Wearable Robotics Design

Shaopeng Jiang
Prof. Jamie Paik
Reconfigurable Robotics Laboratory
EPFL, Switzerland
Lecture slides modified from ME410 Fall 2020

Mechanical Design & Development

- All engineering studies base their goal in creation.
- In mechanical engineering and specifically in the orientation of Design and 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 the physics, limitations, optimization of bringing actual issues involved with design solutions
- To define the product and functionality

New “Mechanical” Design Criteria

Relevance to modern engineering & society

- No human involved
- Highly predictable
- Programmable

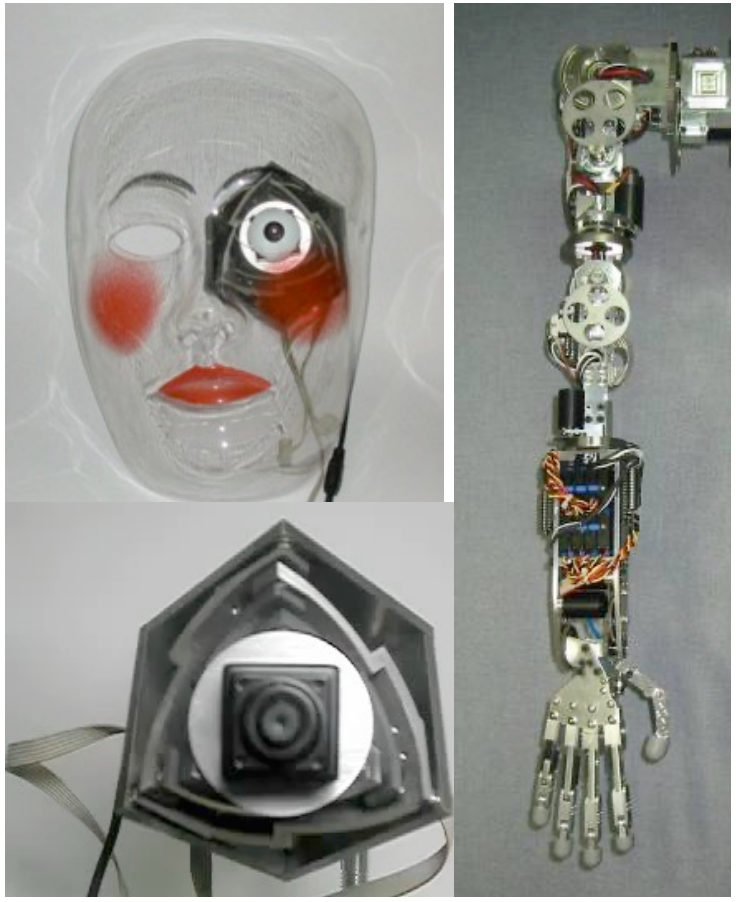
Augmented performance

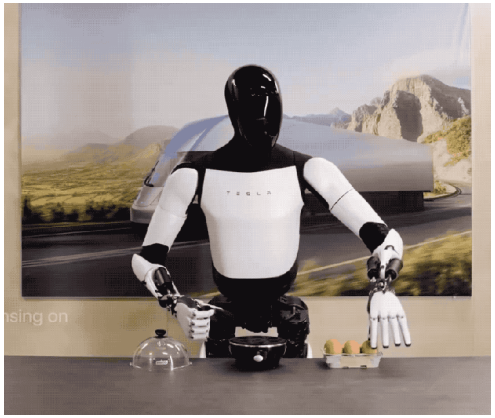
- Highly Automatic
- Force, speed, precision

- Highly unpredictable
- Random tasks and uncertainties

Augmented interactivity:

- Safety
- Reconfigurability
- Adaptability





1. “A Three-Degree-of-Freedom Anthropomorphic Oculomotor Simulator”, Int J of Control, Automation, and Systems, vol 4(2), 2006.
2. “Experimental Evaluation of Several Strategies for Human Motion Based Transparency Control”, Trans. in Advanced Robotics, Vol 54, 2009.
3. Humanoid Dexterous Hand, Paxini (Top) and Tesla Humanoid (bottom)

Spinal Cord Rehabilitation

Project Motivation

- We live in the fast-paced environment that demands interactive technology integrate seamlessly into our lives.

- Light, conforming, dynamic and interactive technologies are the key physical attributes for a product to be closer to the users.

Wearable Scenario

- Medical (rehab, assistive devices)
- Industrial (lifting aids, fatigue reduction)
- Everyday life (fitness, augmentation)
- More...

