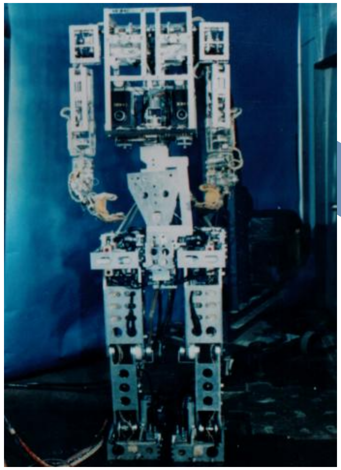
Softness and Compliance in Human-Symbiotic Robots

Alexander Schmitz

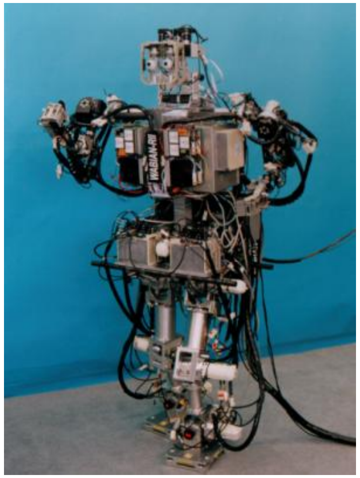
Waseda University

Robotics in Waseda University

1973 : WABOT-1
First Humanoid Robot in the World

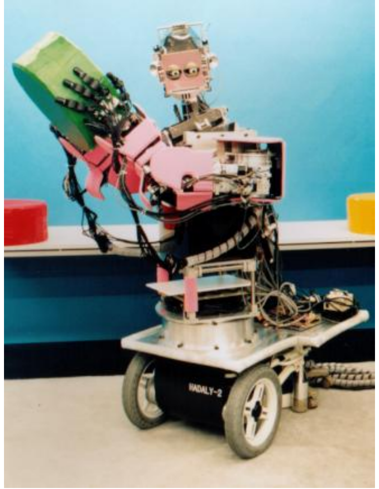


1984 : WABOT-2
Piano playing Robot



1992 : Humanoid Project

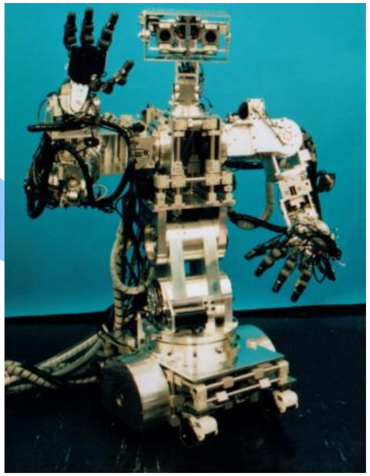
1995 : Hadaly-1



1997 : Hadaly-2

1997 : WABIAN
Biped Robot

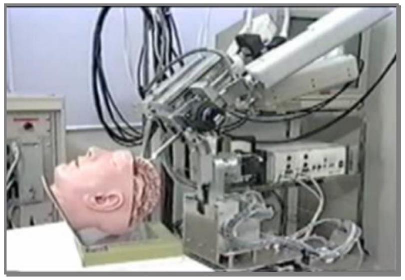
1999 : Wendy
Human Symbiotic Robot



Robotics in Waseda University

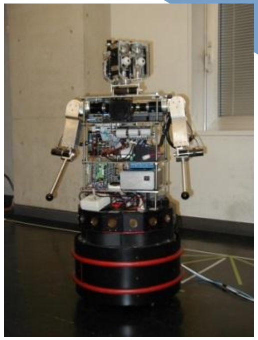
WASEDA UNIVERSITY HUMANOID

2000 : Humanoid Institute
2001 : WABOT-HOUSE Laboratory

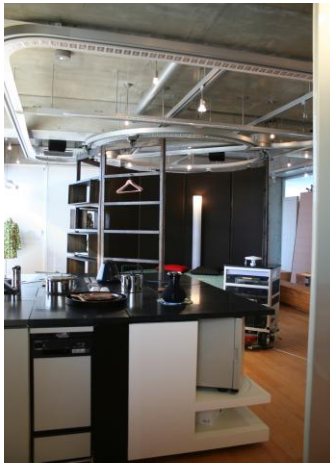


Surgical Robot

2004: WABOT-HOUSE
Structured environment



ROBITA



2005 : WABIAN-II
Biped Robot

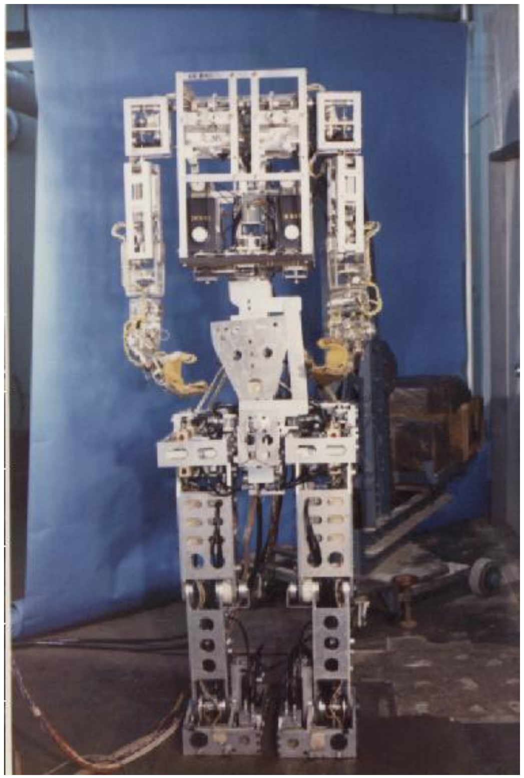
2007 : TWENDY-ONE
Human Symbiotic Robot

2009: SCHEMA
Conversation Robot

2015: Octopus
Disaster Robot

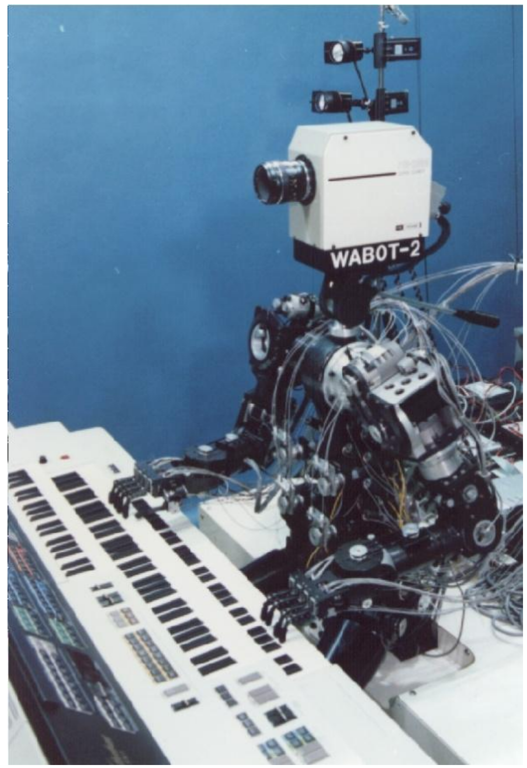
Robots in Waseda

WASEDA UNIVERSITY HUMANOID



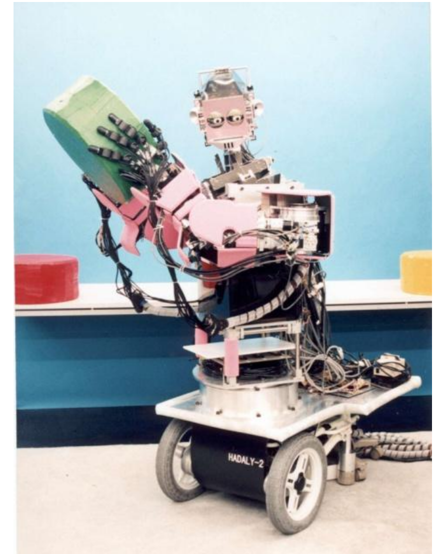
WABOT-1

(1973)



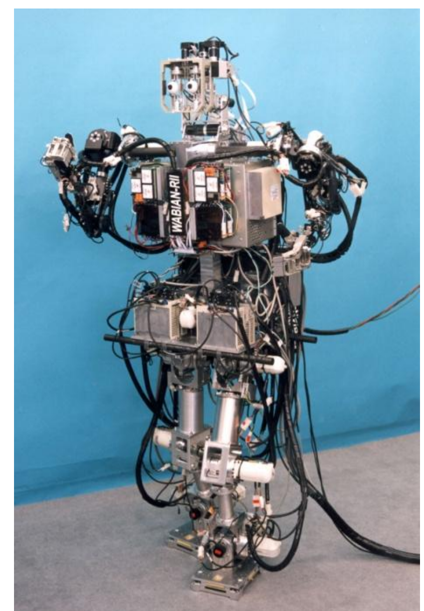
WABOT-2

(1984)



Haday-2

(1997)



