Grasping with the Shadow Dexterous Hand integrated on the mobile robot PR2

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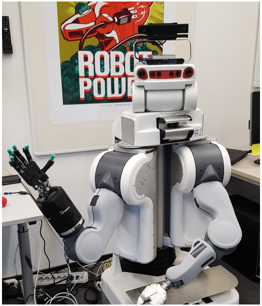
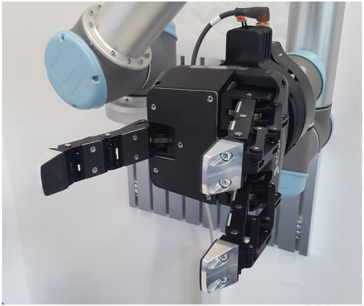
Outline

Introduction
Motivation

- Service robots for daily tasks
  → Picking up objects
- Anthropomorphic gripper in the human environment
- One gripper for "all" kinds of objects



- Project 2015: Delivery service
- Student Assistant: Different tasks of grasping
  - Grasping action server for Robotiq gripper
  - More than just a simple gripper



robotiq s model gripper

Shadow Hand

Designed to imitate and reproduce dexterity of a human hand

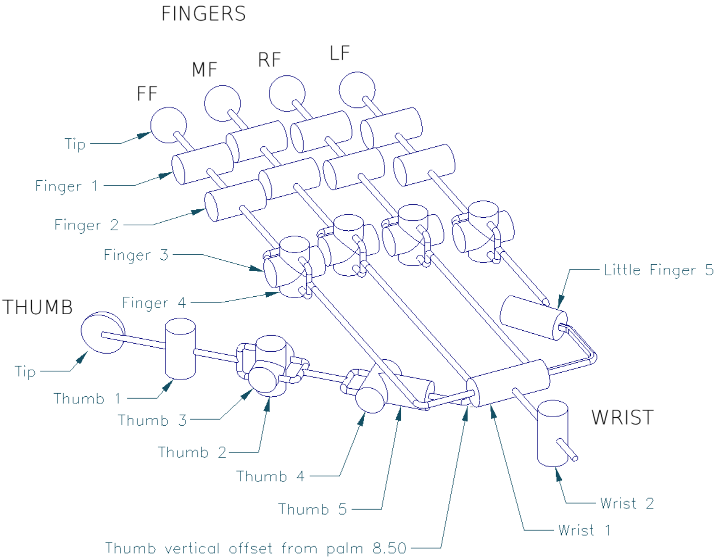
- Size and shape
- Kinematics

Different models:

- Left, **right hand**
- **Motor**, air muscle controlled
- Amount of fingers
- **BioTac** sensors

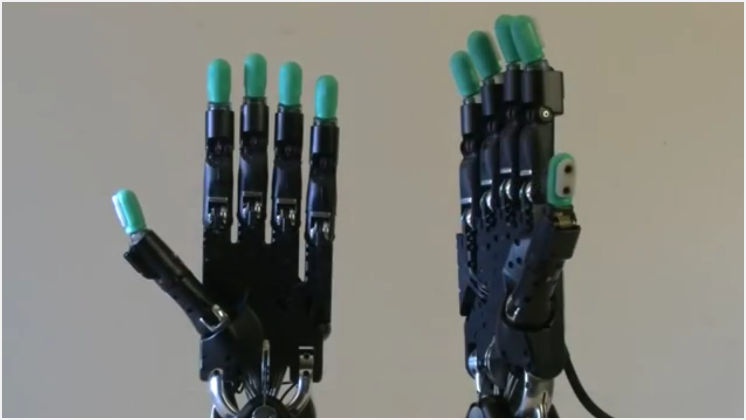
Shadow Dexterous Hand

Shadow Hand



Shadow Dexterous Hand kinematics[src13]

Video



https://www.youtube.com/watch?v=9ubXFMkIEe8

Tactile Sensors

Human sense:

