Tactile Sensing

From Humans to Humanoids

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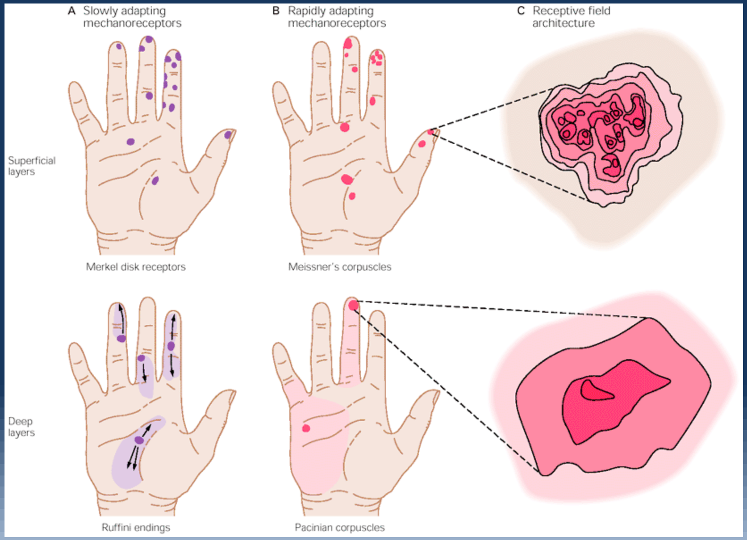
Human Tactile Sensing

"The human sense of touch deals with the spatiotemporal perception of external stimuli through a large number of receptors that are distributed all over the body with various density." – Dahiya et al

This "distribution" of receptors primarily involves:

1. Mechanoreceptors (pressure/vibrations)
2. Thermoreceptors (temperature)
3. Nocioreceptors (damage/pain)



Types of Human Touch

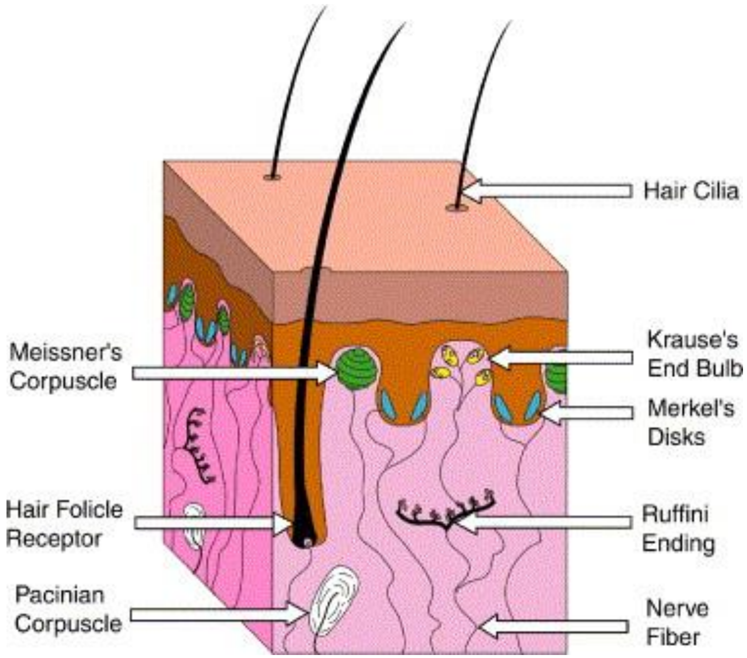
- Cutaneous Sensations - Cutaneous sense receives sensory inputs from the receptors embedded in the skin.
  - *Senses : temperature, pressure, pain*

