Wearable Technology

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EPFL

Mechanical Design and Production

- All engineering studies base their goal in creation.
- In mechanical engineering and specifically in the orientation of Design and Production (Conception et Production), the focus lies in the scientific and practical approach
- To address the design process that include creating the models, setting up experiments, analyzing, evaluating hypothesis and results.
- To introduce, in production and manufacturing, the physics, limitations, optimization of bringing actual issues involved with design solutions.

New "Mechanical" Engineering Criteria

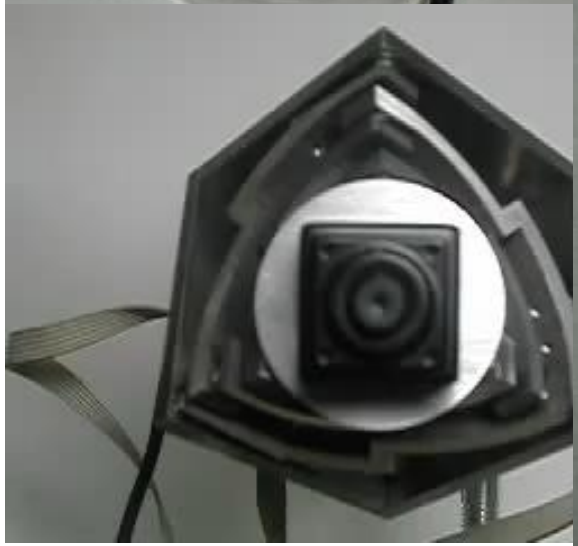
industrial environment → **real-world environment**

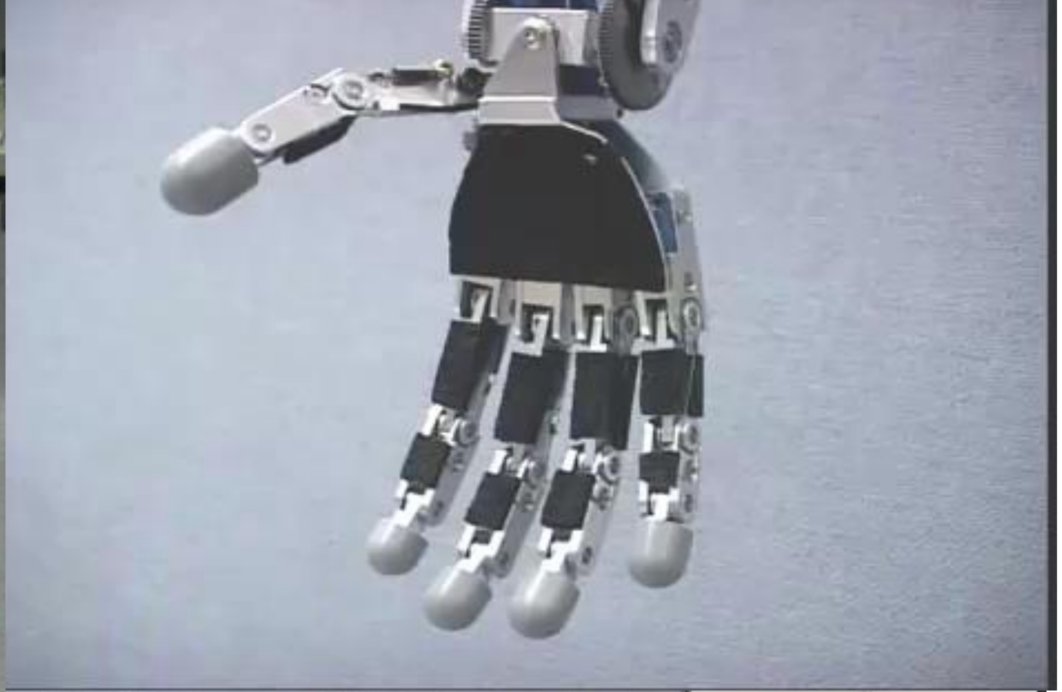
- Highly predictable
- Programmable

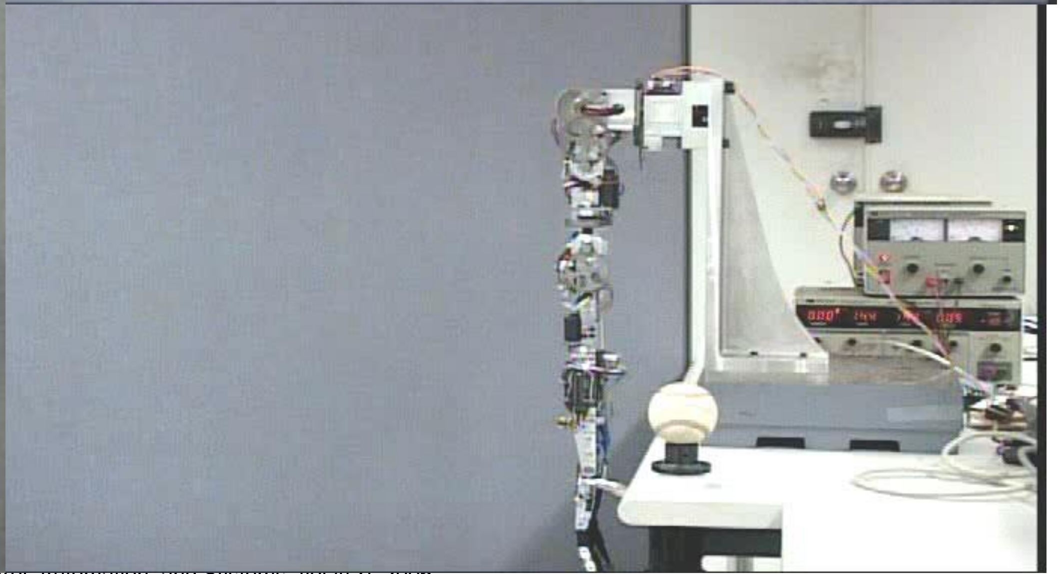
Augmented performance : force, speed, precision

- Highly unpredictable
- Random tasks and uncertainties

Augmented interactivity : Conformity, Reconfigurability, Safety







“A Three-Degree-of-Freedom Anthropomorphic Oculomotor Simulator”, Int J of Control, Automation, and Systems, Vol 4(2), 2006.
“Experimental Evaluation of Several Strategies for Human Motion Based Transparency Control”, Trans. in Advanced Robotics,Vol 54, 2009.
“How Can Human Motion Prediction Increase Transparency?” ICRA 2008.
“Design and Acceptability Assessment of a New Reversible Orthosis” IROS 2008.
“Anthropomorphic Robot Arm and Hand for Interactive Humanoids”, J of Bionic Engineering, 9(2), 2012.
“Motion Teaching Method for Complex Robot Links Using Motor Current”, Int J of Control, Automation, and Systems, 8 (5), 2010.

A. Behrman et al (2000)

Project motivation

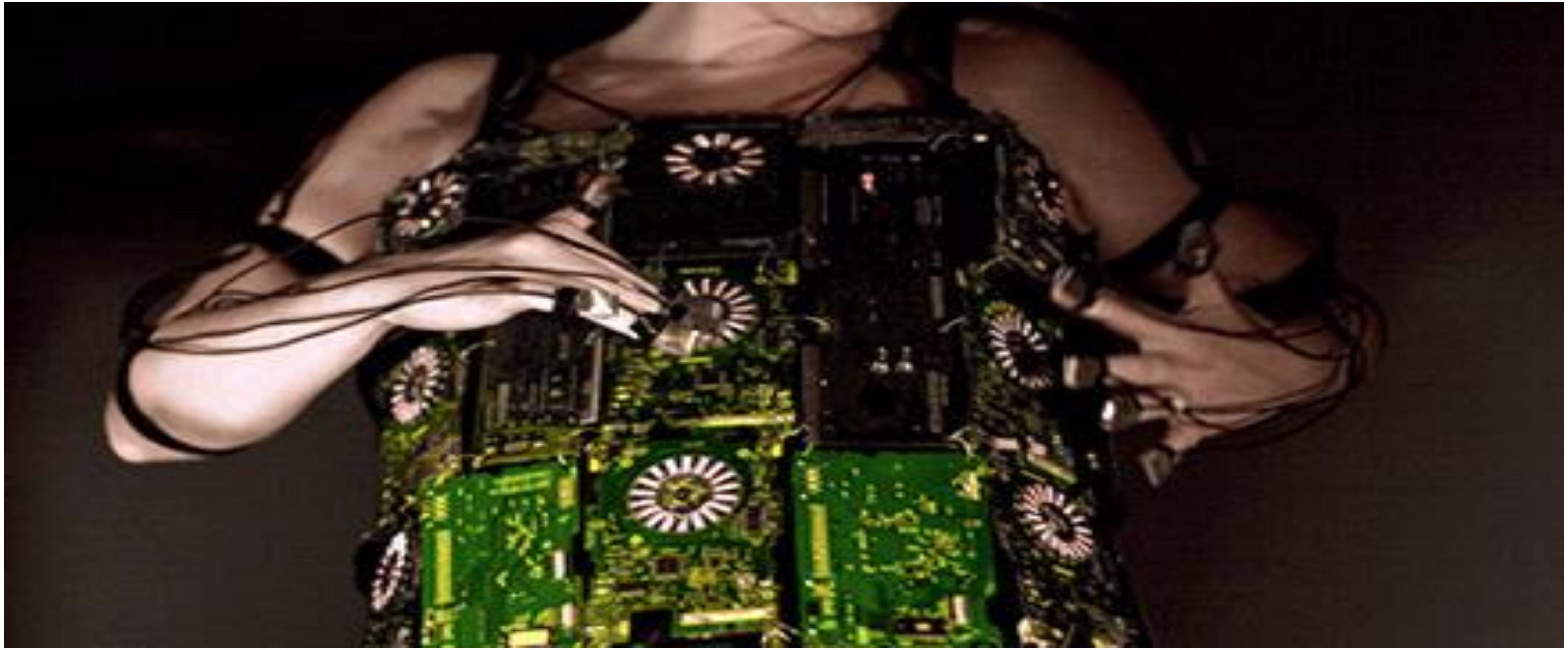
- We live in the fast paced environment that demands interactive technology that can blend effortlessly into our lives
- Light, conforming, dynamic and interactive technologies are the key physical attributes for a product to be closer to the users.

The first wearable technology

Electrophone image from 1890

Wireless headphone

Wearable Boombox?



Apple watch?

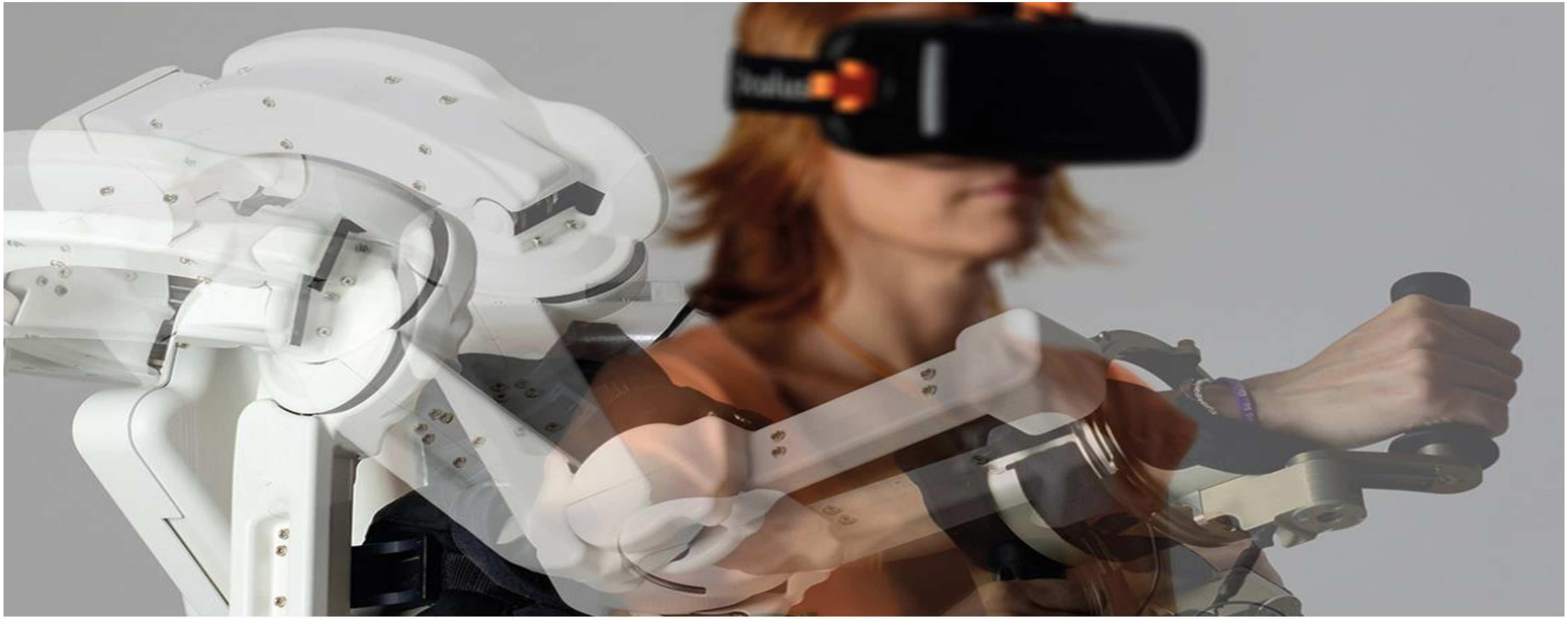
Twitter
Maps
App Store
Camera
Mail
Tuesday
9
Calendar
21:37
Tuesday, February 9

