Tactile Sensing

- Description of touch in human
- Characteristic of touch in human
- Motivation for tactile sensing in robots
- Tactile Sensing on robotic hand

Tactile Sensing

- **Description of the touch in humans**
- **Characteristic of the touch in humans**
- Motivation for tactile sensing in robots
  Tactile Sensing on robotic hand

Touch

- What are the physical stimuli for touch?
- What is touch good for?
- What is the sensory apparatus for touch, and how do these structures change touch stimuli into electrical signals (neural firing rates)?

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- What is the sensory apparatus for touch, and how do these structures change touch stimuli into electrical signals (neural firing rates)?

Touch

- Touch refers to the sensations caused by mechanical displacement of the skin
- Perception of temperature changes
- Sensation of pain
- *Kinesthesis* – *Proprioception* (limb positions, tendons strength, …)

SOMATOSENSATION

Touch

- What are the physical stimuli for touch?
- **What is touch good for?**
- What is the sensory apparatus for touch, and how do these structures change touch stimuli into electrical signals (neural firing rates)?

Touch

- What is touch good for?
  - Grasping an object
  - Recognise an object
  - Buttoning your shirt
  - Brushing your teeth

Touch is useful when we are close to the object

Touch

- What are the physical stimuli for touch?
- What is touch good for?
- **What is the sensory apparatus for touch, and how do these structures change touch stimuli into electrical signals (neural firing rates)?**

Touch Physiology

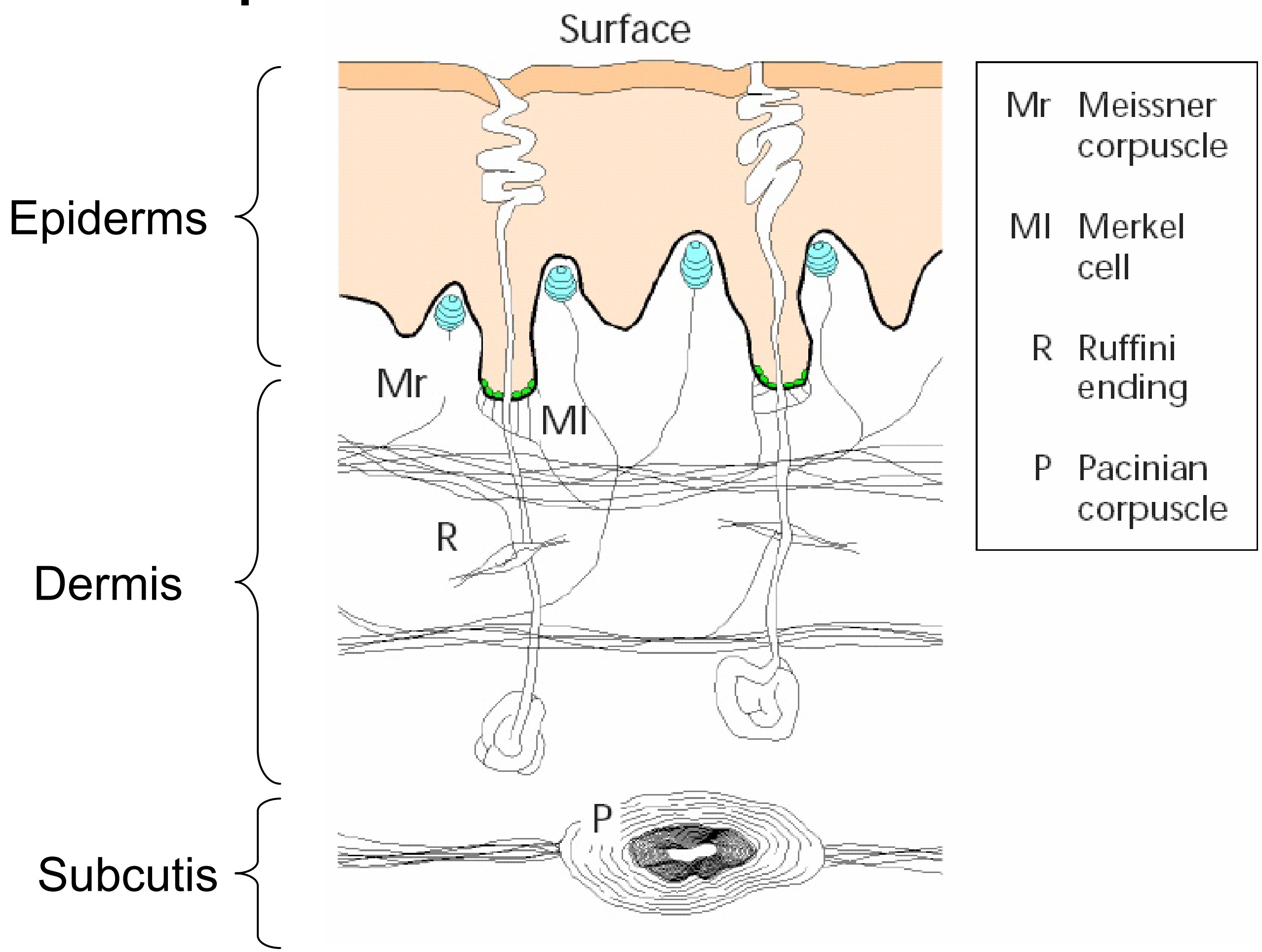
- Mechanoreceptors
- Thermoreceptor
- Nociceptor
- Proprioceptor

Touch Physiology

- **Mechanoreceptors**
- Thermoreceptor
- Nociceptor
- Proprioceptor

Touch Physiology

- Mechanoreceptors

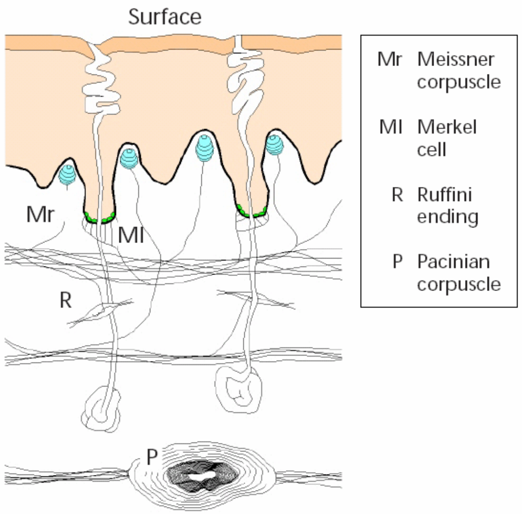


Mechanoreceptors

Merkel cell: Slow rate of adaptation, small size of receptive field

respond best to fine spatial details and are especially important in texture and pattern perception.

…reading Braille

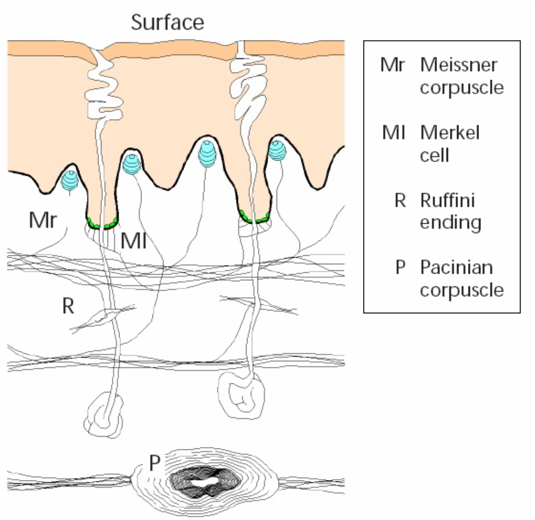


Mechanoreceptors

Ruffini ending: Slow rate of adaptation, large size of receptive field

respond to sustained downwards pressure, and particularly to lateral skin stretch, which occurs when you grasp an object.

…picking up a cup of tea

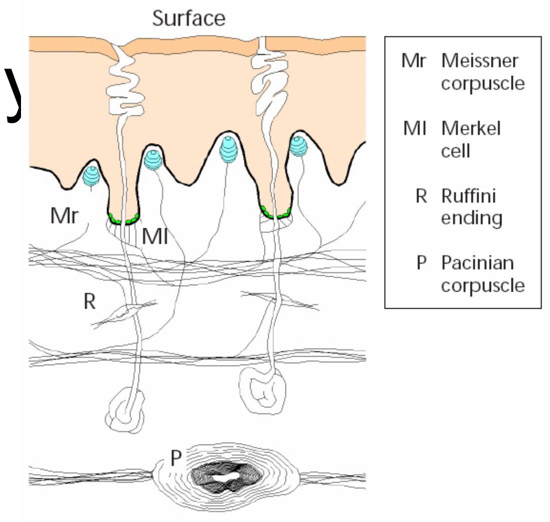


Mechanoreceptors

Meissner corpuscles: Fast rate of adaptetion, small size of receptive field

respond to low frequency vibration (3-40Hz).

…the cup of tea is slipping across y

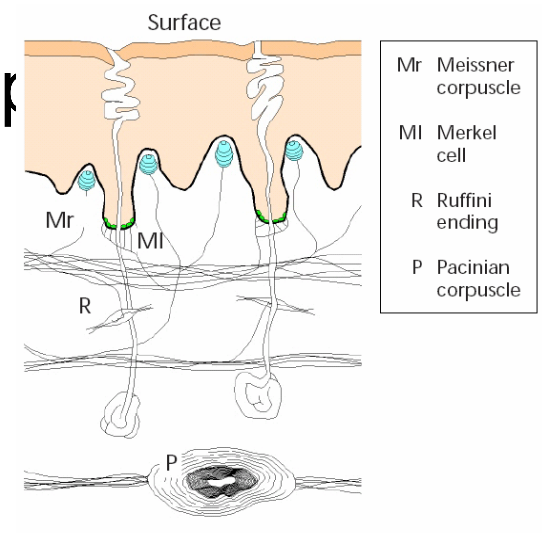


Mechanoreceptors

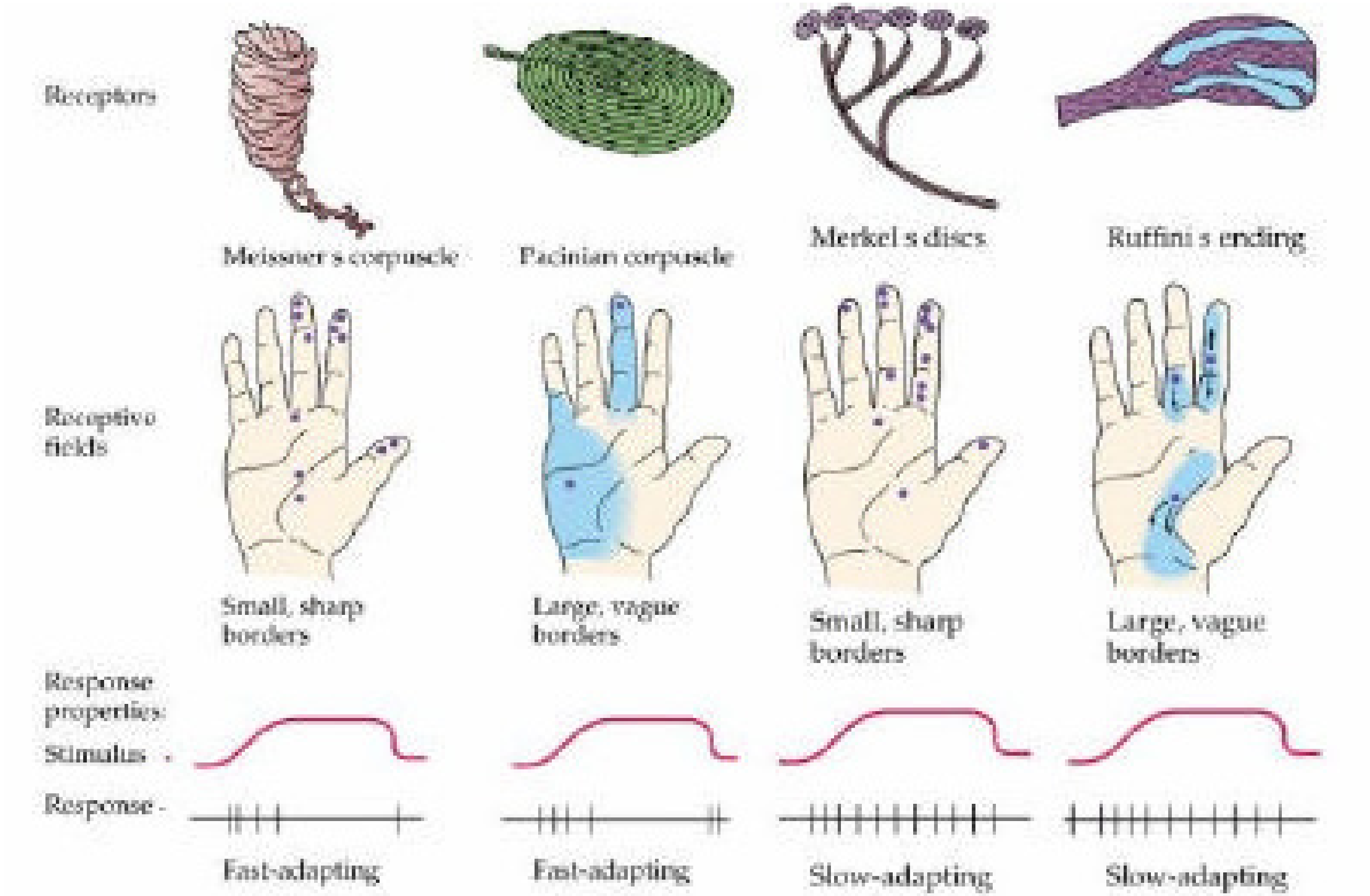
Pacinian corpuscles: Fast rate of adaptetion, large size of receptive field

respond to high frequency vibration (40-500Hz).