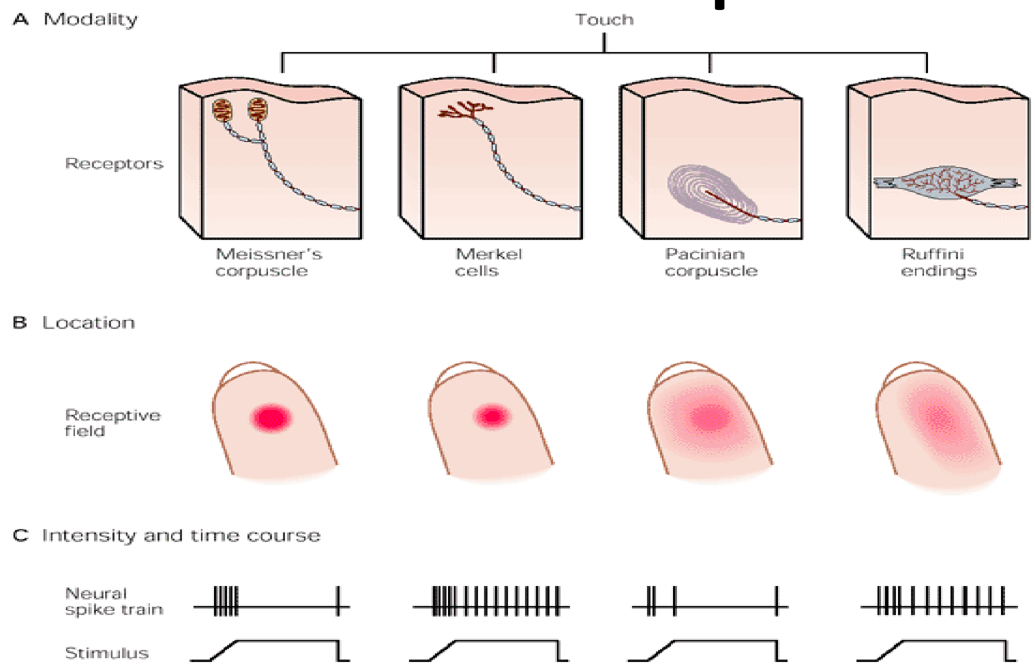
- Kinesthetic Sensations - Kinesthetic sense receives sensory inputs from the receptors located within muscles, tendons and joints.
  - *Senses : body position, movement, equilibrium*

- **Tactile Sensor ← Cutaneous**

Force/Torque sensor: kinesthetic

Human Tactile Mechanoreceptors





A. In the human hand the submodalities of touch are sensed by four types of mechanoreceptors. Specific tactile sensations occur when distinct types of receptors are activated. Firing of all four receptors produces the sensation of contact with an object. Selective activation of Merkel cells and Ruffini endings produces sensations of steady pressure on the skin above the receptor. When the same patterns of firing occur only in Meissner's and Pacinian corpuscles, the tingling sensation of vibration is perceived.
B. Location and other spatial properties of a stimulus are encoded by the spatial distribution of the population of activated receptors. Each receptor fires action potentials only when the skin close to its sensory terminals is touched, ie, when a stimulus impinges on the receptor's *receptive field* . The receptive fields of mechanoreceptors—shown as **red** areas on the finger tip—differ in size and response to touch. Merkel cells and Meissner's corpuscles provide the most precise localization of touch, as they have the smallest receptive fields and are also more sensitive to pressure applied by a small probe.

Ruffini's end organs detect tension deep in the skin. Meissner's corpuscles detect changes in texture (vibrations around 50 Hz) and adapt rapidly. Pacinian corpuscles detect rapid vibrations (about 200–300 Hz). Merkel's discs detect sustained touch and pressure. Hair follicle receptors are located in hair follicles and sense position changes of hairs.

