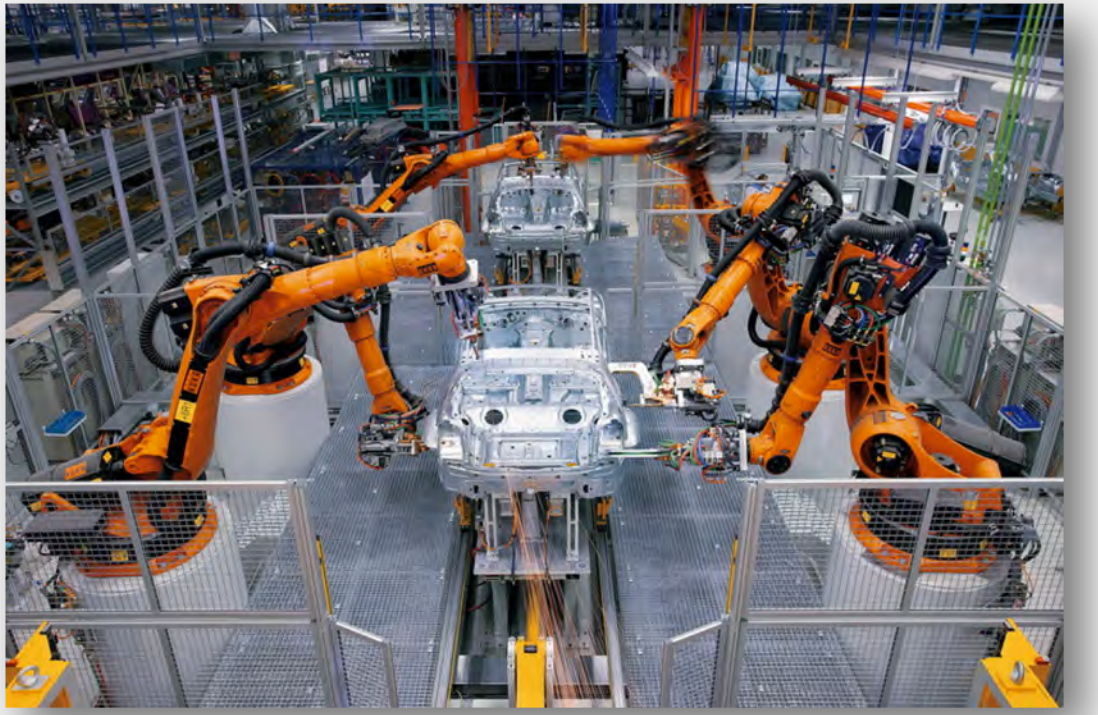
2019 Intelligent Sensing Summer School

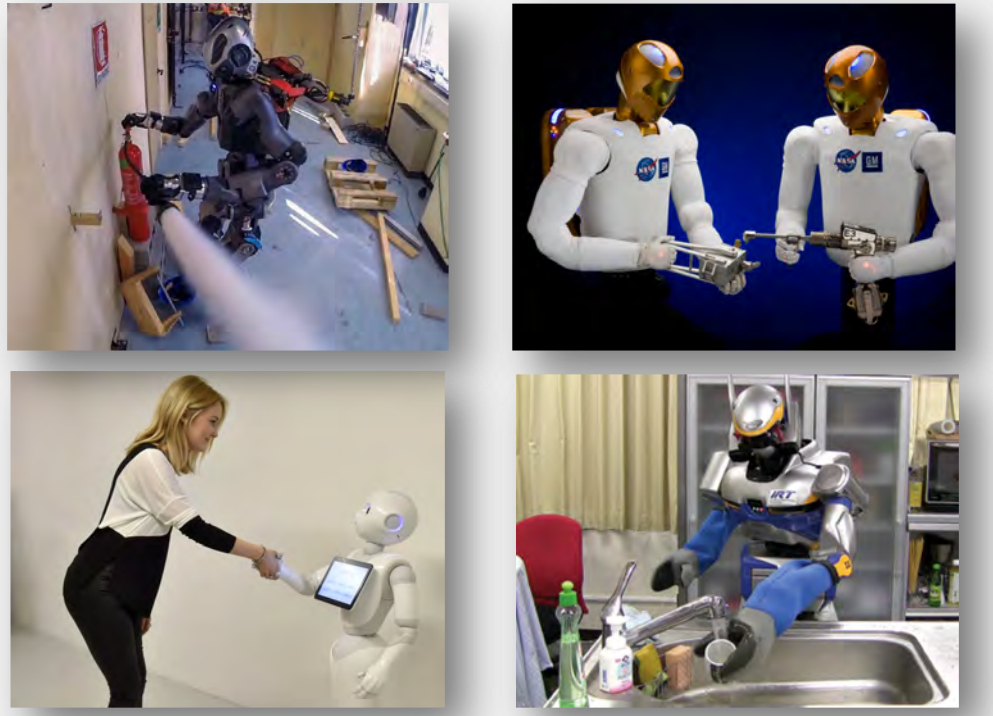
ROBOT WITH A SENSE OF TOUCH:

Dr. Perla Maiolino

TOWARD ROBOT AUTONOMY



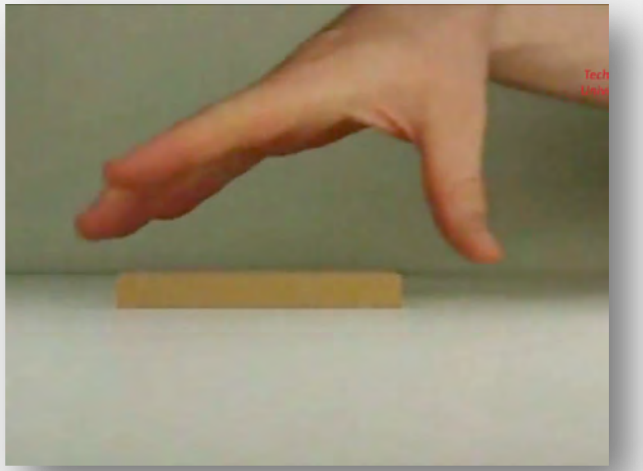
- Constrained environment
- Well-defined tasks
- Limited behavior diversity
- No interaction with humans

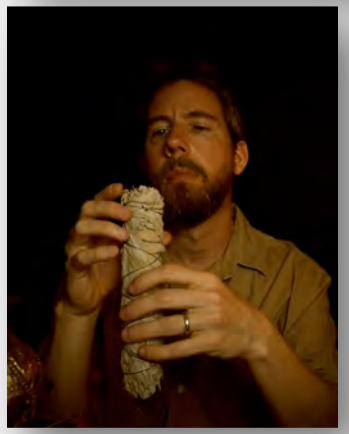


- Unpredictable environment
- Adaptable
- Flexible
- Safe Human-Robot Interaction
- High Behaviors diversity

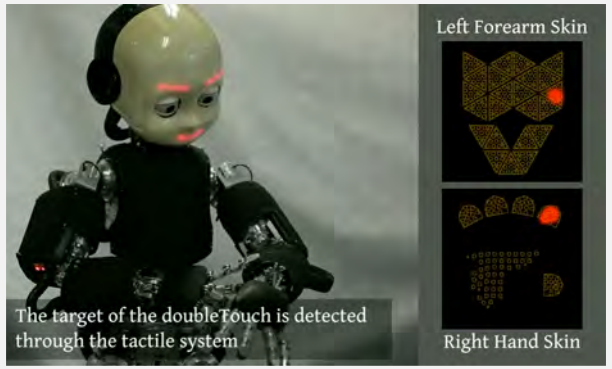
SENSE OF TOUCH

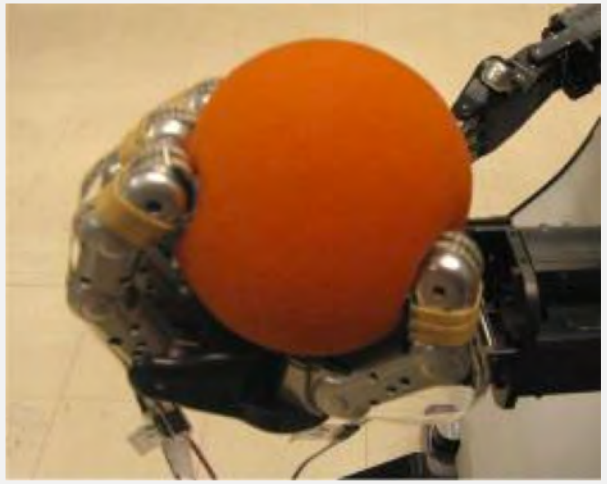
Human





Robots



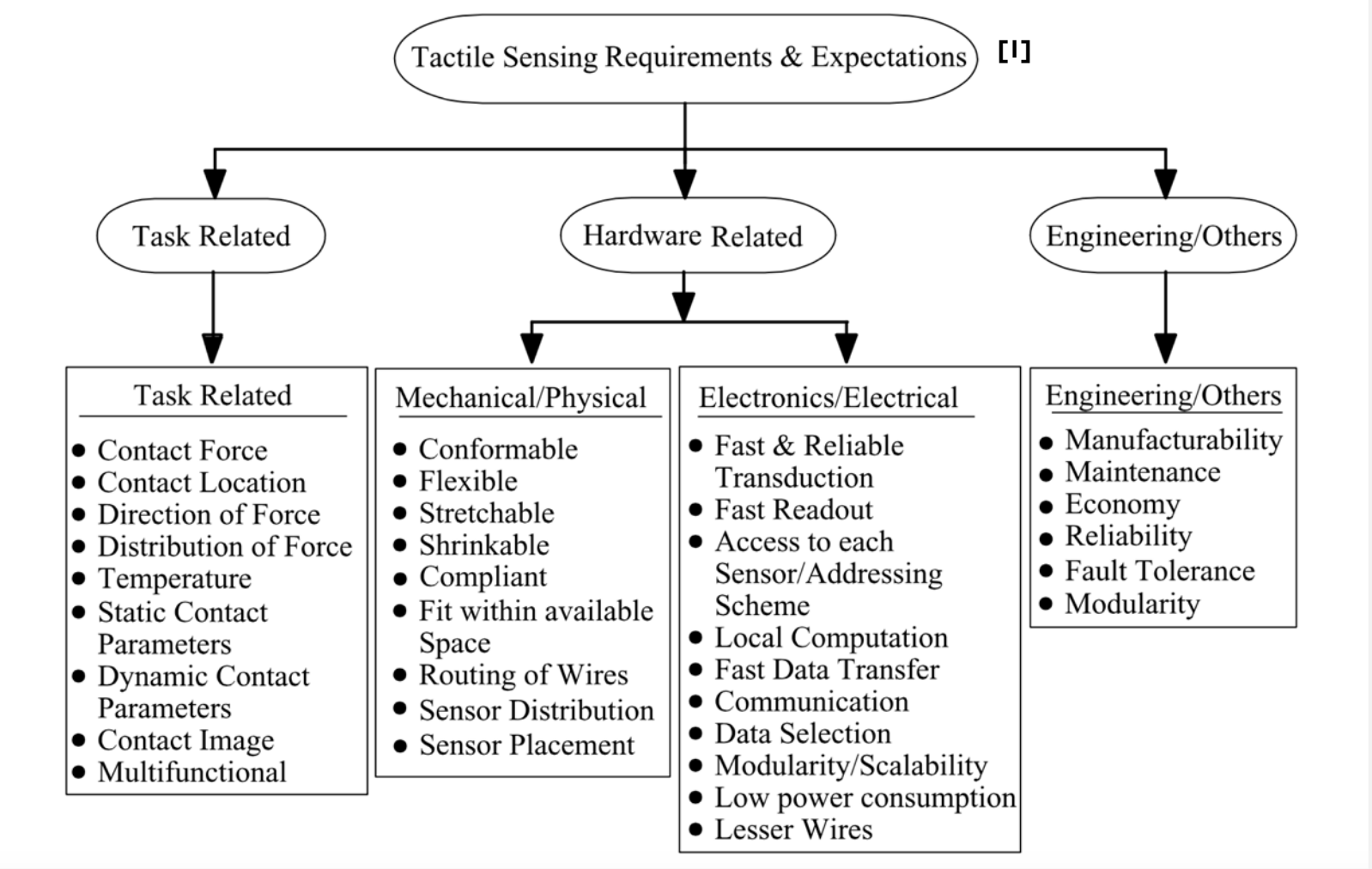


TACTILE SENSORS DESIGN

- **30+ years of research in tactile sensing**
  - *M. H. Lee and H. R. Nicholls (first survey late '80s)*
  - *R. Dahiya et Al. (2009)*

- **Mostly demonstrators (proof of concept).**
- **Few integrated solutions.**
- **Very few portable solutions.**

TACTILE SENSORS DESIGN



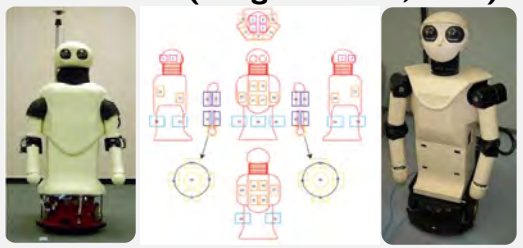
[1] *Dahiya, Ravinder S., and Maurizio Valle. Robotic tactile sensing: technologies and system. Springer Science & Business Media, 2012.*

LARGE SCALE TACTILE SENSOR DESIGN - EVOLUTION

Lumelsky '90s

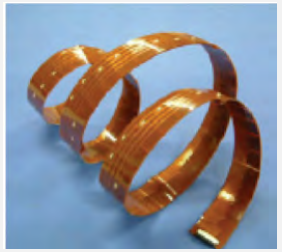
Whole body system – optical sensors

Robovie-IIS (Ishiguro et al., 2006)



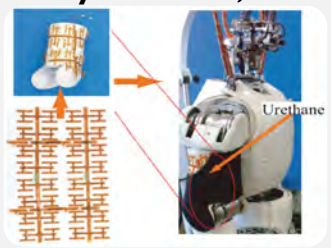
v.1 – 48 PVDF taxels
v.2 – 284 PVDF taxels

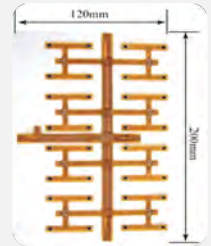
Kotaro (Mizuuchi et al., 2006)



Pressure Conductive Rubber 64 bandages

Kuniyoshi et al., 2007





1864 optical tactile sensors
Embedded networking support

Tomo et al, 2017

Modular and 6-axis force

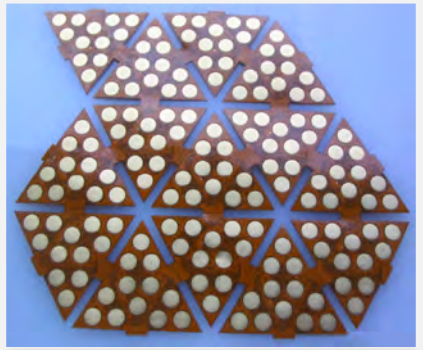
Cheng and Mittendorfer, 2011

Modular and Scalable Multimodal

M. Fritsche et al, 2010

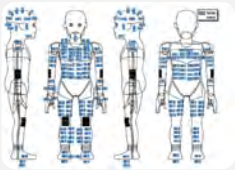
Contact and collision detection

Cannata et al, 2008



Modular and Scalable

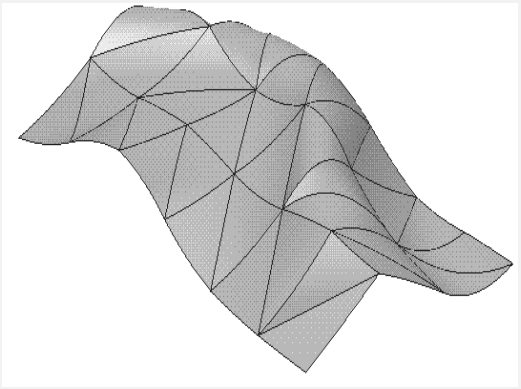
CB^2 (Minato et al., 2007)



