ME 23N: Soft Robots for Humanity
Autumn 2019

Week 5: Rehabilitation and Textile Robots

Allison M. Okamura
Stanford University

Lab 3 recap: Pneumatic Artificial Muscles

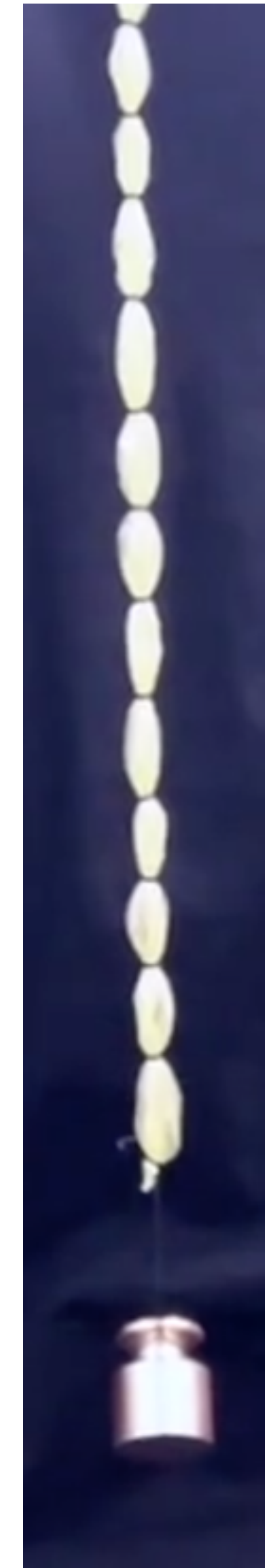
SPAM

1. Describe how the SPAM actuator works

a) How does the actuator shorten as you pressurize it? What is the function of the zip ties?

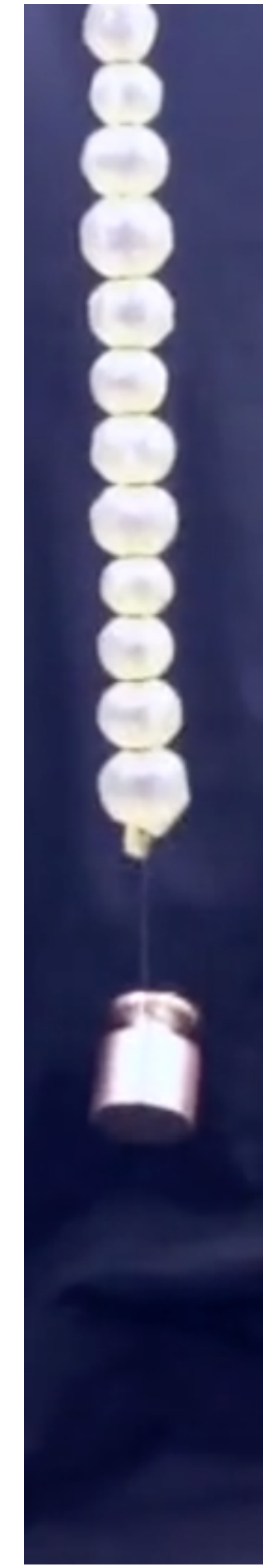
b) If you pull on the actuator, how does it respond in position and force (and how does change with the pressure you use)?

c) Would the actuator work better/worse/ the same if the tube was elastic instead of inextensible?



SPAM

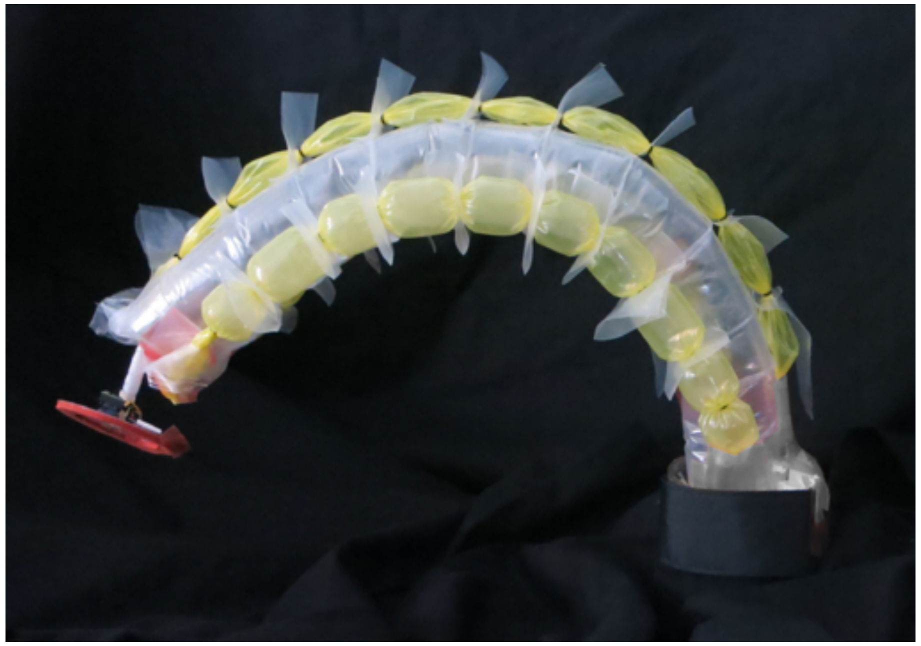
2. For Part 1, you tested different spacings of the zip ties. Measure and record the spacing, the starting length, and the actuated length. Calculate the contraction ratio (actuated length divided by starting length).
   - What spacing gives the best contraction ratio (most contraction)?
   - Why do you think this is the best spacing (or alternatively, why are other spacings worse)?



Continuum Arm

3. What happens when you actuate an sPAM attached to the pneumatic backbone?

   What about when you change the pressure, or when you actuate two sPAMs?



Continuum Arm

4. What could you use the soft continuum arm for?

   What else could you use the sPAM actuators for?