Google glasses

Radar Pace by Oakley

Xmetrics

Alex from Kinetek



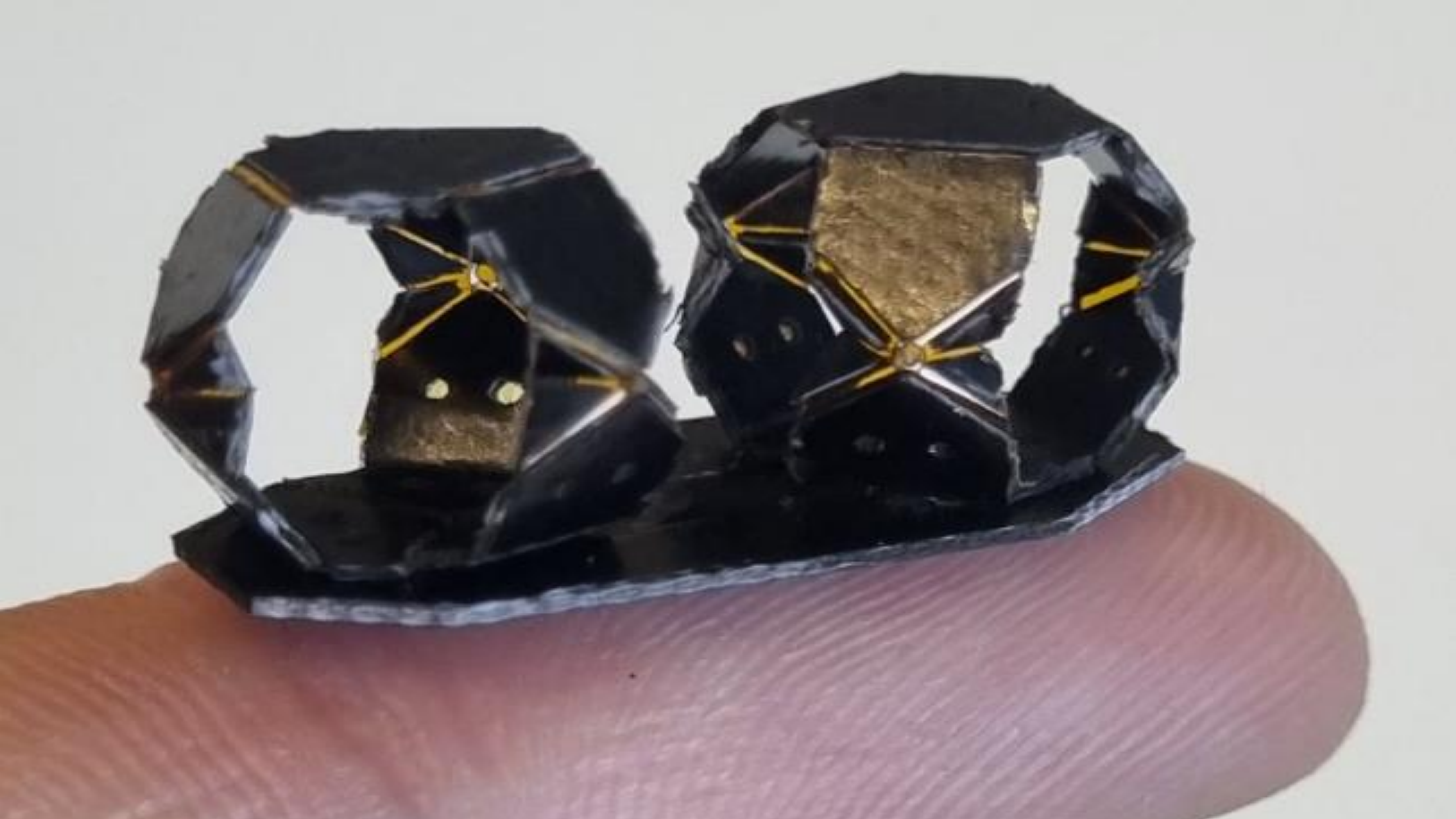
Haptic joystick

- https://www.youtube.com/watch?v=D3g59rIMWw4&list=PLTwKK2djSLhdJ-d6tgCiCOZEDQGUyoGDz&index=2

- https://www.youtube.com/watch?v=Ylye45pvatw&list=PLTwKK2djSLhdJ-d6tgCiCOZEDQGUyoGDz&index=3

Scalable platform for modulable interactions

Giraud, Mete & Paik, ***Advanced Intelligent Systems***, Cover Page (2022)



Salerno, Mintchev & Paik, ***IEEE Haptics Symposium*** *Best Demo Award (2018)*

Nature Machine Intelligence *Cover Page, (2019)*

IEEE RA-L *(2020)*

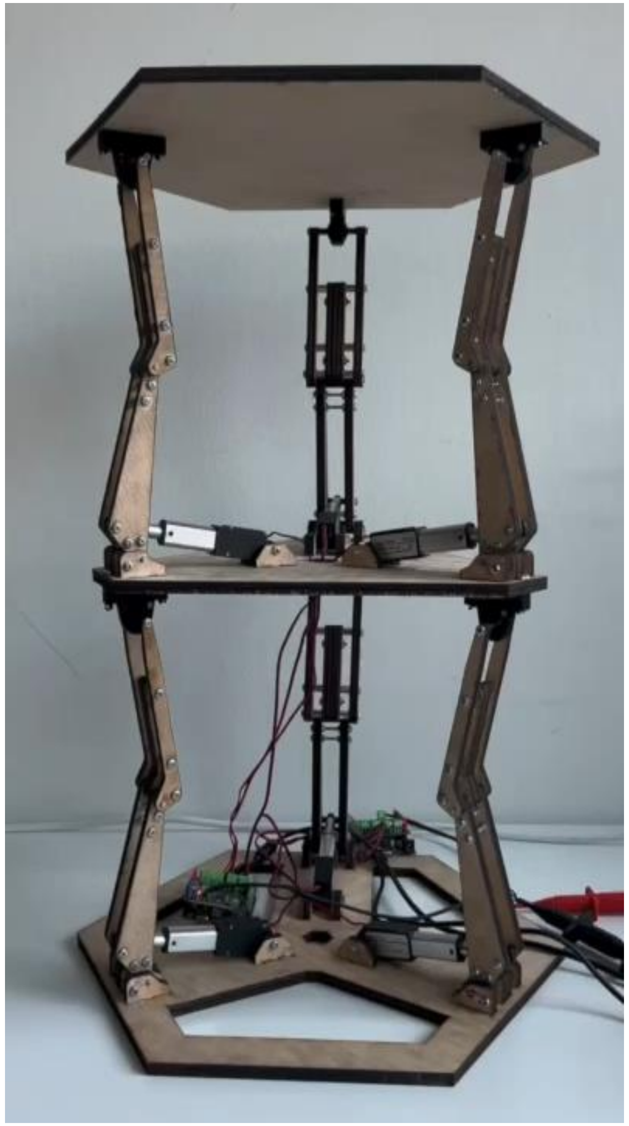
Scaling up workspace via distribution

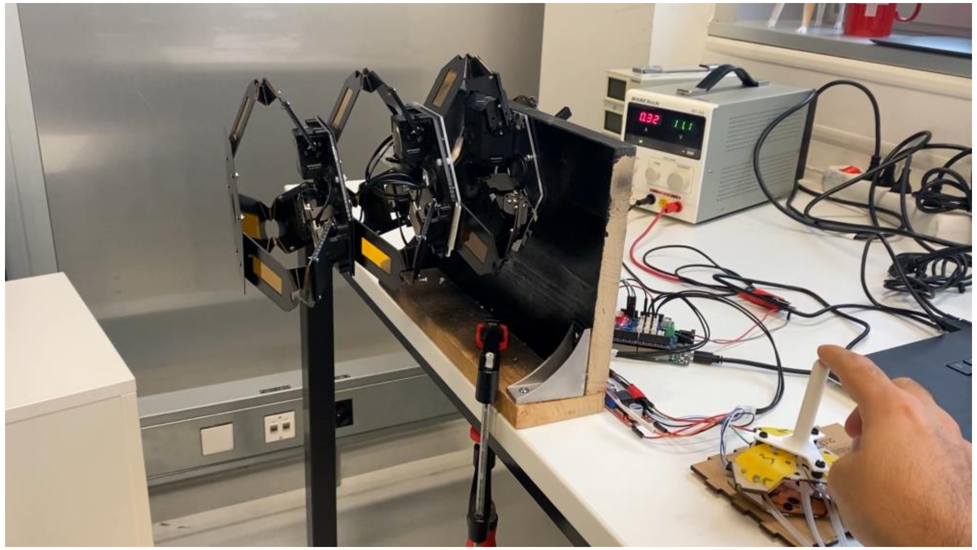
AVTR, Mercedez-Benz @ ***CES 2020***

FOLDAWAY
haptics

EPFL

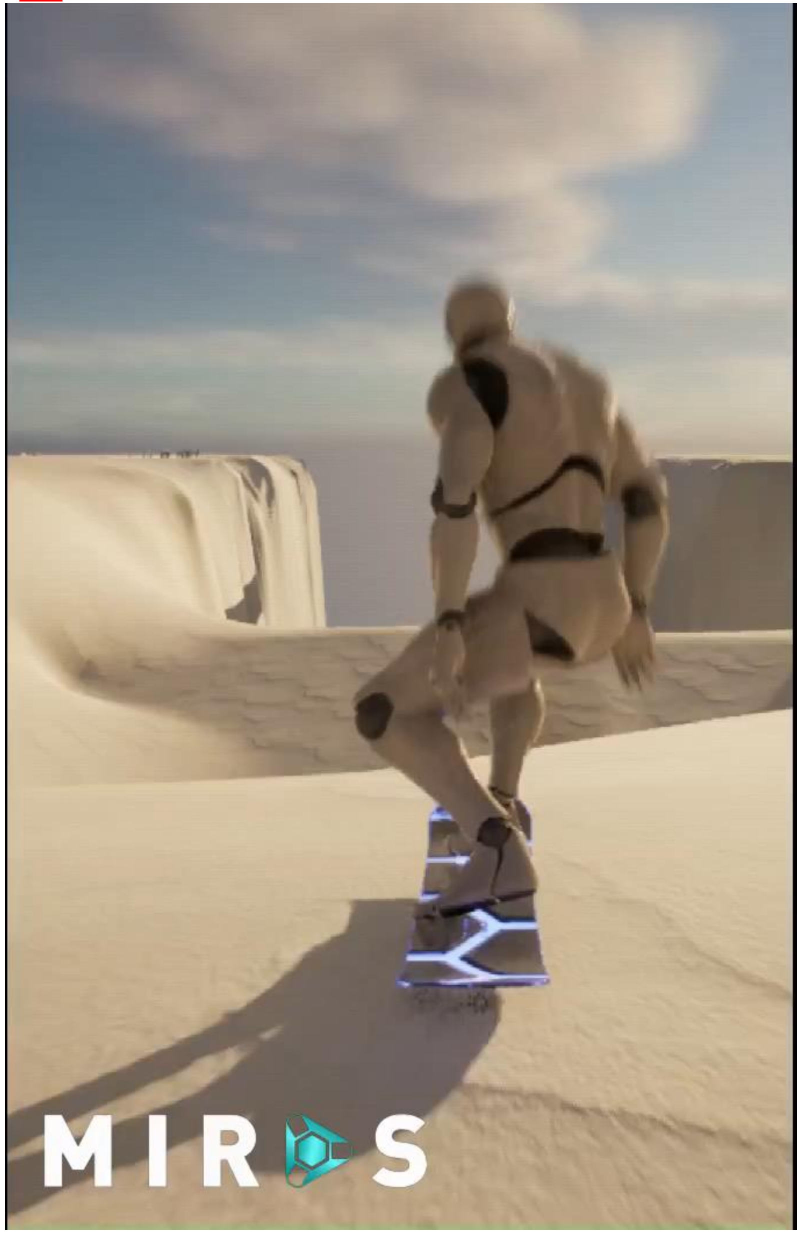
Scaling up workspace via assembly

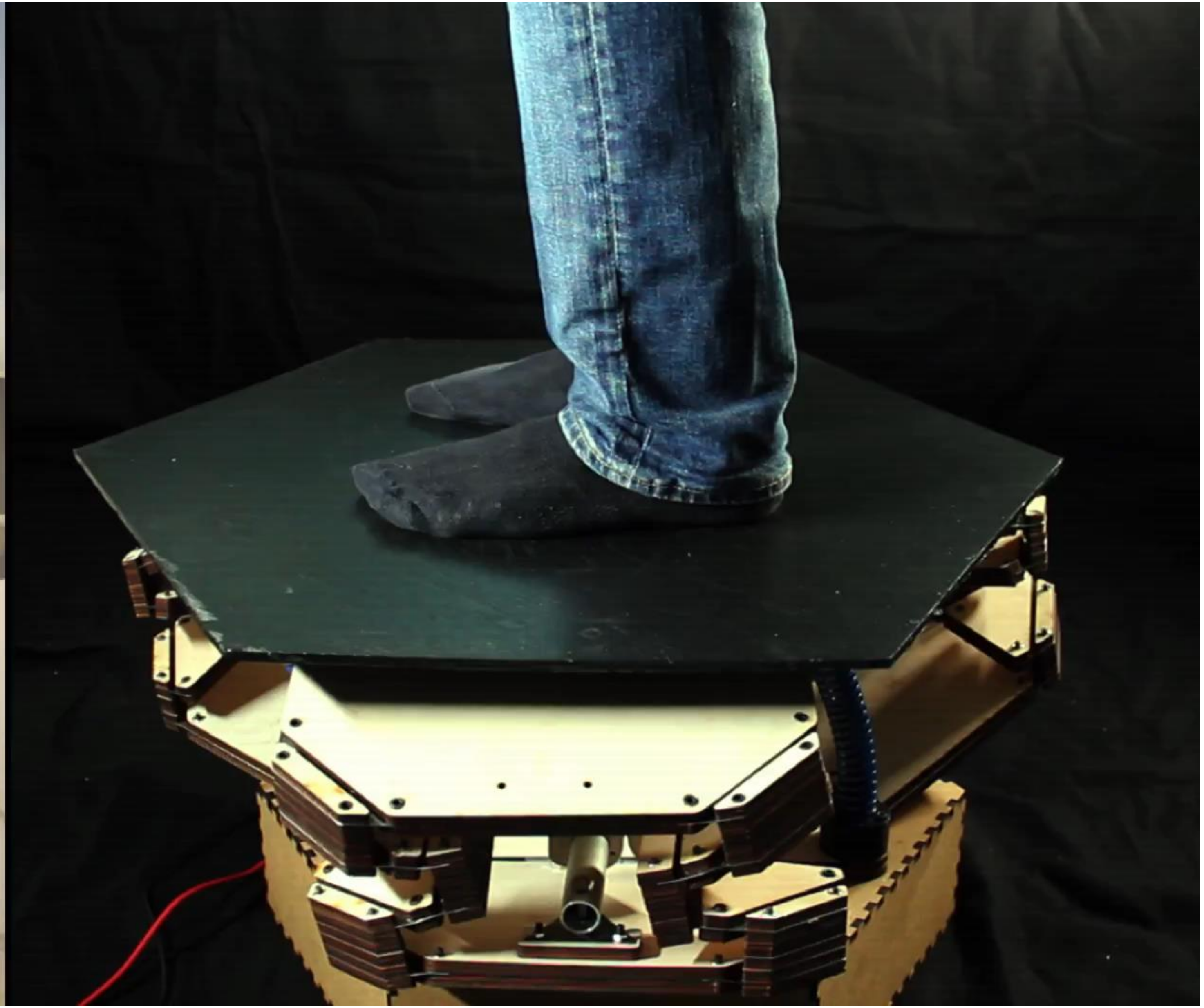




Mete, Huang & Paik, **RoboSoft** (2023)
Mete & Paik, **RA-L** (2021)

