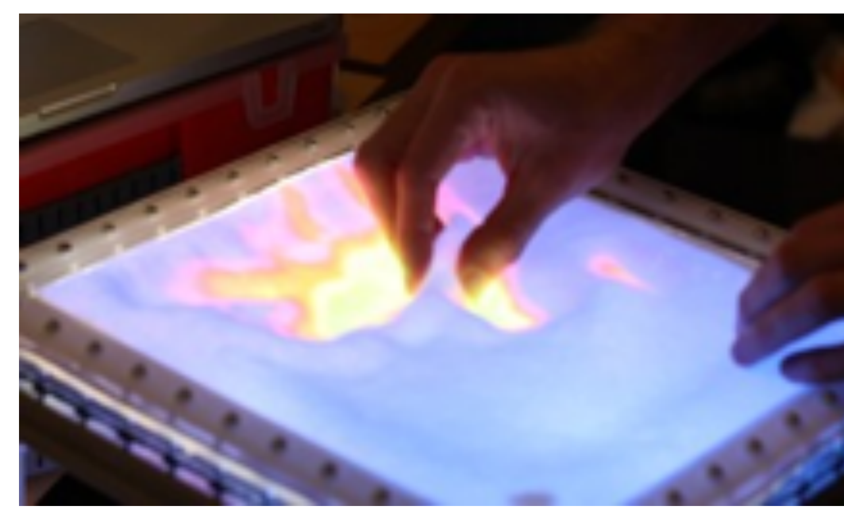
Pin Arrays and Crusts


Leithinger et al. 2010

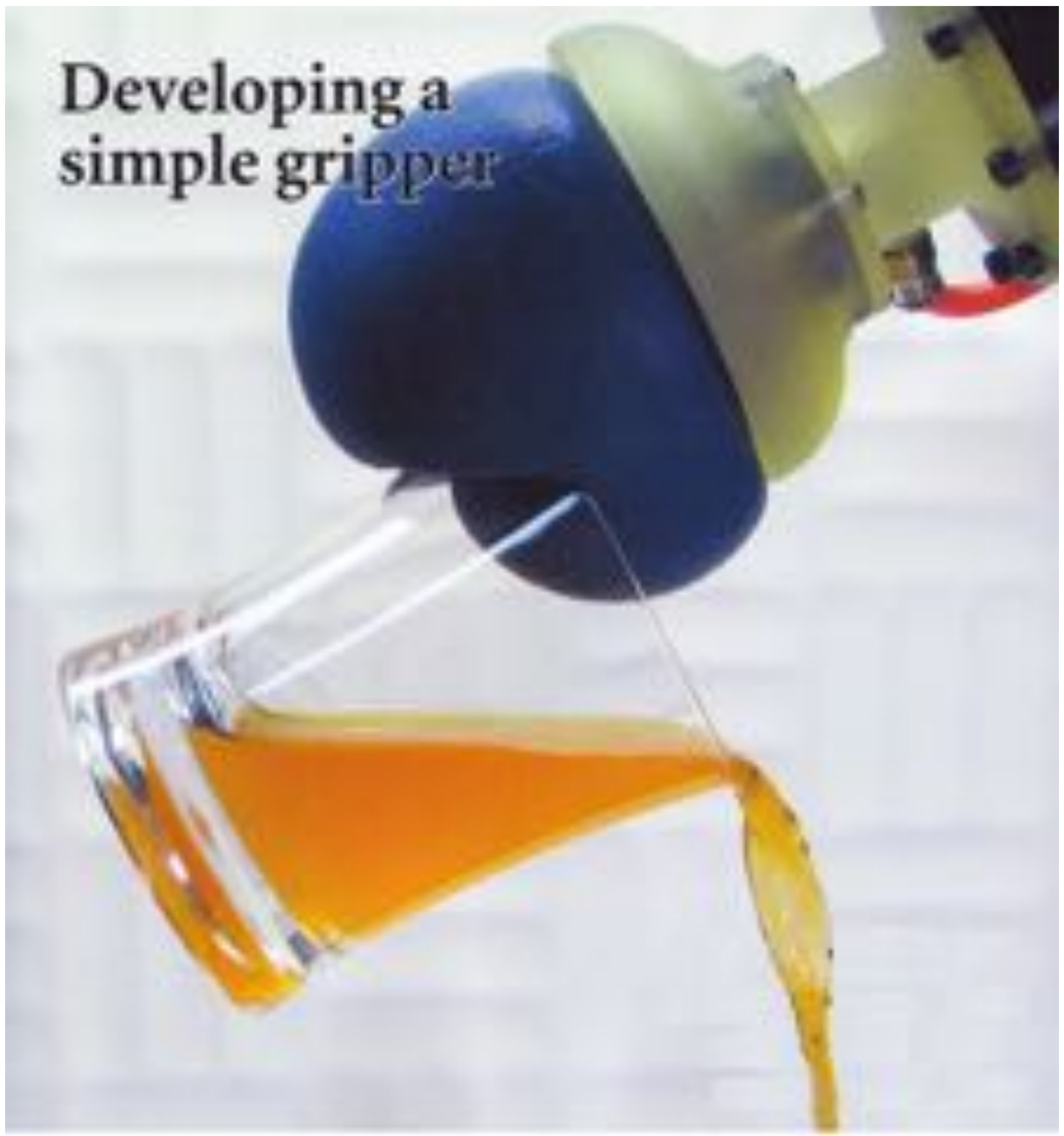

Velazquez et al. 2005


Follmer et al. 2013


Mazzone et al. 2003