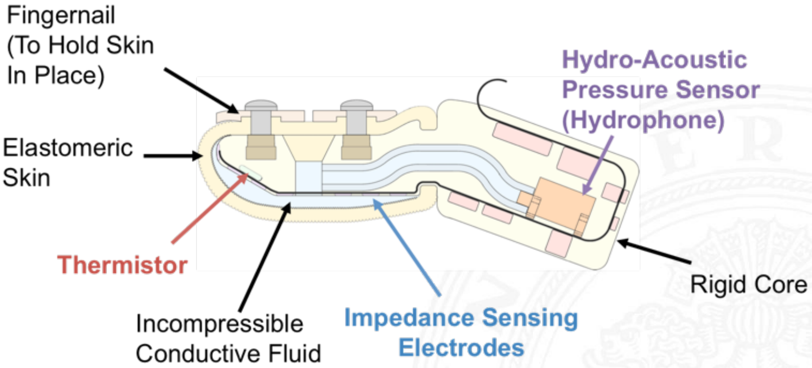
- Cutaneous sensing: Pressure, temperature, pain
- Kinesthetic sensing: Position, movement, equilibrium

Measuring cutaneous sensing data with tactile sensors

Different types of tactile sensors:

- Force/Torque: Pressure and contact point
- Dynamic: Sliding, making and breaking contact
- Thermal: Temperature and thermal conductivity

BioTac [st:15]



BioTac cross section[st:15]

Applications

- Material identification:
  A. Gómez Eguíluz, I. Rañó, S.A. Coleman, T.M. McGinnity [ERCM16]
- Radius of curvature:
  Nicholas Wettels, Gerald E. Loeb [WL11]
- Handover
  A. Gómez Eguíluz, I. Rañó, S.A. Coleman, T.M. McGinnity [ERCM16]
- Point of contact
  V. Ciovanu, D. Popescu, A. Petrescu [CPP14]

Sensor Data

- Electrode voltages (E1 - E19) - Measure voltage
- DC Pressure (Pdc) - Absolute fluid pressure
- AC Pressure (Pac) - Dynamic fluid pressure (vibrations)
- DC Temperature (Tdc) - Device temperature
- AC Temperature (Tac) - Thermal flux

All incoming values from 0 to 4095

Data analysis

Goal

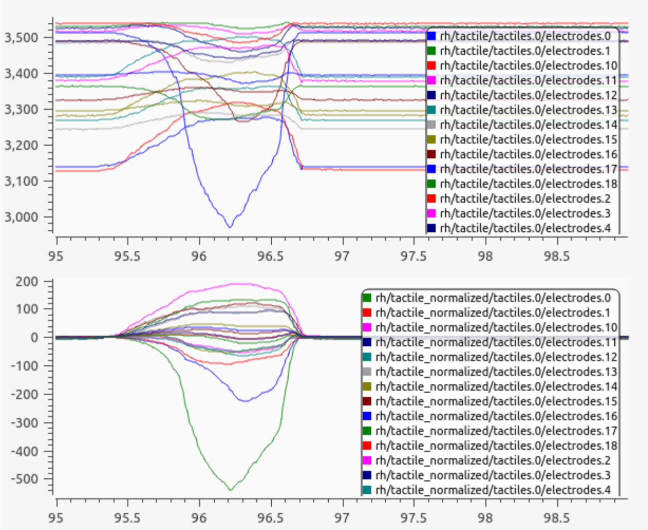
Get information which are useful for grasping.

E.g.: Pressure (force), the point of contact

To reach this goal the data has to be prepared:

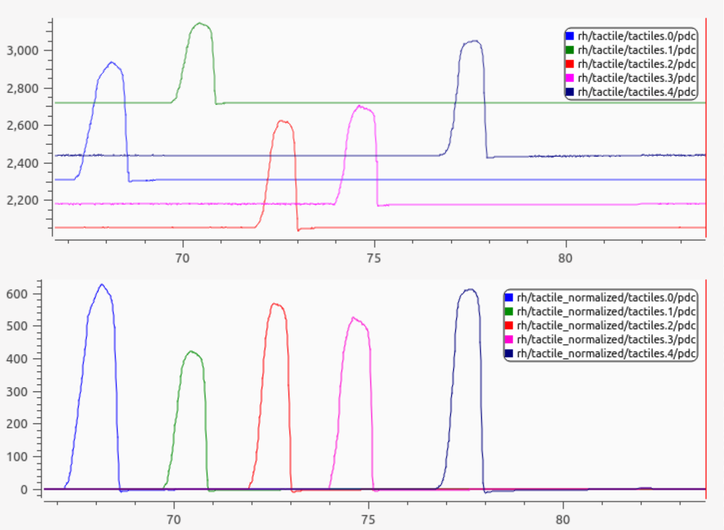
- filtered
- normalized
- *calibrated (comparable, units)*