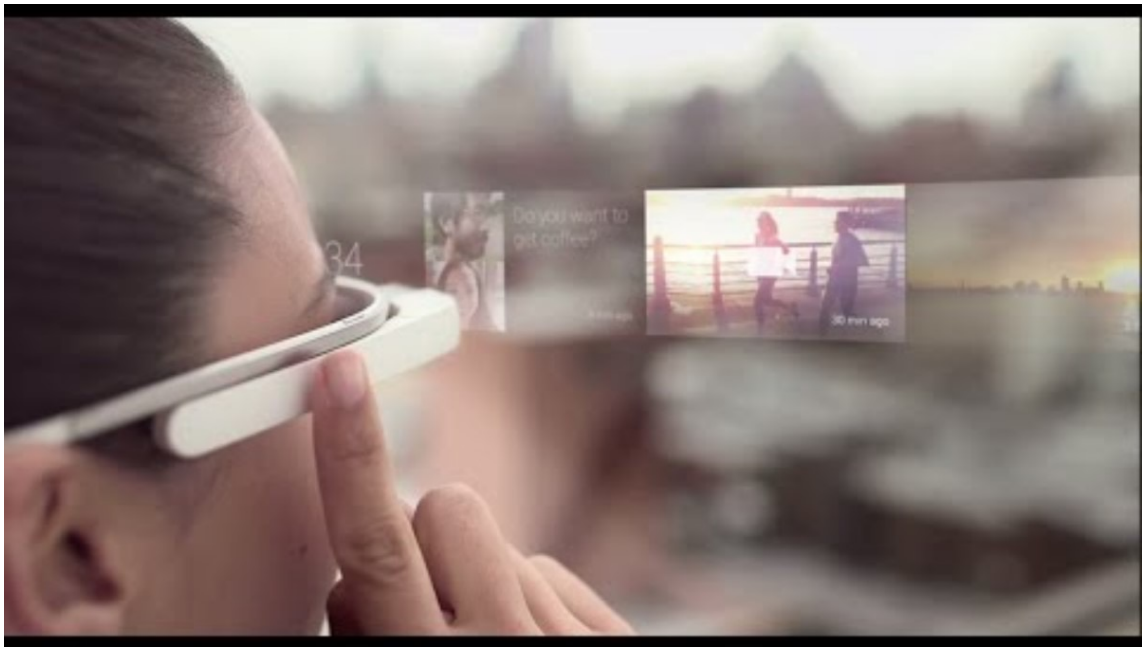
Early Pieces of Wearable 'Technology'

Electrophone, 1890

Wireless Headphone

Smart Eyeglasses?