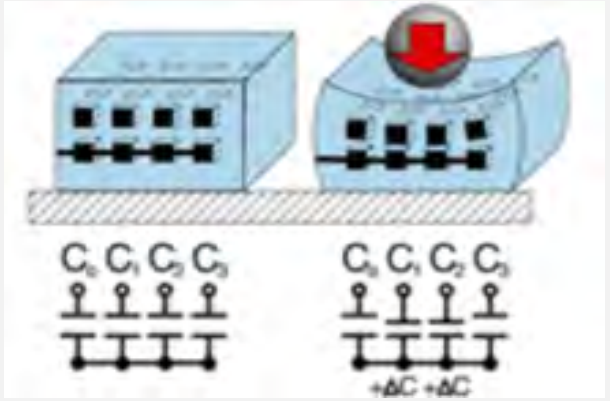
PVDF patches

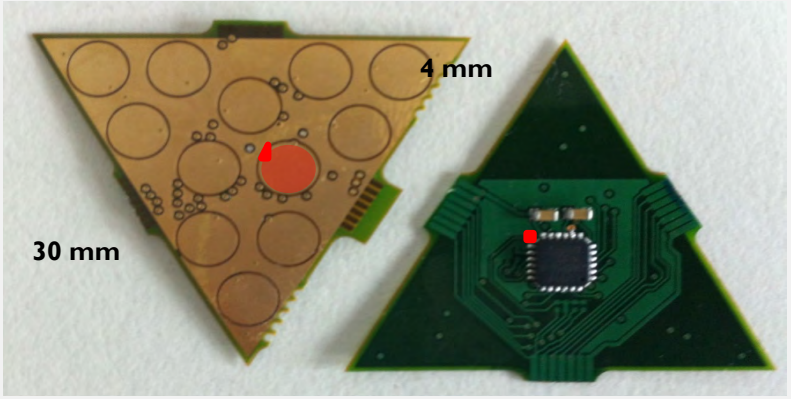
ROBOSKIN TECHNOLOGY

Concept: Polygonal Modeling



Capacitive Transduction

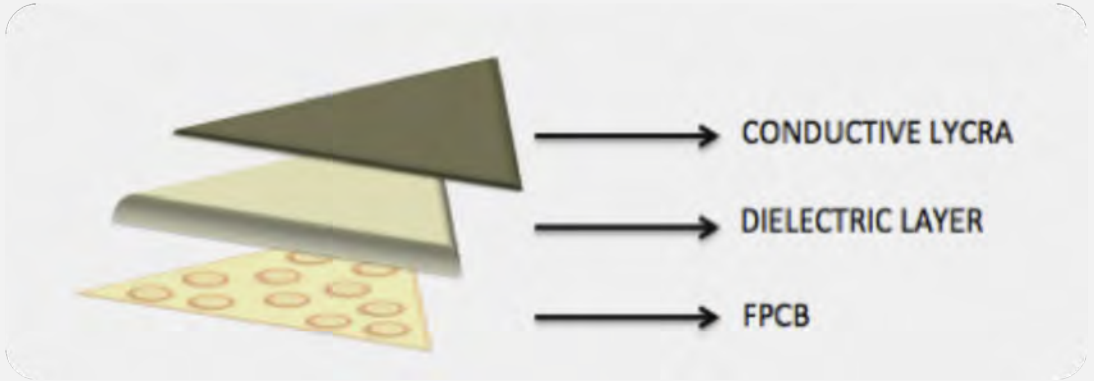




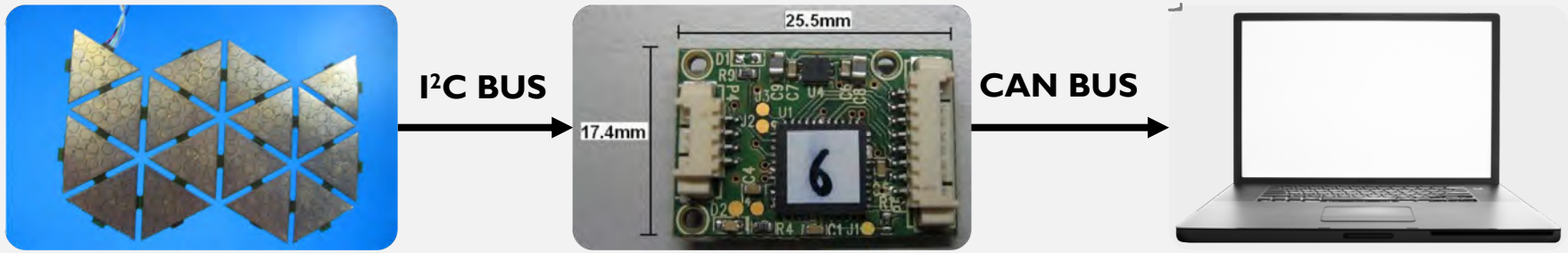
- CDC from Analog Device AD7147
- 12 capacitance measurements (TAXELS)
- 8 bits of pressure resolution

ROBOSKIN TECHNOLOGY

Layered Structure

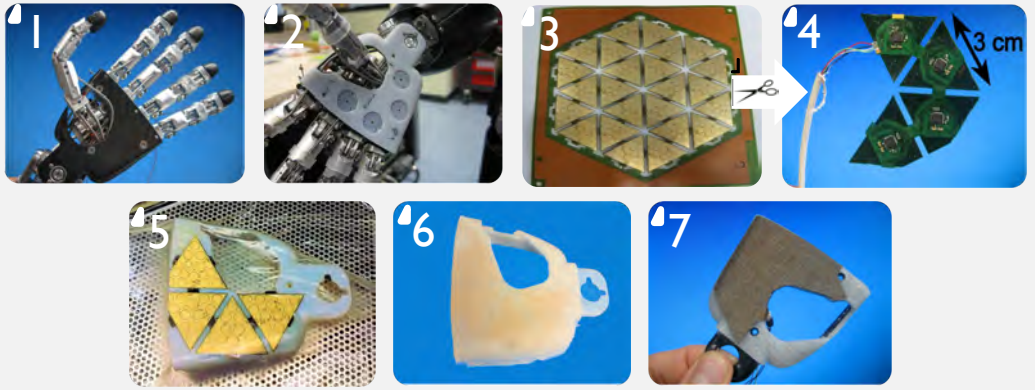


Embedded Network Infrastructure



ROBOSKIN TECHNOLOGY

Conformability to 3D Shapes and Easy Integration Process

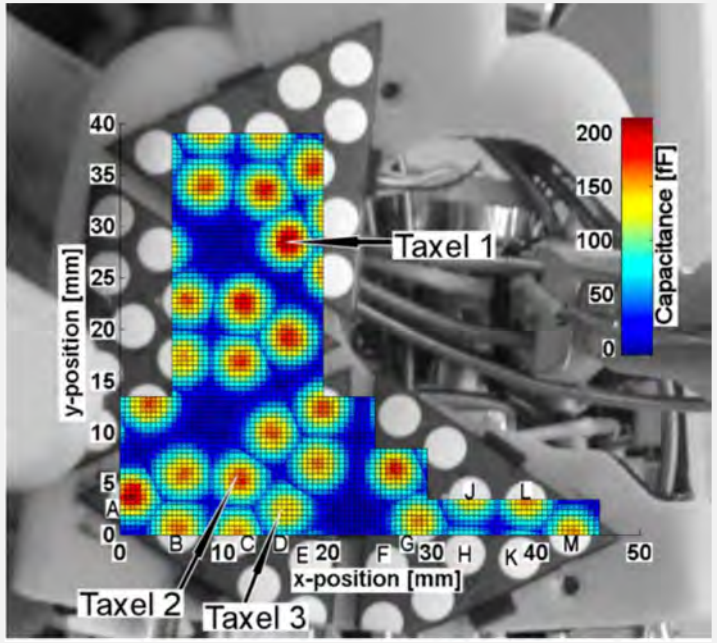


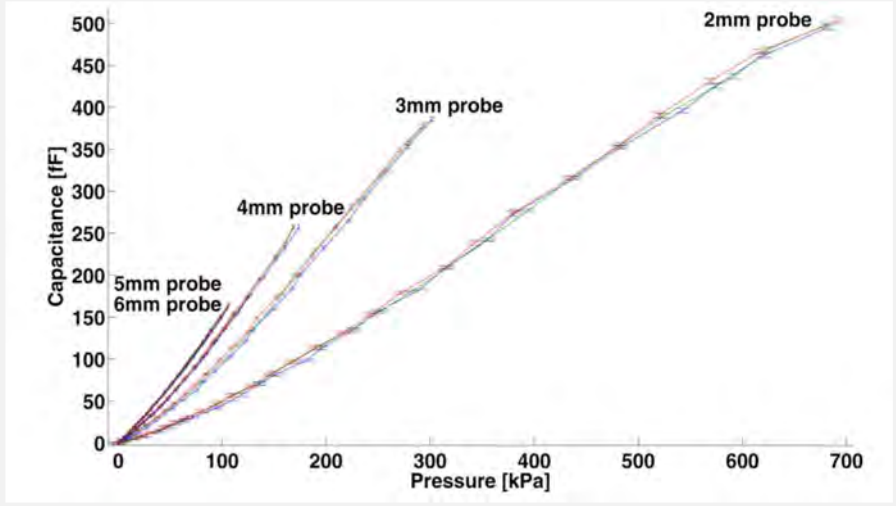
1272 taxels

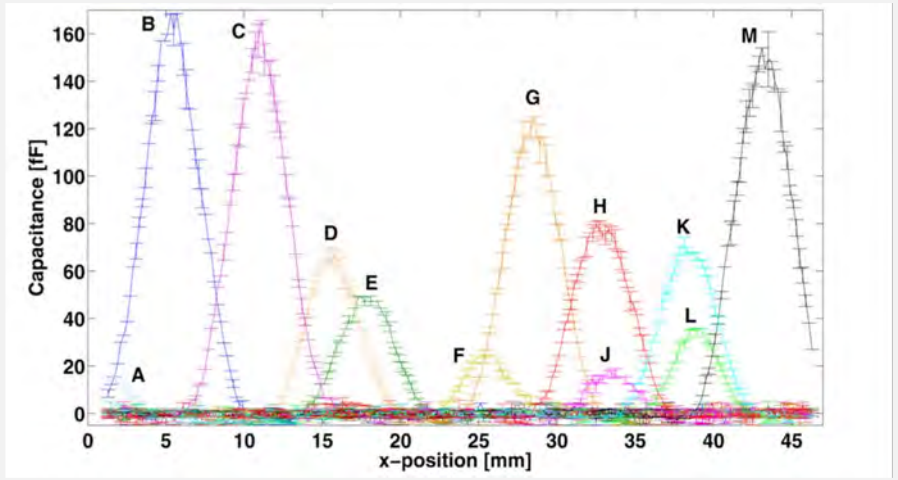
1104 taxels

648 taxels

ROBOSKIN TECHNOLOGY

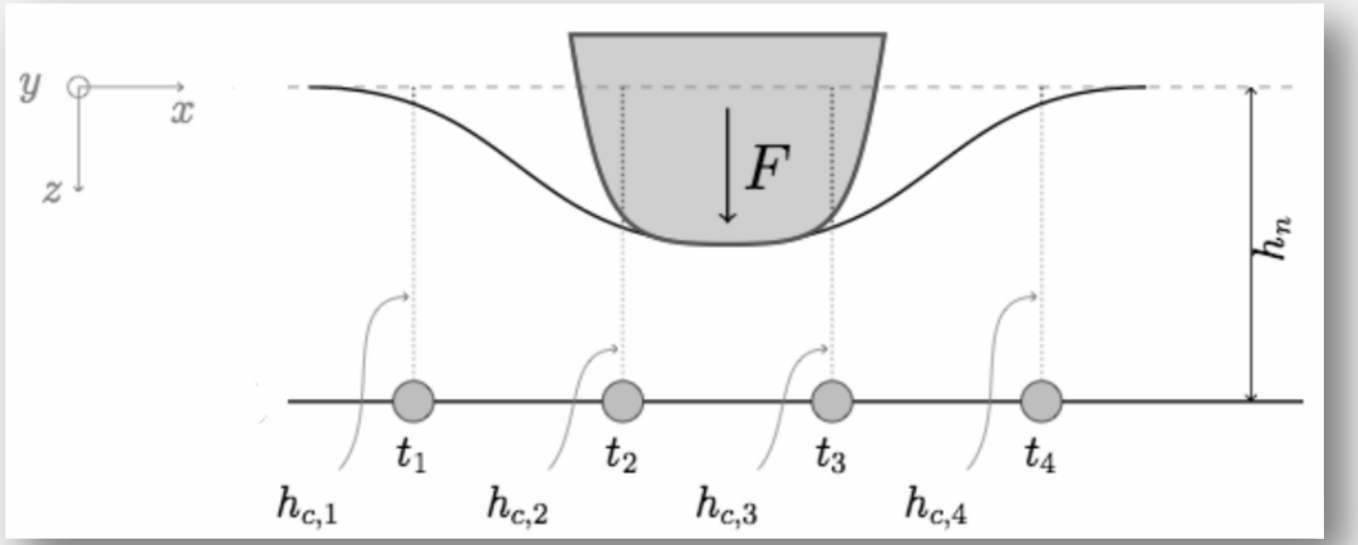






[2] *Schmitz, A., Maiolino, P., Maggiali, M., Natale, L., Cannata, G., & Metta, G. (2011). Methods and technologies for the implementation of large-scale robot tactile sensors. IEEE T-RO, 27(3), 389-400.*

ROBOSKIN TECHNOLOGY



Taxel Response

$$t_i = \Delta C_i = C_{c,i} - C_{n,i} = \varepsilon_0 \varepsilon_r A \frac{h_n - h_{c,i}}{h_n h_{c,i}}$$

$$i = 1, \ldots N$$

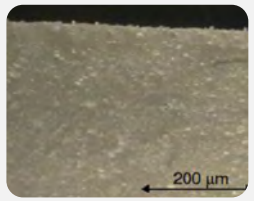
Dielectric Layer affects:

- Sensor Sensitivity
- Spatial Resolution
- Ageing
- Sensor Weight

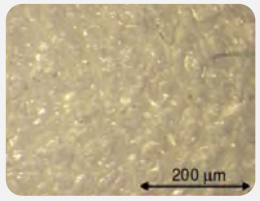
ROBOSKIN TECHNOLOGY

Investigated Solutions For The Dielectric Layer

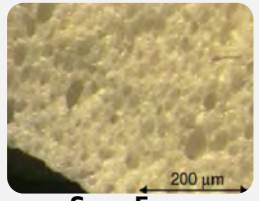
Elastomers and High Dielectric Composites [3]