Types of Signal in Human Touch Sensing

Basis of Classification :

- Type of Signal Frequency of Signal

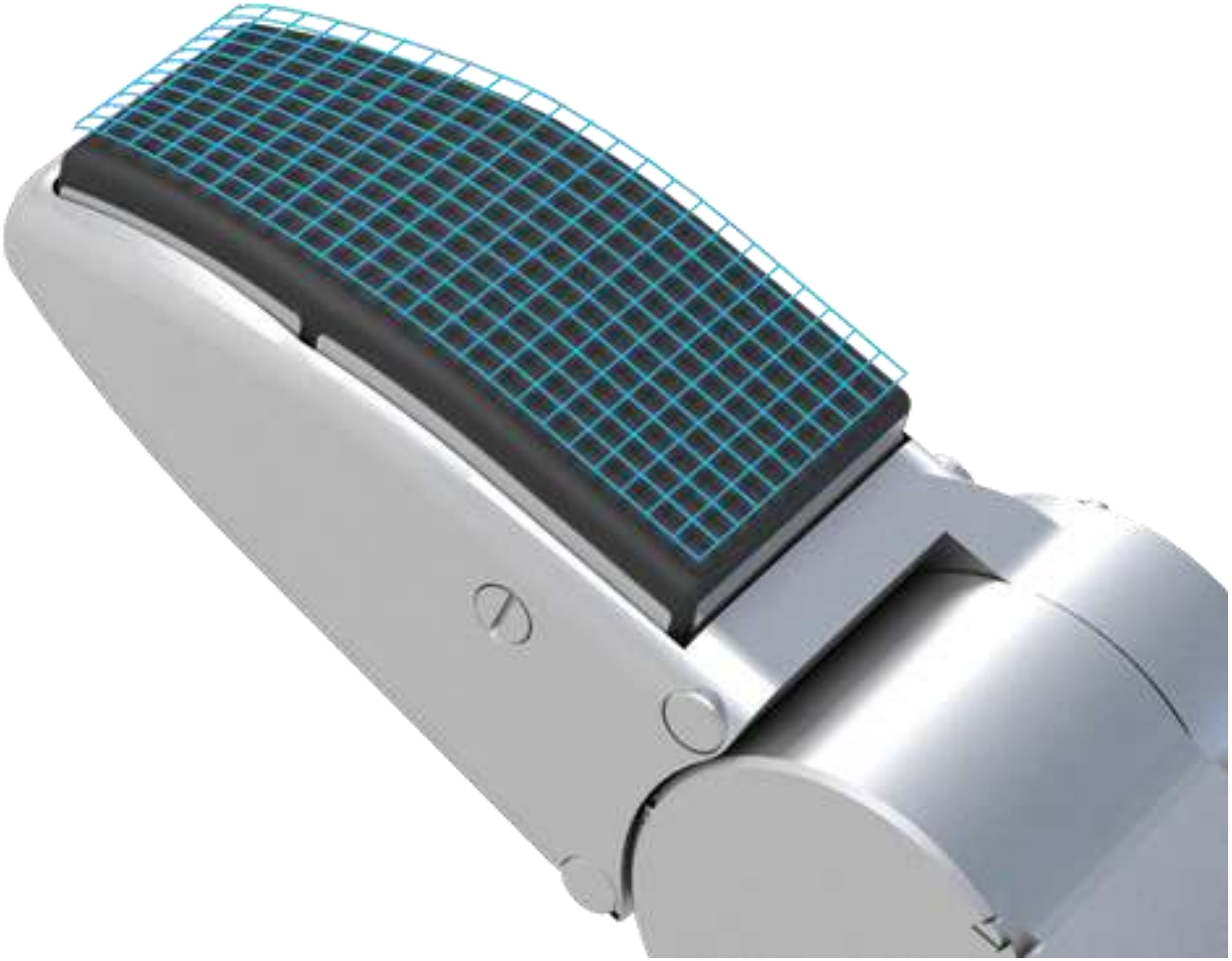
RECEPTOR TYPE	FIELD DIAMETER	FREQUENCY RANGE	POSTULATED SENSED PARAMETER
FAI	3—4 mm	10—60 Hz	Skin stretch
SAI	3—4 mm	DC—30 Hz	Compressive stress (curvature)
FAII	>20 mm	50—1000 Hz	Vibration
SAII	>10 mm	DC—15 Hz	Directional skin stretch