Follmer et al. 2012

Particle Jamming

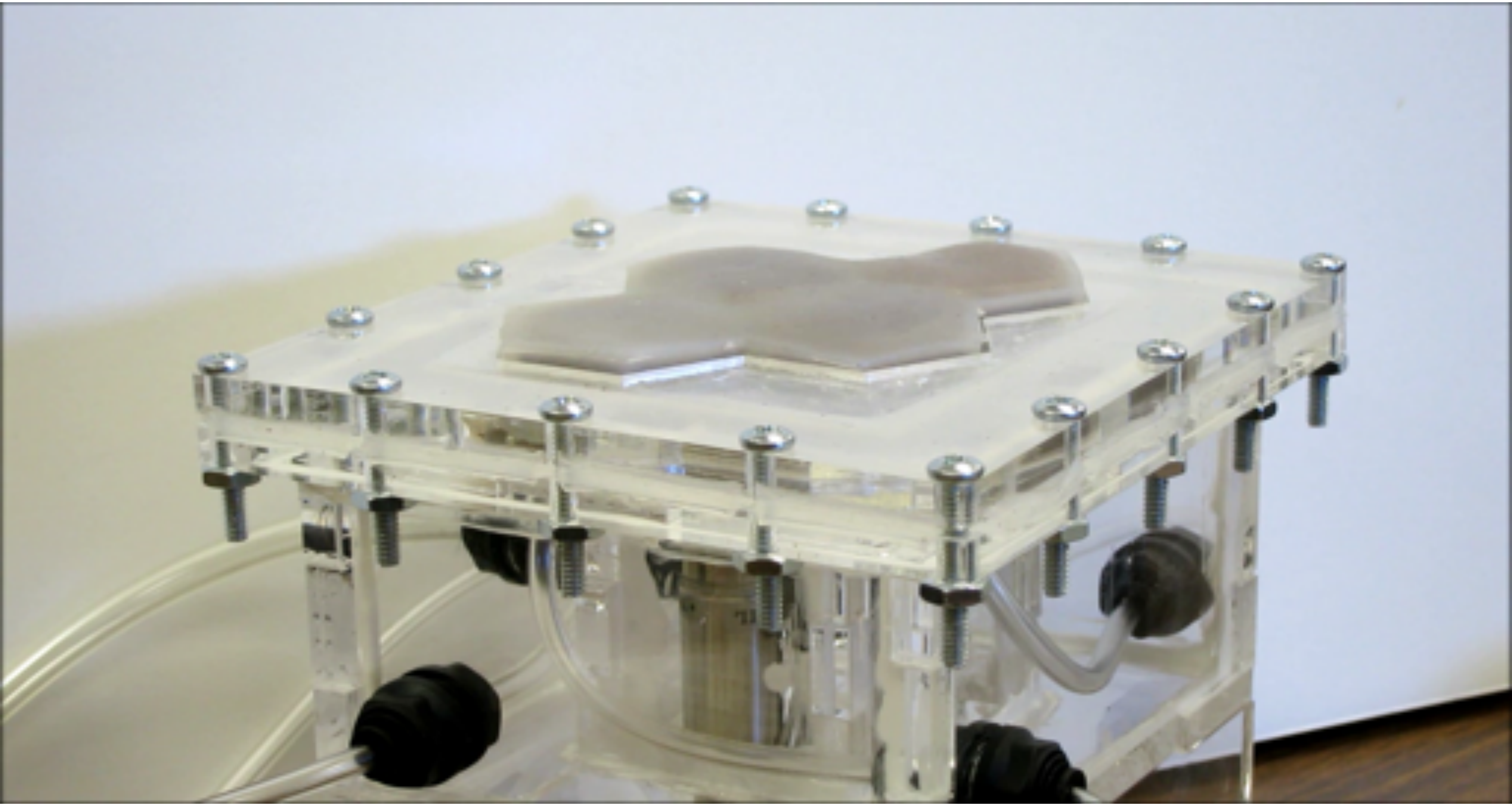


Brown et al. 2010

Cheng et al. 2012

Steltz et al. 2009

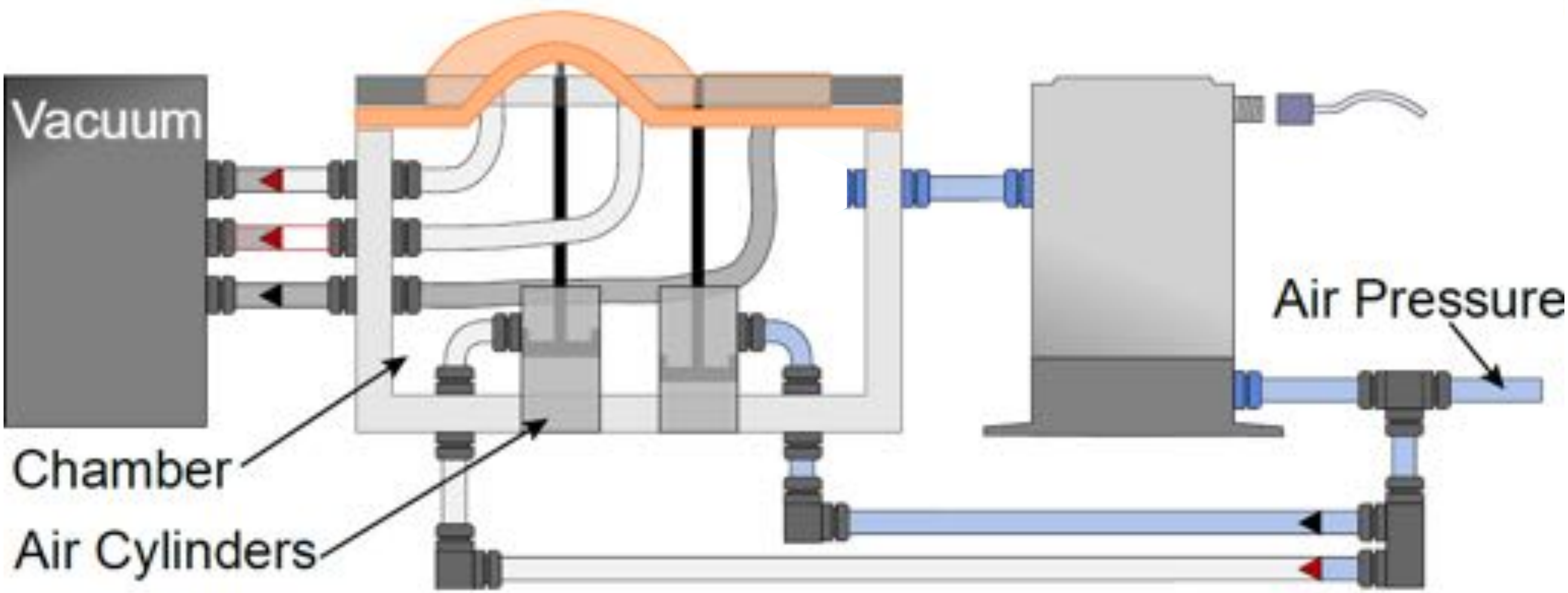