Electrode Voltages (E1 - E19) - Impedance



Top: raw data; Bottom: filtered and normalized

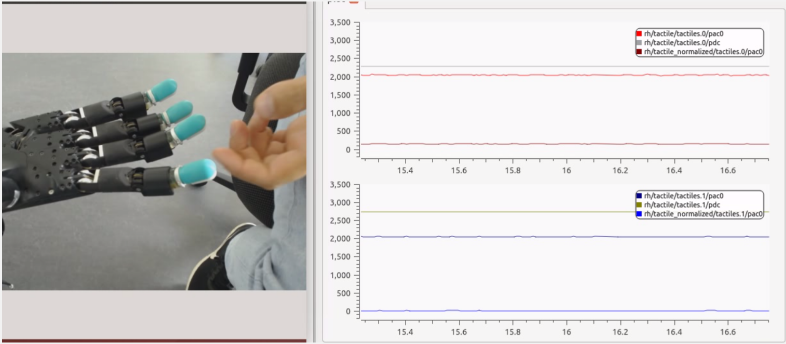
DC Pressure (Pdc)



Top: raw data; Bottom: filtered and normalized

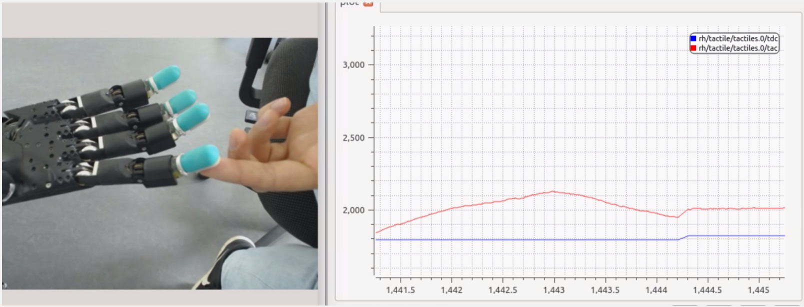
AC Pressure (Pac)

Video



Temperature (Tdc - Tac)