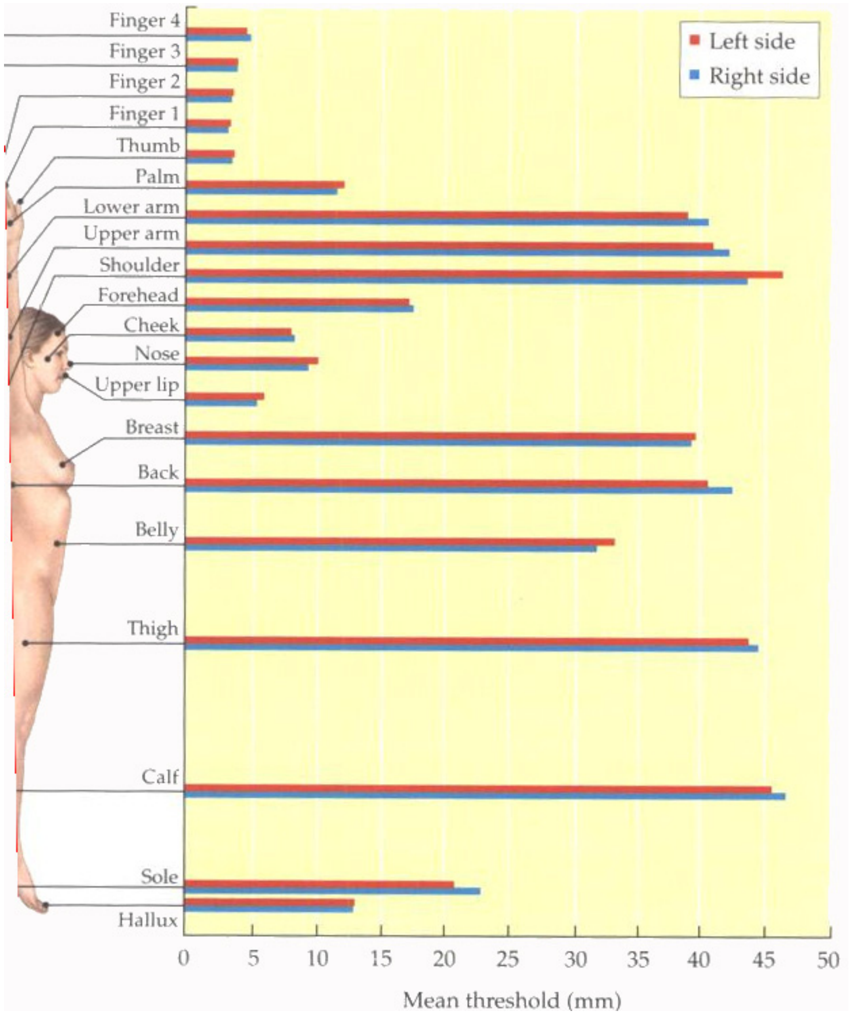
…when you are writing on a piece of p



Mechanoreceptors



Touch



Finger 4
Finger 3
Finger 2
Finger 1
Thumb
Palm
Lower arm
Upper arm
Shoulder
Forehead
Cheek
Nose
Upper lip
Breast
Back
Belly
Thigh
Calf
Sole
Hallux
Left side
Right side
0
5
10
15
20
25
30
35
40
45
50
Mean threshold (mm)

Touch Physiology

- Touch refers to the sensations caused by mechanical displacement of the skin
- Perception of temperature changes **THERMORECEPTORS**
- Sensation of pain **NOCICEPTORS**
- *Kinesthesis – Proprioception* (limb positions, tendons strength, …) **KINESTETIC RECEPTORS**

MUSCLE SPINDLES

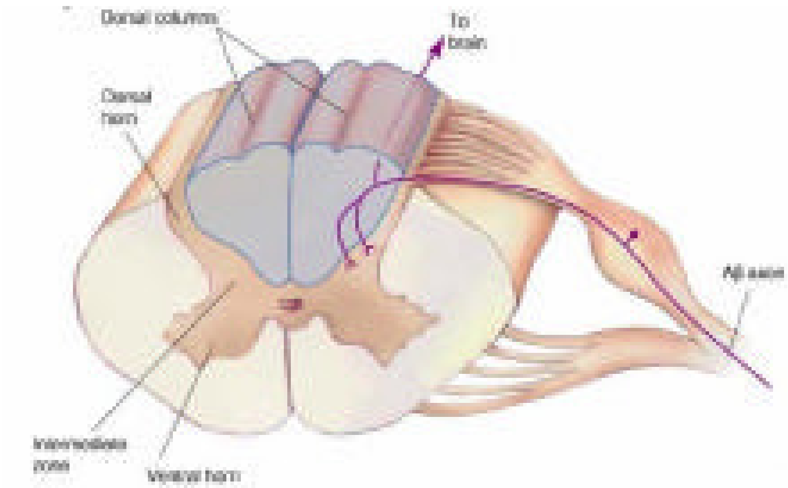
GOLGI TENDONS

SOMATOSENSATION

From skin to brain

- Axons of various tactile receptors are combined into single nerve trunks
- There are many somatosensory nerve trunks, arising hands, arms, feet, legs,…
- There are axons synapse in the spinal cord.

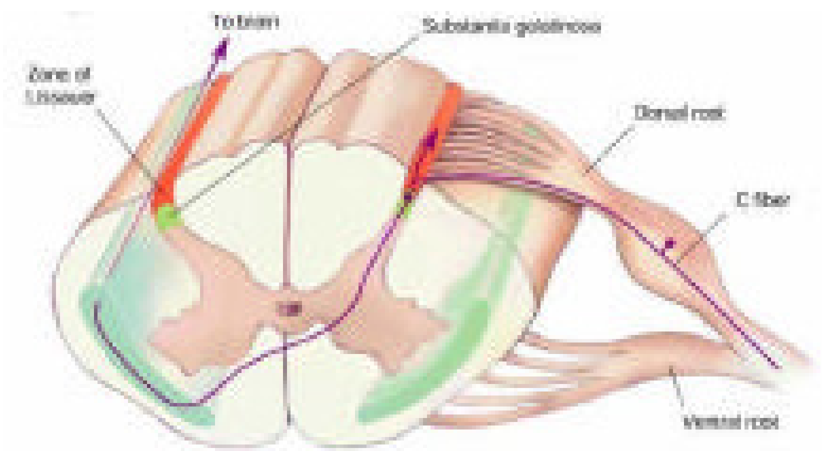
From skin to spinal cord



Dorsal Column Medial <u>Lemniscal</u>

(Fibers Aα, Aβ, Aδ)

Touch, Vibration, proprioception



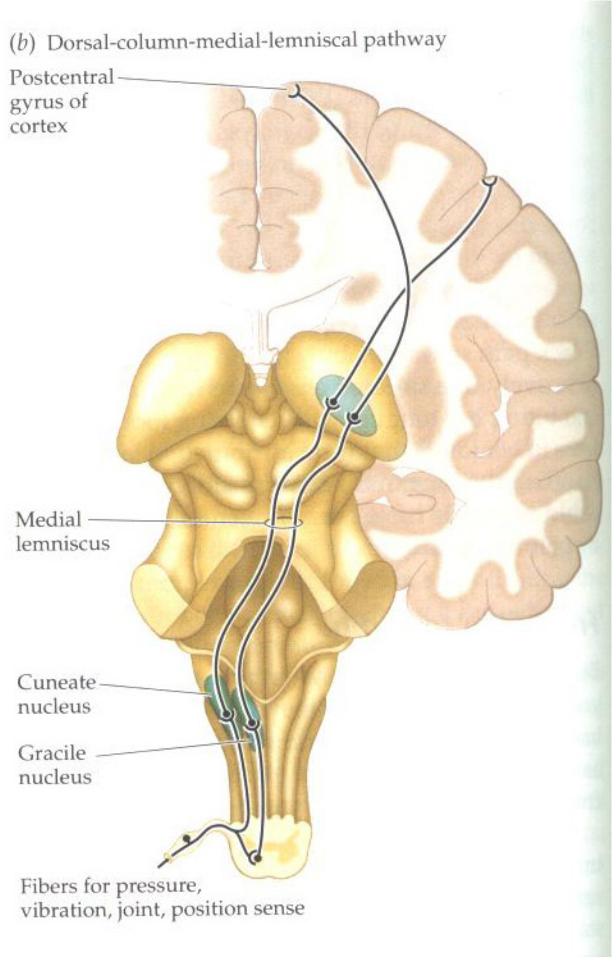
Ventral Spinothalamic pathway

(Fibers C)

Temperature, pain

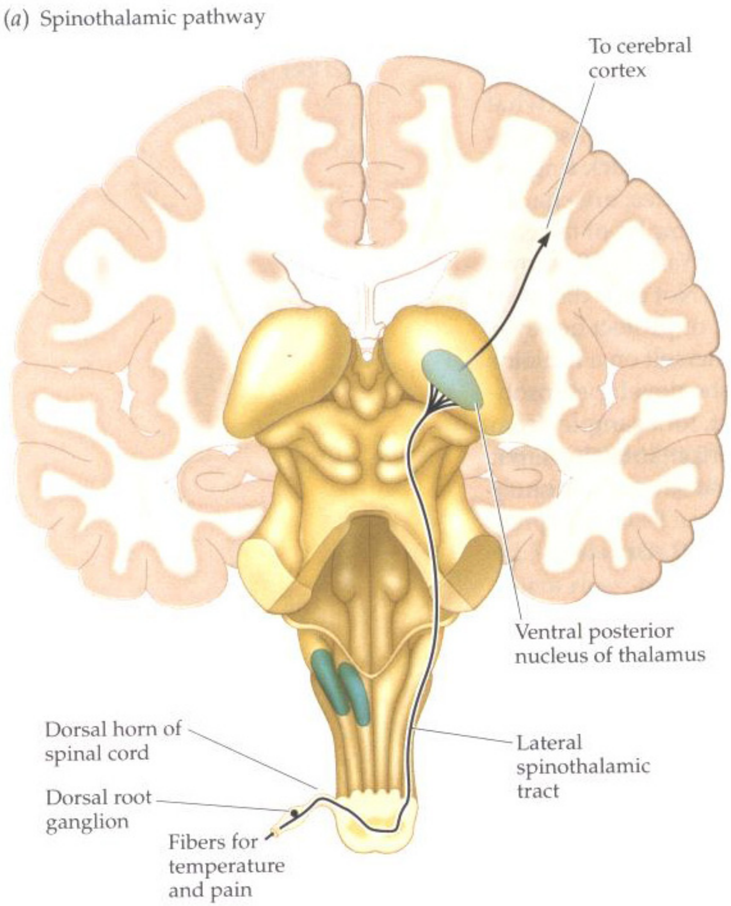
From spinal cord to the brain

- **Dorsal-column-medial-lemniscal pathway (DCML)**
  - Wider diameter axons
  - Faster
  - Tactile and proprioceptive information

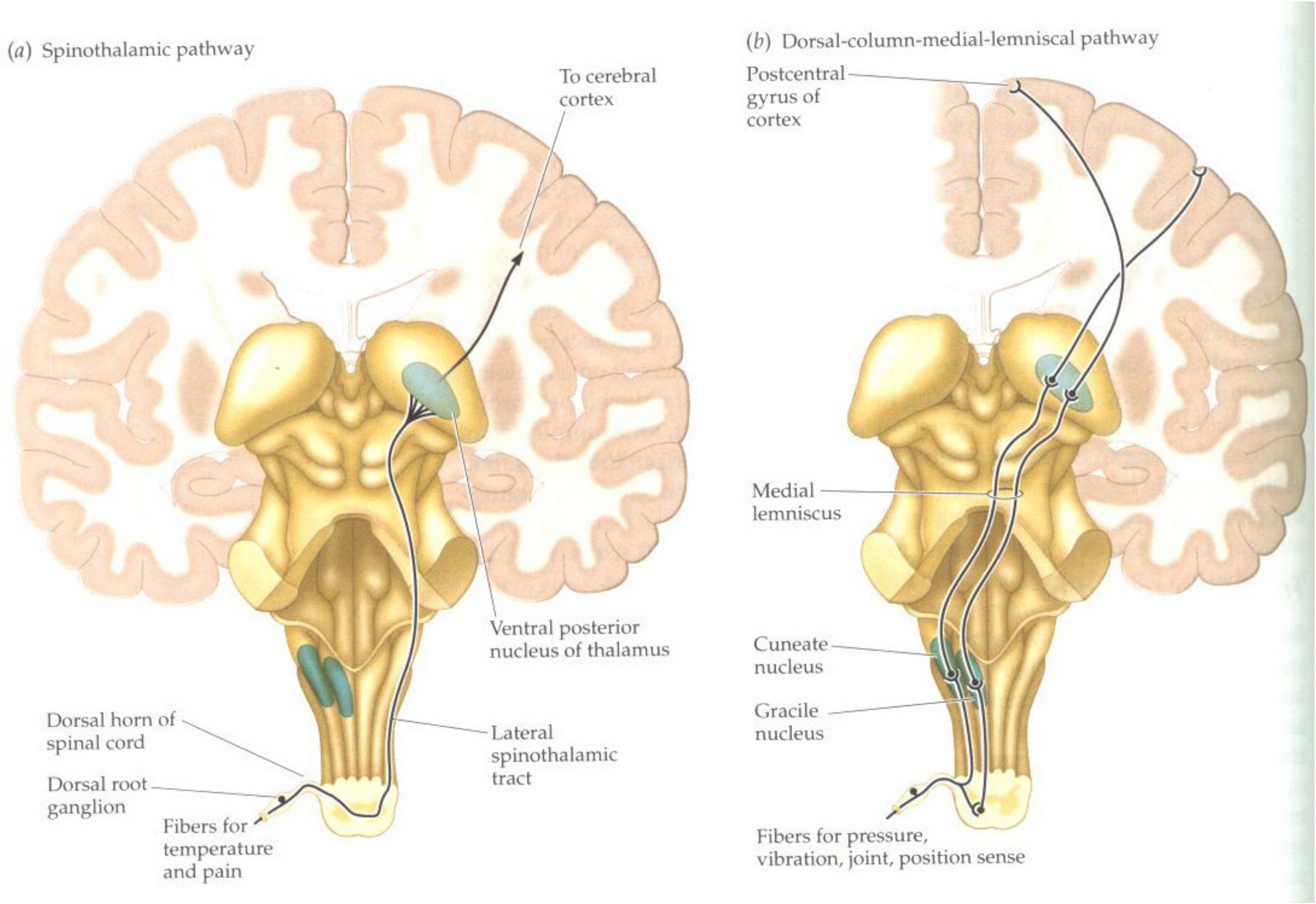


From spinal cord to the brain

- **Spinothalamic pathway**
  - The slower pathway
  - Nociceptor and Thermoreceptor