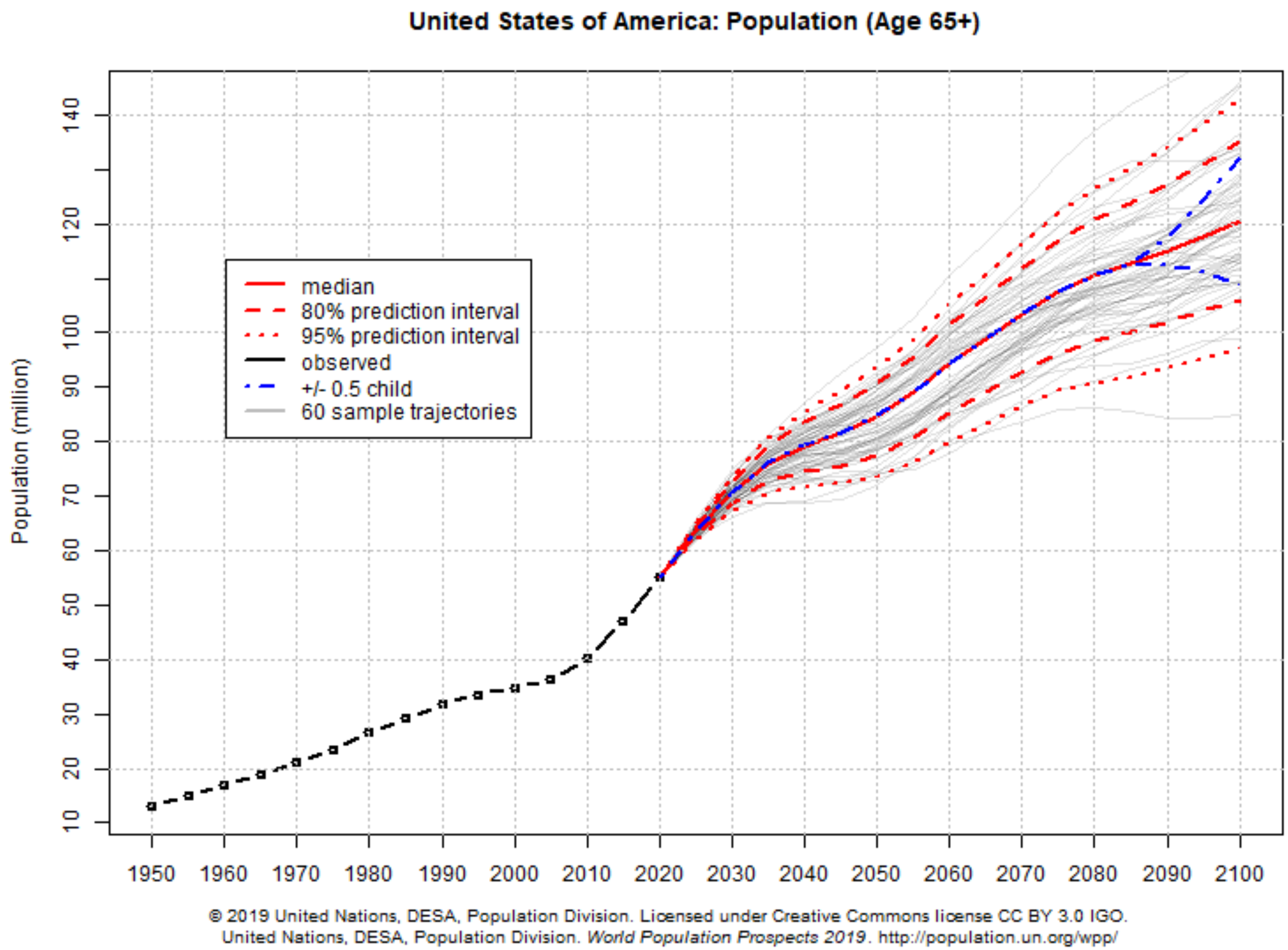
5. Any other thoughts?

Rehabilitation Robots

Growing Healthcare Challenges

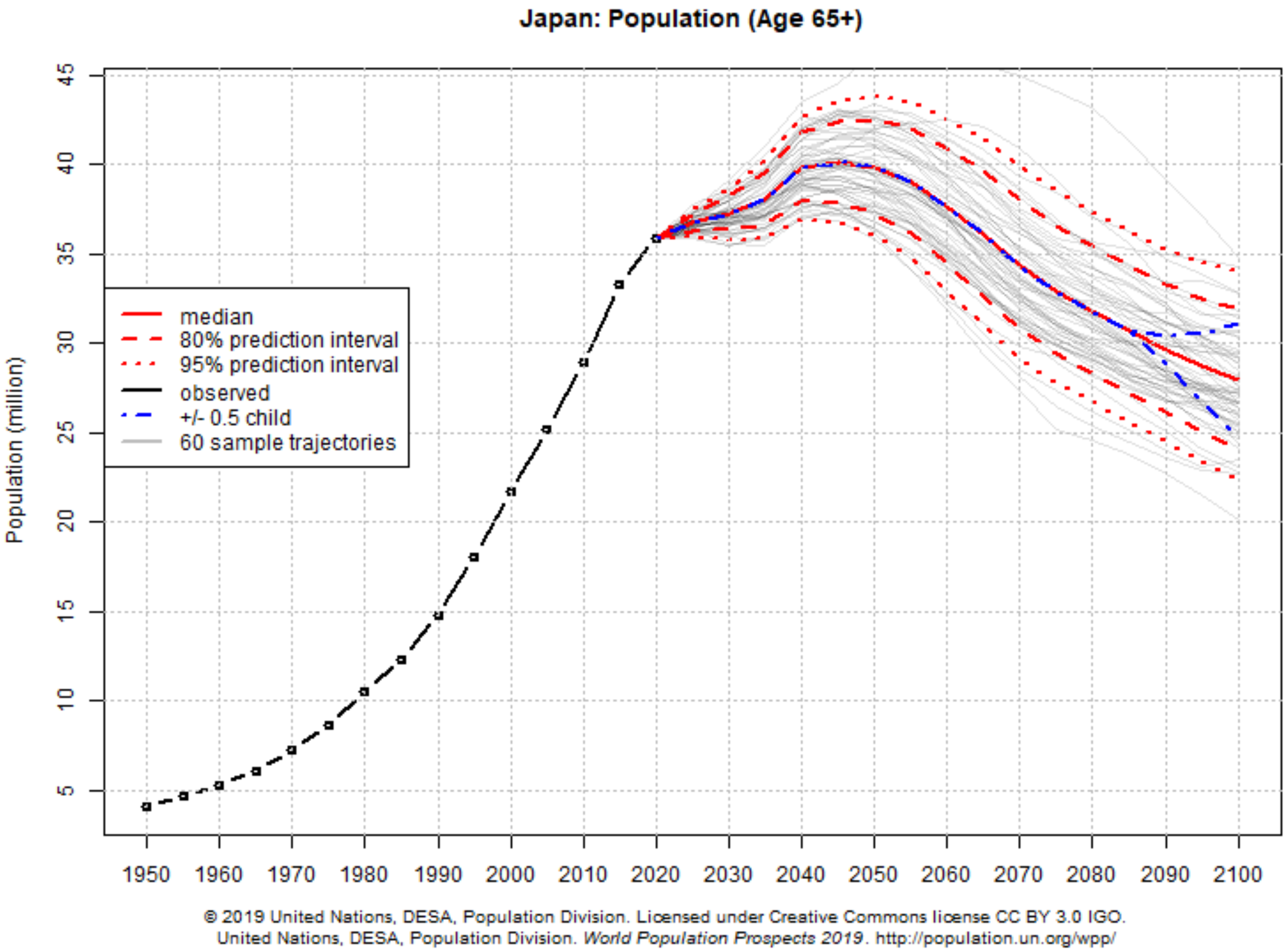
Maja Mataric (USC)