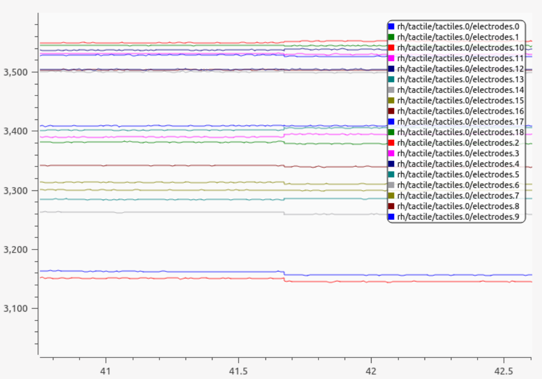
Video



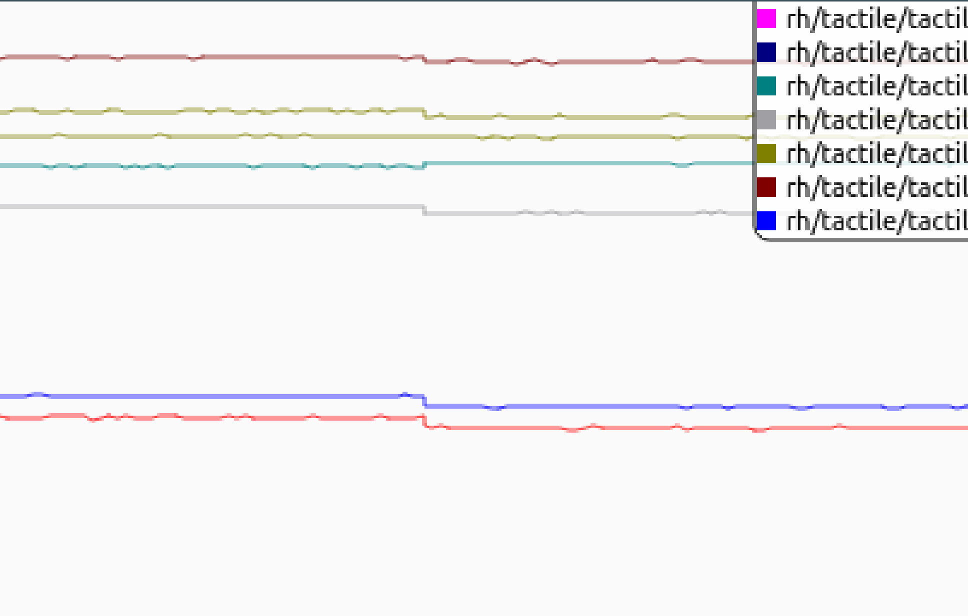
Problems

- Different amount of liquid in every fingertip
- Temperature inflates volume
- Skin wear inflates volume

→ frequent calibration is necessary



Problems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rh/tactile/tactil

Filter

Noisefiltering with the Exponentially Weighted Moving Average (EMA)

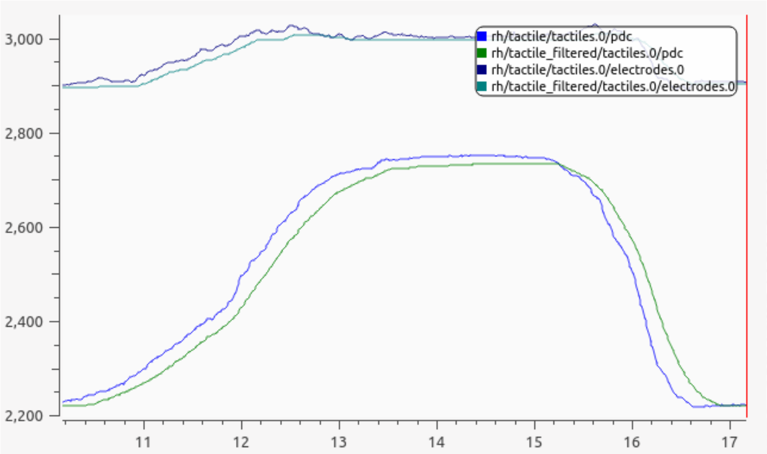
$$EMA_n = \alpha \cdot x_n + (1 - \alpha) \cdot EMA_{n-1}$$

With:

- α: From 0 to 1
- $EMA_0 = 0$
- x_n: New value

- Advantage: Reduce noise, smoothing the curves
- Disadvantage: Delay of values with low alpha

Filter



$\alpha = 0.05$: Delay of ~20 ms

Normalization

Goal

All values should be comparable to each other.

Naive approach: Set all values to 0 at the beginning.

→ Problem: The values are drifting.

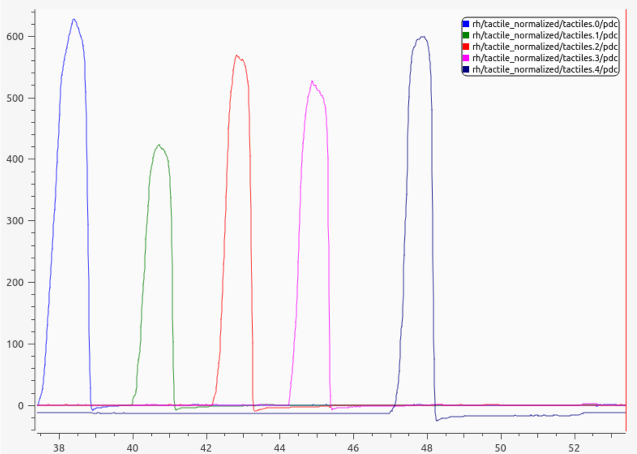
Better approach: Detect contacts and zeroing values when there is no contact.