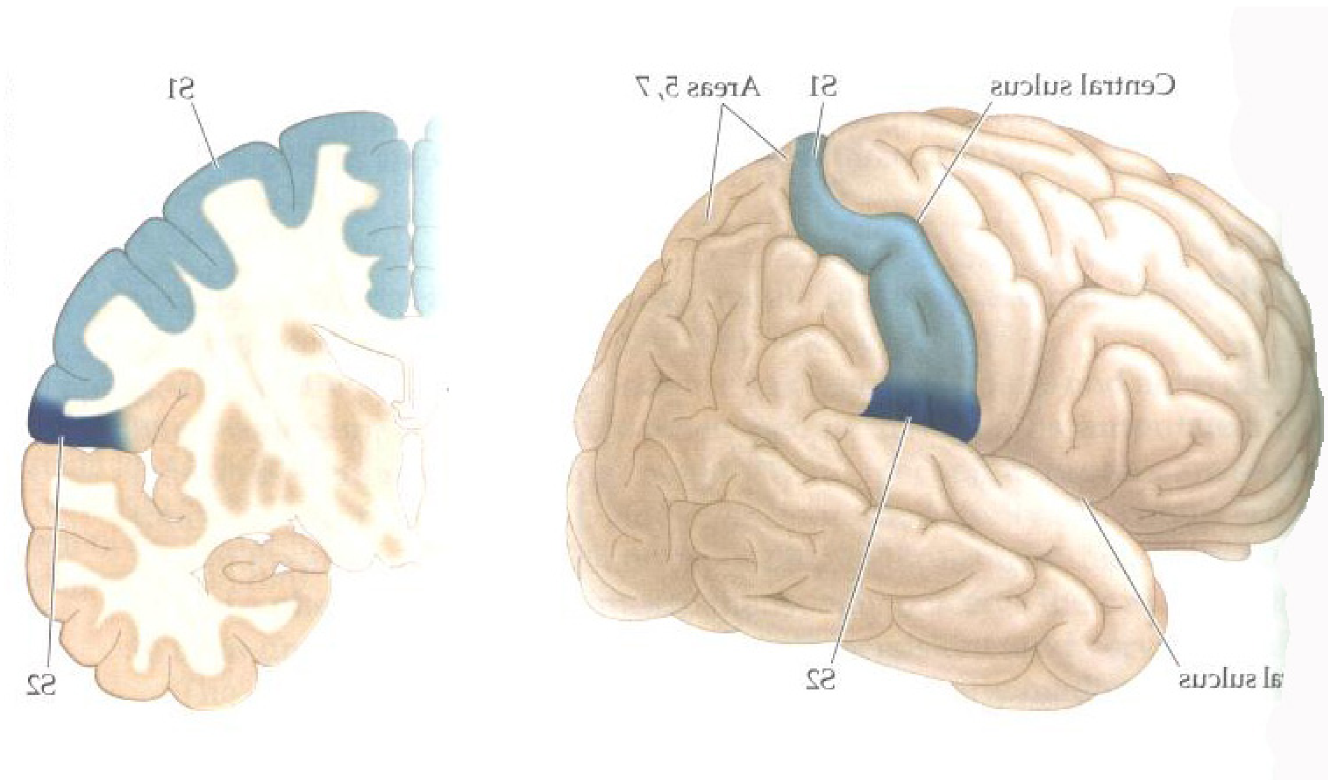


From spinal cord to the brain

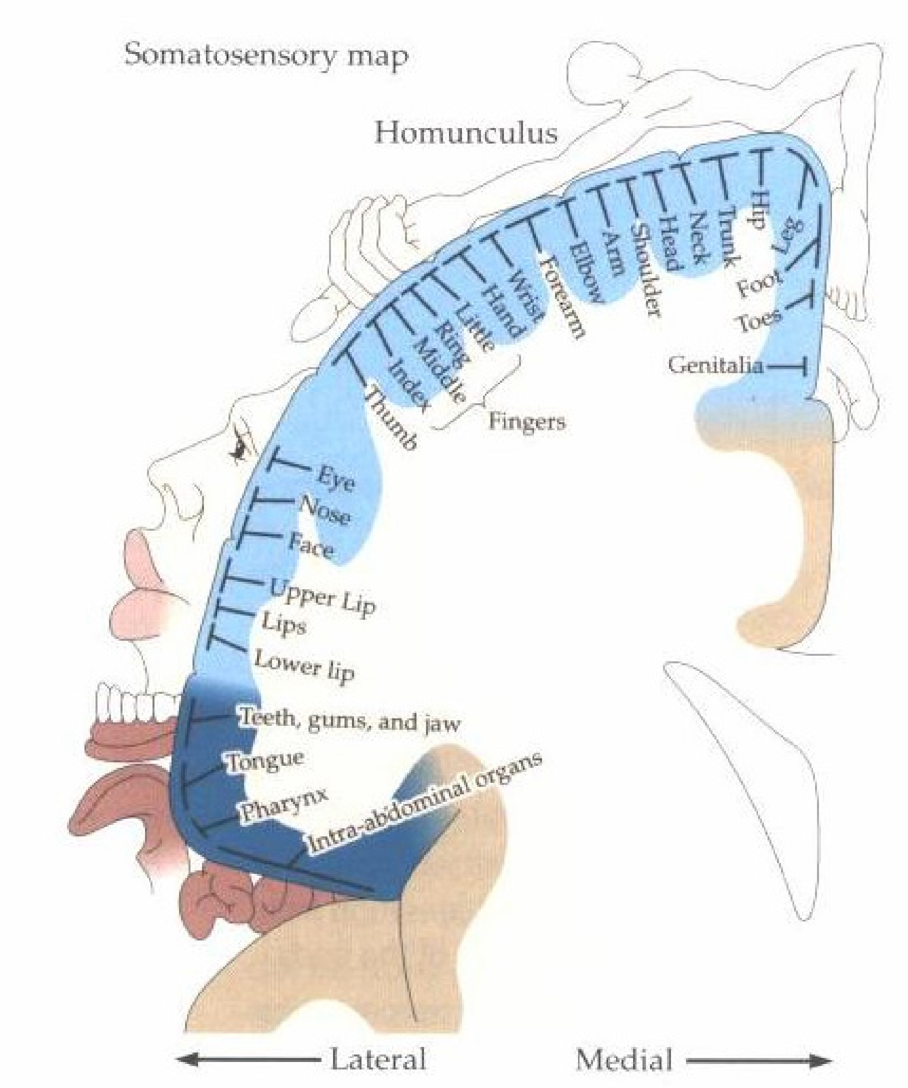


Somatosensory Map

- From the thalamus to S1



Somatosensory Map



Somatosensory Map

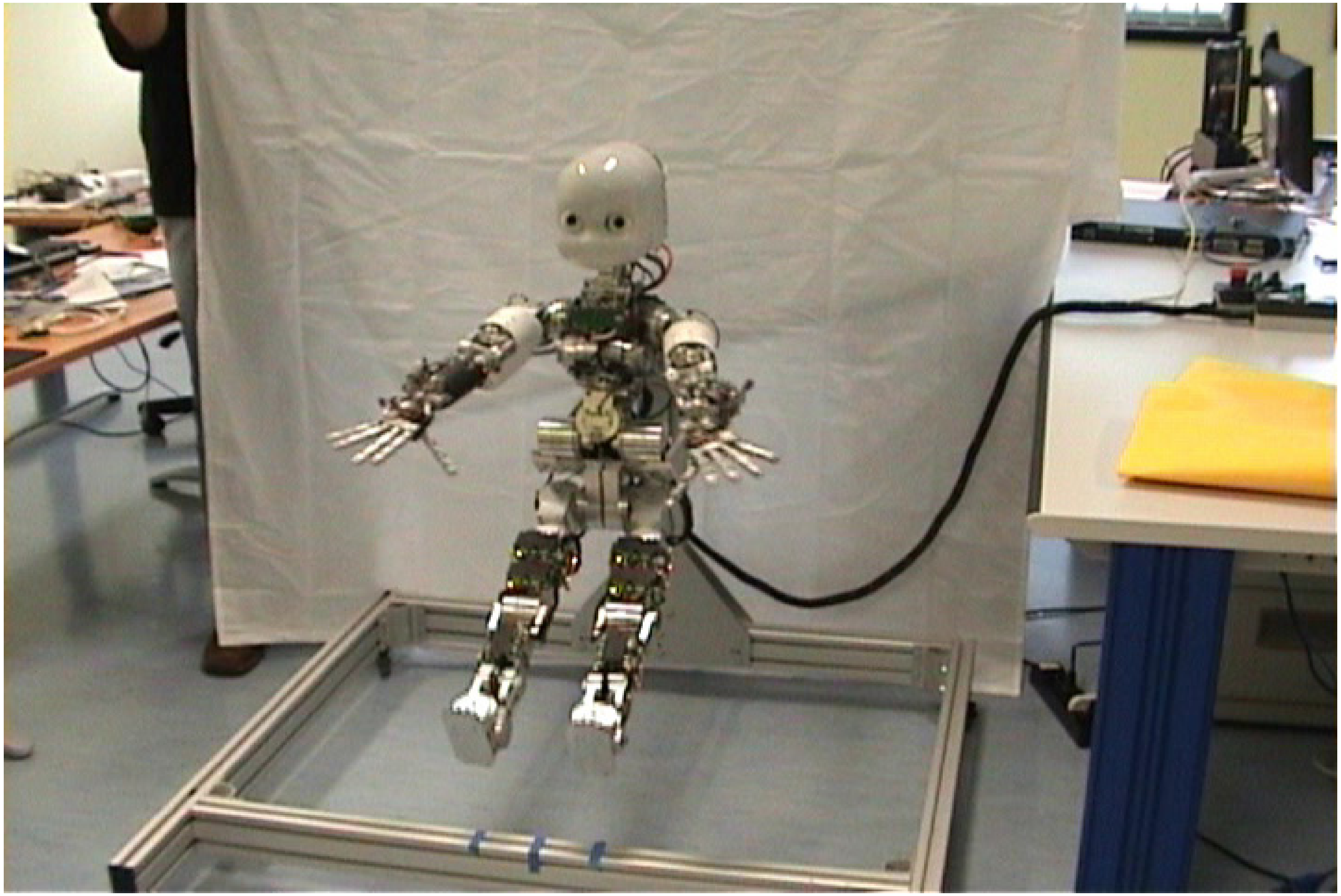
Tactile Sensing

- Description of the touch in humans
- Characteristic of the touch in humans
- **Motivation for tactile sensing in robots**
- Tactile Sensing on robotic hand

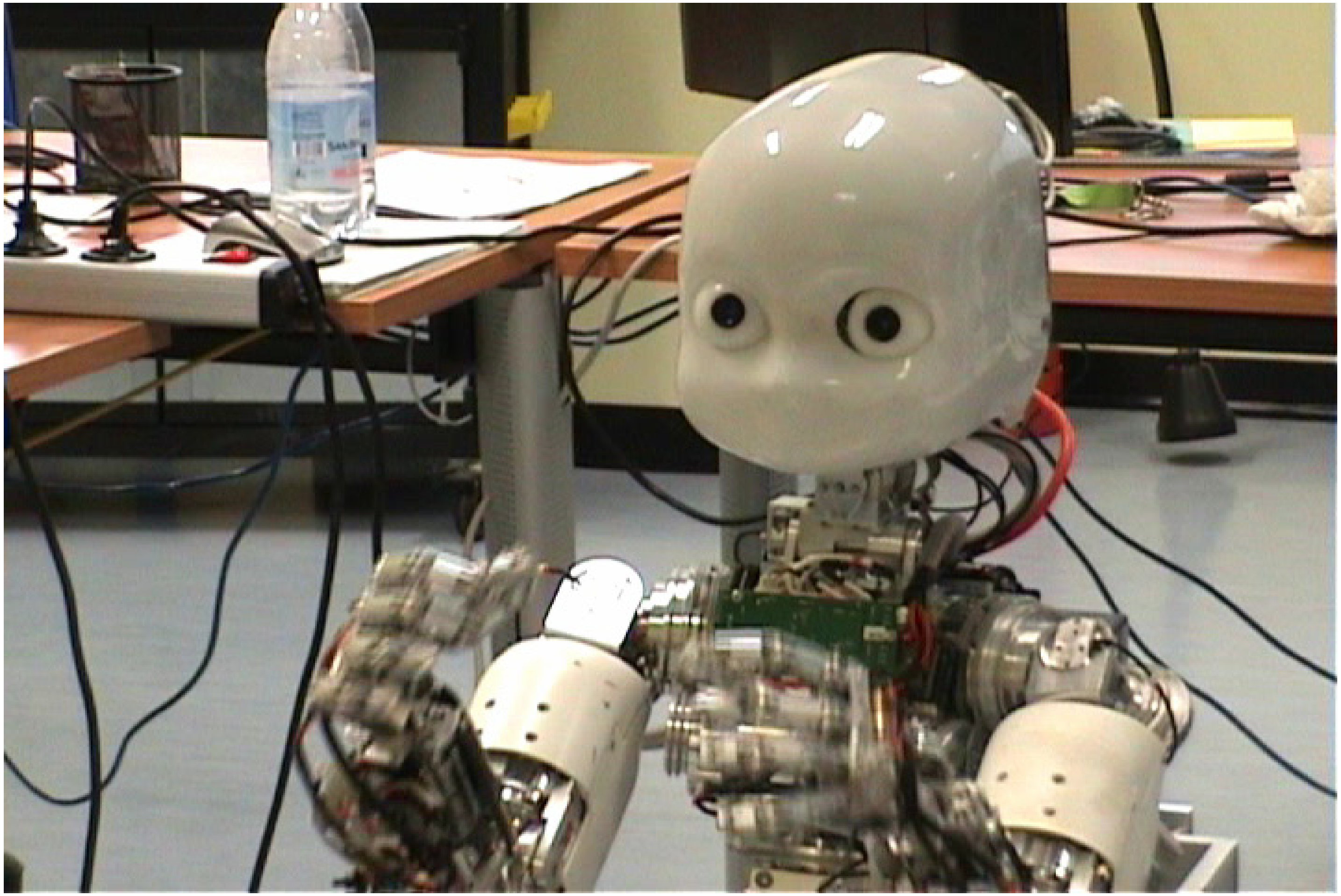
Tactile Sensing in robots

- Detecting contact with the environment
- Safety
- Grasping an object
- Walking/ Crawling
- Cooperative task with humans

Tactile Sensing in robots



Tactile Sensing in robots



Tactile Sensing

- Description of the touch in humans
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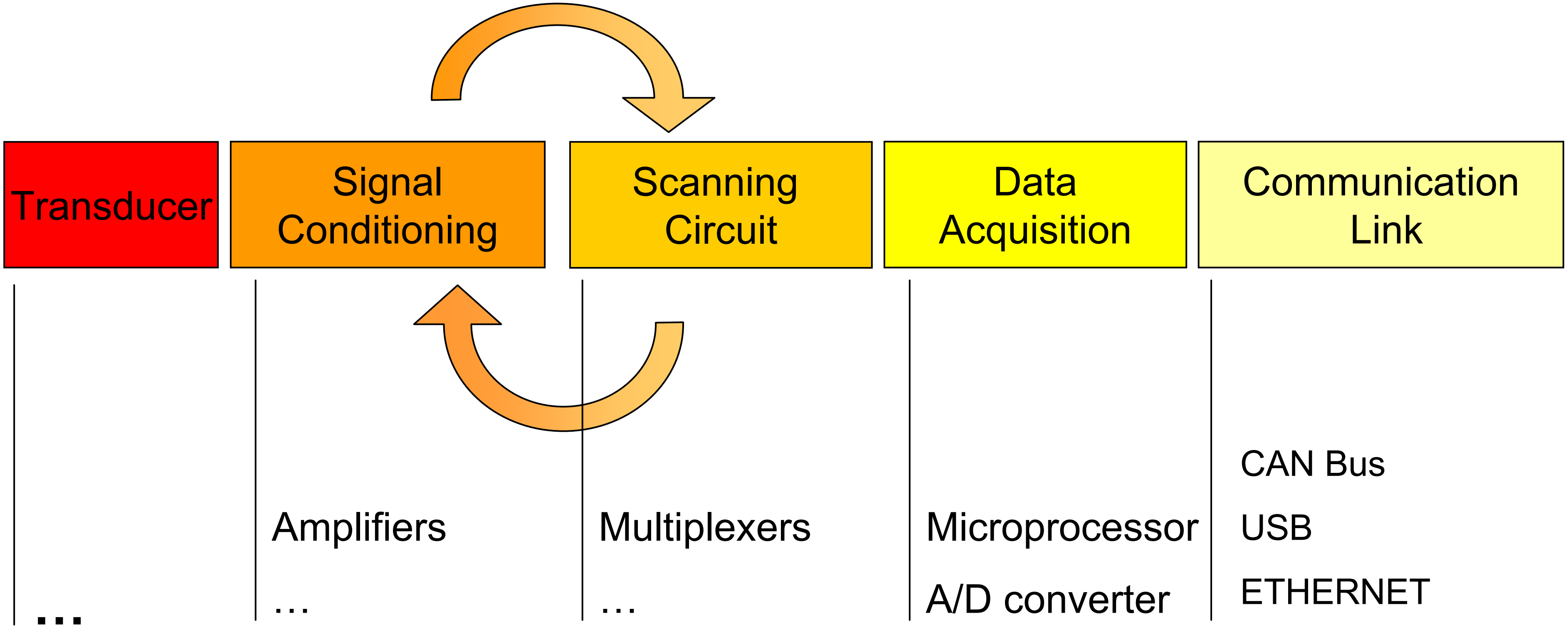
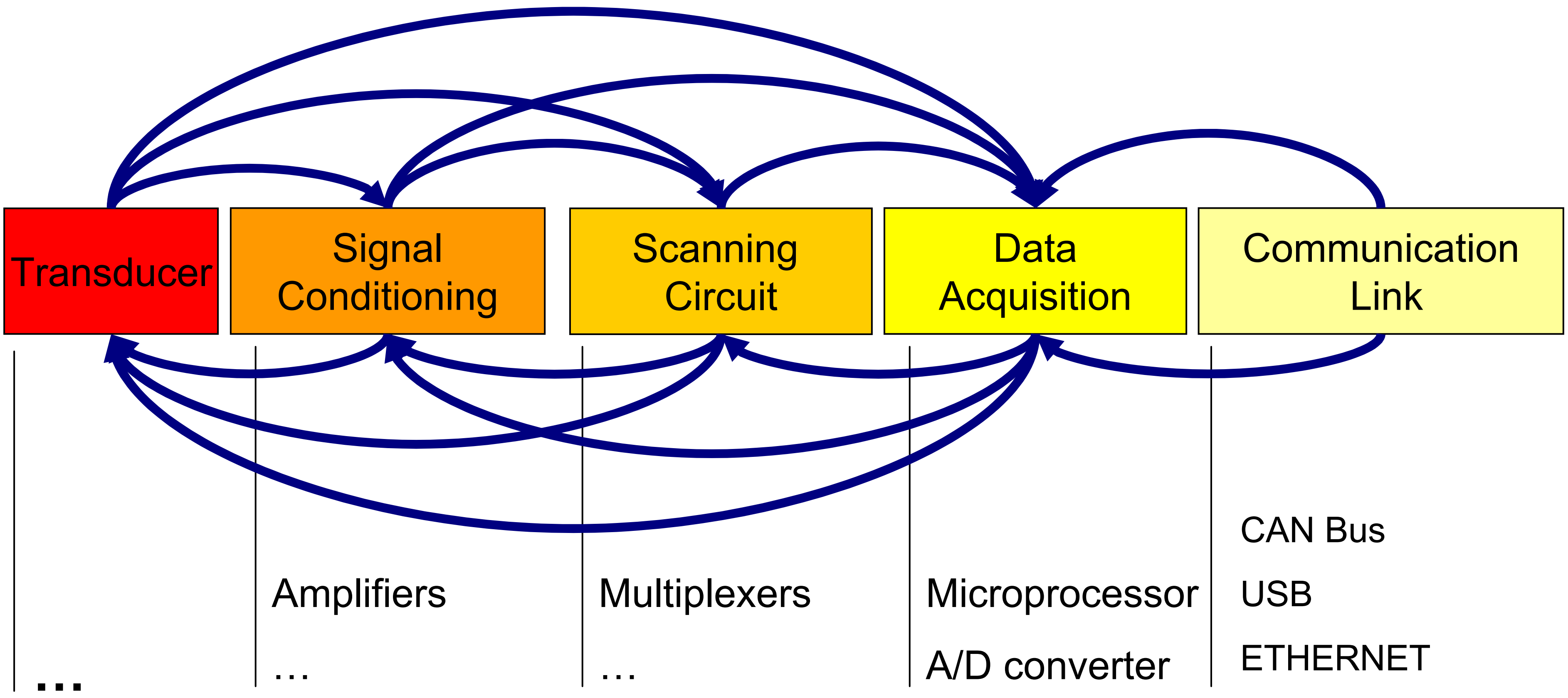
Tactile Sensing on robotic hands