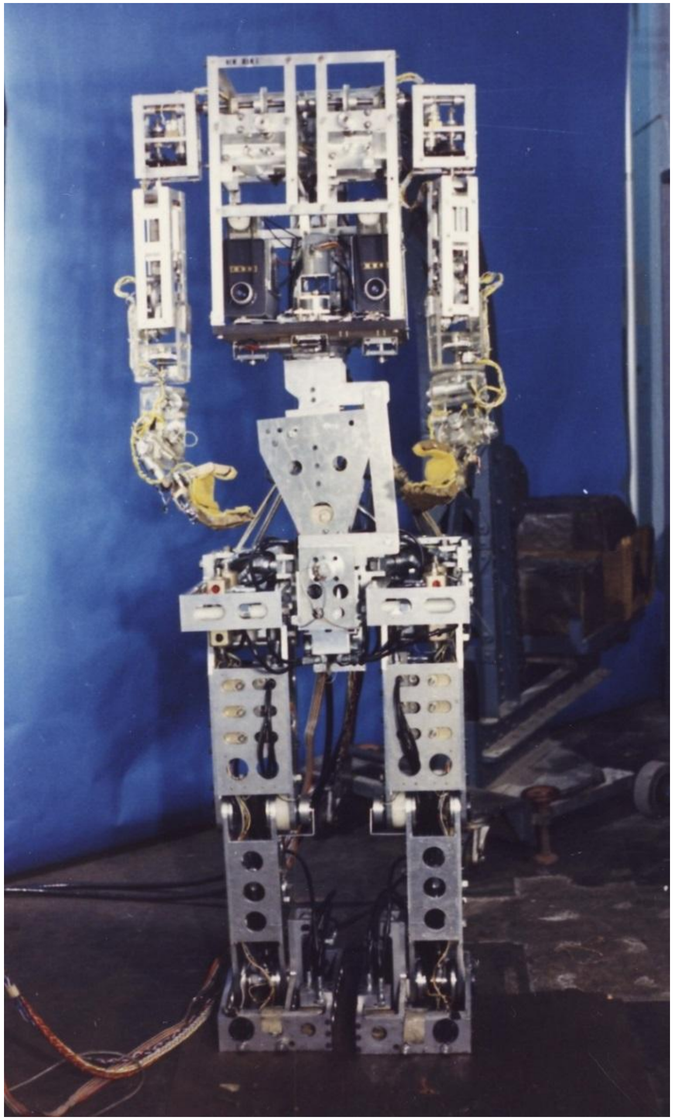
WABIAN

(1997)

1973 WABOT-1

Waseda University
Bio-engineering Research Group

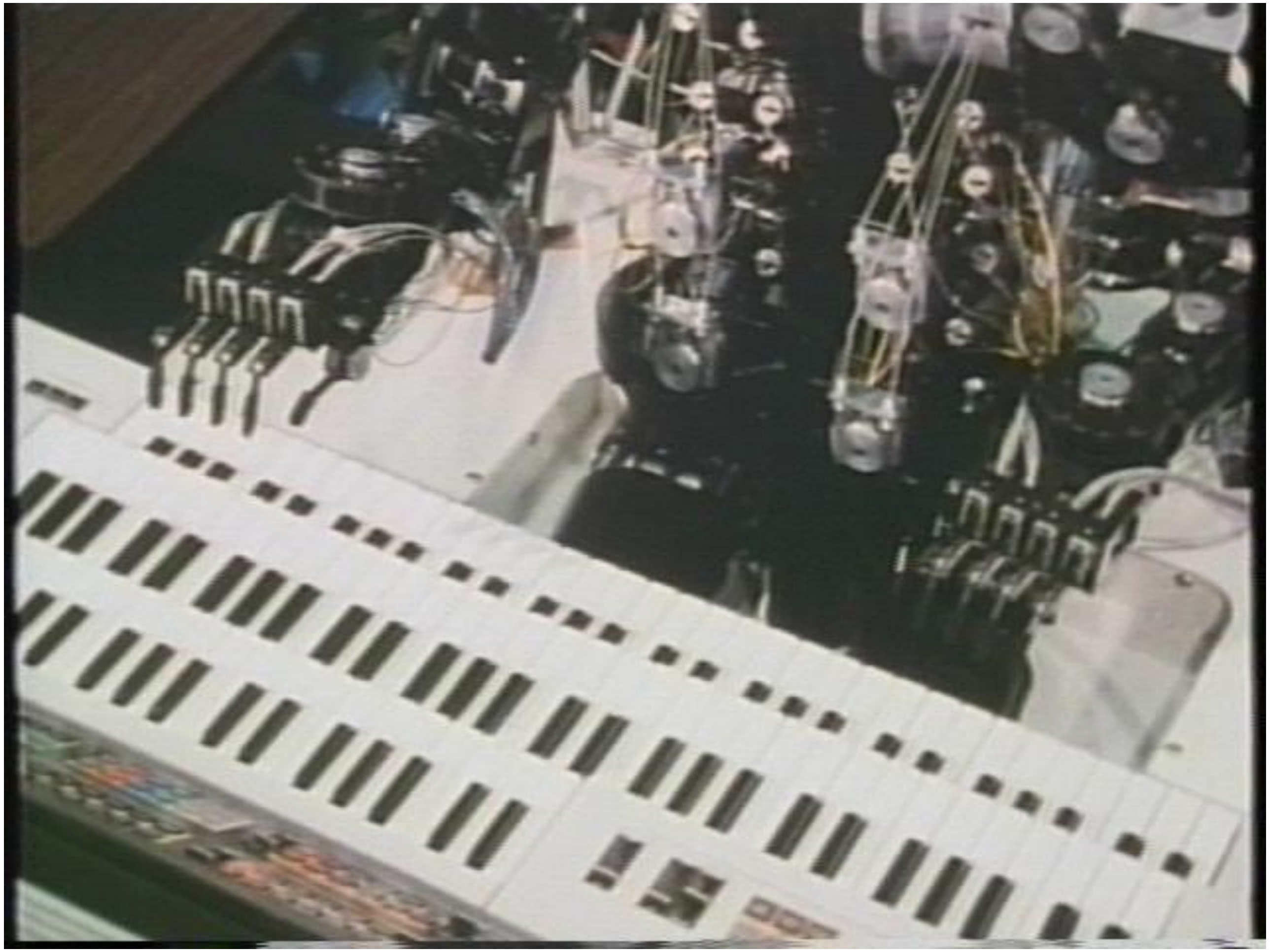
Ichiro Kato, Katsuhiko Shirai, etc.



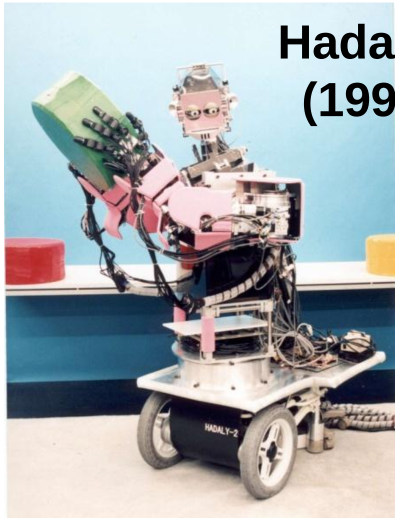
1964 Bullet Train (210 Km/h)

1969 Apollo 11 (Moon Landing)

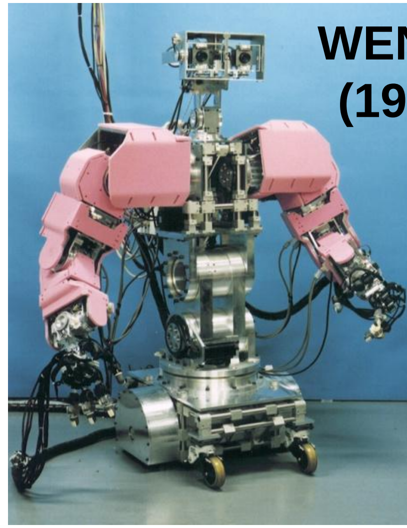
WABOT-2



Robots in Waseda

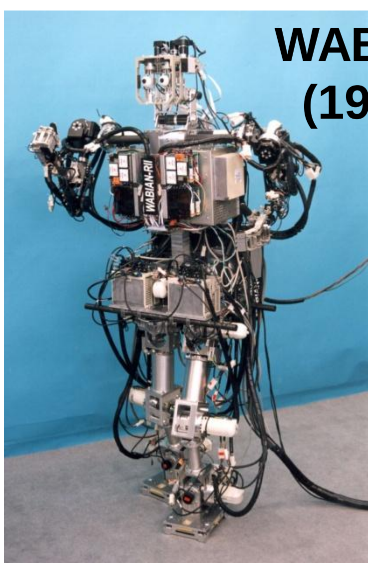


Haday-2
(1997)

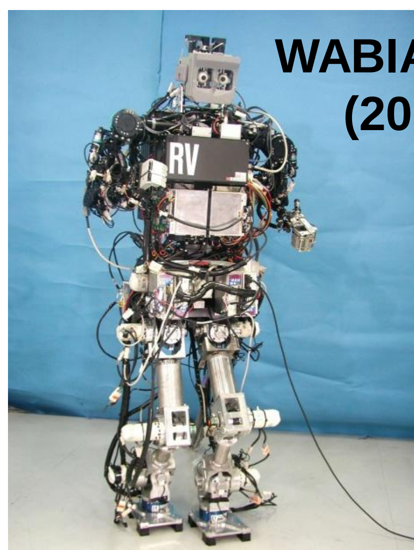


WENDY
(1999)

TWENDY-ONE
(2007)



WABIAN
(1997)

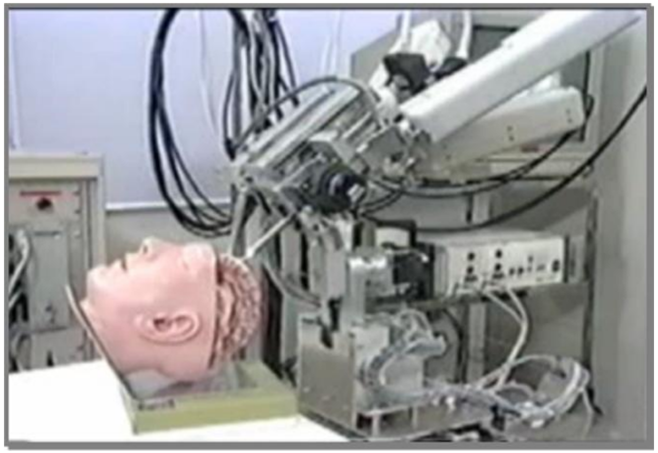


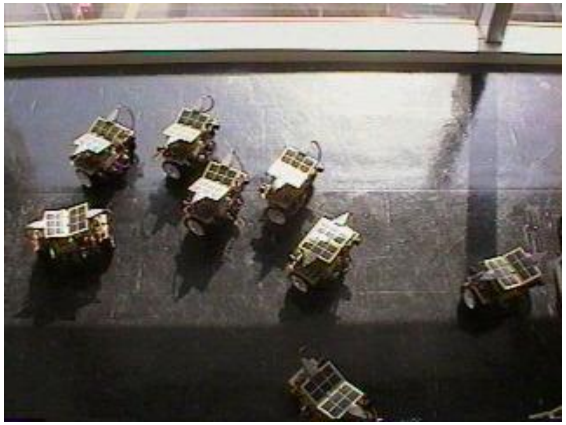
WABIAN-RV
(2001)