Haptic Jamming: Four-Cell Surface



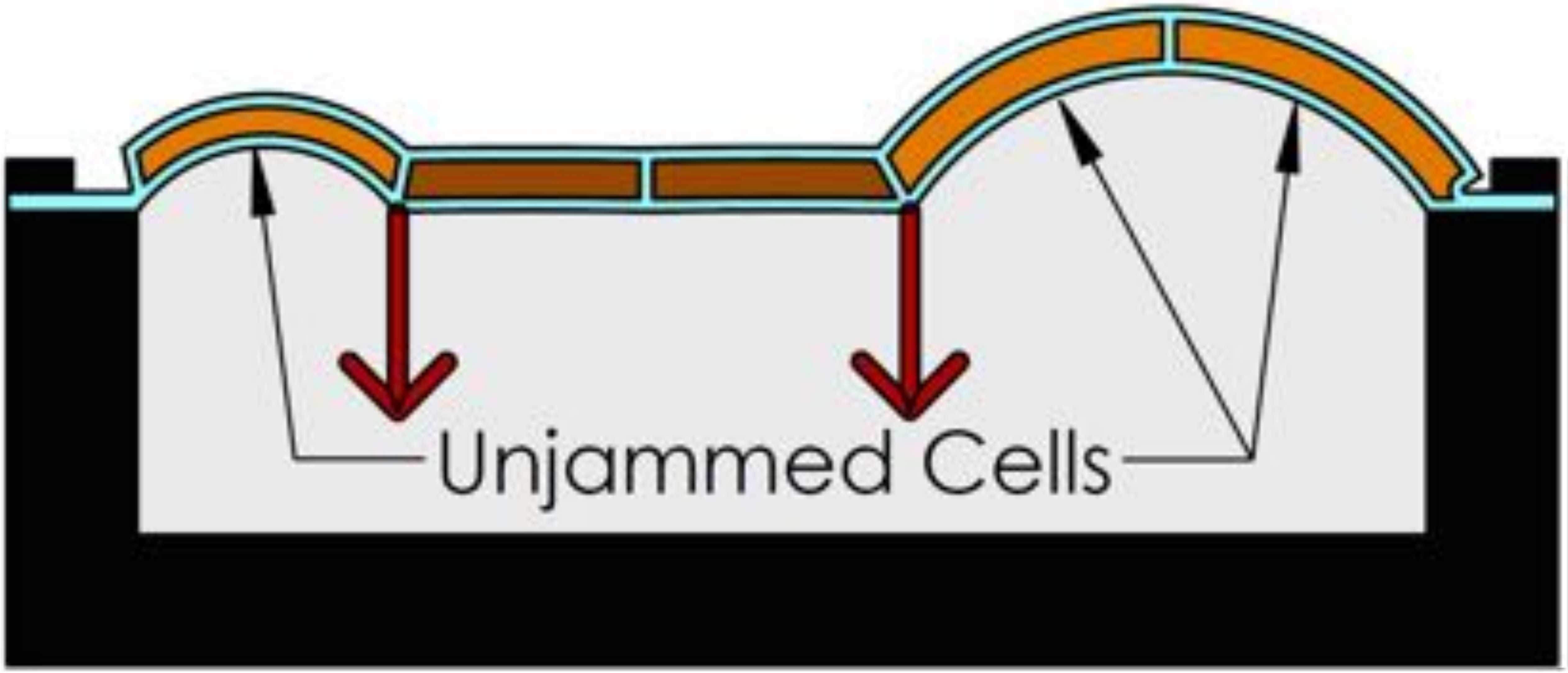
Video is real time

Stanley et al. MMVR 2013

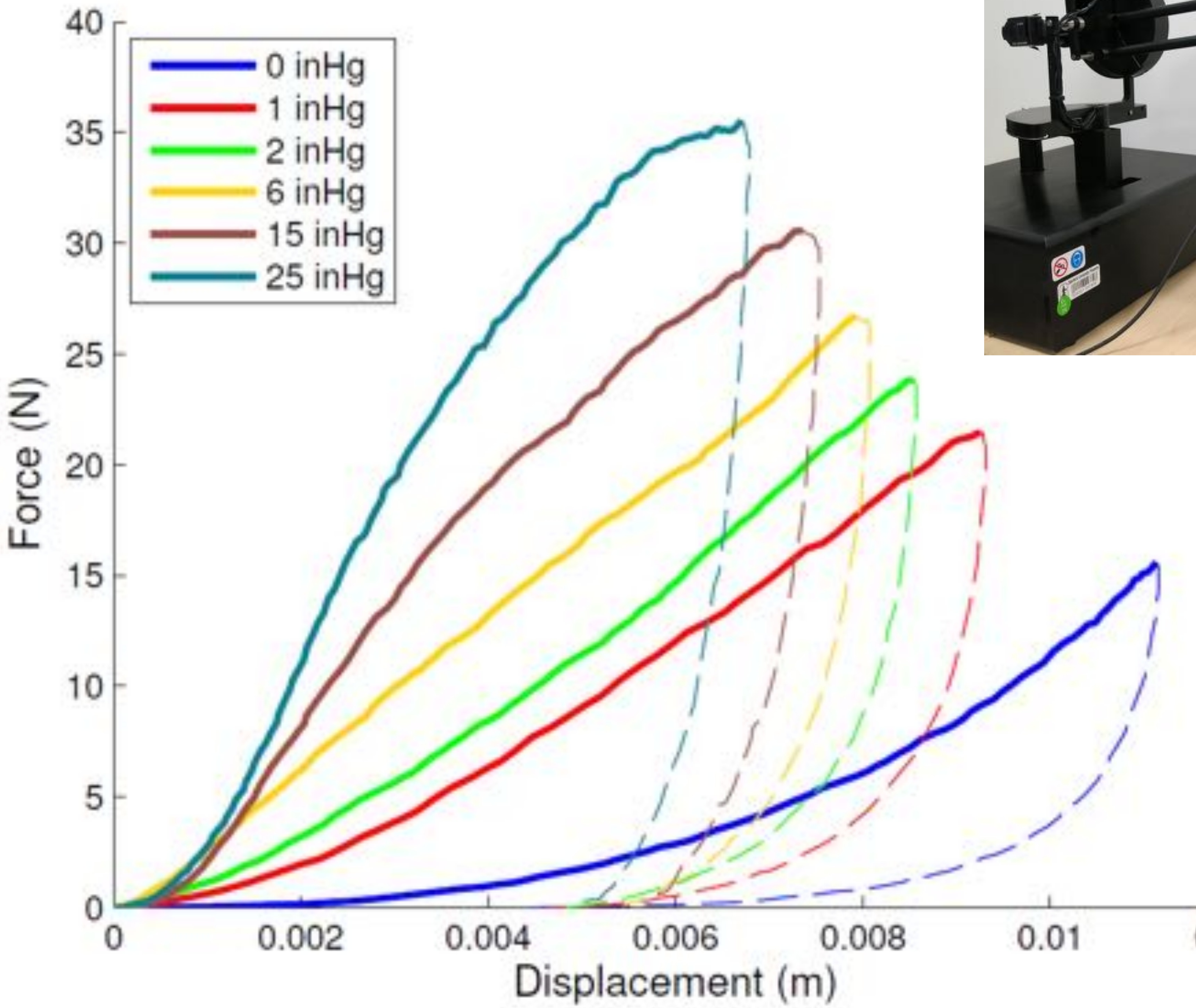
Haptic Jamming Actuation