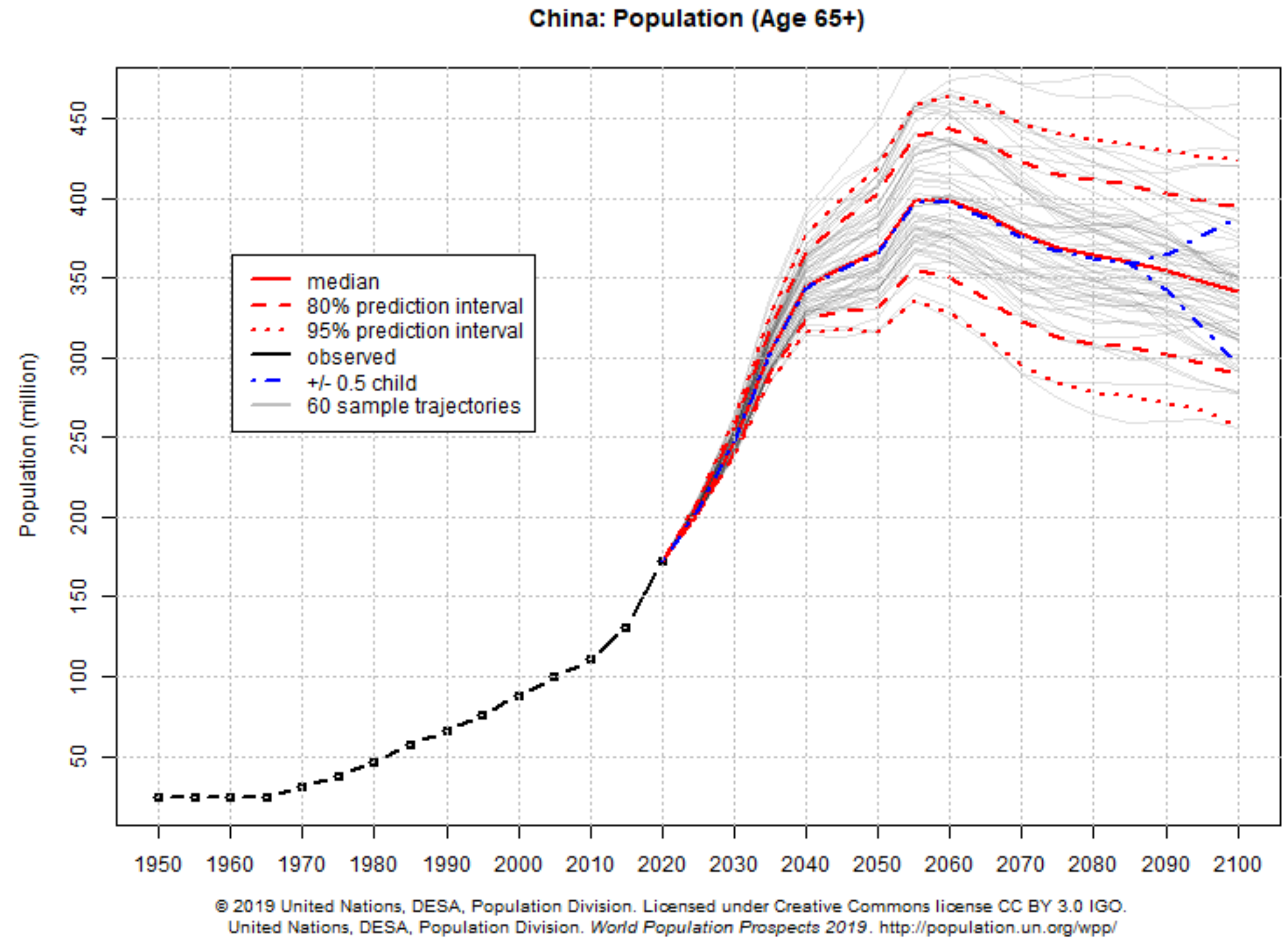
Past and anticipated population above age 65 (USA)