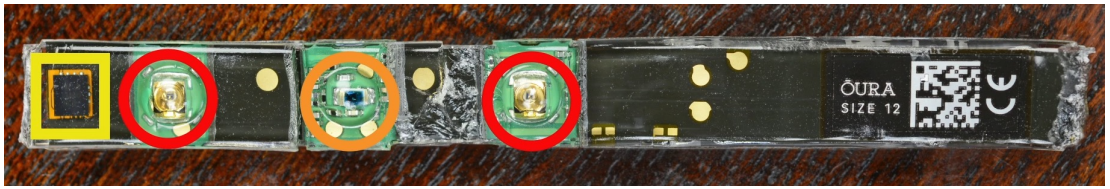
Wearable eyeglasses,
13th century



Google Glass, 2013

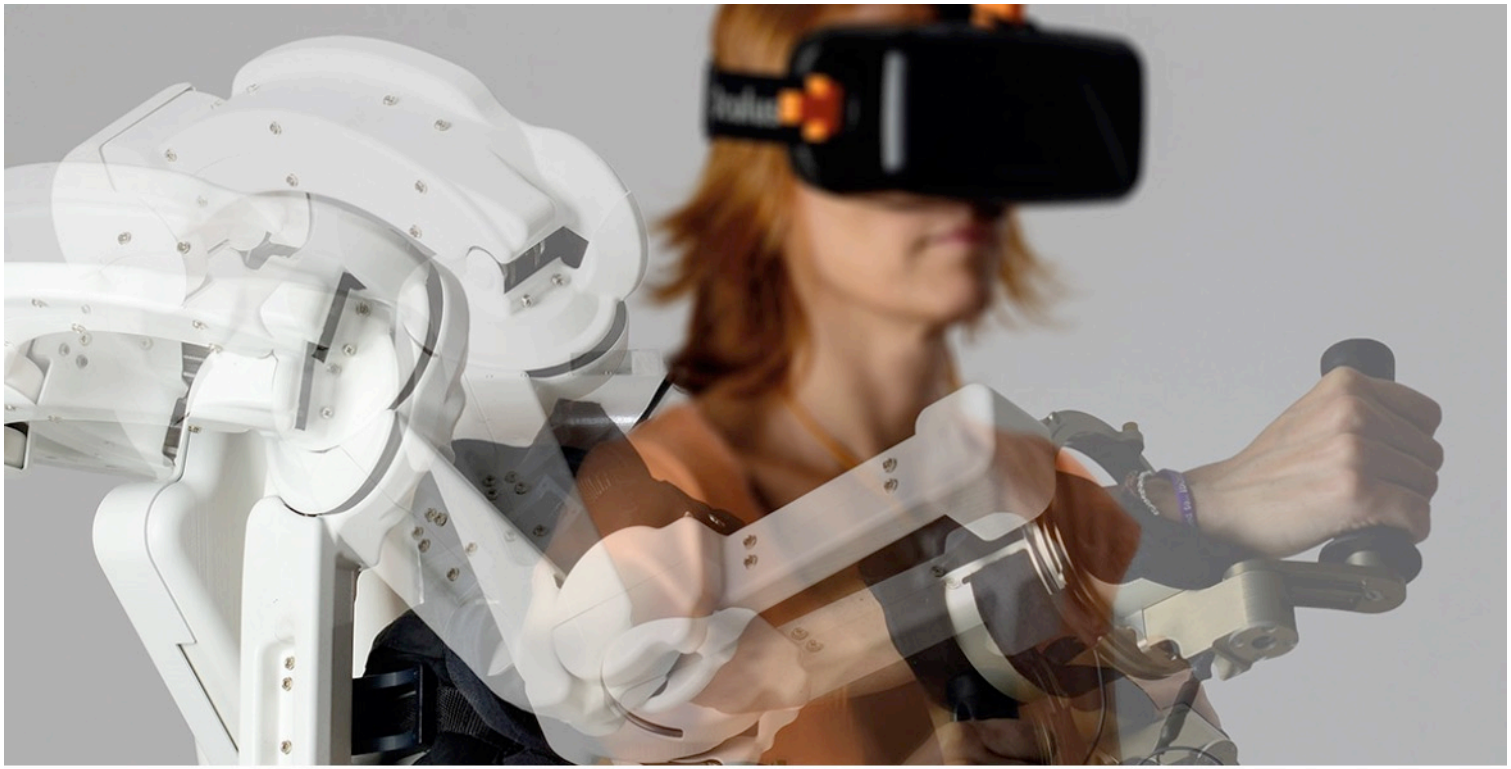
Smart Jewelry

Wearable robot?