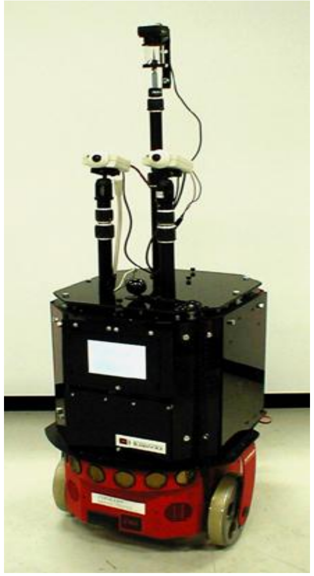
WABIAN-II
(2005)

Robots in Waseda

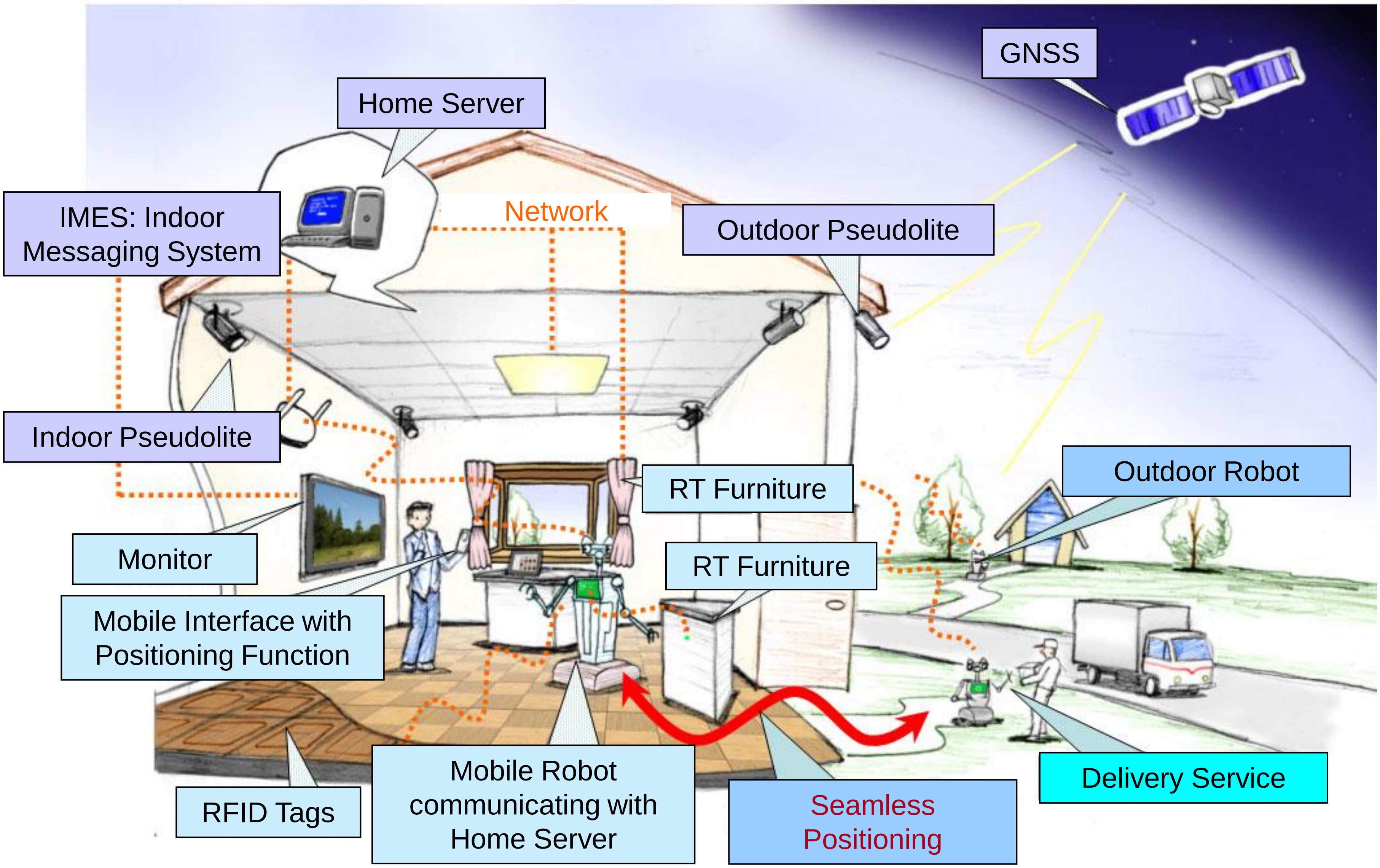




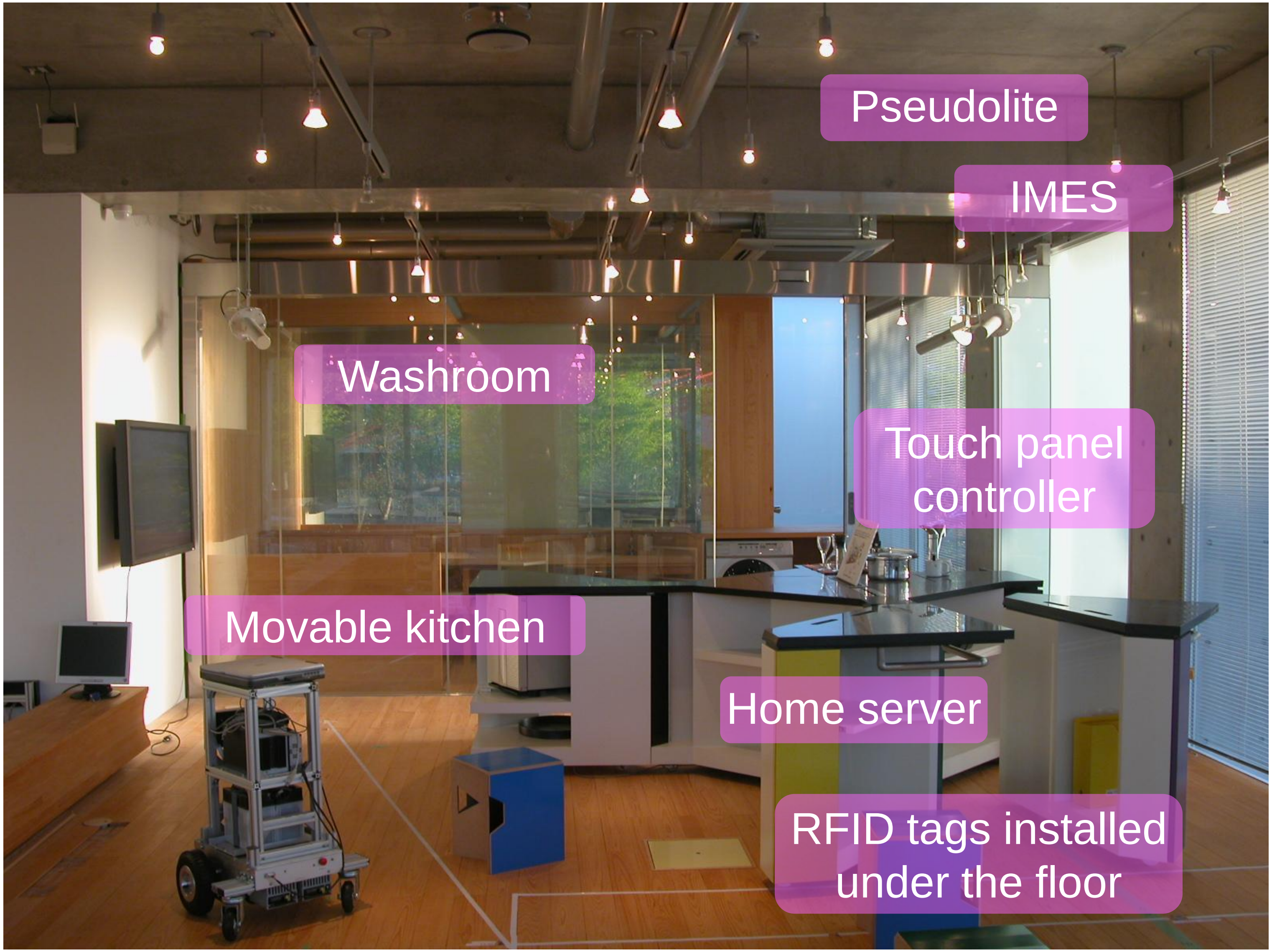




Structured Environment

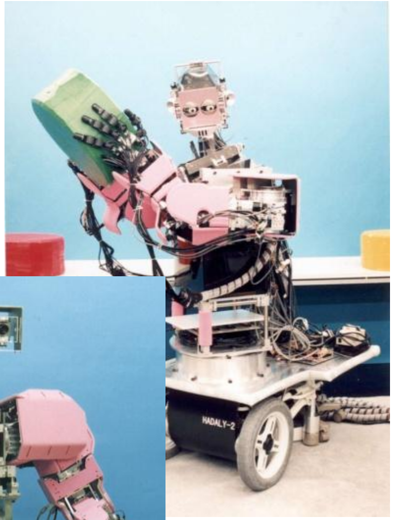


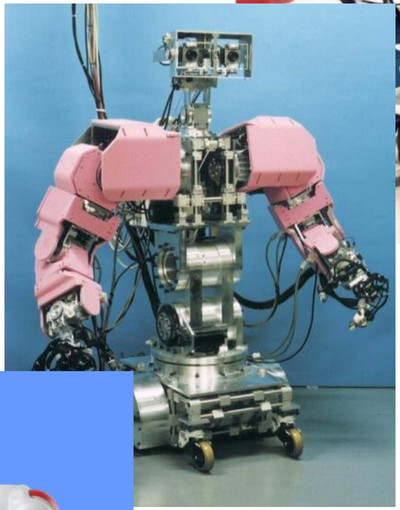
WABOT-HOUSE Project (2001-2011)

