Soft Robotics

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Schedule & Handouts

https://www.ritsumei.ac.jp/~hirai/edu/2025/soft_robotics/soft_robotics.html

Web lecture
10/3, 10/10, 10/31, 11/7, 11/14, 11/21

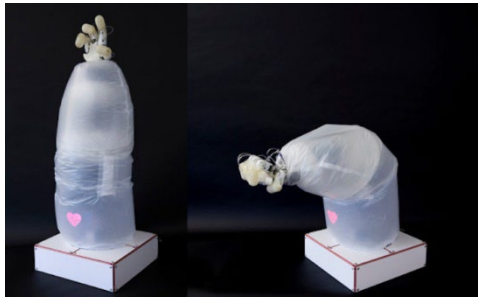
Robots vs Creatures

mainly hard materials
precise mechanism

hard and soft materials
loose mechanism

Soft Robotics






Soft Robotics

Soft robotics is a branch of robotics focused on creating mechanical systems from compliant, flexible materials like silicone, gels, and polymers, which allows them to deform, adapt, and safely interact with their environment, much like biological organisms. Unlike rigid robots, soft robots can operate in unstructured or delicate settings, manipulate fragile objects without damage, and perform complex, adaptive movements inspired by living creatures.

Soft Robot Features

Materials: soft, deformable materials, including elastomers, gels, and fluids.
Inspiration: inspired by biological structures, such as the movement of an octopus or a caterpillar.
Adaptability: conform to irregular shapes, adapt to different obstacles, and change their own shape to perform tasks.
Safety: inherently safer for human interaction and manipulation of delicate objects due to their compliance and reduced risk of damage.
Motion: complex and varied motions, including bending, twisting, and expanding, which are difficult for rigid machines.

Soft Robot Potential Applications

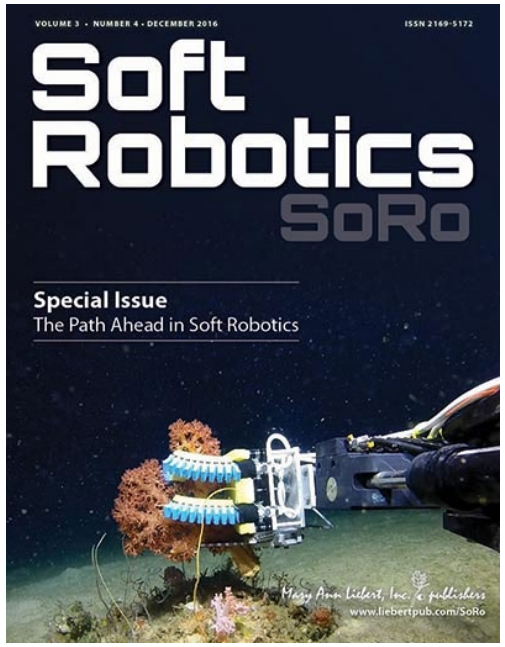
Medical devices: For surgery, patient rehabilitation, and wearable health solutions.
Manipulation and gripping: Safely picking up delicate or irregularly shaped objects in manufacturing or logistics.
Locomotion: Moving through complex environments, like uneven terrain or narrow spaces.
Wearable technology: Creating comfortable and adaptive devices for human use.

Soft Robotics Activities

SIG Soft Robotics

Special Interest Group on Soft Robotics

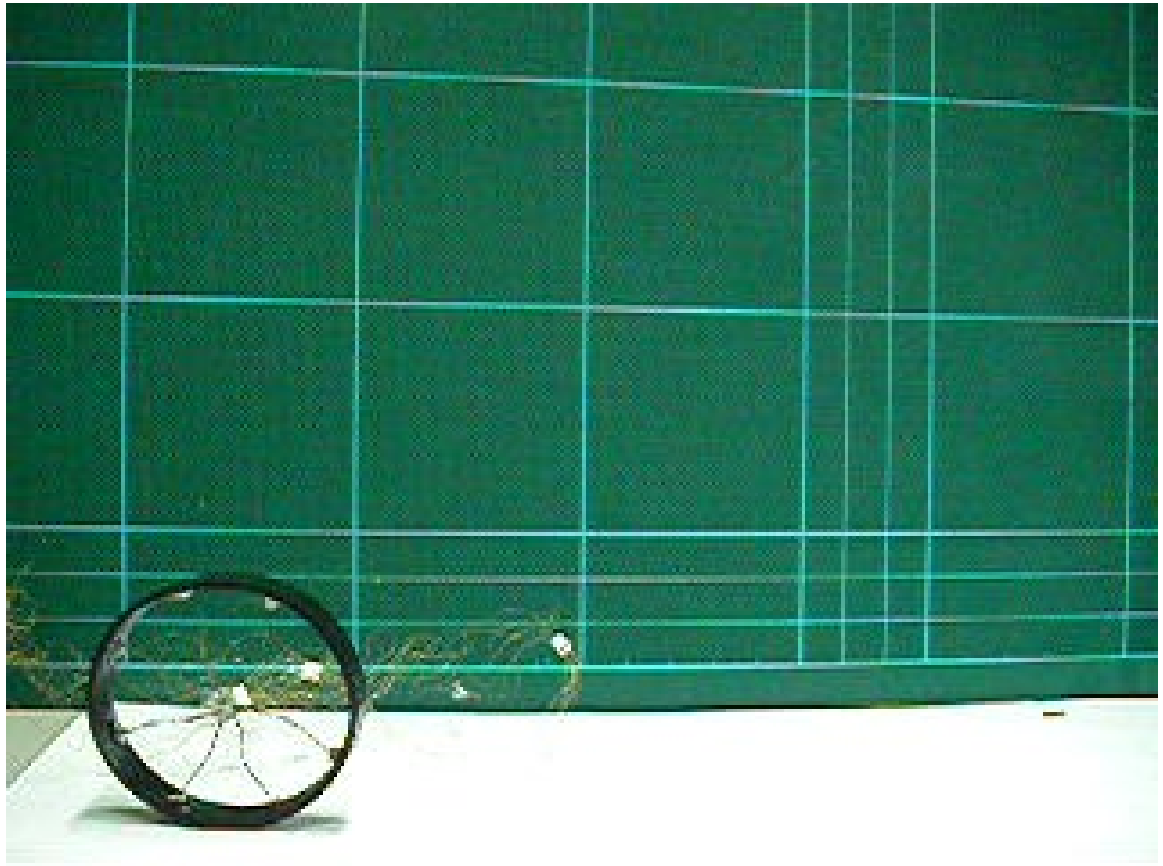
新学術領域「ソフトロボット学」
Science of Soft Robot



IEEE Int. Conf. on Soft Robotics

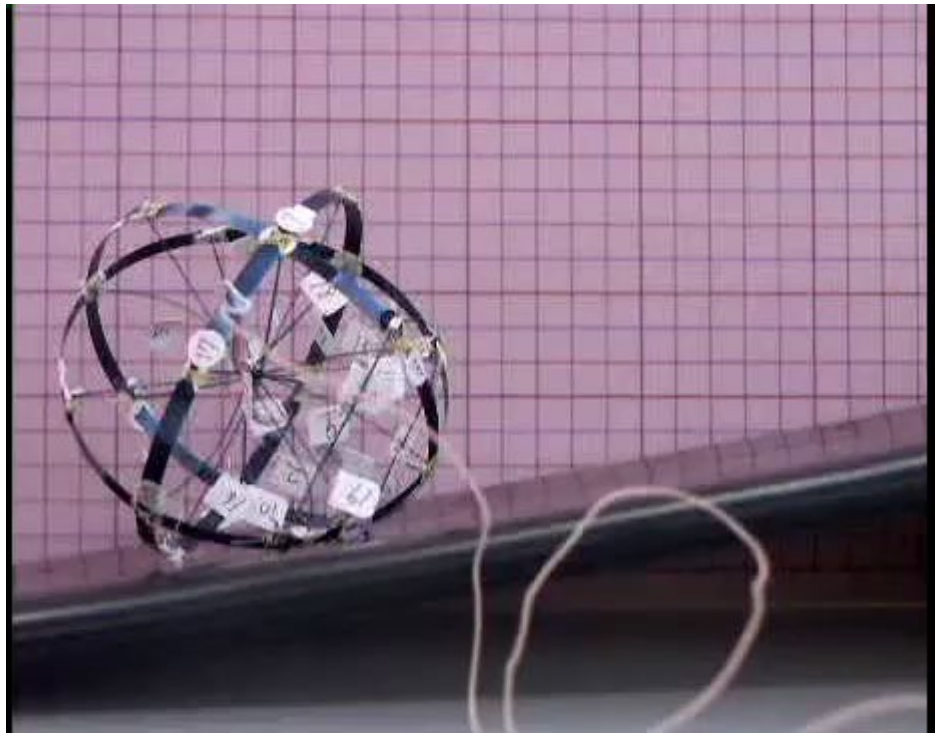
The First RoboSoft, Livorno, Italy, 2018

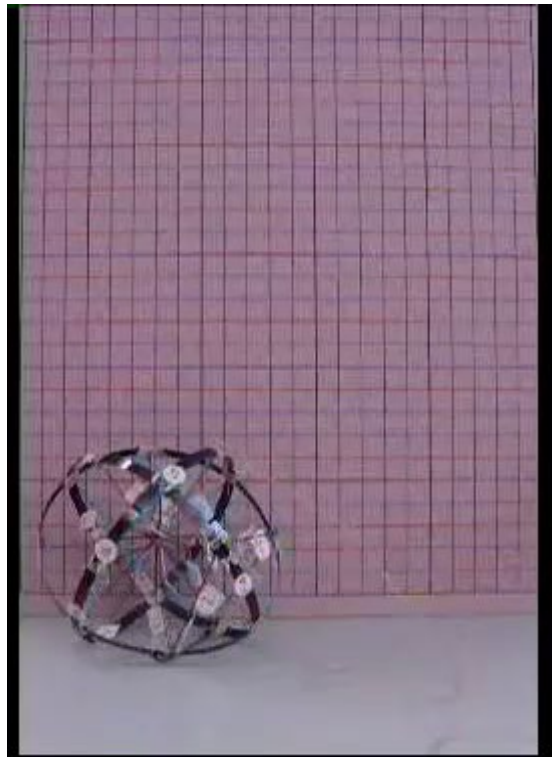
Circular Soft Robot



Sugiyama and Hirai, Crawling and Jumping by a Deformable Robot, IJRR, 25-5/6, 603-620, 2006

Spherical Soft Robot



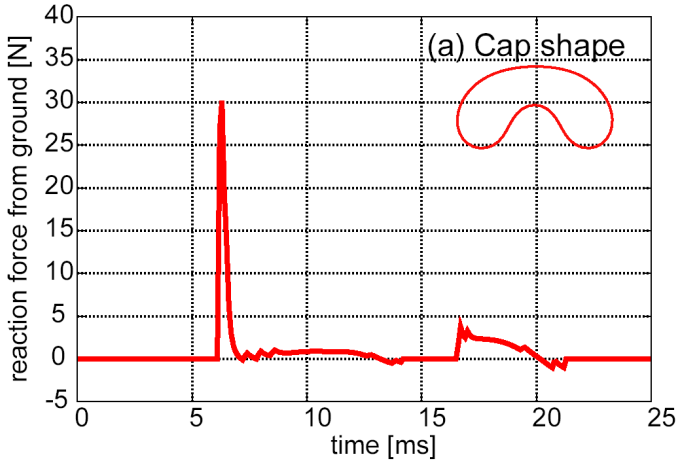


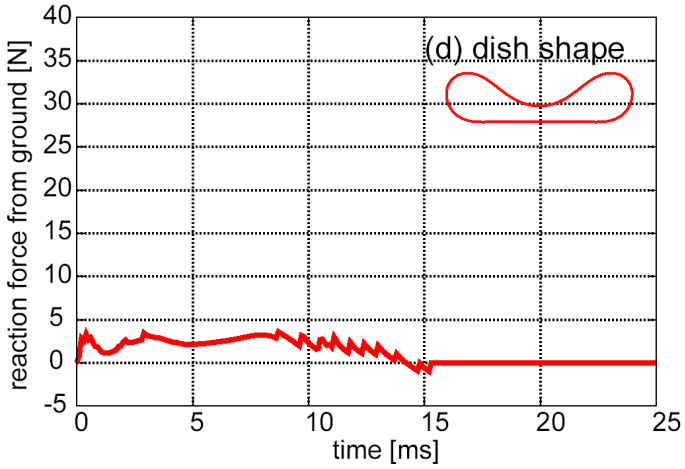
Sugiyama and Hirai, Crawling and Jumping by a Deformable Robot, IJRR, 25-5/6, 603-620, 2006