Oura Ring, 2020

Exoskeleton

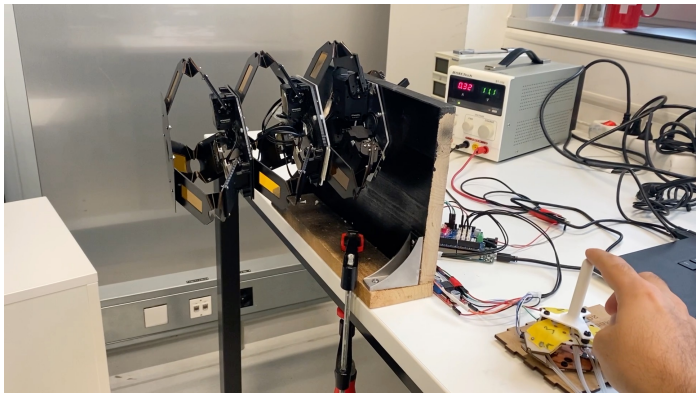


ALEx from Kinetek

Wearable Robots

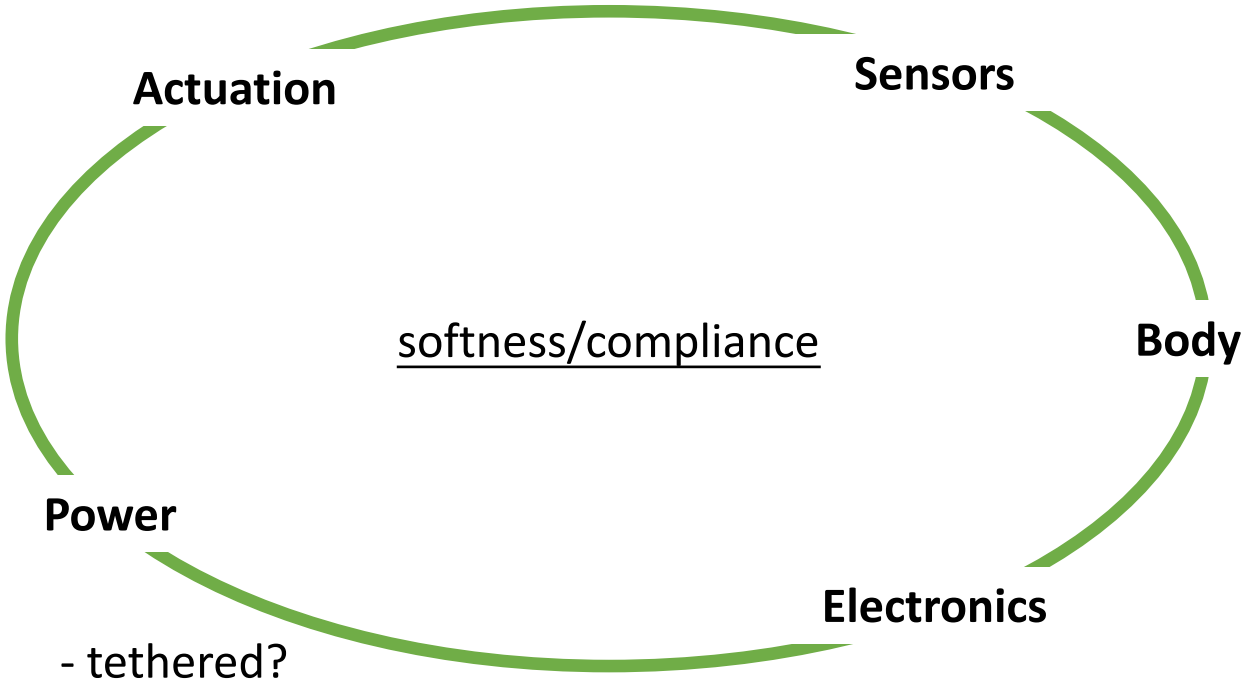
- Wearable interface - similar looking but achieve distinct functionalities.
- Maybe same sensor/motor but for different application.
- Specify the missing need and what additional technology can be introduced to improve user's quality of life.

Scalable platform for interaction?



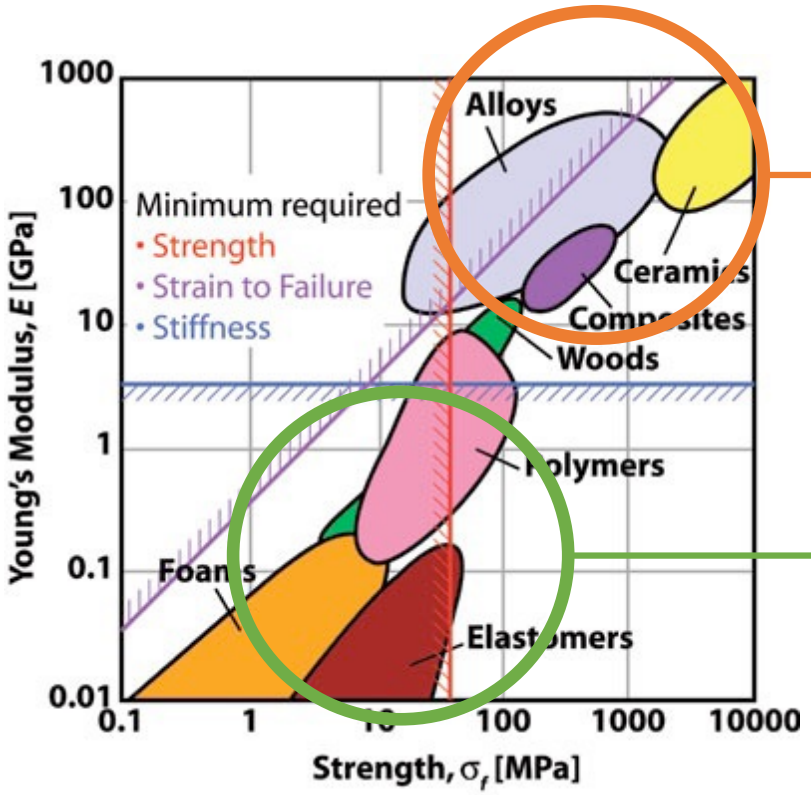
Mete, Huang & Paik, RoboSoft (2023)
Mete & Paik, RA-L (2021)

Softness and Wearable Robotics Design



- tethered?