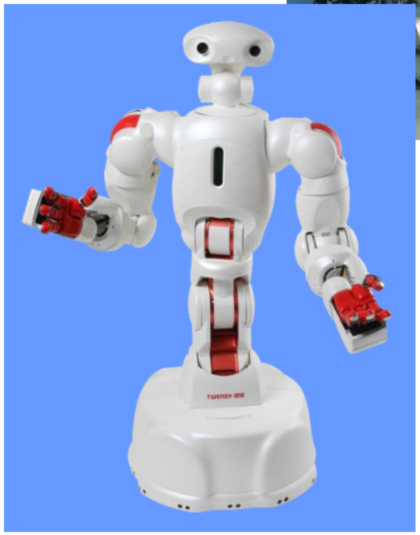


Requirements of Human-Symbiotic Robots

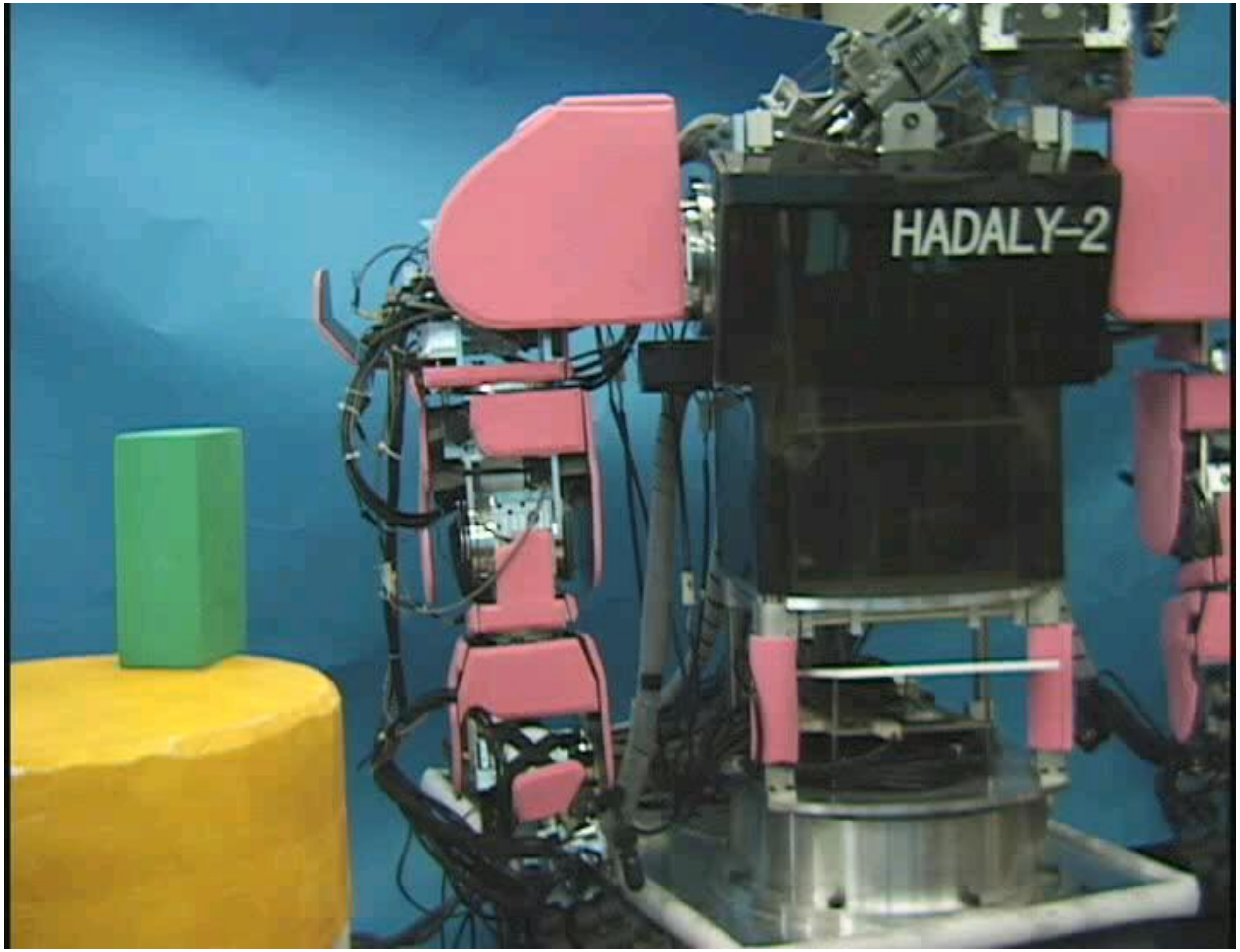
- **Co-existence with Human**
  - Low Risk (Safety)
  - Physical Interaction
  - Communication
- **Task Executability**
  - Dexterity
  - Force Controllability
  - Mobility
  - Intelligence