Soft Robot Jumping



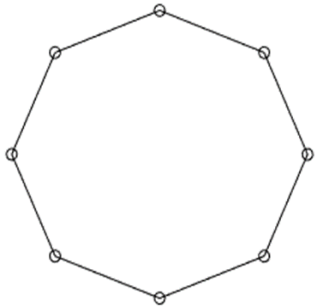

Cap 
Cup 
Peanut 
Dish 



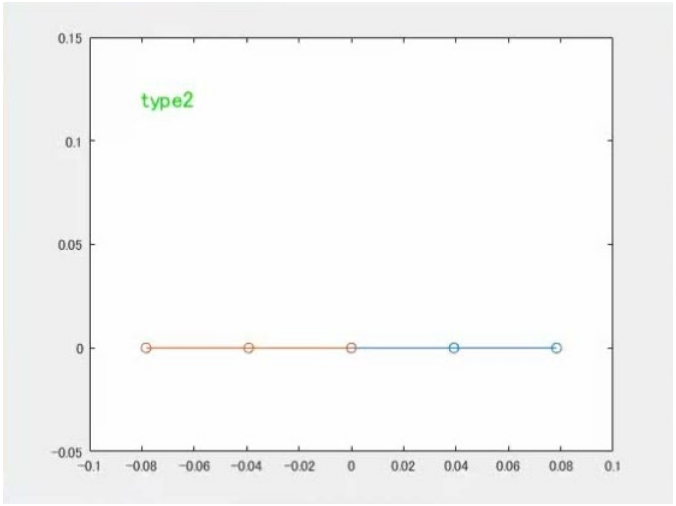


Matsuyama and Hirai, IEEE ICRA, 2007

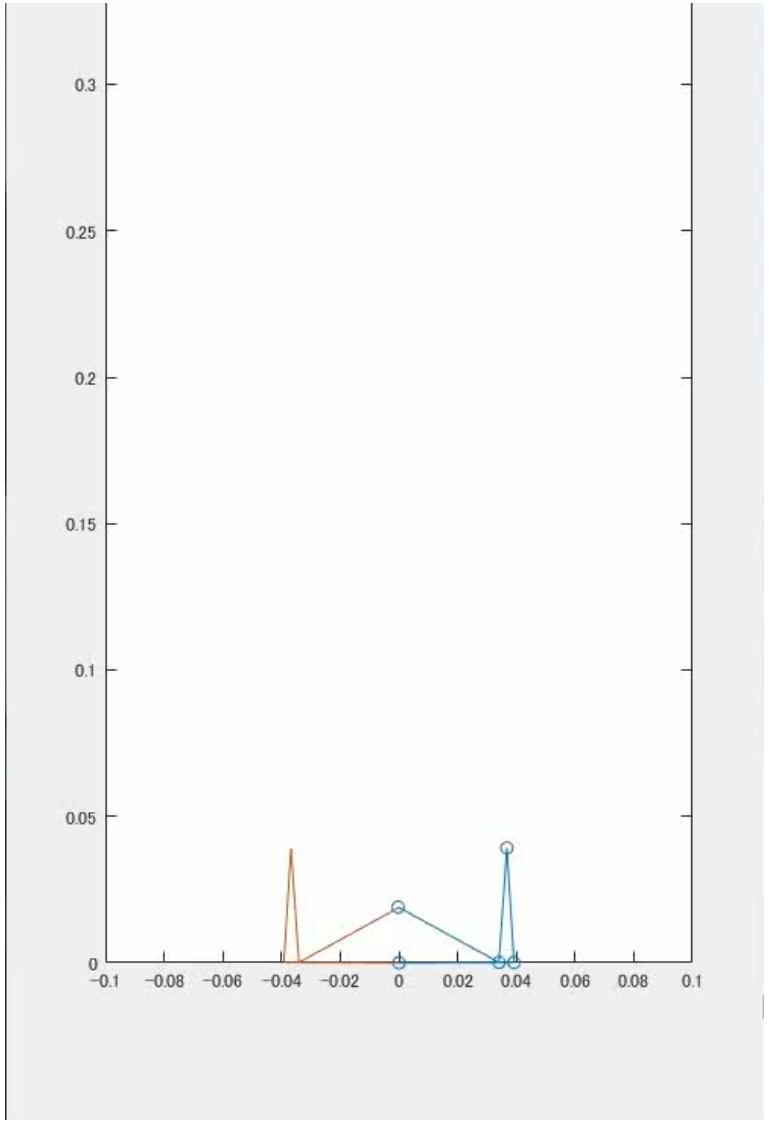
Soft Robot Jumping



soft robot model

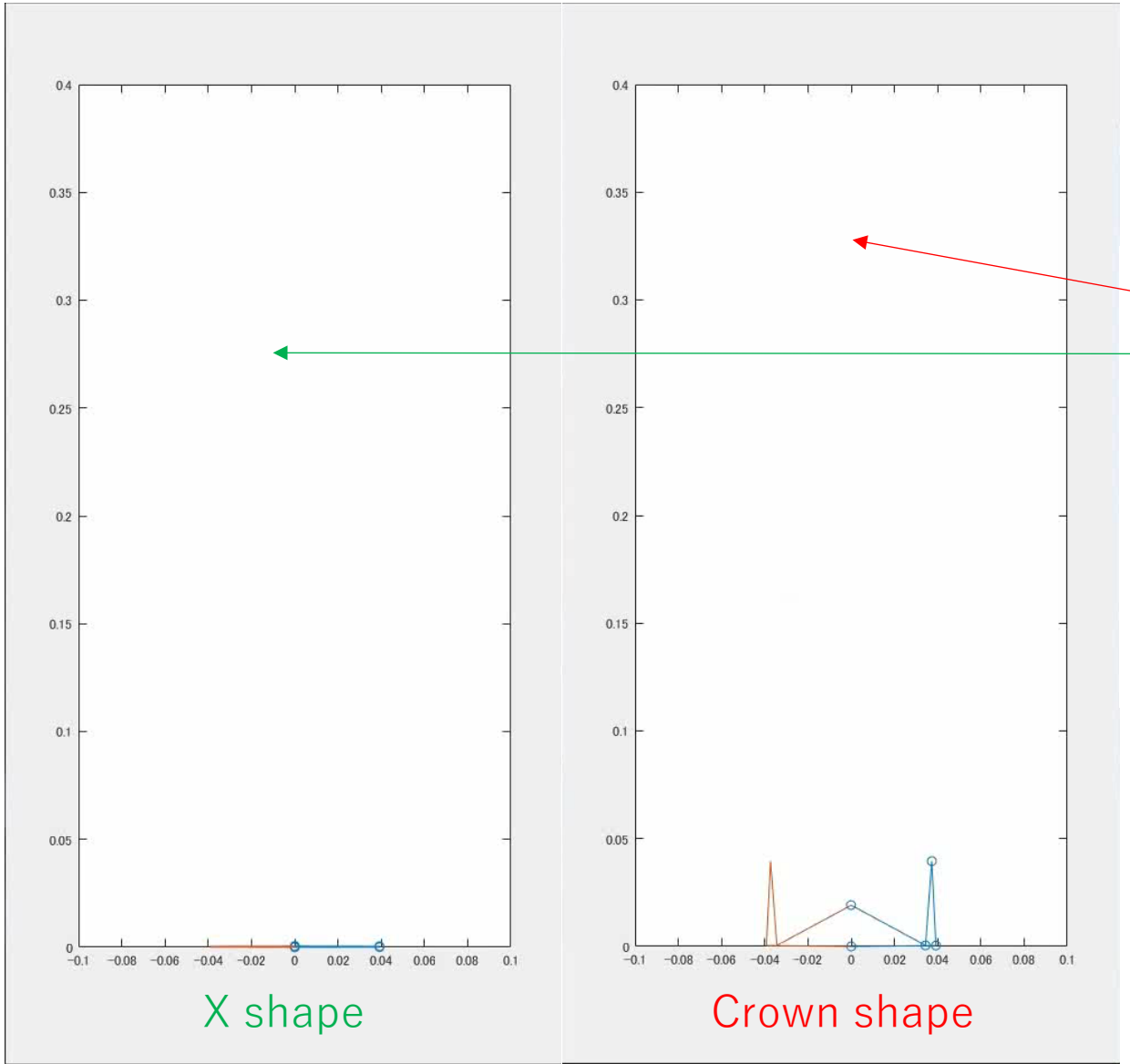


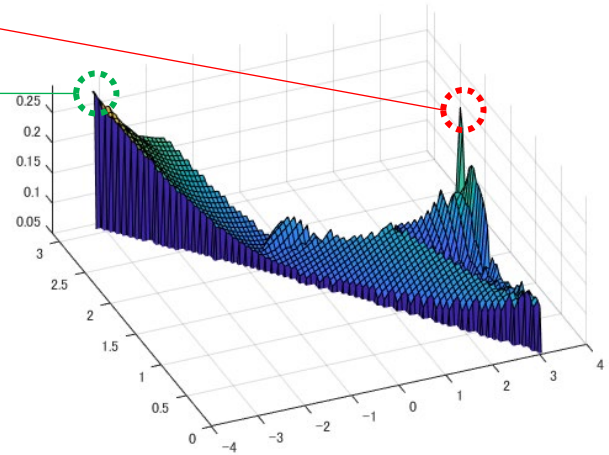
calculation process



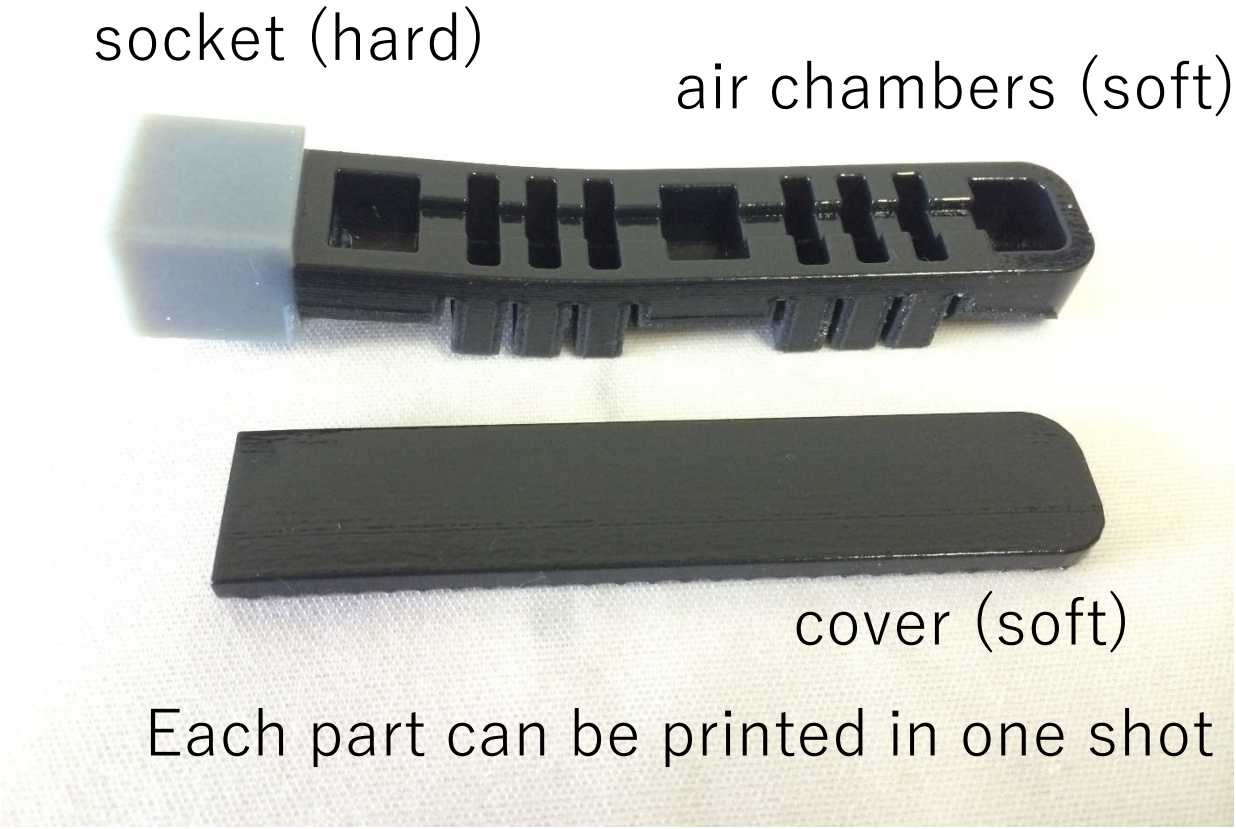
Matsuno and Hirai, RoboSoft 2020

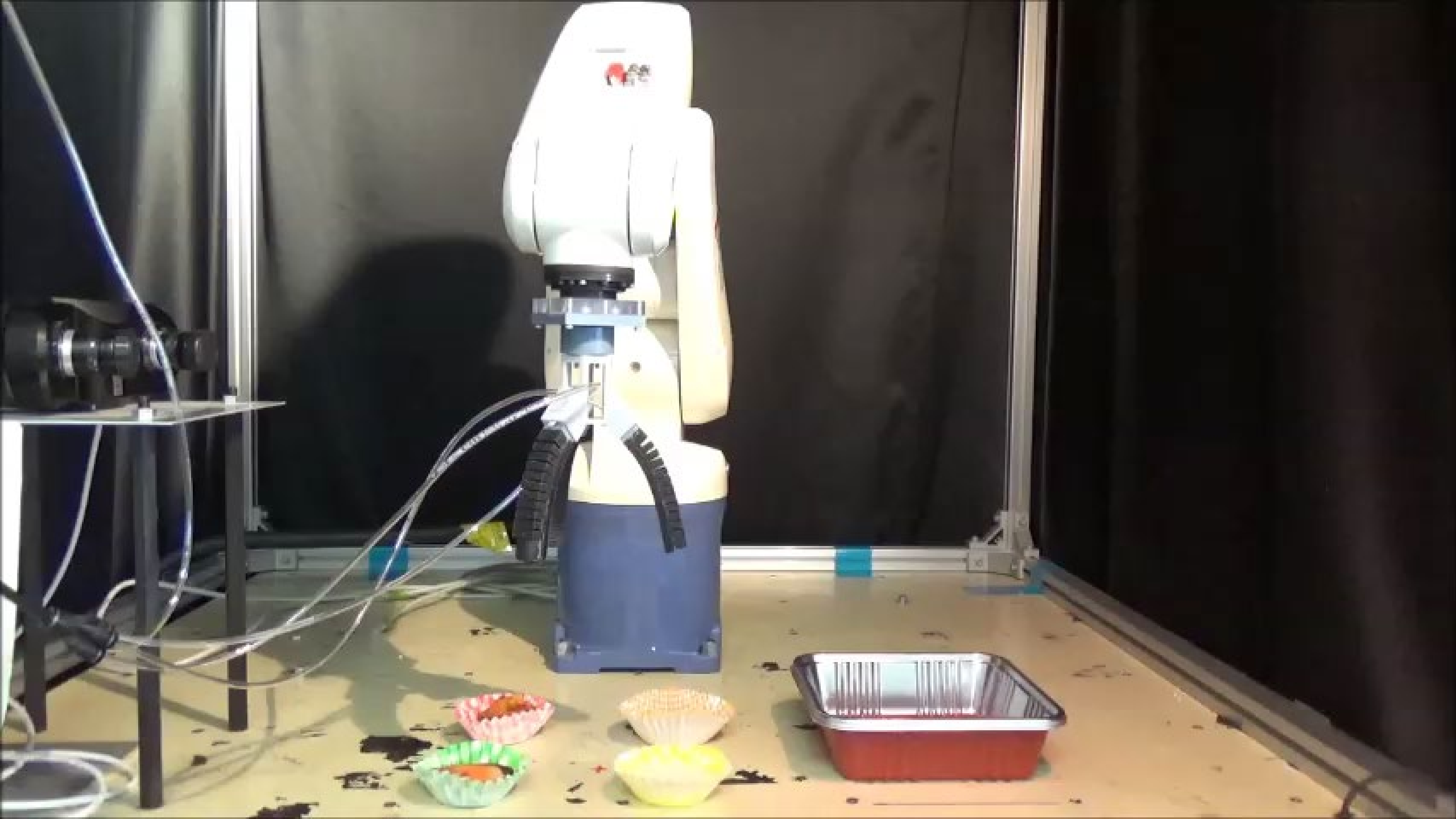
Soft Robot Jumping



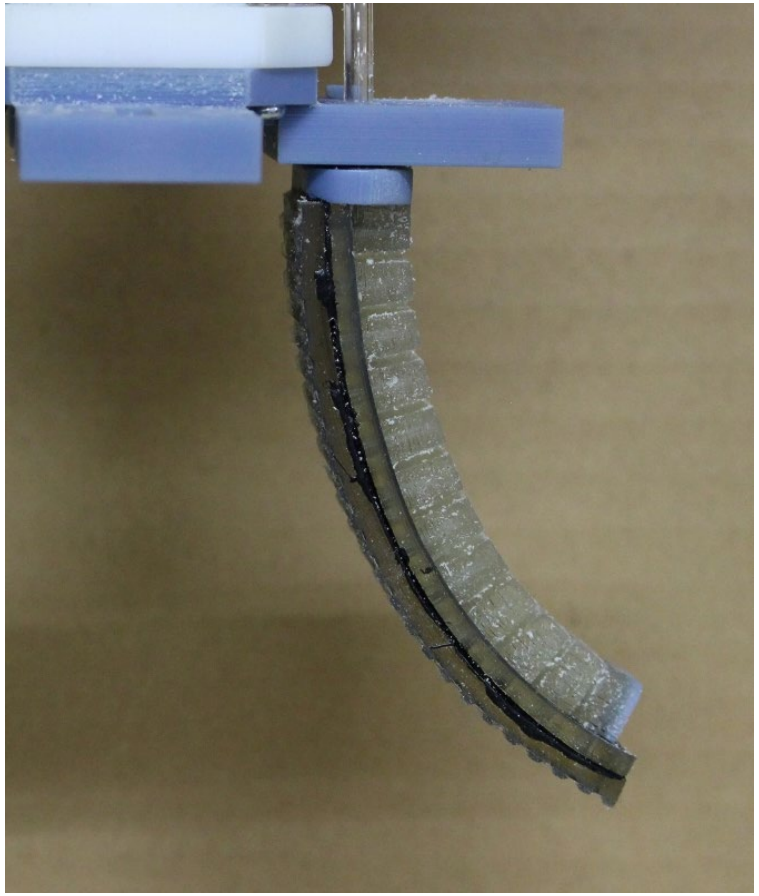


Soft Bendable Fingers

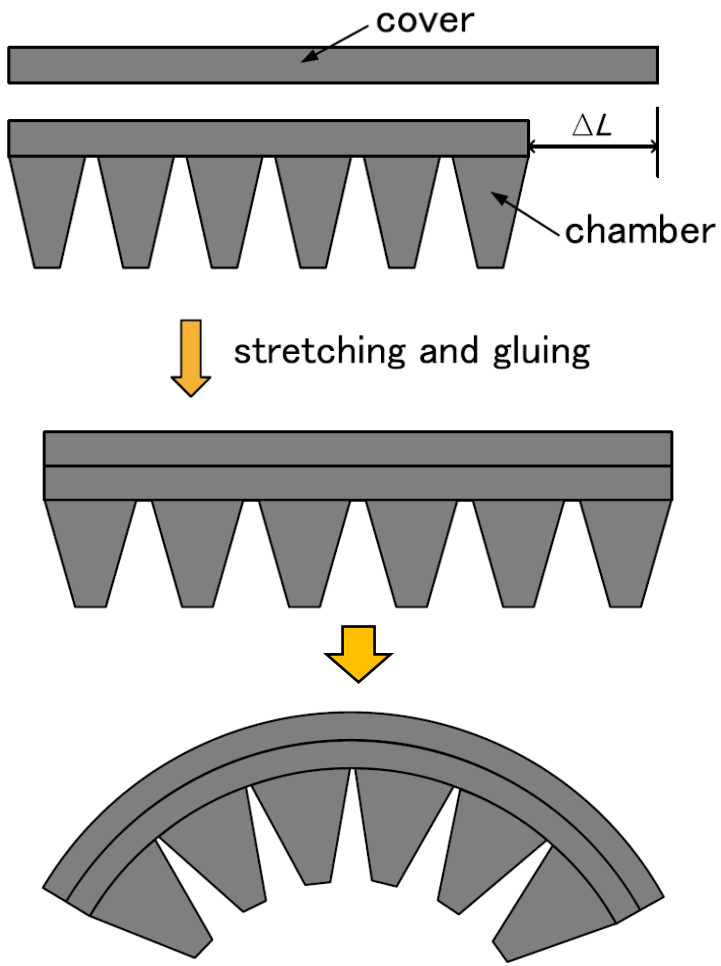


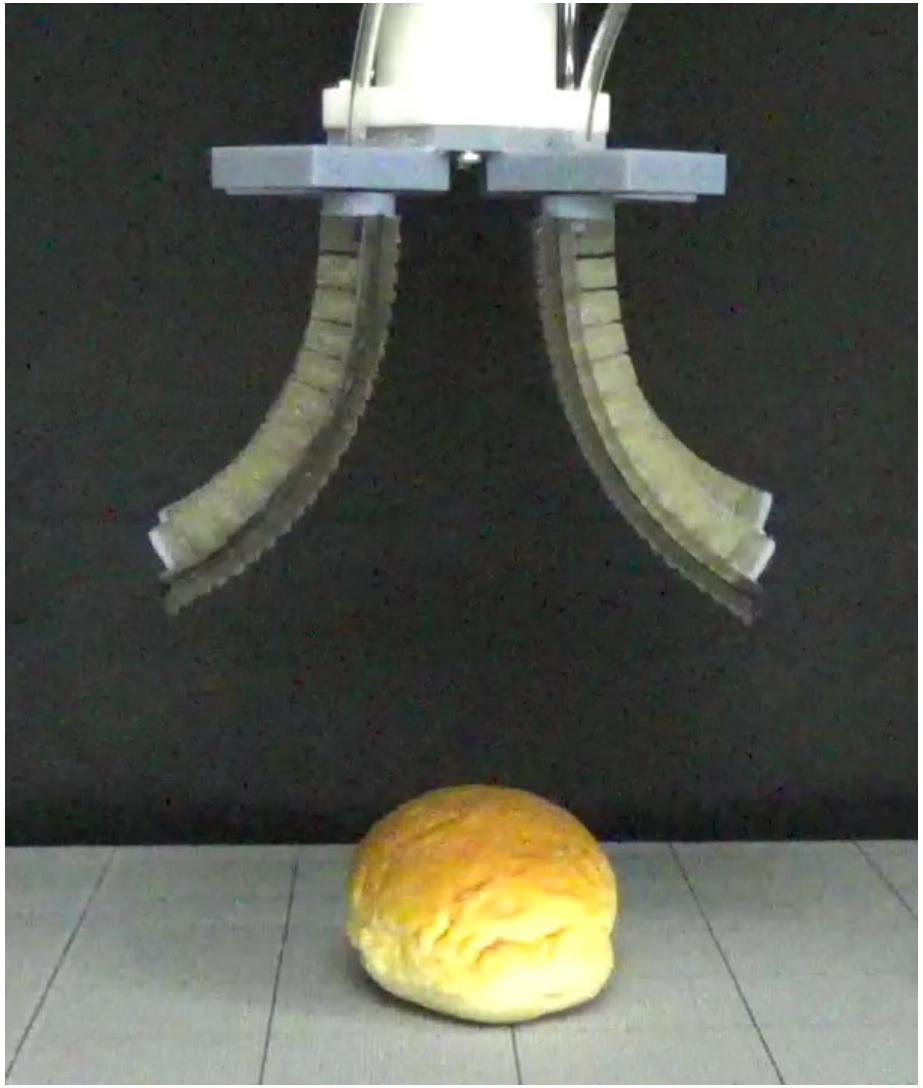


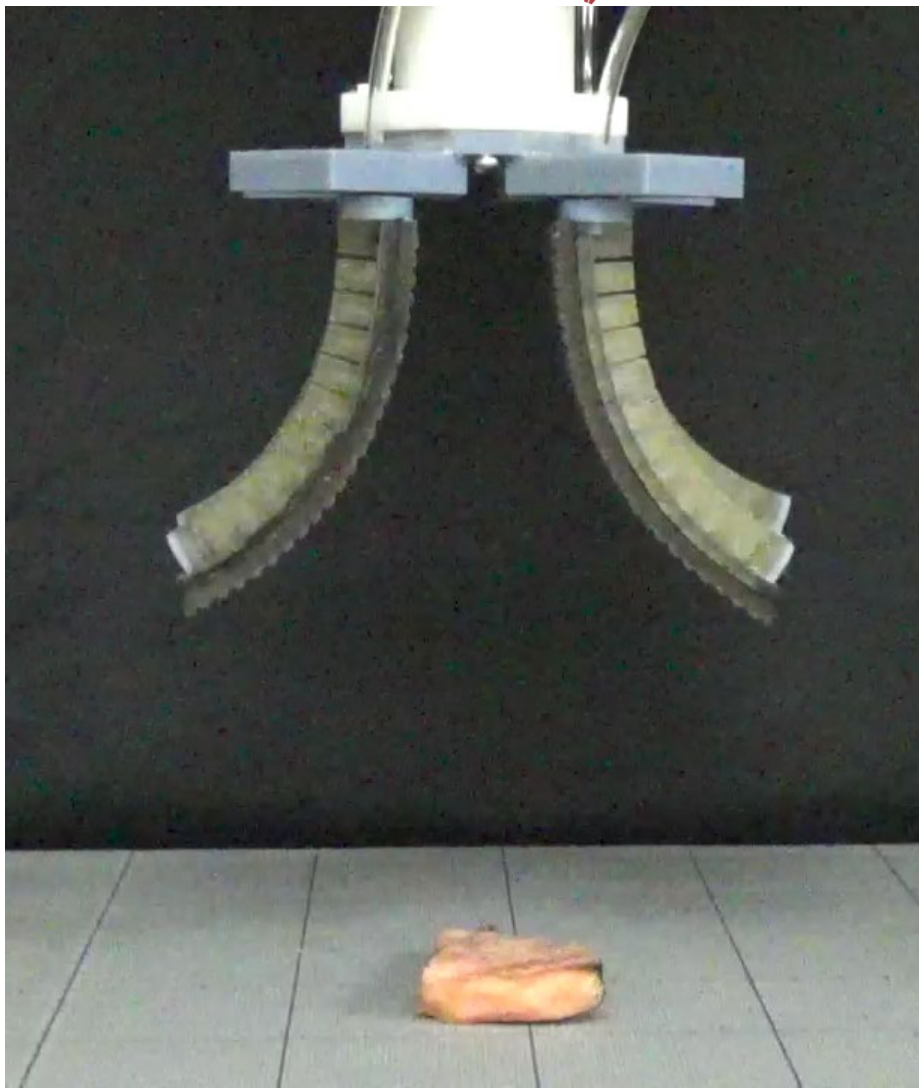
Soft Bendable Fingers



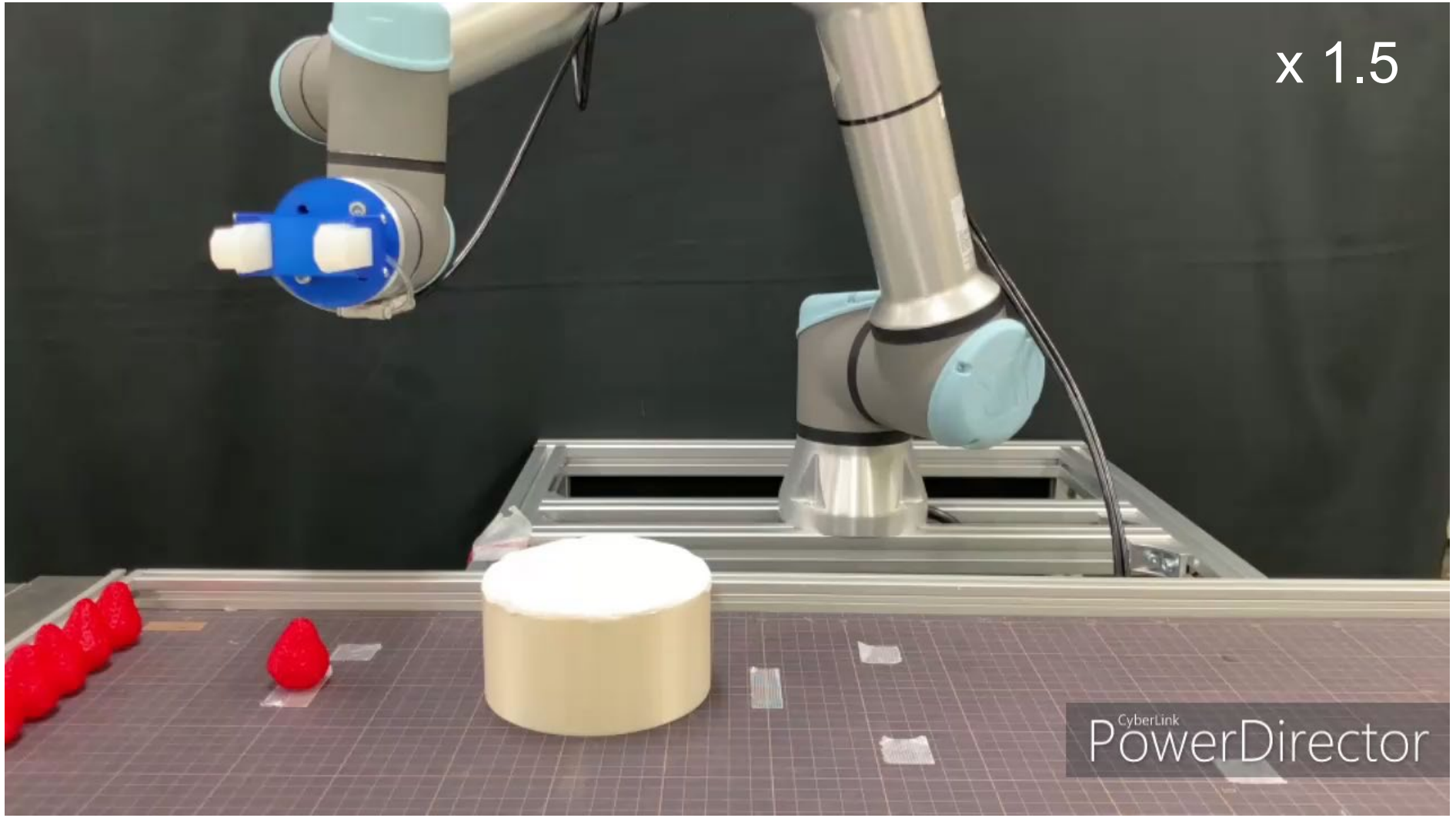
Wang et al., IEEE RAL, 2017





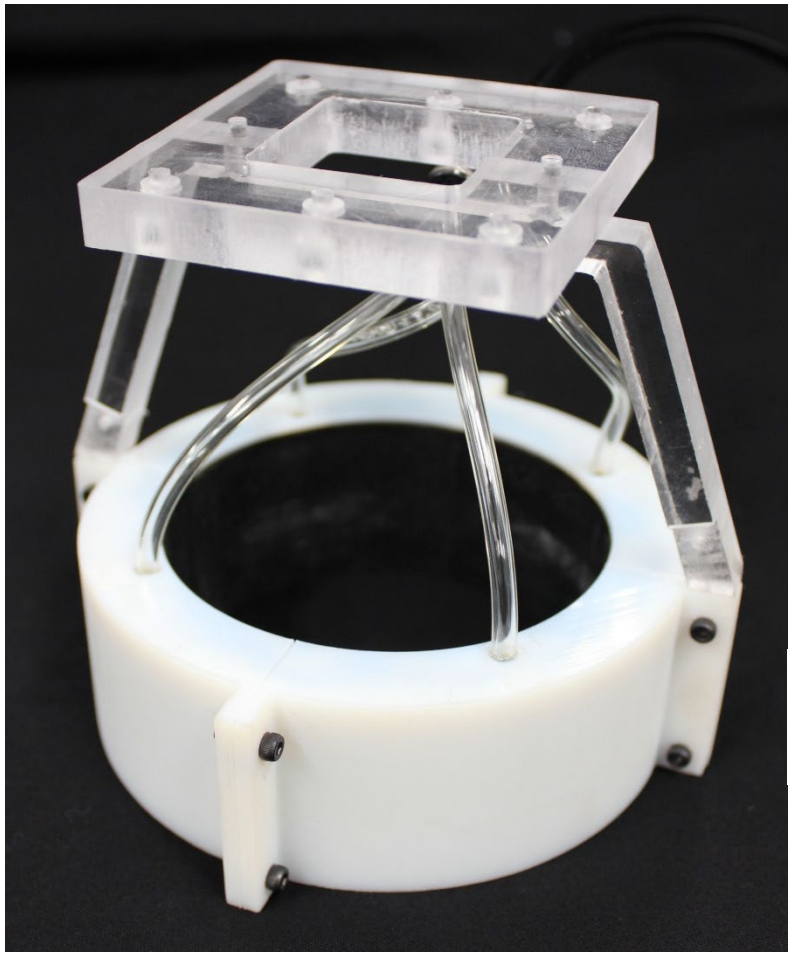


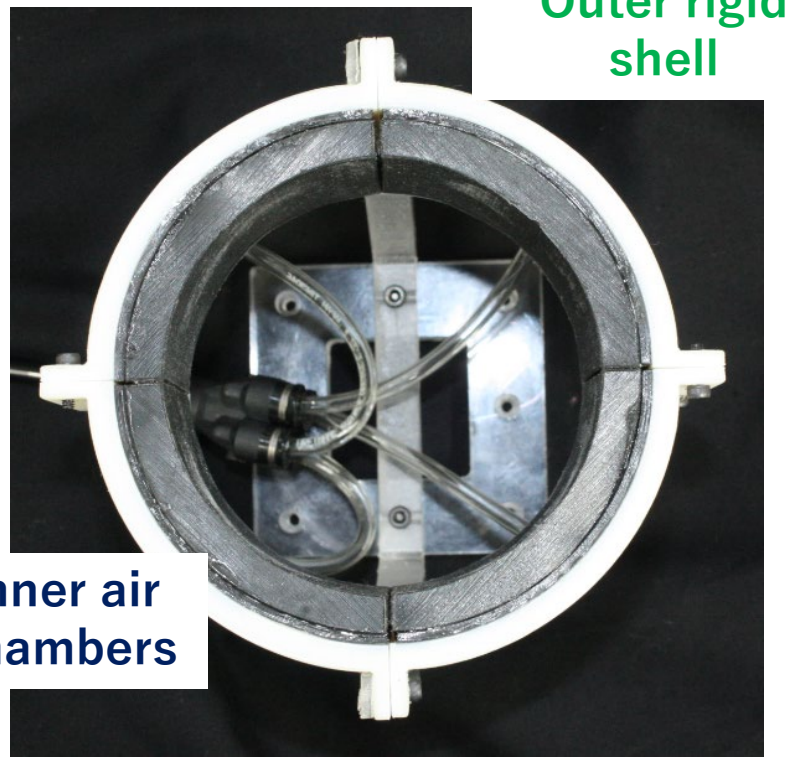
Manipulating Delicate Objects

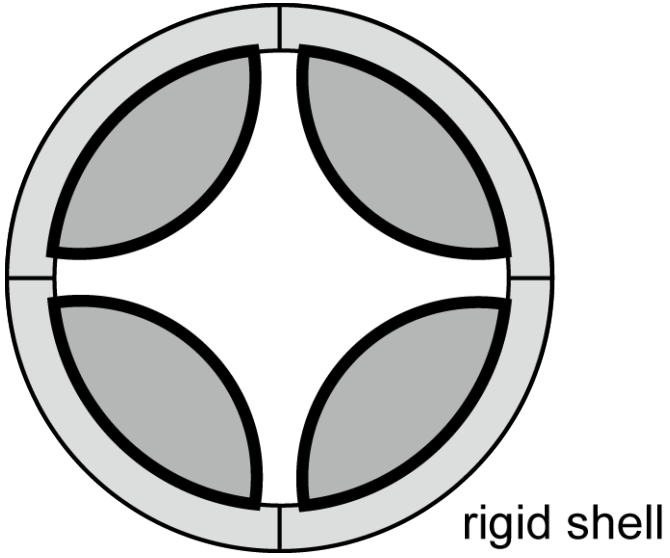


Matsuno et al., IEEE/SICE SII 2024

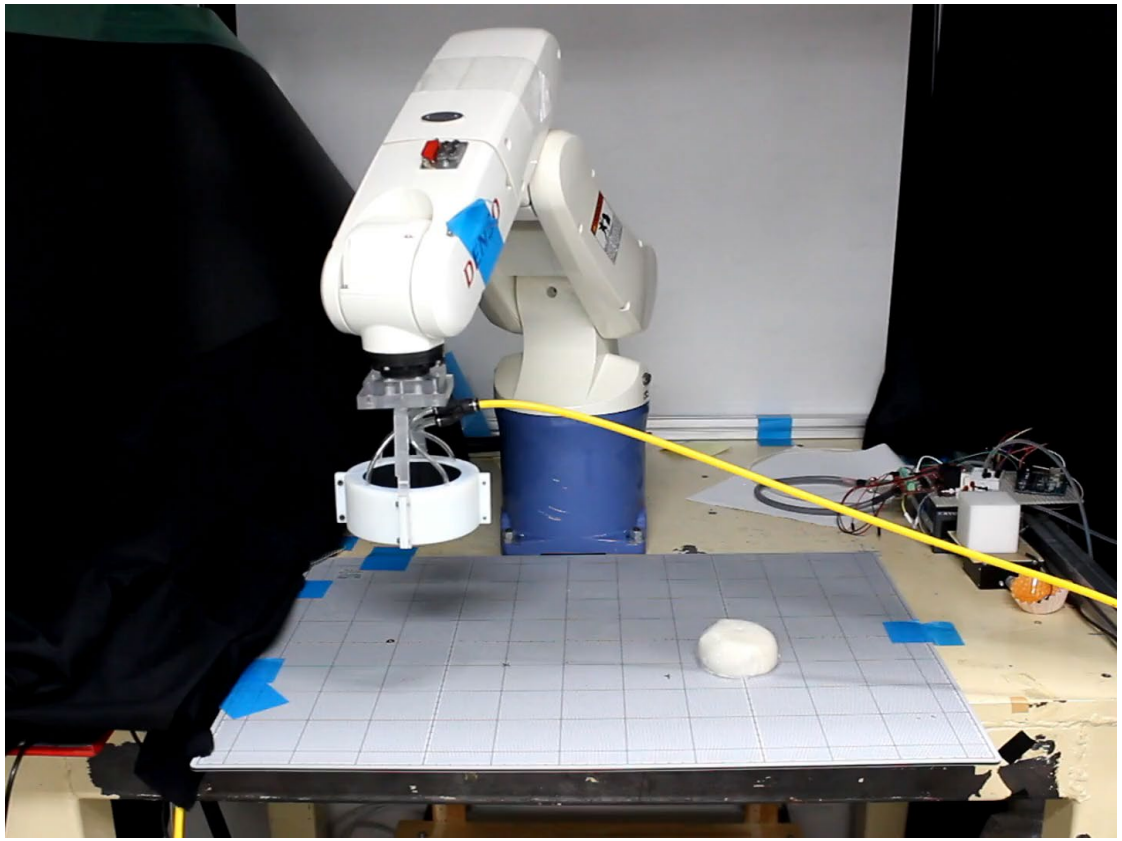
Expanding Membrane Hand

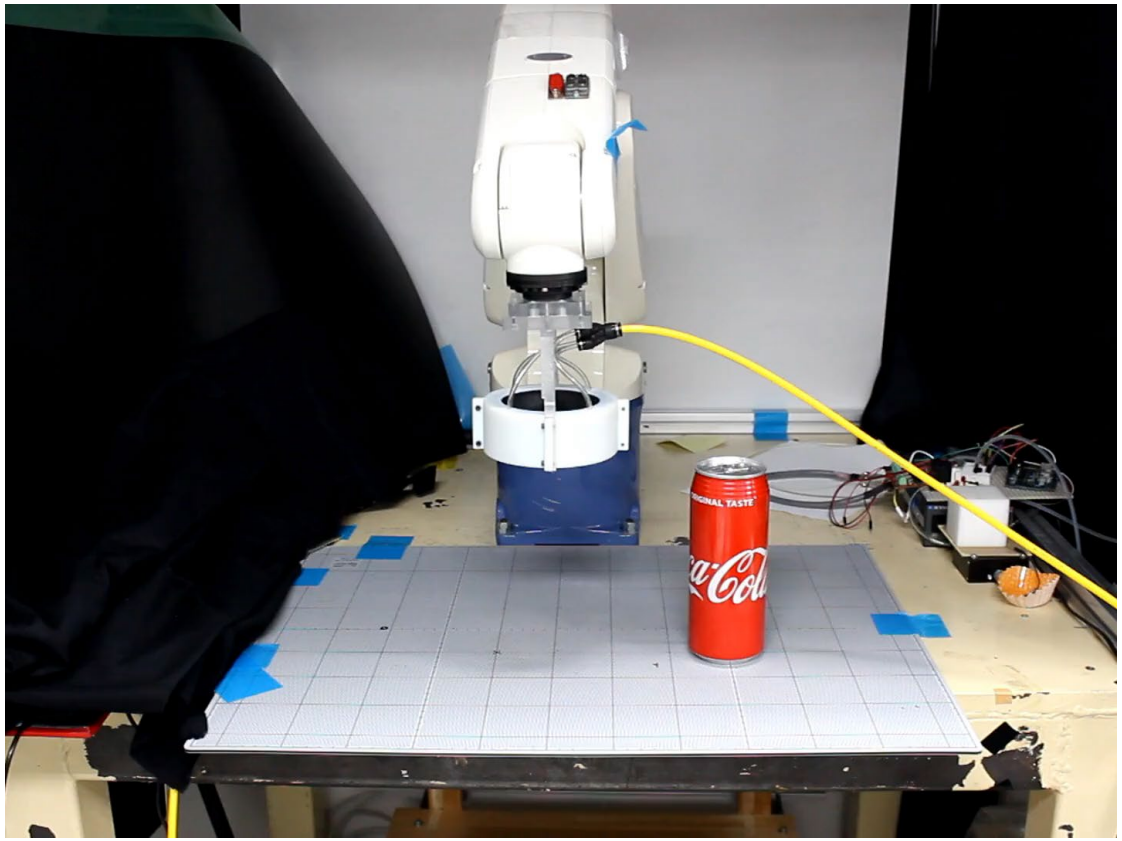




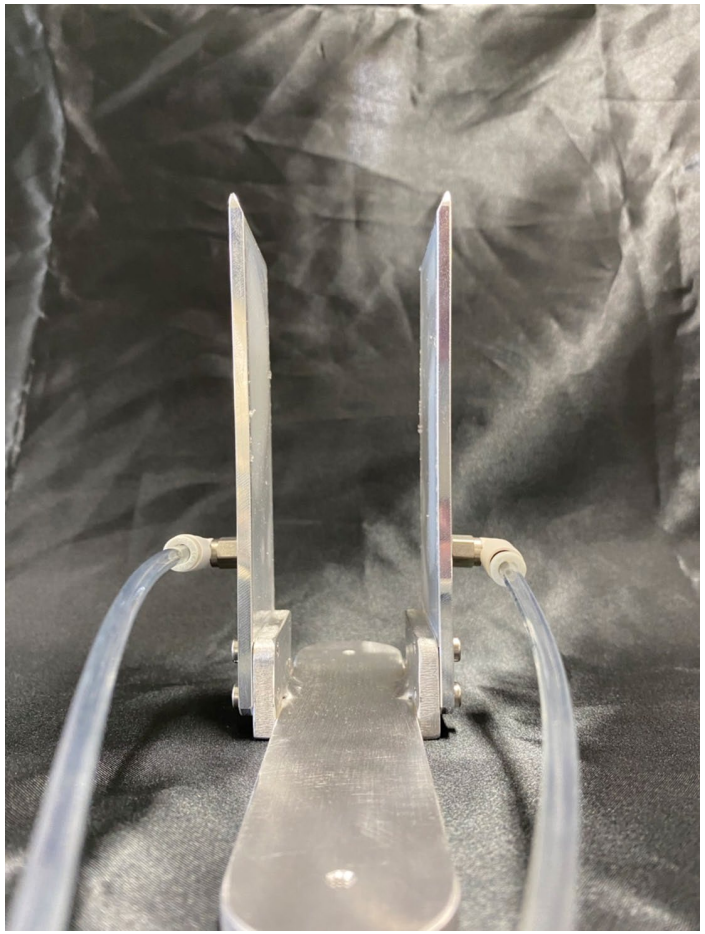


Wang, Kanegae, and Hirai, Circular Shell Gripper for Handling Food Products, Soft Robotics, 2020