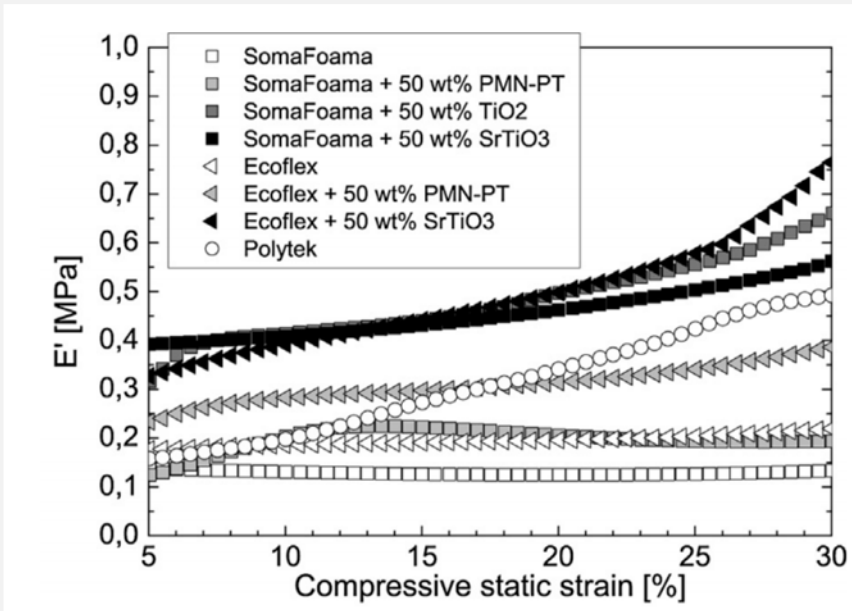
Ecoflex + 50% PMN-PT



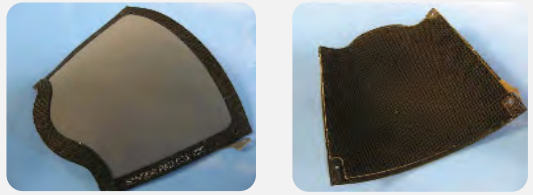
SomaFoama + 50% PMN-PT

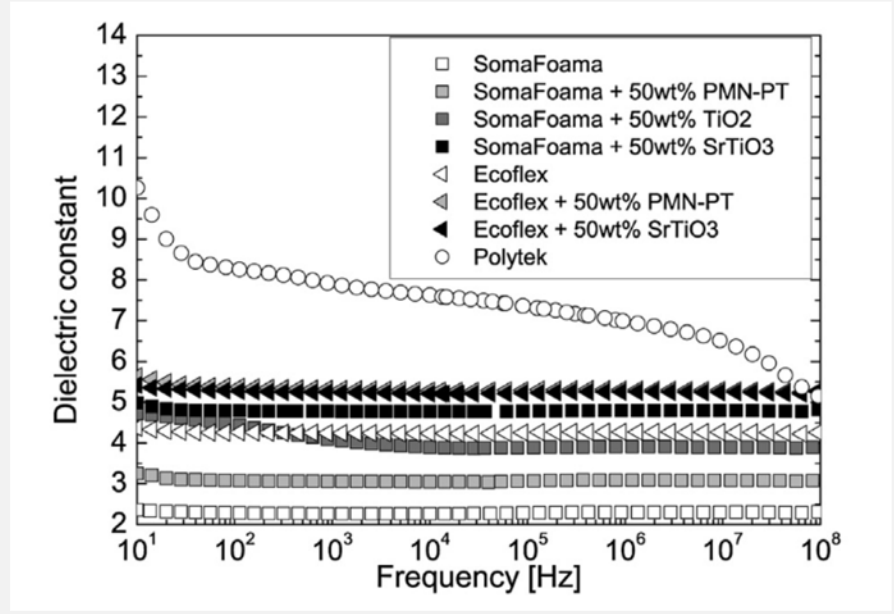


SomaFoama



3D fabric made with Industrial Clothing Techniques[4]

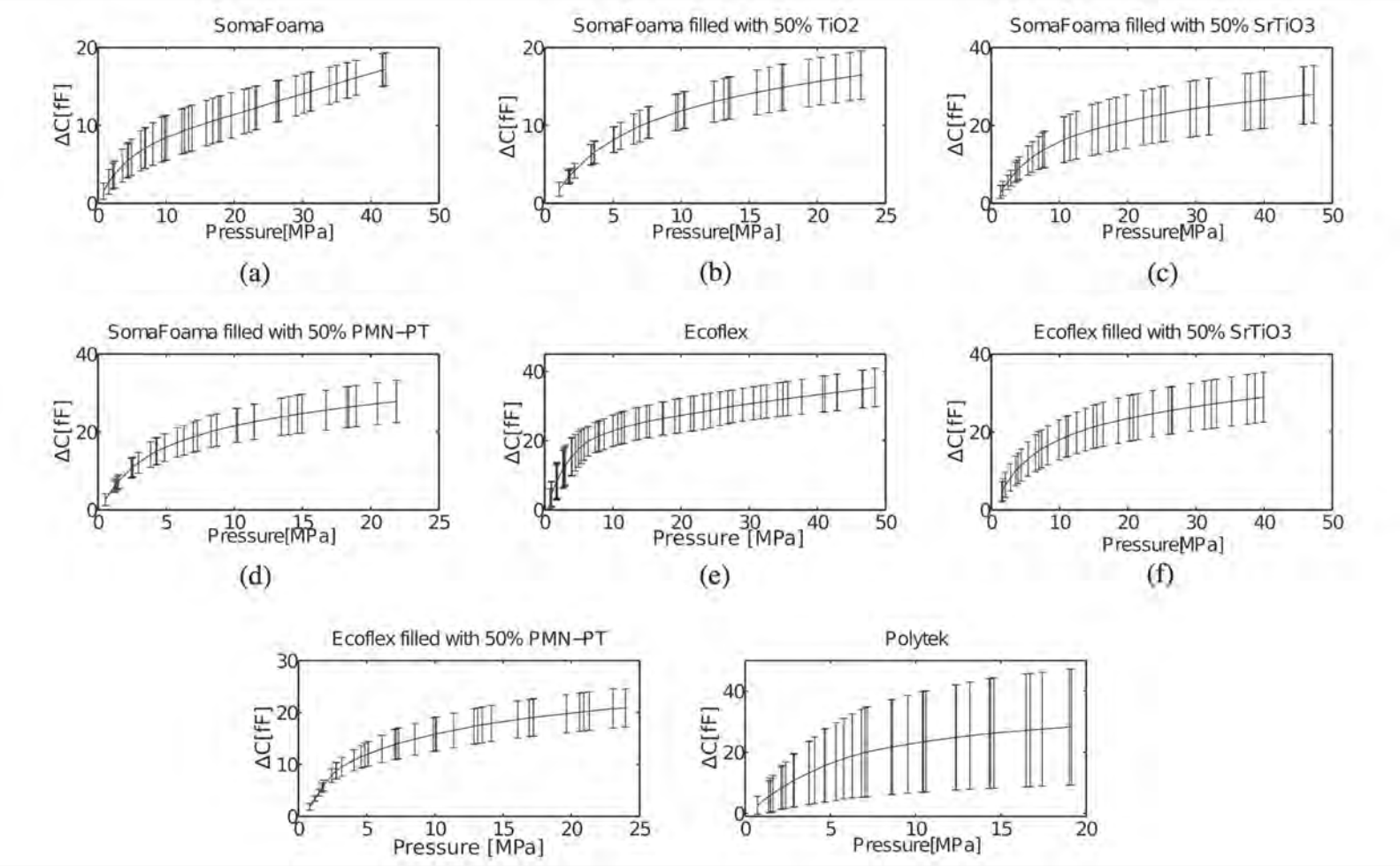




[3] *Maiolino, P., et al. "Soft dielectrics for capacitive sensing in robot skins: Performance of different elastomer types." Sensors and Actuators A: Physical 226 (2015): 37-47.*
[4] *Maiolino, Perla, et al. "A Flexible and Robust Large Scale Capacitive Tactile System for Robots." IEEE Sensors Journal 13.10 (2013): 3910-3917.*

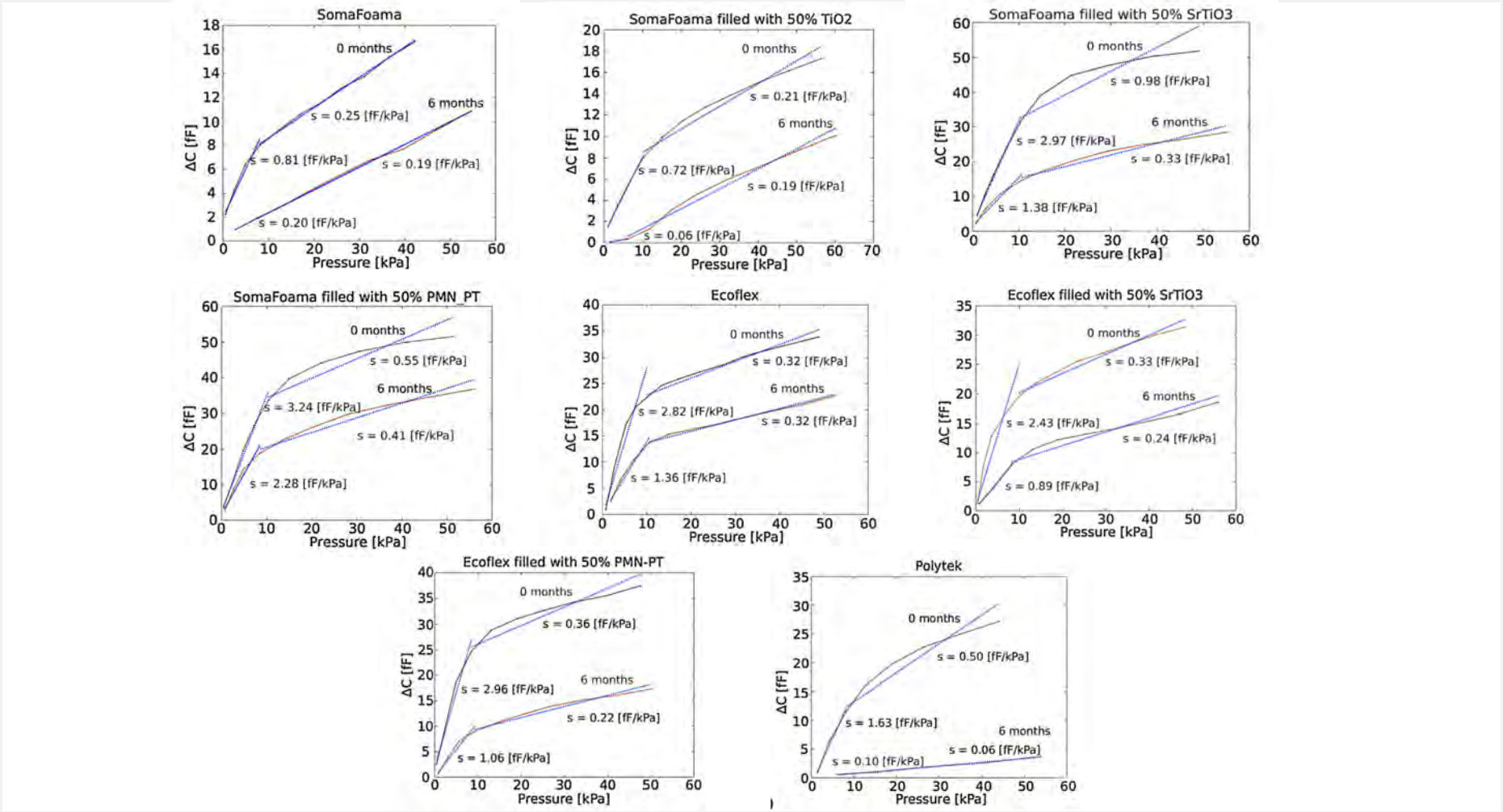
ROBOSKIN TECHNOLOGY

Average and standard deviation of sensor response for the different sample of each material



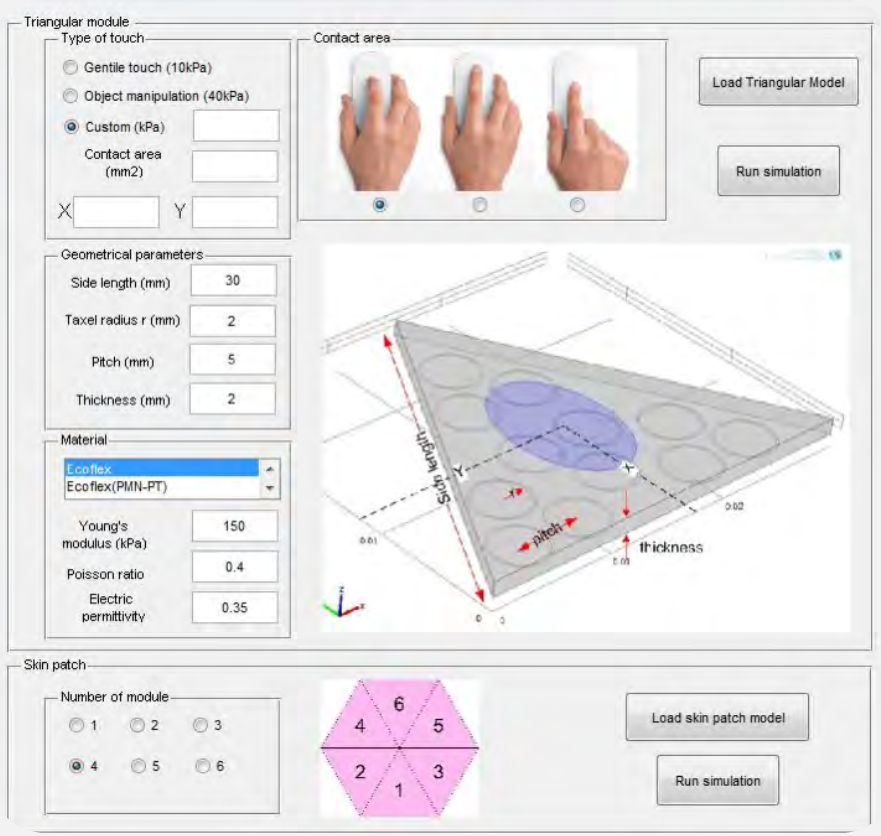
ROBOSKIN TECHNOLOGY

Sensor response for the different elastomers as newly made sample (0-months) and after ageing (6-months)

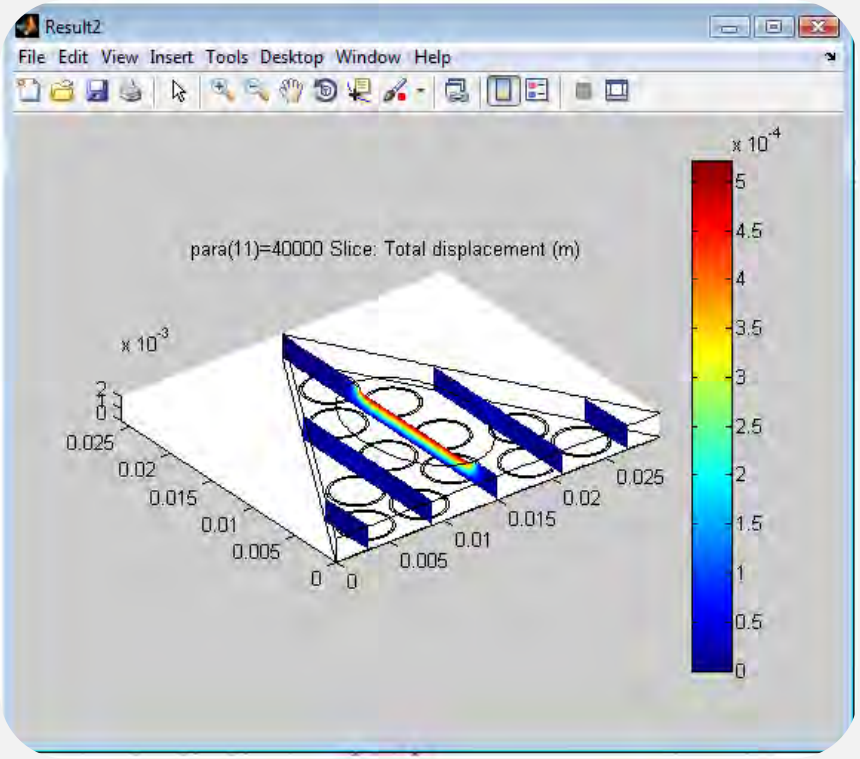


ROBOSKIN TECHNOLOGY

Toolbox for tactile sensor FEM and simulation [5]