RRL
EPFL

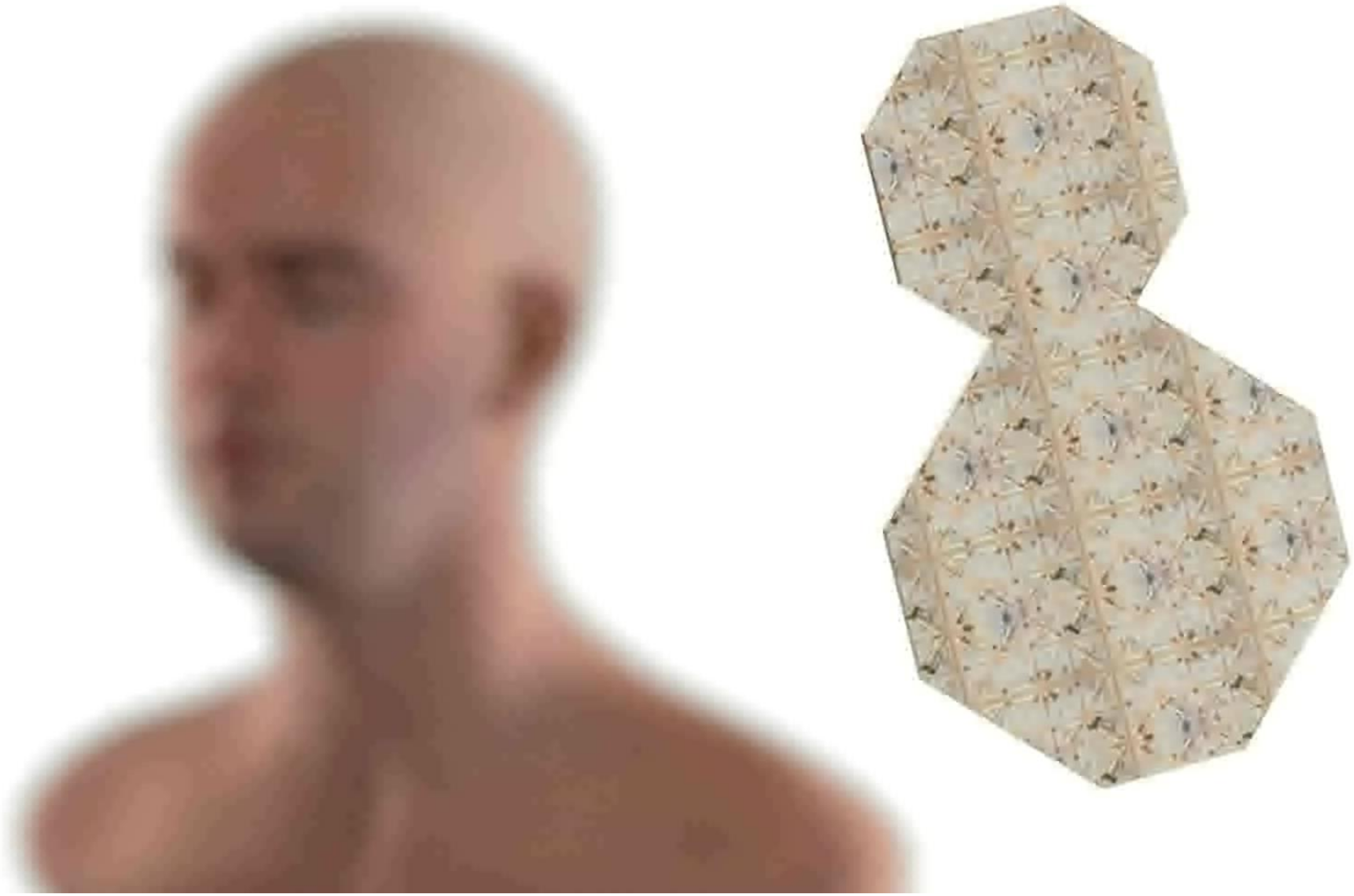





MIROS
Reconfigurable
Robotics Lab

Applications

Origami Robots for Active, Adaptive and Wearable Interface



https://www.youtube.com/watch?v=Kmm9WmLd2Mo

Origami robots

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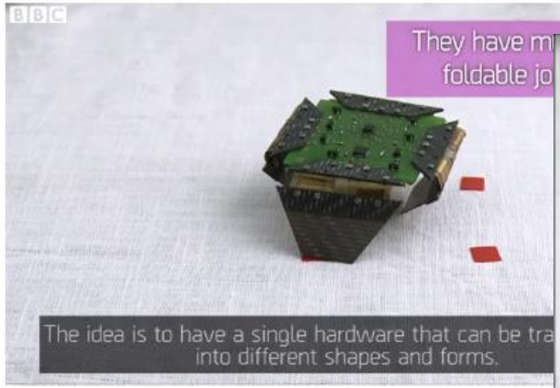


Robogami: the future of robotics?

18 November 2015 Last updated at 08:33 GMT

Scientists in Switzerland are developing a form of r resembles origami.

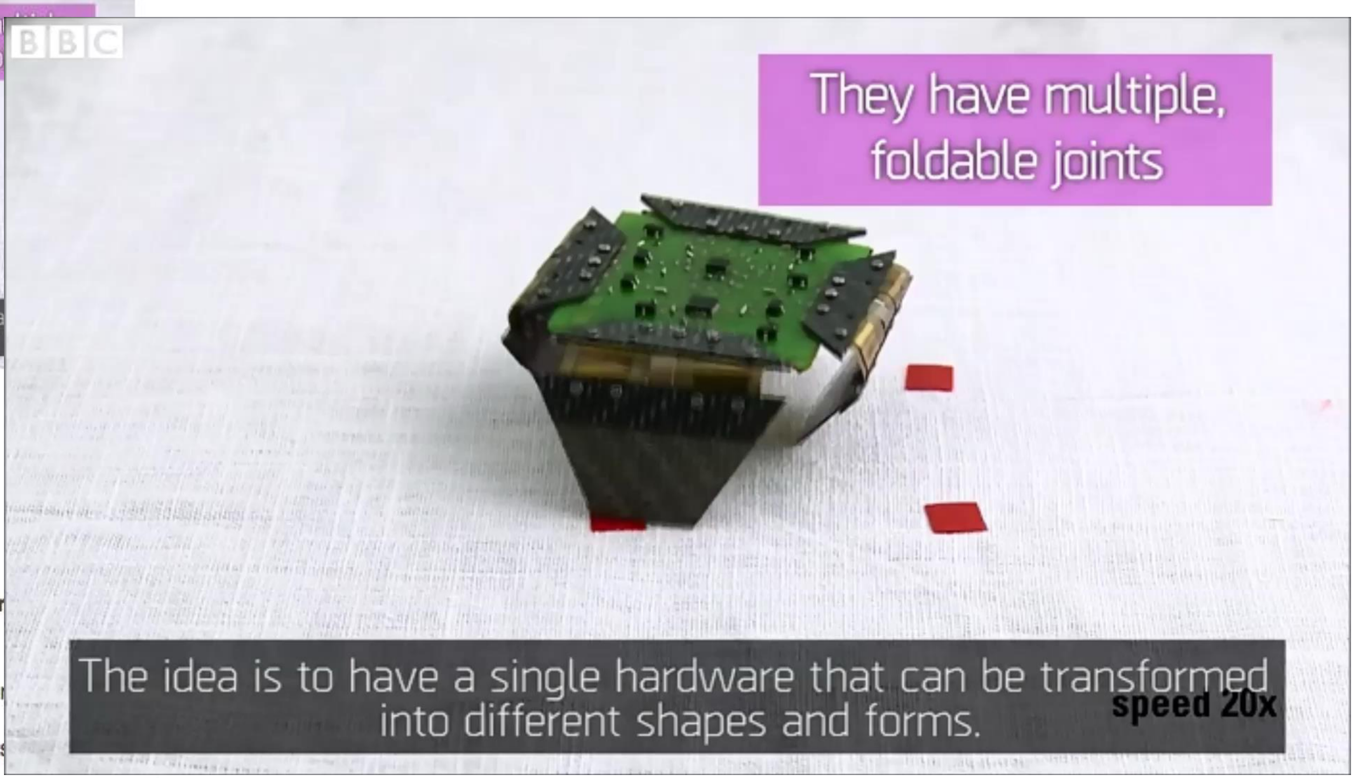
They hope the design will make them cheaper and mor

The robots are a combination of multiple, foldable joints aim is to help make a more flexible form of robot.

This means that unlike other robots, "robogamis" do not need to be built with a clear function in mind.

BBC Click's Vieri Capretta spoke to Jamie Paik, the Director of the Reconfigurable Robotics Laboratory in Lausanne, Switzerland.

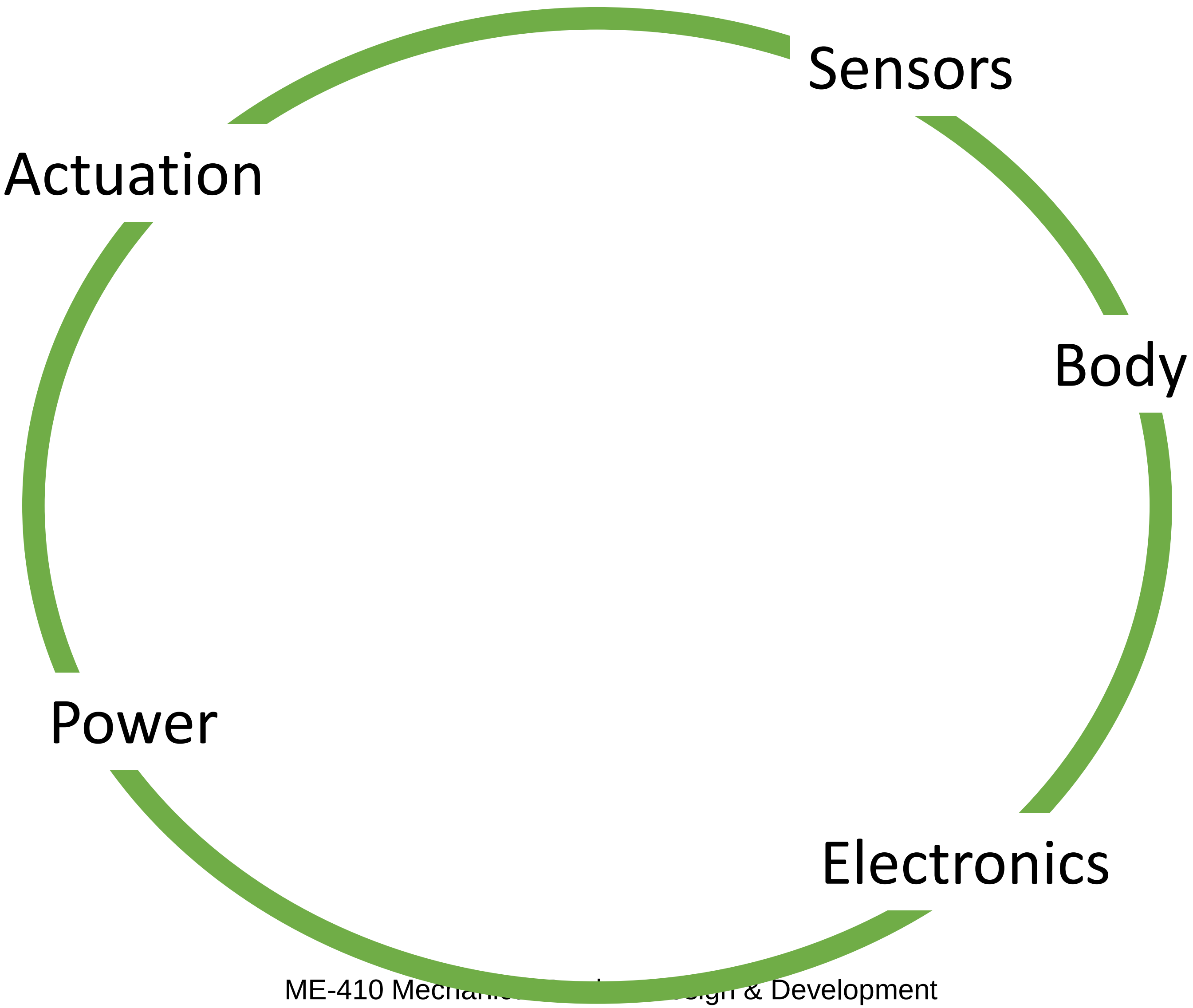
More at BBC.com/Click and @BBCClick.