Tactile Sensor System



Block dependences



What we want to minimize?

- Transducer size
- Signal Conditioning components
- Scanning circuit components
- Wires
- Bandwidth of the communication link

What we want to maximize?

- Sensitivity of the Taxels (tactile element)
- Spatial Resolution
- # of Taxels
- # of measurements (normal force, shear stress, …)

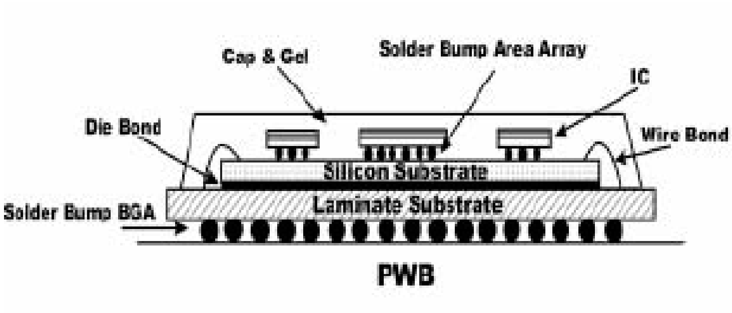
What we want to minimize?

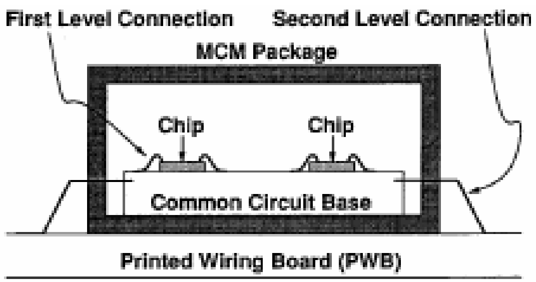
- Transducer size
- Signal Conditioning components
- Scanning circuit components
- Wires
- Bandwidth of the communication link

Silicon based transducers with Amp embedded on a single chip are under development

HIGH DENSITY PACKAGING

HIGH DENSITY PACKAGING





Multi - Chip - Package

What we want to minimize?

- Transducer size
- Signal Conditioning components
- Scanning circuit components
- Wires ⇨ **MID Technology**
- Bandwidth of the communication link

•Molded Interconnect Device

MID technology is to unite electrical and mechanical functions in a single construction unit.

What we want to minimize?

- Transducer size
- Signal Conditioning components
- Scanning circuit components
- Wires
- Bandwidth of the communication link

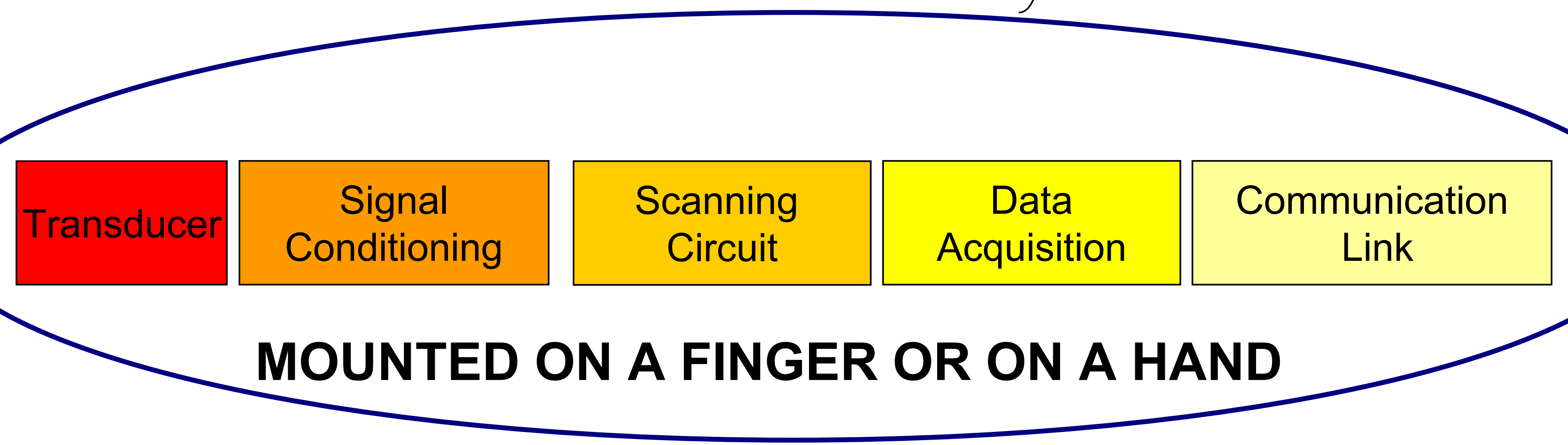
FlexRay (Fast CAN 10 Mb/s)

IEEE1355 SpaceWire (100 Mb/s to 1Gb/s)

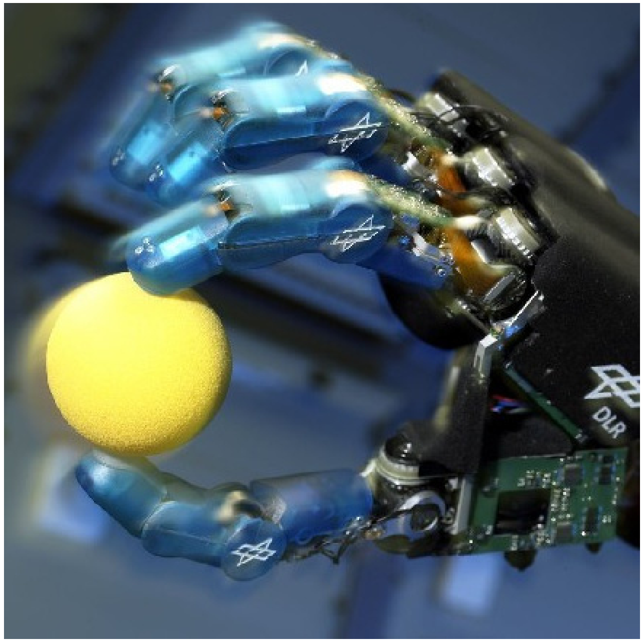
What we want to minimize?

- Transducer size
- Signal Conditioning components
- Scanning circuit components
- Wires
- Bandwidth of the communication link

Embedded Electronic

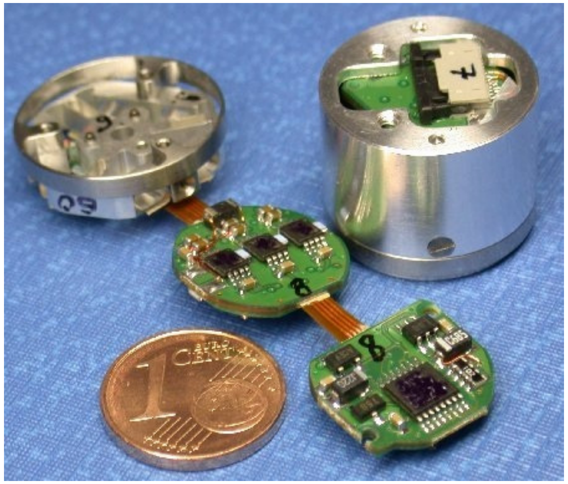


DLR II Hand 2004

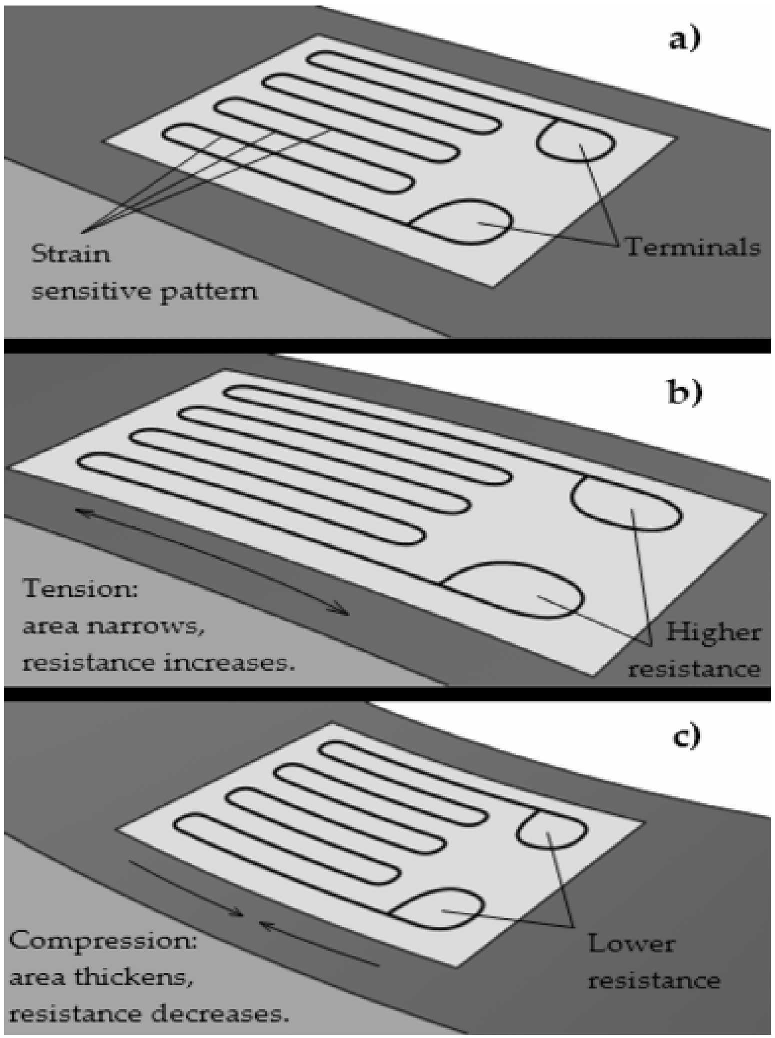


6-axis force sensor custom made with strain gauges and embedded electronic on the fingertip.

Serial communication with PowerPC

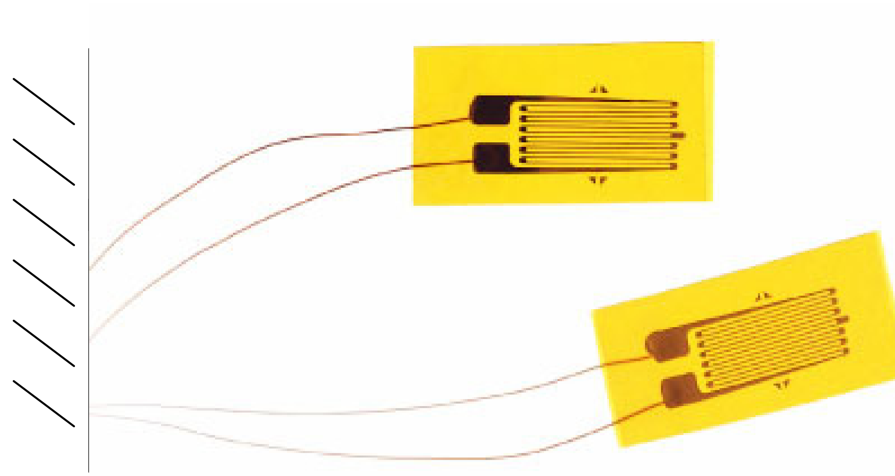


Strain Gauges



A mechanical stress produces a variation in the resistance.

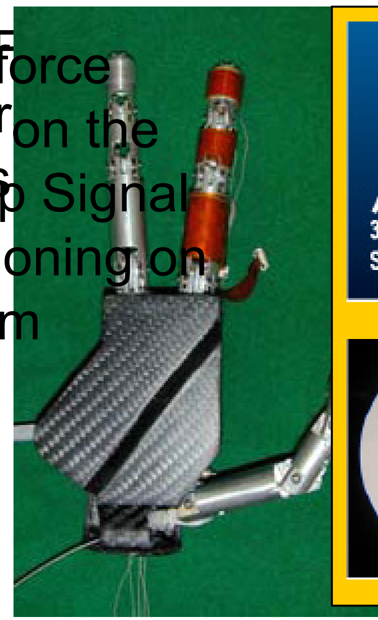
The variation in the resistance due to the stress is comparable with the one due to the temperature variation so it is required to do differential measurements.