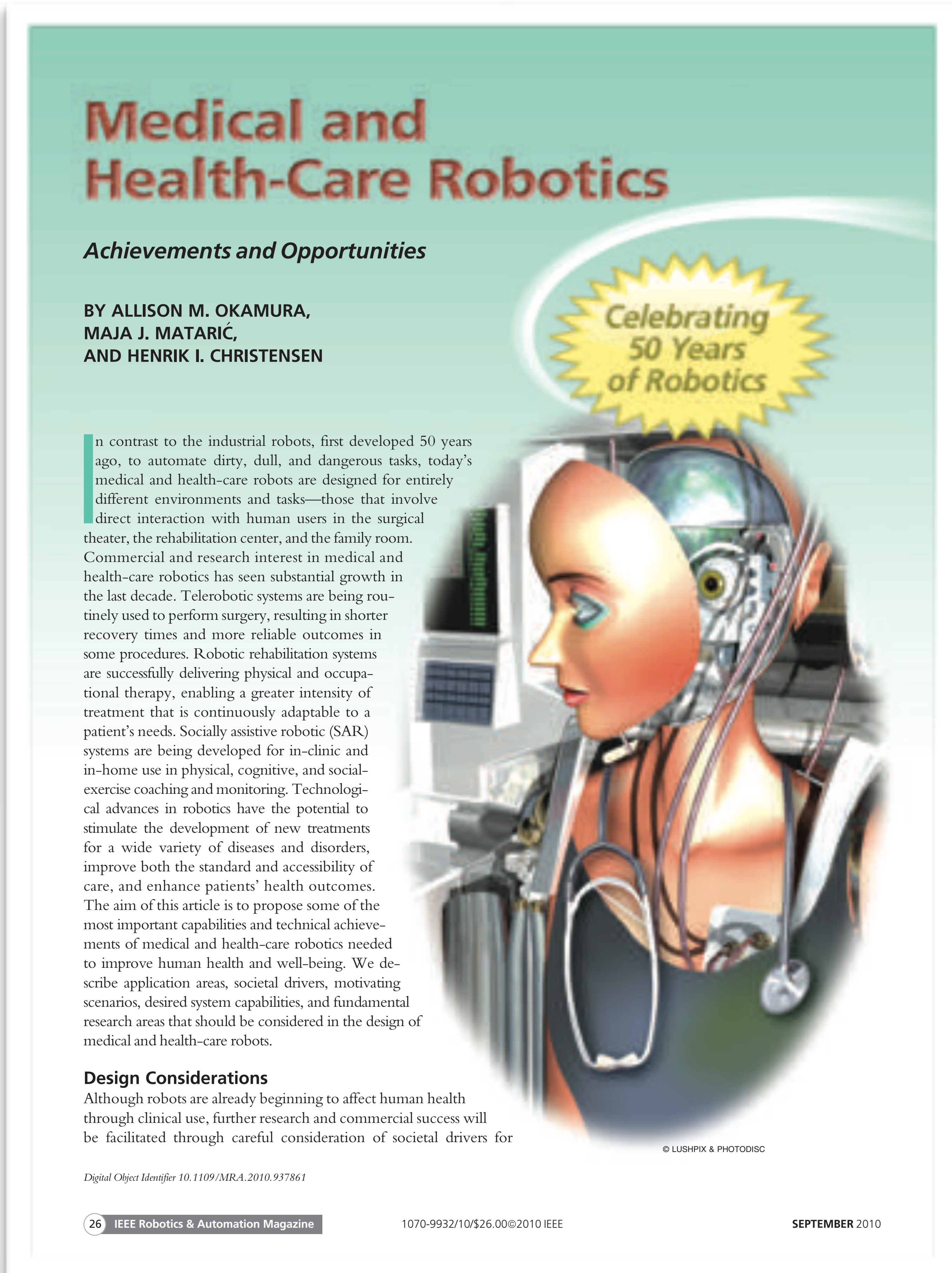
United Nations Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2019 Revision. https://population.un.org/wpp/Graphs/

Past and anticipated population above age 65 (Japan and China)





United Nations Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2019 Revision. https://population.un.org/wpp/Graphs/



Medical and Health-Care Robotics

Achievements and Opportunities

BY ALLISON M. OKAMURA,
MAJA J. MATARIĆ,
AND HENRIK I. CHRISTENSEN

In contrast to the industrial robots, first developed 50 years ago, to automate dirty, dull, and dangerous tasks, today's medical and health-care robots are designed for entirely different environments and tasks—those that involve direct interaction with human users in the surgical theater, the rehabilitation center, and the family room. Commercial and research interest in medical and health-care robotics has seen substantial growth in the last decade. Telerobotic systems are being routinely used to perform surgery, resulting in shorter recovery times and more reliable outcomes in some procedures. Robotic rehabilitation systems are successfully delivering physical and occupational therapy, enabling a greater intensity of treatment that is continuously adaptable to a patient's needs. Socially assistive robotic (SAR) systems are being developed for in-clinic and in-home use in physical, cognitive, and social-exercise coaching and monitoring. Technological advances in robotics have the potential to stimulate the development of new treatments for a wide variety of diseases and disorders, improve both the standard and accessibility of care, and enhance patients' health outcomes. The aim of this article is to propose some of the most important capabilities and technical achievements of medical and health-care robotics needed to improve human health and well-being. We describe application areas, societal drivers, motivating scenarios, desired system capabilities, and fundamental research areas that should be considered in the design of medical and health-care robots.

Design Considerations

Although robots are already beginning to affect human health through clinical use, further research and commercial success will be facilitated through careful consideration of societal drivers for

Digital Object Identifier 10.1109/MRA.2010.937861

For a big-picture review, see:

A. M. Okamura, M. J. Mataric, and H. I. Christensen. Medical and healthcare robotics: Achievements and opportunities. IEEE Robotics and Automation Magazine, pp. 26-37, September 2010.

For more extensive reading, see:

From Internet to Robotics:
A Roadmap for US Robotics
http://www.us-robotics.us/reports/CCC%20Report.pdf

Application areas for medical and healthcare robotics

- **medicine**: the **application** of science and technology to treat and prevent injury and disease
  - surgery, interventional radiology
  - physical and occupational therapy
  - replacing lost limb function
- **health care**: the **availability** of treatment and prevention of illness
  - therapy oversight
  - coaching and motivation

In addition...

- Creating a robotic system that mimics biology has been used as a way to study and test how the human body and brain functions

- Robots can be used to acquire data from biological systems with unprecedented accuracy, enabling us to gain quantitative insights into both physical and social behavior.

Societal drivers: Economics

What economic impact could result from increased use of robotics in medicine and healthcare?

Societal drivers: Economics

- faster recovery times lead to improved worker productivity
- new technologies improve risk-benefit and cost-benefit ratios
- lower costs to society by decreasing impact on families, caregivers, and employers
- training to lower number of medical errors and lawsuits
- objective approaches for accountability and certification/assessment

Societal drivers: Access

What how can robotics increase the access to medicine and healthcare?