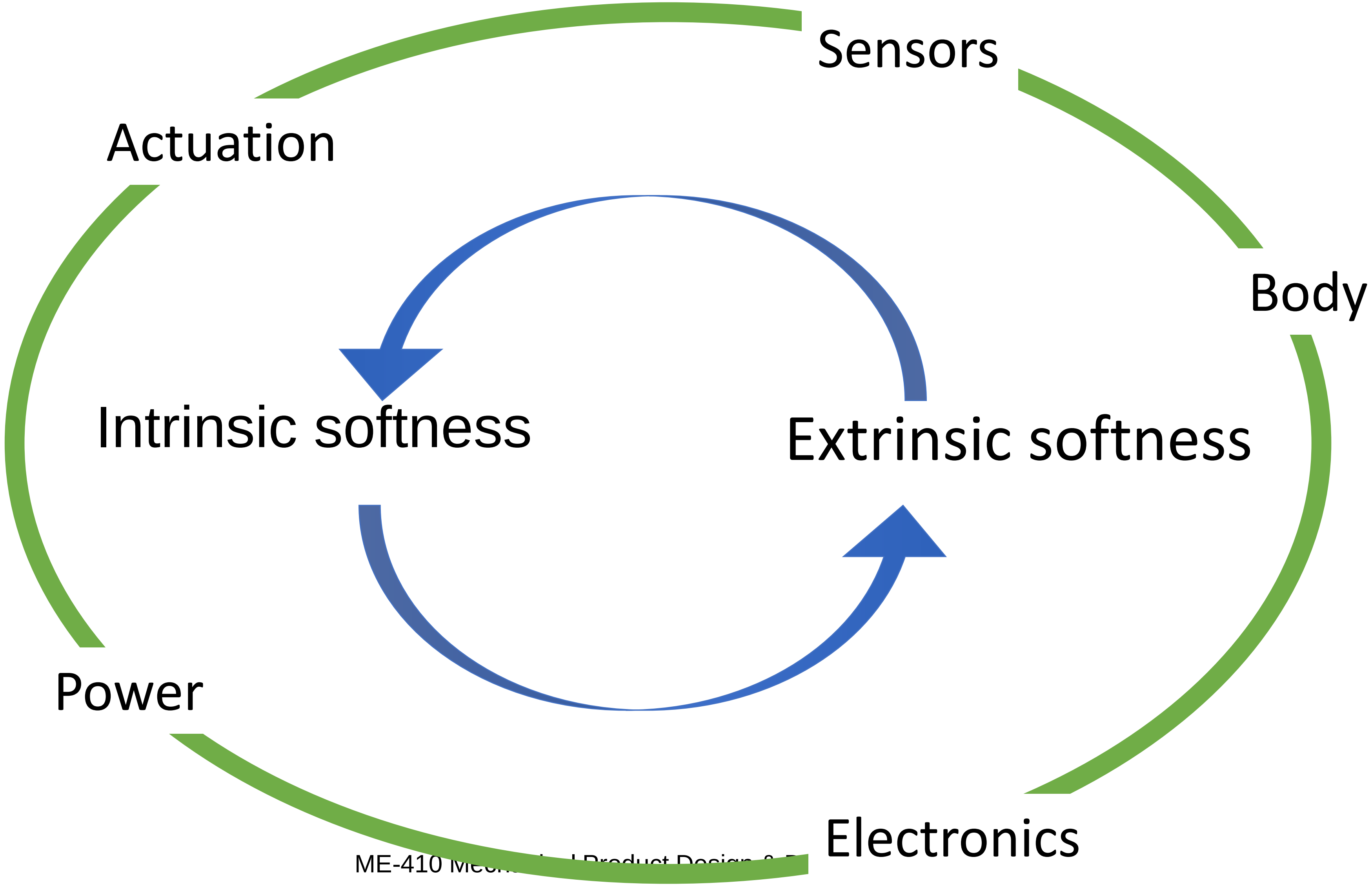
https://www.youtube.com/watch?v=IGe6bhJkTtk

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

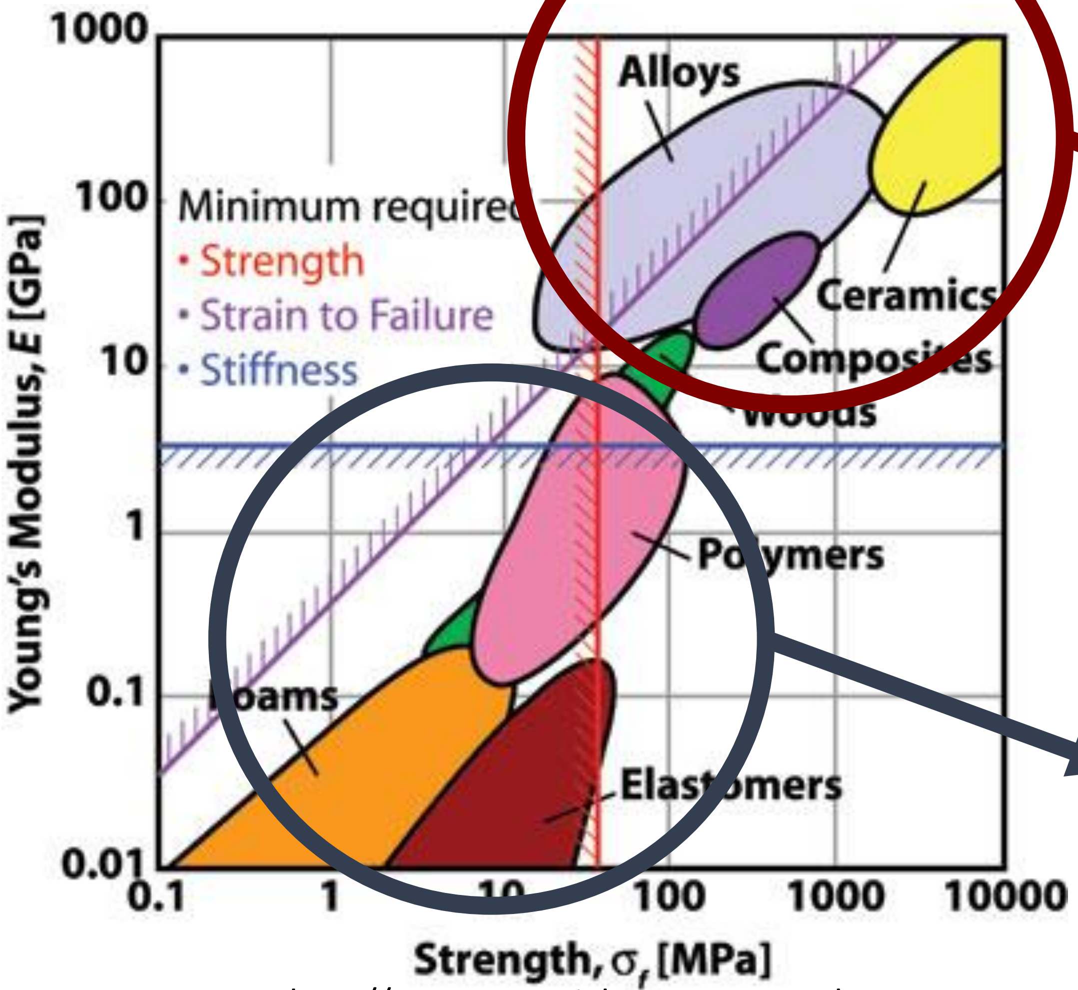
Softness in robotic components



Softness in robotic systems



Engineering materials



http://www-materials.eng.cam.ac.uk

Extrinsic softness:
Via design and control

Intrinsic softness:
Via material property

Wearable Technlogy Essentials

1) Design of soft **sensing**
2) Design of soft **actuators**
3) Design of soft **controllers**

Wearable Technlogy Essentials

1) Design of soft **sensing**
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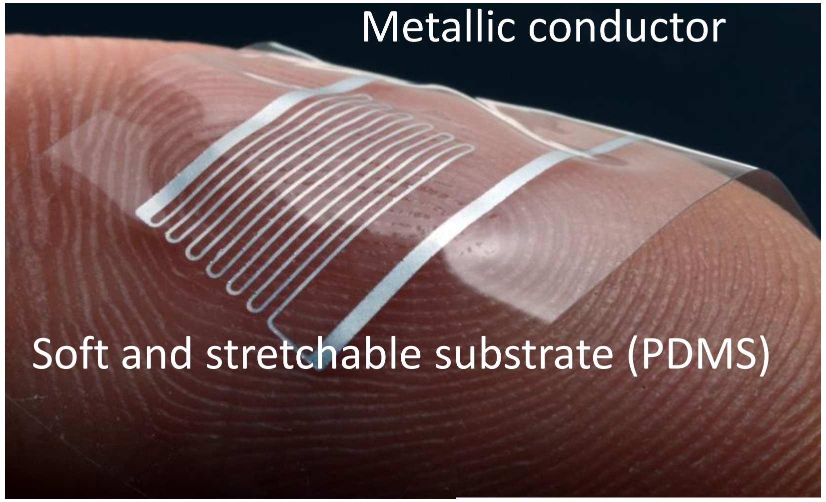
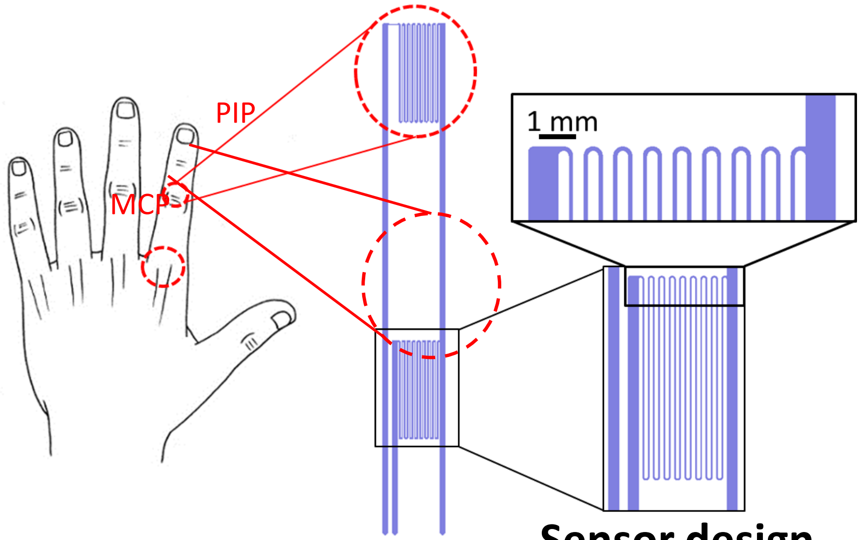
Full Integration

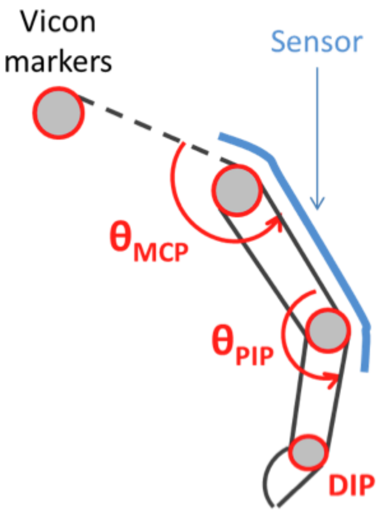
Resistive strain sensor





Sensor design

Vicon motion tracking



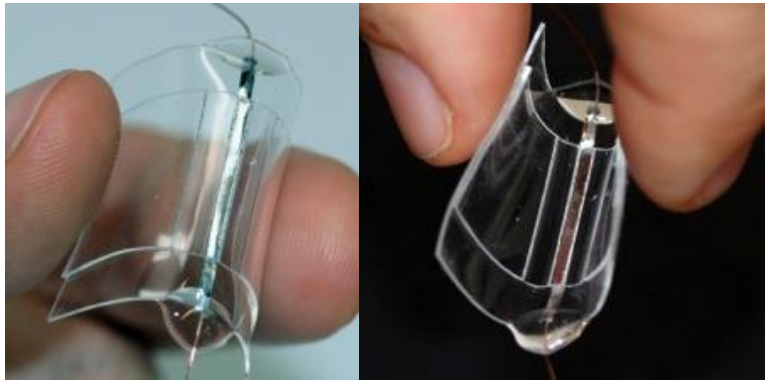
Comparison between sensor-sensed angles and Vicon angles

Objectives

- **Maximize** the resistance change at the bending areas
- **Decouple** joints from each other

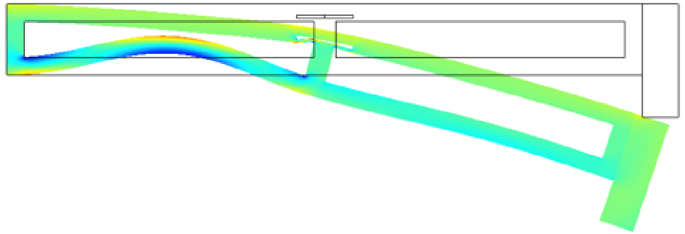
Soft Sensors

Liquid metal-based sensors

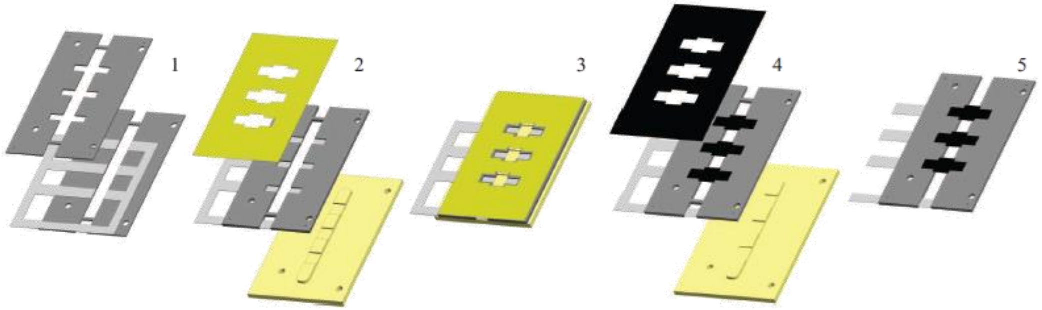


PDMS micro-channeled sensor, 700um thick
thick micro channel

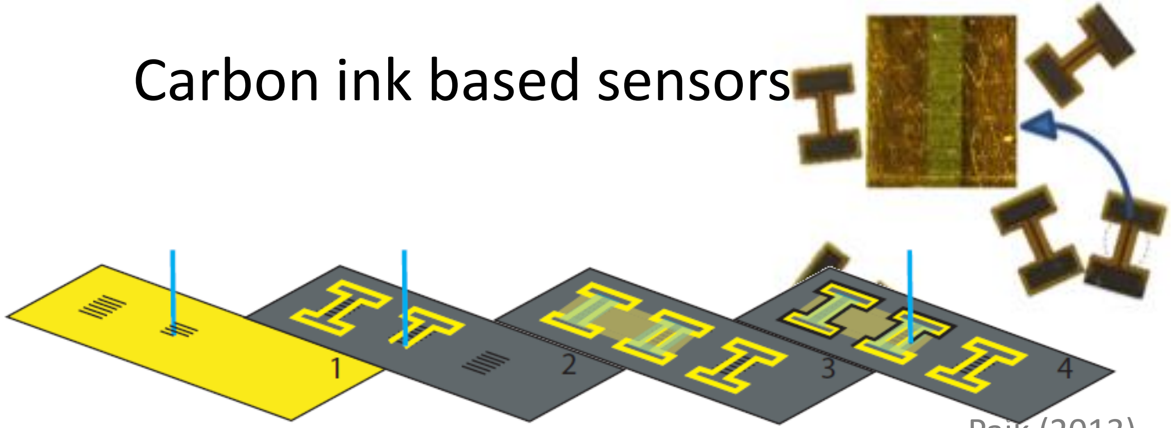
Paik (2011)