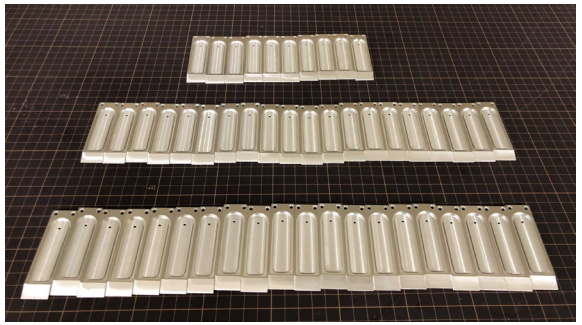


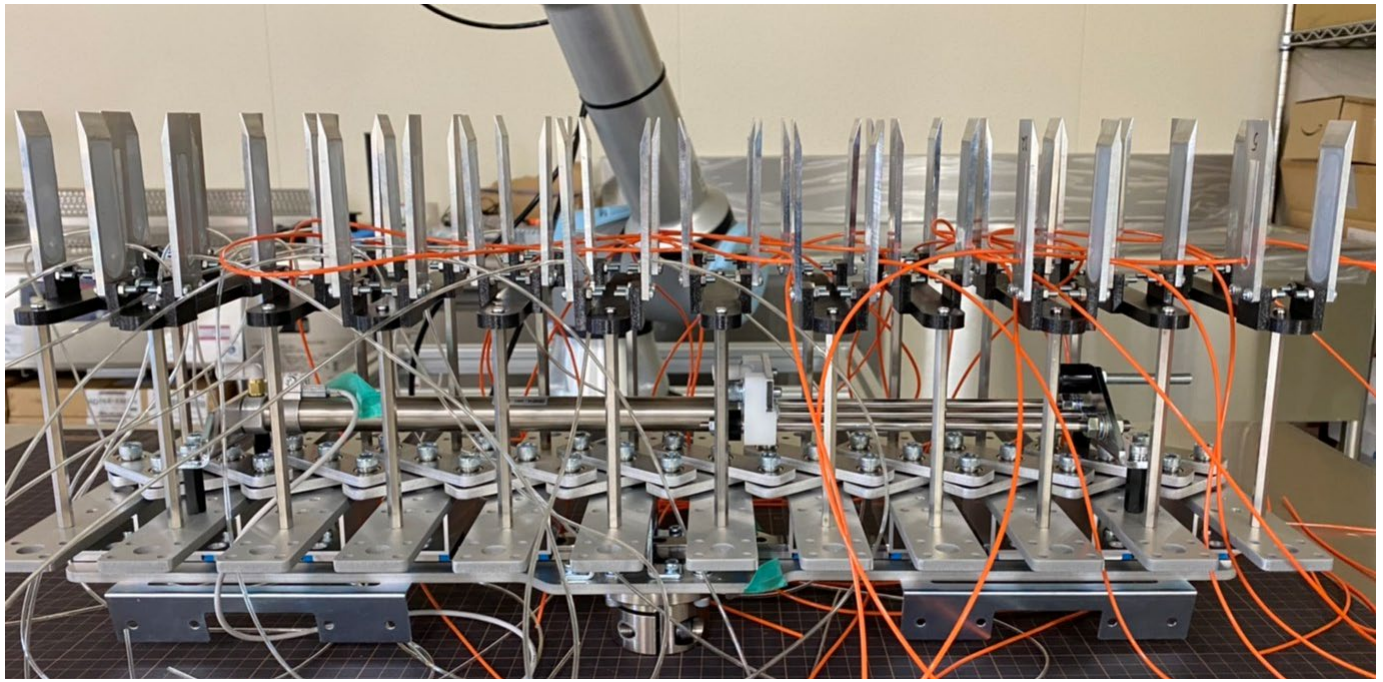
Application to Agriculture



Aoyama et al., Shell Gripper Inspired by Human Finger Structure for Automatically Packaging Agricultural Product, Humanoids 2022

Application to Agriculture





Simultaneous grasping of multiple cucumbers

Aoyama et al., Shell Gripper Inspired by Human Finger Structure for Automatically Packaging Agricultural Product, Humanoids 2022

Aoyama et al., IEEE Humanoids 2022

Fabric Manipulation

Motivation

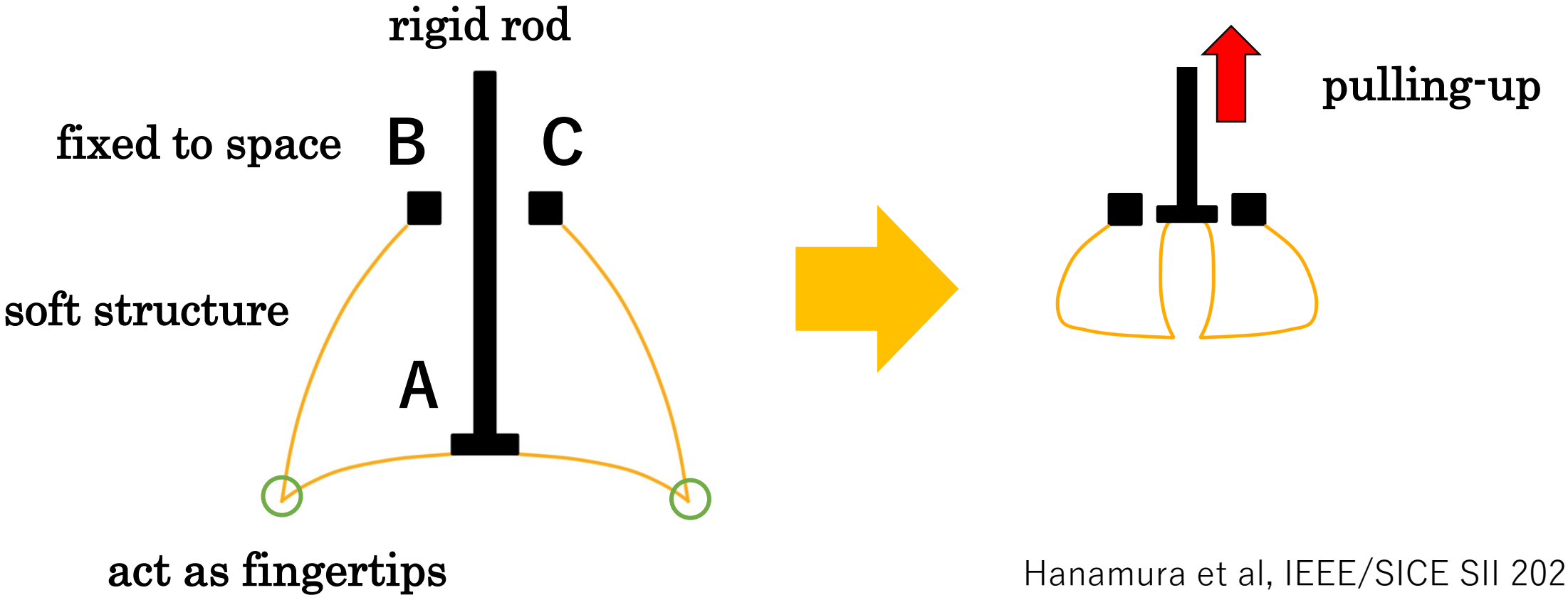
https://vn-bizmatch.com/vietnamese-35/

https://www.temjin-tv.com/works/2023/09/27/2561/

Principle

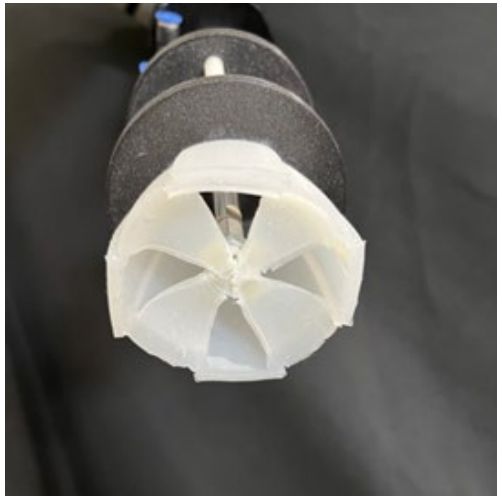
- soft fingertips contacting with a fabric
- large friction between fingertips and the fabric
- fingertips moving along the fabric

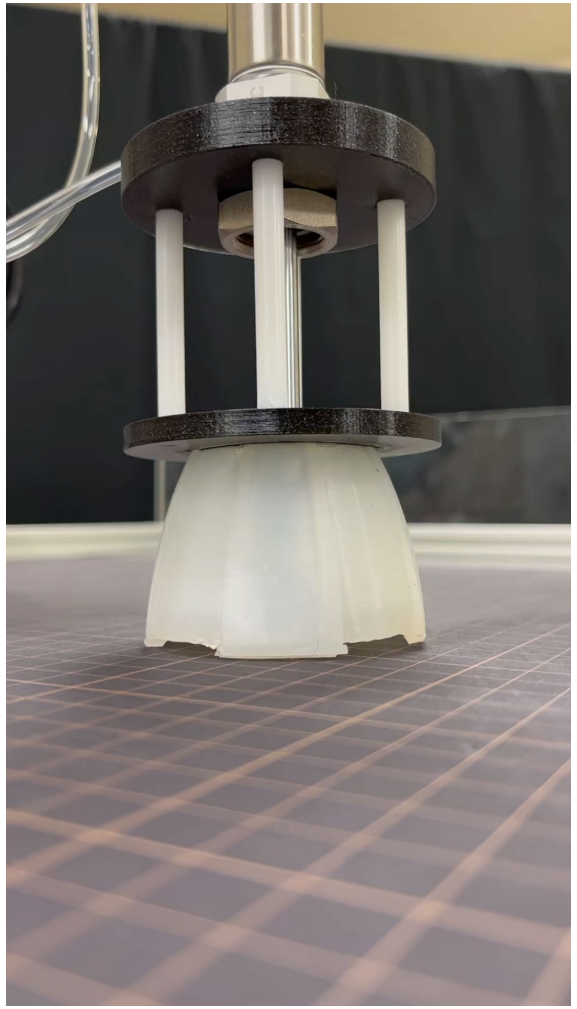
Pulling-Driven Soft Hand



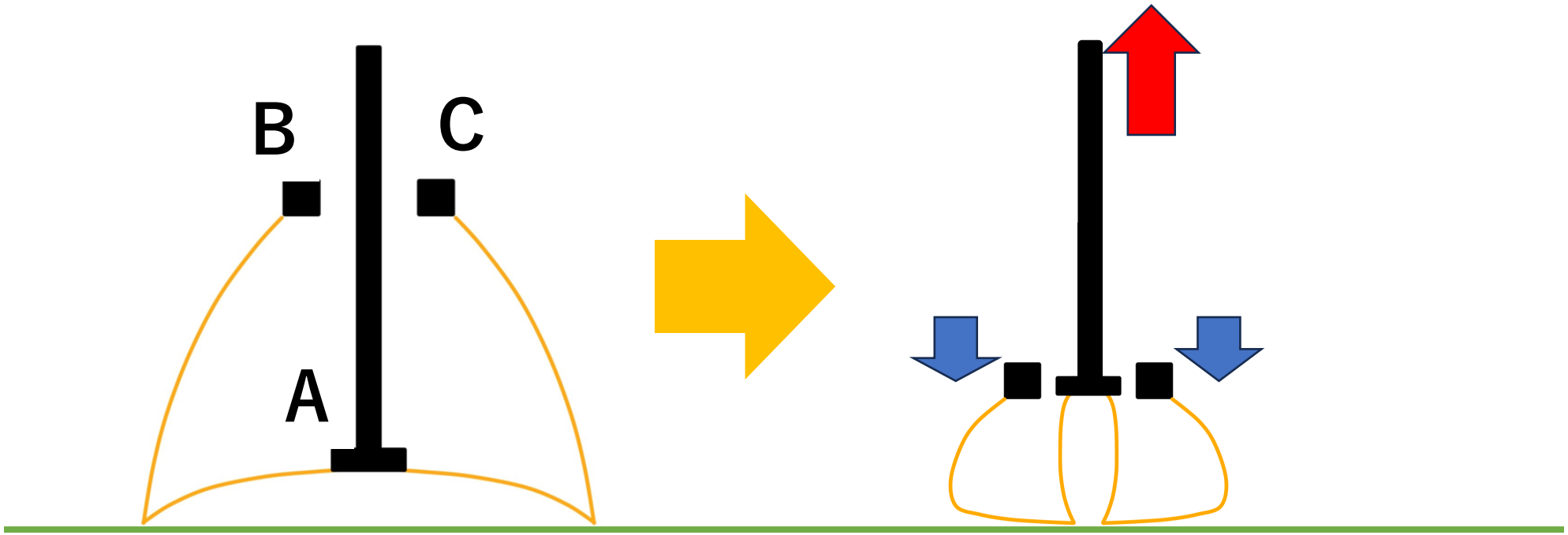
Hanamura et al, IEEE/SICE SII 2024

Pulling-Driven Soft Hand

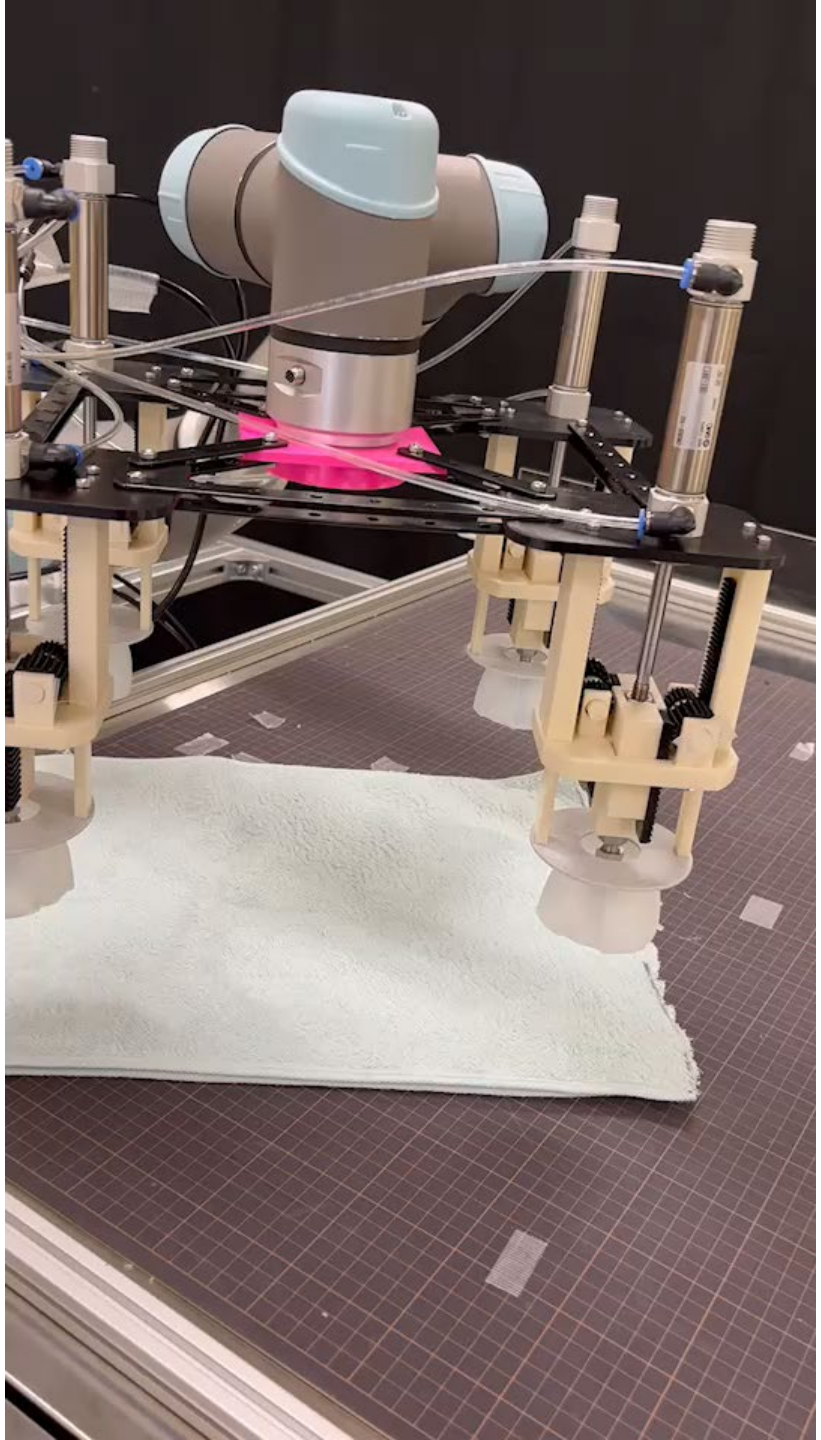


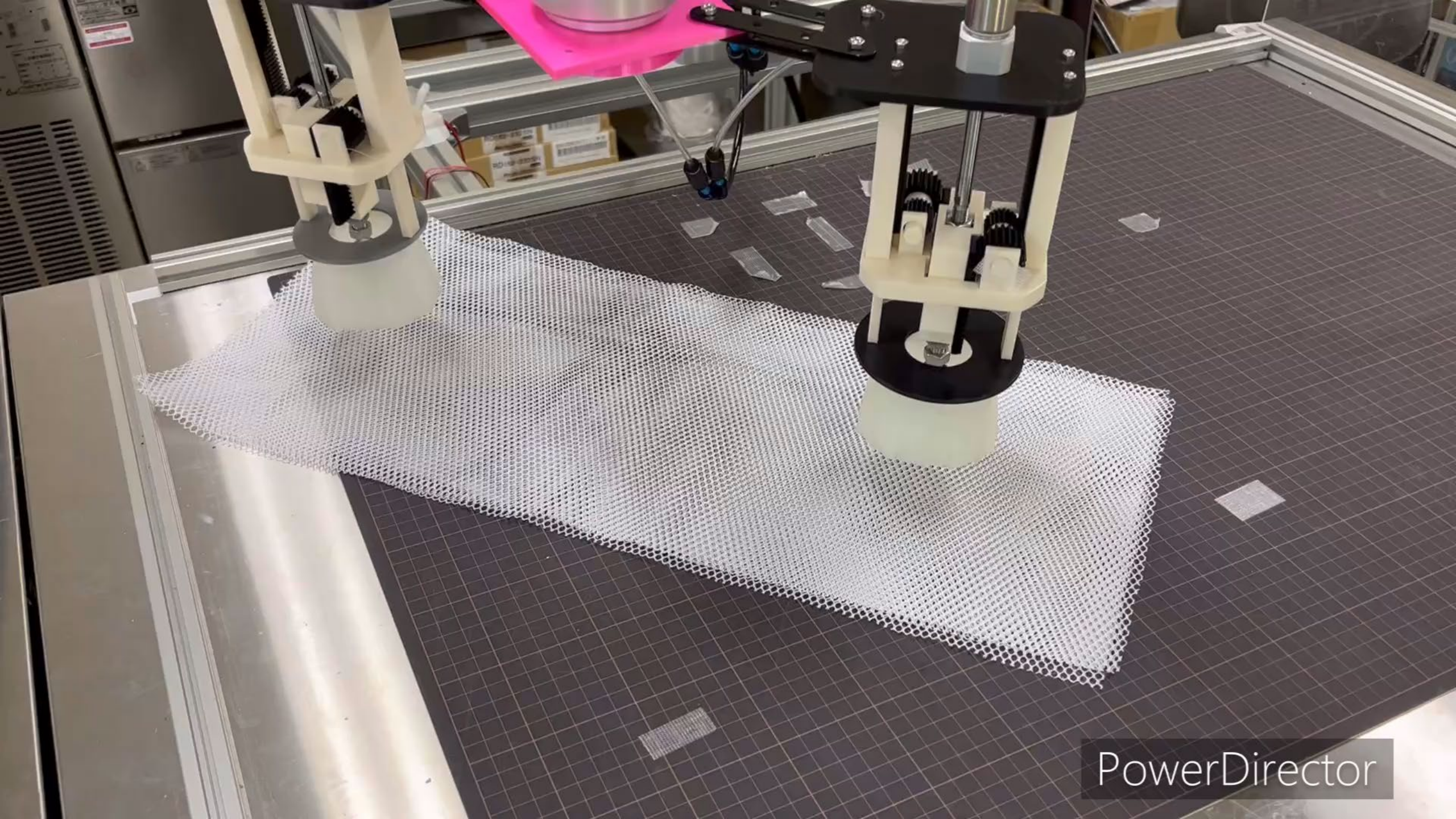


Closing-Approaching Coupling



Hanamura et al, IEEE/SICE SII 2024




PowerDirector

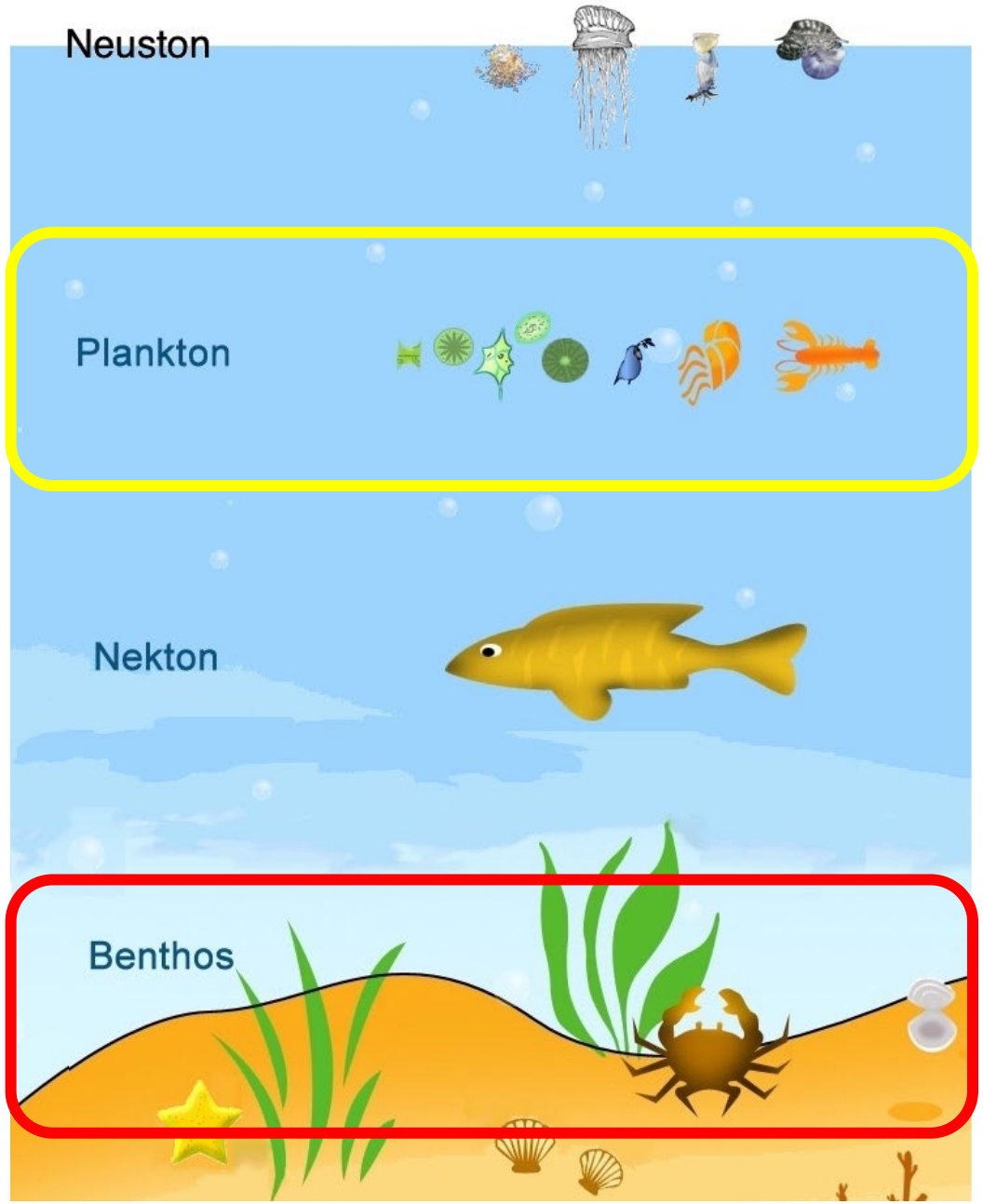
Living Organism Manipulation

https://job.fishermanjapan.com/column/3042/

https://mainichi.jp/articles/20200217/k00/00m/040/024000c

Motivation

Grasping and manipulation of underwater organisms
Electricity in water may cause problems
→ Non-electric hands

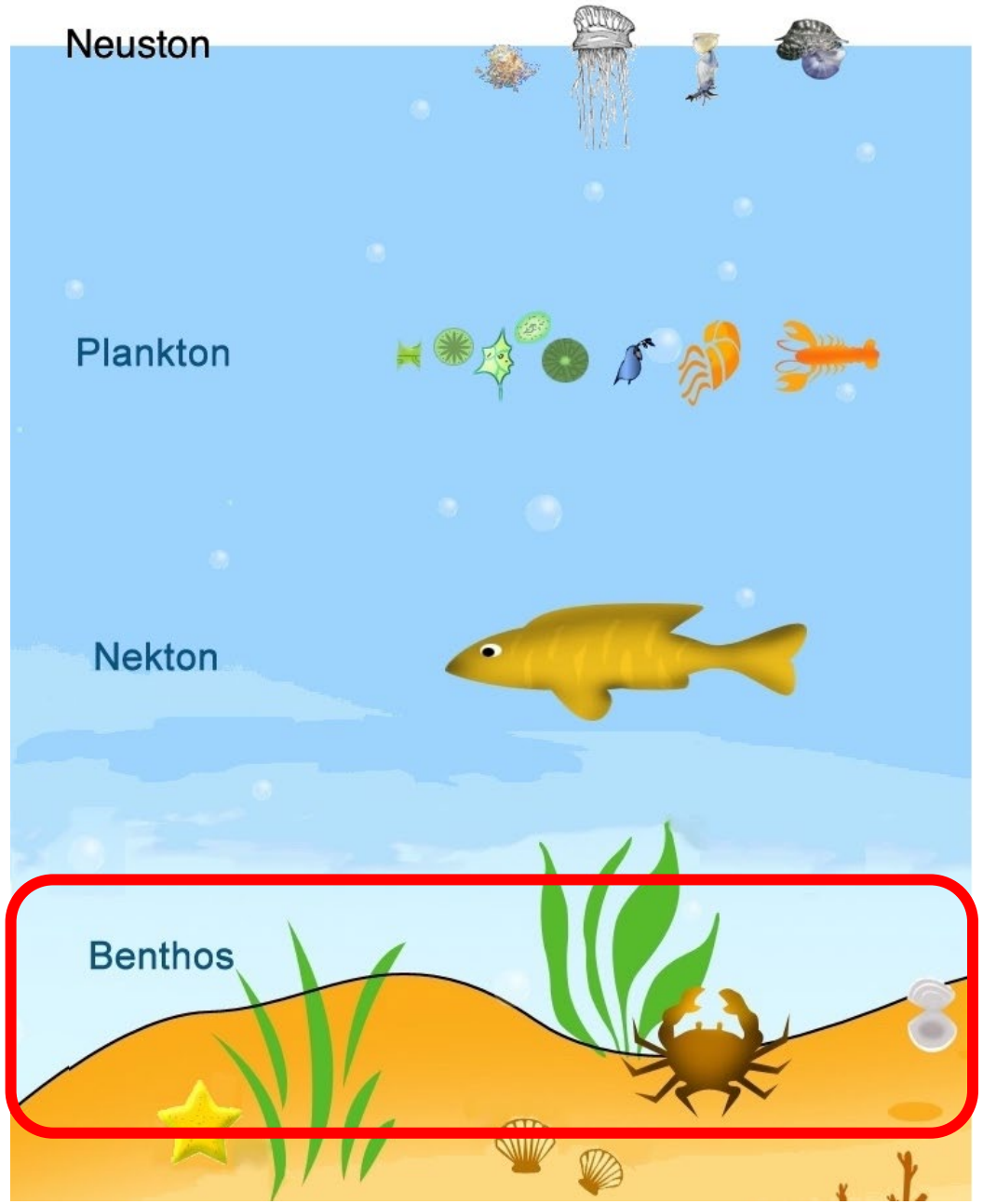


Plankton : organisms that drift in water but are unable to actively propel themselves against currents

https://en.wikipedia.org/wiki/Plankton

Benthos : organisms that live on, in, or near the bottom of a sea

https://en.wikipedia.org/wiki/Benthos



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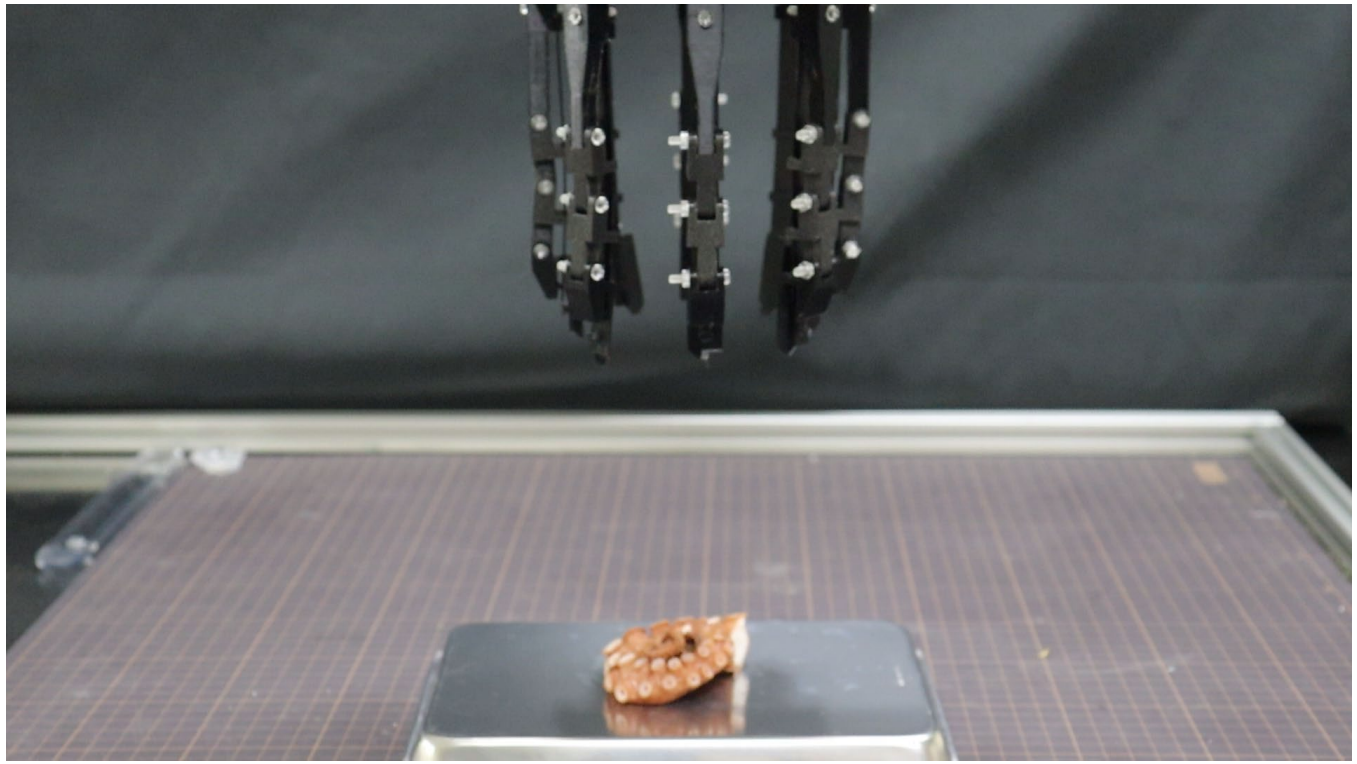
https://en.wikipedia.org/wiki/Benthos