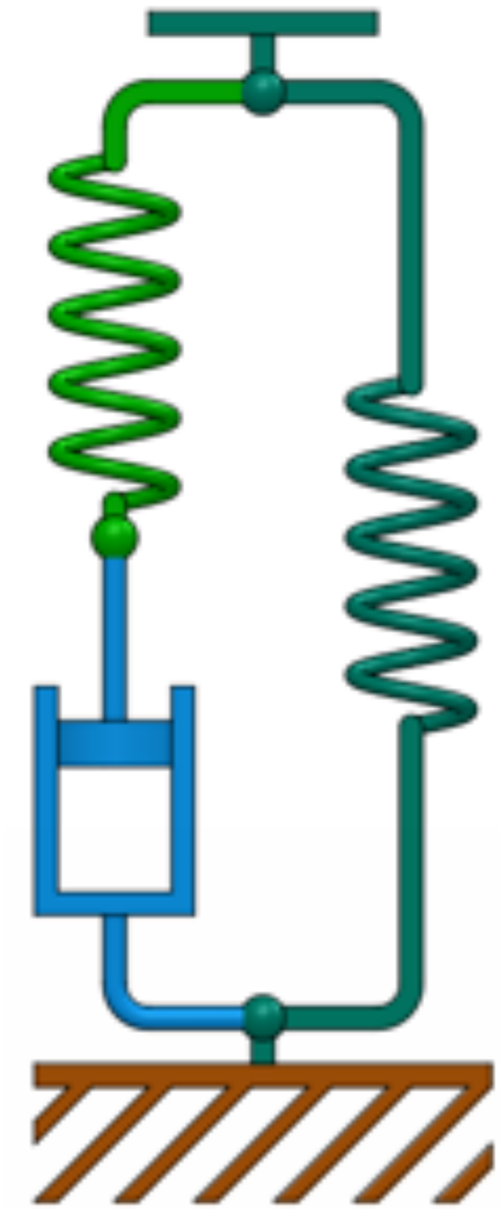


Haptic Jamming Actuation



Mechanical Properties

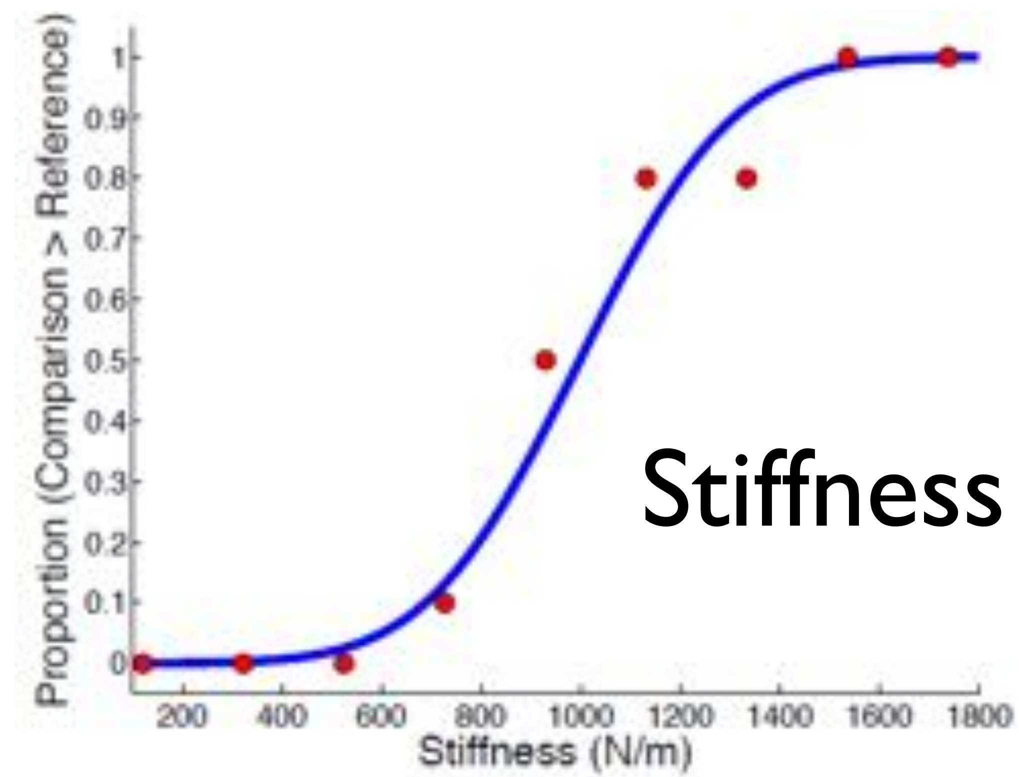


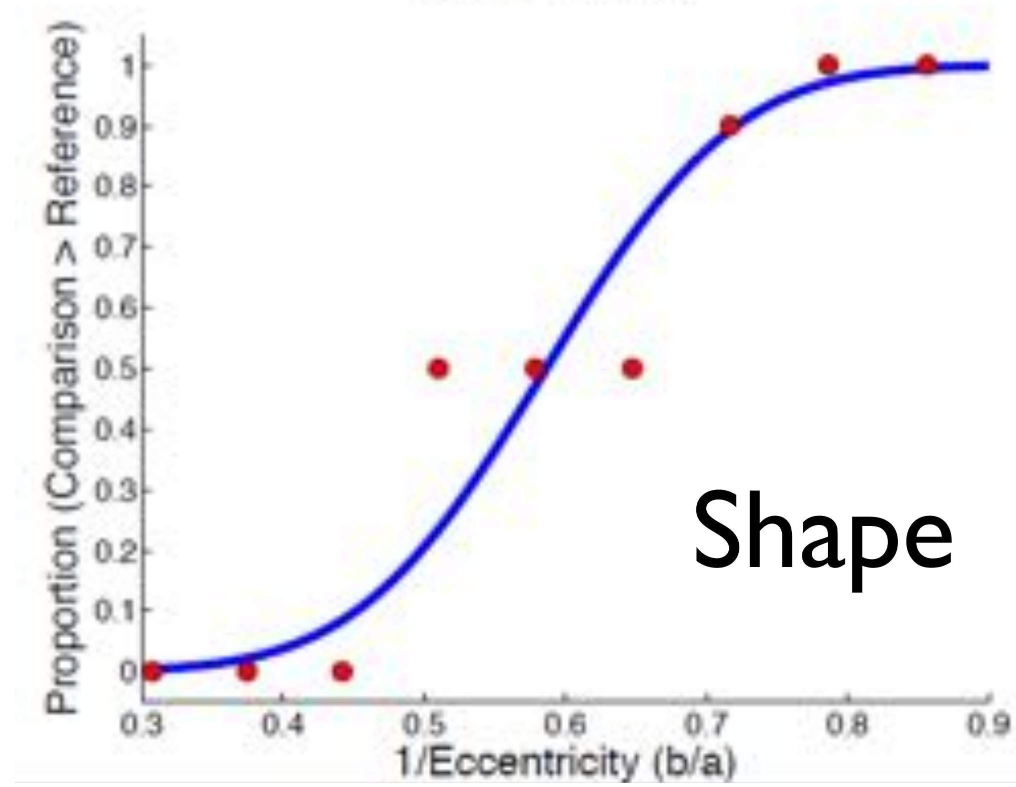


Zener (standard linear solid)