Normalization
No contact detection

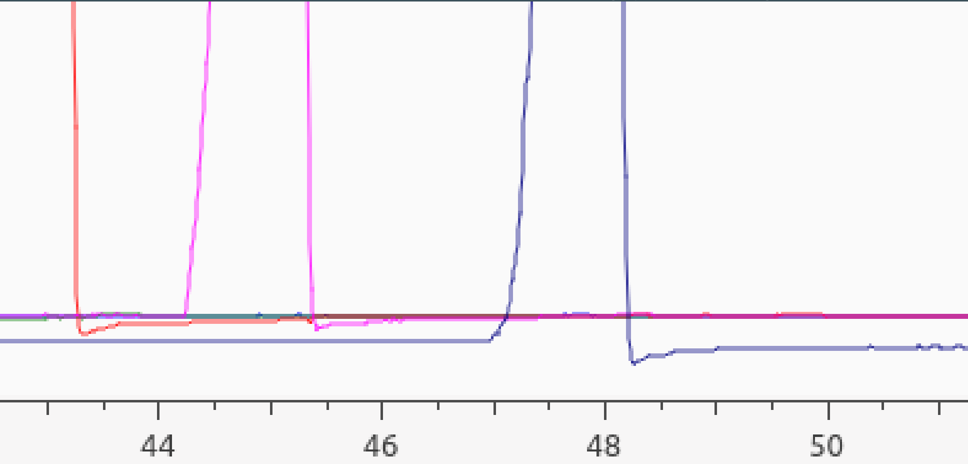
- Assumption: Starting the normalization in a rest state
- Conditions for no contact:
  - Mean of Pdc values has to be under threshold (5).
  - Difference between min and max value of electrodes has to be under threshold (10).
- Prevent zeroing with very small contacts:

  → Safe values every 0.5 seconds and mean over 5 values.

Problems: Shift after contact



Normalization
No contact detection



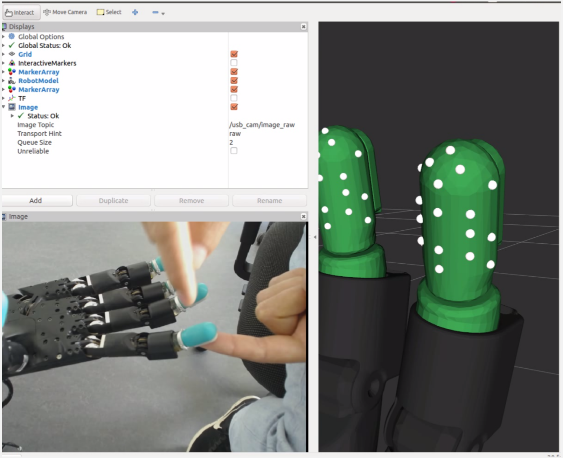
Normalization
No contact detection

Possible solutions:

- Improve thresholds
- Consider finger efforts
- External service when there is no contact (e.g. after grasp)

Point of Contact

Video



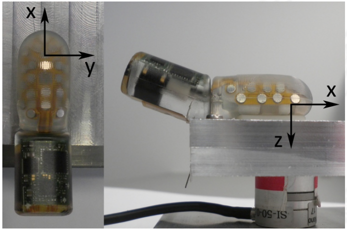
Point of Contact

Idea:

1. Get the average of the electrode position, weighted with the impedance value

→ position on the core of the BioTac

2. Map position to surface and distinguish between:
   - Cylindrical part
   - Spherical part



[CHLL13]

Point of Contact

Compute the PoC by a weighted average of the position of the electrodes:

$$\langle x_c, y_c, z_c \rangle = \frac{\sum_{i=1}^{19}(|e_{i*}|^n \langle x_i, y_i, z_i \rangle)}{\sum_{i=1}^{19}(|e_{i*}|^n)}$$

e_{i*}: Normalized electrode values
n: Impect of the single electrode

→ Turns out, considering just the negative values produces a way better result.