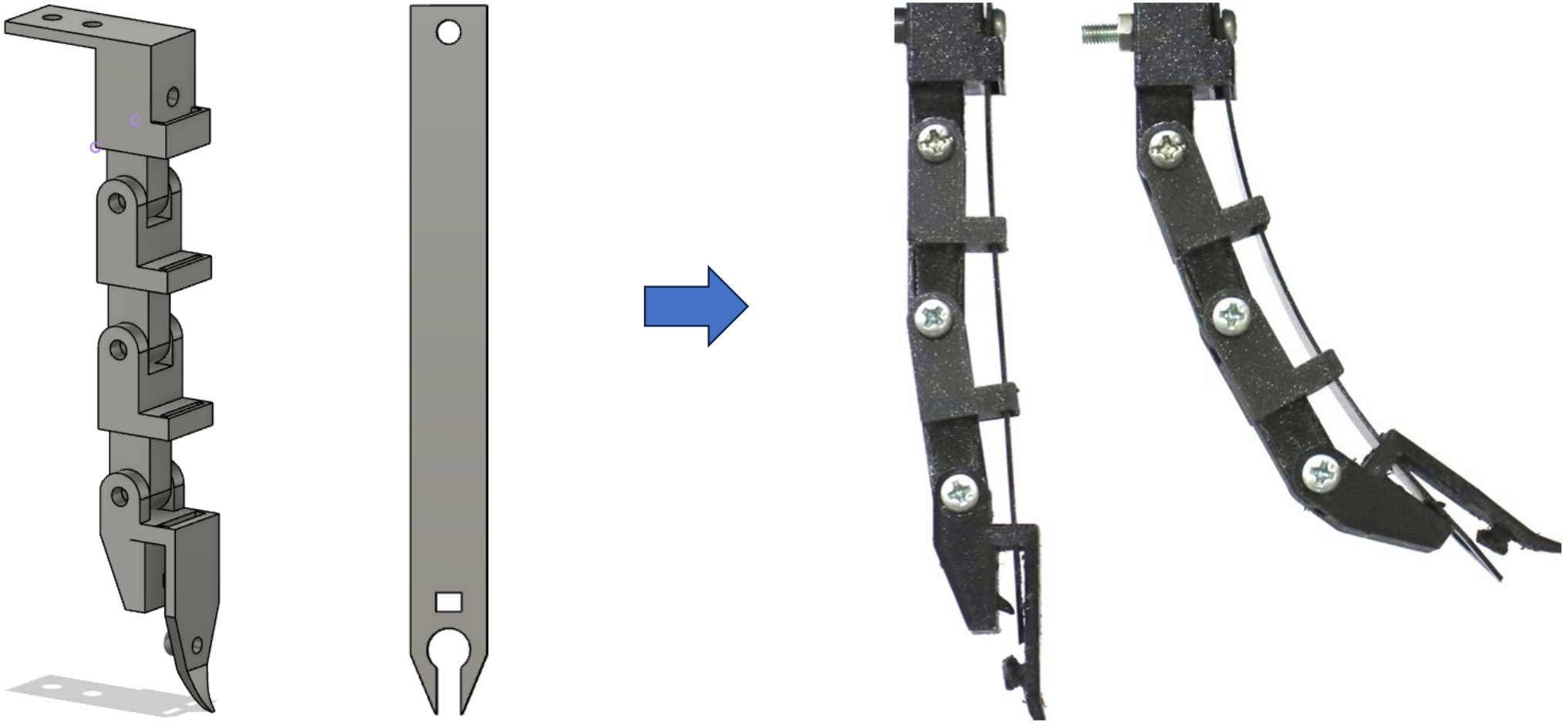
Contact-driven Hand

Grasping of benthos ←
Opening/closing via contact force

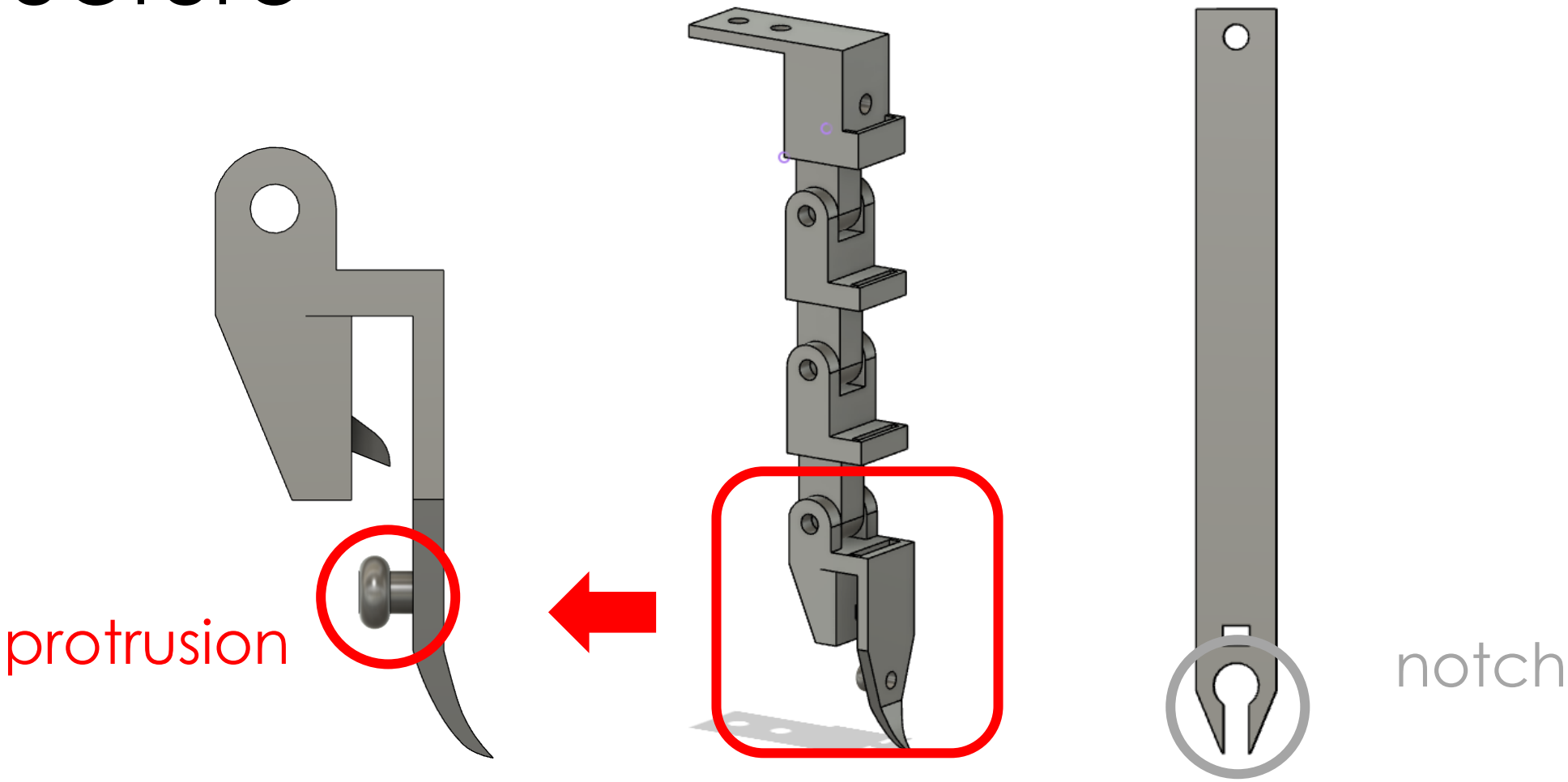
Nate et al., IEEE ICRA 2023



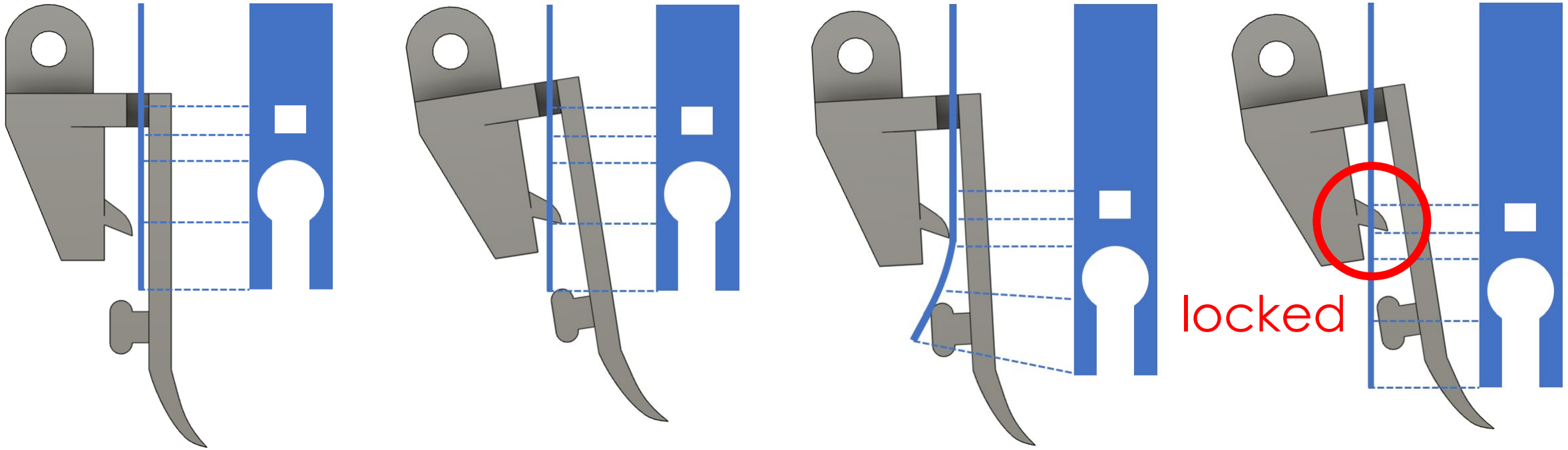
Structure



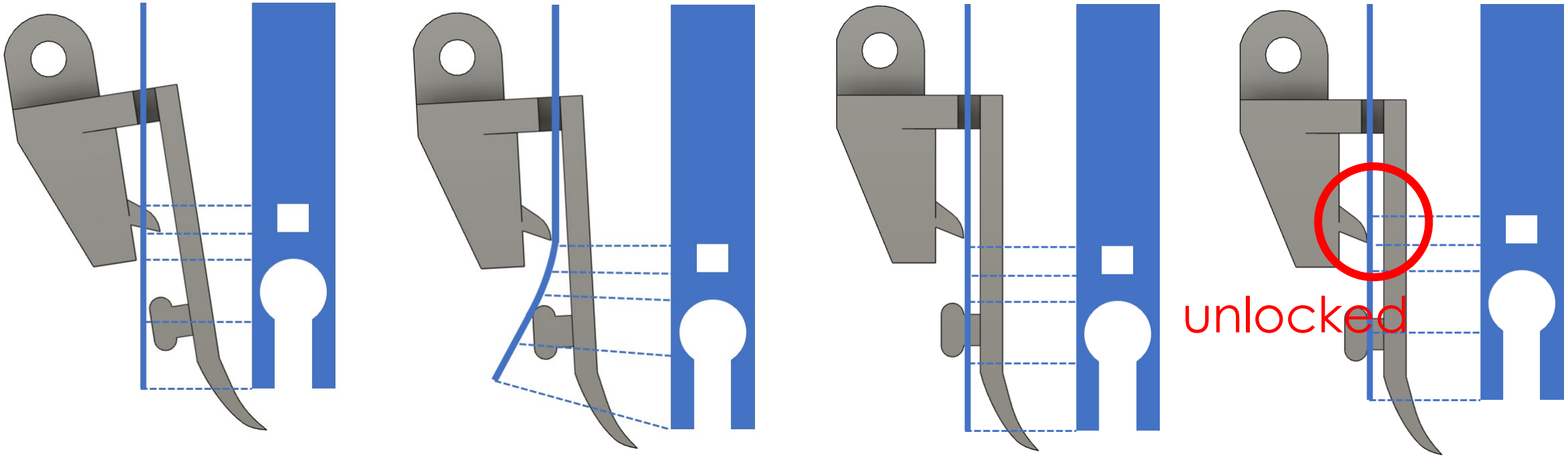
Structure



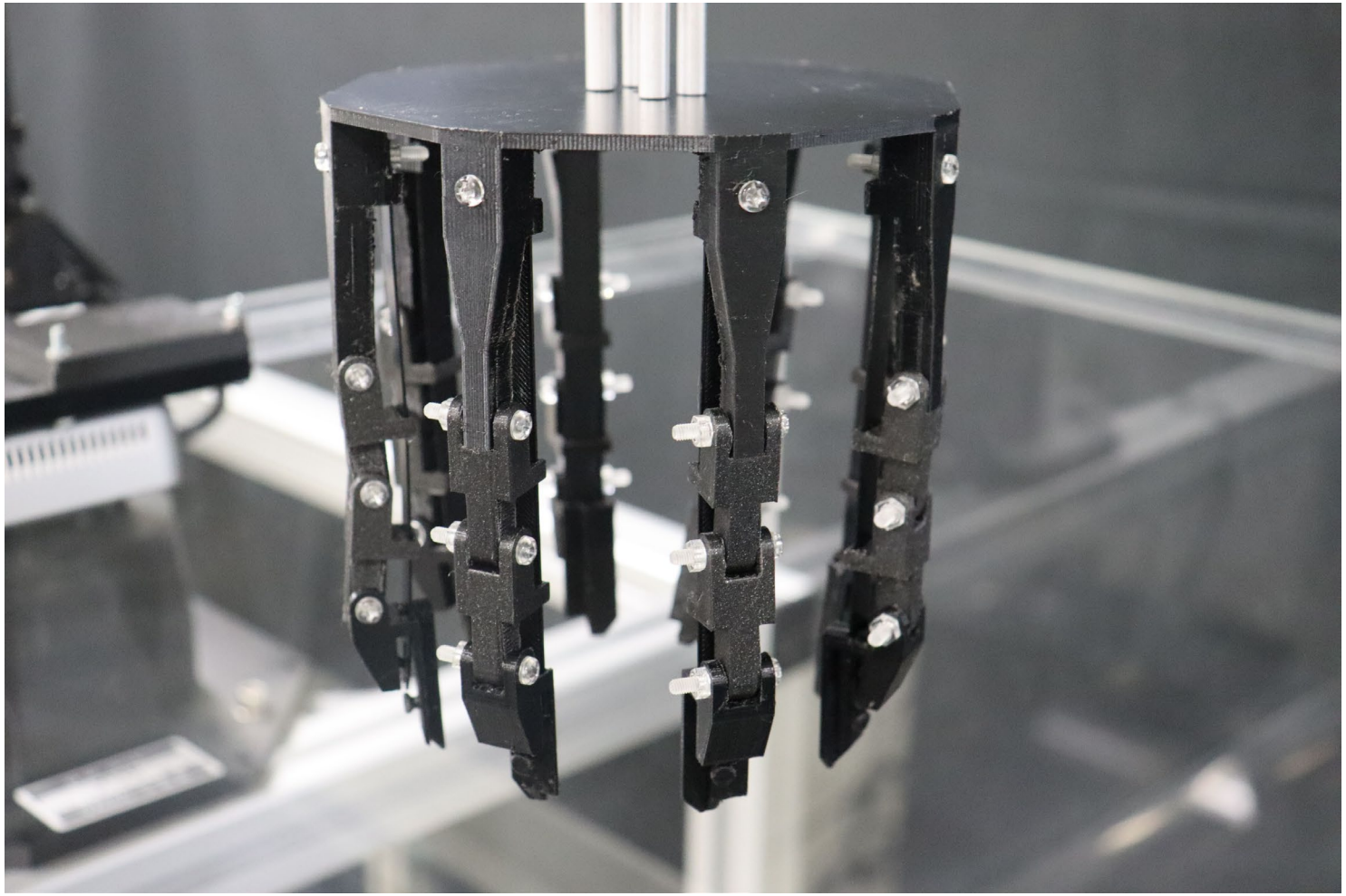
Locking via contact force



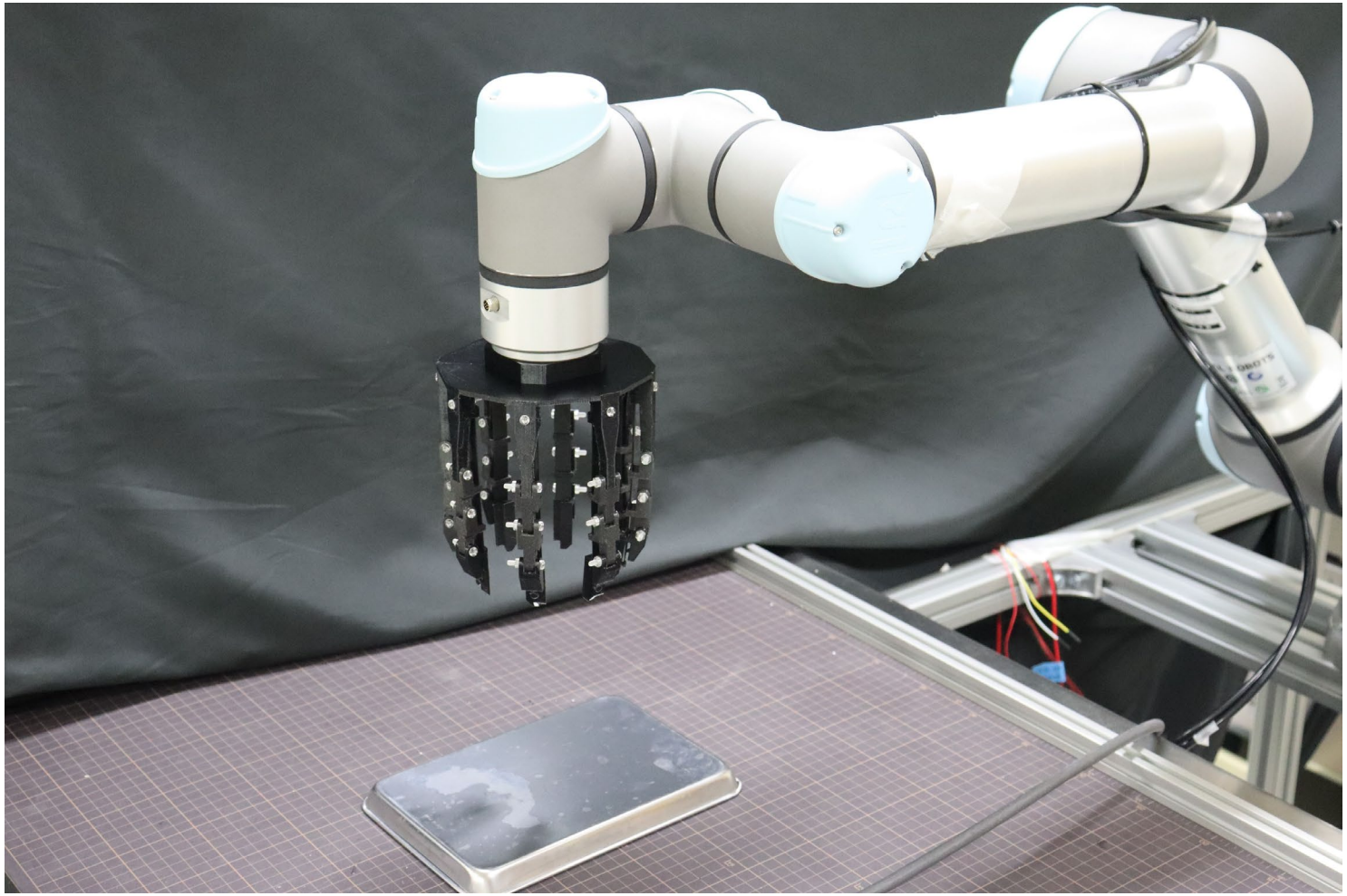
Unlocking via contact force

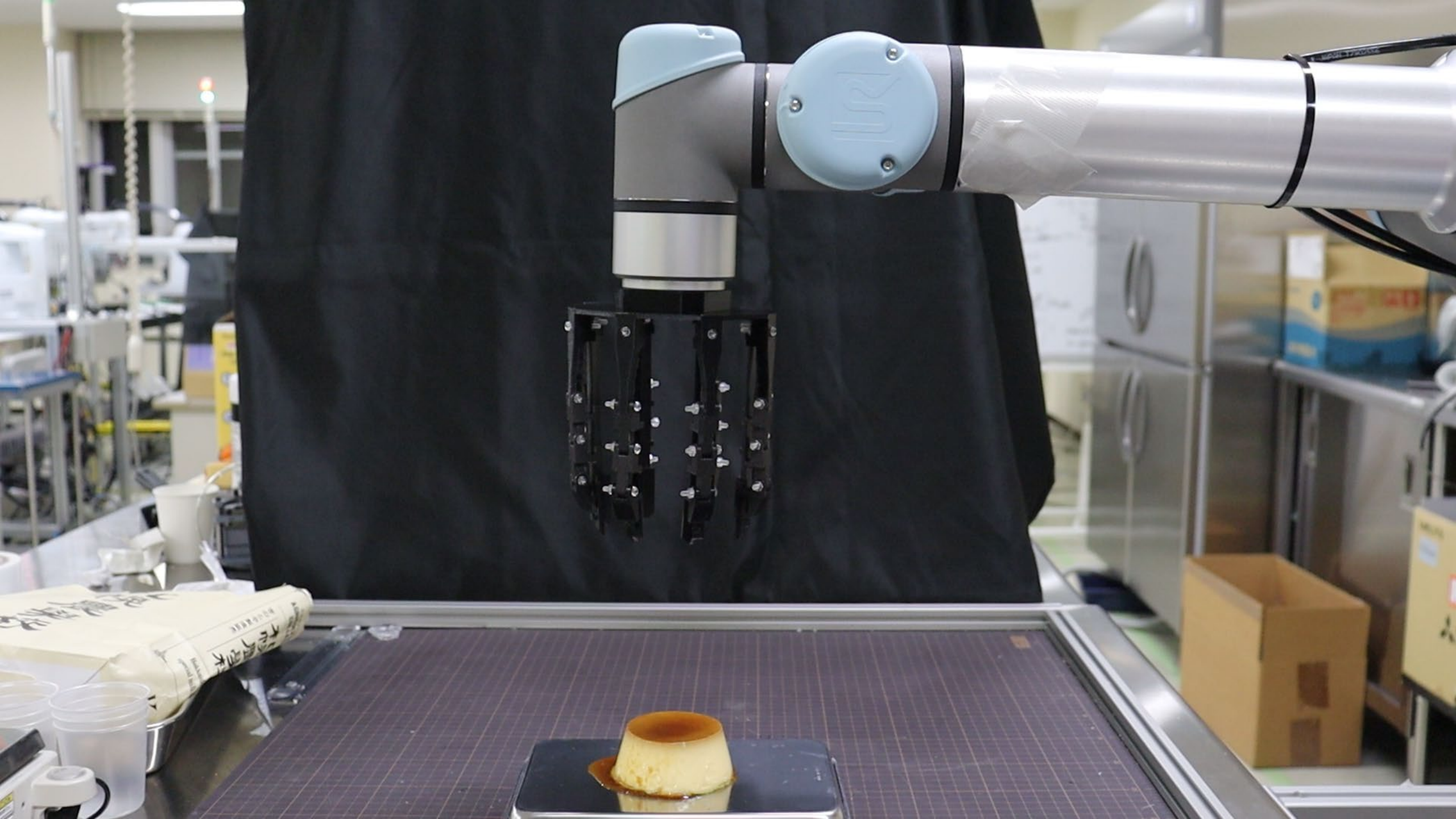


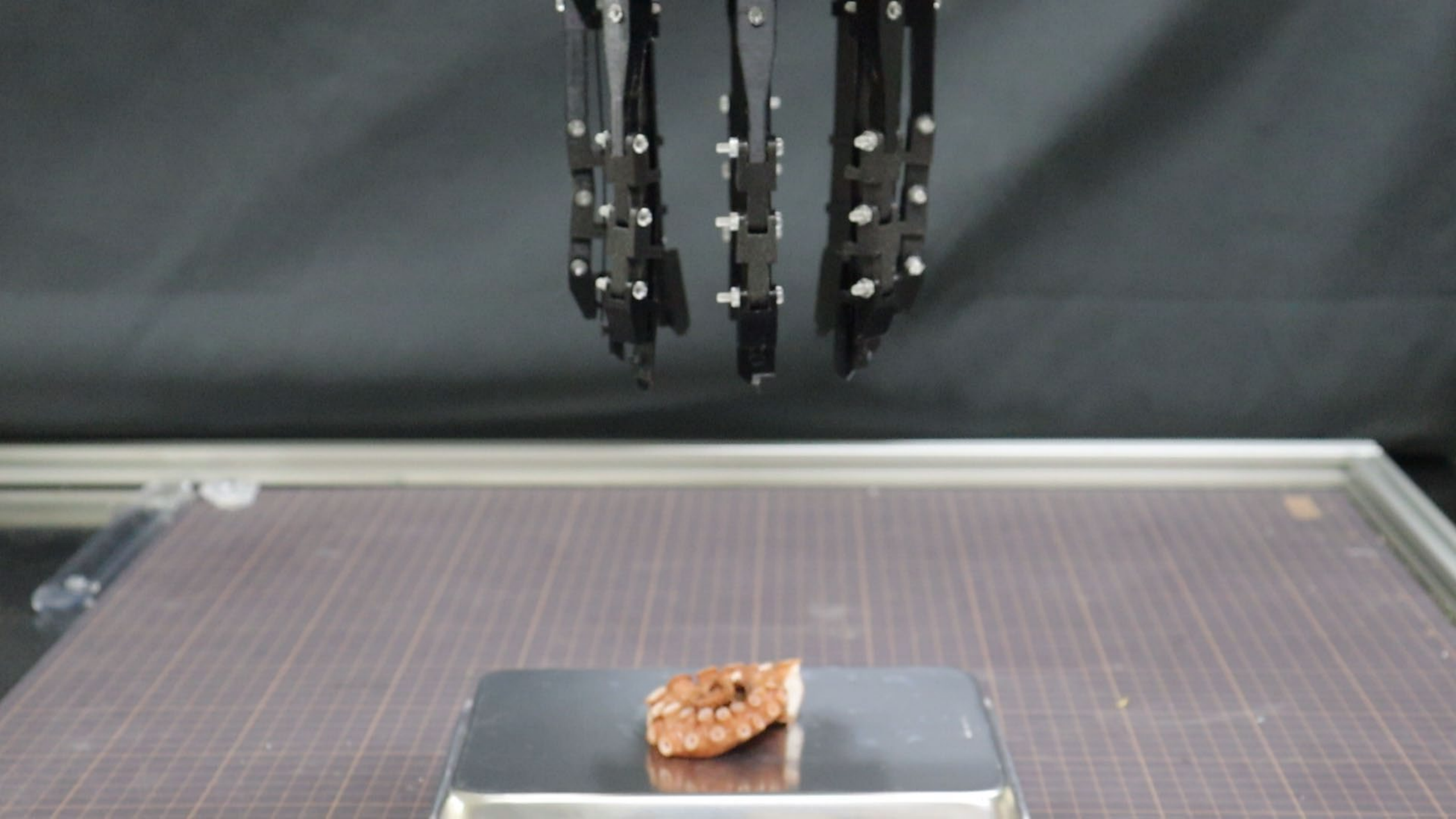
Hand



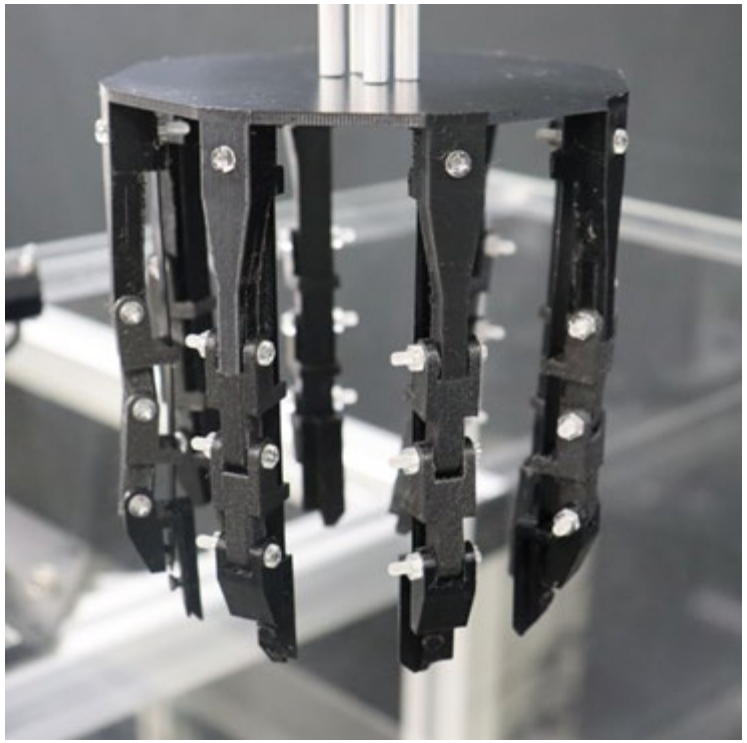
Experiments



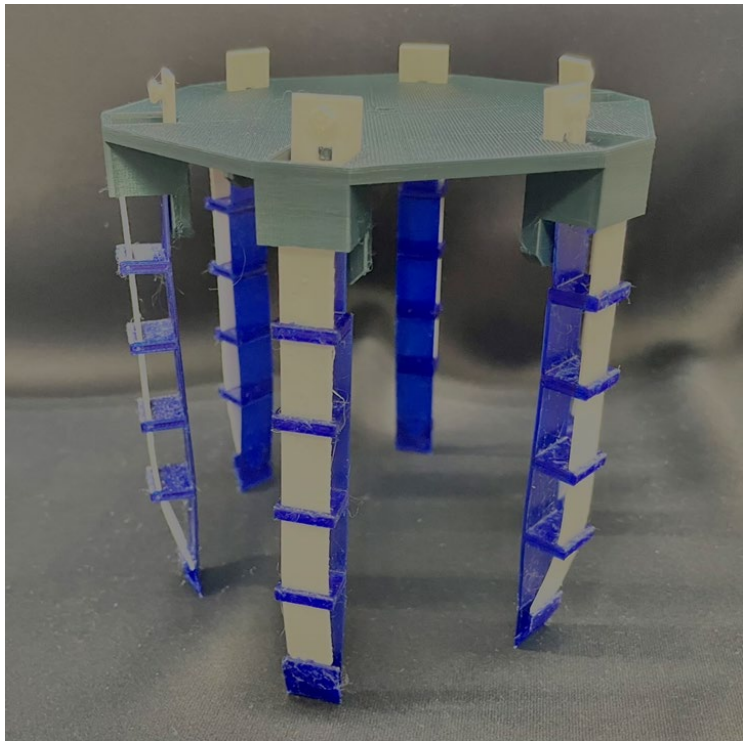




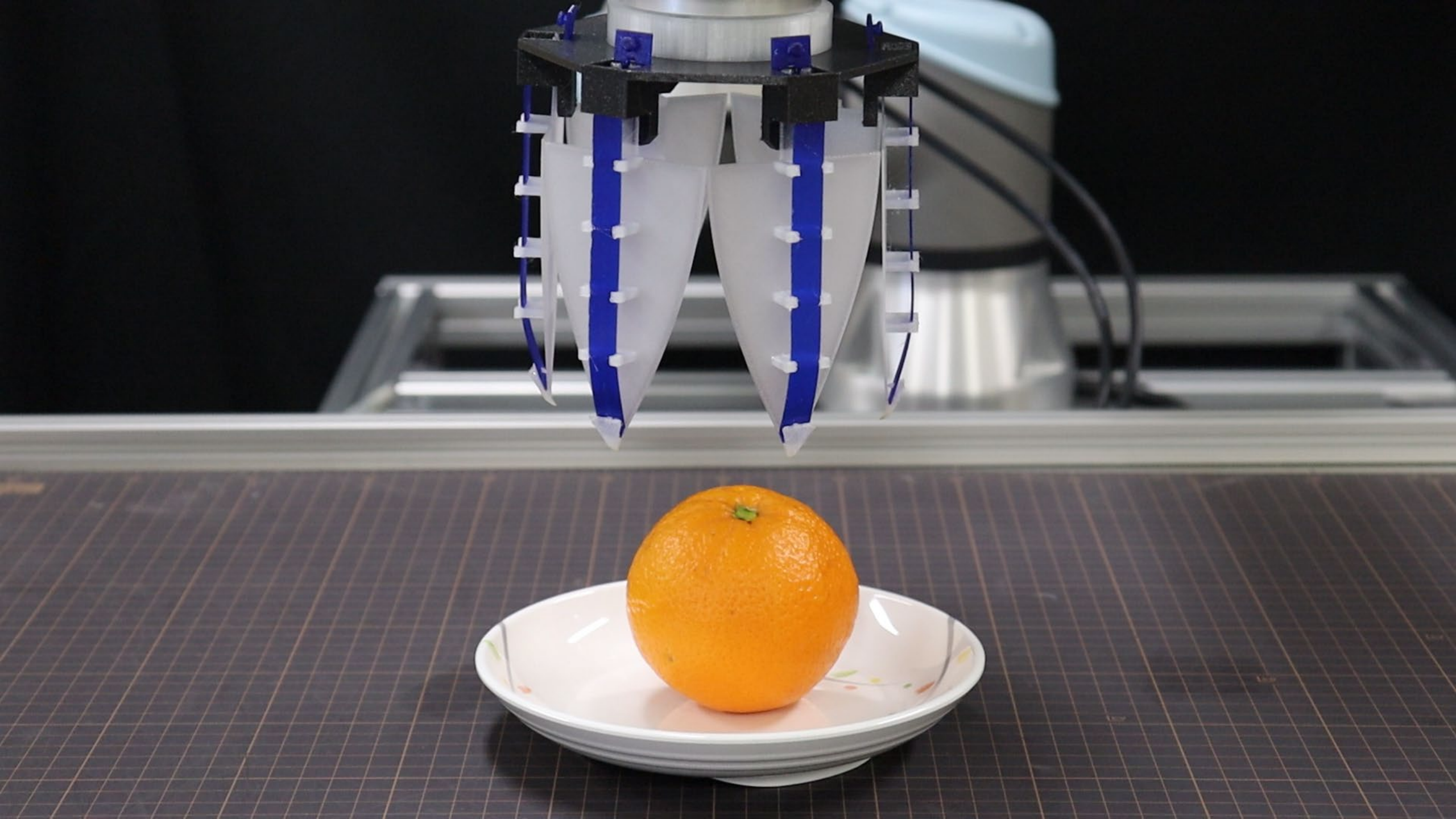