Stanley & Okamura ToH 2014

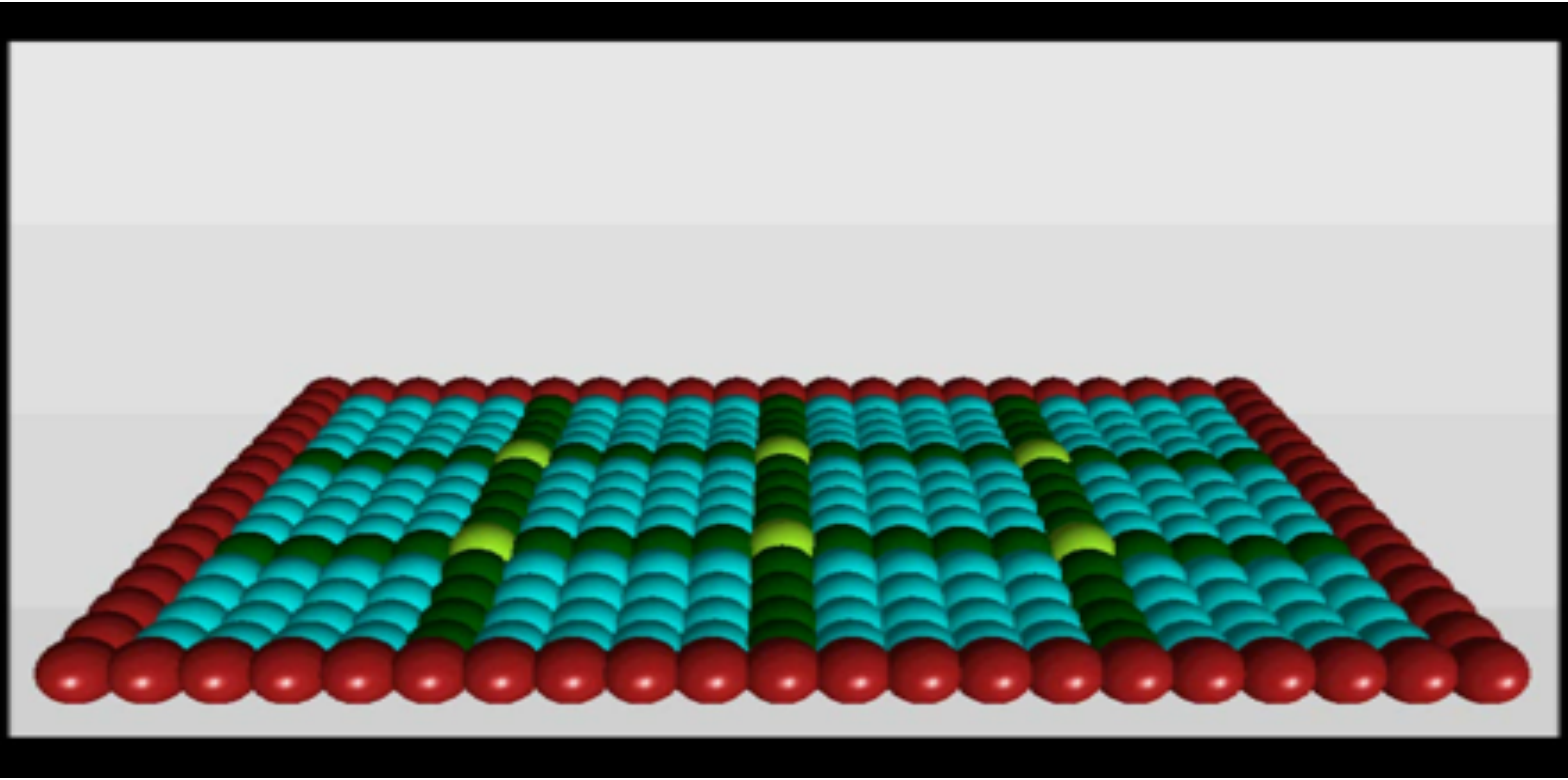
Perception





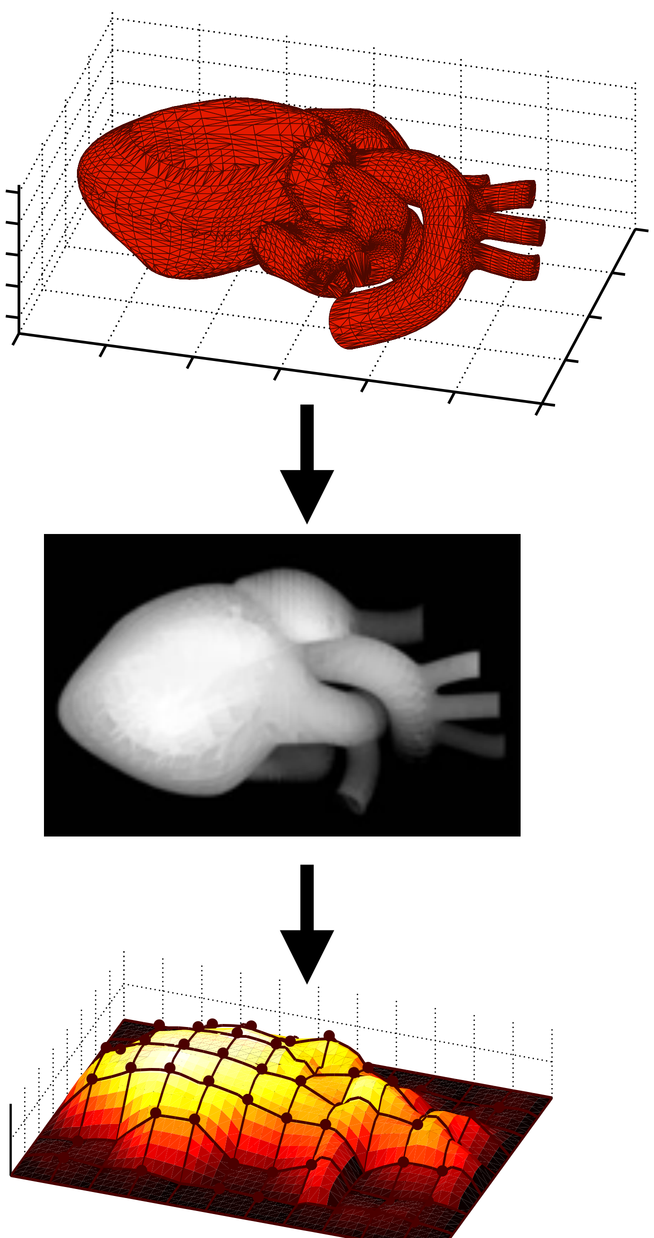
Genecov et al. Haptics Symp 2014