Softness: Engineering Materials



Extrinsic softness:
Via mechanical design and control

Intrinsic softness:
Via material property

Wearable Robotics Essentials

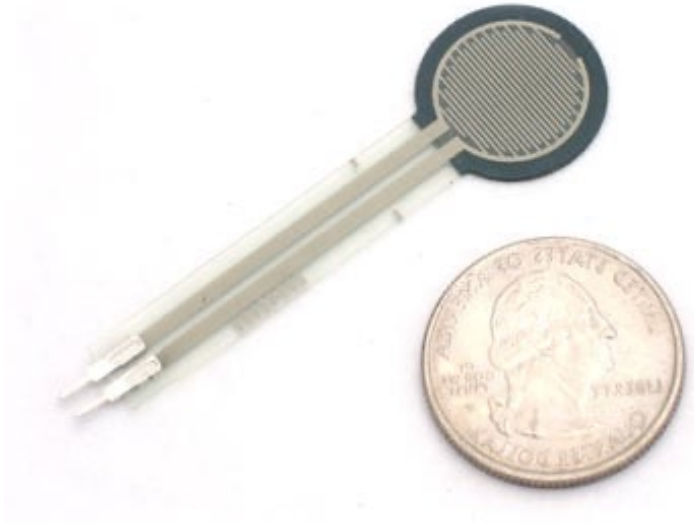
1. Design of soft sensing
2. Design of soft actuators
3. Design of soft controllers

Wearable Robotics Essentials

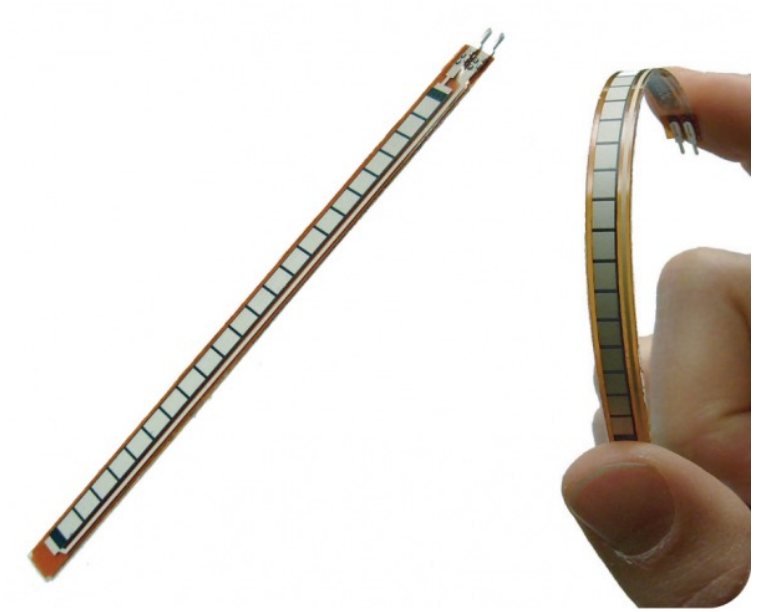
1. Design of soft sensing
2. Design of soft actuators
3. Design of soft controllers

Integrate on wearable structure

Flexible Sensors

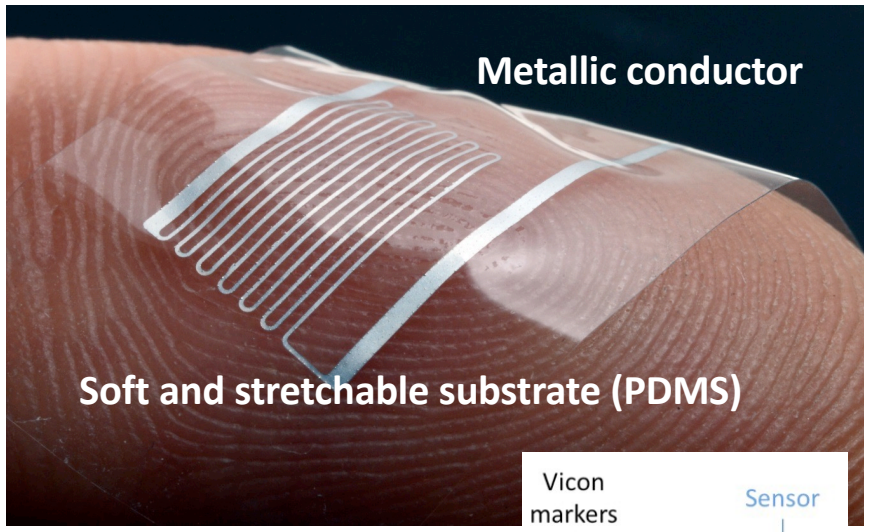


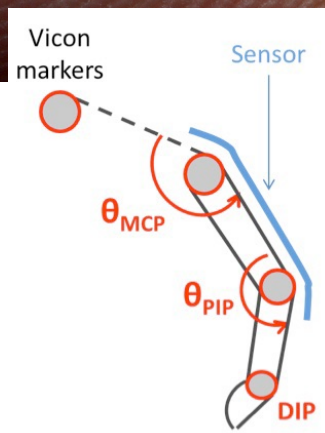
Force Sensitive Resistor (FSR)