Simplified finger

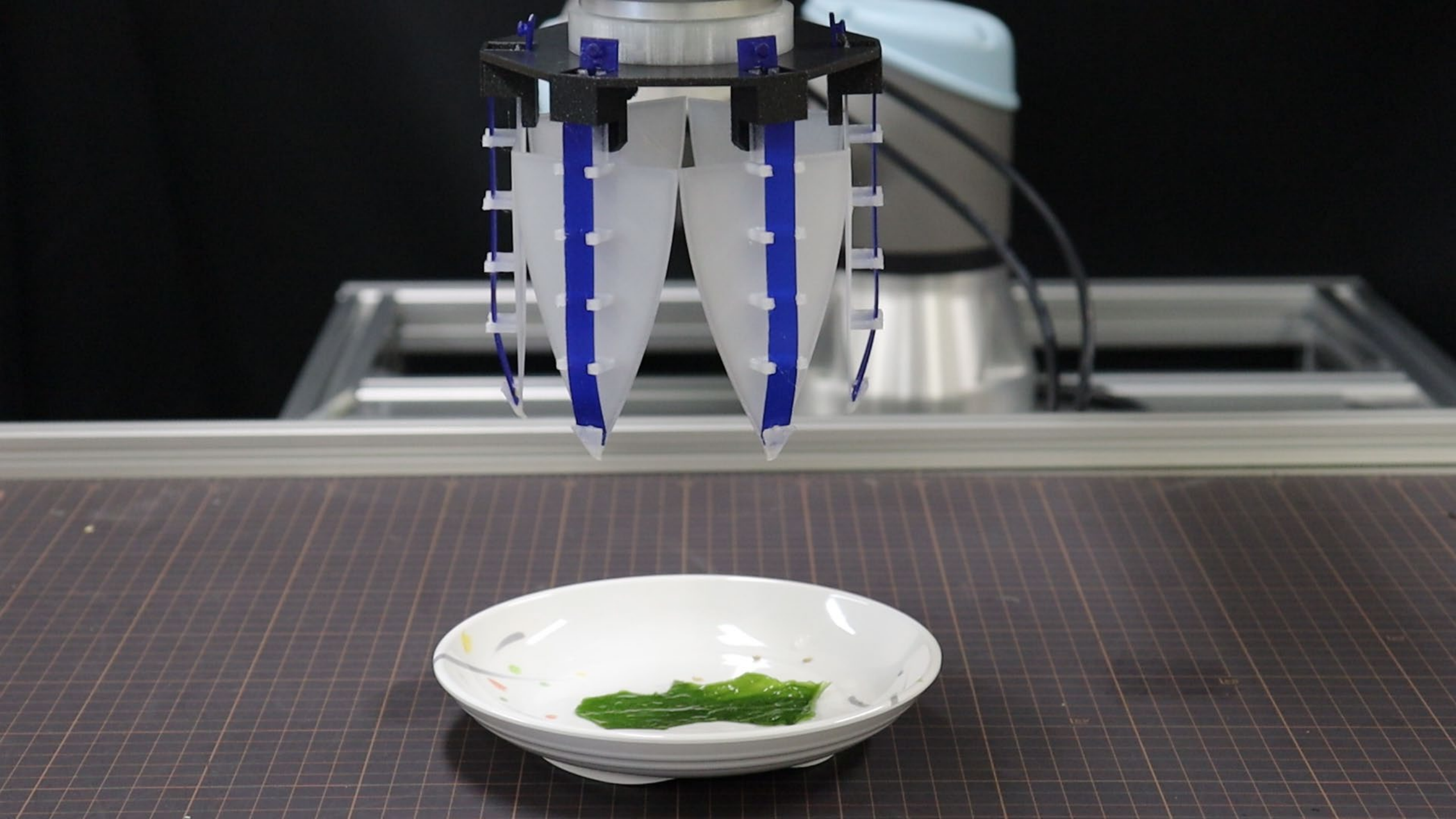


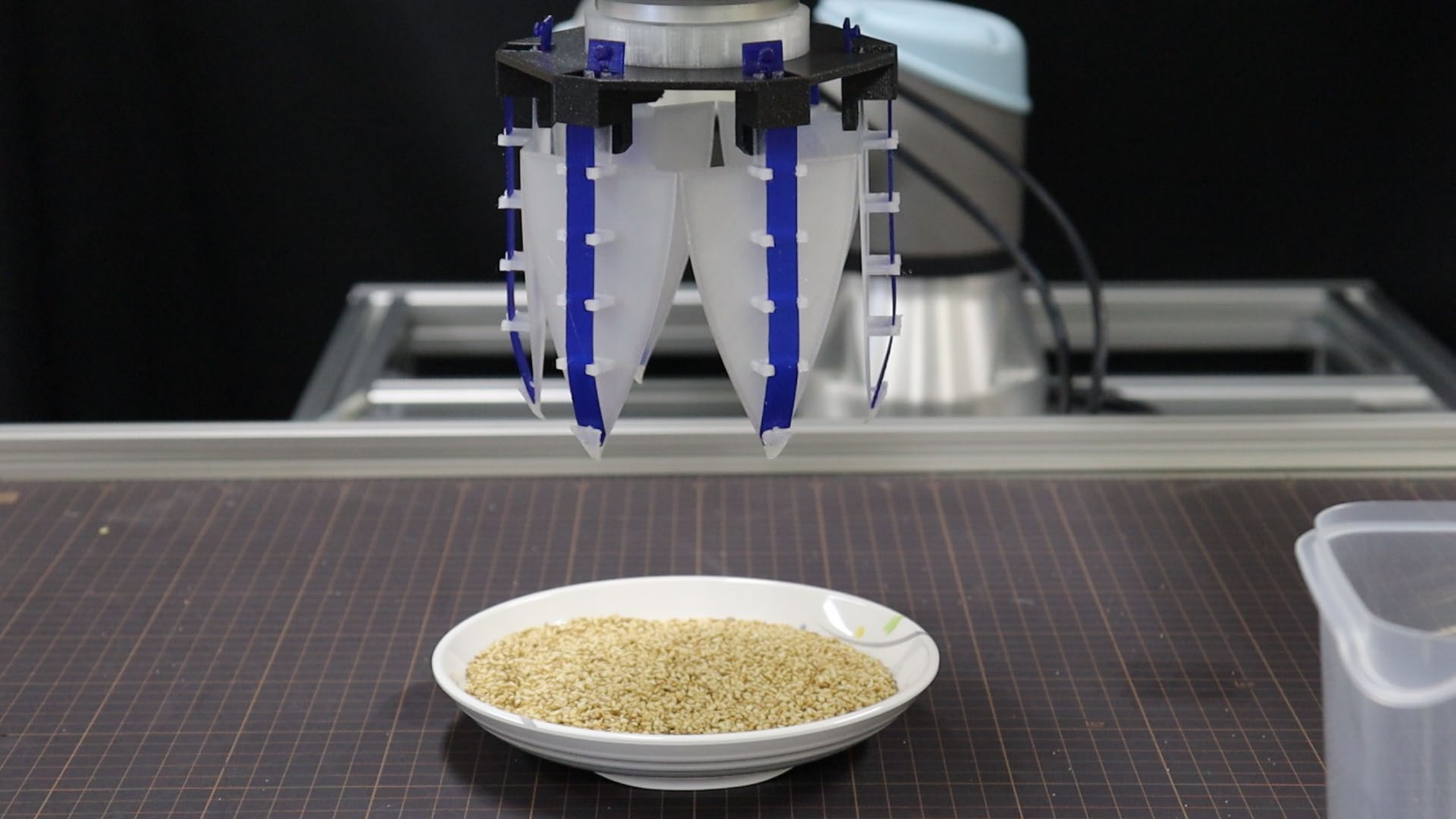
rigid links connected by bolts and nuts

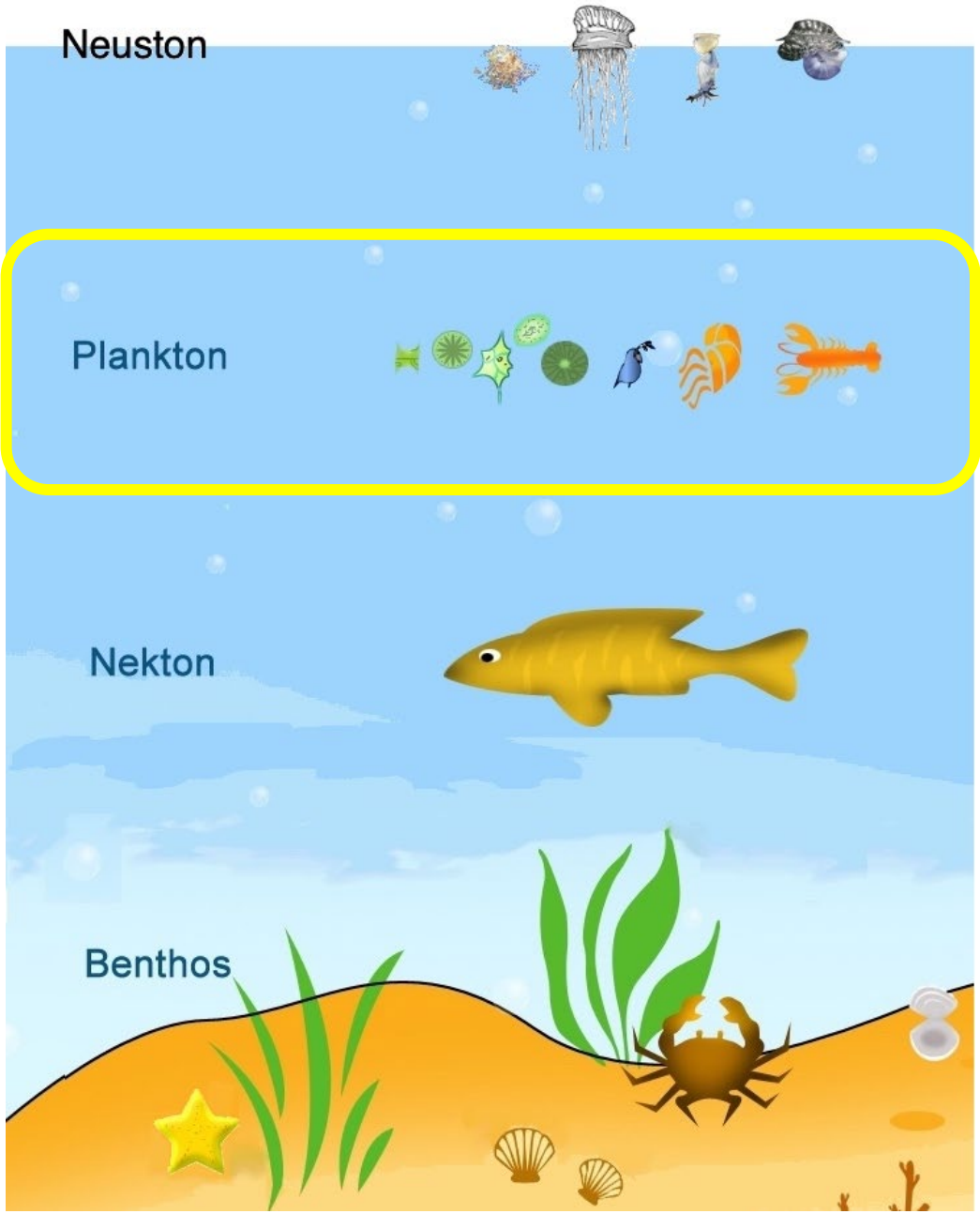


finger consisting of flexible link and plate









Plankton : organisms that drift in water but are unable to actively propel themselves against currents

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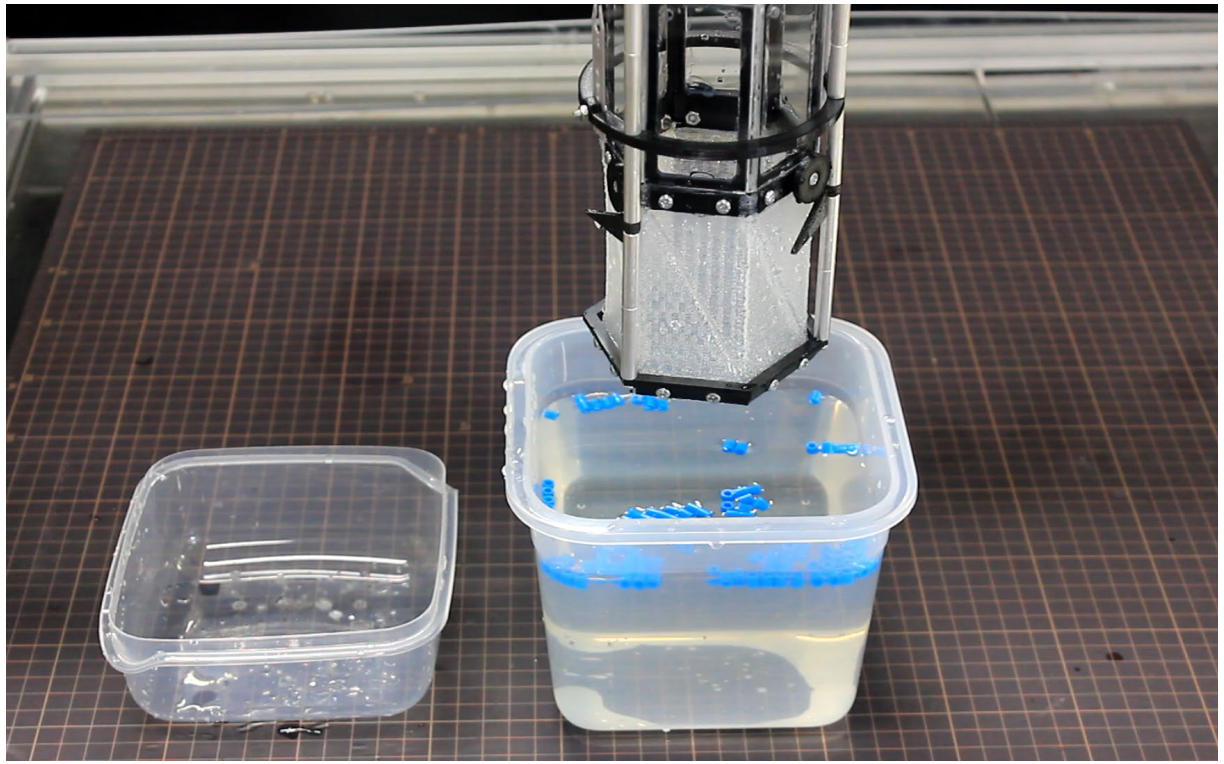
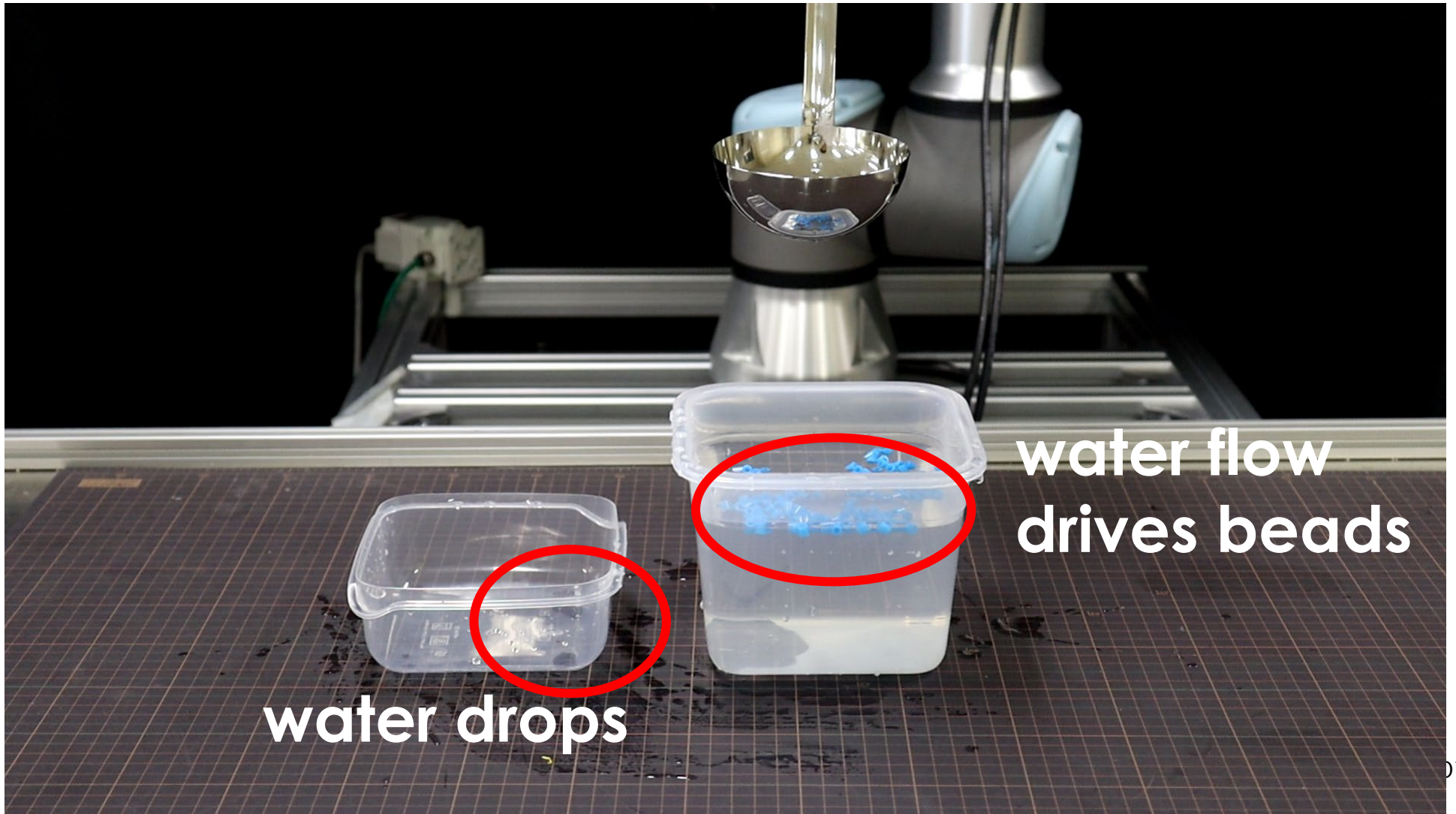
Origami-membrane Hand

Nate et al., IEEE/SICE SII 2024

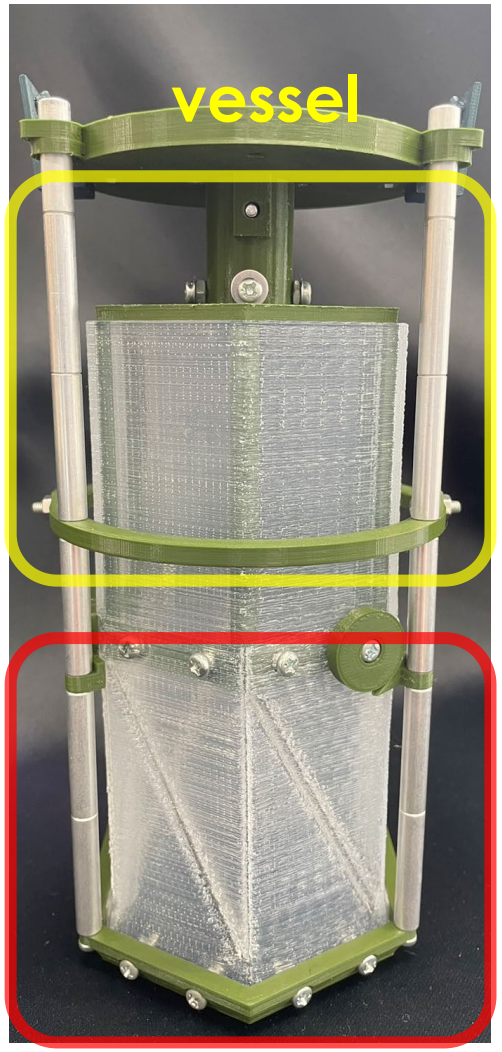
Grasping of plankton near bottom ←
Enveloping by origami-membrane