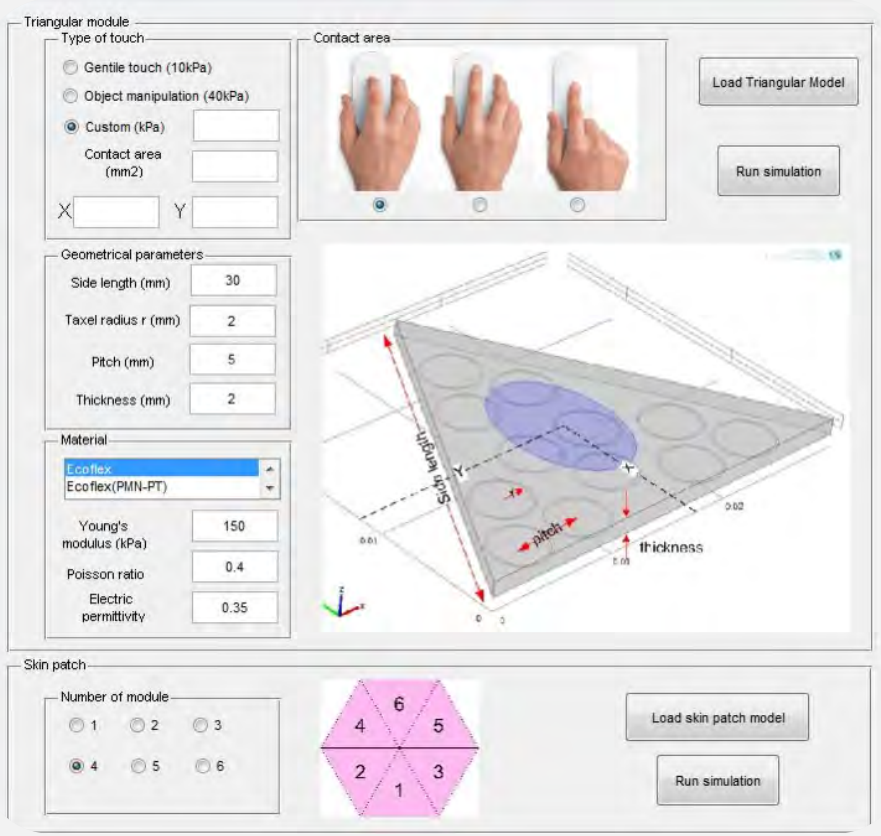
Sensor Parameterization and Simulation



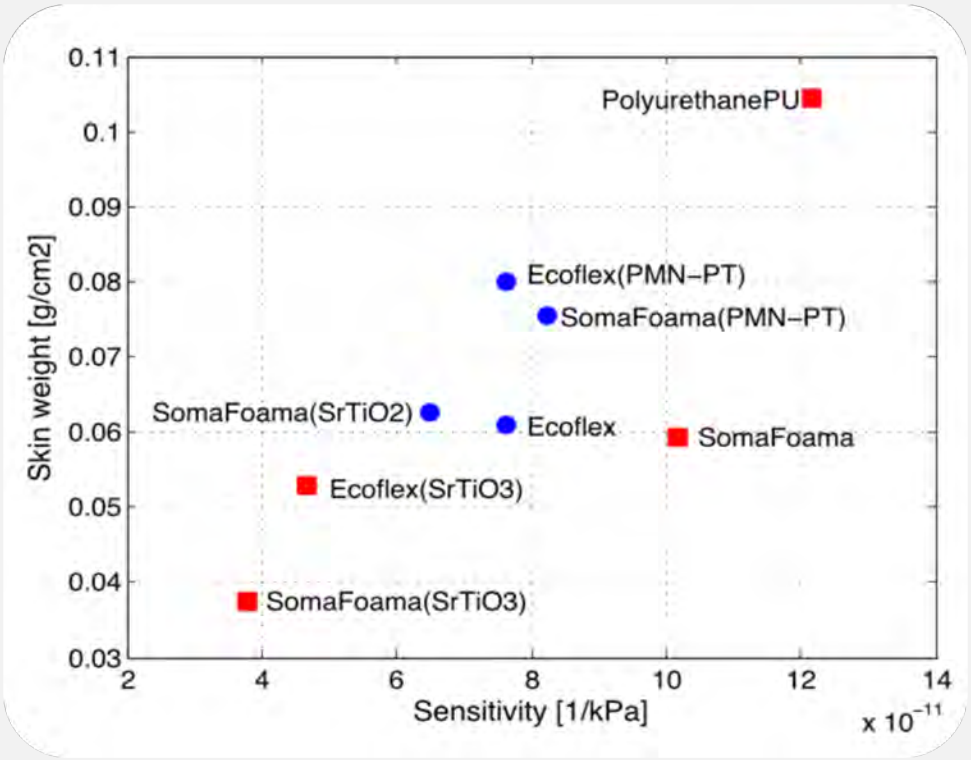
[5] *Maiolino, P., Mastrogiovanni, F., & Cannata, G. (2016). Skinning a Robot: Design Methodologies for Large-Scale Robot Skin. IEEE Robotics & Automation Magazine, 23(4), 150-159.*

ROBOSKIN TECHNOLOGY

Toolbox for tactile sensor FEM and simulation [5]



Single and Multi objective optimization



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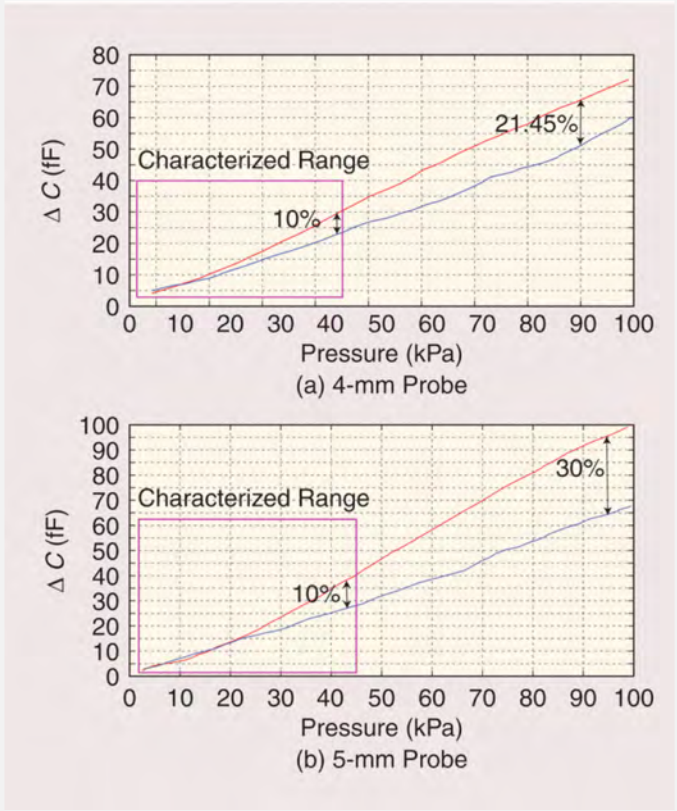
ROBOSKIN TECHNOLOGY

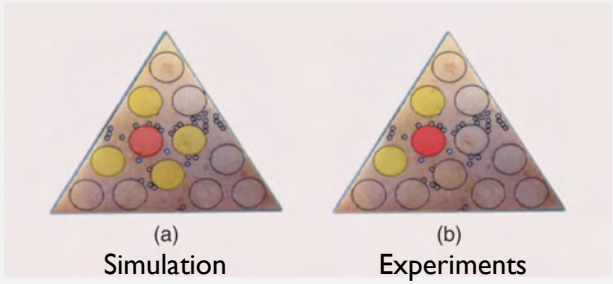
Toolbox for tactile sensor FEM and simulation [5]

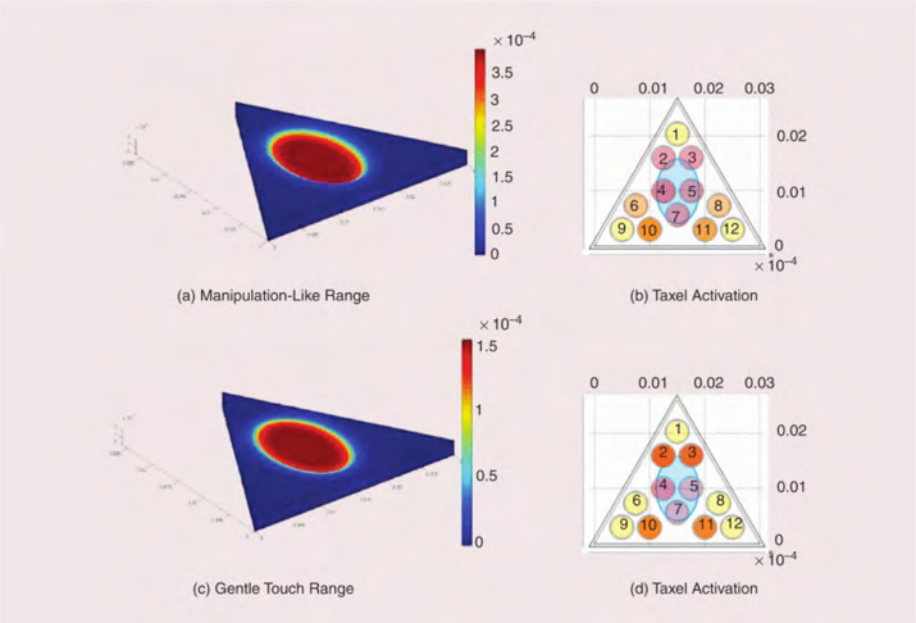
SENSOR RESPONSE



- EXPERIMENTAL
- RESULTS

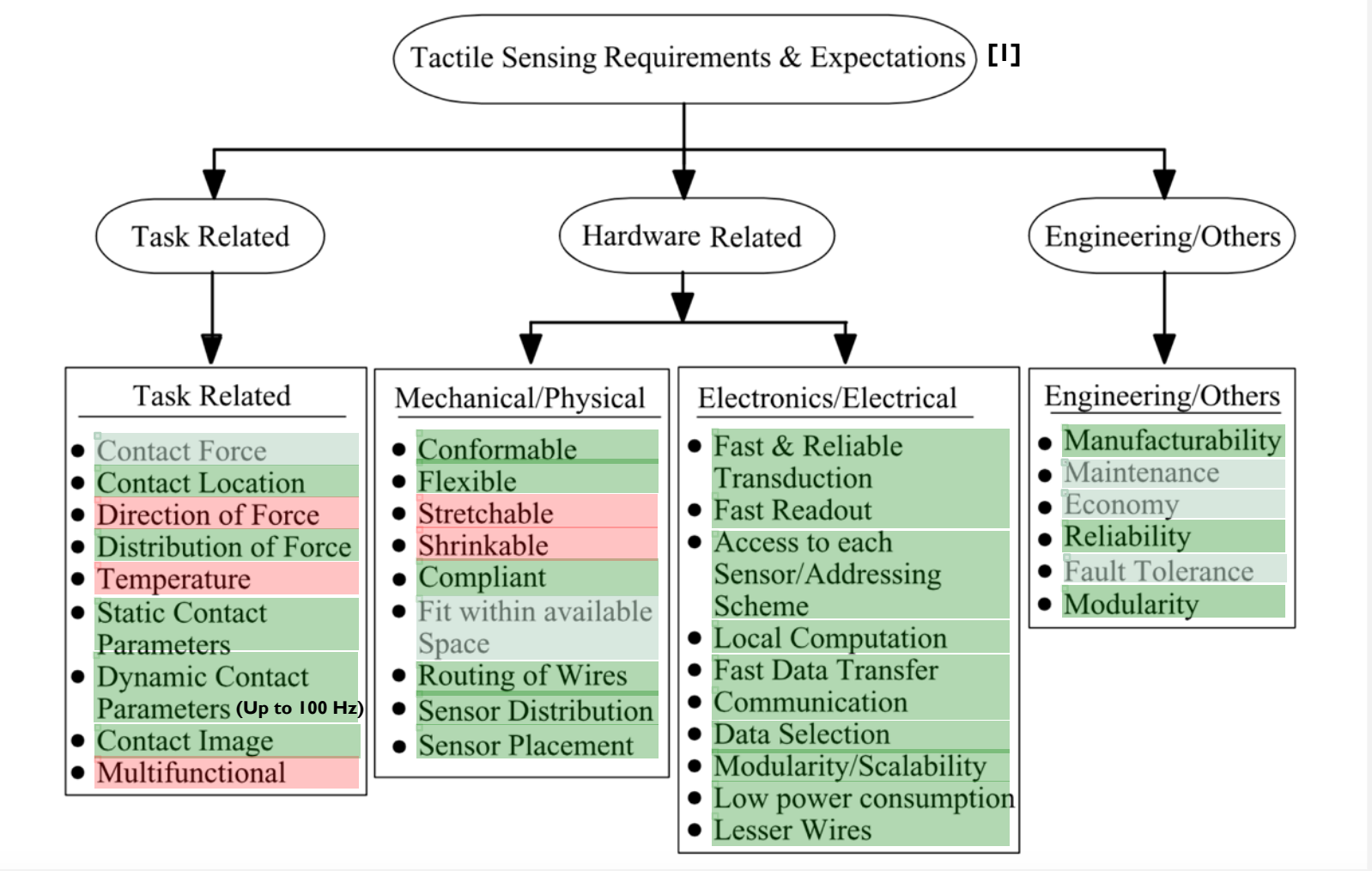
SPATIAL FILTERING 6 mm INDENTER





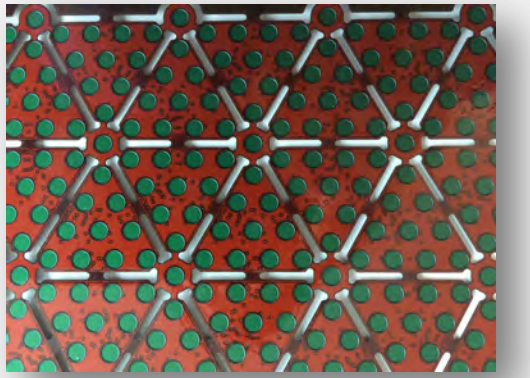
[5] *Maiolino, P., Mastrogiovanni, F., & Cannata, G. (2016). Skinning a Robot: Design Methodologies for Large-Scale Robot Skin. IEEE Robotics & Automation Magazine, 23(4), 150-159.*

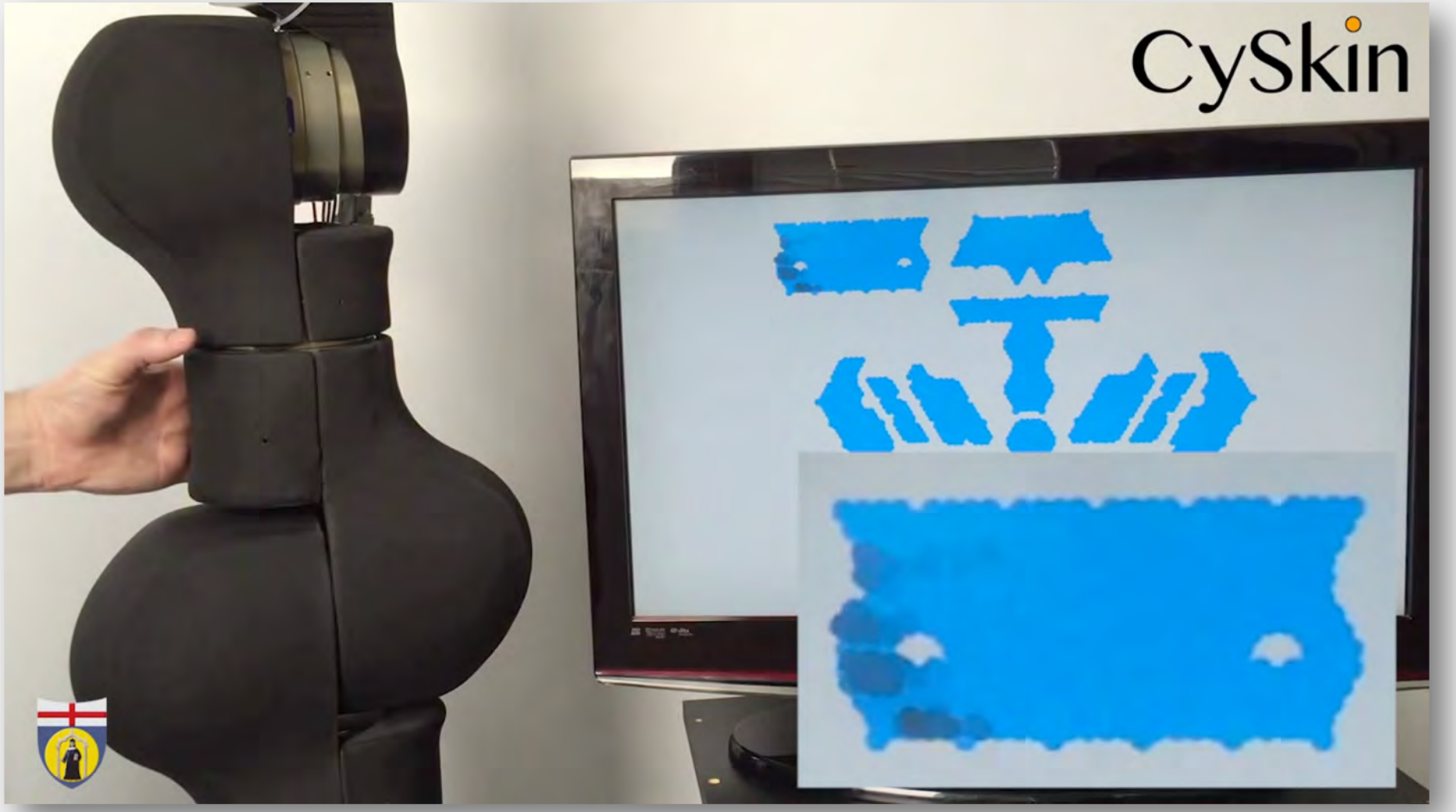
TACTILE SENSORS DESIGN



[1] *Dahiya, Ravinder S., and Maurizio Valle. Robotic tactile sensing: technologies and system. Springer Science & Business Media, 2012.*