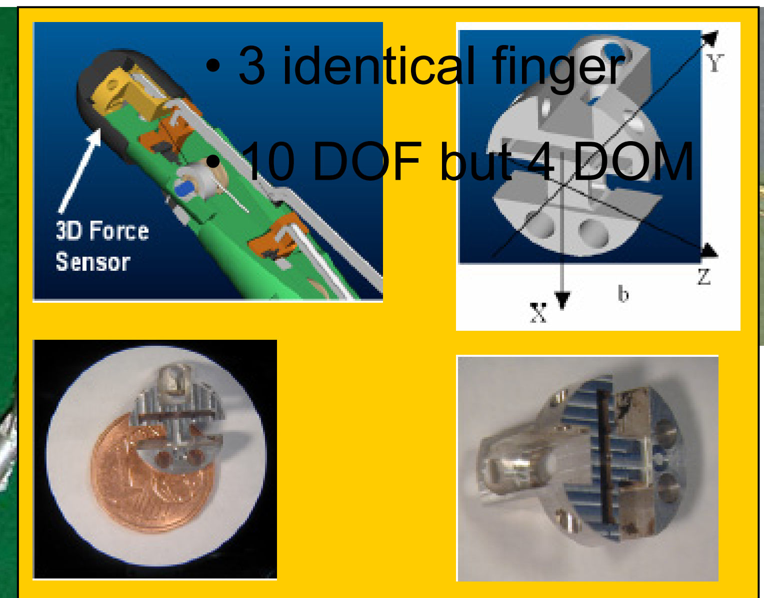


RTR II Hand

ON-OF
sensor
fingers
to 40)

3-axis force sensor on the fingertip Signal Conditioning on the palm

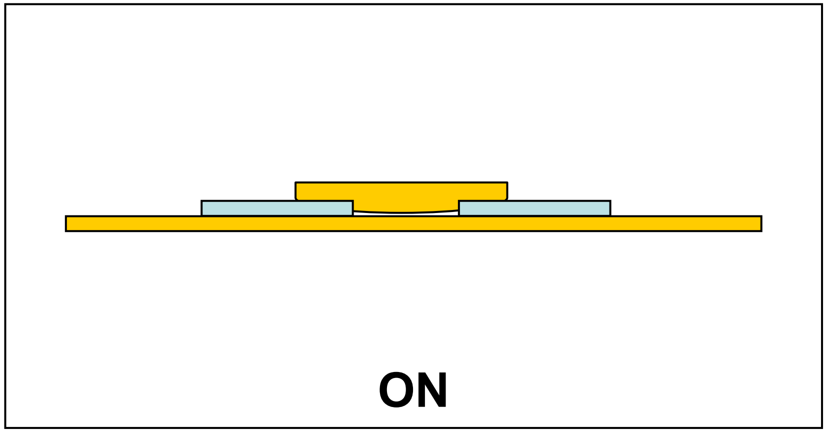


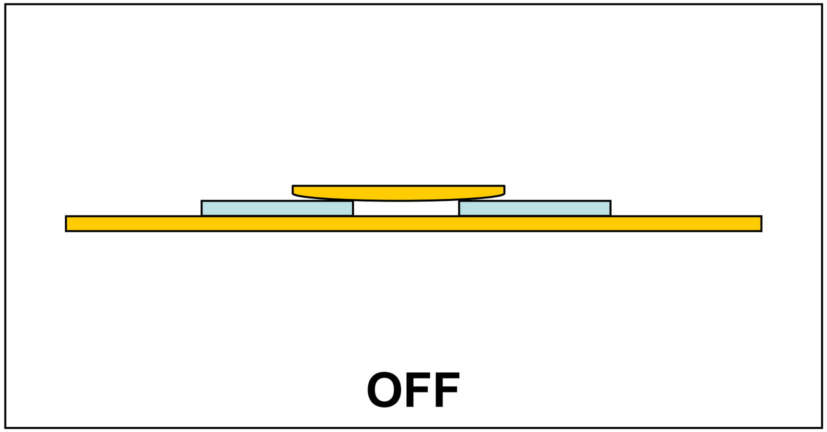


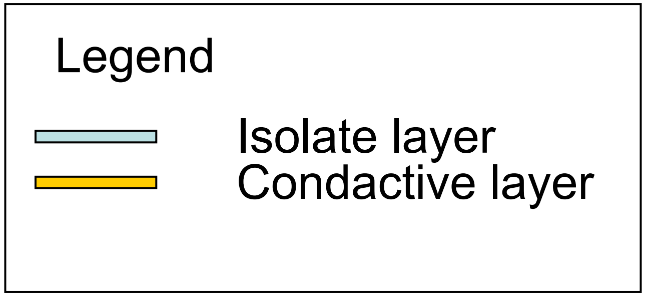
- 3 identical finger
- 10 DOF but 4 DOM

ON-OFF Sensor

- They provide only a digital information Contact or Not Contact







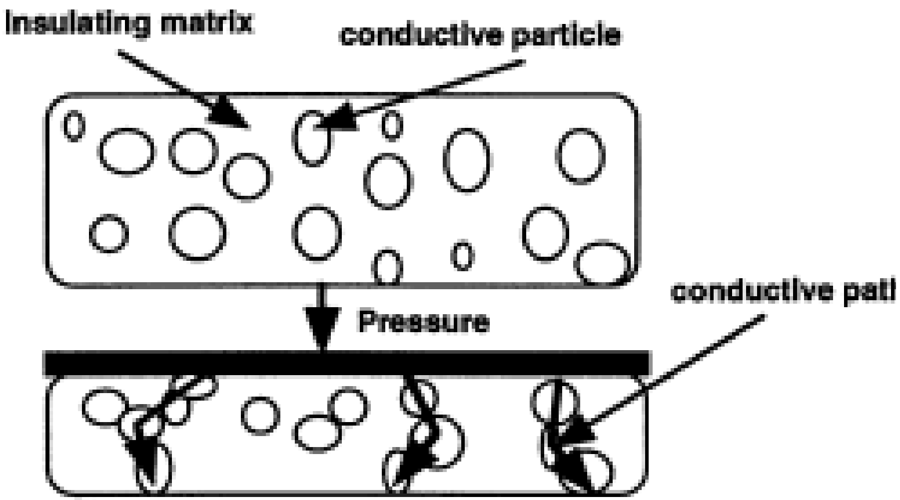
GIFU HAND III

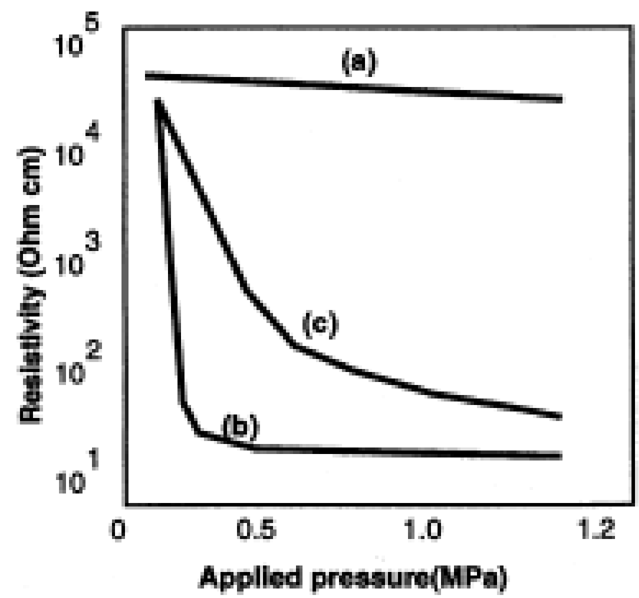

Gifu Hand III

number of detecting points:	
total	624
palm	312
thumb	72
finger	60
maximum load [N/m^2]	$7.4x10^{-4}$
electrode width [mm]	2
column pitch [mm]	4
row pitch [mm]	6
sampling cycle [ms/flame]	10
resolution [bit]	8
thickness of sensor sheet [mm]	0.1
weight [gf]	12.5

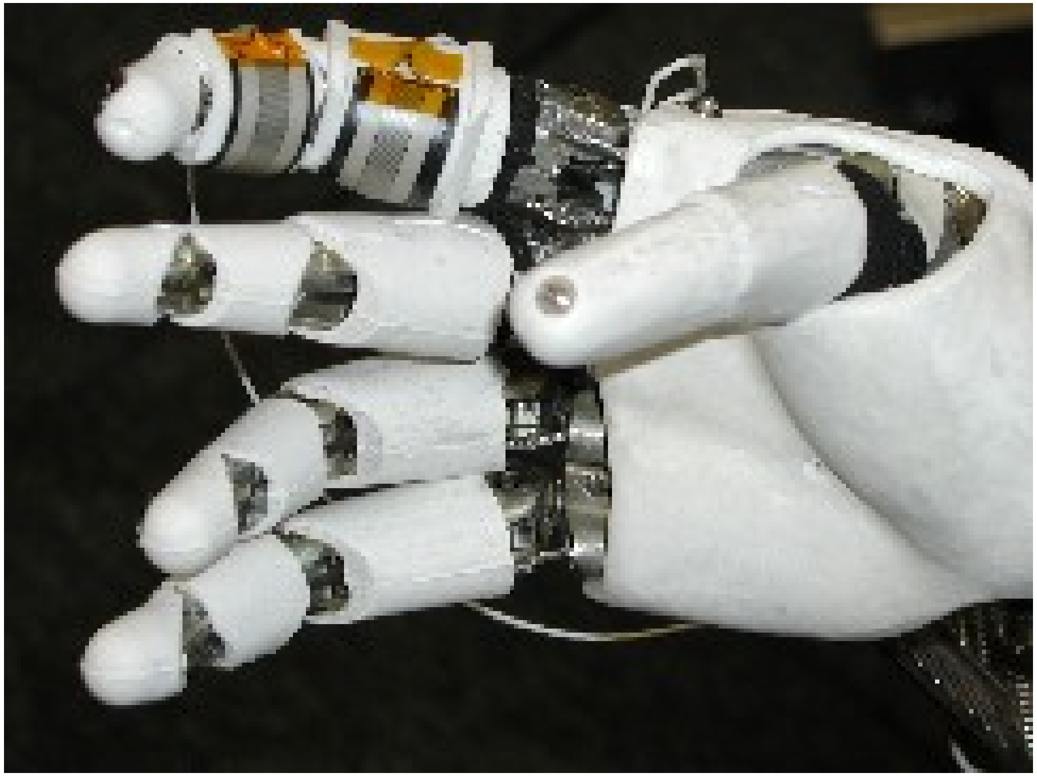
Based on Pressure Sensitive Ink

Pressure Conductive Rubber





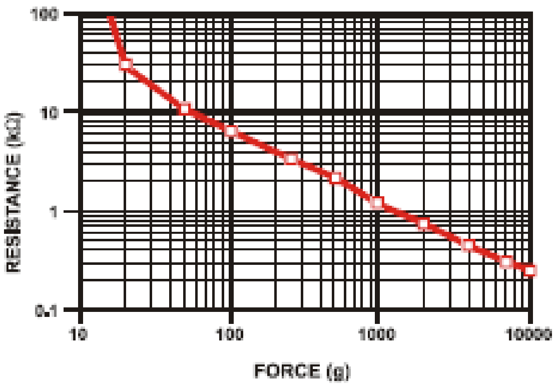
Robonaut Hand



FSR based tactile sensor

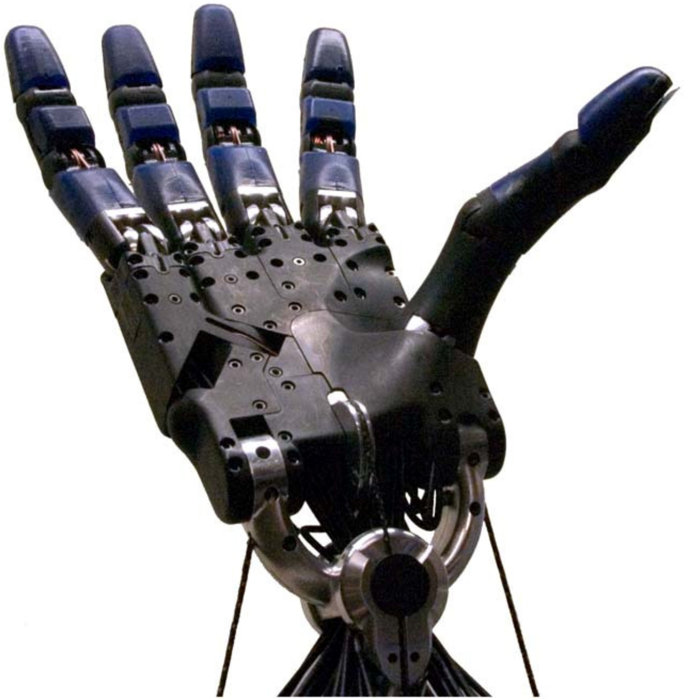
FSR

Force Sensor Resistor



Force Sensing Resistors (FSR) are a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface

Shadow Hand

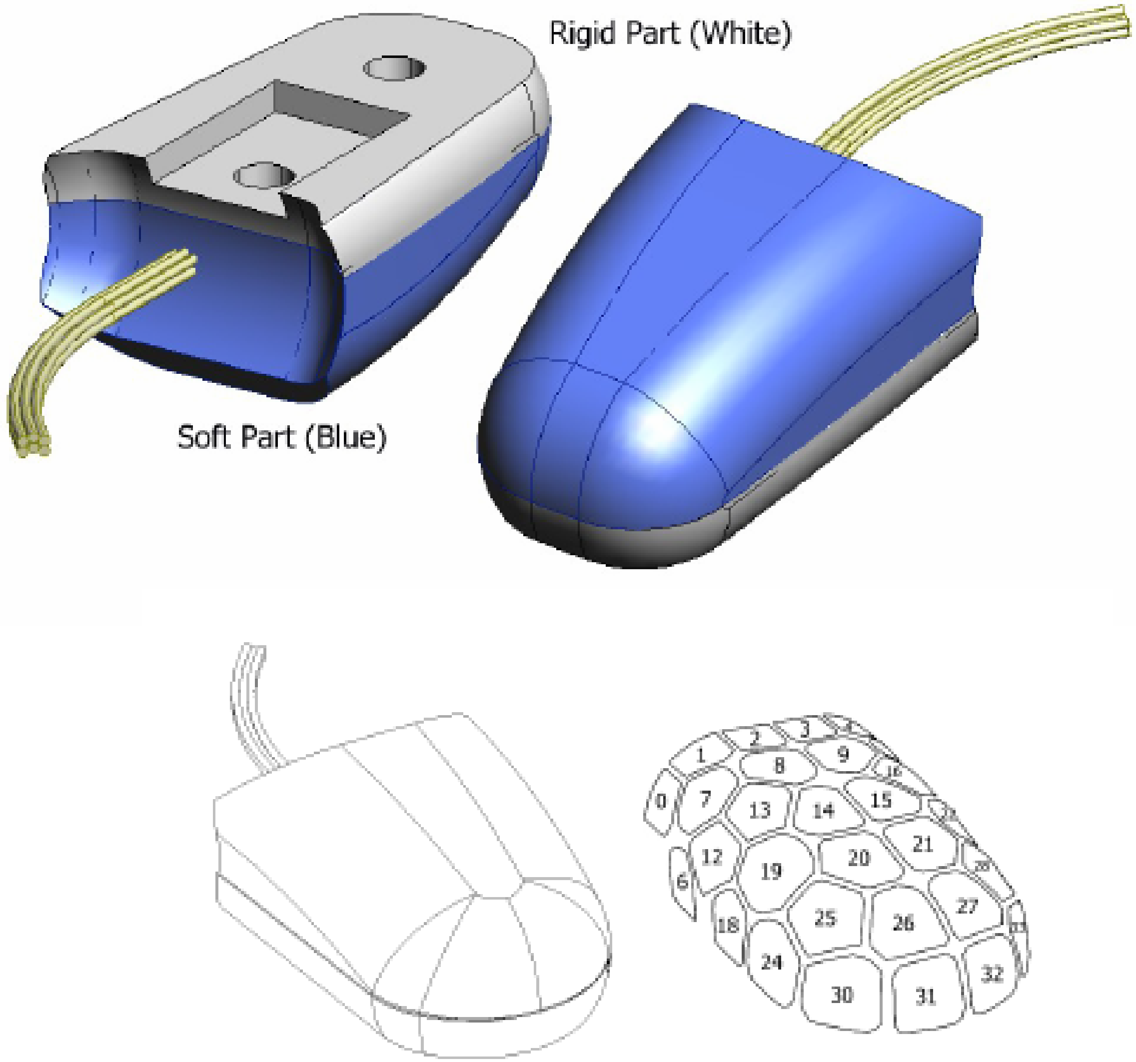


- **Tactile Sensors based on QTC**
- **Embedded electronic on the fingers**

QTC:

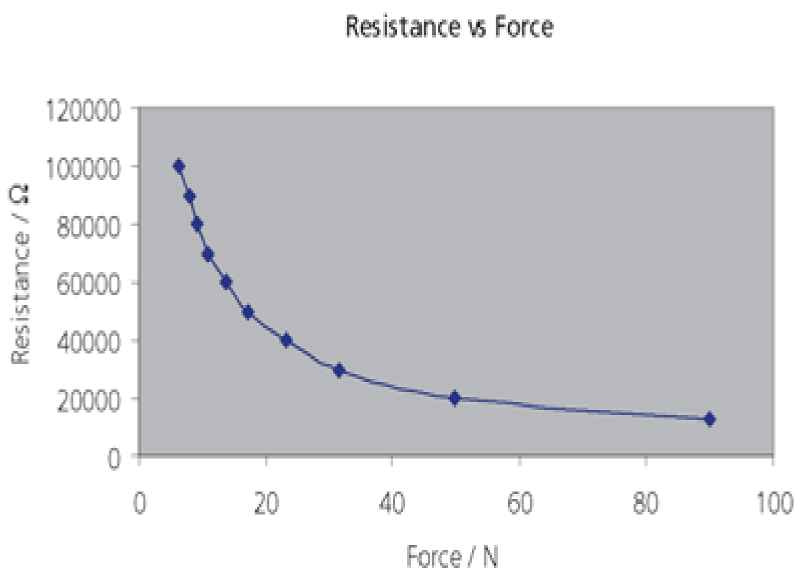
In QTCs the metal particles never come into contact. They do however get very close. So close that Quantum Tunnelling is possible between the metal particles.