Societal drivers: Access

- affordability
  - robots could reduce the cost of clinical rehabilitative care
  - in-home systems for motivating and coaching physical and cognitive exercise for prevention and rehabilitation
  - caretaking of the elderly to promote aging in place (i.e., at home), delay the onset of dementia, and provide companionship to mitigate isolation and depression
- location
  - natural and man-made disasters
  - battlefield; remote working environments (space, undersea, underground)
  - rural populations

physically assistive robots

Movement Therapy and Assistance

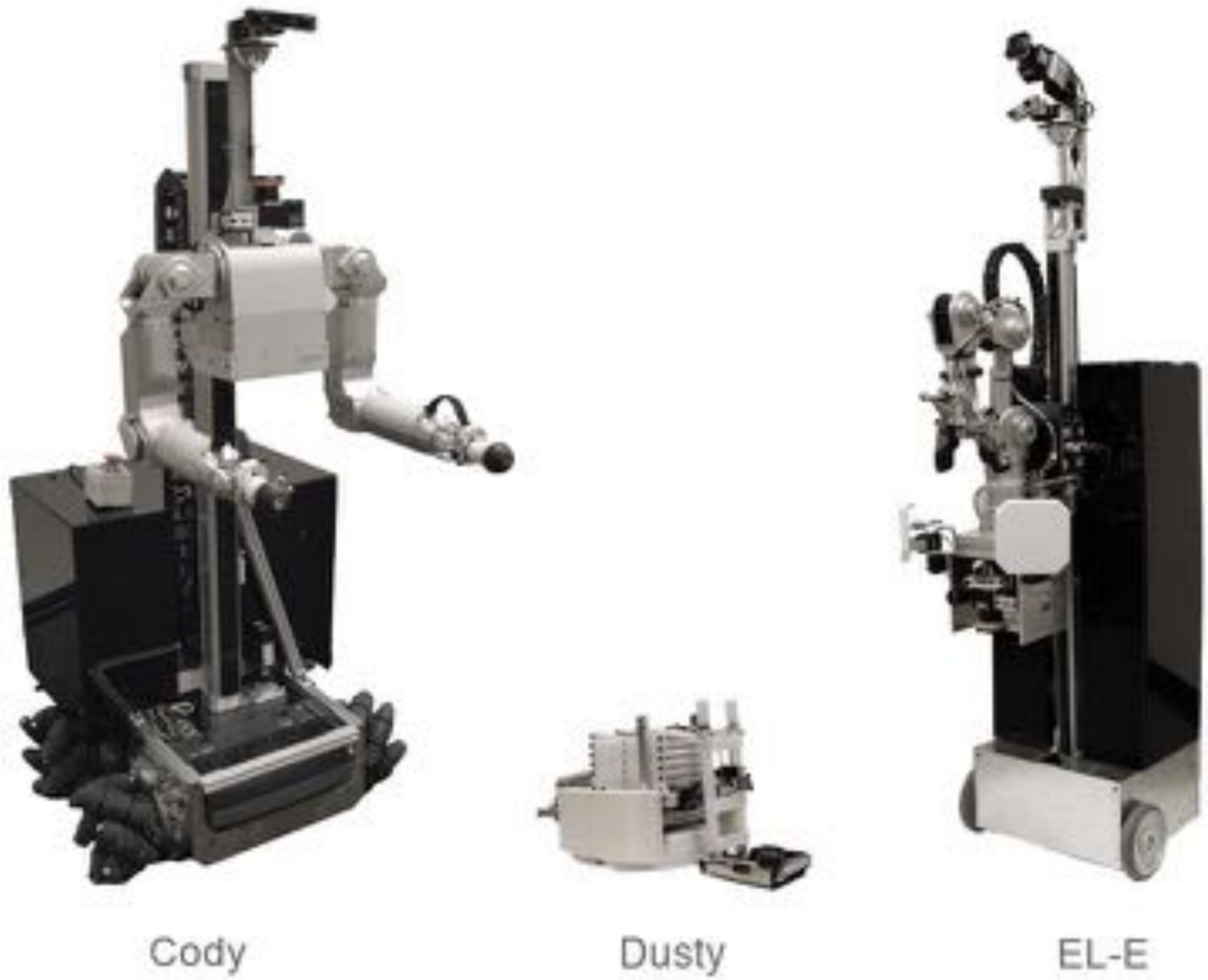
- Over 25% of U.S. population has some functional physical limitation that affects normal living
- 6.5M people in the US have had a stroke (by 2050, cost projected to be $2.2 Trillion)

Wheelchair robots

ibot (Dean Kamen)

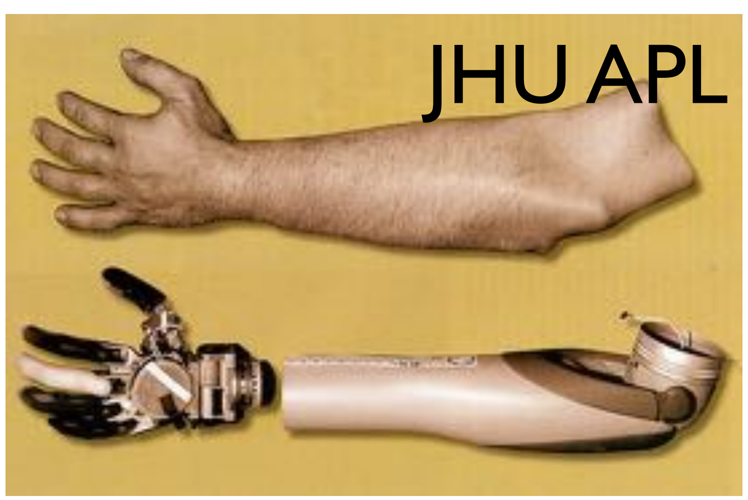
Wheelchair-Mounted Robotic Arm
(Waseda University)

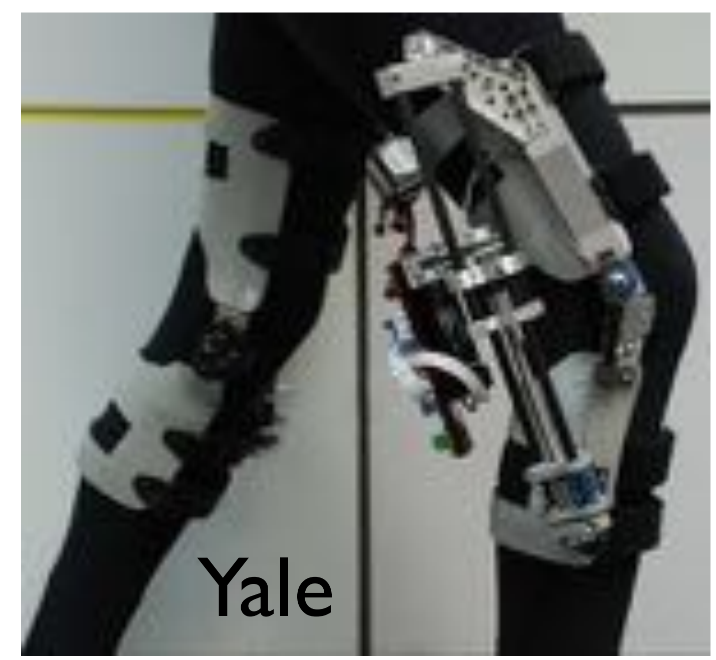
Household/Activities of Daily Living (ADL) helpers