CYSKIN TECHNOLOGY





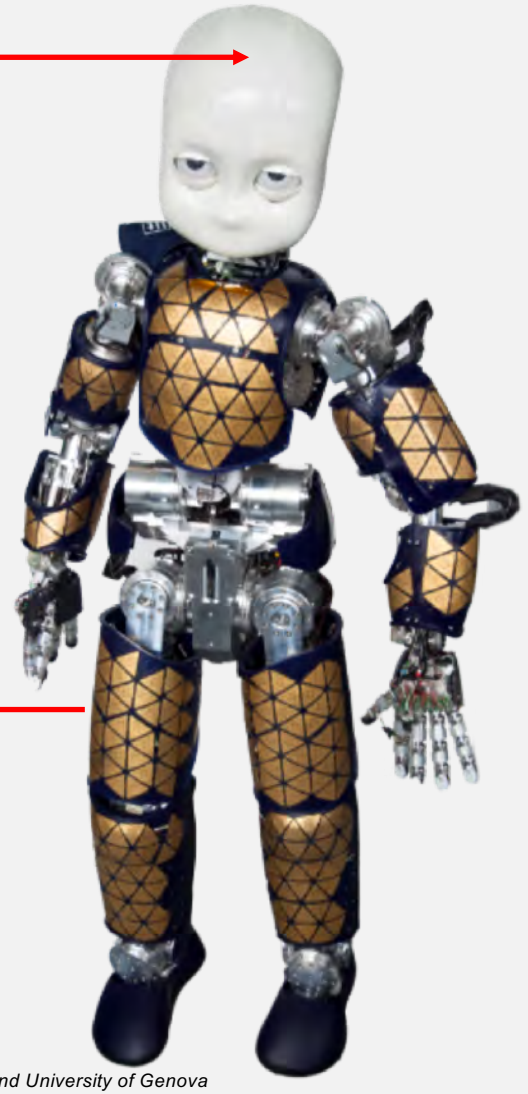
FROM SENSING TO PERCEPTION

[46185,10341,9964,10064,9572,10022,10096 , 9440,9917,9915,10234]

[46187,10324,9970,10061,9579,10070,10207, 9687,9981,9923,10245]

[46191,10317,9983,10095,9607,10082,11285,19590,9922,9881,10249]

[46185,10341,9964,10064,9572,10022,10096, 9440,9917,9915,10234]



Pictures courtesy of Istituto Italiano Tecnologia (IIT) and University of Genova

FROM SENSING TO PERCEPTION

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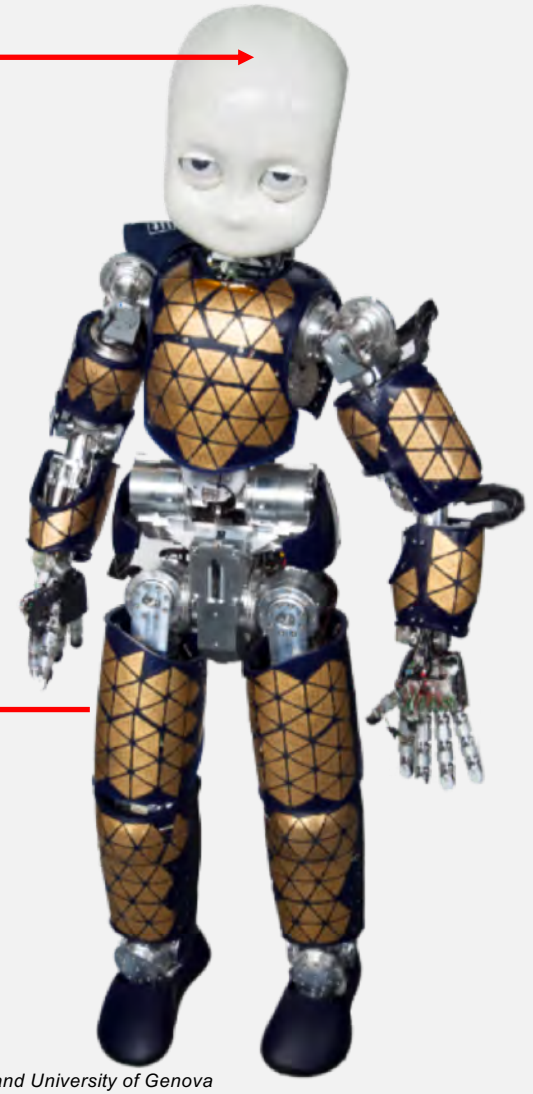
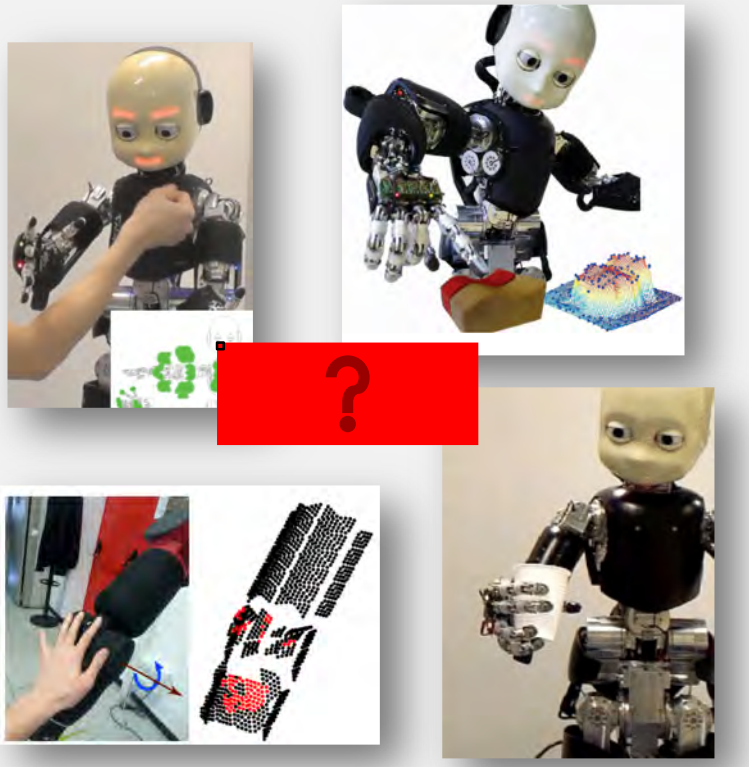
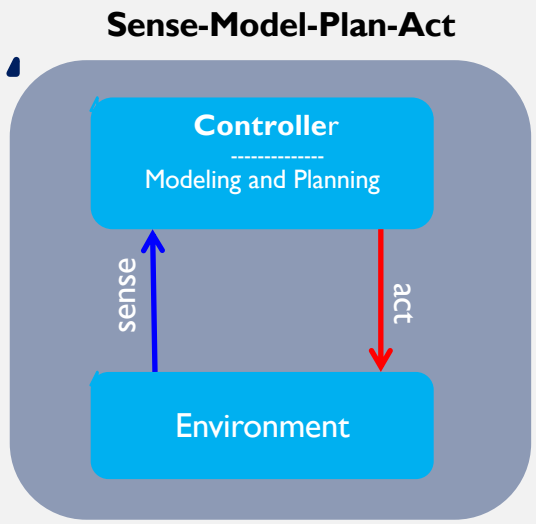


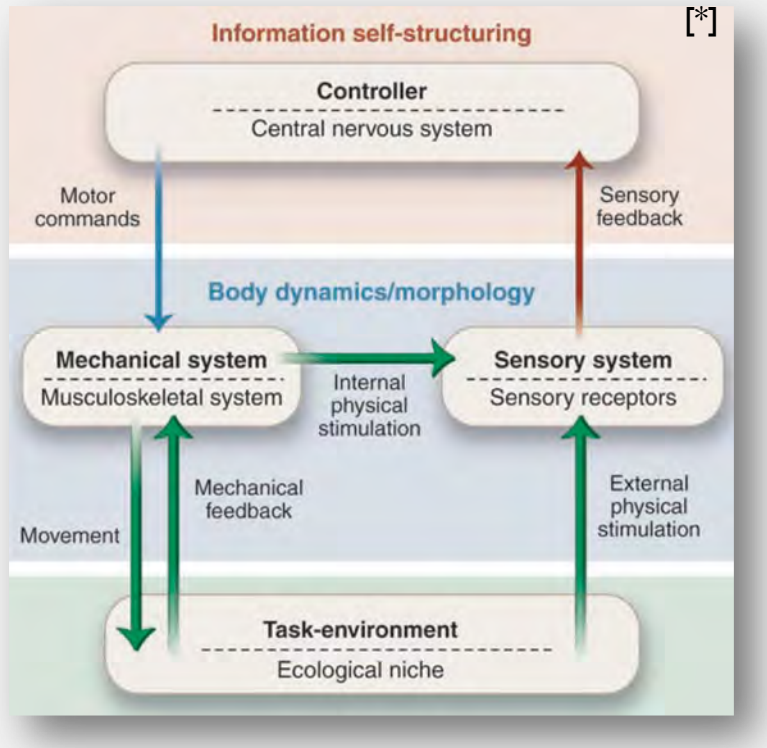


Pictures courtesy of Istituto Italiano Tecnologia (IIT) and University of Genova

BIOLOGICAL INSPIRATION

FROM SENSING TO PERCEPTION



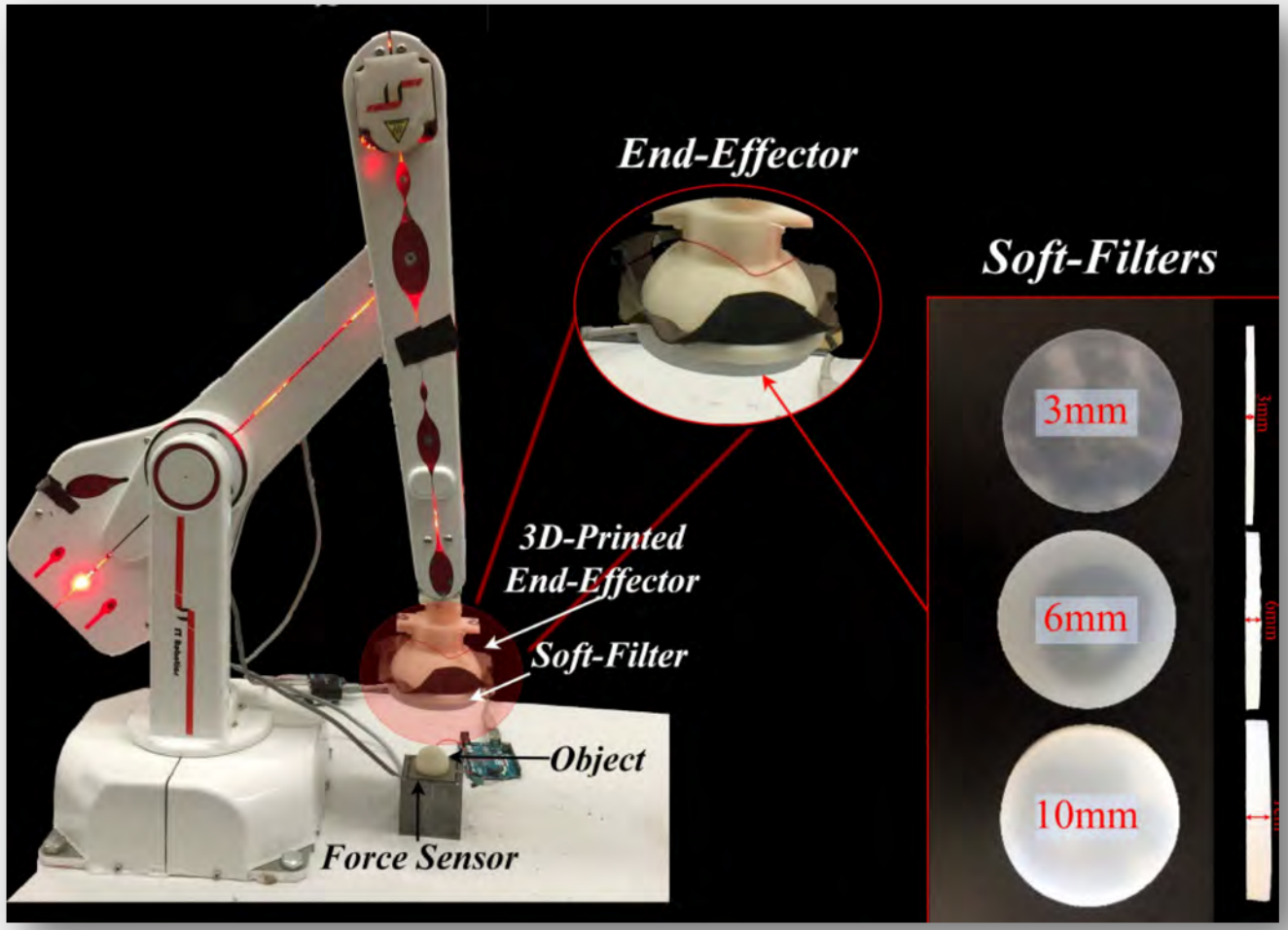


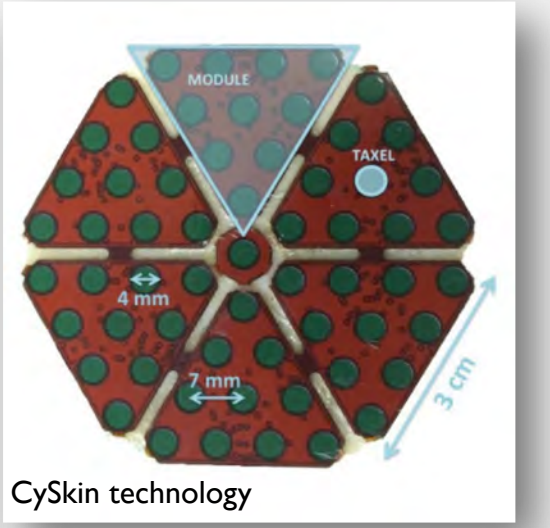
- Perception is passive and disembodied
- Objective is Representation/building world model

- Perception is active and through the body
- Objective is not just building world model but also behaviours

[*] Pfeifer, Rolf, Max Lungarella, and Fumiya Iida. "Self-organization, embodiment, and biologically inspired robotics." science 318.5853 (2007): 1088-1093.

