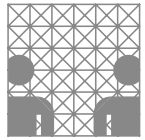
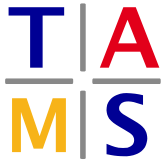
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

MIN Faculty
Department of Informatics



Tactile based grasping with the biomimetic sensors BioTac and the Shadow Dexterous Hand

Yannick Jonetzko



University of Hamburg
Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics

Technical Aspects of Multimodal Systems

12. December 2017

Outline

Review of last talk

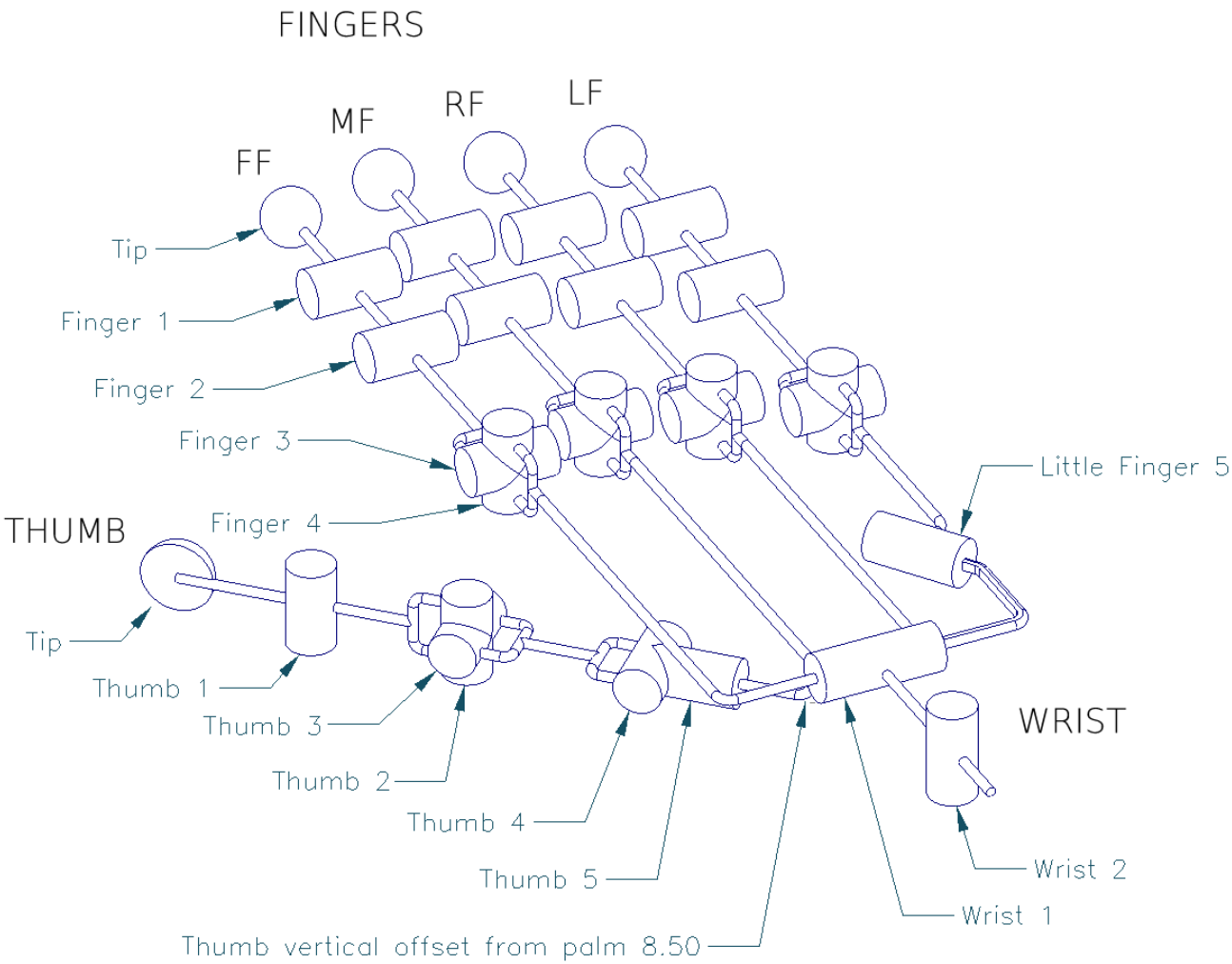
1. Introduction
2. Shadow Hand
3. BioTac
   - Raw Data
   - Filter
   - Normalization
   - Point of contact
   - *Calibration*
4. *Stable grasp*
   - *Controller*
5. *Integration with the PR2*