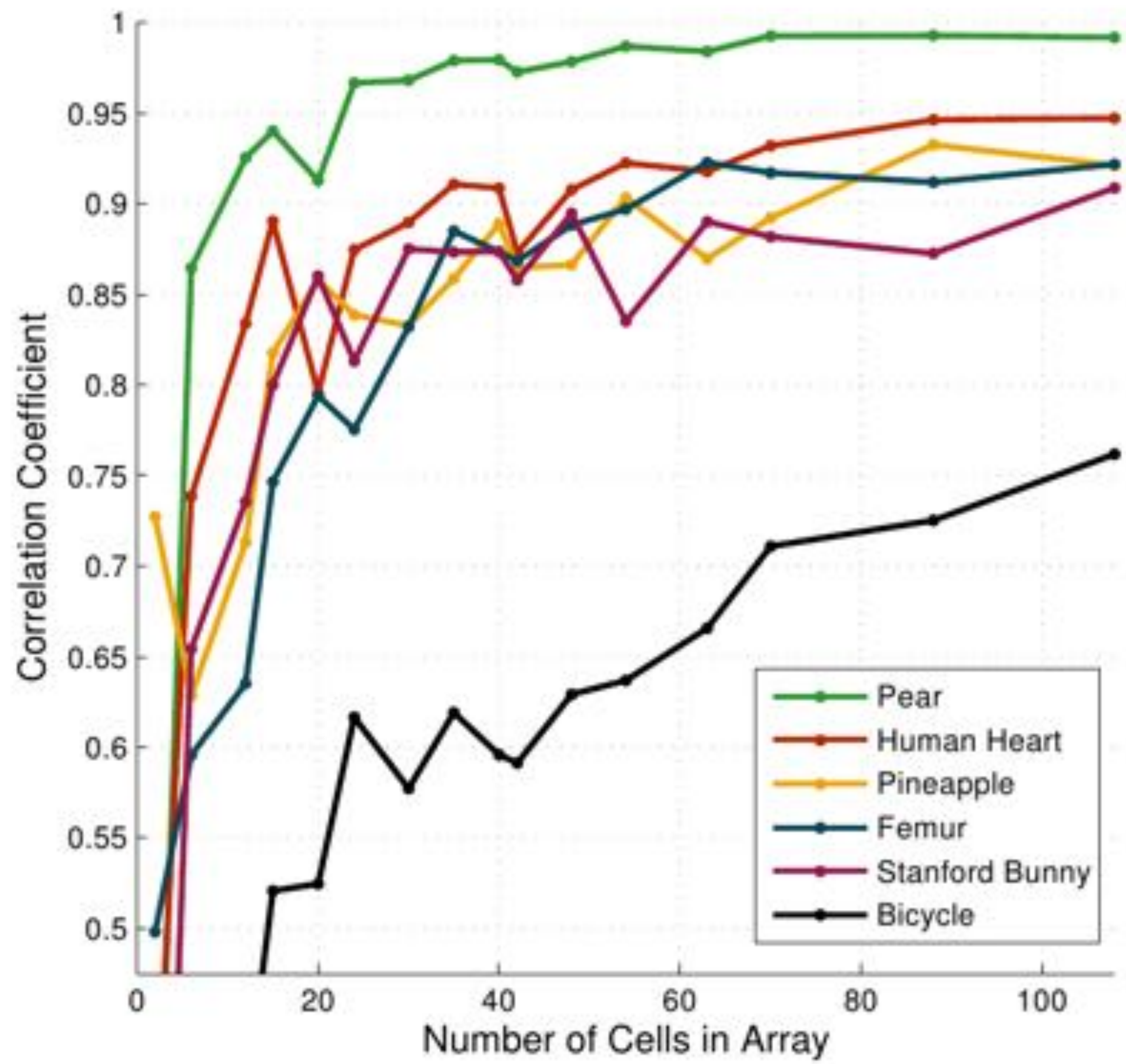
Shape Simulation



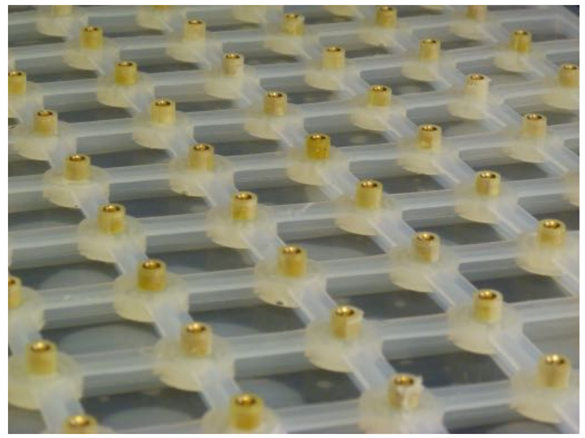
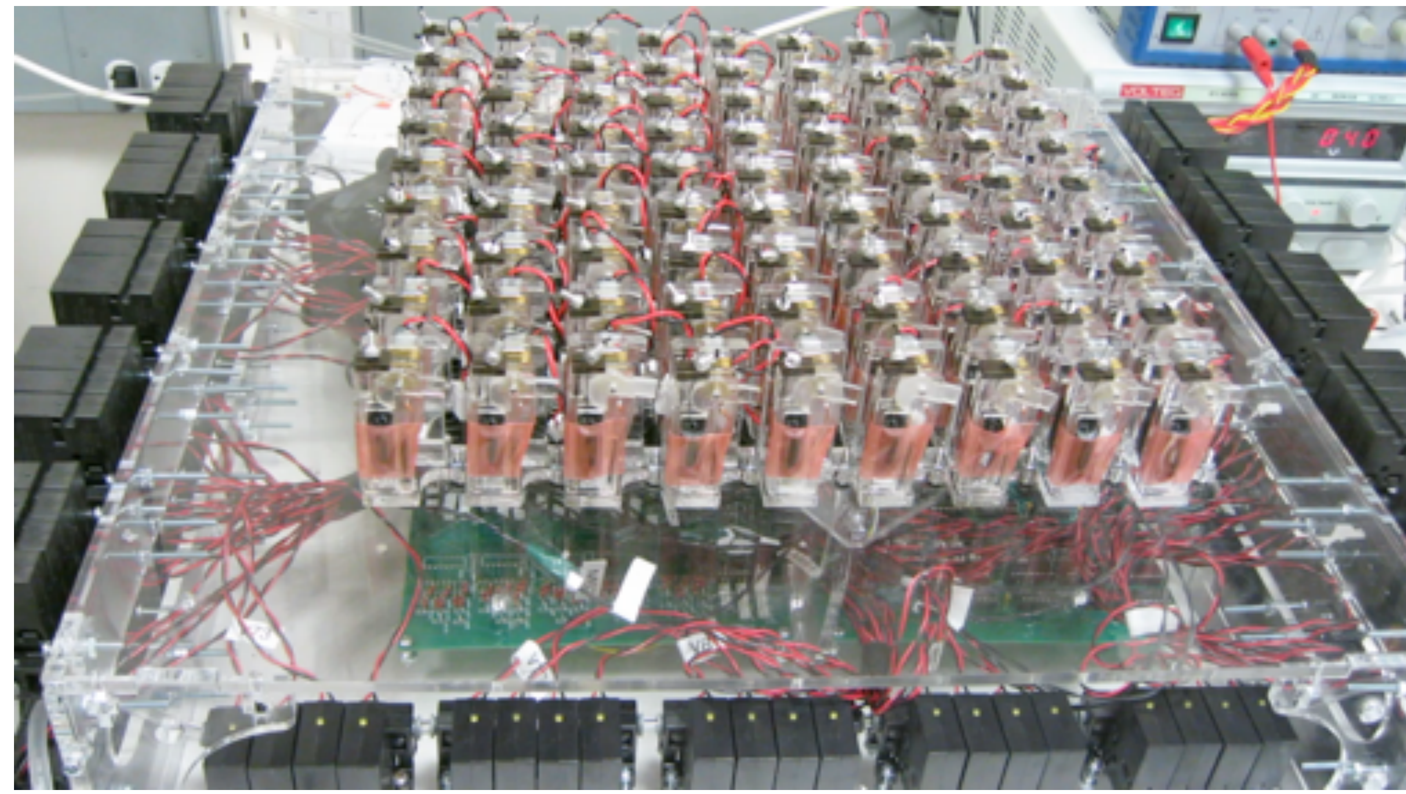
Shape Simulation