FingerTip Sensor



QTC

Quantum Tunneling Composite



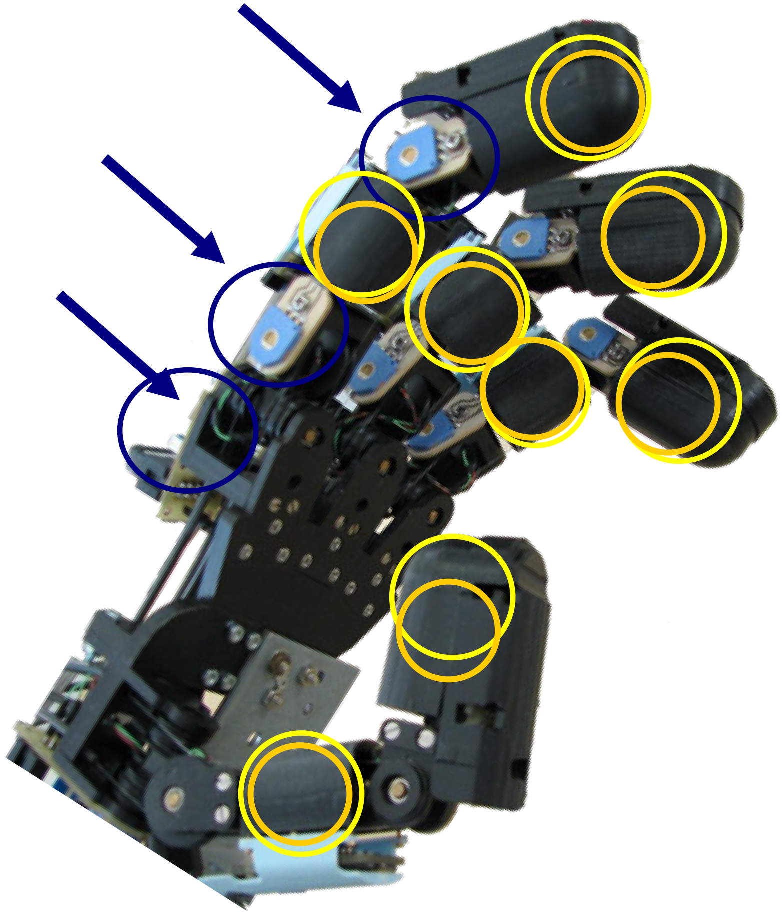
QTC:

In QTCs the metal particles never come into contact. They do however get very close. So close that Quantum Tunnelling is possible between the metal particles.

PRO:

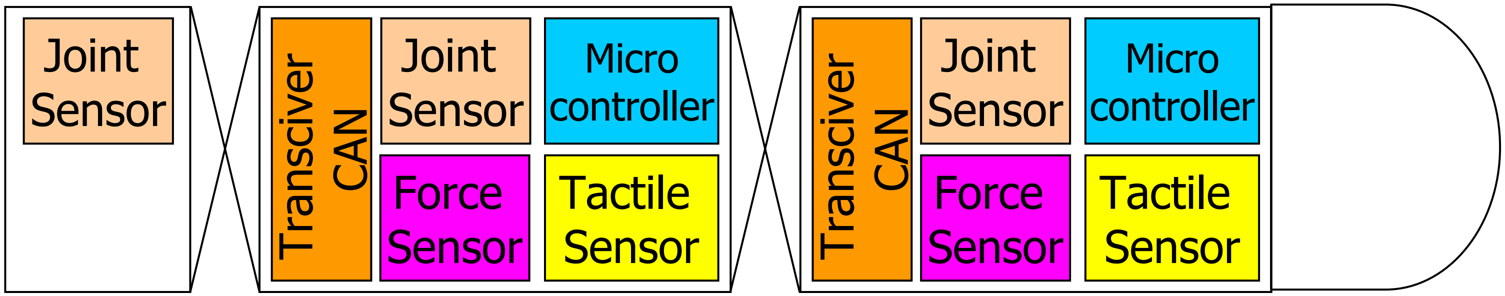
- **Noise Reduction**
- **Repeatability**

MAC HAND

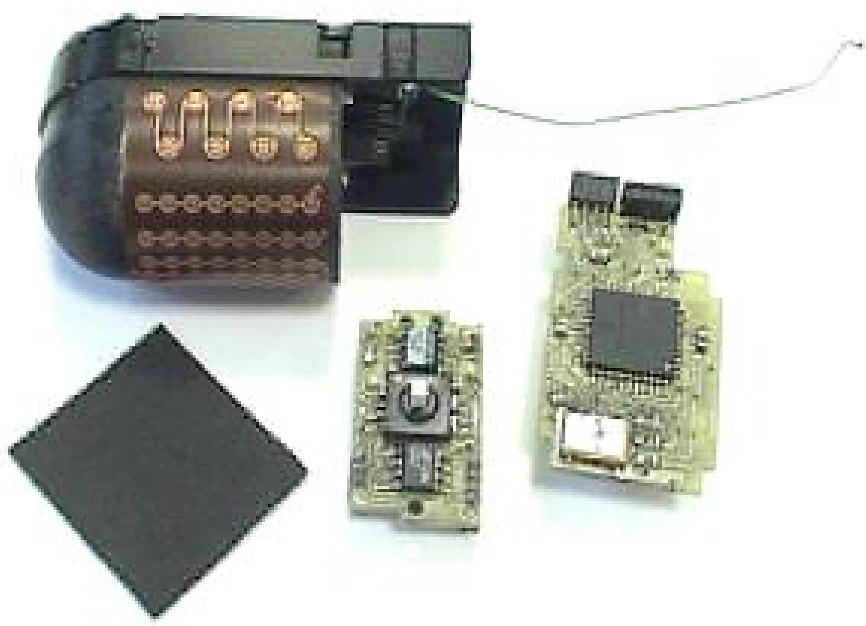


- Four fingered hand
- Twelve degrees of freedom (DOF)
- Tendons driven (4 for each finger)
- Absolute Position Sensors
- Force Sensors
- Tactile Sensors

MAC HAND



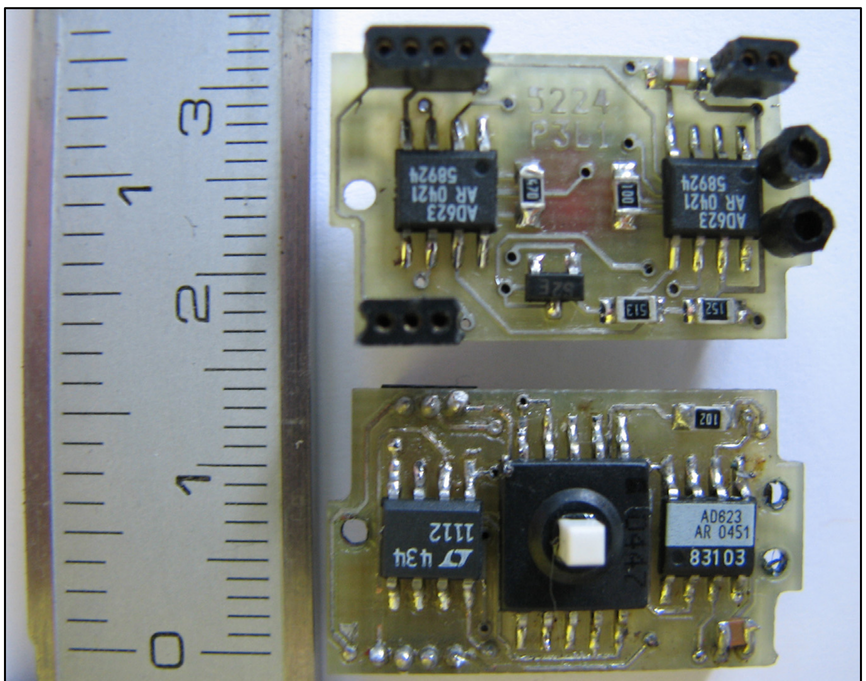
- Different Sensors
- Embedded Electronics
- Communication Links

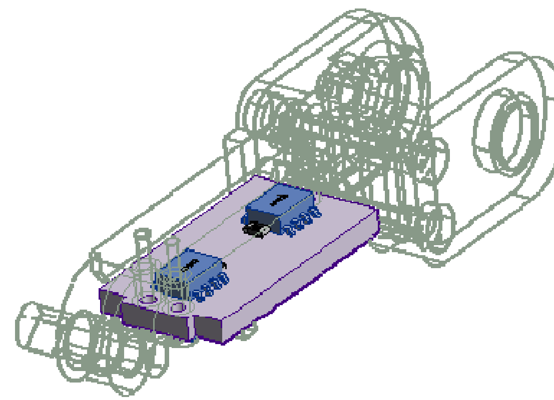


MAC HAND

Force Sensor

- Three axis integrated micro-joystick
- COTS component (micro-joystick)



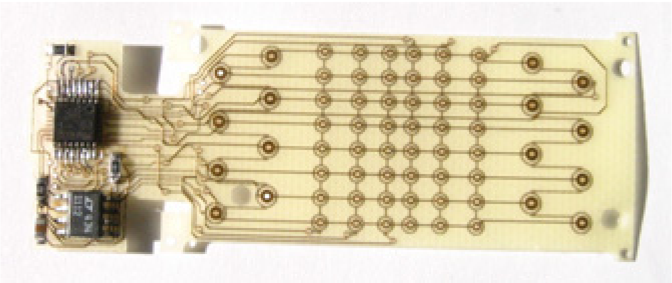


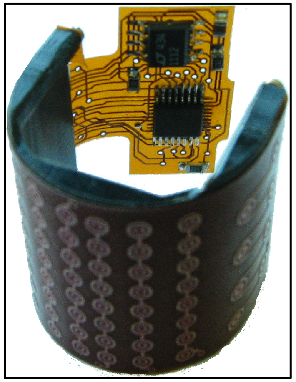
Output Linearity	1.0 %
X,Y Axis Output	0.85 μV/V/g
Z Axis Output	0.125 μV/V/g
Maximum Overload Force	40 N
Dimensions	10 × 7.5 × 5.5 mm

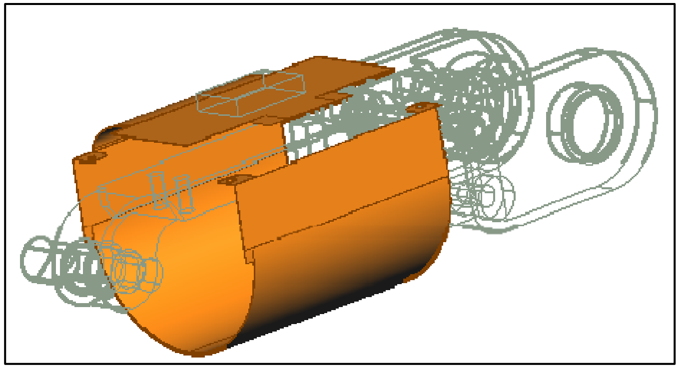
MAC HAND

Tactile Sensor

- 64 taxels for each phalange etched on flexible circuit
- Pressure conductive rubber based transducer