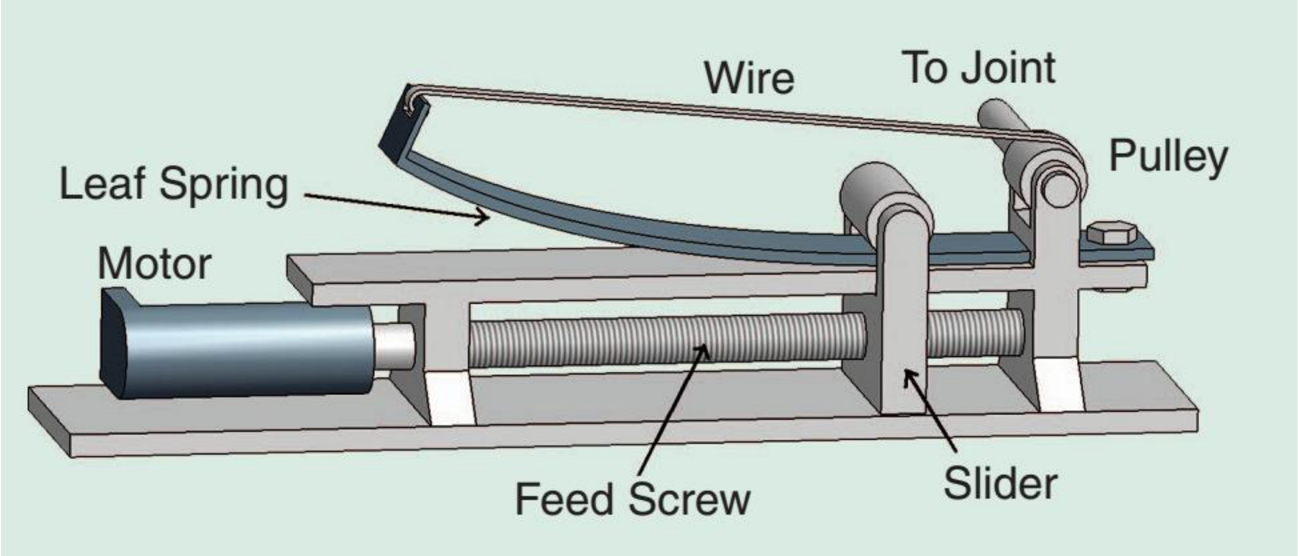


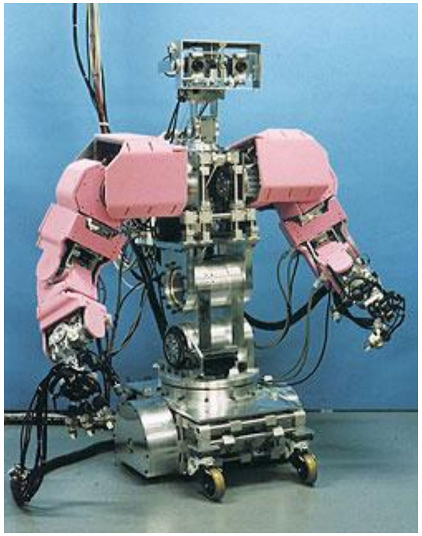
Low Risk



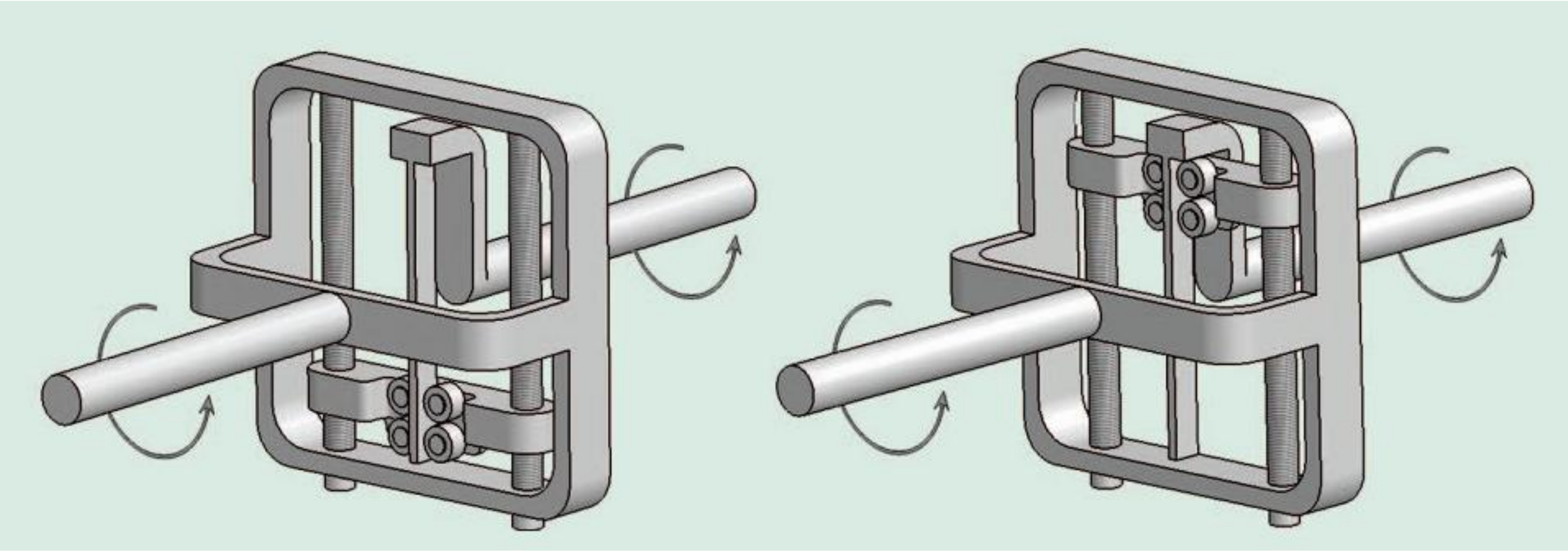
Mechanical Impedance Adjuster

- **Vary the effective length of the compliant element**

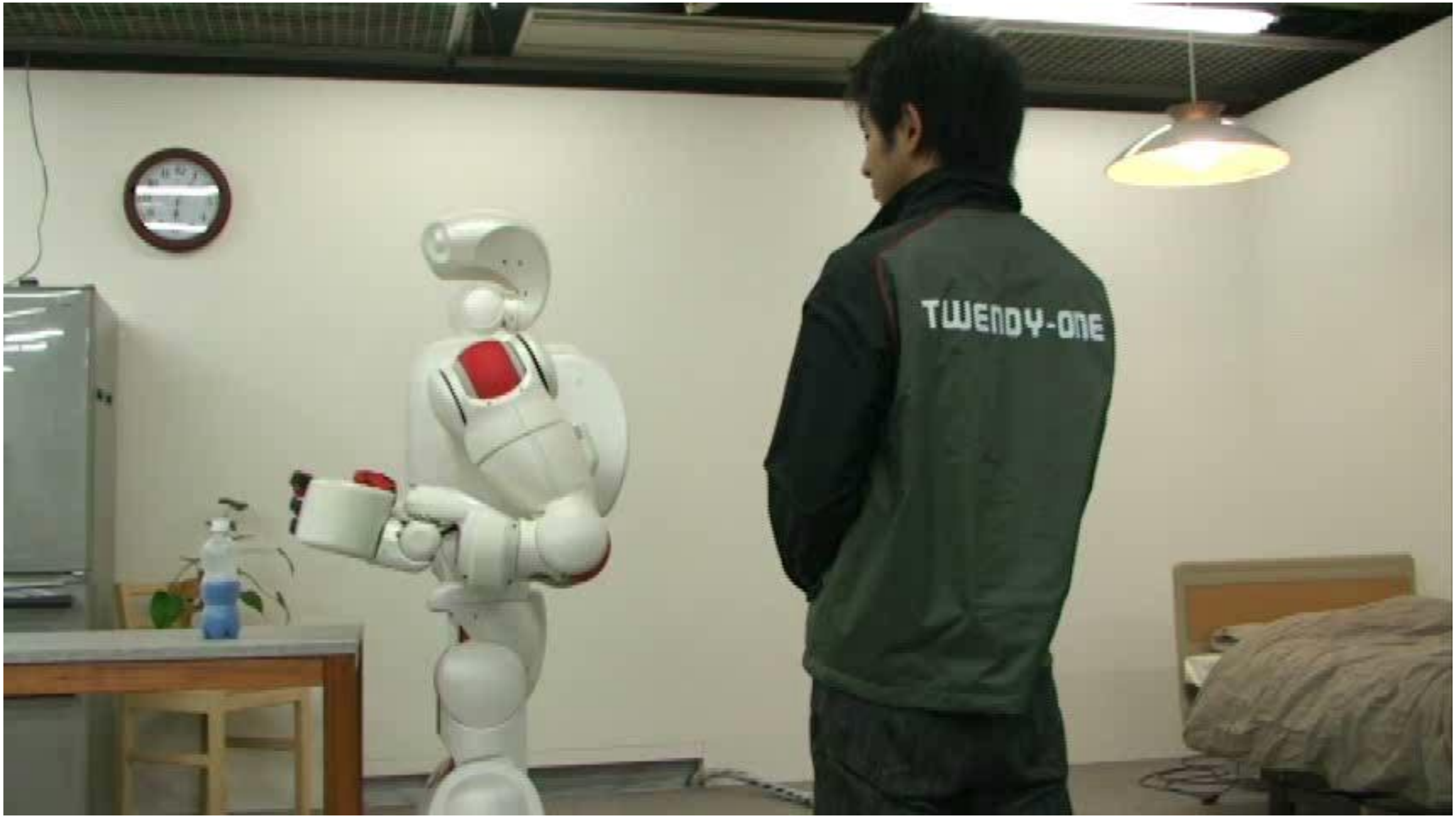




Rotational Version



TWENDY-ONE

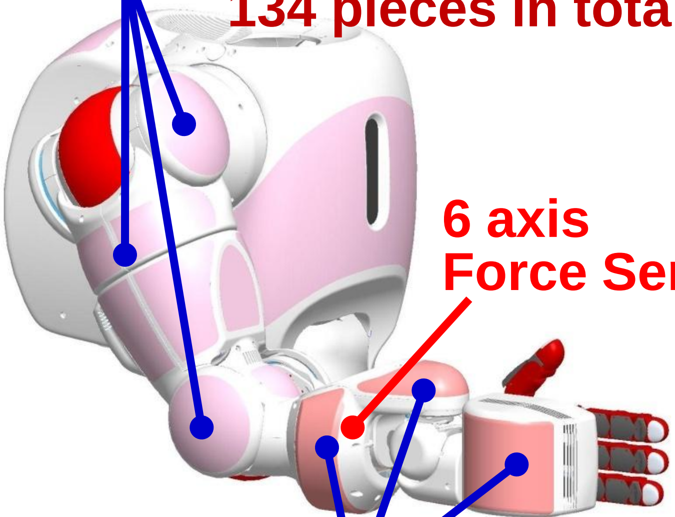


Adaptive Grasping
and Following to Human Motion

TWENDY-ONE Arm

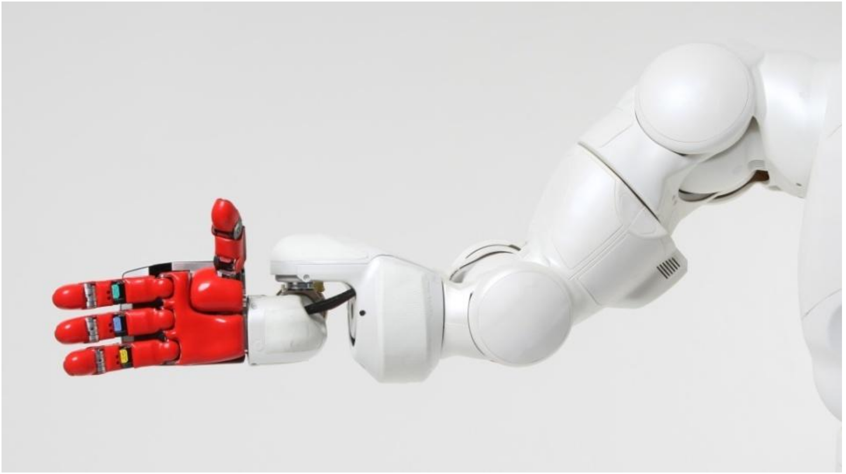
Silicone Rubber with
Tactile Force Sensors

134 pieces in total



6 axis
Force Sensor

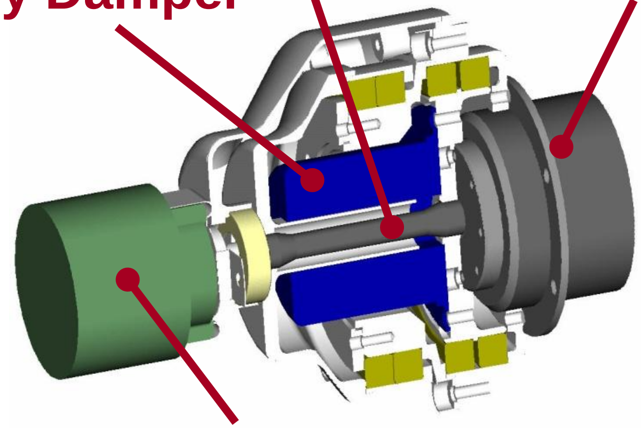
Shock Absorbing Gel with
Tactile Force Sensors



Torsion Bar (GUMMETAL)