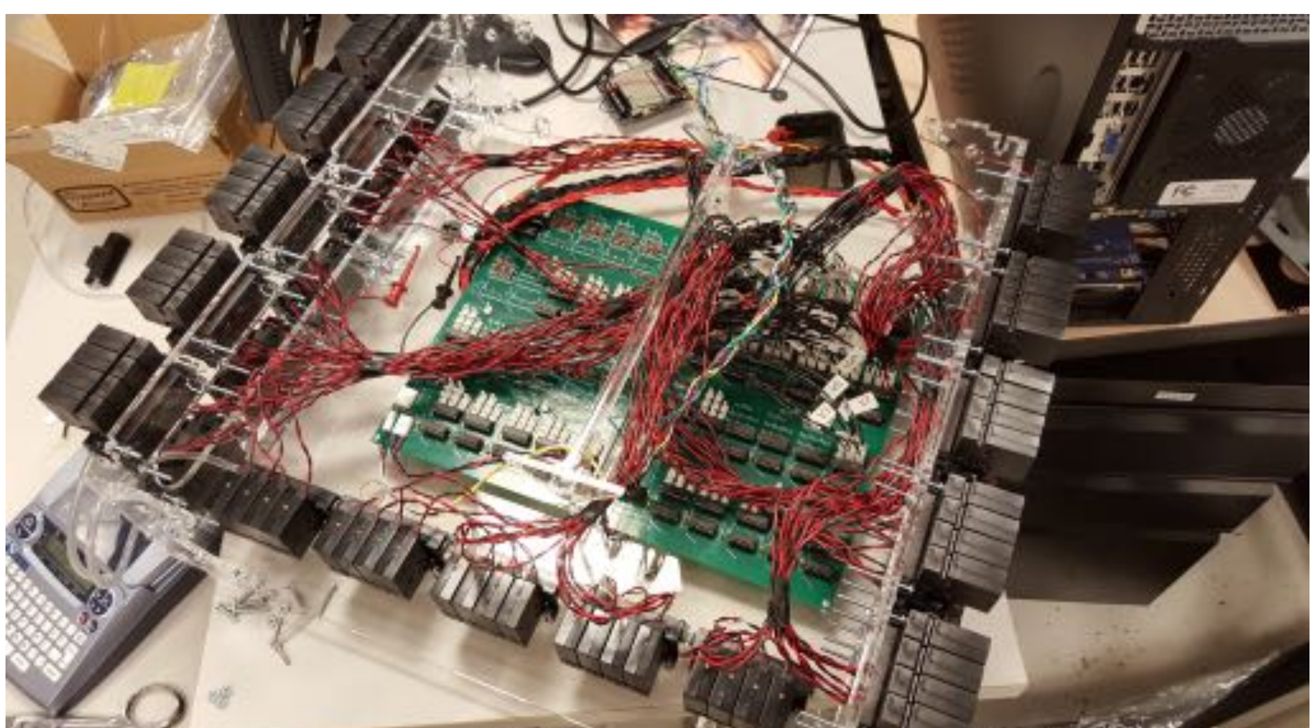
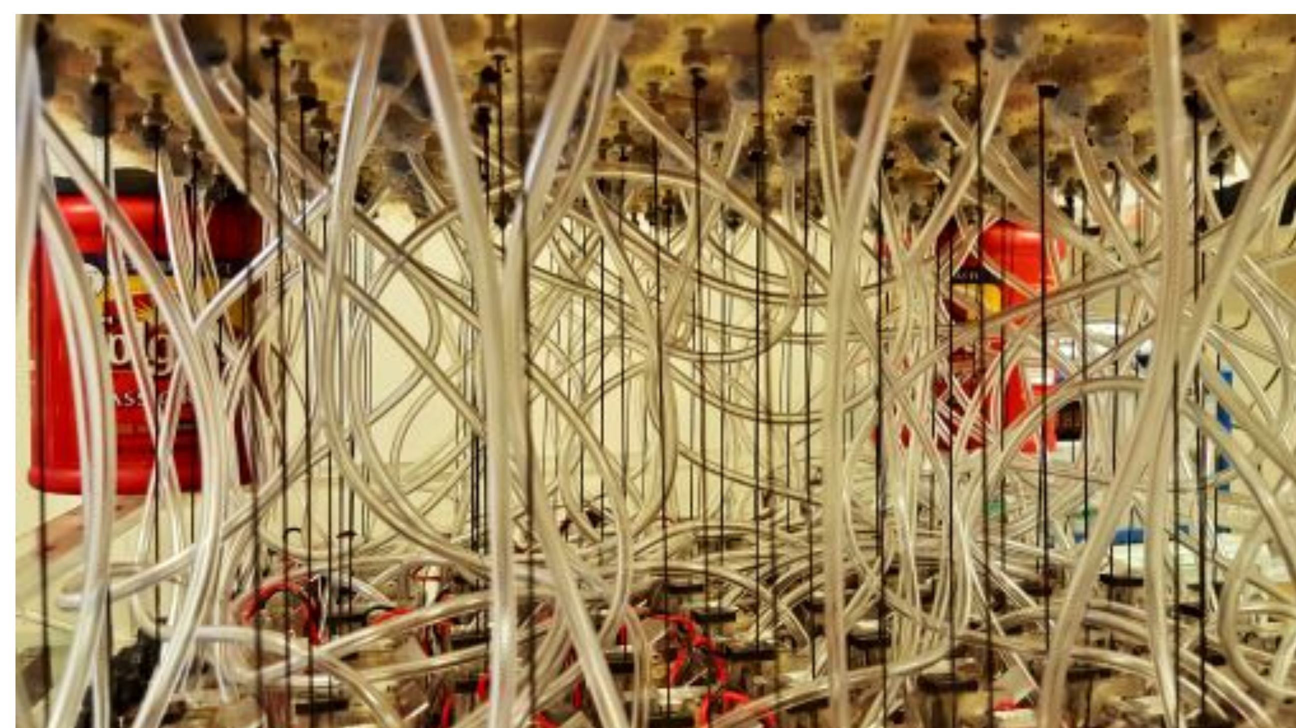
Which shapes will render well?