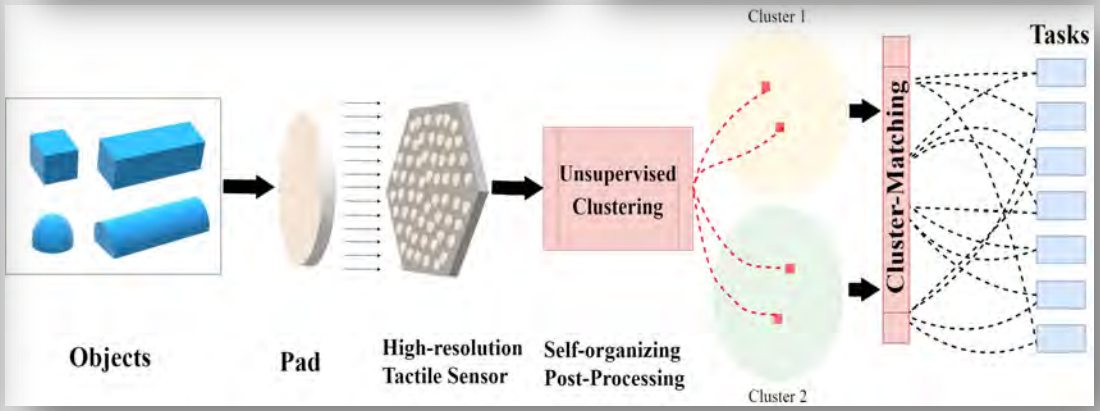
SENSOR MORPHOLOGY





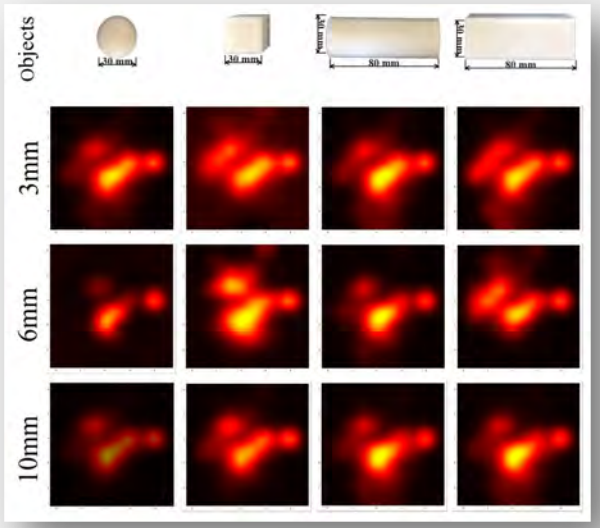
CySkin technology

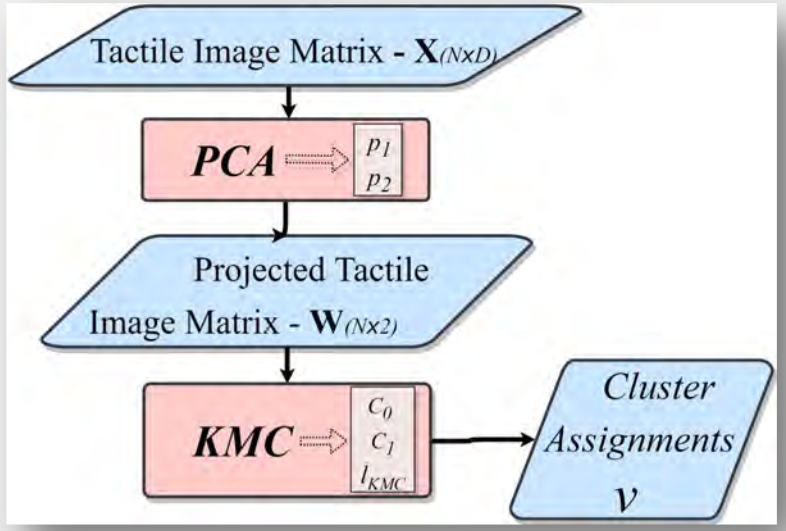
Task Table	Cluster 1	Cluster 2
Task 1	○	□ ⬭ ▭
Task 2	□	○ ⬭ ▭
Task 3	⬭	○ □ ▭
Task 4	▭	⬭ ○ □
Task 5	○ ⬭	▭ □
Task 6	▭ ⬭	○ □
Task 7	○ ▭	⬭ □

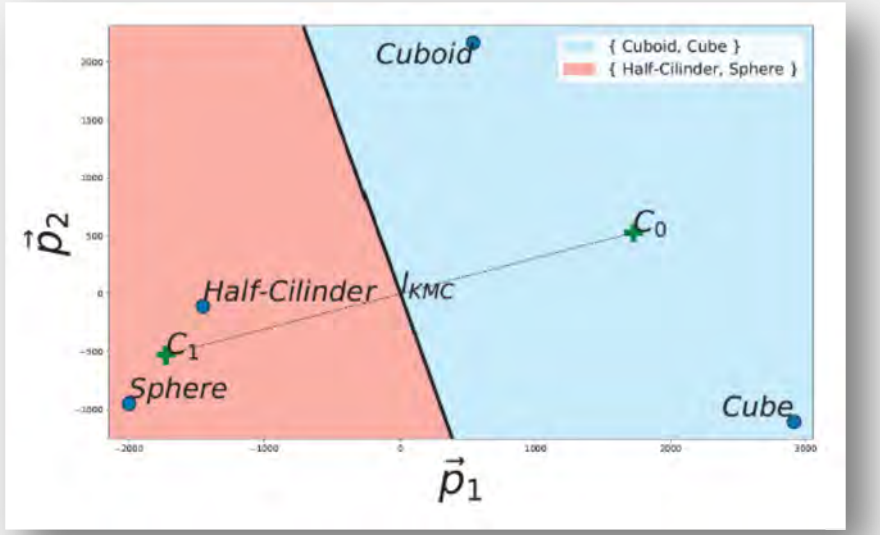


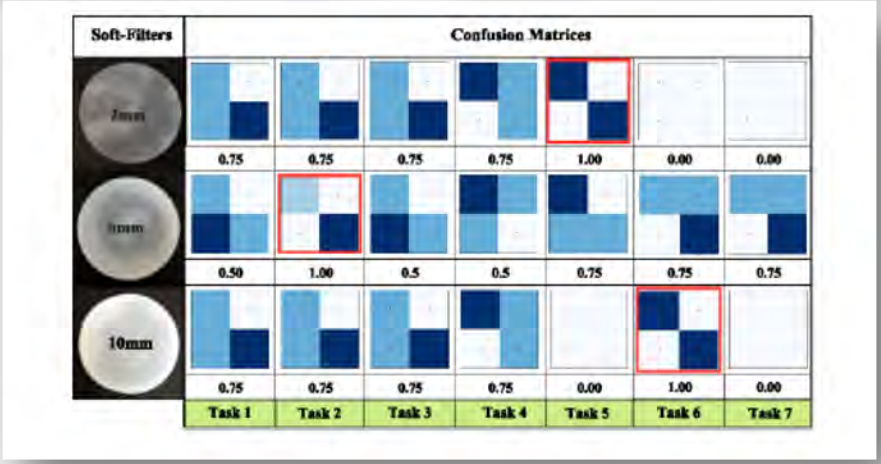
Scimeca, Luca, Perla Maiolino, and Fumiya Iida. "Soft morphological processing of tactile stimuli for autonomous category formation." *2018 IEEE International Conference on Soft Robotics (RoboSoft)*. IEEE, 2018.

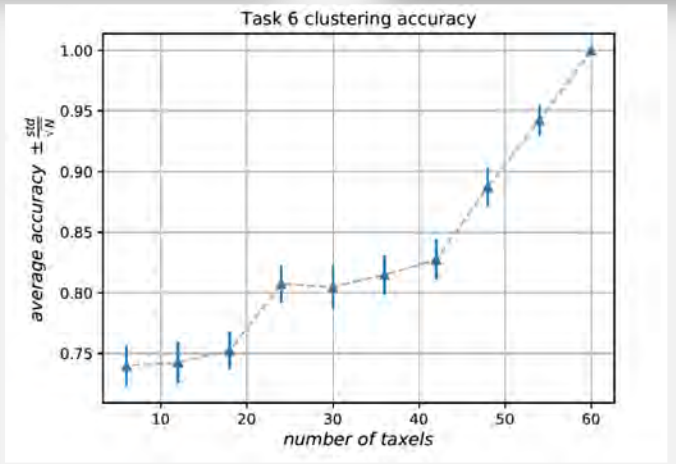
SENSOR MORPHOLOGY











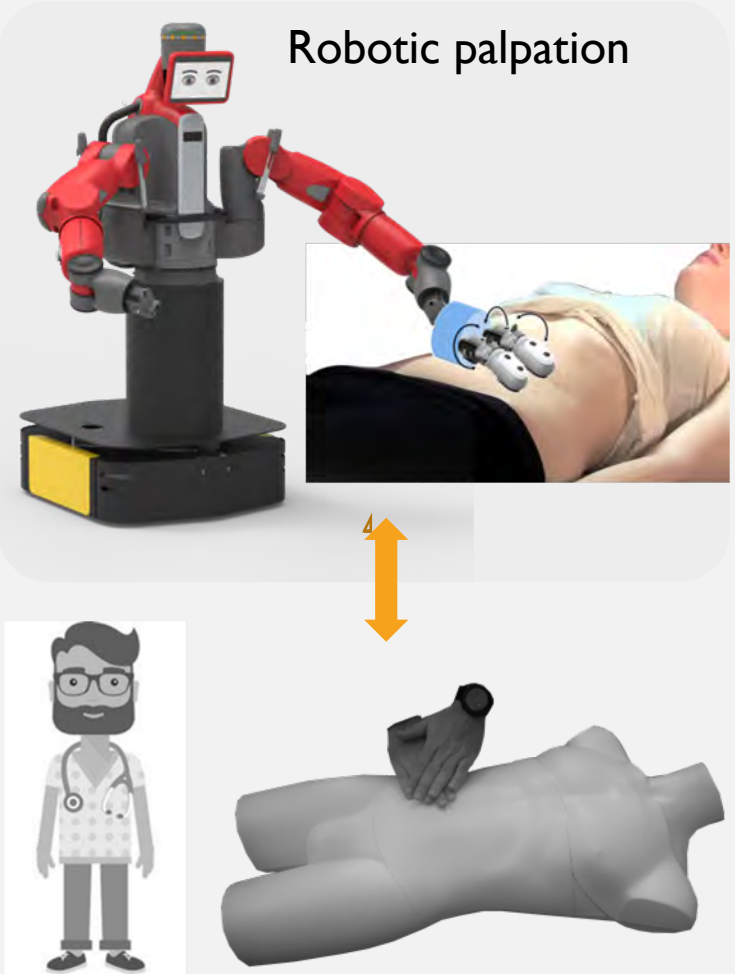
Scimeca, Luca, Perla Maiolino, and Fumiya Iida. "Soft morphological processing of tactile stimuli for autonomous category formation." *2018 IEEE International Conference on Soft Robotics (RoboSoft)*. IEEE, 2018.

MOTION
Morphological Computation of Perception And Action

EPSRC

Objectives:

- To realize a robotic system for **remote palpation**
- **To understand the role of mechanical impedance** in regulating the morphological computational basis of **coupled haptic perception and action**

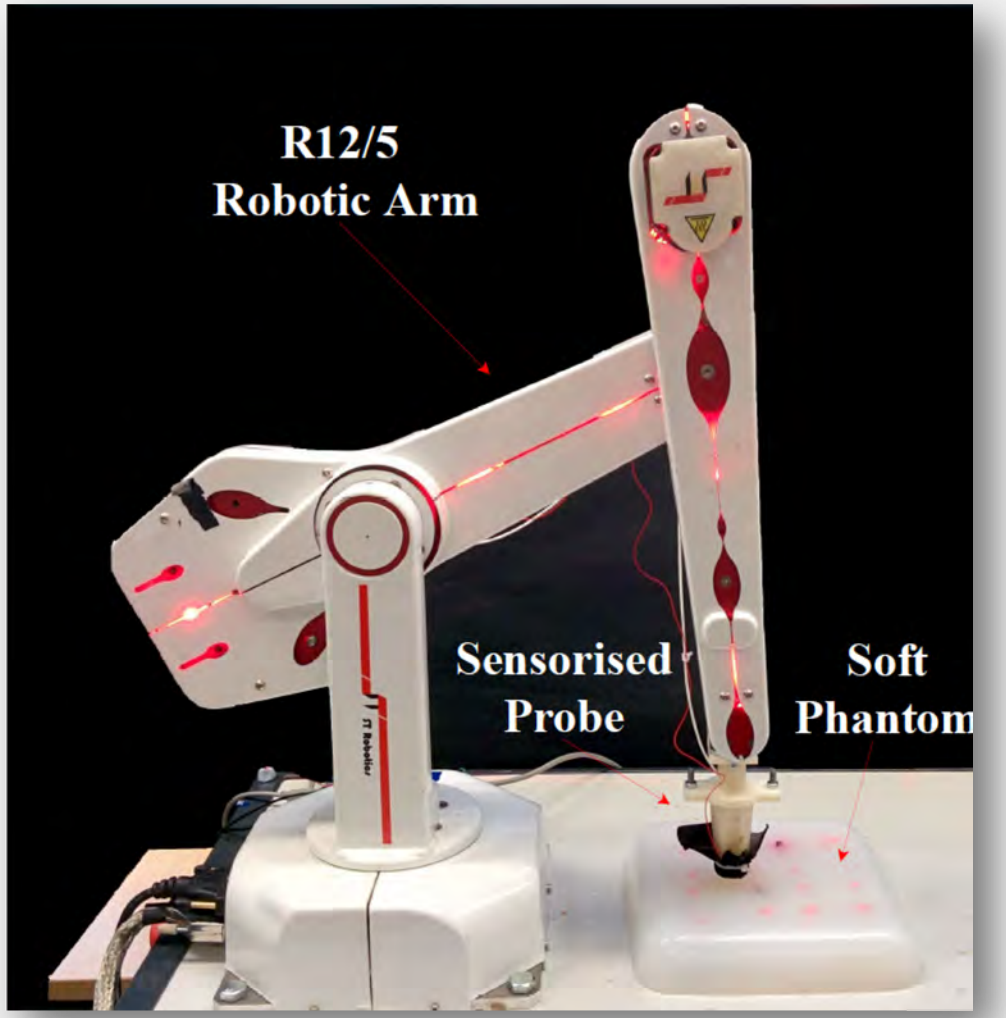


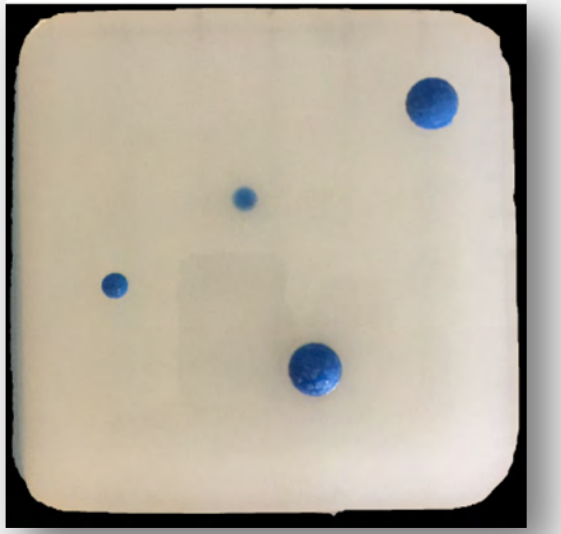
UNIVERSITY OF CAMBRIDGE Department of Engineering