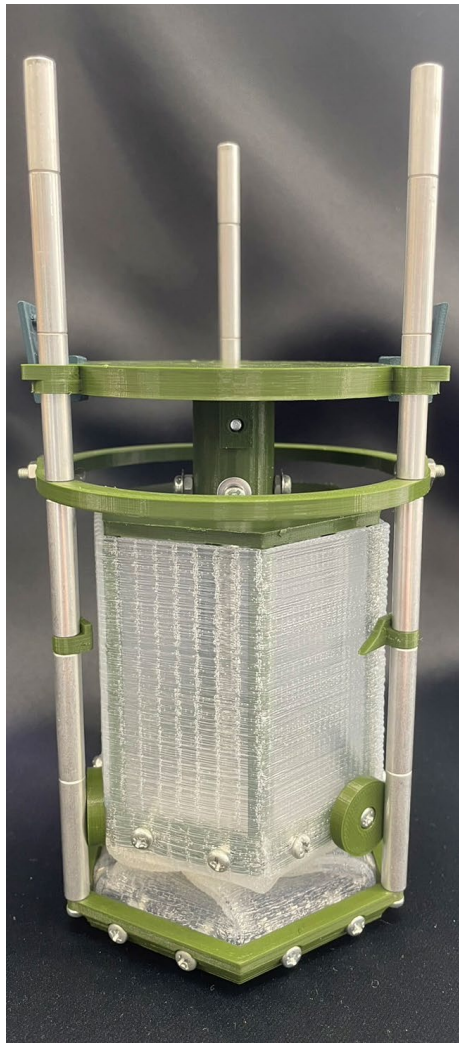
Scooping by ladle



Origami-membrane Hand



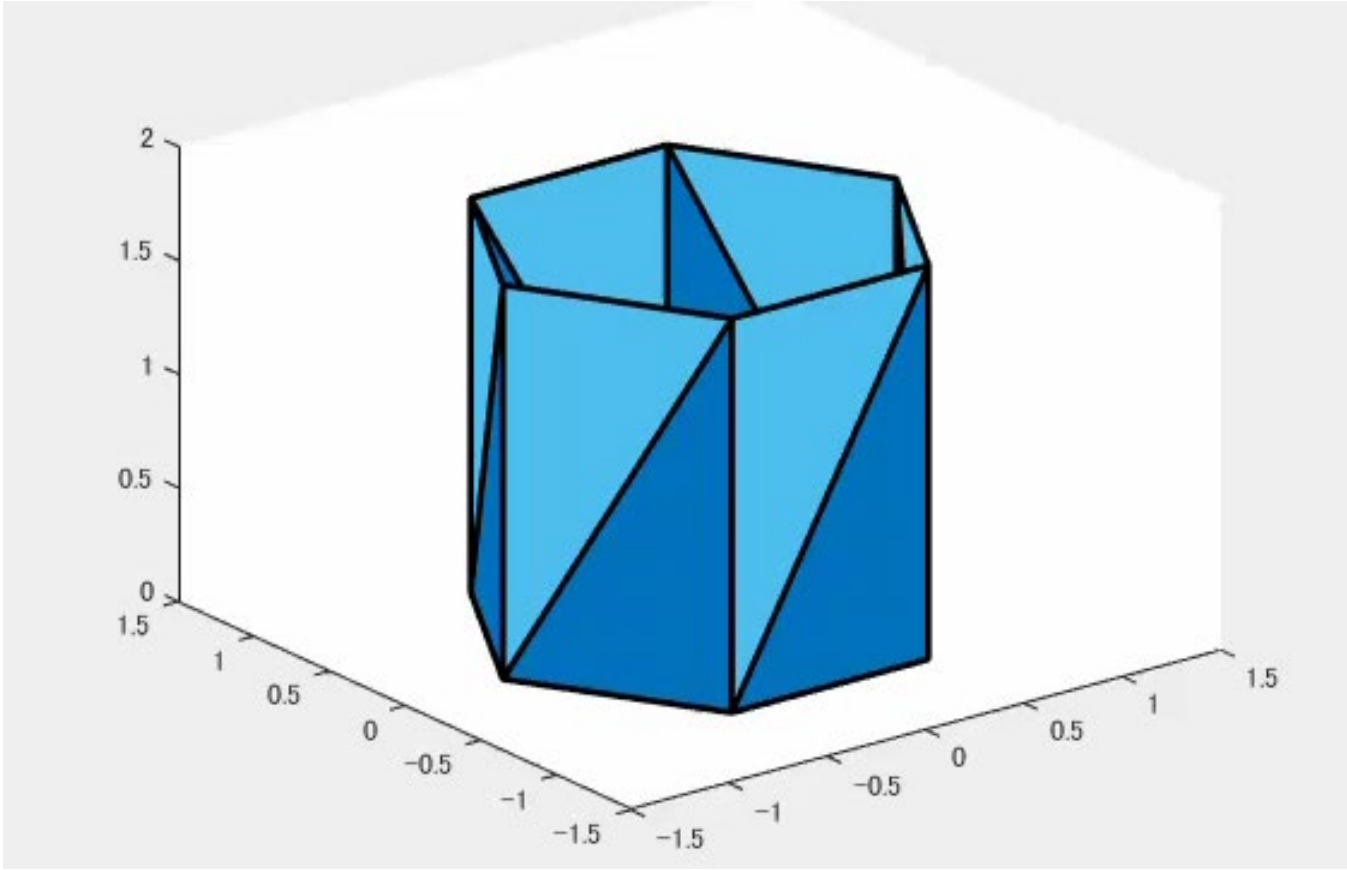
origami-membrane



Origami-membrane

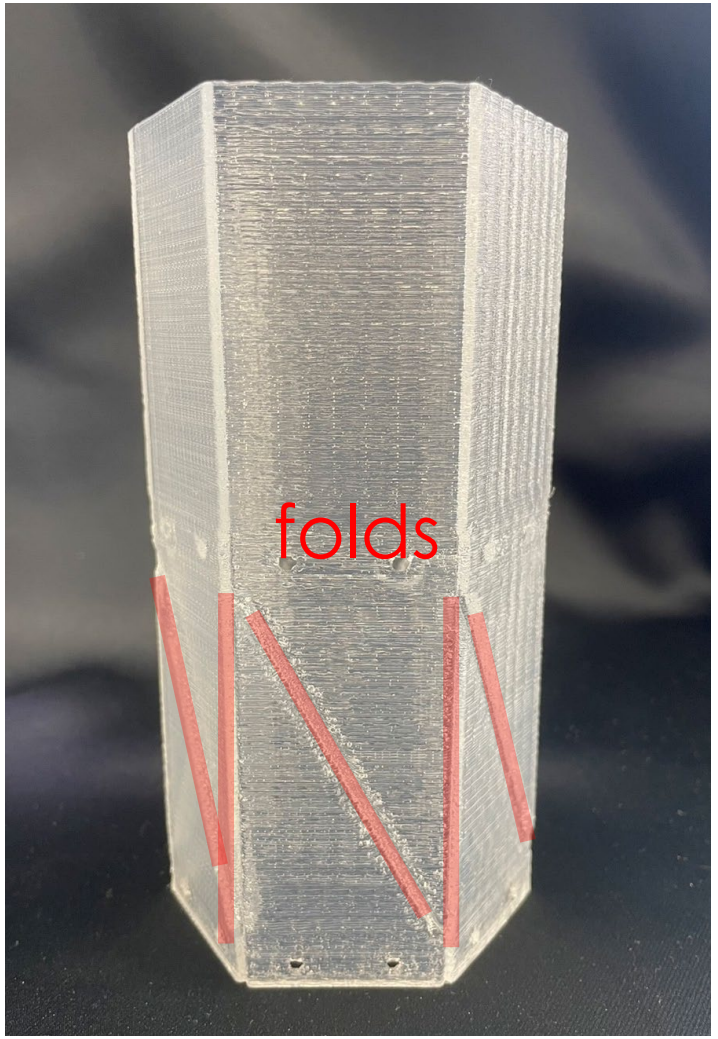
Kresling pattern

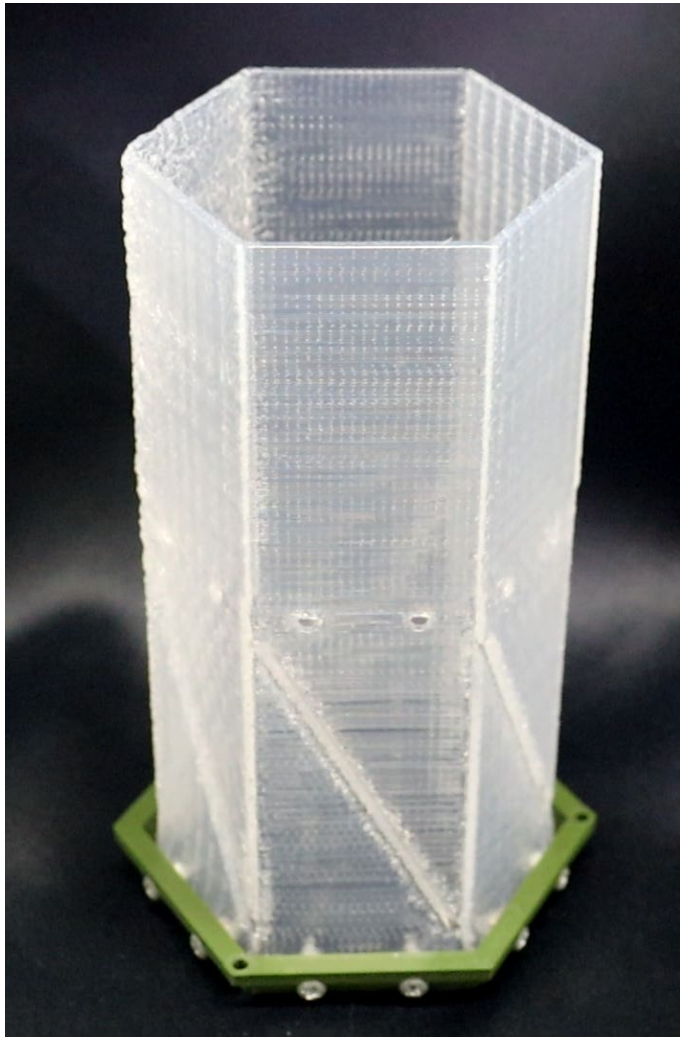
polygonal prism
→ flat shape



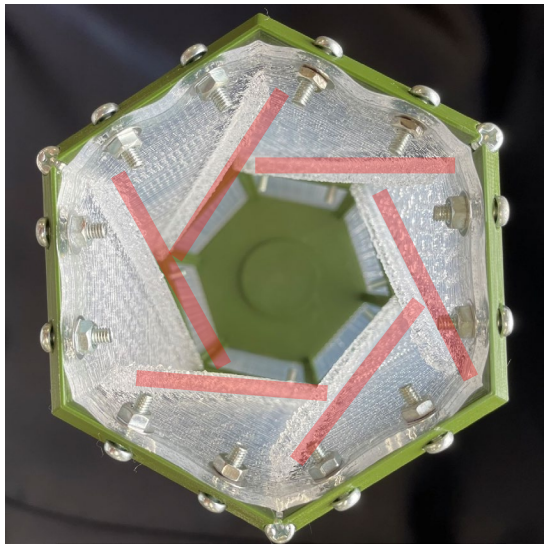
Fabrication

membrane : fabricated by liquid silicone printer

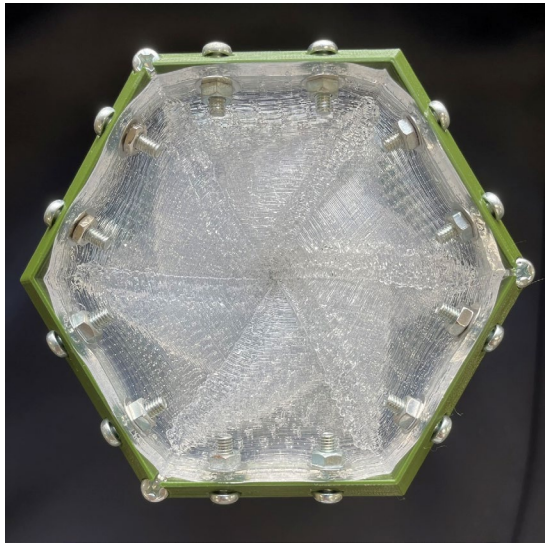




Membrane deformation



open



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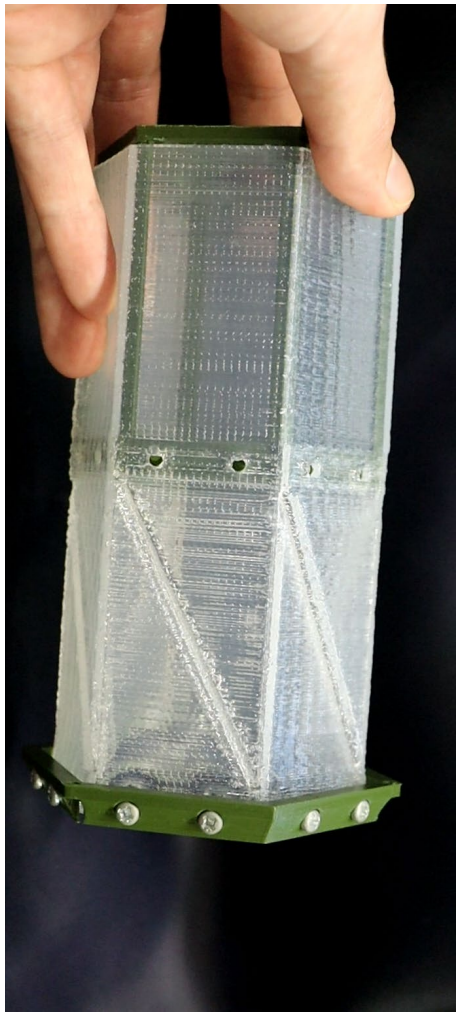
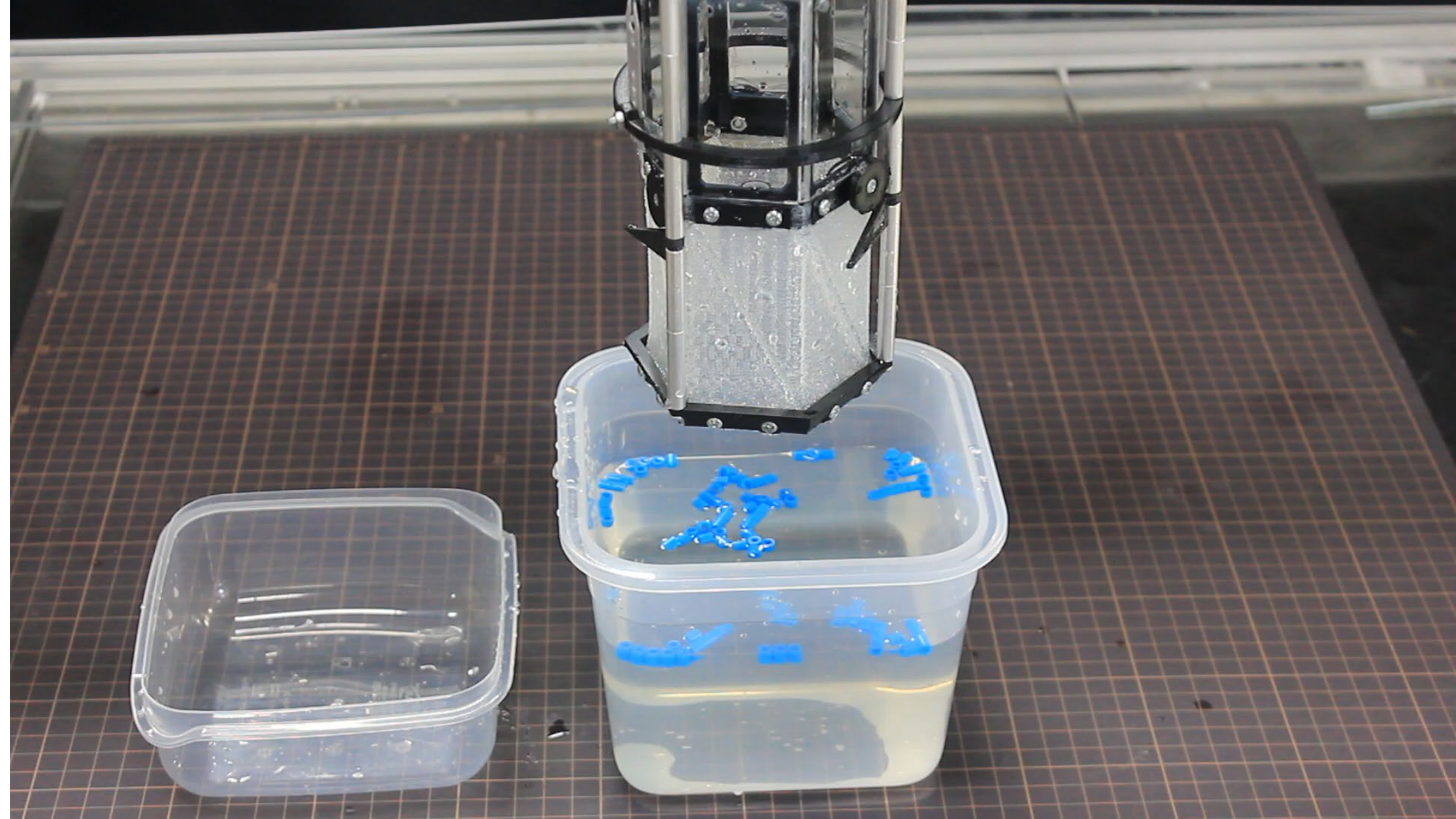
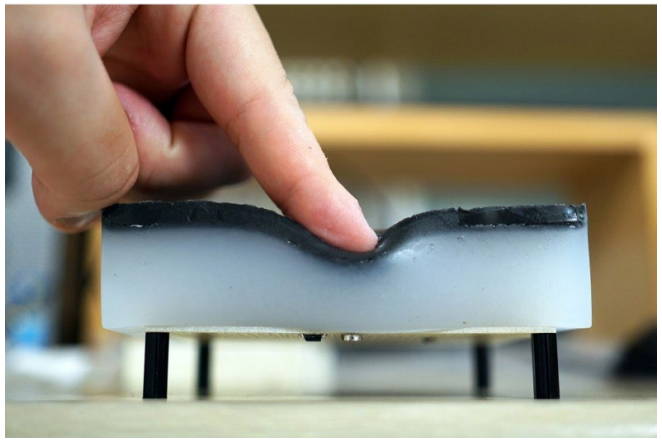
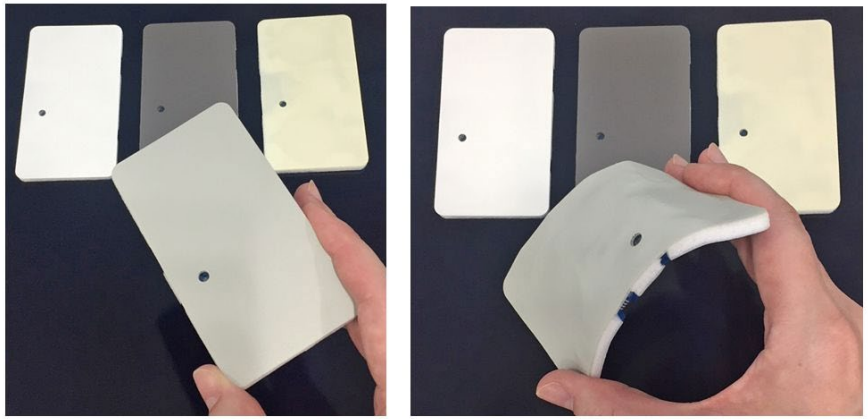




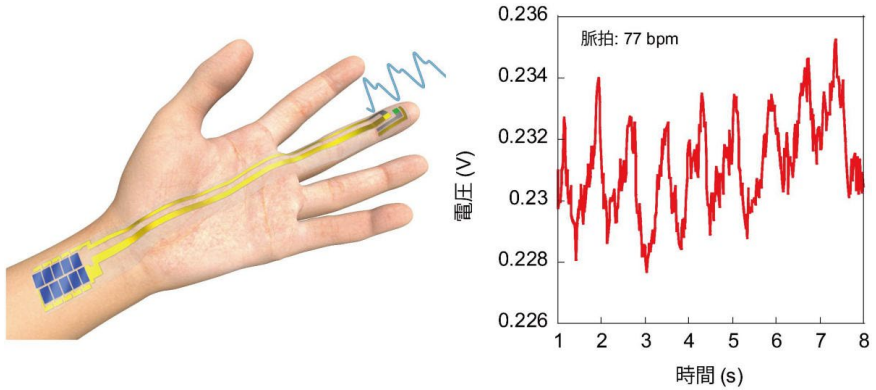
Soft Sensors



http://www.ams.eng.osaka-u.ac.jp/user/ishihara/wp-content/uploads/2016/08/sensor_ver1-e1541744713909.jpg

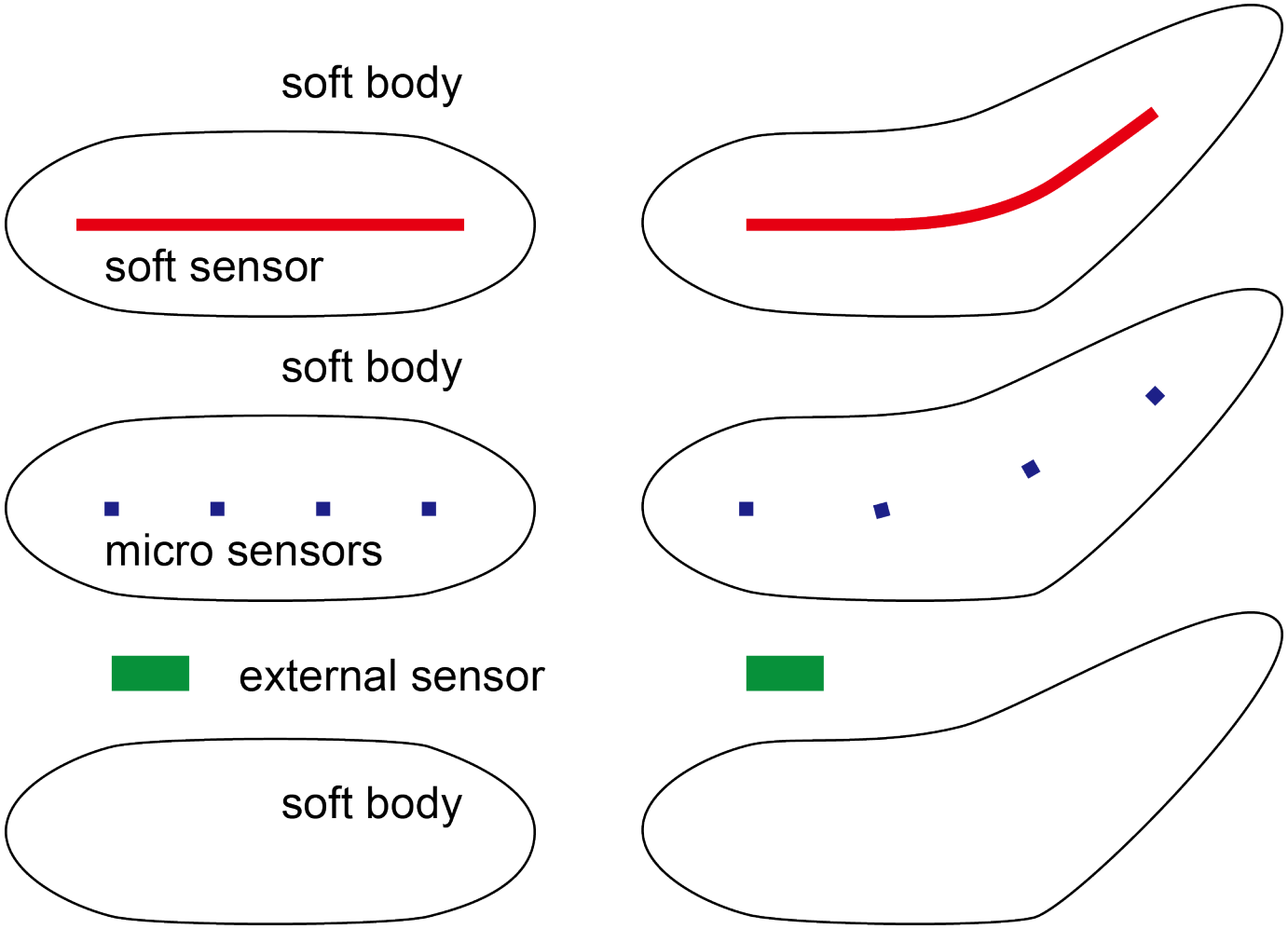


https://www.dic-global.com/news/news_file/file/20190201_%E3%83%93%E3%83%AB%E3%82%BB%E3%83%B3%E3%82%B7%E3%83%B3%E3%82%B0%EF%BC%92.jpg

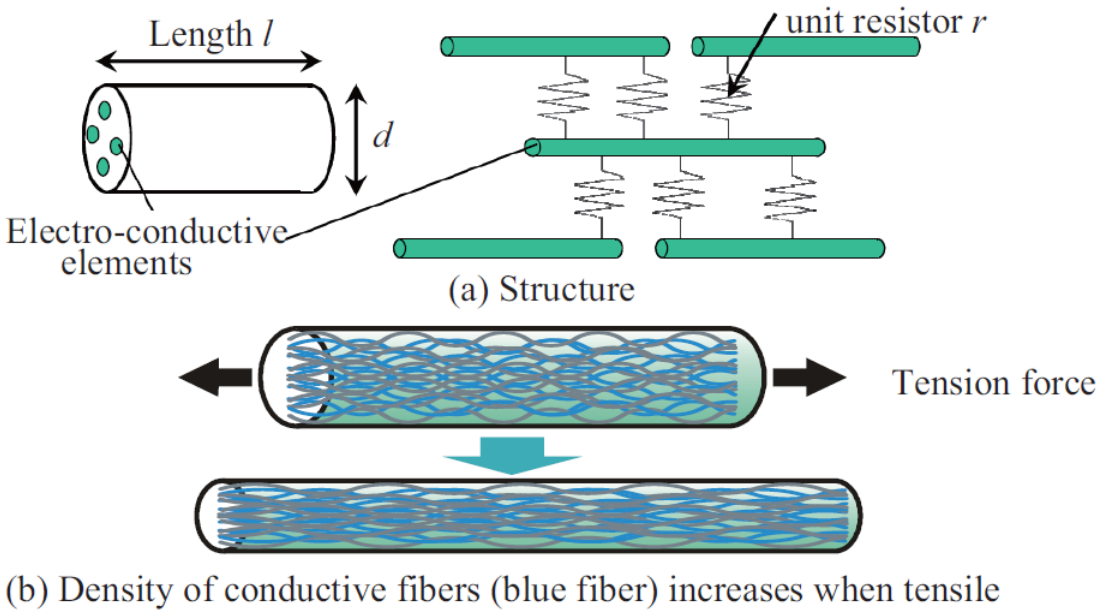


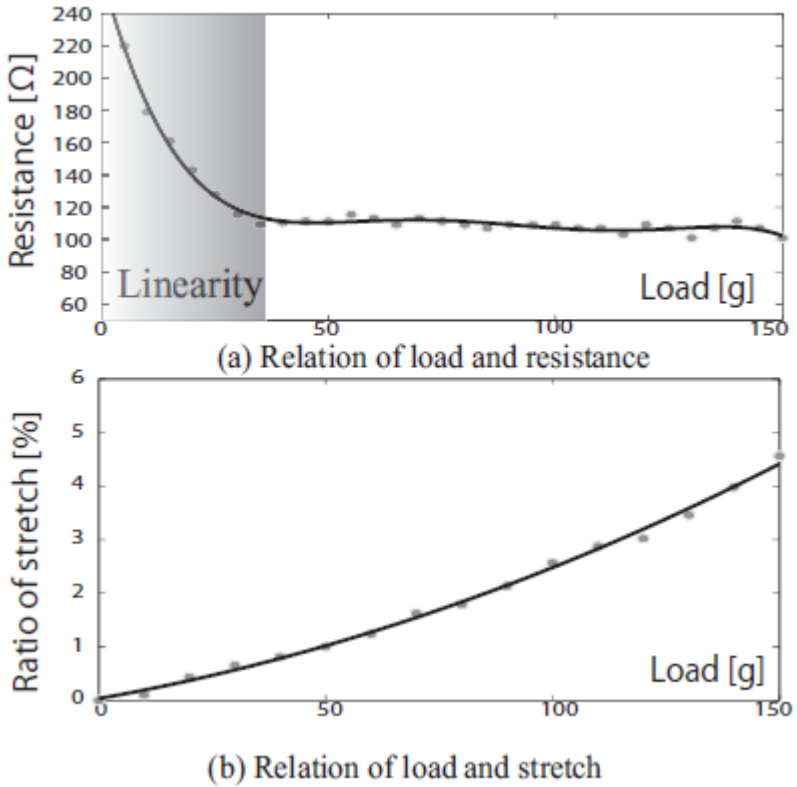
https://news.mynavi.jp/techplus/article/20210422-1876923/images/003.jpg