- A **tactile sensor** is a device that measures information arising from physical interaction with its

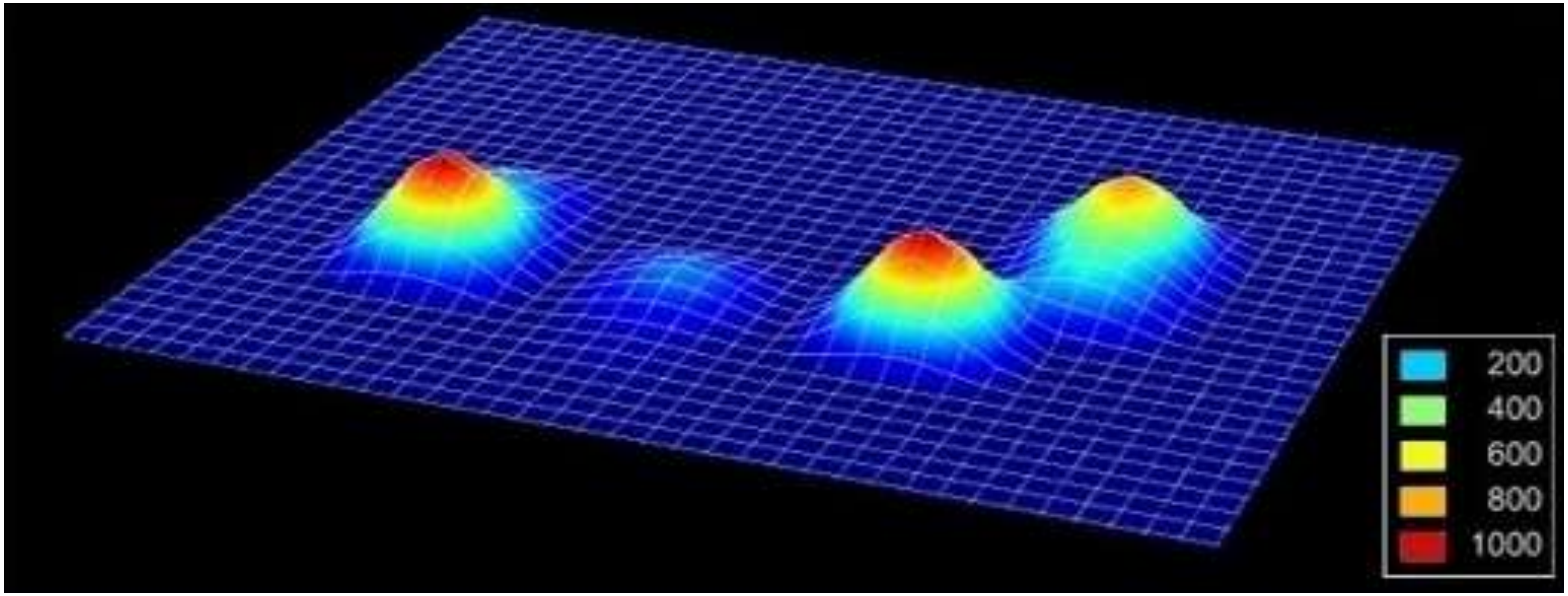
- **What does it sense ?**

Deformation of bodies (strain) or fields (electric or magnetic).