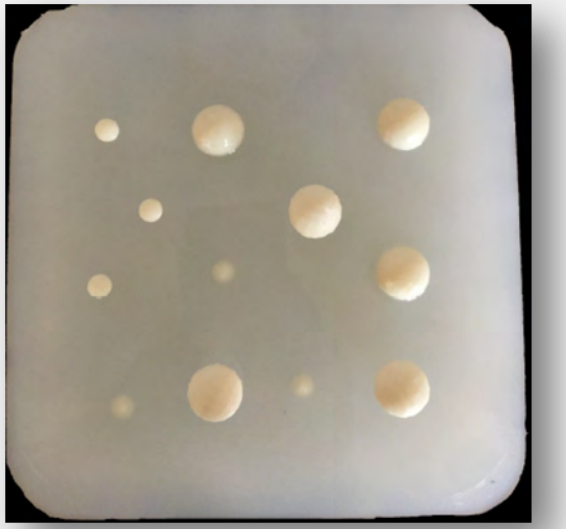
Imperial College London

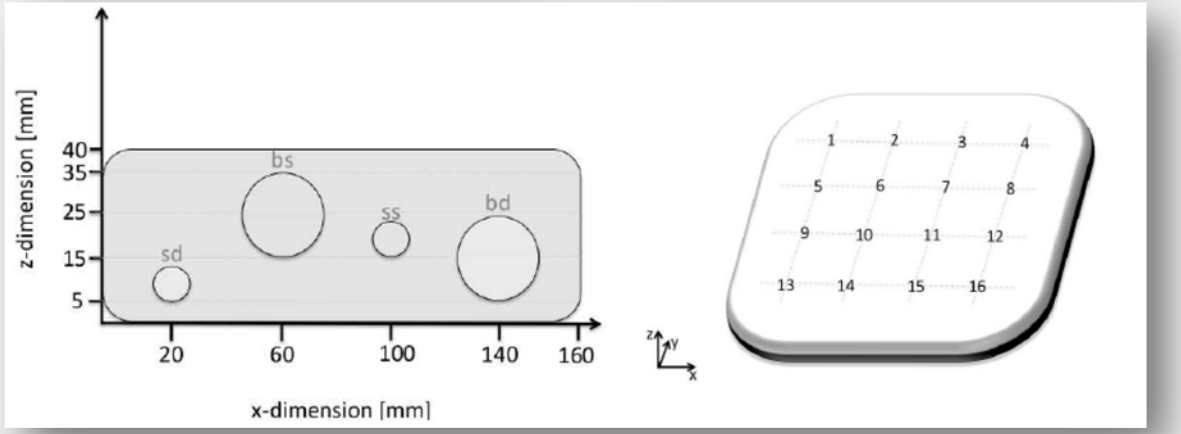
UNIVERSITY OF SURREY

SOFT INTERACTION - SENSORY-MOTOR COORDINATION



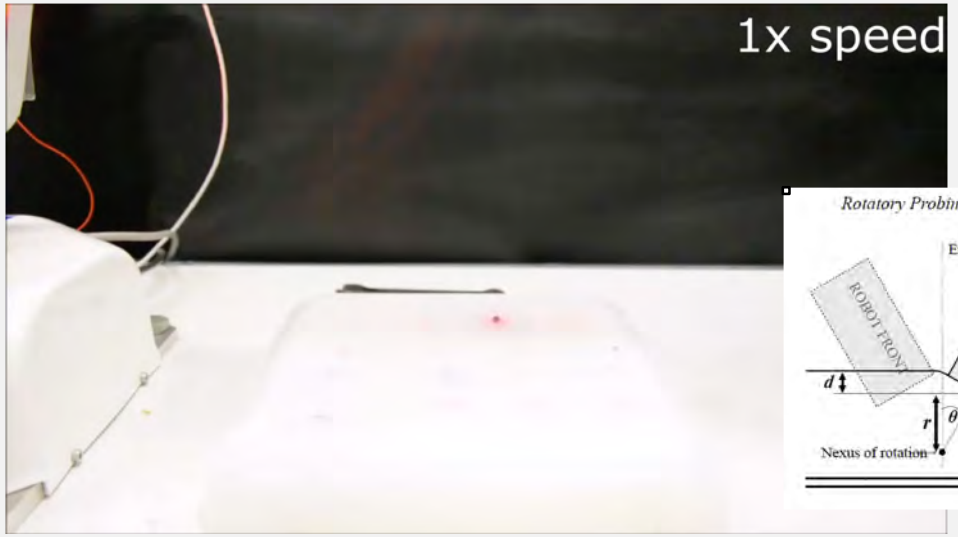


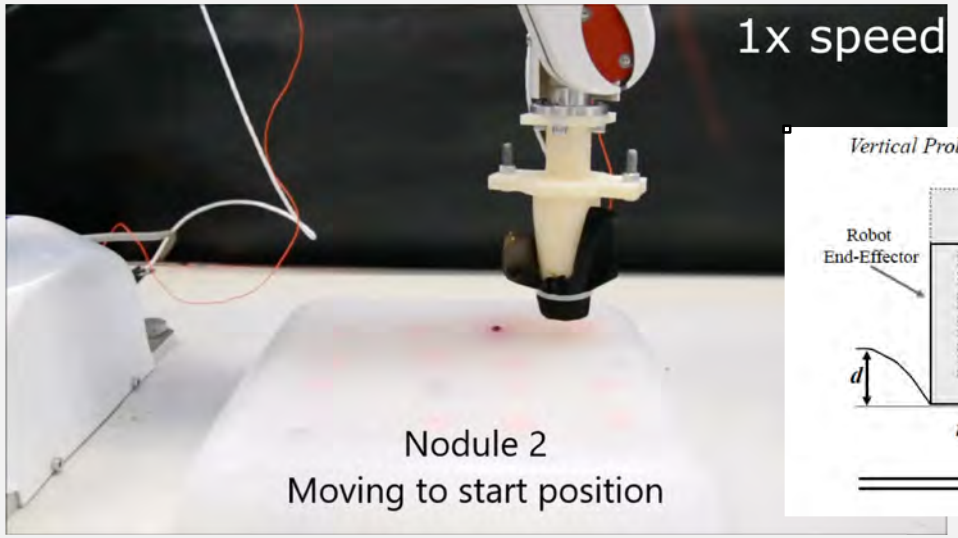


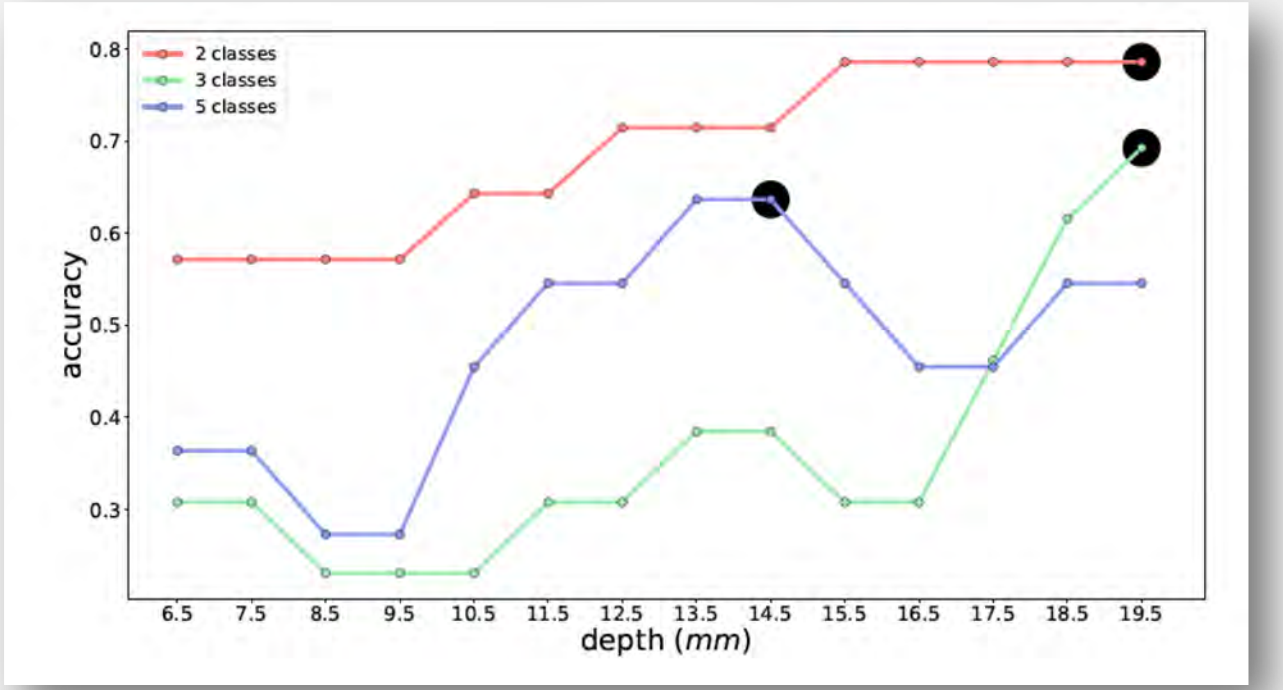


Scimeca, Maiolino, Iida Structuring of Tactile Sensory Information for Category Formation in Robotics Palpation. Submitted to Autonomous Robots Journal (2019)

SOFT INTERACTION - SENSORY-MOTOR COORDINATION

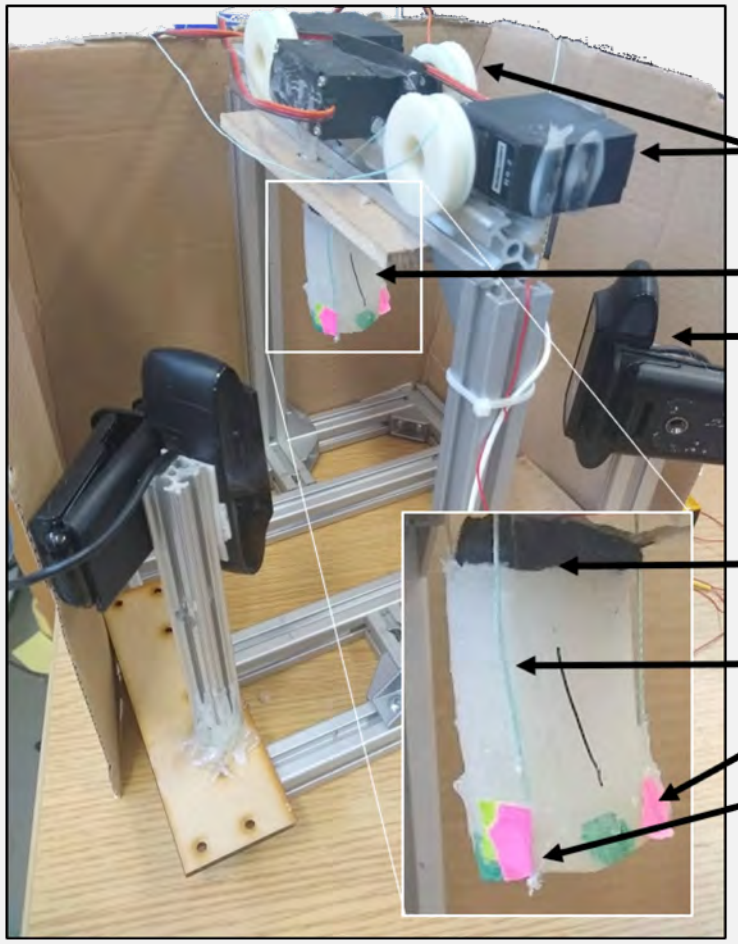


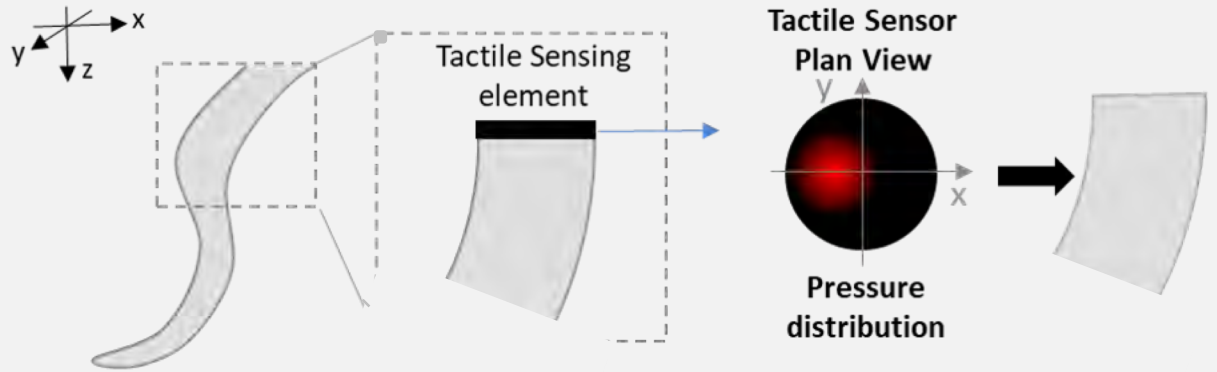




K = 2, presence vs. absence of an hard inclusion;
K = 3, absence vs. small vs. large inclusion;
K = 5, all inclusion types (SD, BS, BD, SS, NA).

PROPRIOCEPTION





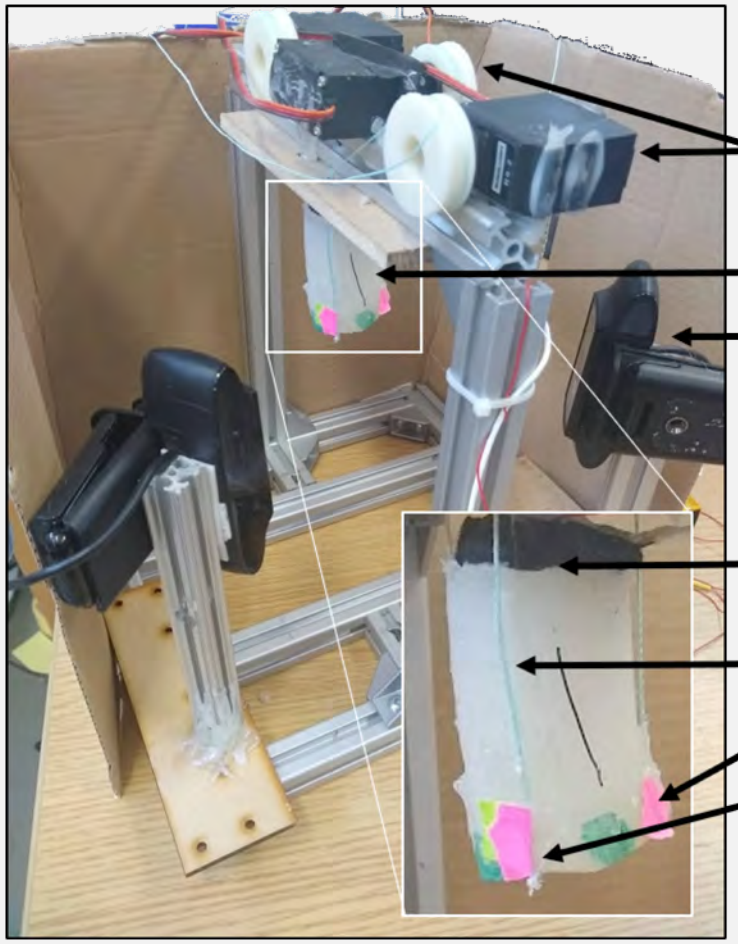
Continuum Body Structure

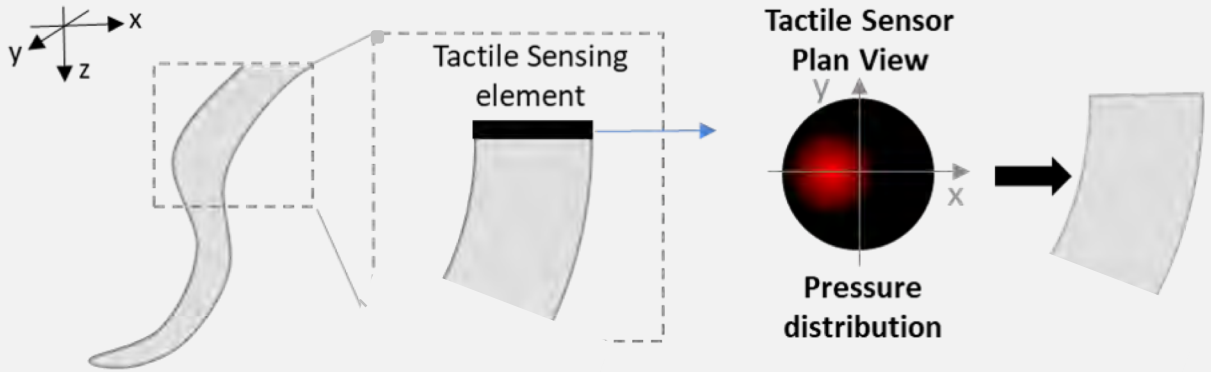
Segmented Internal Tactile Sensing

Reconstruct 3D shape

Luca Scimeca, Josie Hughes, Perla Maiolino and Fumiya Iida Model-free Soft-Structure Reconstruction for Proprioception using Tactile Arrays. RA-L 2019.