Robots to aid the sick and elderly (Kemp lab, Georgia Tech)

robotic replacement of diminished/lost function (i.e., prosthetics and orthotics)

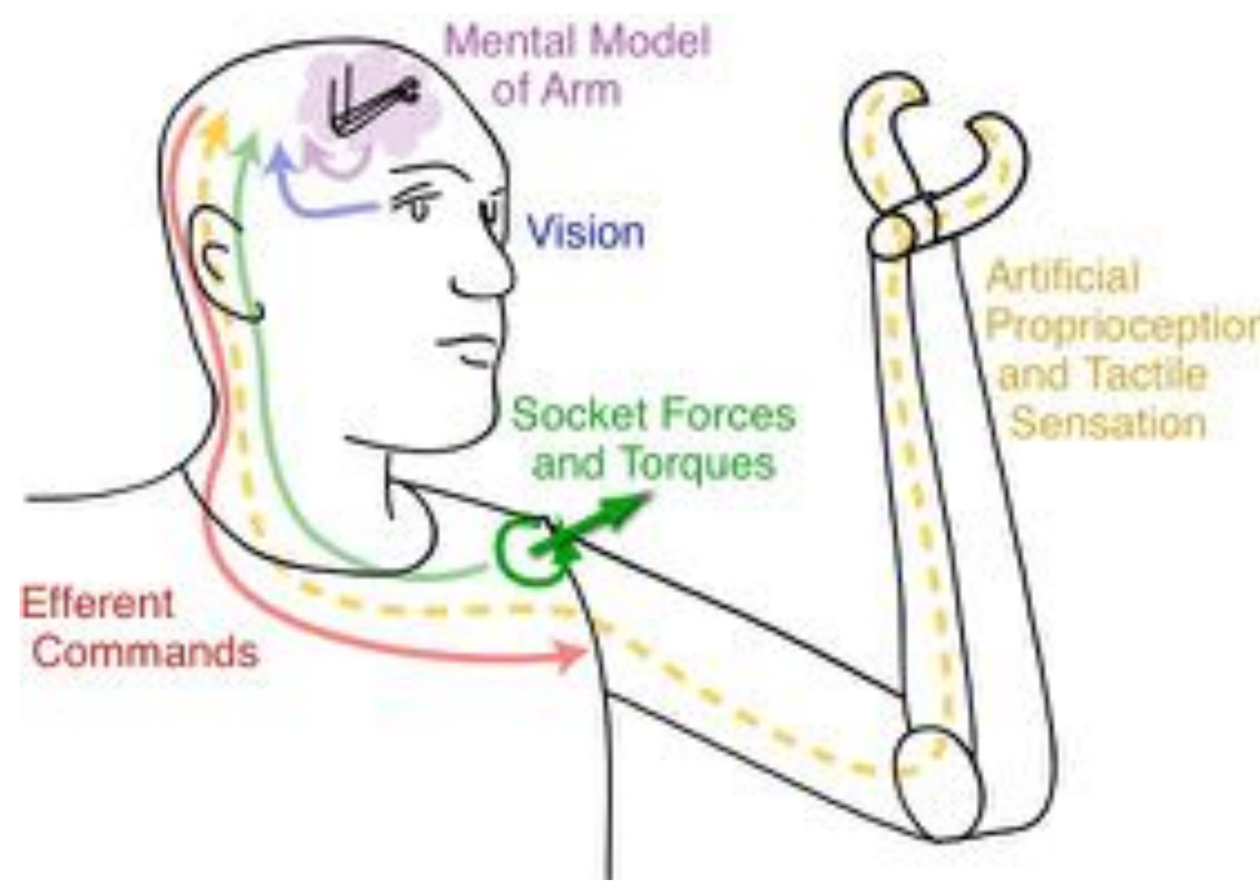




robotic replacement of diminished/lost function (i.e., prosthetics and orthotics)

Challenges include:

- cosmesis
- neural interfaces
  - control
  - communicating sensory information
- level of autonomy
- size and weight vs. functionality



socially assistive robots

slides provided by Maja Mataric

Socially Assistive Robotics

Problem: cost/population size and growth trends
Need: personalized medium to long-term care
Part of the solution: human-centered robotics to improve health outcomes

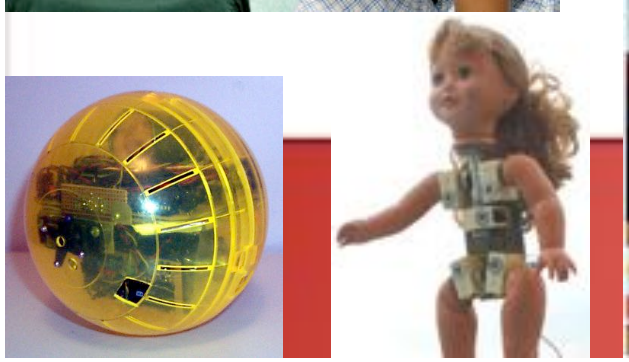
- Monitoring
- Coaching/training
- Motivation
- Companionship/socialization

Robots can be a "force multiplier" for caregivers, reducing health care costs and improving quality of life

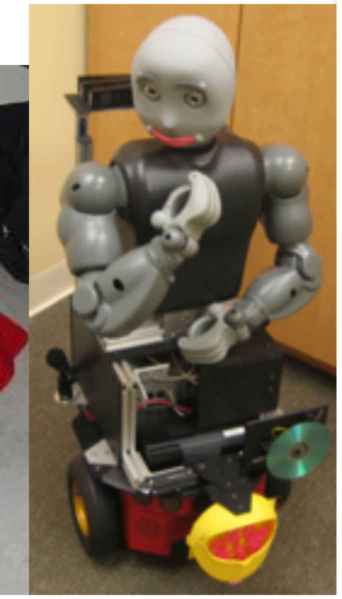
Maja Mataric (USC)