Conductive silicone based sensors

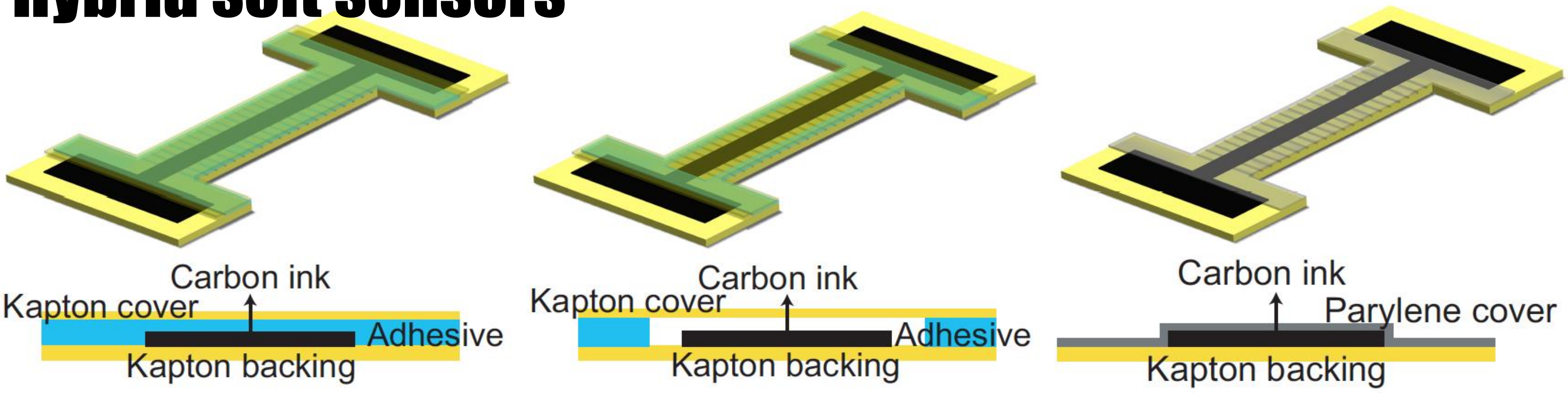


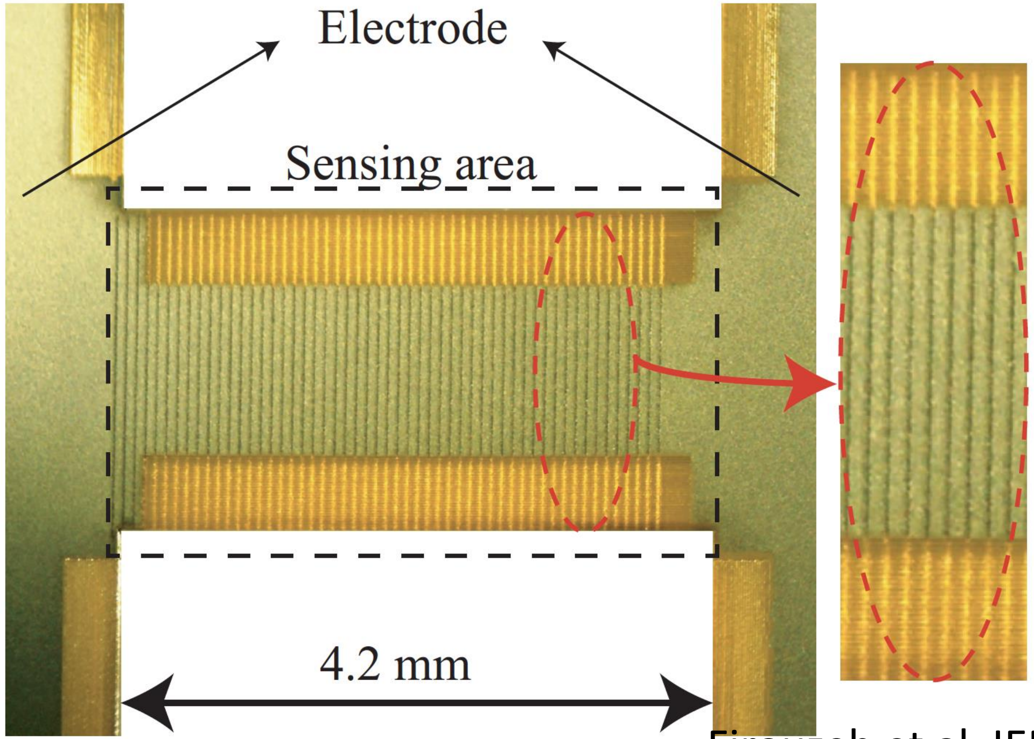
Carbon ink based sensors



Paik (2013)

Hybrid soft sensors



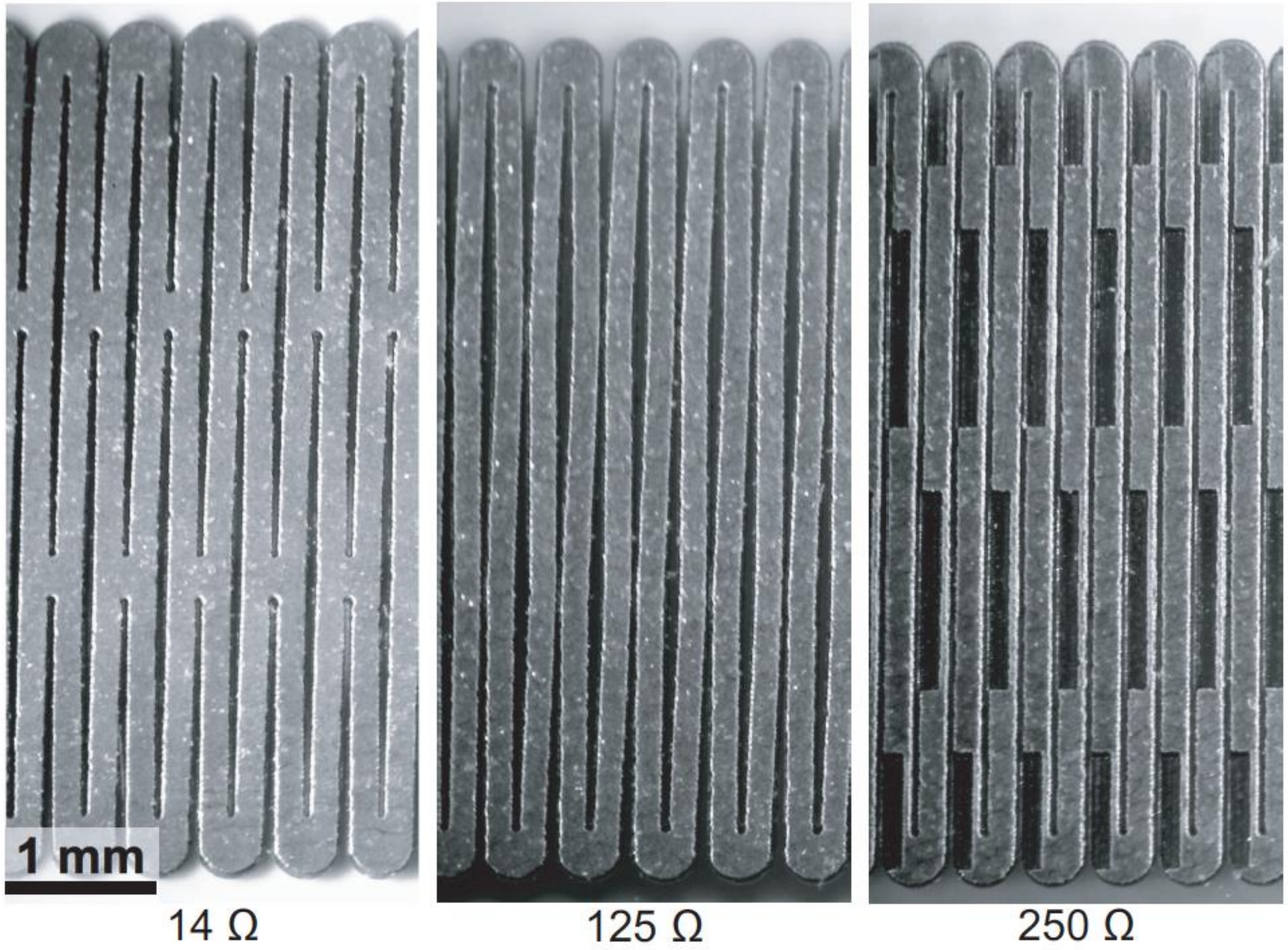


Firouzeh et al. IEEE Sensors Journal (2015)

EPFL

Soft metal sensors / heaters

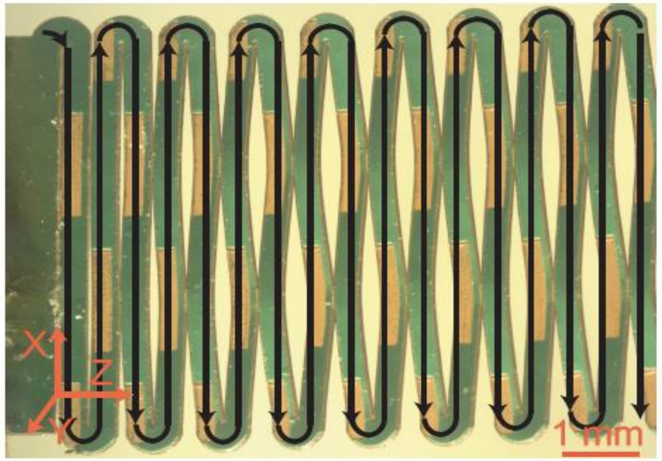
Meander patterns on metal film for improving compliancy

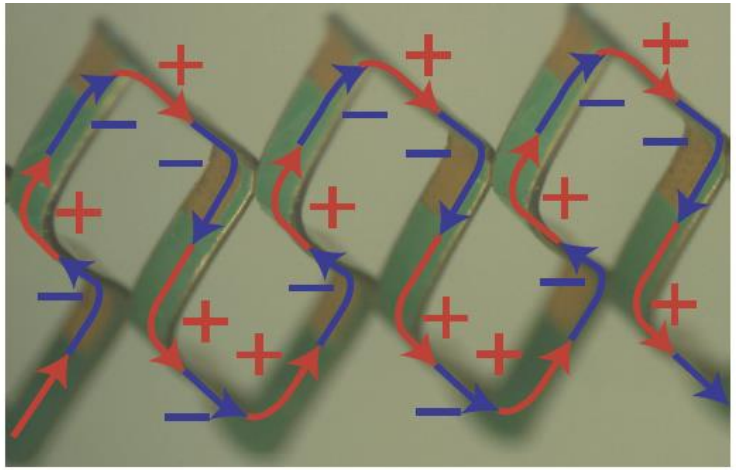


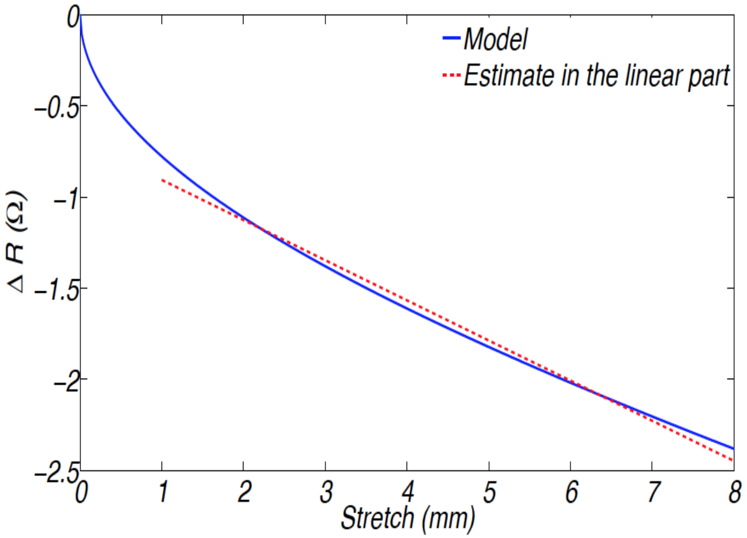
Soft Metal Sensors

If no resistance change under strain → circuits

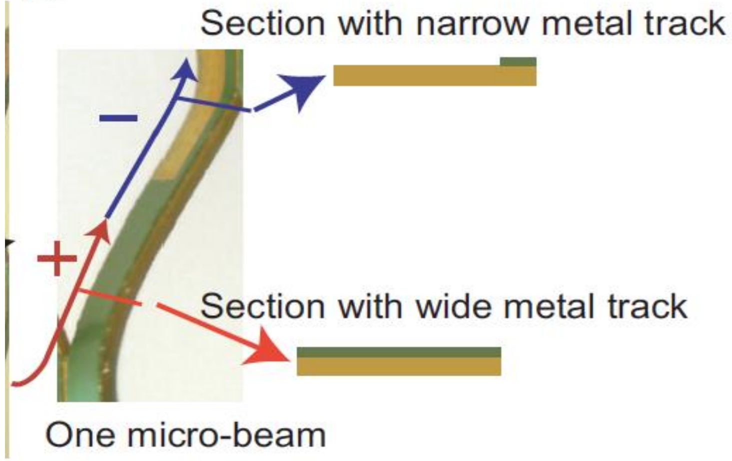
If resistance change under strain → strain sensor







(a)



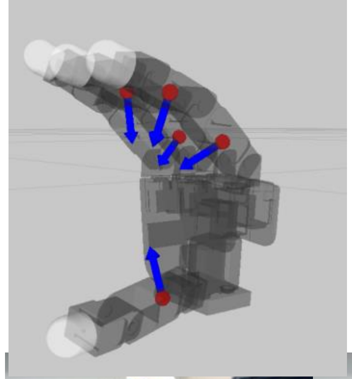
(b)

"Tunable high-stretch metal sensor" Firouzeh & Paik (2015)

“Tunable high-stretch metal sensor” Firouzeh & Paik (2015)