Sensing for Soft Robots



Fiber Sensor

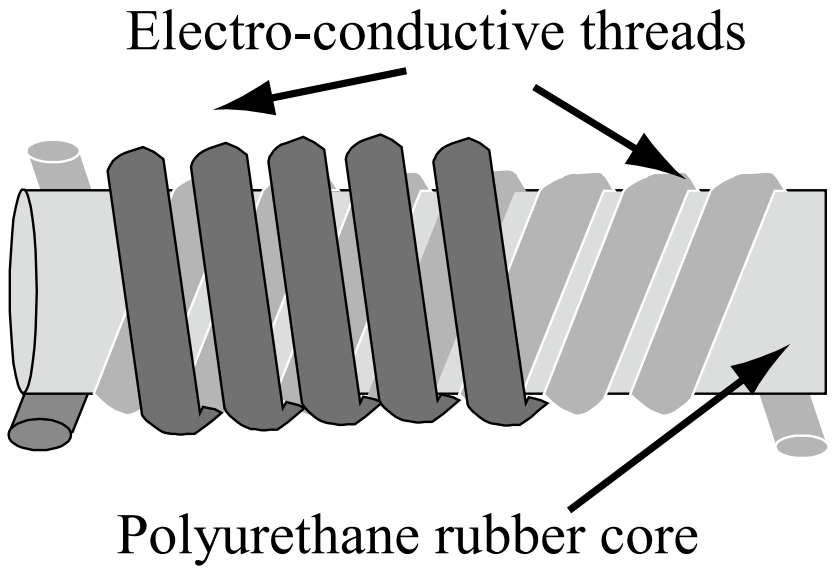


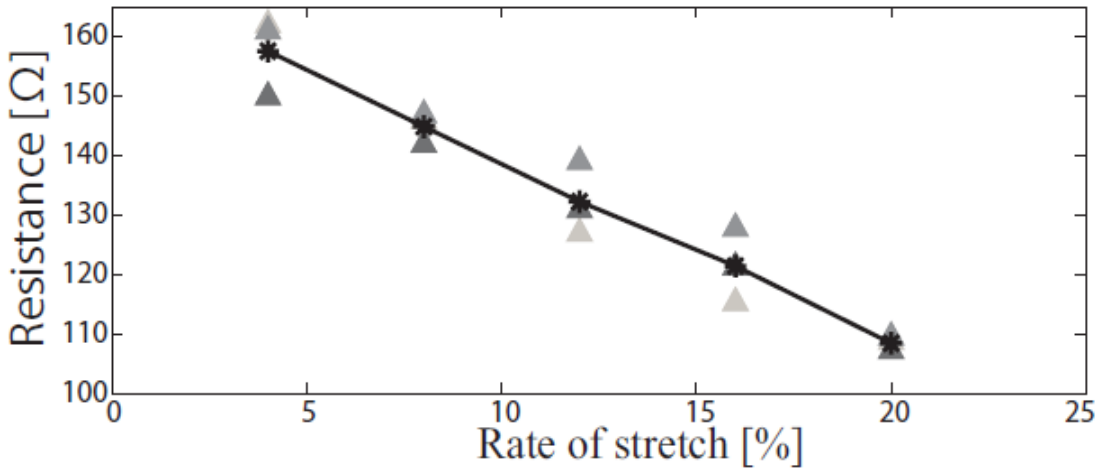


Ho et al., IEEE Sensors J., 13(10), 2013

Sensing range ~ 2%

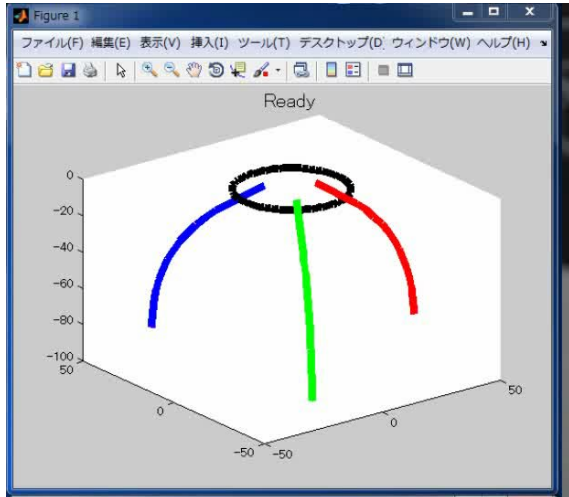
Double-Covering Structure

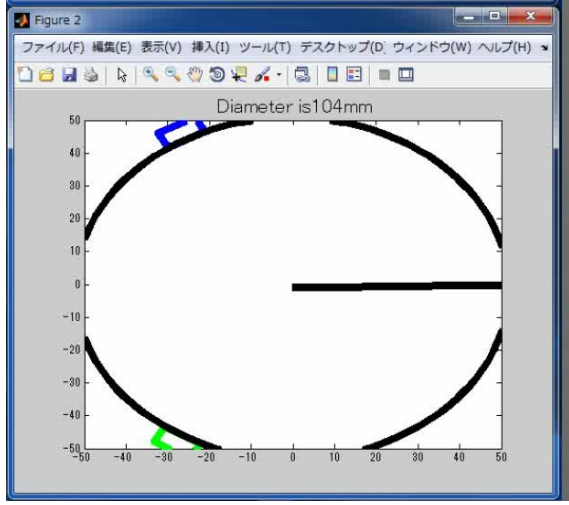


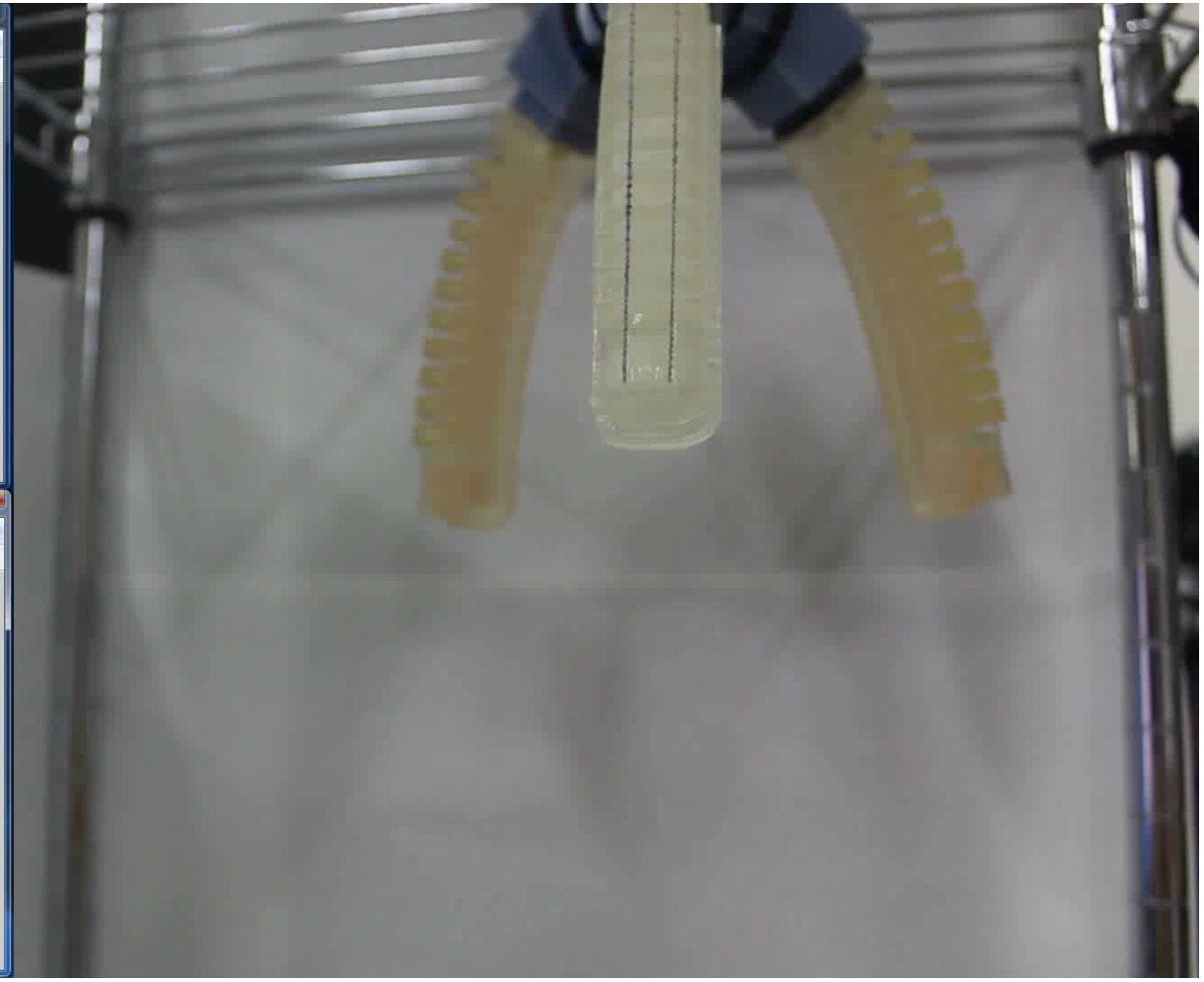


Sensing range ~ 20%

Estimation of finger bending

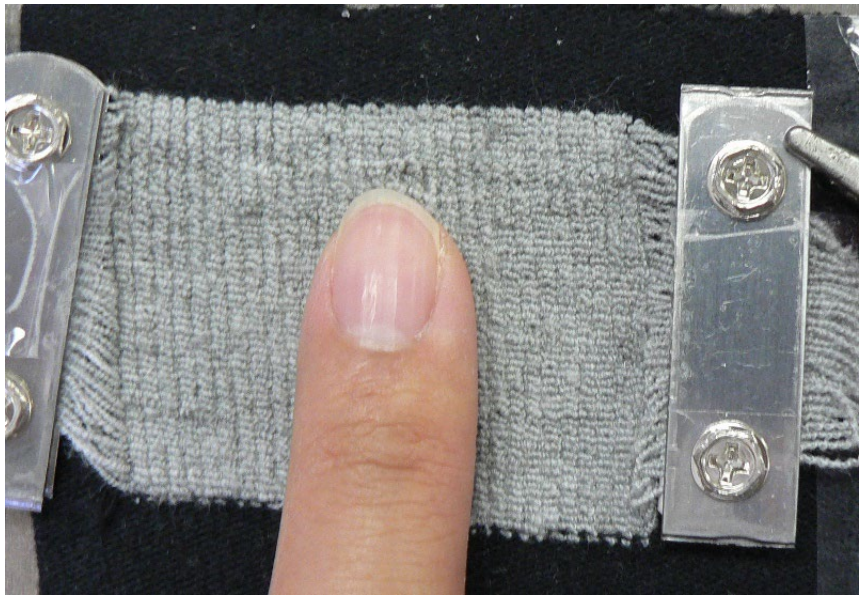


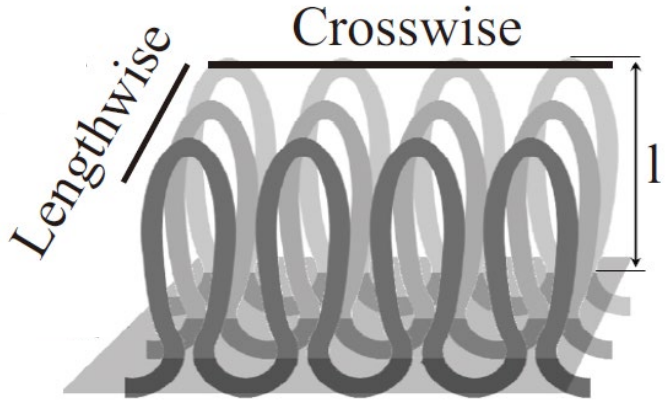




Matsuno et al., IEEE RCAR 2017

Fabric Sensor

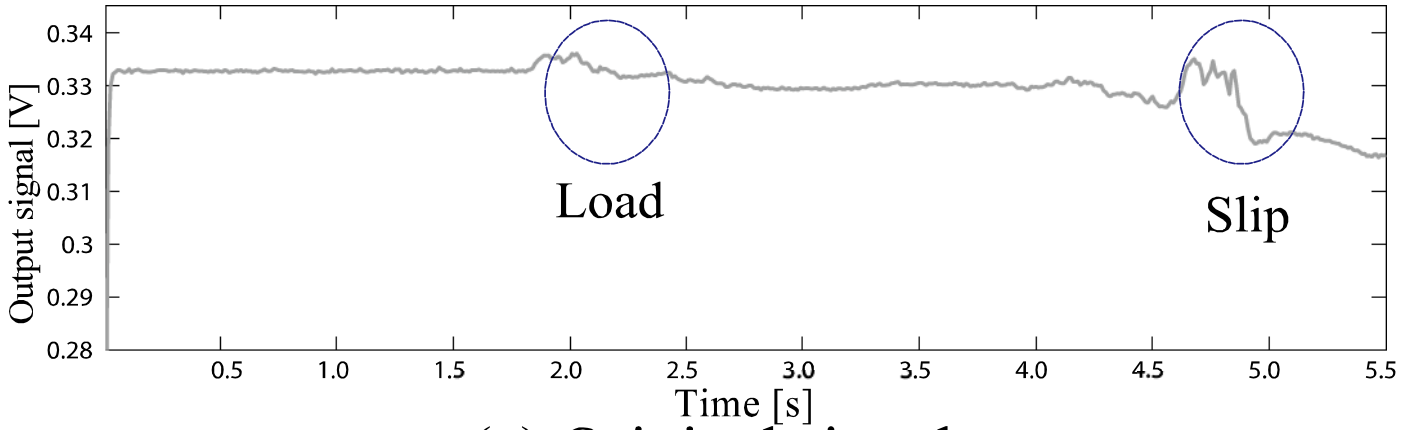




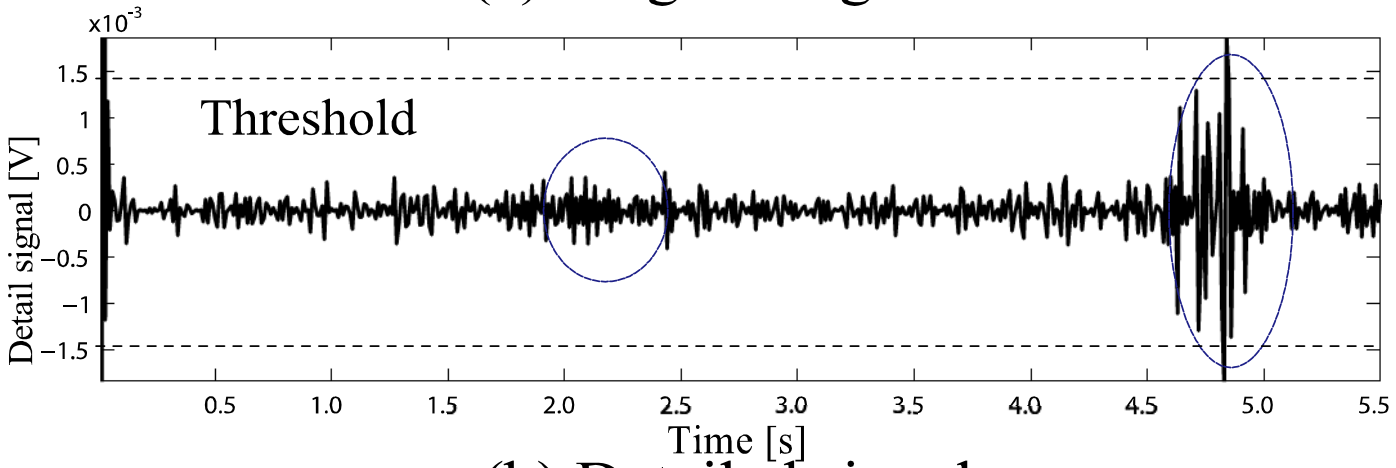
Slip Detection

Wavelet transform Amplitude of high-frequency

Van Ho and Shinichi Hirai
Robotics: Science and Systems VII
pp.129-136, 2012

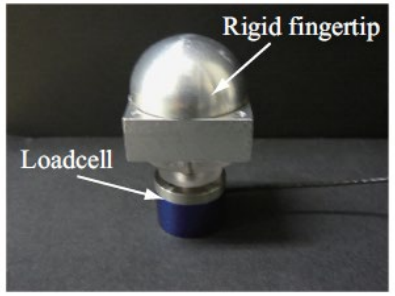


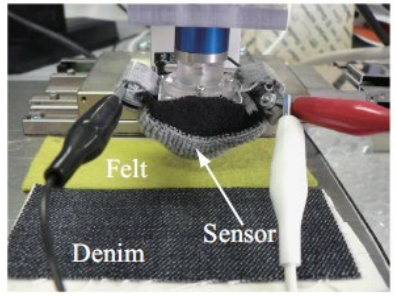
(a) Original signal

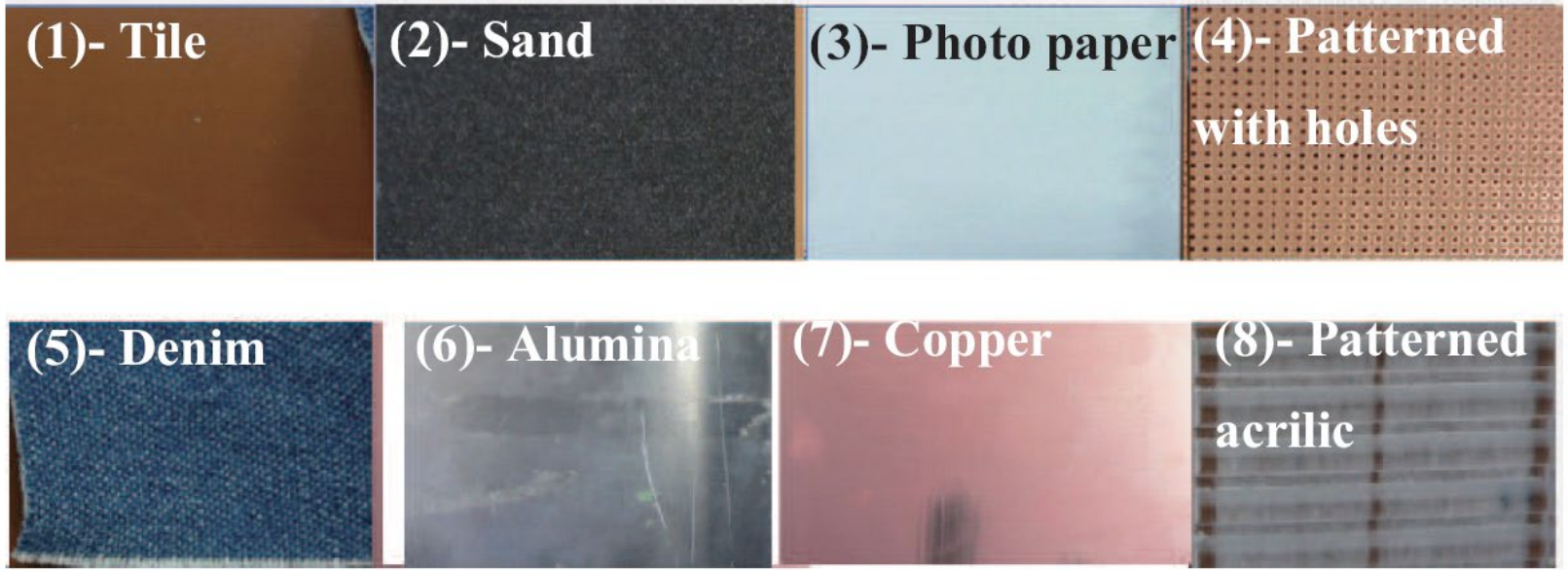


(b) Detailed signal

Discriminating Surface Textures







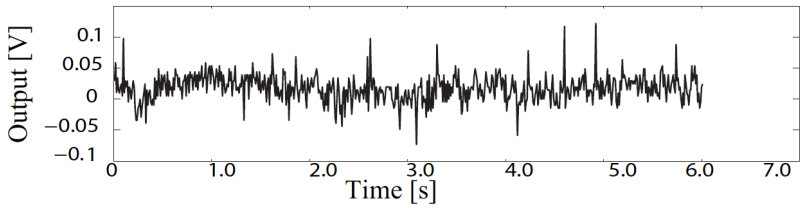
Ho, Makikawa, and Hirai, IEEE Sensors Journal, 2013

Discriminating Surface Textures

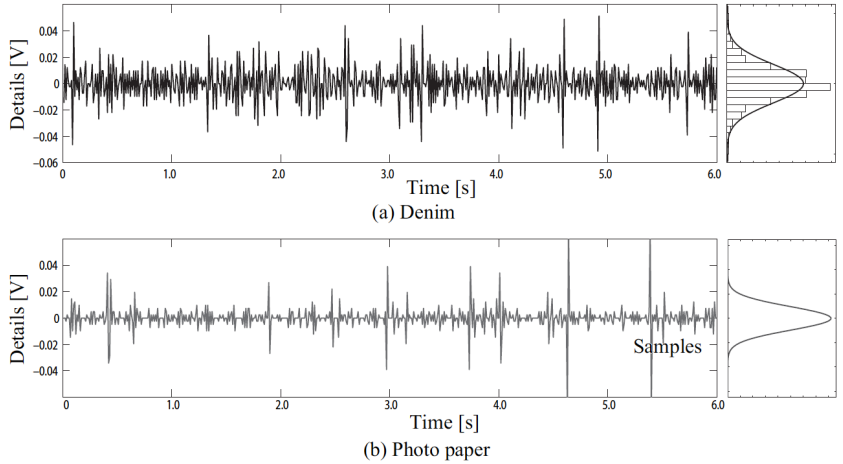
センサ　　離散ウェーブレット変換　　特徴量の計算　　人工ニューラルネットワーク

デニム

写真用紙



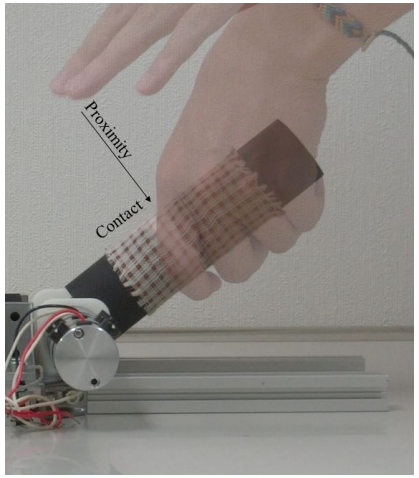
布センサの出力

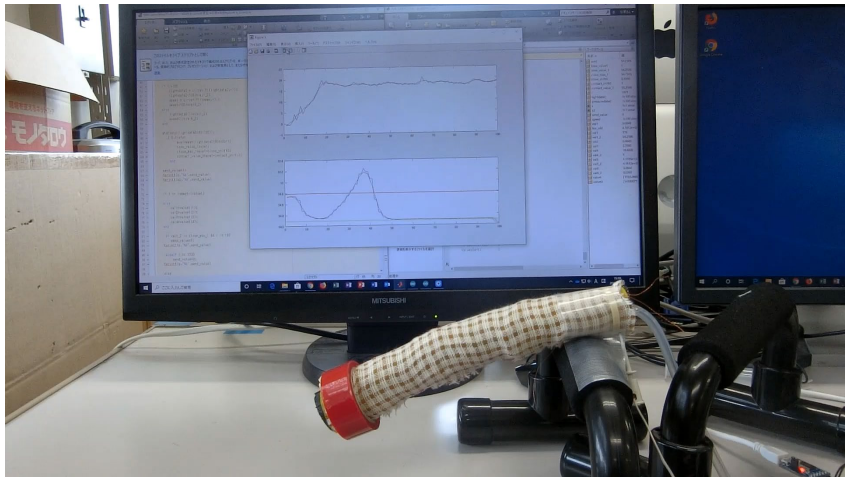


離散ウェーブレット変換の詳細係数

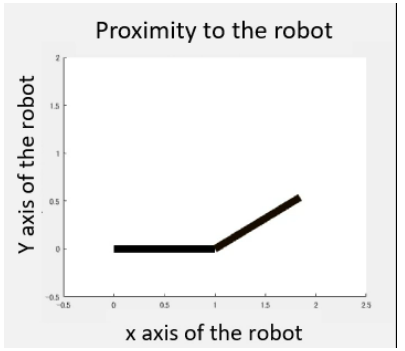
Fabric-based Proximity/Contact Sensor

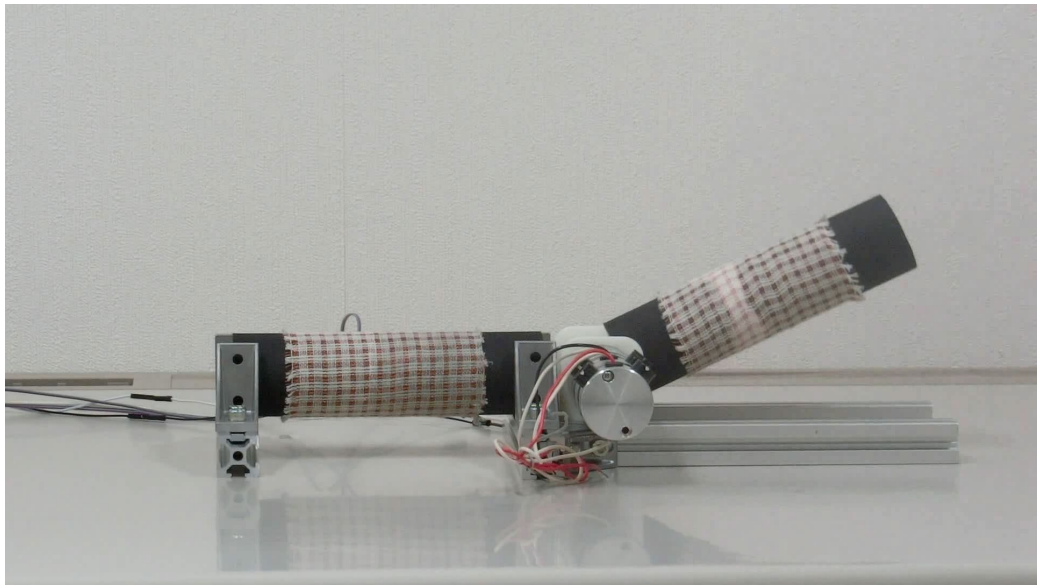
Sensor made of conductive fabric
Can detect approaching/contacting objects