PROPRIOCEPTION

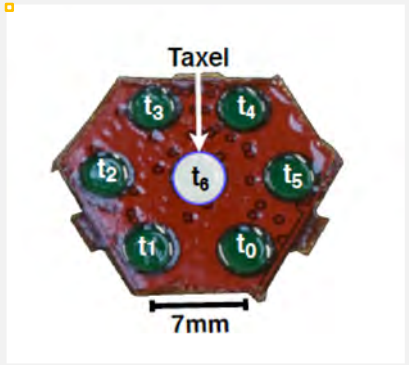




Continuum Body Structure

Segmented Internal Tactile Sensing

Reconstruct 3D shape



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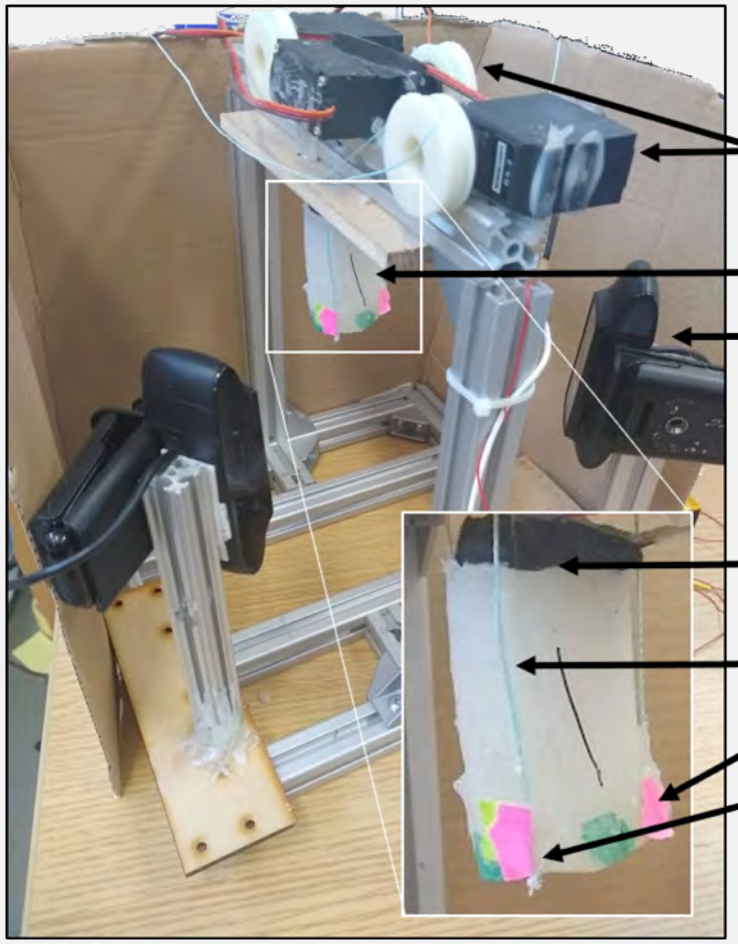
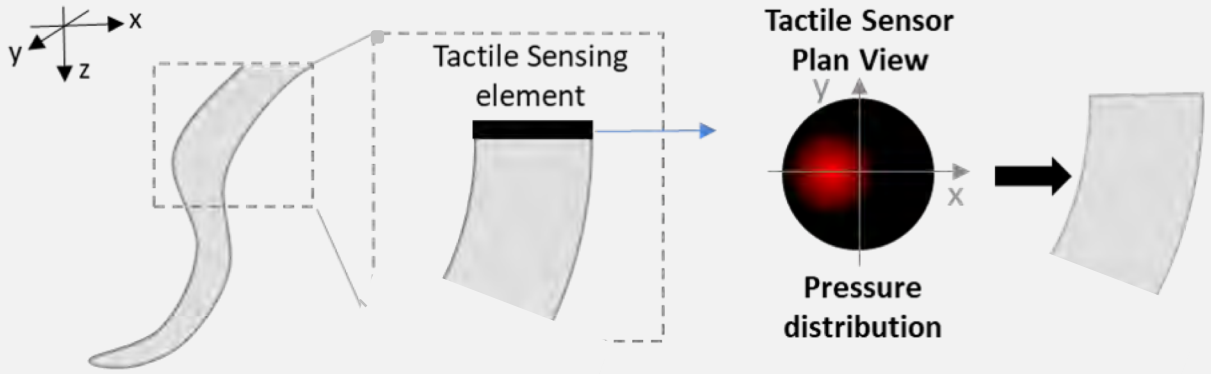
PROPRIOCEPTION

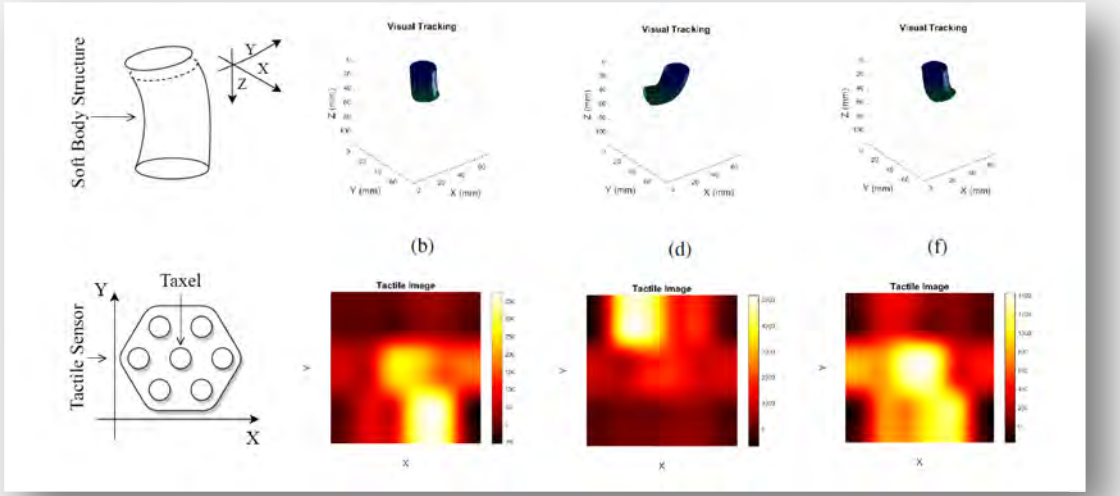




Continuum Body Structure

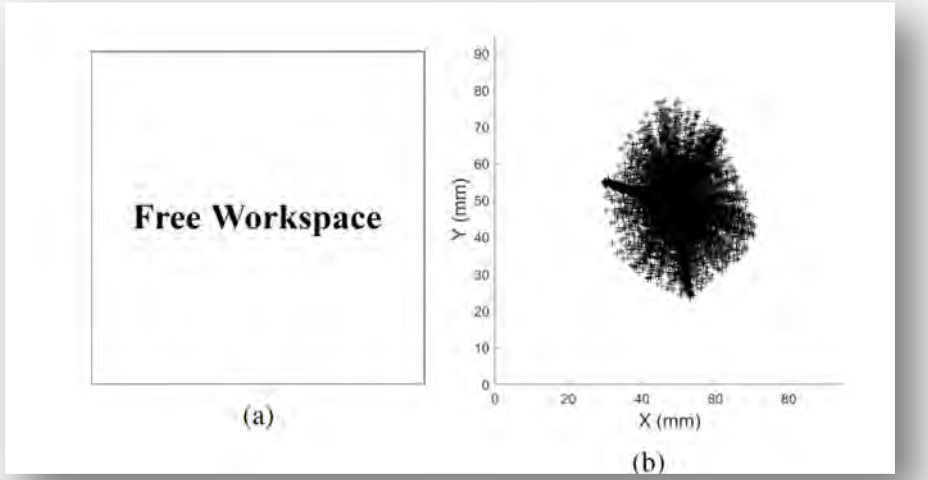
Segmented Internal Tactile Sensing

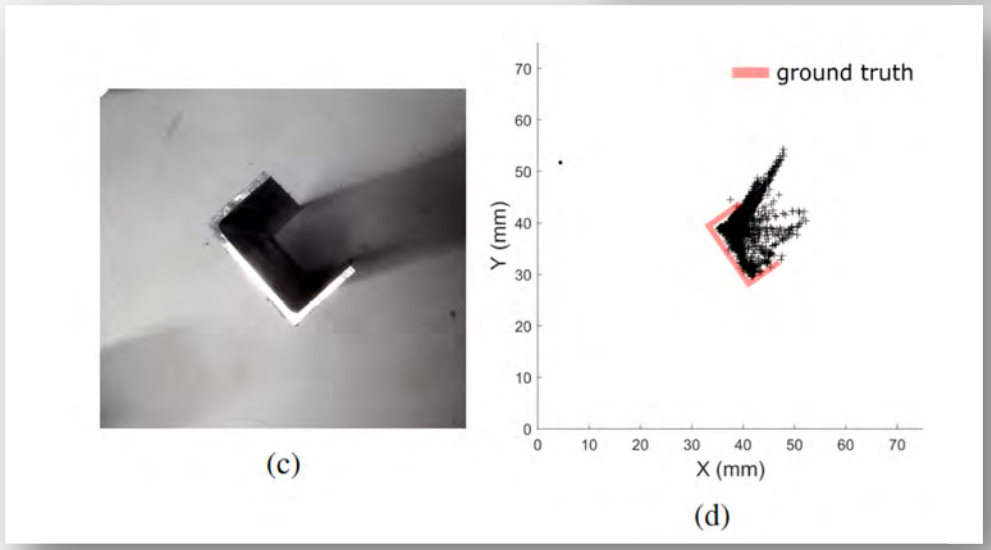
Reconstruct 3D shape

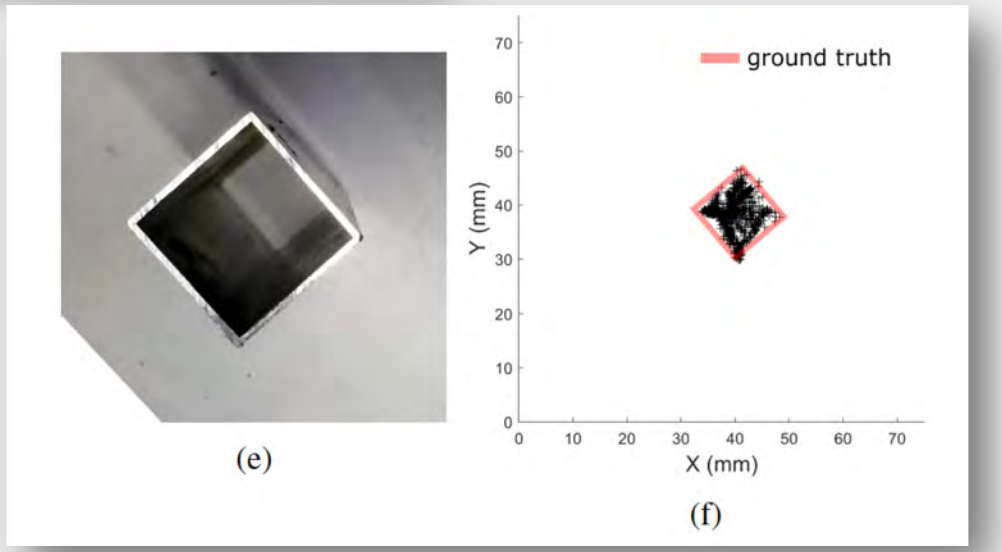


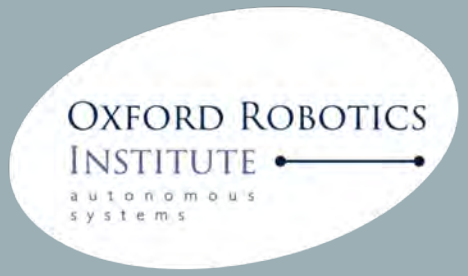
PROPRIOCEPTION

WORK-SPACE RECONSTRUCTION



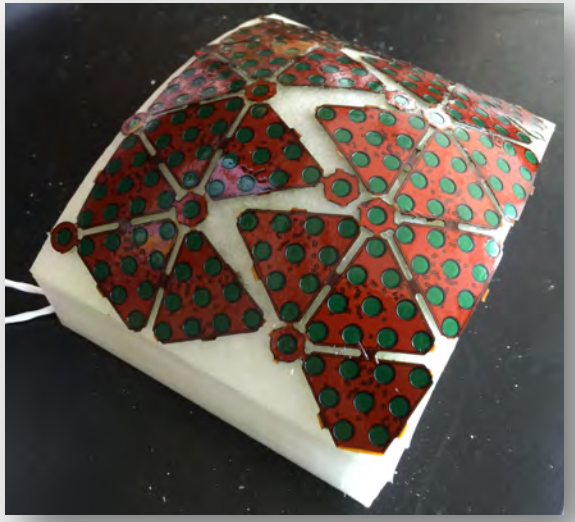




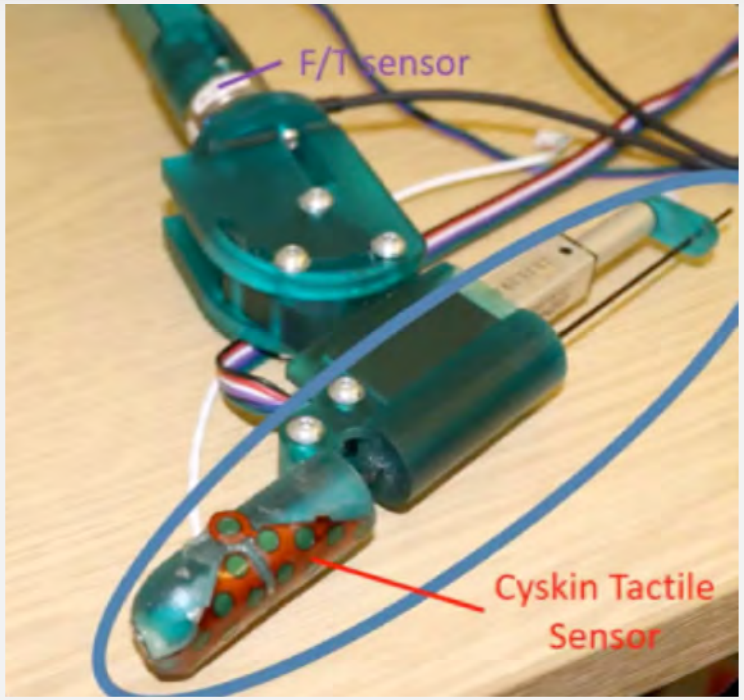


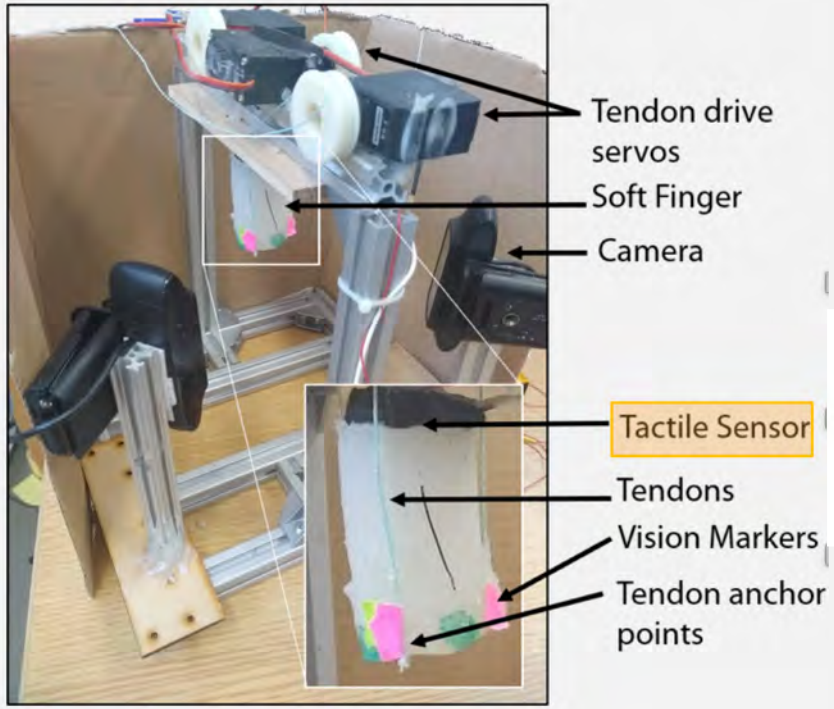
2019 Intelligent Sensing Summer School

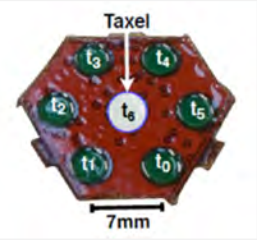
THANK YOU




CySkin


F/T sensor
Cyskin Tactile Sensor


Tendon drive servos
Soft Finger
Camera
Tactile Sensor
Tendons
Vision Markers
Tendon anchor points


Taxel
7mm