Point of Contact

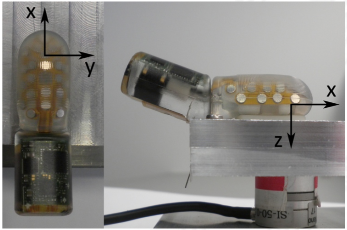
Map to surface

Cylindrical part

$$\langle x_{c'}, y_{c'}, z_{c'} \rangle = \langle x_c, \frac{r * y_c}{\sqrt{y_c^2 + z_c^2}}, \frac{r * z_c}{\sqrt{y_c^2 + z_c^2}} \rangle$$

Spherical part

$$\langle x_{c'}, y_{c'}, z_{c'} \rangle = \langle x_c, y_c, z_c \rangle \frac{r}{\sqrt{x_c^2 + y_c^2 + z_c^2}}$$



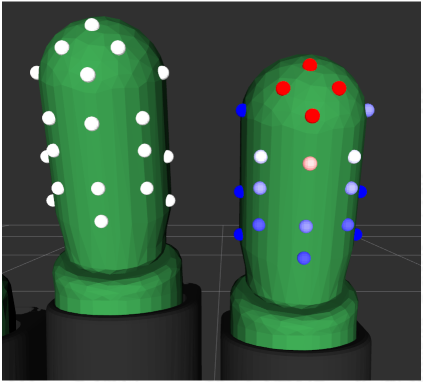
[CHLL13]

Visualize electrodes

Positioning similar to point of contact, without weighted average

Color:

- Red: Small impedance
- Blue: High impedance



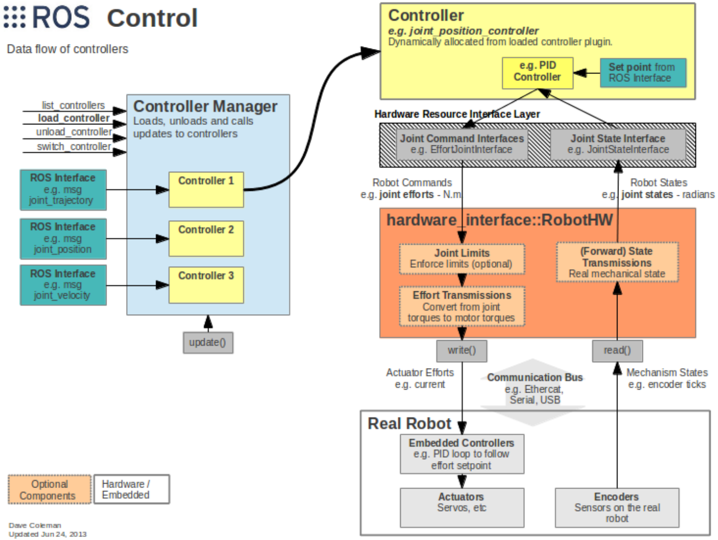
Current state

Calibration

For a stable grasp the calibrated pressure is the most interesting part:

1. Calibrate fingers among each other
   → Press finger at the same contact point against each other.
2. Calibrate with real force units
   → External way to measure force is necessary.
   It might work with effort values from Shadow Hand fingers.

ROS Control



http://wiki.ros.org/ros_control

Common controllers

- Effort controller
- Position controller
- Velocity controller
- Trajectory controller
- Mixed controller

New controller

Goal

Integrate tactile feedback to hold an effort.

Possible solution:

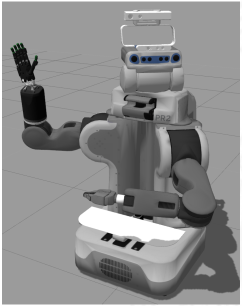
1. Close fingers with effort and velocity controlled motion.
2. Stop motion when contact is detected.
3. Hold effort within a threshold when two contact points with opposite force directions are detected.

Problems: Moving hand around affects pressure feedback.

Integration with the PR2

Current state:

- Simulation works
- Shadow Hand is controlled with base station
- Shadow Hand and PR2 are not tested together



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