Actuator Unit

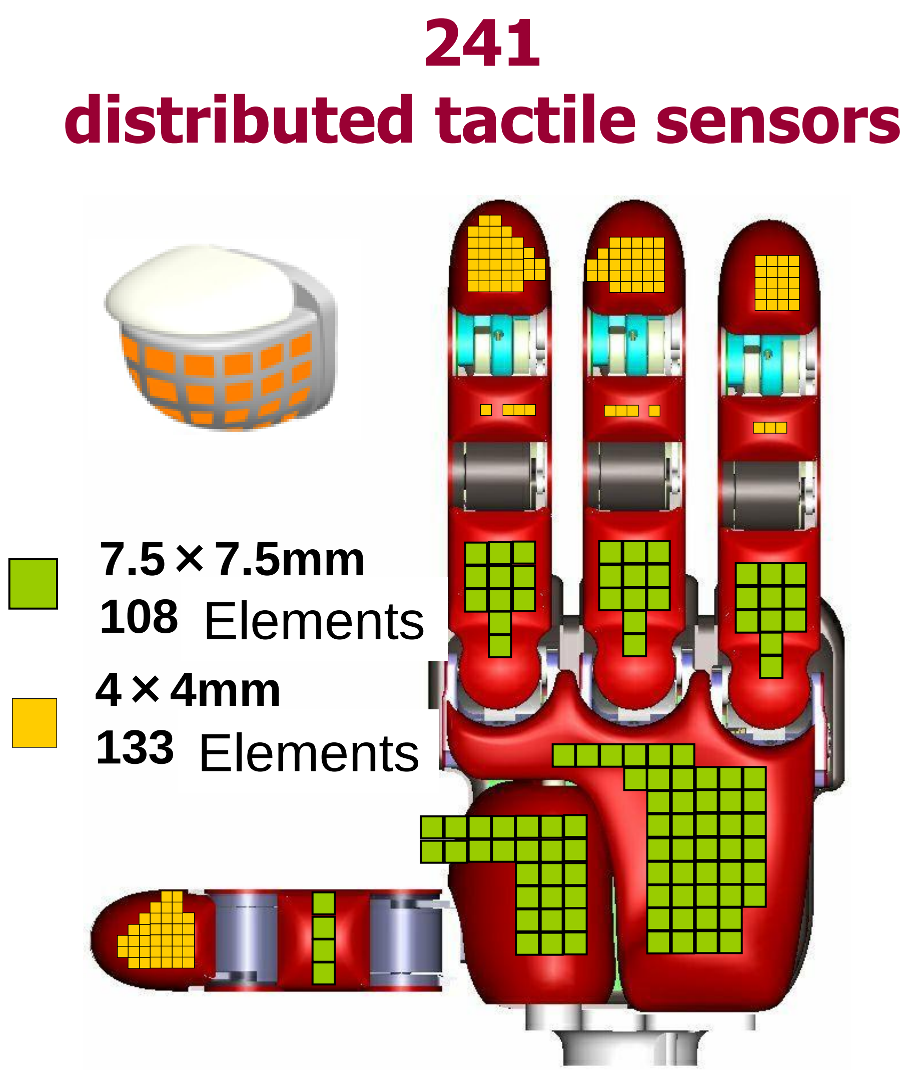
Rotary Damper

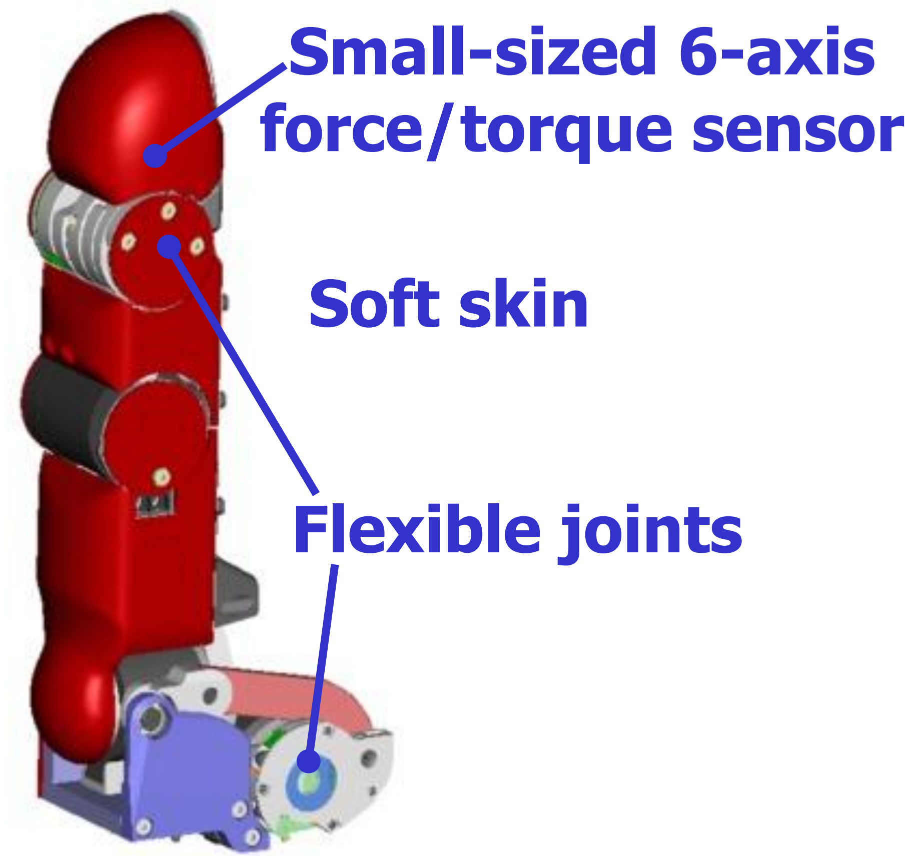


Absolute Rotary Encoder

DOF : 7
Passivity : Shoulder, Elbow
Length : 555 mm
Weight : 14.2 kg

TWENDY-ONE Hand



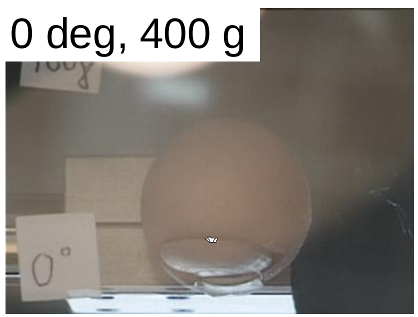


Design of Fingertip

Human Mimetic Finger Tip

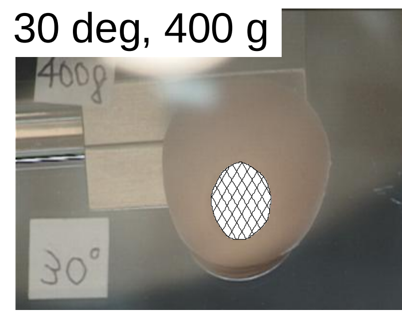
Finger Tip Orientation and Contact Area

0 deg, 400 g



15 deg, 400 g

30 deg, 400 g



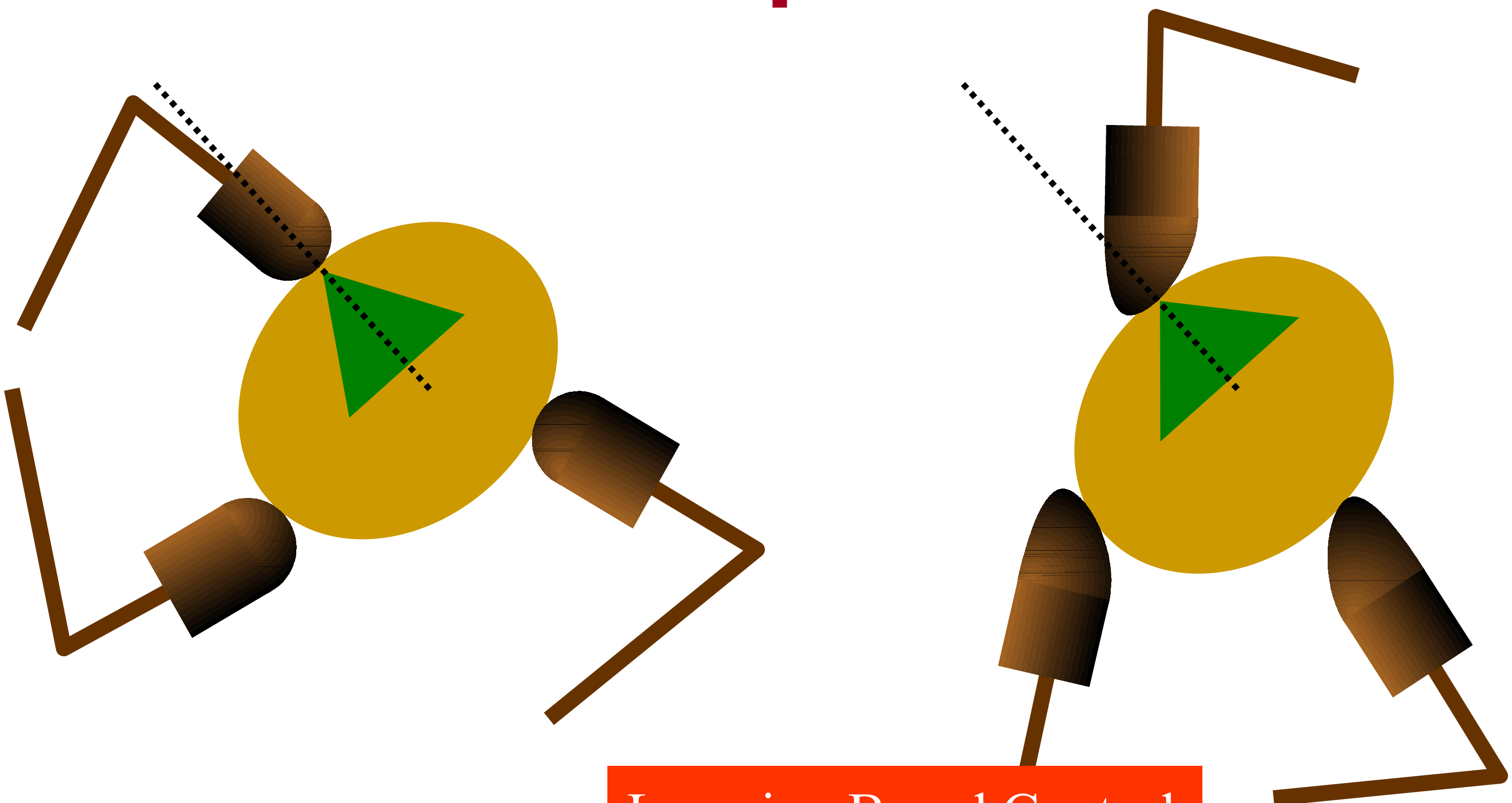
45 deg, 400 g

60 deg, 400 g

75 deg, 400 g

Design of Fingertip

Mechanics of Manipulation

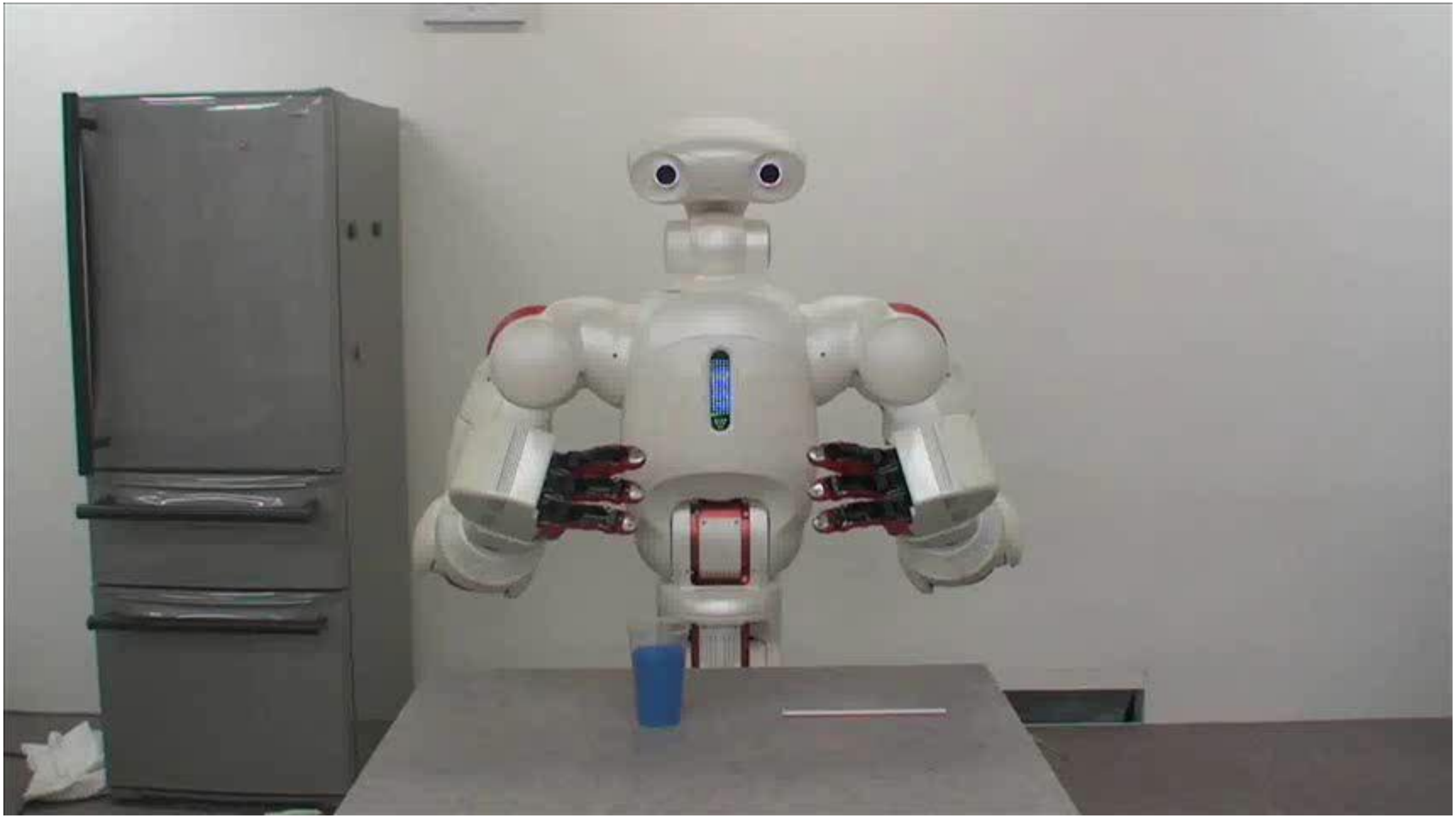


Learning Based Control

Easy to Converge

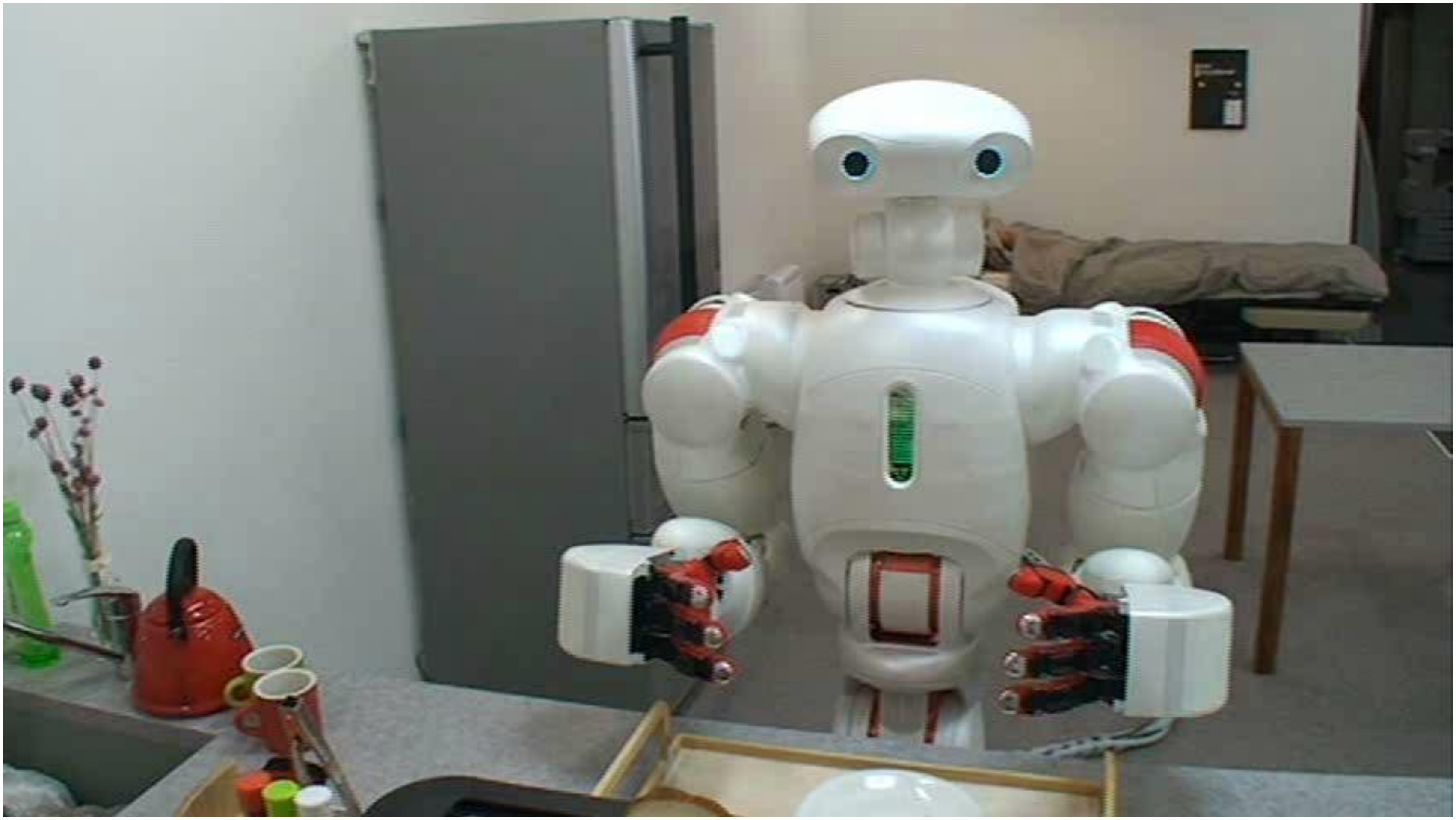
Egg Cooking

TWENDY-ONE



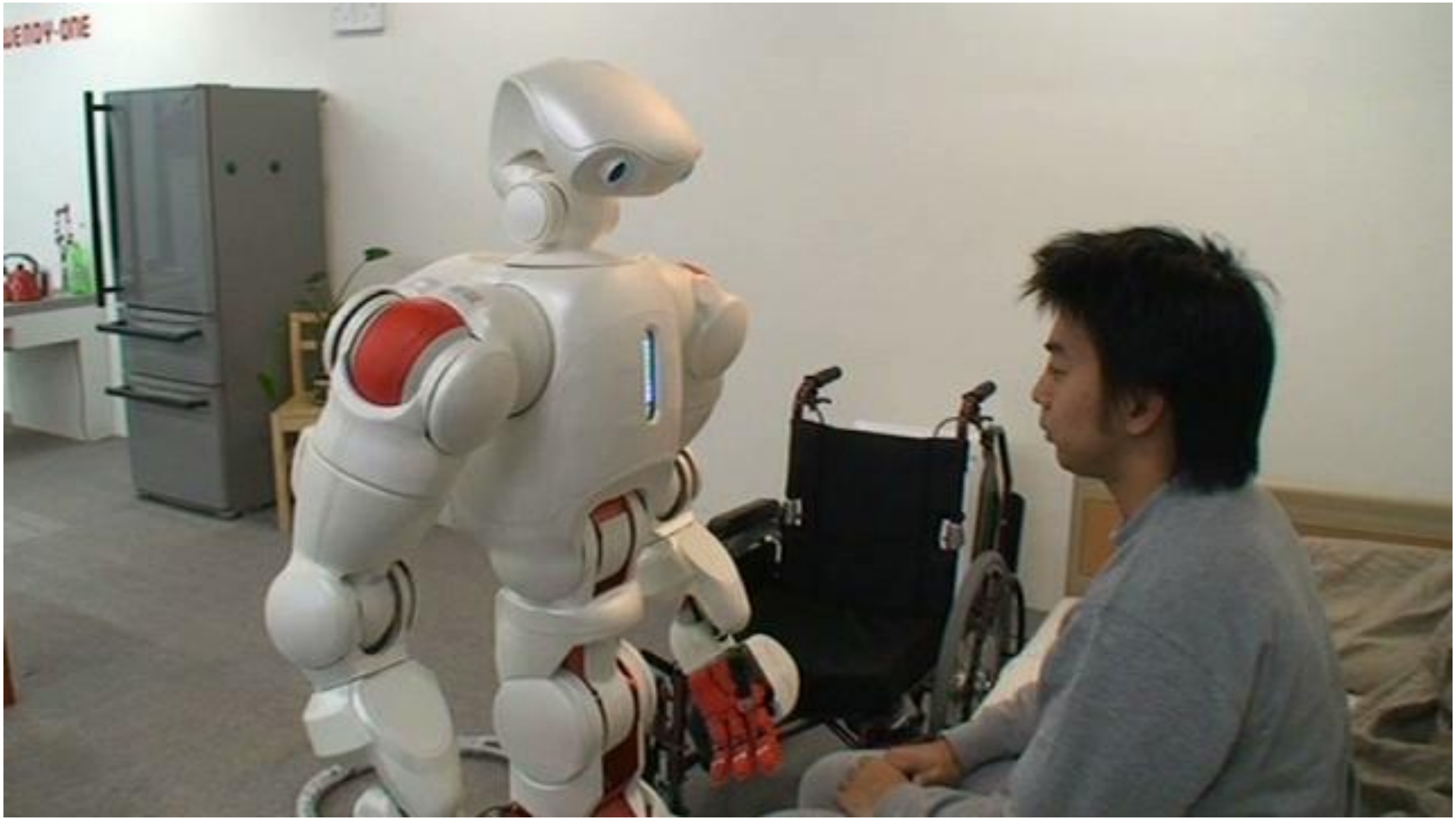
Dexterous Manipulation

TWENDY-ONE



Cooking Assistance

TWENDY-ONE



Human Assist

TWENDY-ONE

Human Assist

Tactile Object Recognition Team