Active compliance control

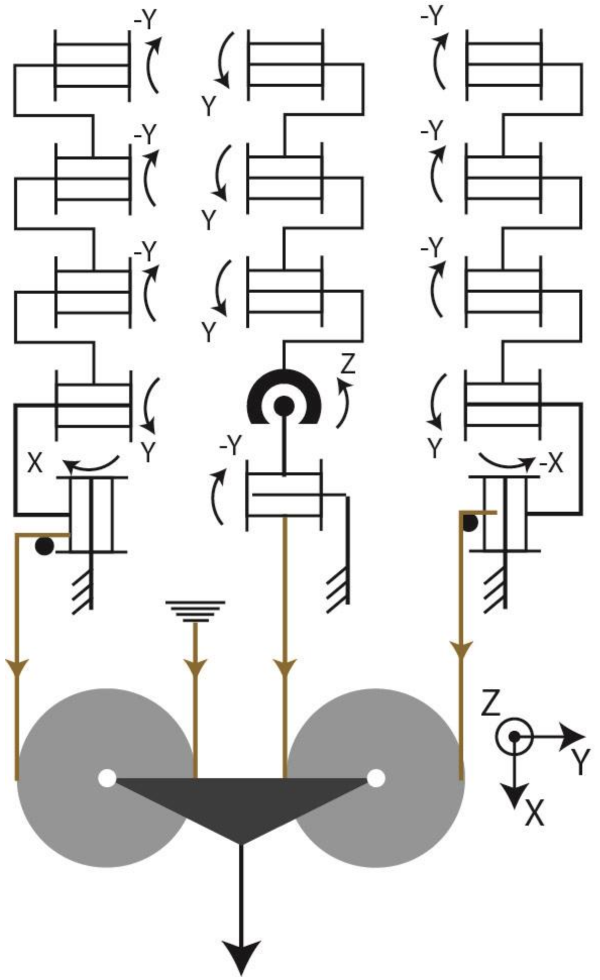
Grasping: use existing info to pre-shape the hand and a map of desired contact points w/ force distribution

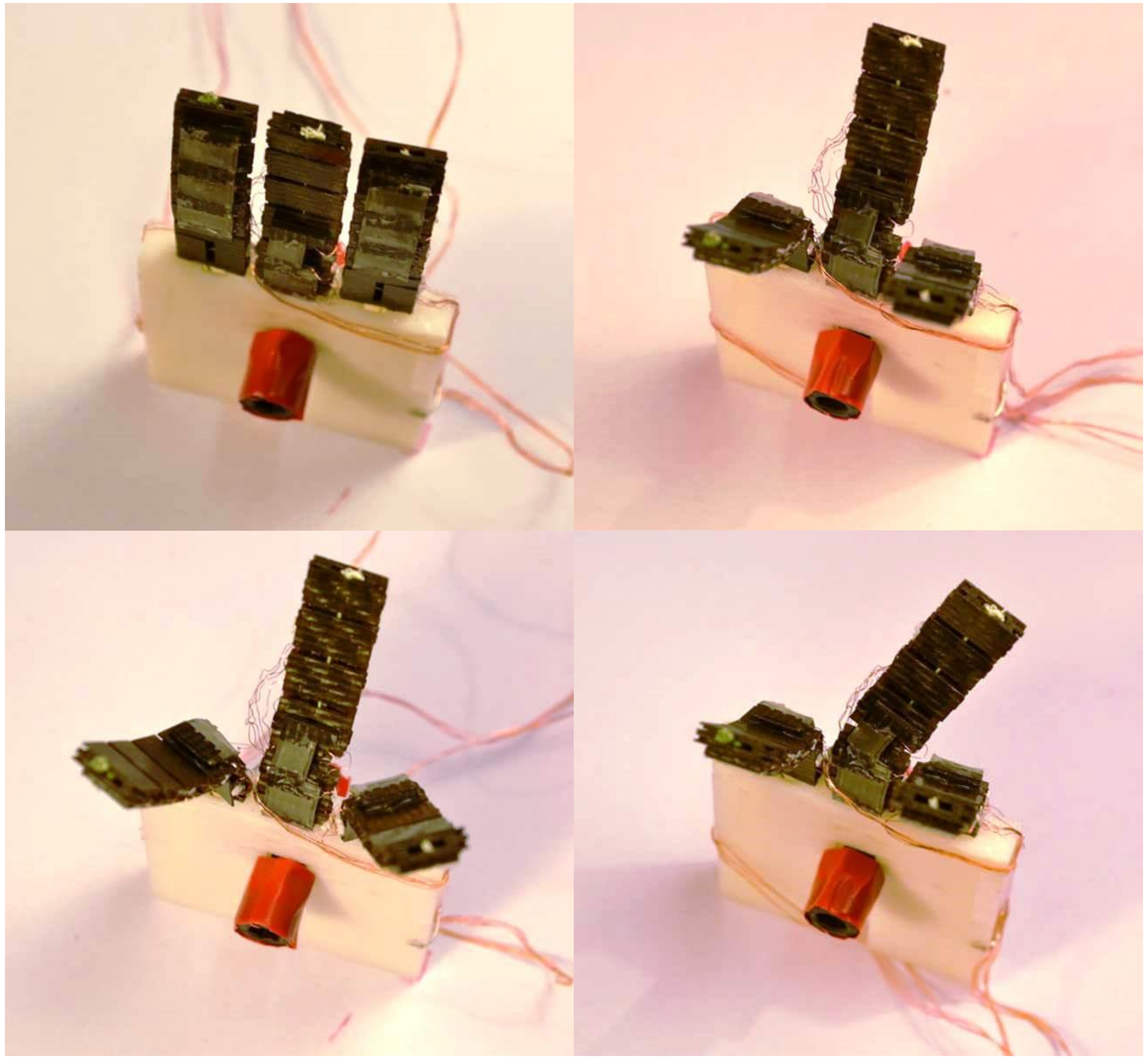


Desired contacts representation during the motion

Grasping compliantly a soft shoe

Active compliance control through material property





Wearable Technology Essentials

1) Design of soft **sensing**
2) Design of soft **actuators**
3) Design of soft **controllers**

Full Integration

Wearable Technology Essentials

1) Design of soft **sensing**
2) Design of soft **actuators**
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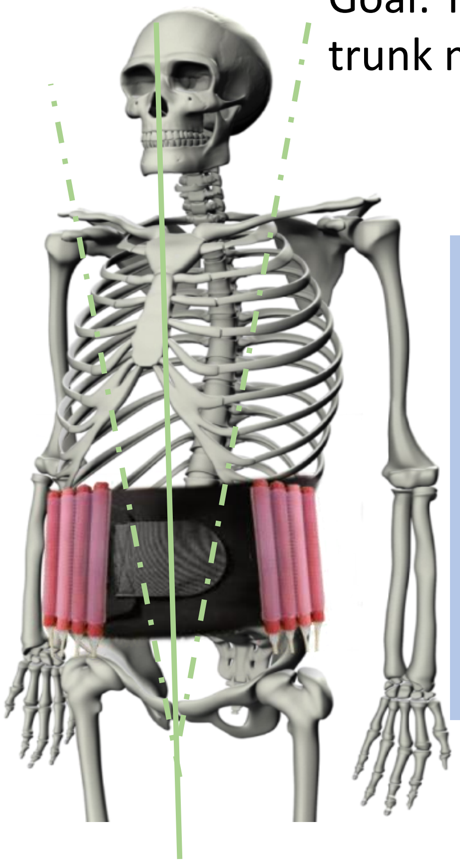
Full Integration

Your project

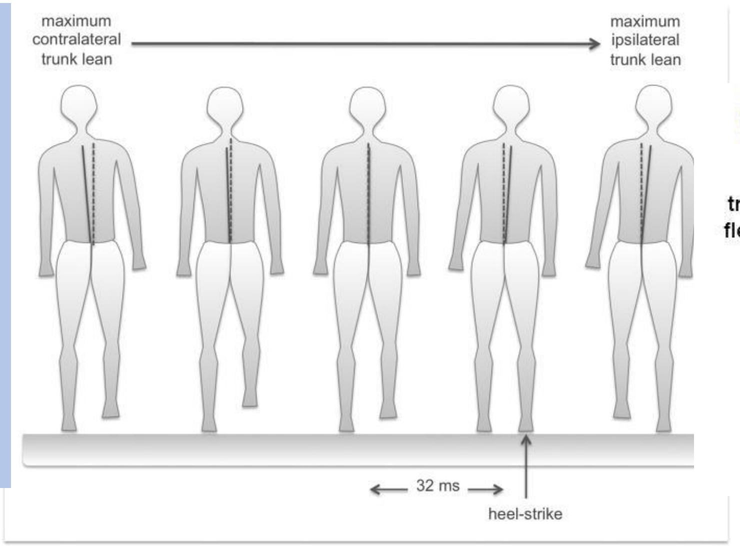
Trunk carapace for humans:

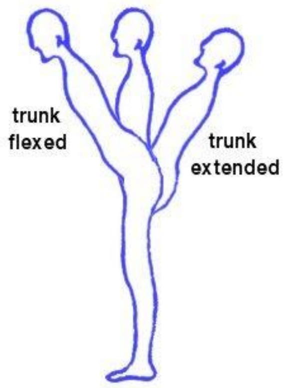
- Objective: to translate previous achievements in animal models Into a robot interface that provides optimal assistance to trunk movements during rehabilitation in humans .

Goal: To develop a trunk carapace to actively control multidimensional trunk movements with soft actuation and smart passive structures.



Strategic placement of distributed soft actuator modules to provide assistance to contralateral, lean, and flexion / extension of the trunk. (5 active DoF)





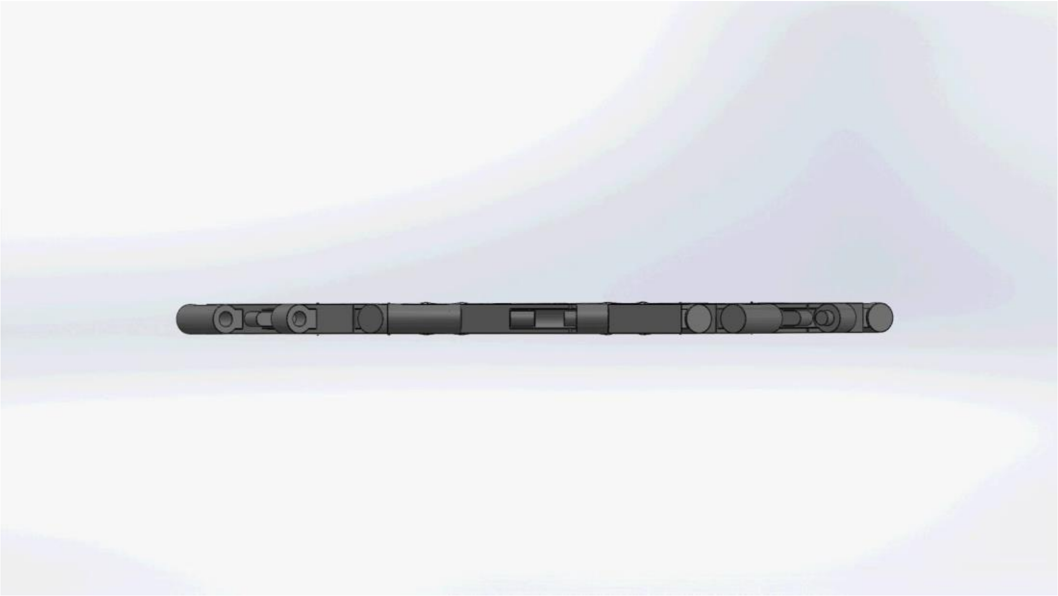
Trunk carapace for humans: *Robogami-based design*

Robogami-based support structure:

A origami module- based belt will provide support and distributed actuation for physical interactions.

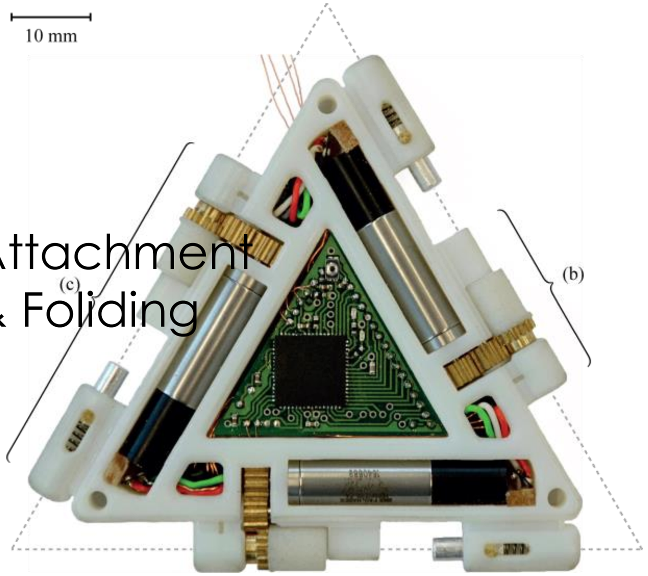
Single module dimensions (6 triangles):

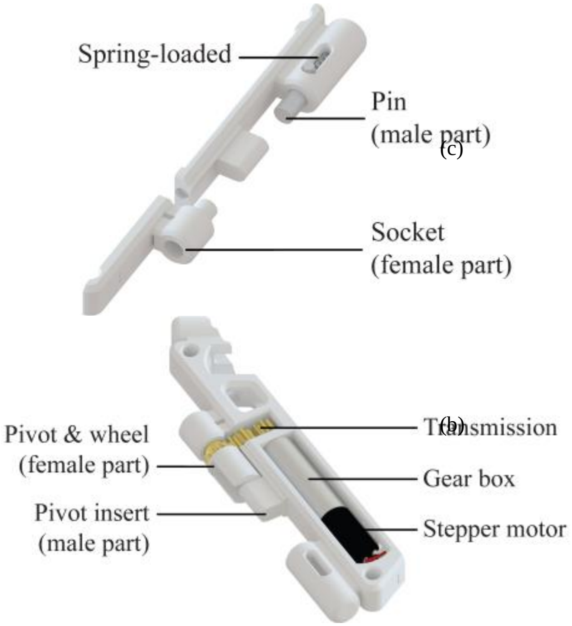
- Total weight: < 30 g
- Thickness: 6 mm
- Size: L = 75 mm,