Maja Mataric (USC)

Autism Spectrum Disorder





Eldercare, Alzheimer's Disease, and Dementia





Textile and Wearable Robots

Wearability

Ideally:

- Lightweight
- Small size
- Conforms to the body

Wearability

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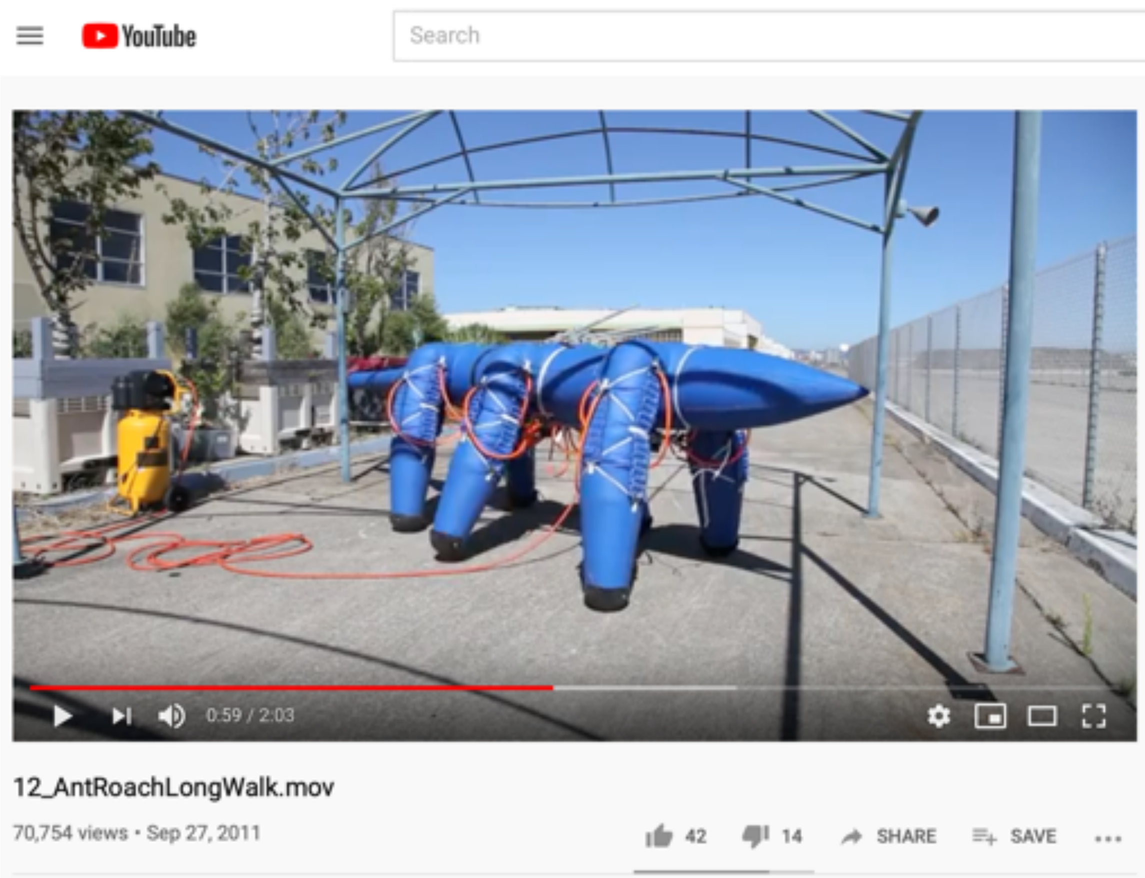
- Lightweight
- Small size
- Conforms to the body

Textile Robotics

Living jewelry (MIT)