Learning Method	Deep Learning	Shallow ANN
Recognition Rate	88.1	67.6

Comparison of Recognition Rate for Each Object

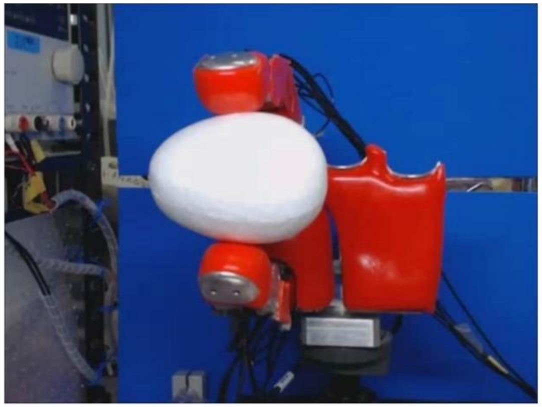
Object										
Shallow ANN (%)	16.4	70.2	69.8	68.8	62.3	78.5	28.7	90.6	5.12	56.5
Deep Learning (%)	83.1	99.8	99.2	98.8	85.3	88.8	69.6	91.7	63.7	87.6

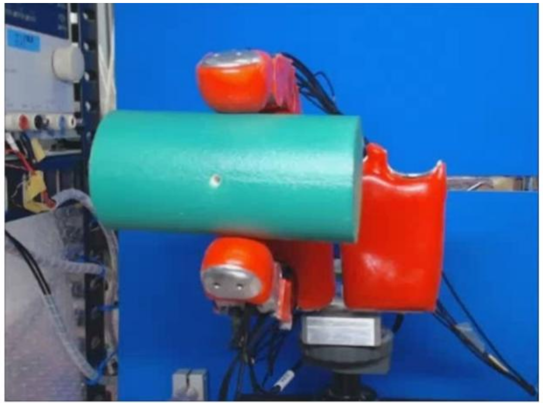
Object										
Shallow ANN (%)	48.8	95.71	89.8	58.8	19.9	95.5	96.97	99.65	99.6	99.2
Deep Learning (%)	93.1	92.6	97.5	76.9	70.6	92.8	100	97.6	74.8	97.8

Robust In-Hand Manipulation of Variously Sized and Shaped Objects

Satoshi FUNABASHI, Alexander SCHMITZ,
Takashi SATO, Sophon SOMLOR and Shigeki SUGANO
Waseda University, Japan

- TWENDY-ONE’s hand: 13 motors, springs, 6-axis F/T in fingertips, soft and sensitive skin
- Learning from demonstration
- Untrained/unknown object shape and posture
- Object size from initial grasping posture
- More stable with sensors