A grid of Tactels



A Thermal Image formed by a Tactel

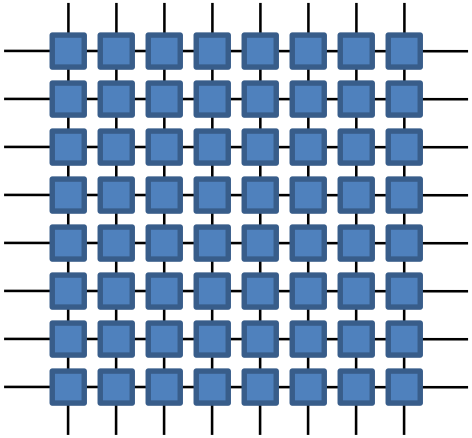


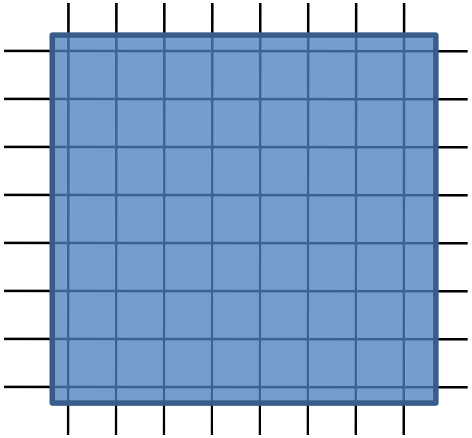
Tactile Sensing

- Tactile Sensors currently used on hands, feet
- Requirement: skin-like sensors, all over the body
- Need both proprioceptive and exteroceptive sensing
- Technologies: capacitance, resistance, optical, utrasonic, magnetic, piezoresistive
- Criteria: Robustness, spatial resolution, dynamic range
- Question: how anthropomorphic? Humans have 4 different kind of tactile sensor cells: slow or fast response, shear or normal forces

Tactile sensing: Methods of transduction

- Usually an array of discrete sensing elements.
- Sensing elements can be many types:
  - Resistive: strain gauge, piezoresistive.
  - Capacitive
  - Piezoelectric
  - & others like (magnetic, optical, conductive rubber, ultrasonic)





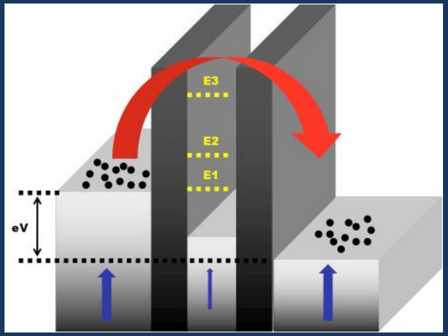
Different Sensor Types and Materials

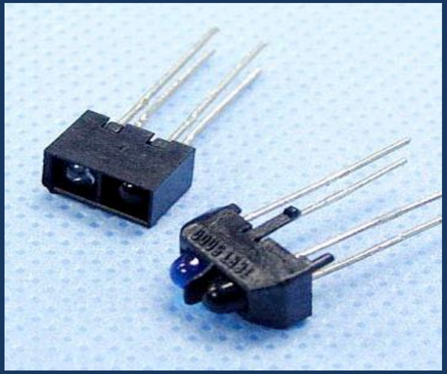
<u>Sensor Types</u>

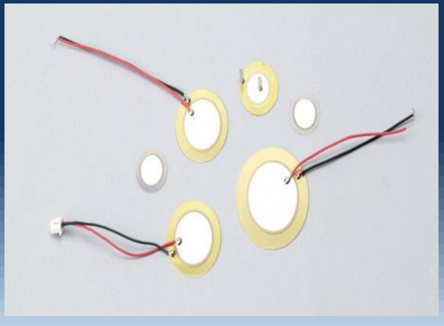
- Resistive Sensor
- Tunnel Effect Sensor
- Capacitive Sensor
- Optical Sensor
- Ultrasonic Sensor
- Magnetic Sensor
- Piezoelectric Sensor