Flex Bending Sensor

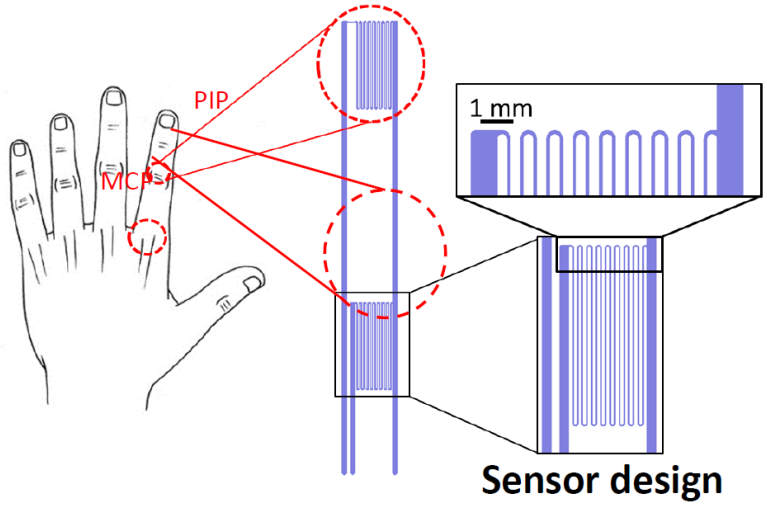
Resistive Strain Sensor





Vicon motion tracking

Comparison between strain sensor and Vicon bending angles

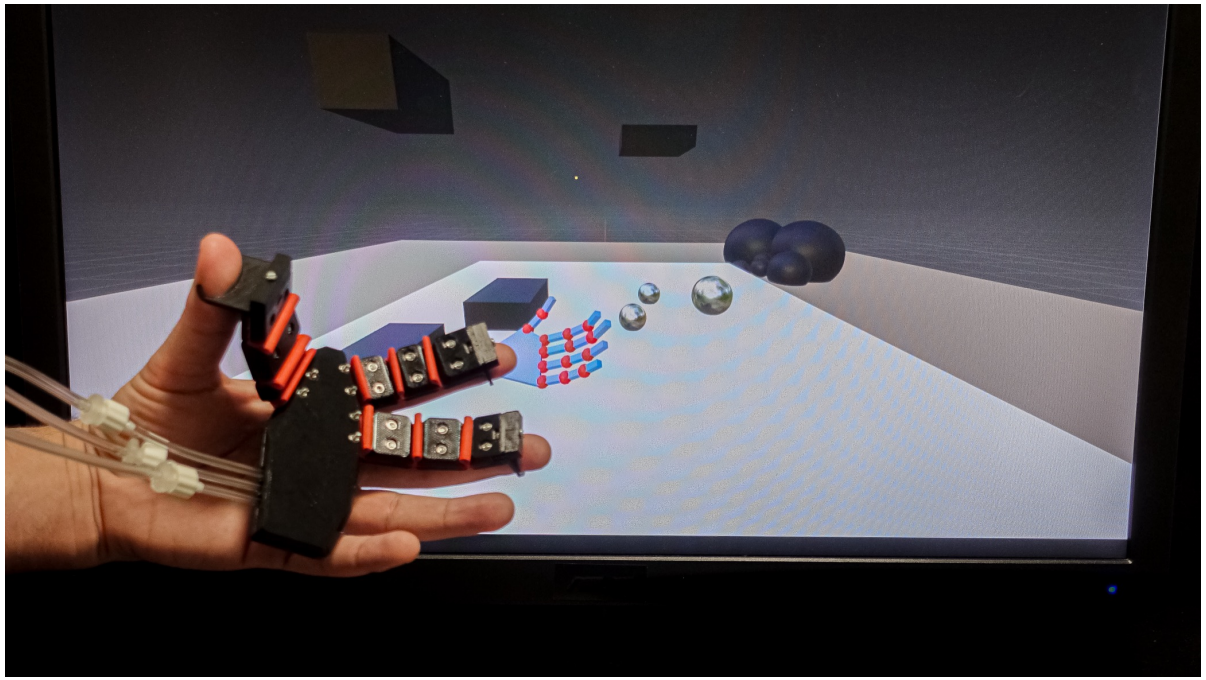


Sensor design

Objectives

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

Soft robotic glove



Pneumatic actuator?