- More robust than interpolation control
- With deep learning less supervised learning necessary





Soft Actuation for Industry

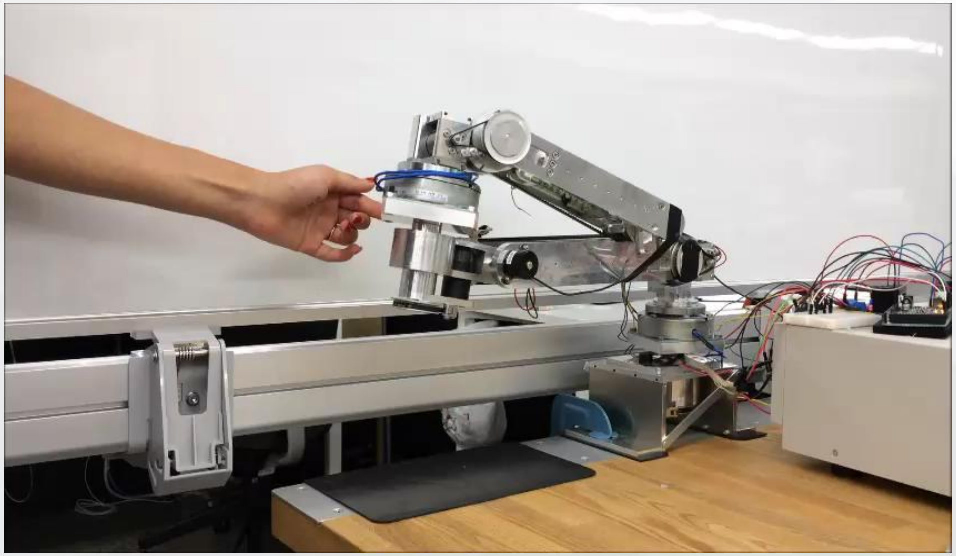
- Most industri... stiff
- Complianc... sensors
  - No intrin...
  - Time del...
- Instrinsic s... springs (SEA)
  - Used a lo...
  - But rarely...
    compromised position control

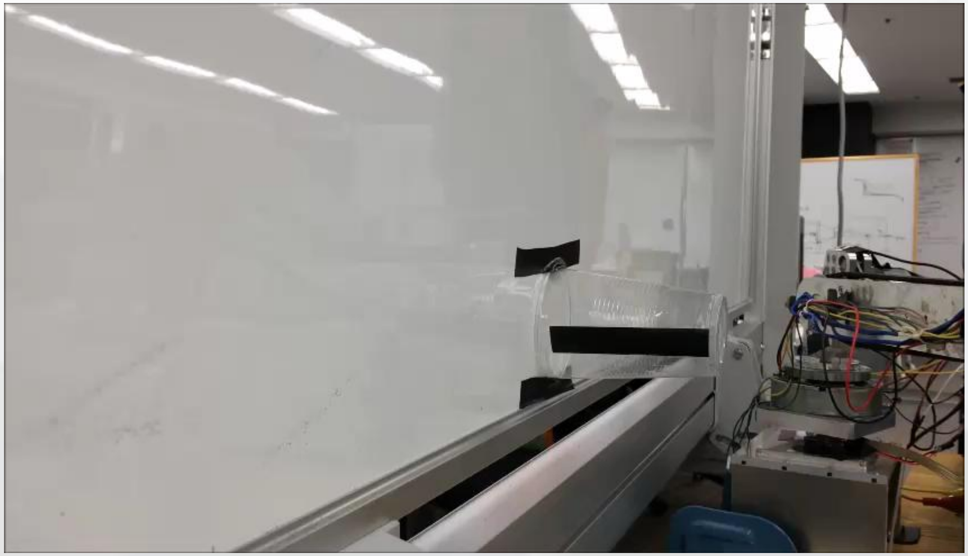
We want:

- **Precise**
- **Fast**
- **Safe**

Our approach

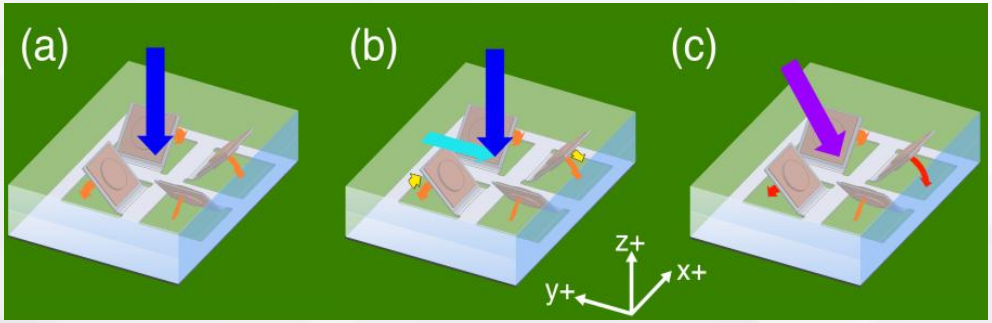
- Controllable impedance
- Backdrivable
- Separated force and position control



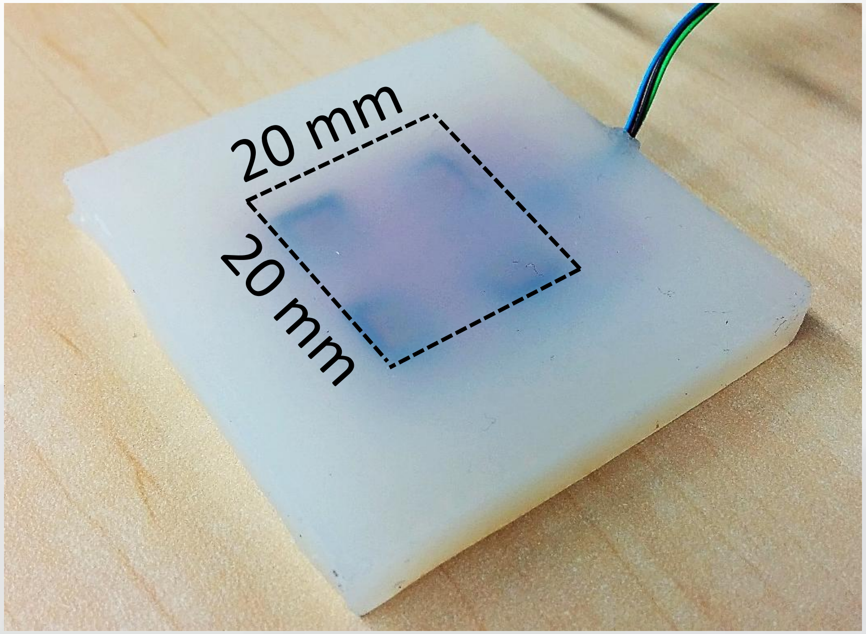


Importance of skin

- Furthermore, soft cover is crucial against impact forces
- Sensitive skin would add another layer of safety
- Current sensors: too big, mostly only 1-axis force



Soft. 3-axis measurements.
Physically small.
Digital output. Easy to produce.



Thanks

For listening