<u>Materials</u>

- Rubber
- Fluids
- Gels
- Sponges
- Pastes



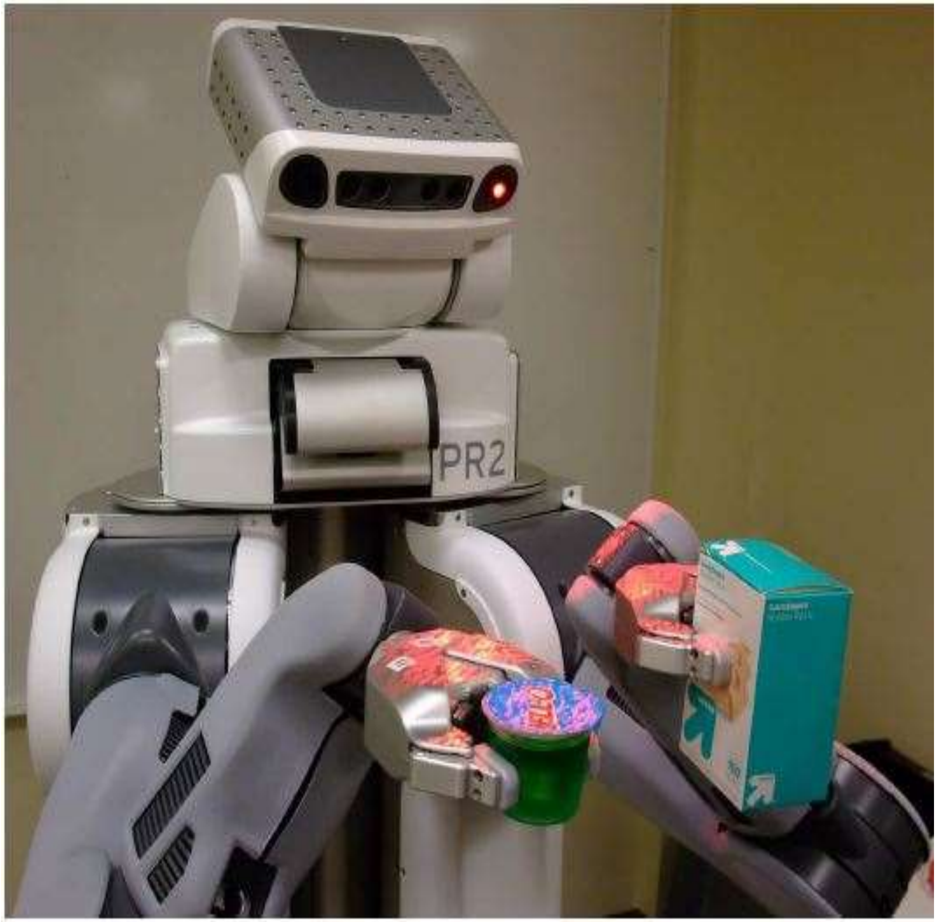




Type	Merits	Demerits
Resistive	• Sensitive • Low Cost	• High Power Consumption • Generally detect single contact point • Lack of Contact force measurement
Piezoresistive	• Low cost • Good sensitivity • Low noise • Simple electronics	• Stiff and frail • Non linear response • Hysteresis • Temperature sensitive • Signal drift
Tunnel Effect	• Sensitive • Physically flexibile	• Non Linear response
Capacitive	• Sensitive • Low cost • Availabilityof commercial A/D chips.	• Cross-talk • Hysteresis • Complex Electronics
Optical	• Immunity to electromagnetic Interference • Physically flexible • Sensitive • Fast • No interconnections.	• Bulky • Loss of light by micro bending • Chirping • Power Consumption • Complex computations.
Ultrasonic	• Fast dynamic response • Good force resolution	• Limited utility at low frequency • Complex electronics • Temperature Sensitive
Magnetic	• High sensitivity • good dynamic range, • no mechanical hysteresis • physical robustness	• Suffer from magnetic interference • Complex computations • Somewhat bulky • Power Consumption
Piezoelectric	• Dynamic Response • High Bandwidth	• Temperature Sensitive • Not so robust electrical connection.
Conductive Rubber	• Physically flexible	• Mechanical hysteresis • Non linear response

Applications :