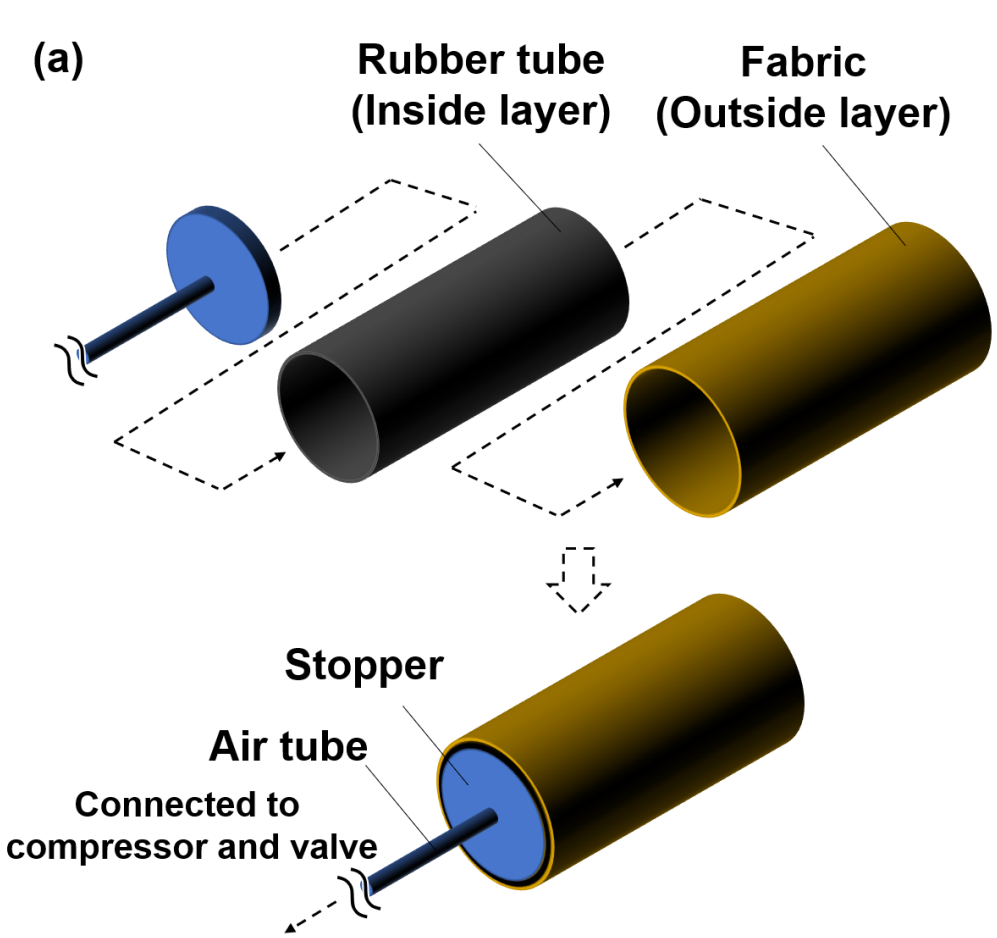
■ → ■:Proximity
■:Contact

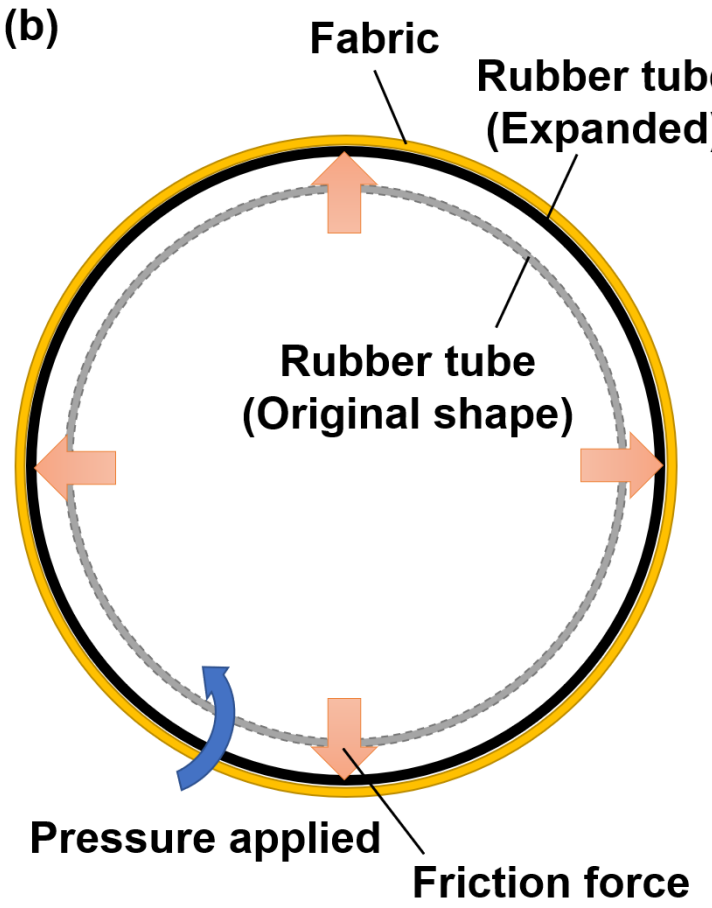




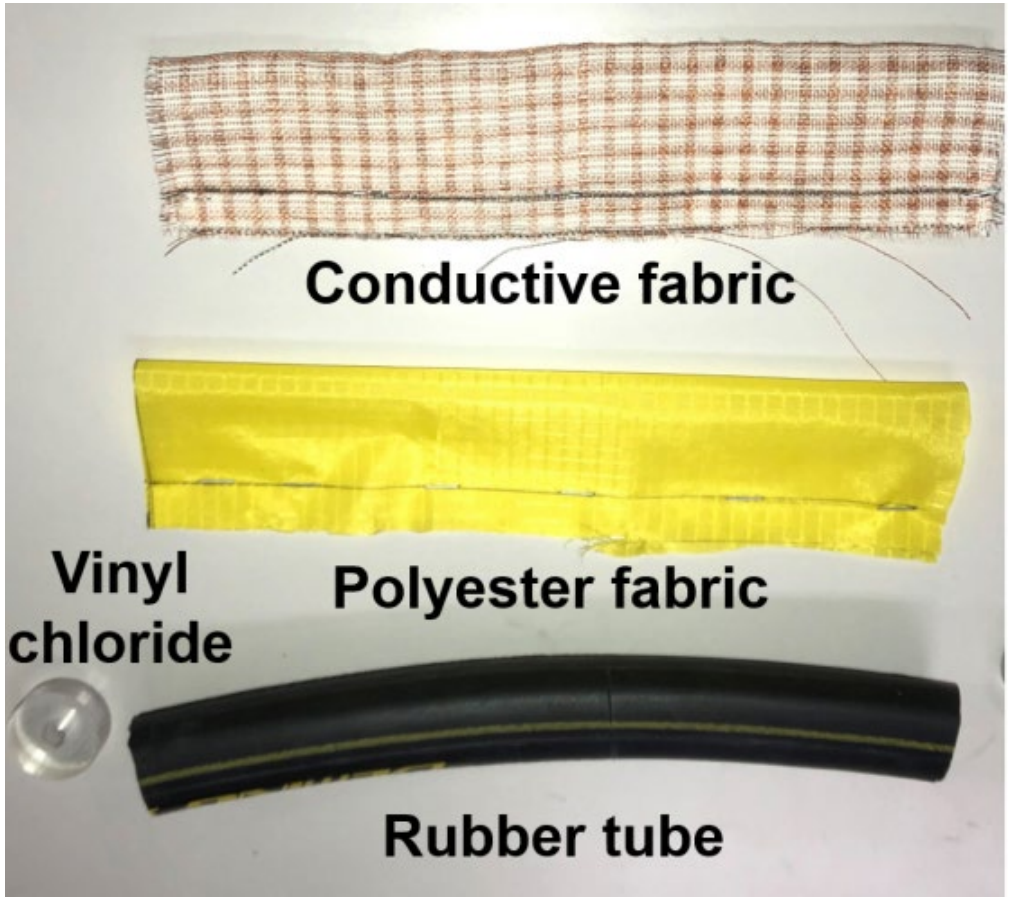
Can cover curved surfaces of rigid/soft robots
Applicable to safety sensors of robots

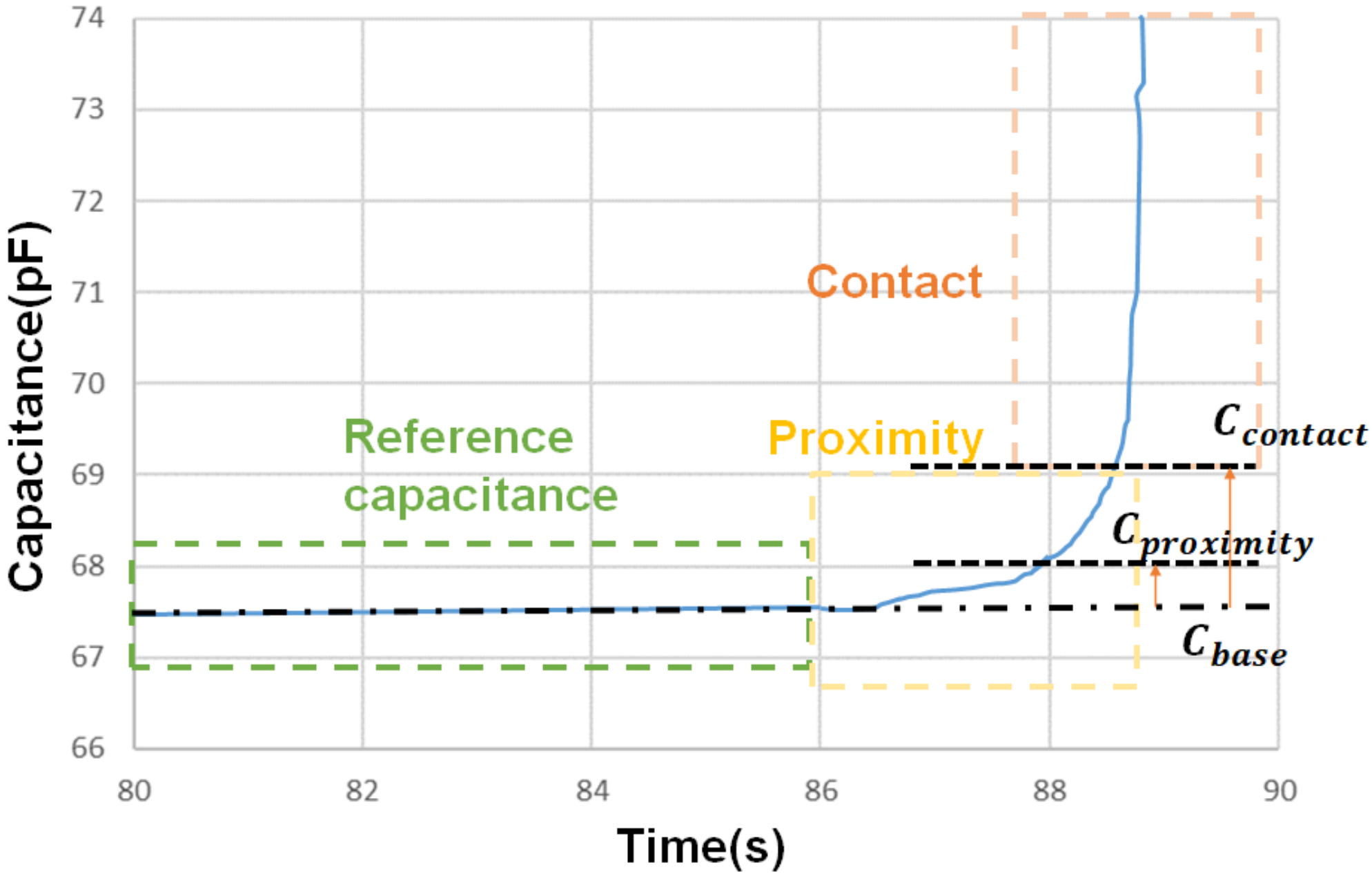
Variable Stiffness Link with Fabric Sensor



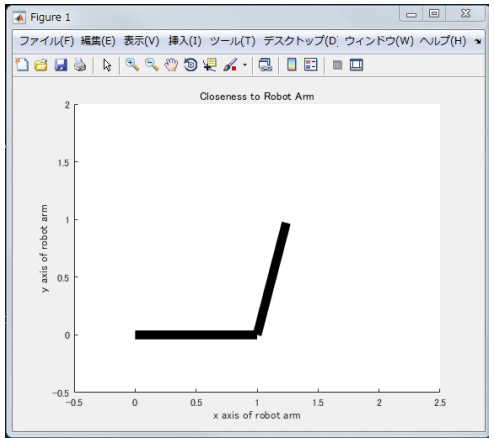


Variable Stiffness Link with Fabric Sensor



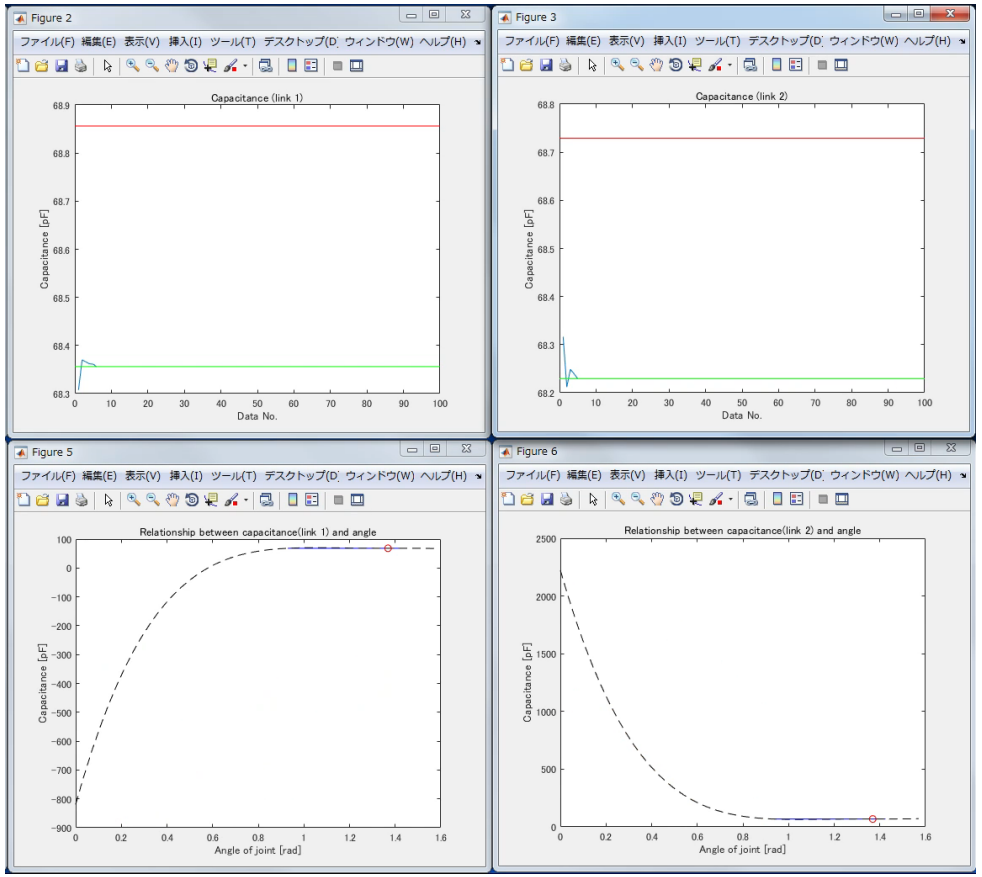

74
73
72
71
70
69
68
67
66
Capacitance(pF)
80
82
84
86
88
90
Time(s)
Contact
Proximity
Reference
capacitance
$C_{contact}$
$C_{proximity}$
C_{base}

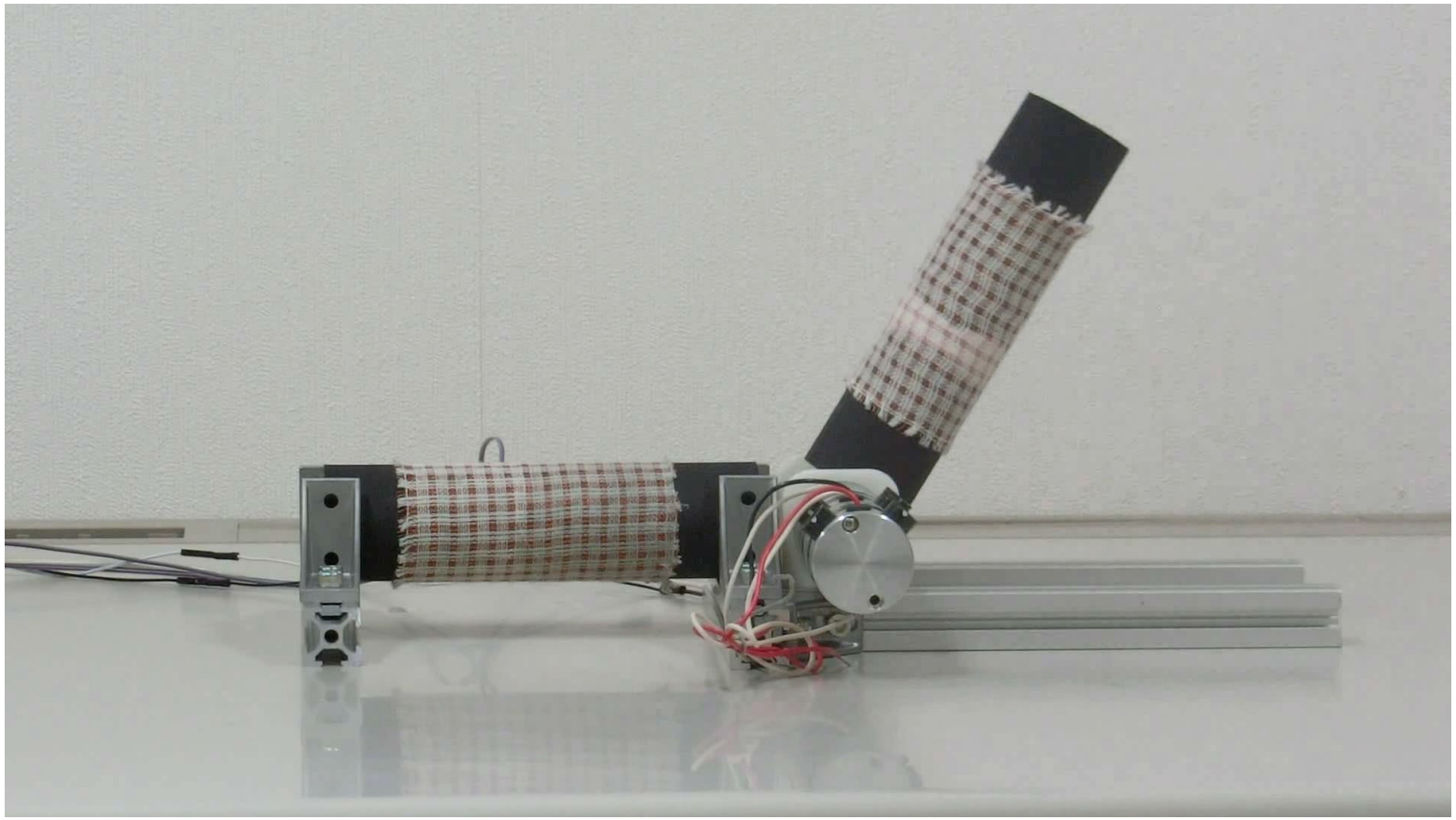
Matsuno et al., IEEE RAL, 4(2), 2212-2219, 2019



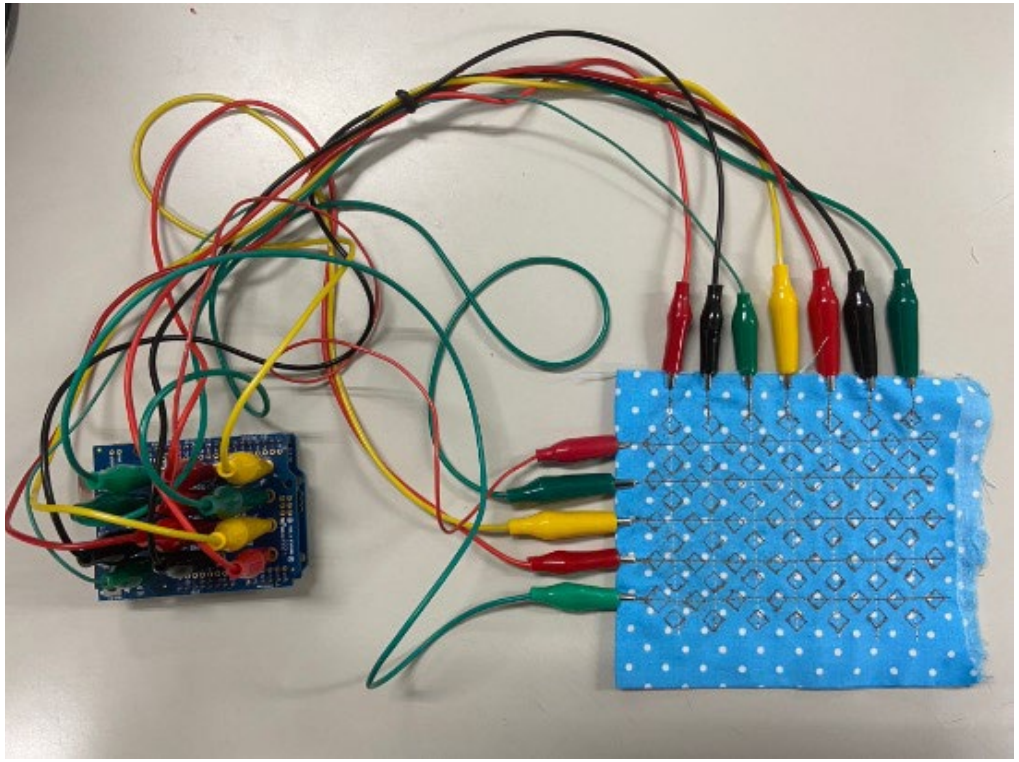
:Proximity
:Contact

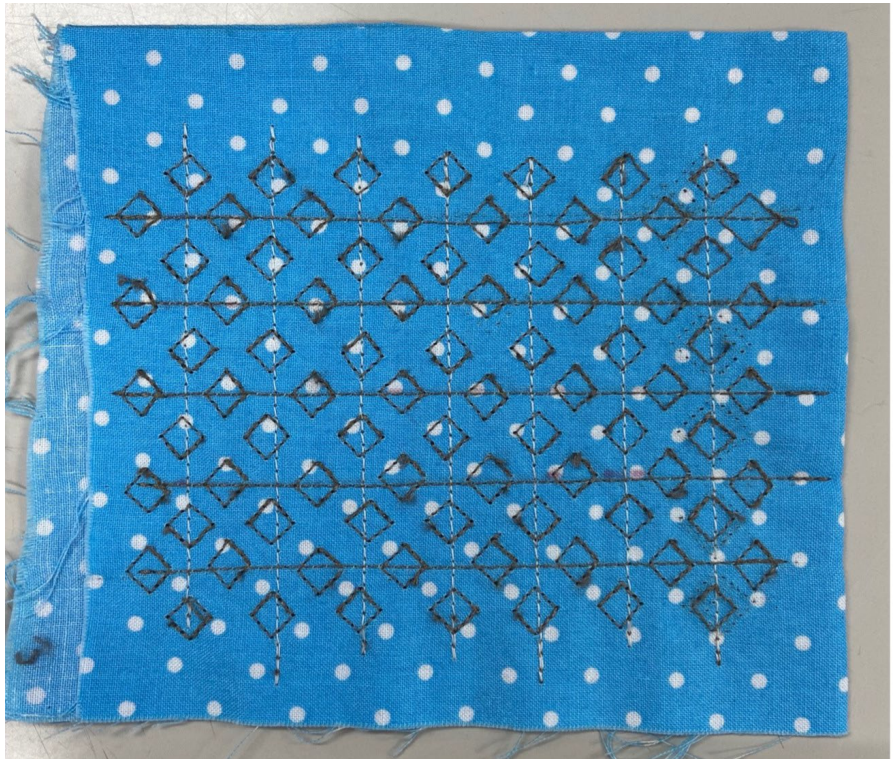
:Measured
:Reference



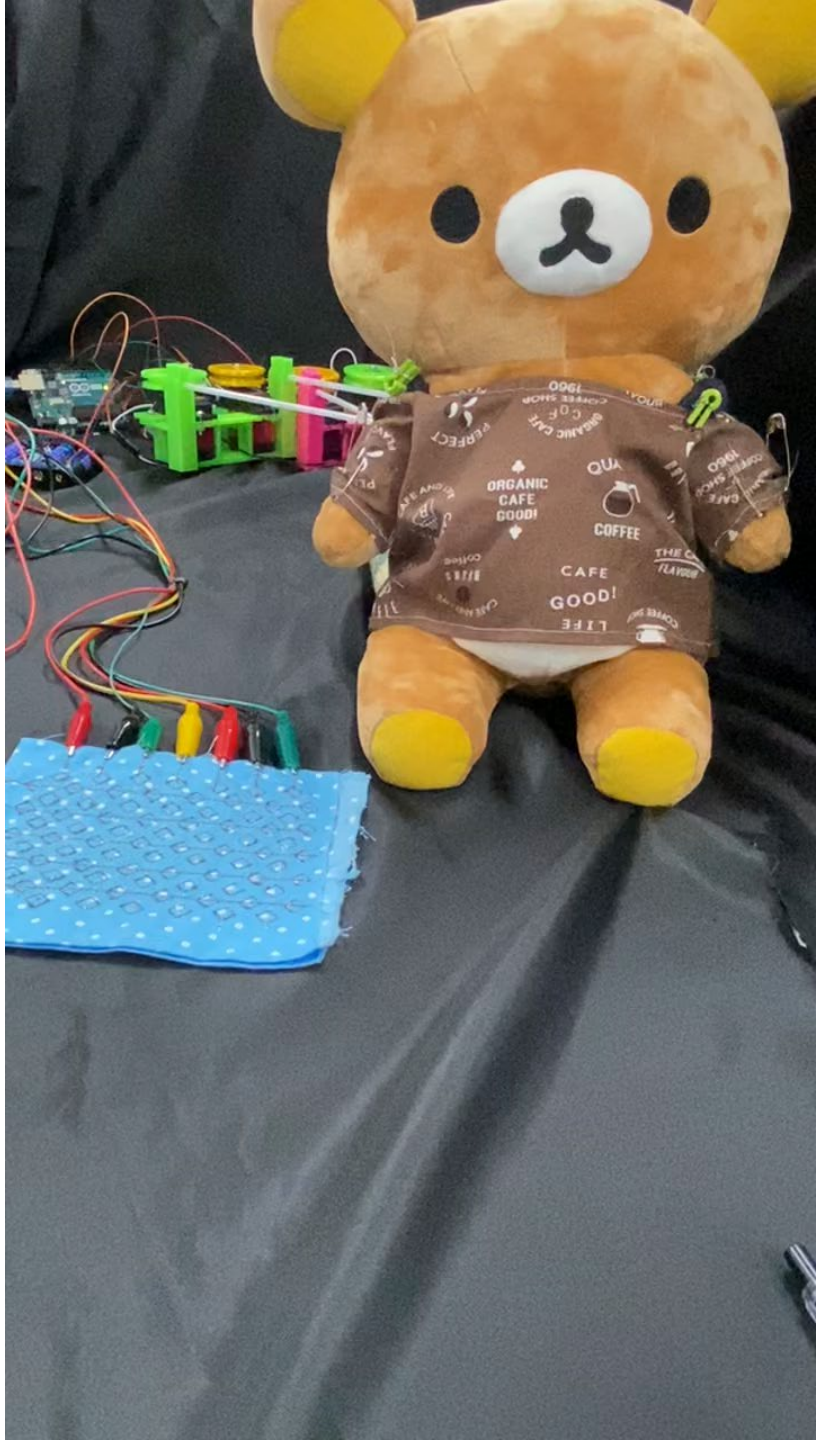
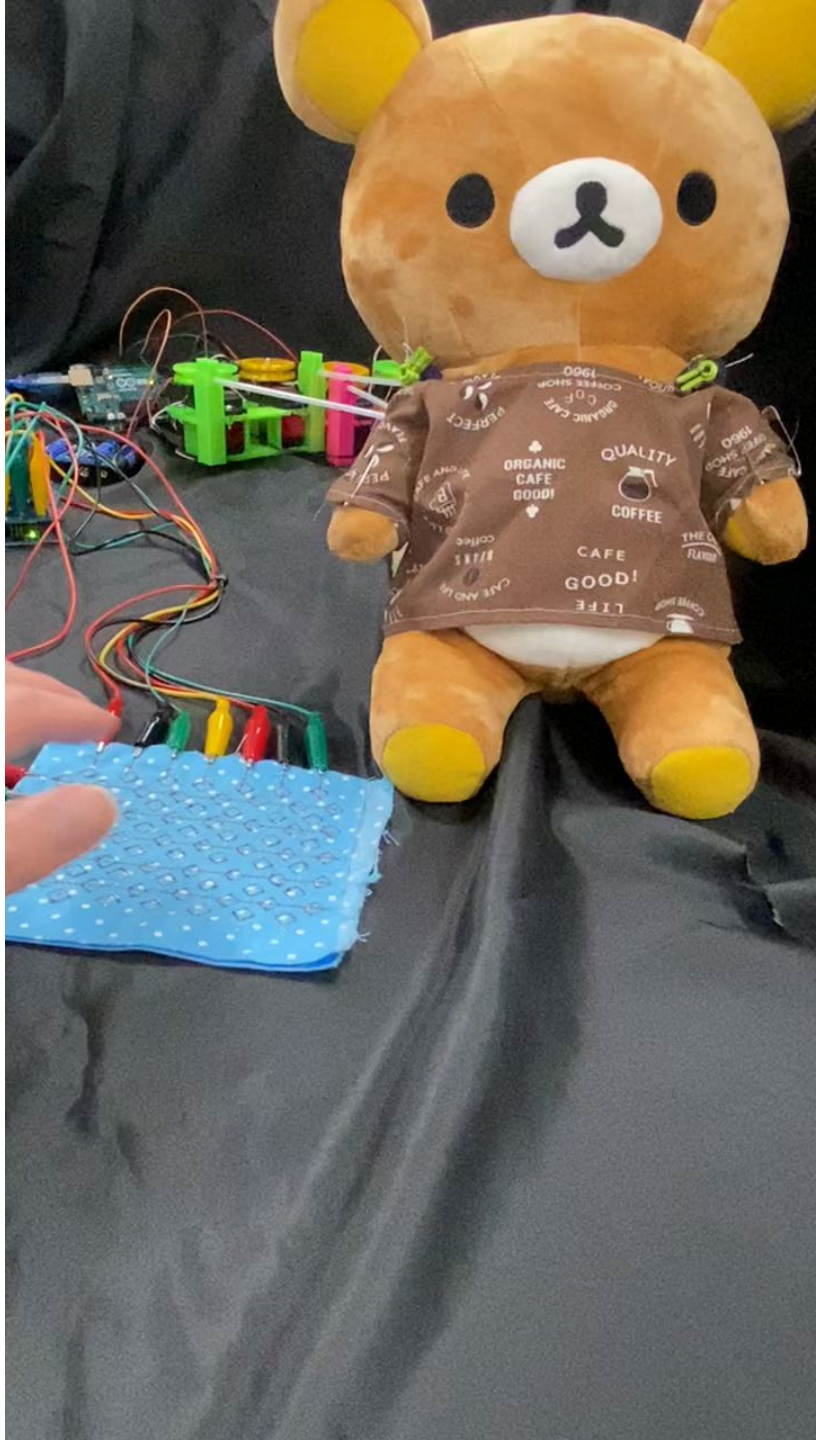


Fabric Touch Sensor





Shinichi Hirai and Takahiro Matsuno, Finger Stroke Detection by Fabric Touch Panel with its Application to Stuffed Animal Robot, SICE 2024


ORGANIC
CAFE
GOOD!
COFFEE
CAFE
GOOD!

ORGANIC
CAFE
GOOD!
COFFEE
CAFE
GOOD!

ORGANIC
CAFE
GOOD!
QUALITY
COFFEE
CAFE
GOOD!

Softness is Opportunities

More Details

http://www.ritsumei.ac.jp/~hirai/

hirai@se.ritsumei.ac.jp