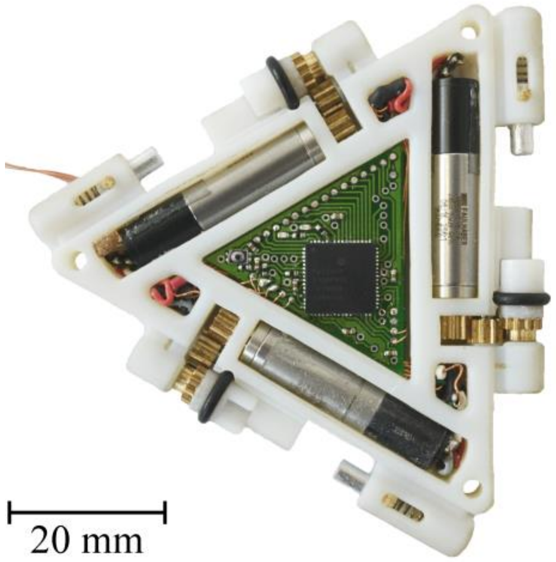
Robogami w/ Brushless DC motors

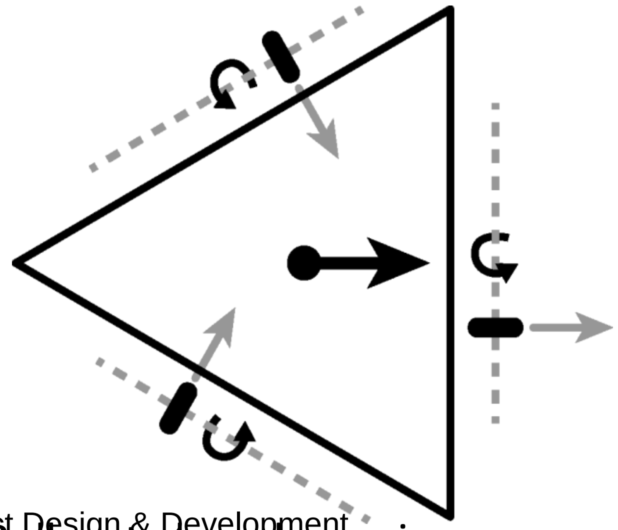
Attachment & Folding





Mobile Robot





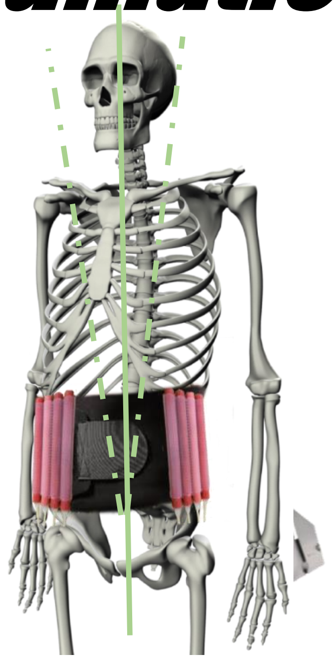
Belke et al. under review

Robogami with Brushless DC motors

Modular Origami Robot, Mori

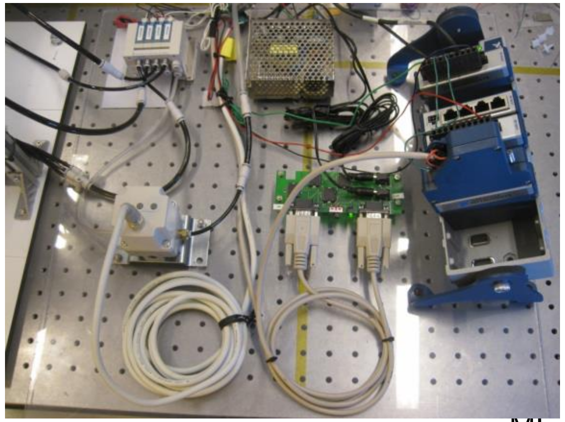
https://www.youtube.com/watch?v=1uO0mlIIkug

Trunk carapace for humans:
Pneumatic actuator-based design



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

Prototype in two deadband settings at 2 bar



- Current control test bed condition

Number of SPA modules	4 linear modules
working pressure	2 bars
Actuation frequency	0.5 - 1 Hz
range of motion	About ±10 degrees in pitch and roll axis
Payload	> 11 kg

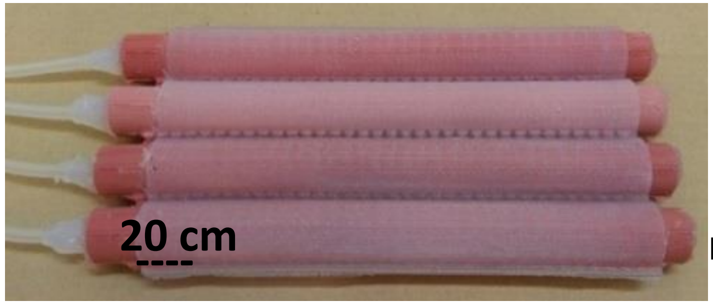
Trunk carapace for humans: *Pneumatic actuator-based design*

- Biomimetic Approach:

  Mimic postural muscle groups for assistance and control of trunk movements.

- For example:
  - Erector Spinae: runs parallel with the spinae to extend vertebral column, produces erect posture and allows the spine to flex from side to side.

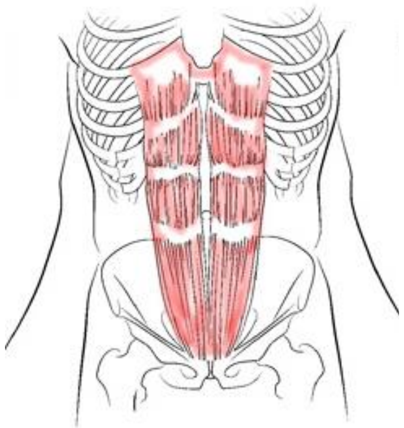
Module Characteristic	Value
Dimensions (WxLxT)	86x140x20 mm
Weight	170 g
Pressure range	0-2 Bar
Max Force	100 N
Frequency Range	< 1Hz
Longitudinal Stiffness	≈ 7500 N/m (vs 5000 N/m when OFF)
Bending Stiffness	≈ 200 N/m

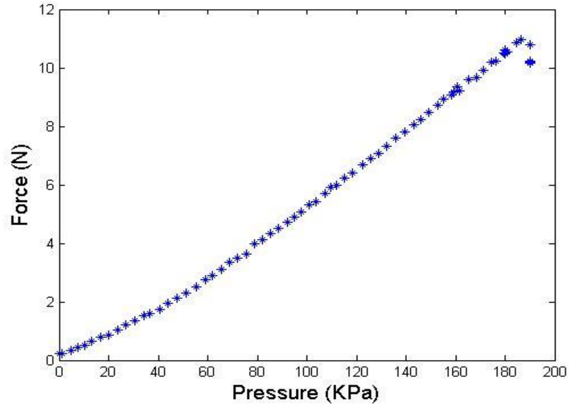


	I.D. (mm)	O.D. (mm)	length (mm)	weight (g)	theoretical force	Actuating dir
FESTO pneumatic cylinder	12	20	158	95	61 N @ 6 bar	tension
Single SPA	12	16	140	30	25 N @ 2 bar	tension
FESTO Pneumatic muscle	10	20	40-600	75	630 N @ 6 bar	contraction

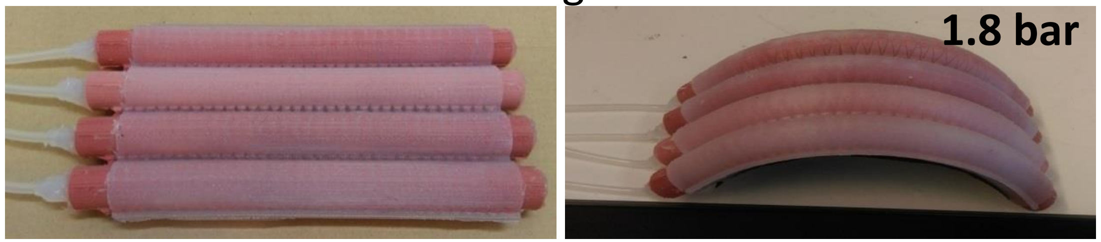
Trunk carapace for humans: *Pneumatic actuator-based design*

- Rectus abdominis: enables the tilt of the pelvis and the curvature of the lower spine.
- Actively modulating surface stiffness.





Bending Actuator



Contractile muscle groups are functionally simulated by SPA modules. We have 2 modules : bending and linear

Module Characteristic	Value
Dimensions (WxLxT)	86x140x20 mm
Weight	180 g
Pressure range	0-2 Bar
Max Bending Force	12 N
Frequency Range	< 1Hz
Bending Stiffness*	**≈ 950 N/m @ 2Bar (≈ 400 N/m @ 0.5Bar)**

Vibratory SPA skin for tactile feedback

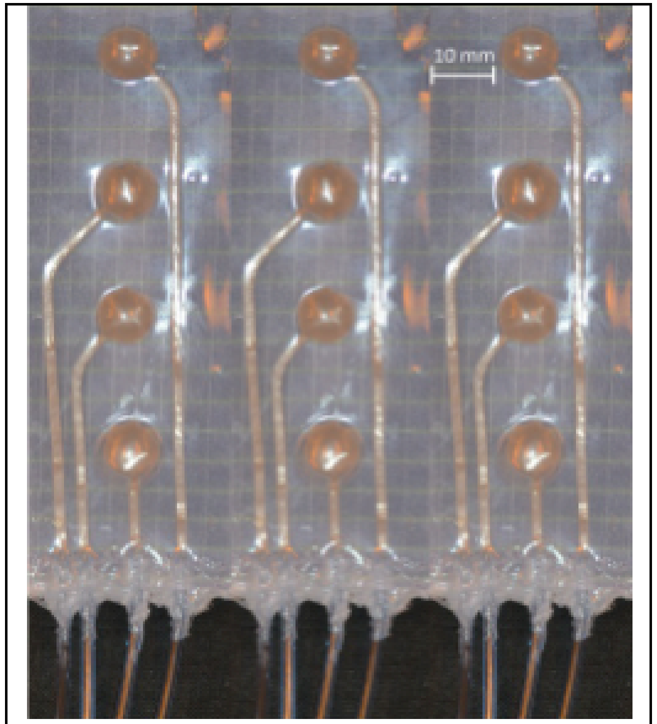
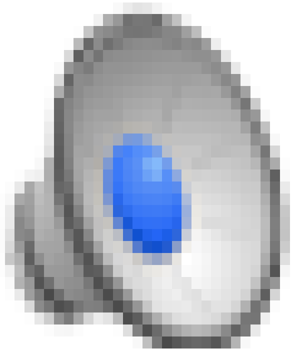


Figure 1 Soft skin array: The figure shows final prototype for 4x3 soft skin array with unstrechable base layer as support.



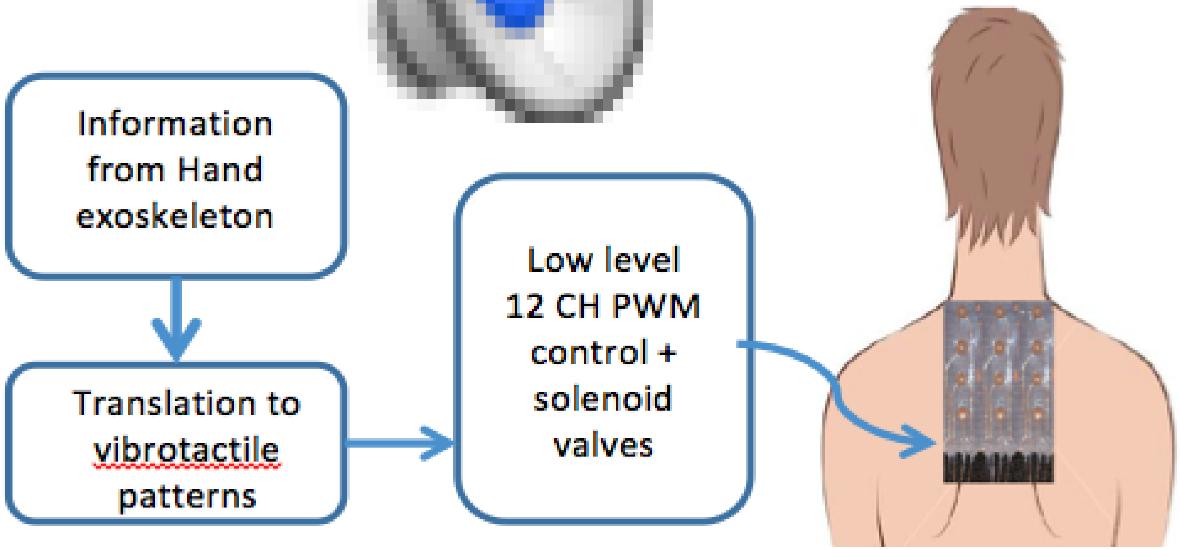
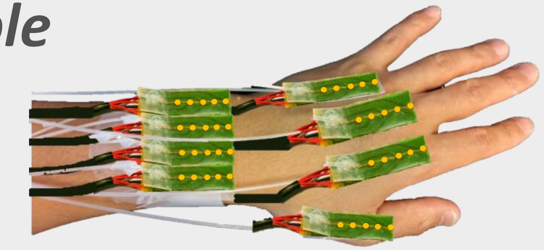


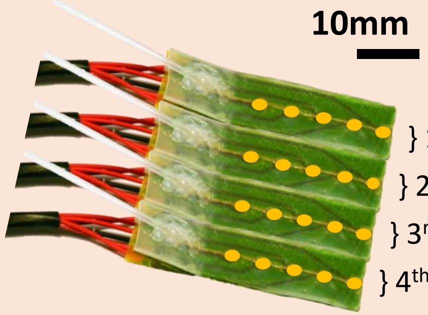
Figure 2 Vibrotactile feedback system: The figure represents block diagram of vibrotactile feedback system with 4x3 actuator array actively controlled using data from hand exoskeleton.