Digits, S. Demirtas & J.Paik

Softness Controller

Mete, Jeong, Wang & Paik, PNAS (2024)

Wearable Robotics Essentials

1. Design of soft sensing
2. Design of soft actuators
3. Design of soft controllers

Integrate on wearable structure

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

Design of wearable structure

Key Design Principles:

- Safety & reliability
- Generation of movement
- Compliance & adaptability (focus on soft/reconfigurable structures)
- Modularity & scalability
- Comfort & ergonomics

Typical Issues

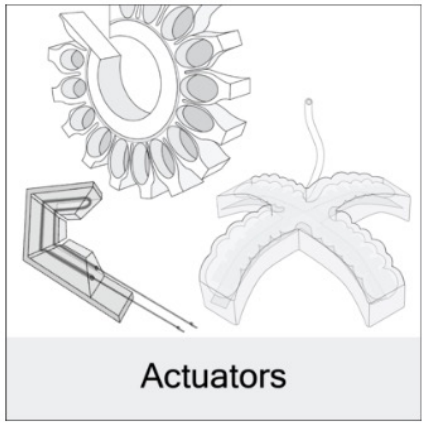
Bulkiness, discomfort, lack of compliance, insufficient testing

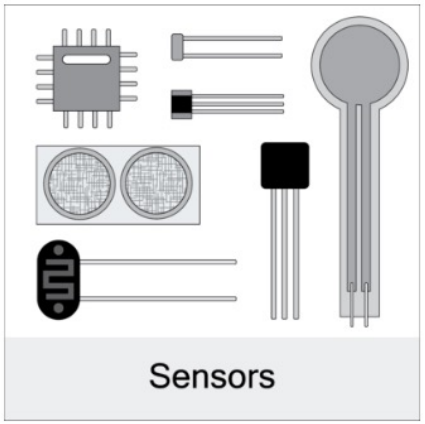
Wearable Toolkit

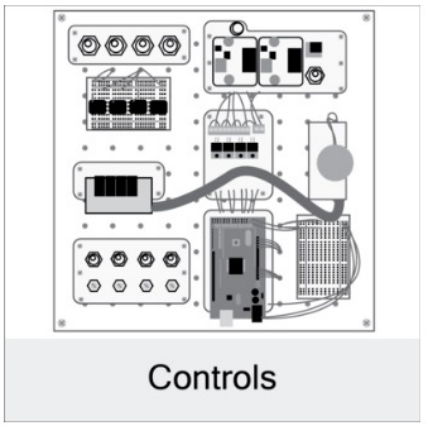
Static Simulation

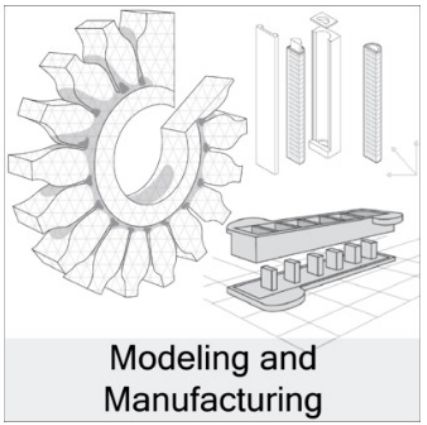
- **Mathematical Simulation**: solving mathematical models in Python, MATLAB, etc.
- **CAD software:** SolidWorks, Fusion 360, etc.
- **Finite Element Analysis(FEA) Software**: ANSYS, COMSOL, Abaqus, etc.