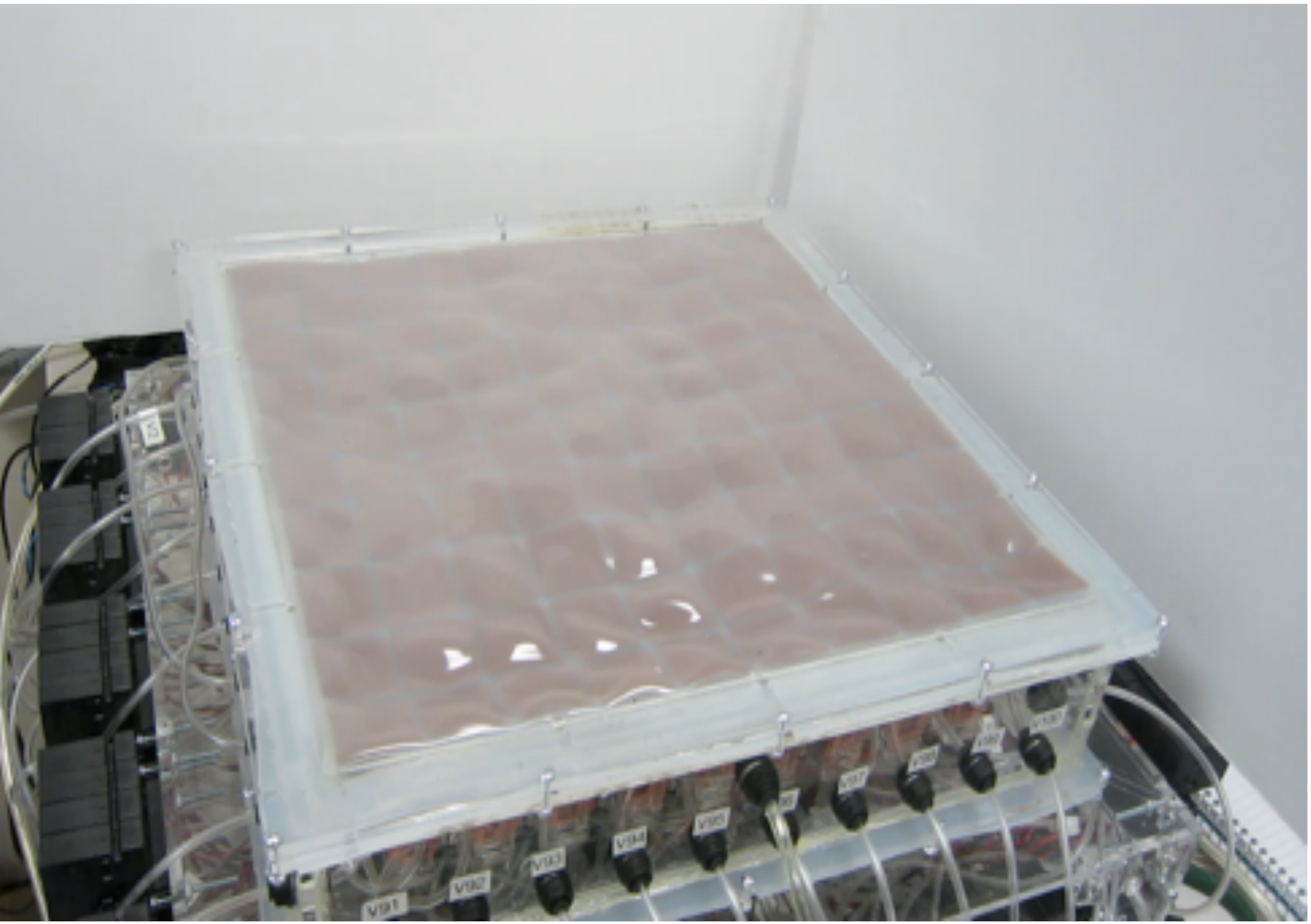


100-Cell Array

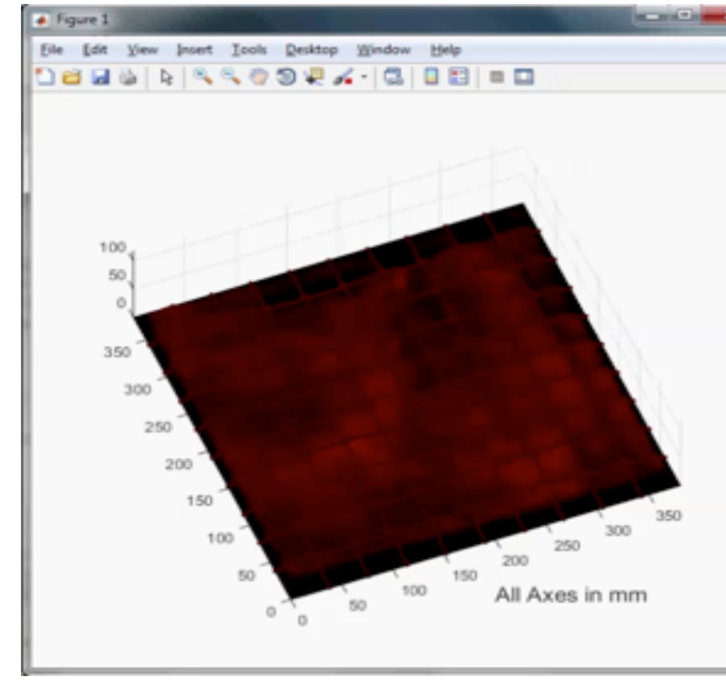




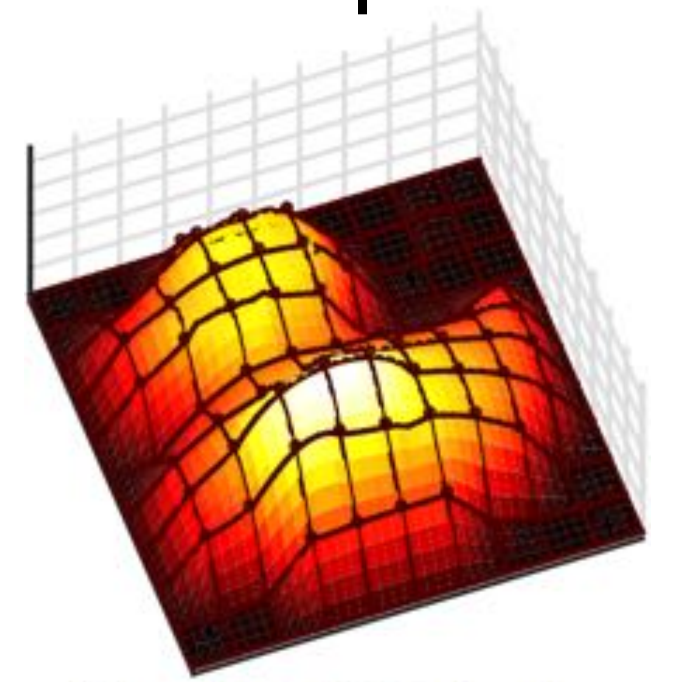
100-Cell Array



Measured Output



Simulated Output



Video is real time

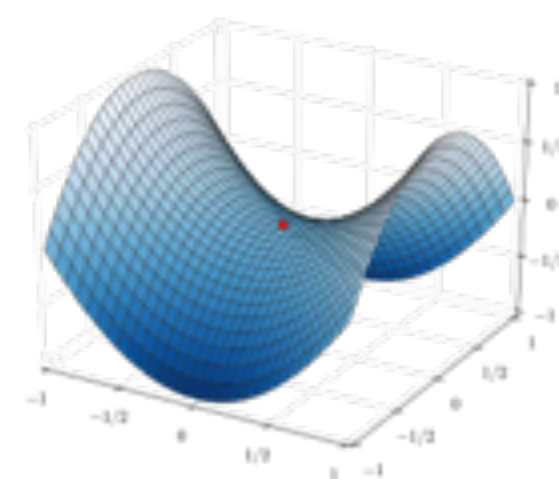
Stanley & Okamura in preparation

Other Applications

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

consumer

assistive/rehab



education

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 2”). 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 2

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