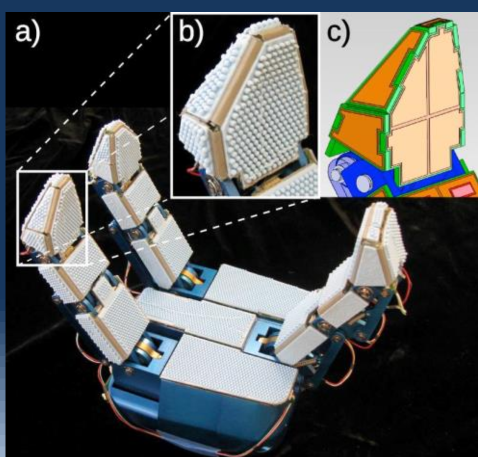
- ***Manipulation**:* Grasp force control; contact locations and kinematics; stability assessment.
- ***Exploration**:* Surface texture, friction and hardness; thermal properties; local features.
- ***Response**:* Detection and reaction to contacts from external agents.

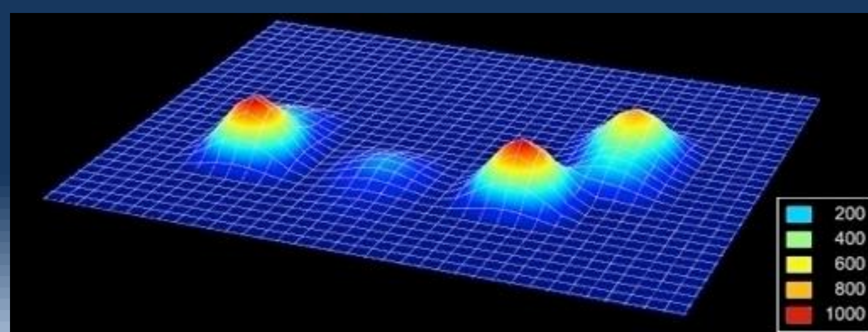


The Design for a Robotic Tactile Sensing System

What's the recipe???

1. Varied and distributed receptors
2. Correlation between size and sensitivity for sensors
3. High range of sensitivity-measure contact & normal
4. Ability to detect dynamic and static contact
5. Quick Response, little hysteresis
6. Preprocessing within sensors
7. Flexible shape, curved surfaces

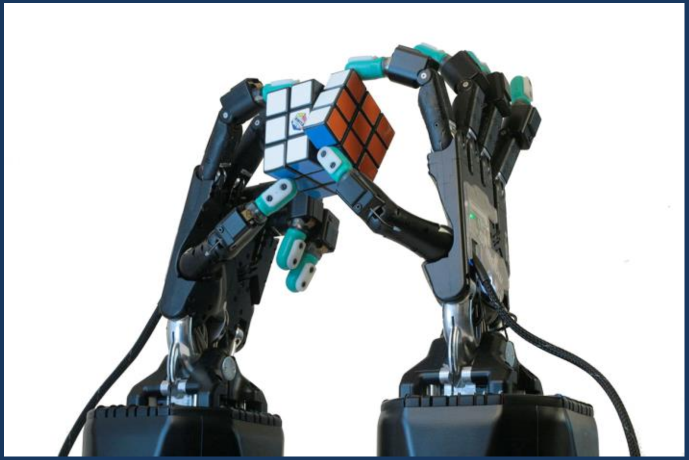




Current Trajectory

<u>Main Challenges</u>

1. Transduction
2. Signal Handling
3. Wiring



<u>Tactile Sensing (video)</u>

https://www.youtube.com/watch?v=ZCZ8Gmh59i0

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https://www.youtube.com/watch?v=w1EBdbe4Nes

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https://www.youtube.com/watch?v=GJ_Zki8e8Kw

Links of Interest

- http://www.iinuu.eu/en/wisdom/human-body-and-nature/what-human-hand-tells
- http://www.nicehdwallpaper.com/wp-content/uploads/2013/06/Beautiful-butterfly-in-robot-hand-hd-wallpaper.jpg
- http://ndpbluenote.com/2012/11/14/steamed-chicken/robot-human-hand-2/
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