Soft Robotics Toolkit https://softroboticstoolkit.com/components

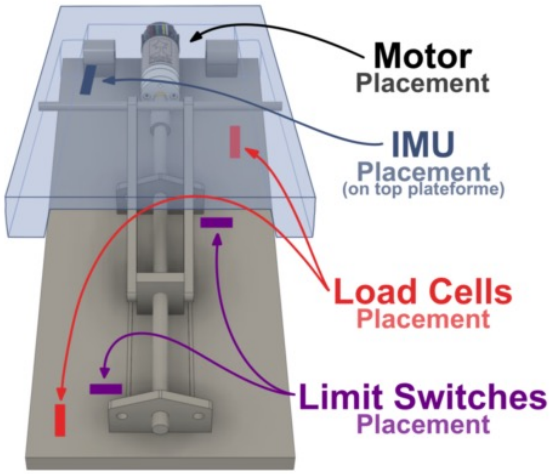


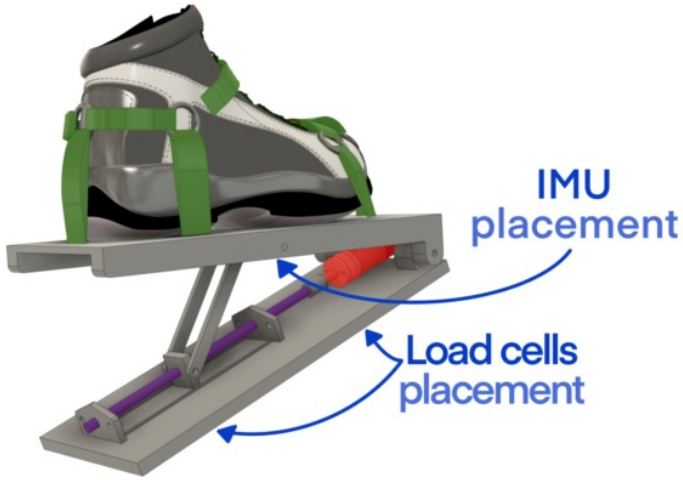






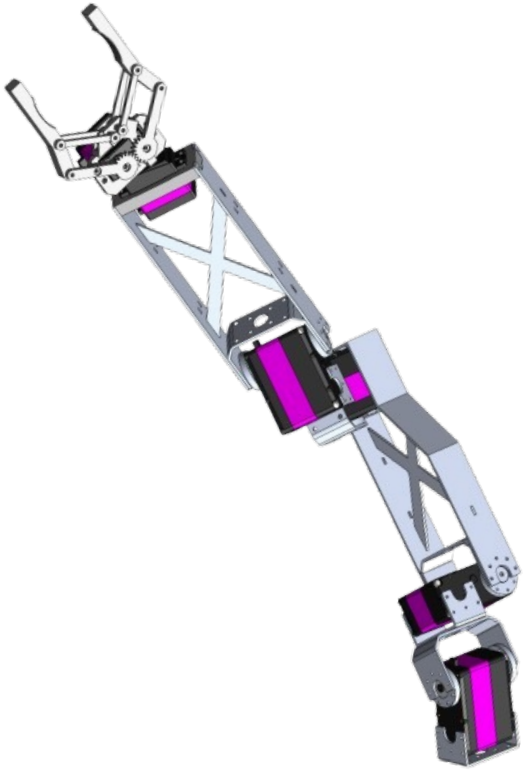
Case Study: Previous Projects

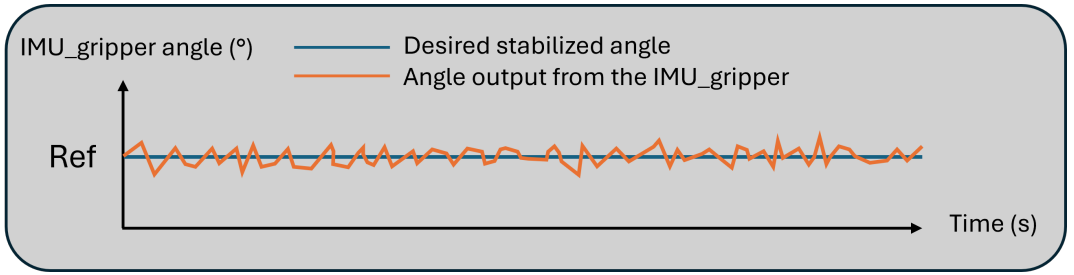




H3adMotion Arm, ME410 Fall 2024

Case Study: Previous Projects





H3adMotion Arm, ME410 Fall 2024

Summary & Takeaways

Key points:

- What are wearable robots
- Why they matter
- How to approach their design

Looking Ahead:

- You can do this
- User-centered design
- Practical design in final projects
- Safety

Resources

1. Google Glass, YouTube Video: https://www.youtube.com/watch?v=4EvNxWhskf8&t=21s
2. Oura Ring, YouTube Video: https://www.youtube.com/watch?v=BwA1hmSVgVY&t=462s
3. Suggested reading: Wearable Assistive Robotics: A Perspective on Current Challenges and Future Trends. https://pmc.ncbi.nlm.nih.gov/articles/PMC8539021/.
4. Flex sensor guide: https://learn.sparkfun.com/tutorials/flex-sensor-hookup-guide/all
5. Resource: soft robotics toolkit https://softroboticstoolkit.com/

Questions?

How: The Wearable Robotics Design Process

Design Thinking Approach
- User-centered design: Understanding real needs

Ideation & Concept Development
- Brainstorming, sketching, concept selection

Prototyping & Iteration
- Rapid prototyping, testing, and refining