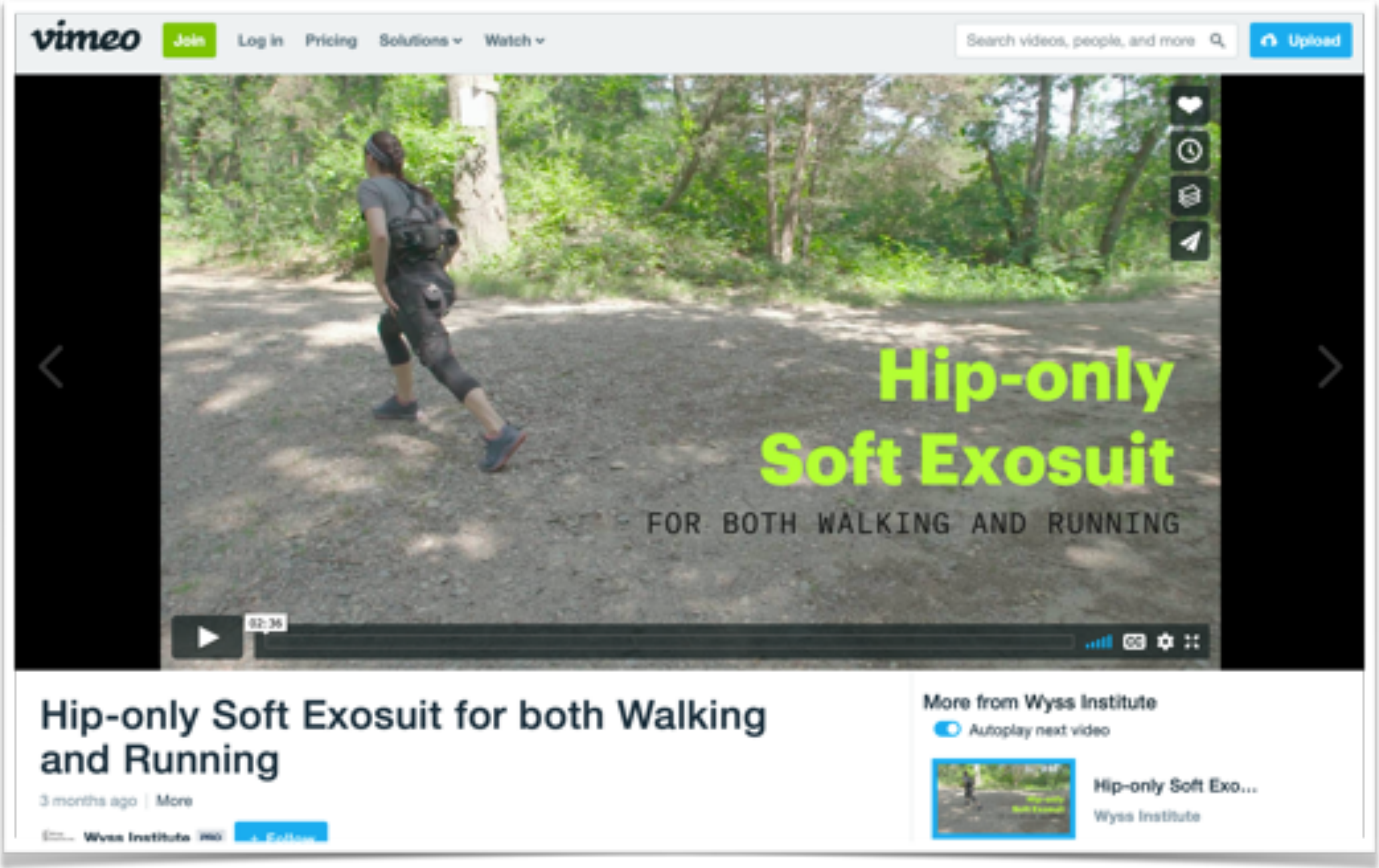
Textile Robotics



https://youtu.be/Y9dv24BqIZQ

https://youtu.be/zhItc7anwpk

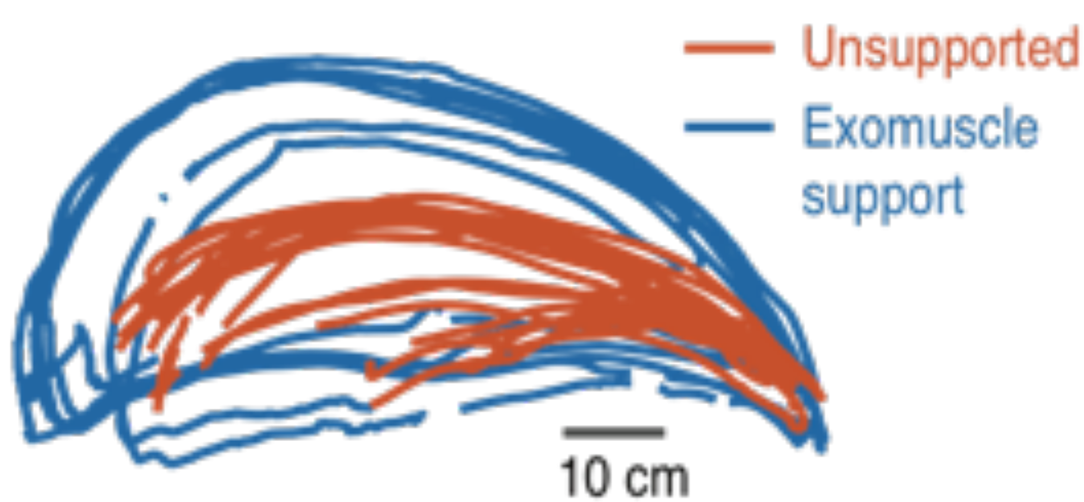
Pneubotics/Otherlab



https://vimeo.com/348390281

Exomuscle

Cole Simpson



Simpson et al. 2017

HapWRAP

Wearable Restricted Actuator Pneumatics

Michael Raitor

Nathaniel Agharese

Raitor et al. ICRA 2017, Agharese et al. ICRA 2018

Textile types

Textiles/fabrics are made from many materials, with four main sources:

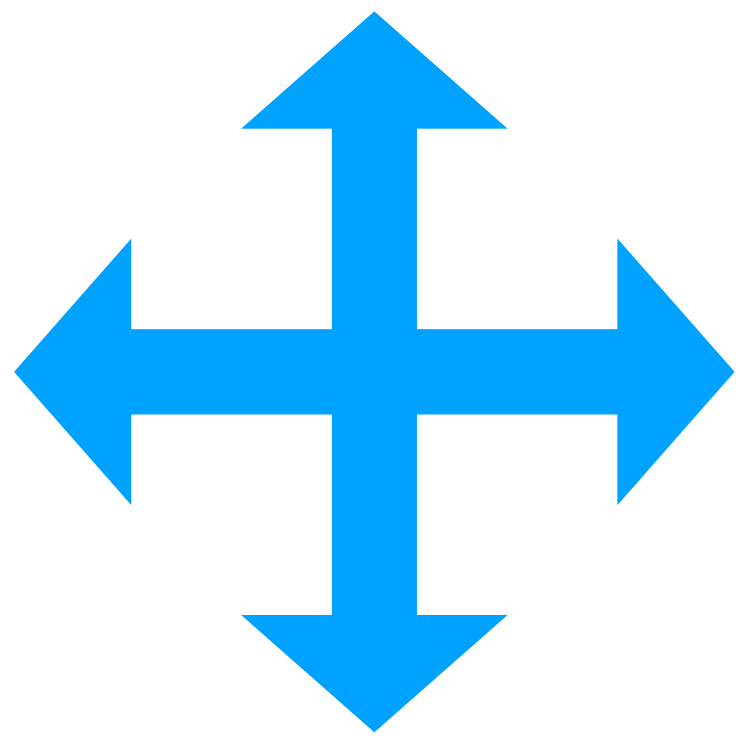
- animal (wool, silk)
- plant (cotton, flax, jute, bamboo)
- mineral (asbestos, glass fibre)
- synthetic (nylon, polyester, acrylic, rayon)

Features for Soft Robots

- lightweight
- flexible
- doesn't tear/puncture easily
- air/water tight
- opaque vs. transparent?

Ripstop fabrics are woven fabrics, often made of nylon, using a special reinforcing technique that makes them resistant to tearing and ripping. Can be coated with **thermoplastic polyurethane (TPU)** or impregnated with **silicone**.

2-way vs. 4-way fabric stretch



To Do

- Turn in your lab notebook at the end of today so I can check off Lab 3
- Take over a lab bench with your partner (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 4"). 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 4

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