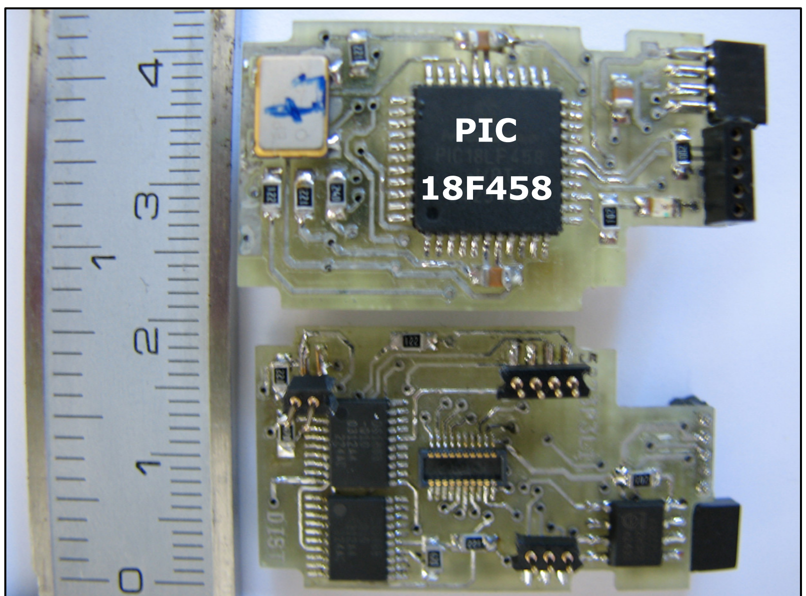


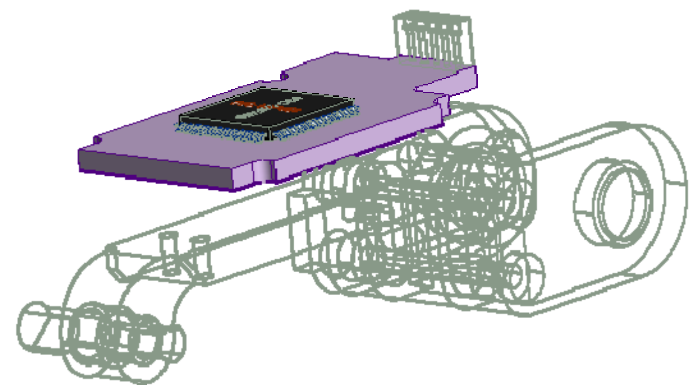


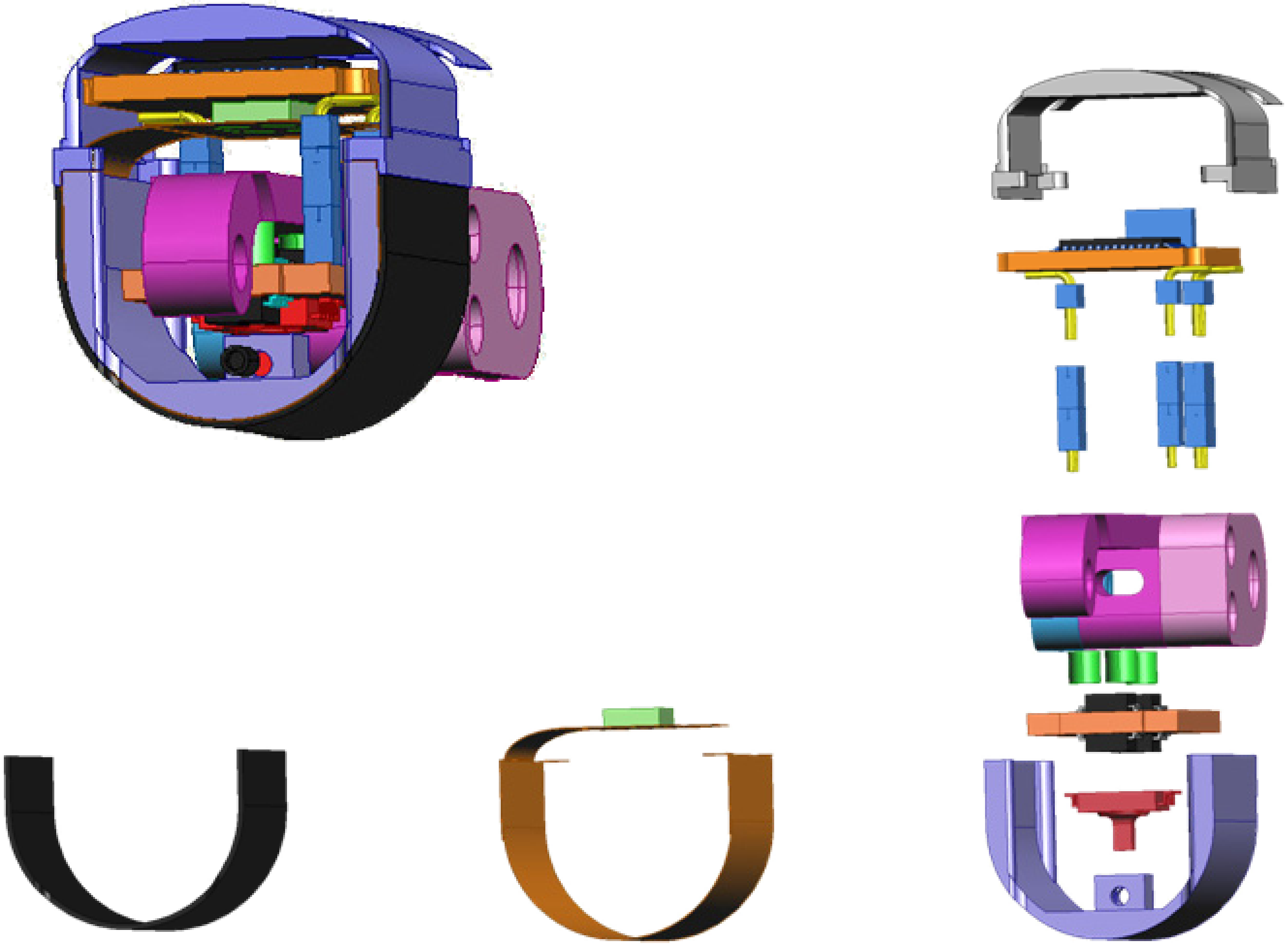


MAC HAND

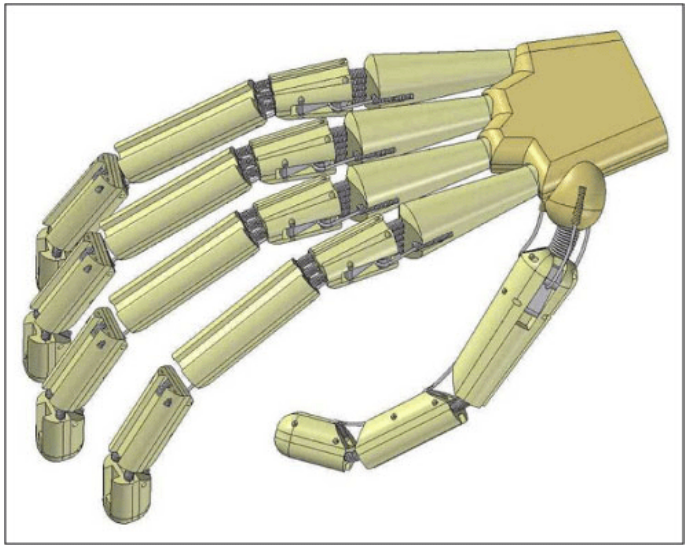
- PIC18F458 microcontroller
- CAN BUS Link





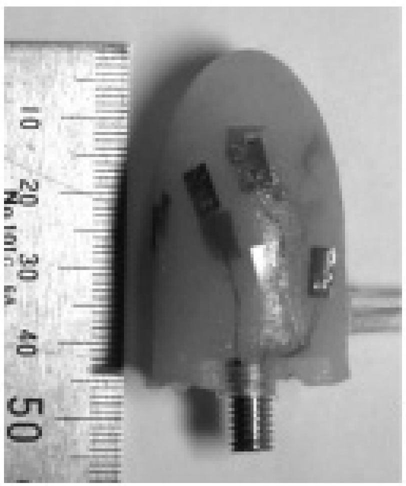


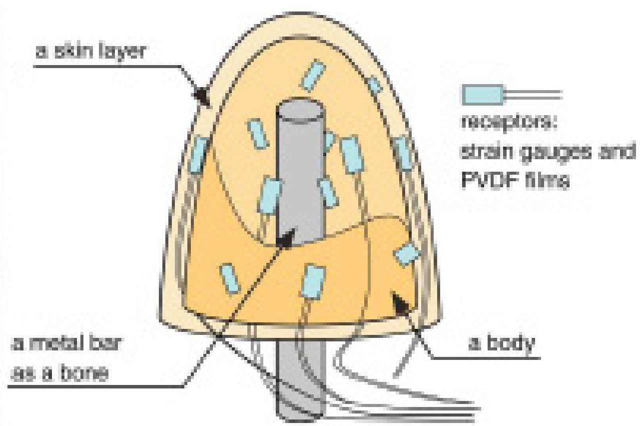
UB HAND 3



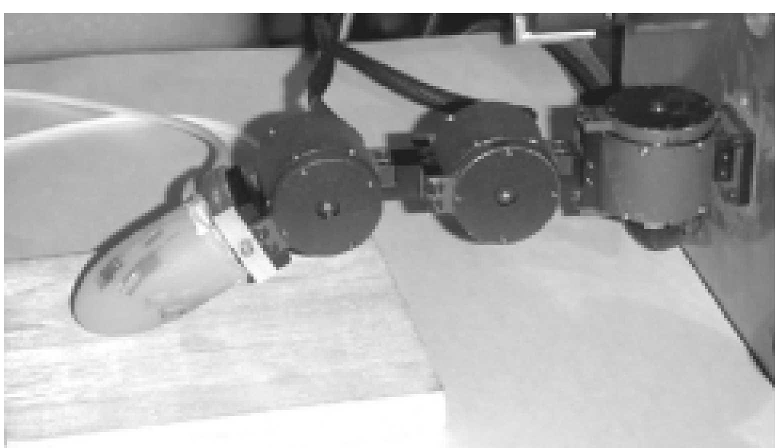
They are investigating on the development of a glove with sensors.

Robot Finger with randomly distributed receptors
(Asada 2006)



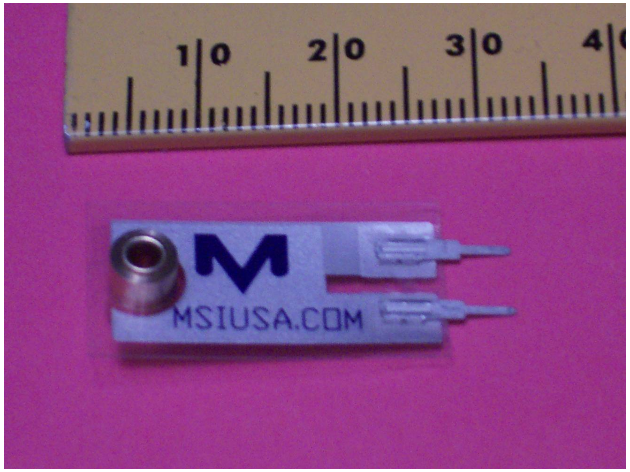


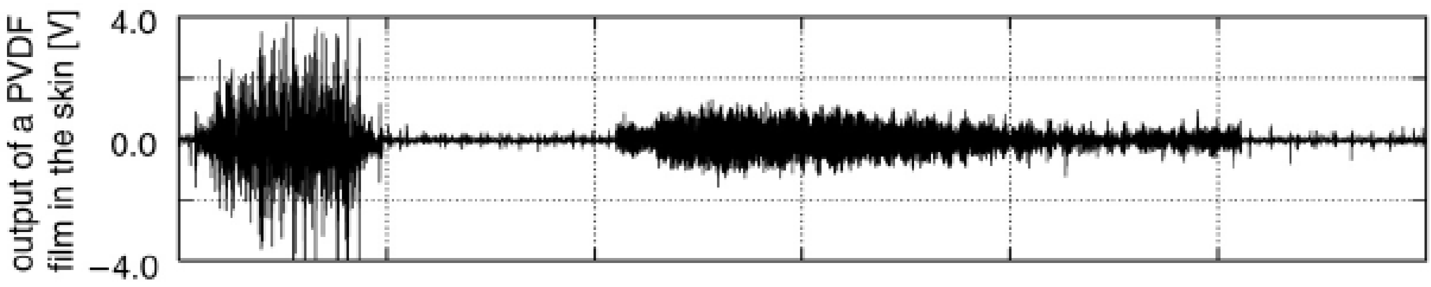
It is based on PVDF films and strain gauges embedded on a silicone rubber in a random way on the fingertip



PVDF

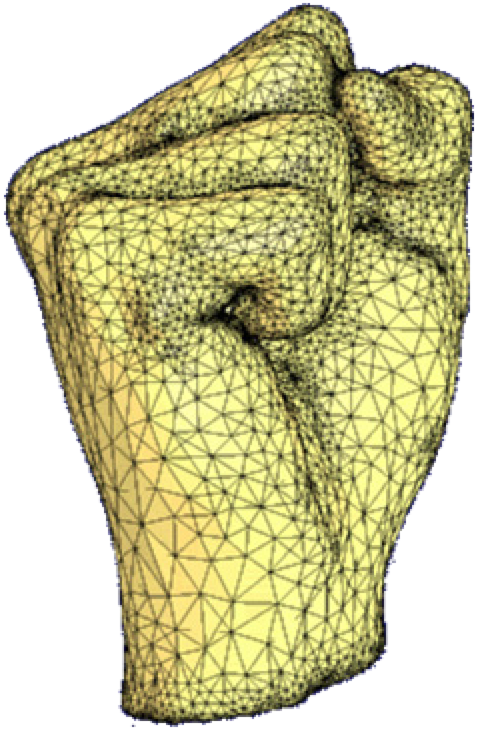
- PVDF is a piezo-electric material
- It generates a voltage in response to applied mechanical stress.
- No constant response