Concept of Soft Pneumatic Actuator - Skin

Wearable device



Distributed sensing & actuation



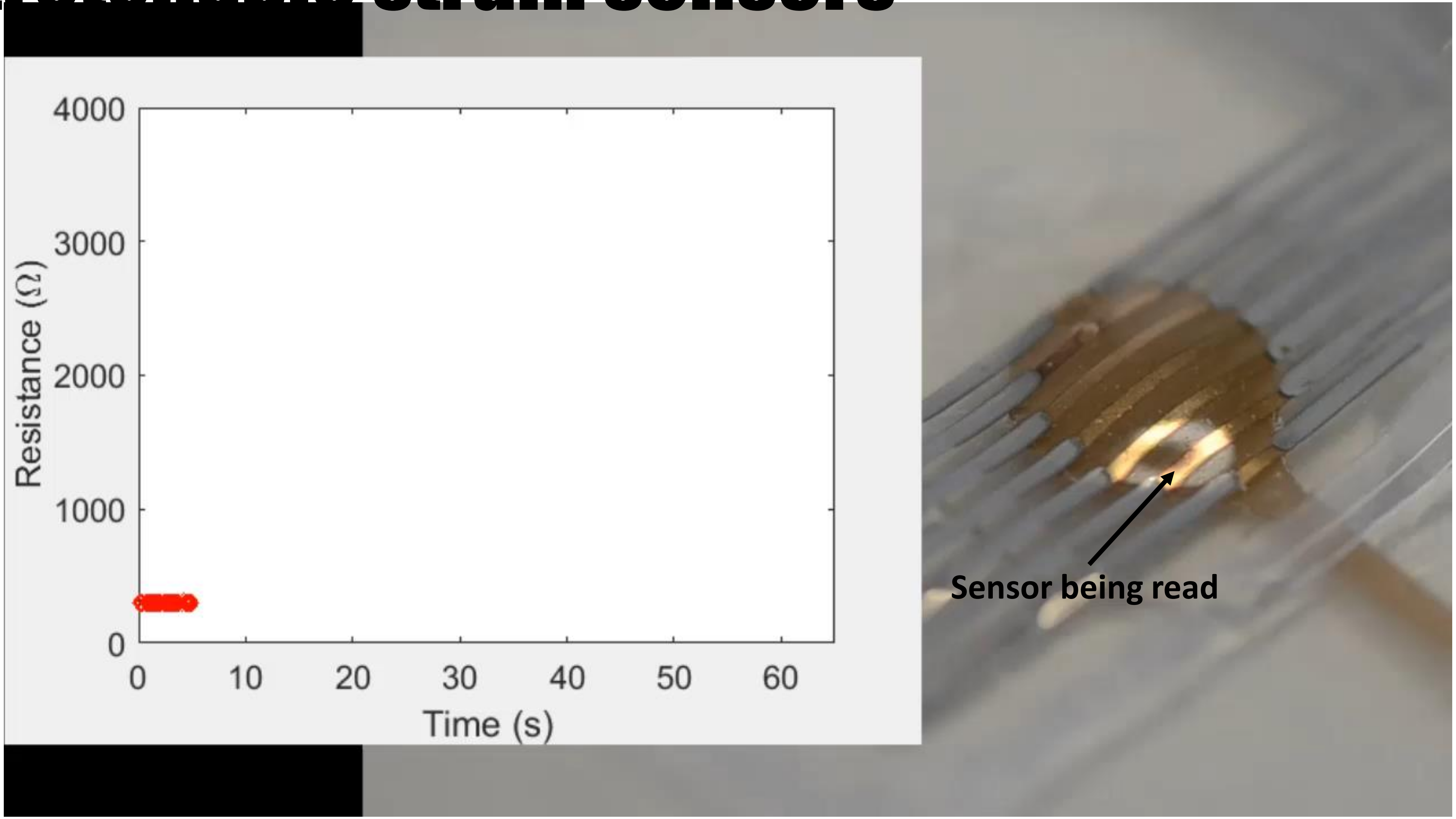
Input & Output device

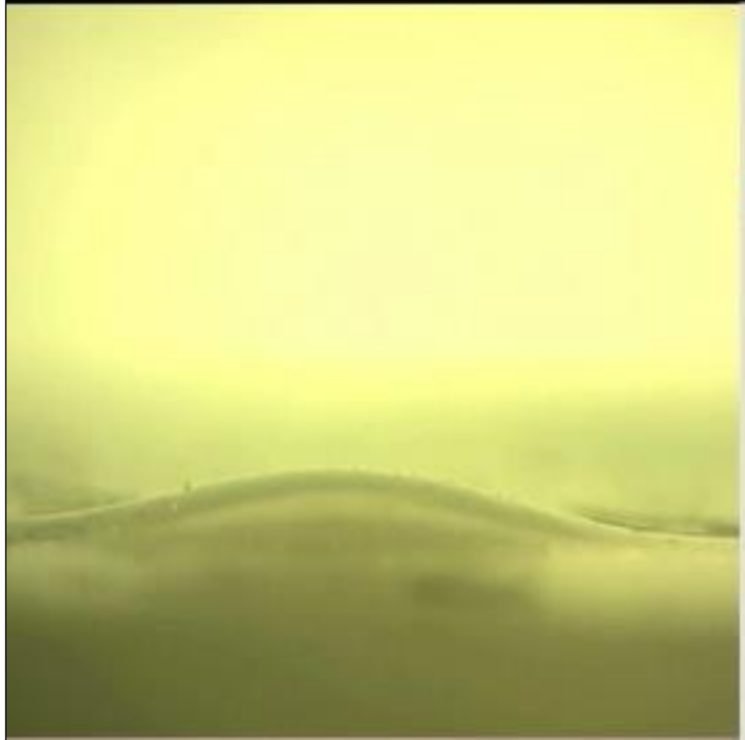
Actuation layer

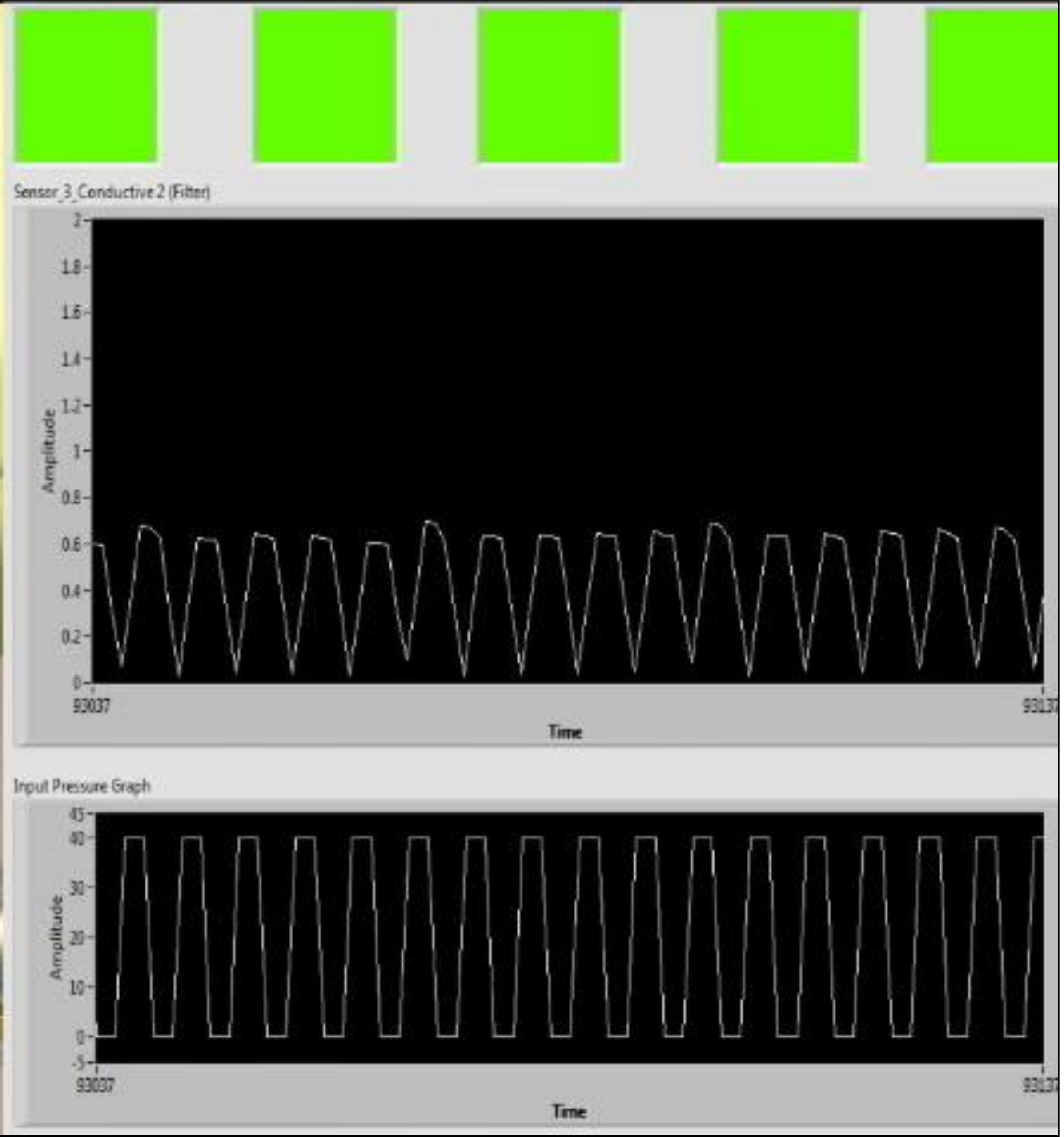
Sensing layer

Detects external load incl. vibration

Low-Profile Soft Pneumatic Skin with stretchable strain sensors







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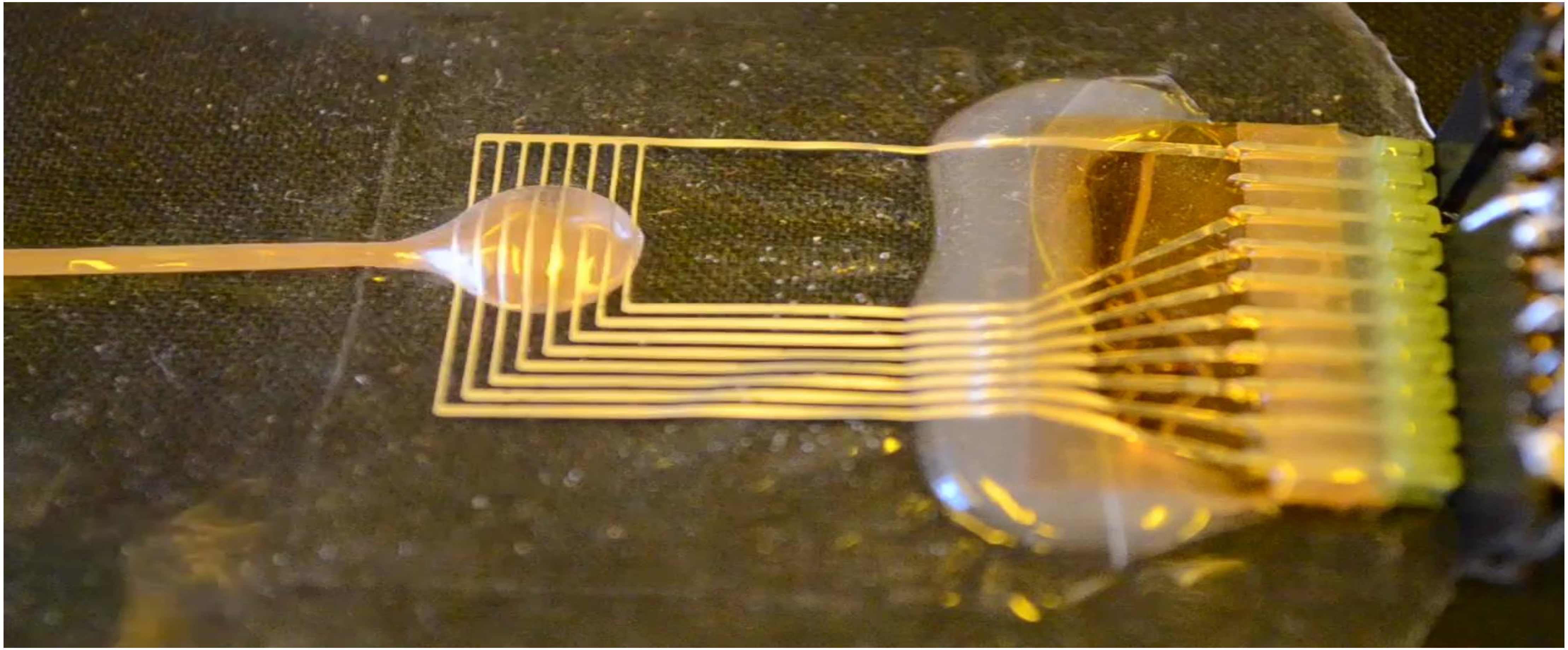
in Research

Low-Profile Soft Pneumatic Skin with stretchable strain sensors.



TPs and Demos

- Equip you with the latest soft actuator options in theory and practical use
- ”Softness” may not necessarily be the main solution for the project but useful tools and knowledge.

Arduino and electronics

- Simple electronics to build your own motor circuit
- Use Arduino kit to program your sensor and actuator feedback loop for controlling your wearable
- You will be given a complete kit before the lecture and TP

Brainstorming

- Brainstorm 3 potential “active” wearable product idea→ straps, fasteners, micro actuations, pumps, are also viable options.
- Prepare a 3 slides for 3 ideas that describes
  - The need
  - Existing concurrent products / patens (Pros and Cons)
  - Functionality – how does it move/ function ? Based on which information?

Potential Projects

- Design and fabrication of **wearable device**:
  - For joint assistance or rehabilitation exercise of wrist, ankle, elbow, finger/thumb glove…
  - Therapeutic shoe insole: change height, angle, center of pressure
  - Self tightening/loosening shoe, sandals, belt, for limited mobility/strength users

Upload by the end of day

- Make a group of 5-6 (put group member names and number on the moodle)
- Brainstorm 3 examples of sustainable technology and make 3 slides
- Upload the slides with your group number

NEXT WEEK: Homework: TinkerCAD

Create account in tinkerCAD and learning its basics

- Creating account:
  - Youtube tutorial
    - https://www.youtube.com/watch?v=4L8ViGqaZbE
  - TinkerCad website
    - https://www.tinkercad.com/
- Basics of tinkercad:
  - How to make a basic LED circuit in Tinkercad Circuits
    - https://www.youtube.com/watch?v=LrOM2GABK1g
  - Controlling LED brightness using a potentiometer in Tinkercad Circuits
    - https://www.youtube.com/watch?v=A7HpLRWm81Q