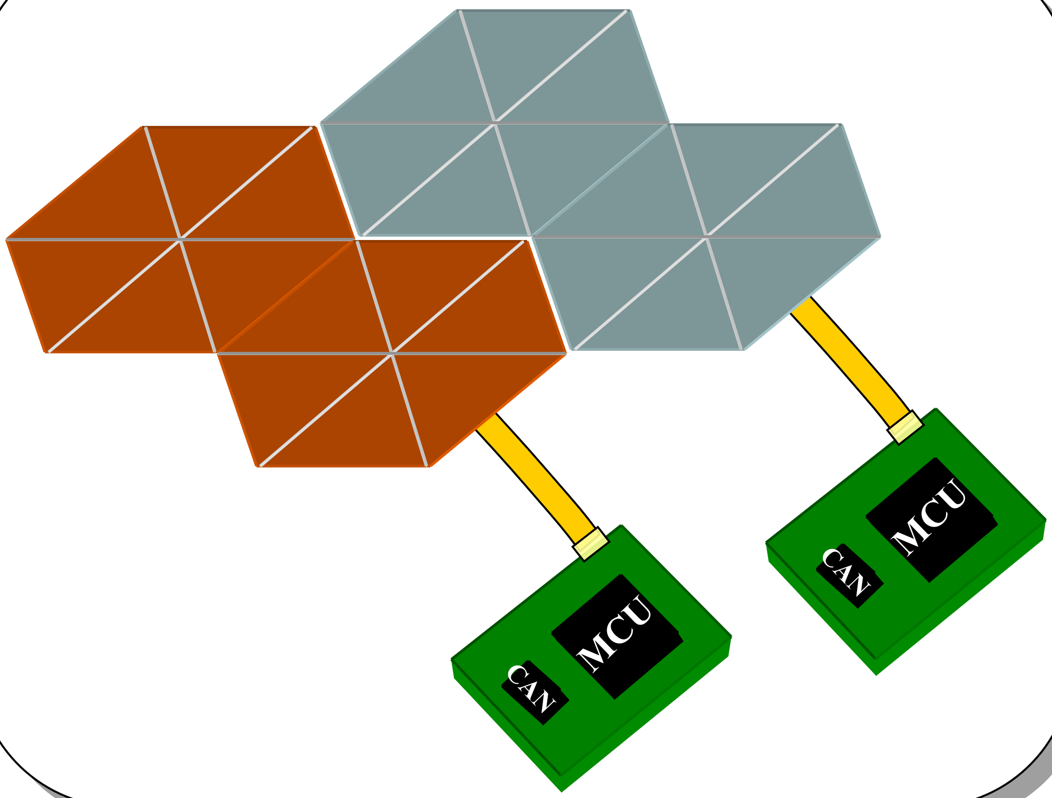


Artificial skin for humanoid robots

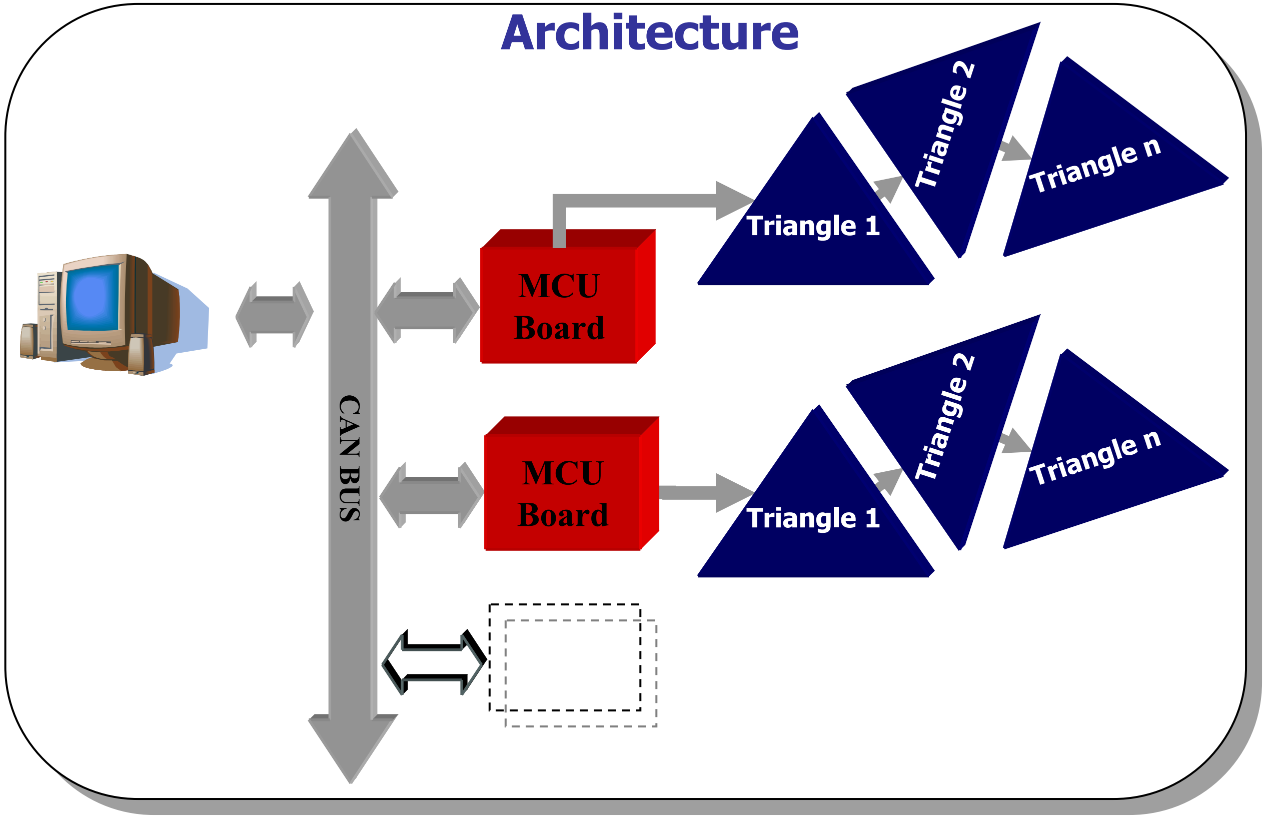
Main idea



Architecture

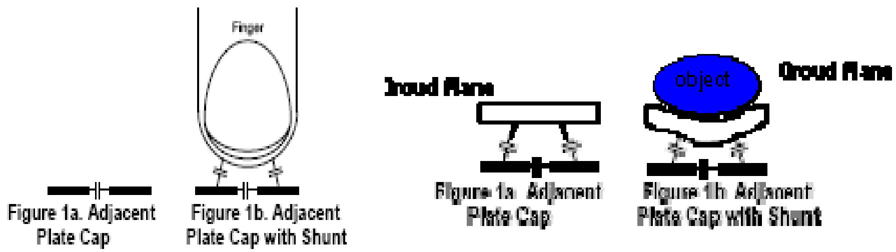


Artificial skin for humanoid robots

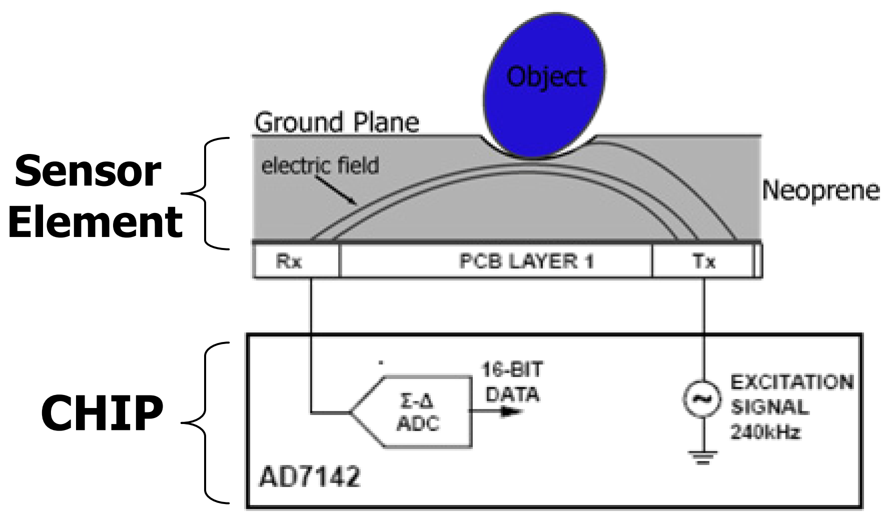


Artificial skin for humanoid robots

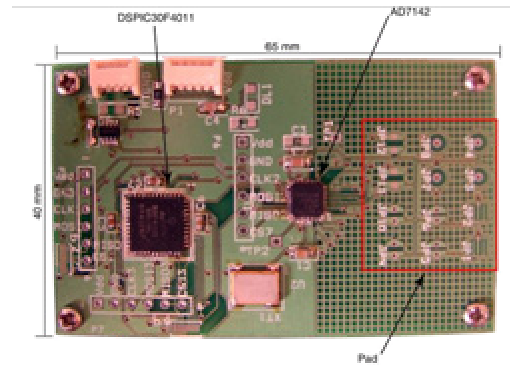
Capacitive Tactile Sensor



Capacitive Tactile Sensor

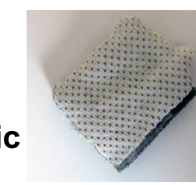


Prototype



Urethane foam

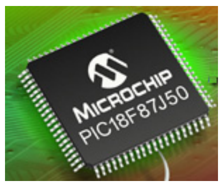
Conductive Fabric



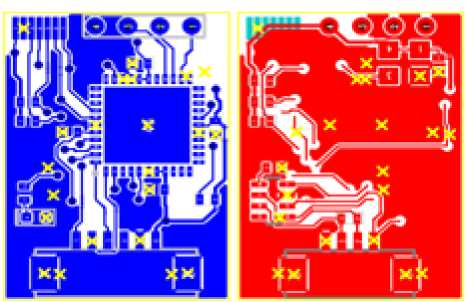
Artificial skin for humanoid robots

MCU Module

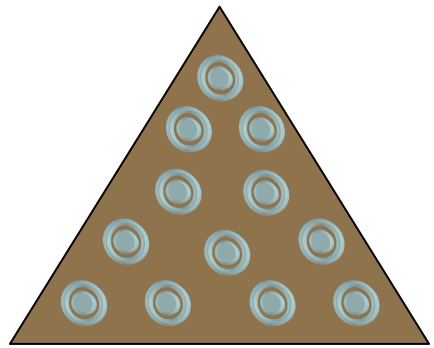
- MCU
- I2C bus
- CAN bus



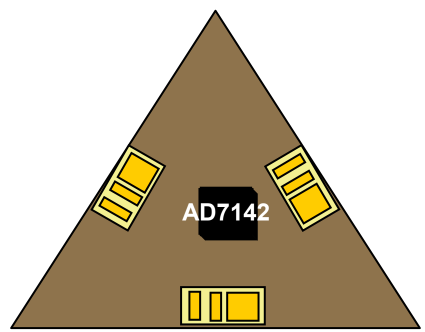
MCU Layout



Triangle Module

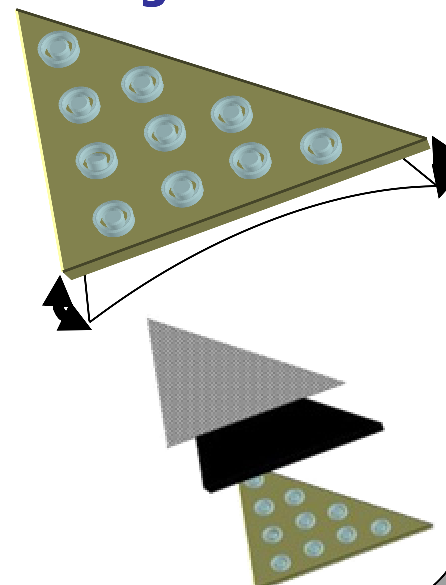


Top view

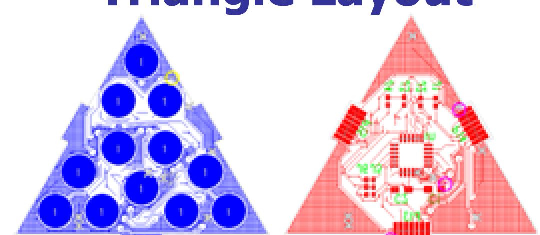


Bottom view

Triangle Module

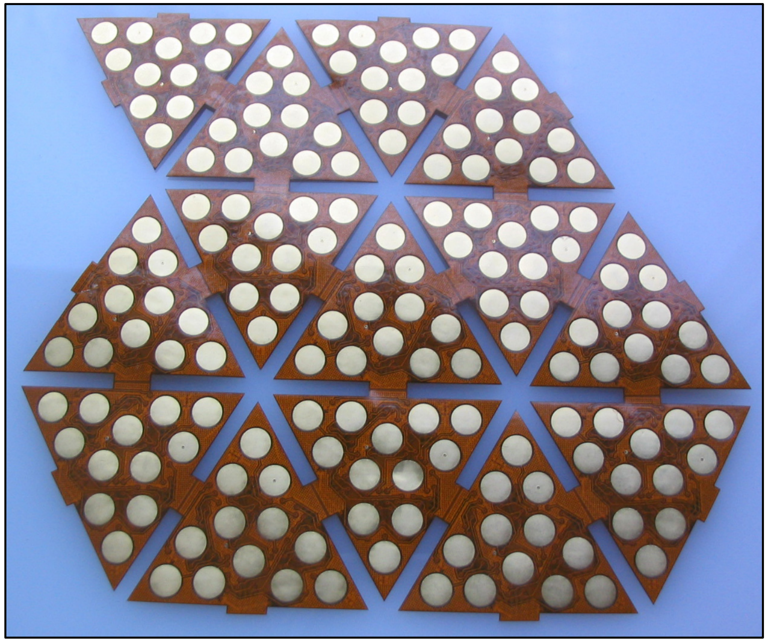


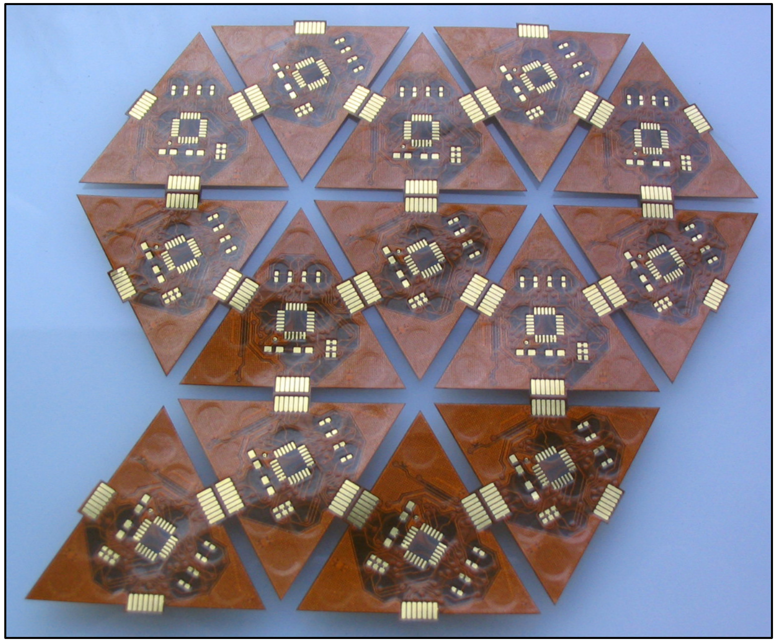
Triangle Layout



Artificial skin for humanoid robots

Prototype on a flexible circuit



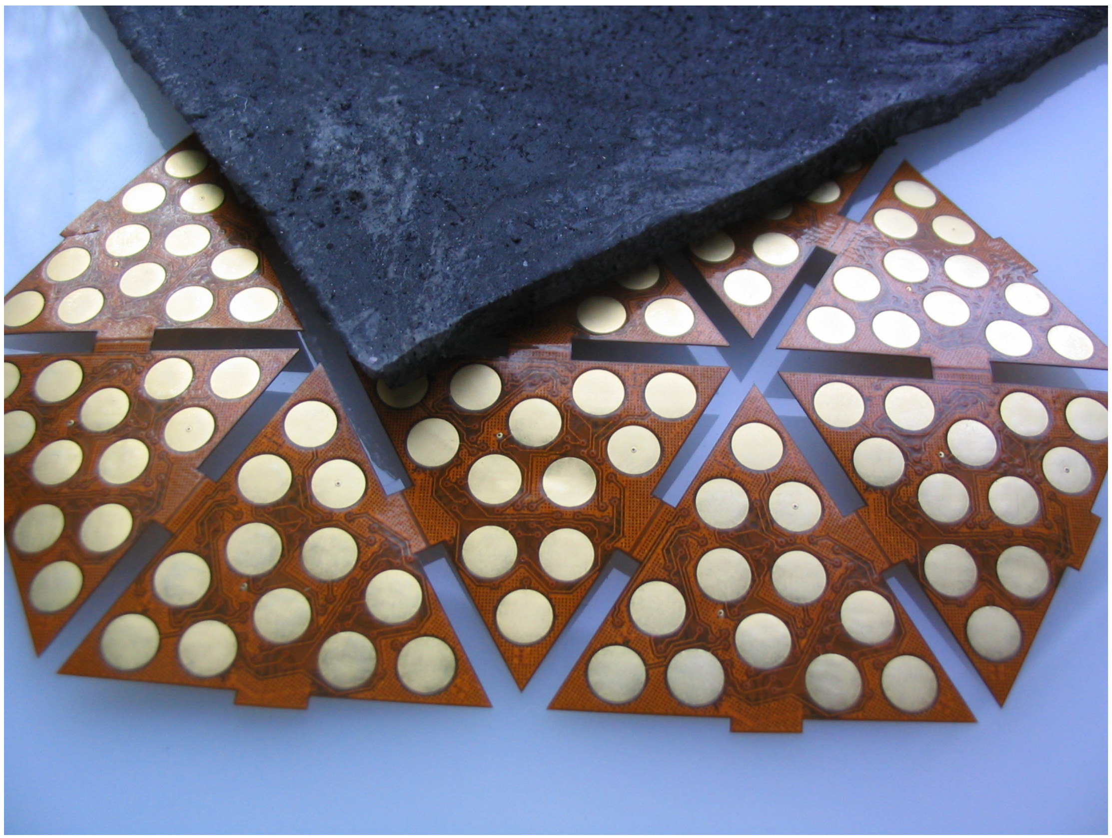


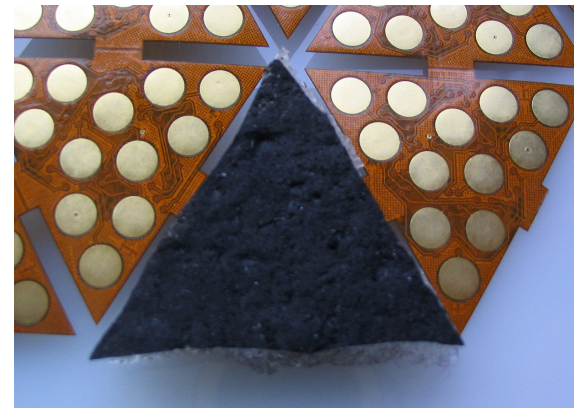
Artificial skin for humanoid robots

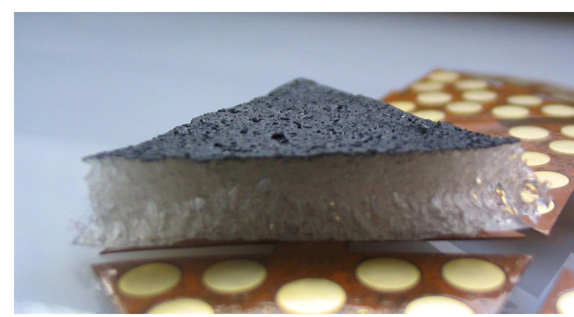
Comformability

Artificial skin for humanoid robots

Prototype covered by silicon rubber







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