Shadow Hand

Shadow Dexterous Hand[1]

[1] https://www.shadowrobot.com/

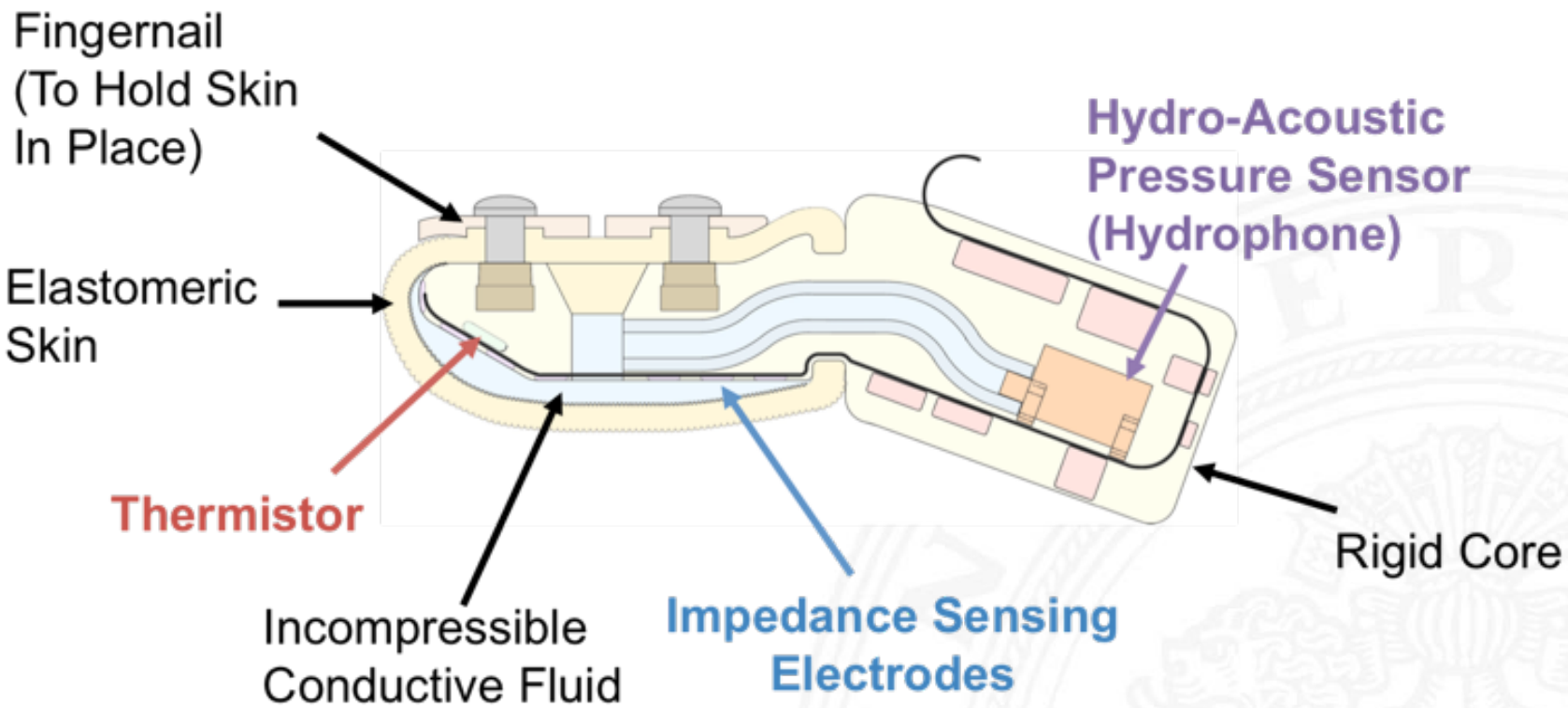
Shadow Hand - Kinematics



Shadow Dexterous Hand kinematics [2]

[2] http://www.shadowrobot.com/wp-content/uploads/shadow_dexterous_hand_technical_specification_E1_20130101.pdf

BioTac



BioTac cross section[3]

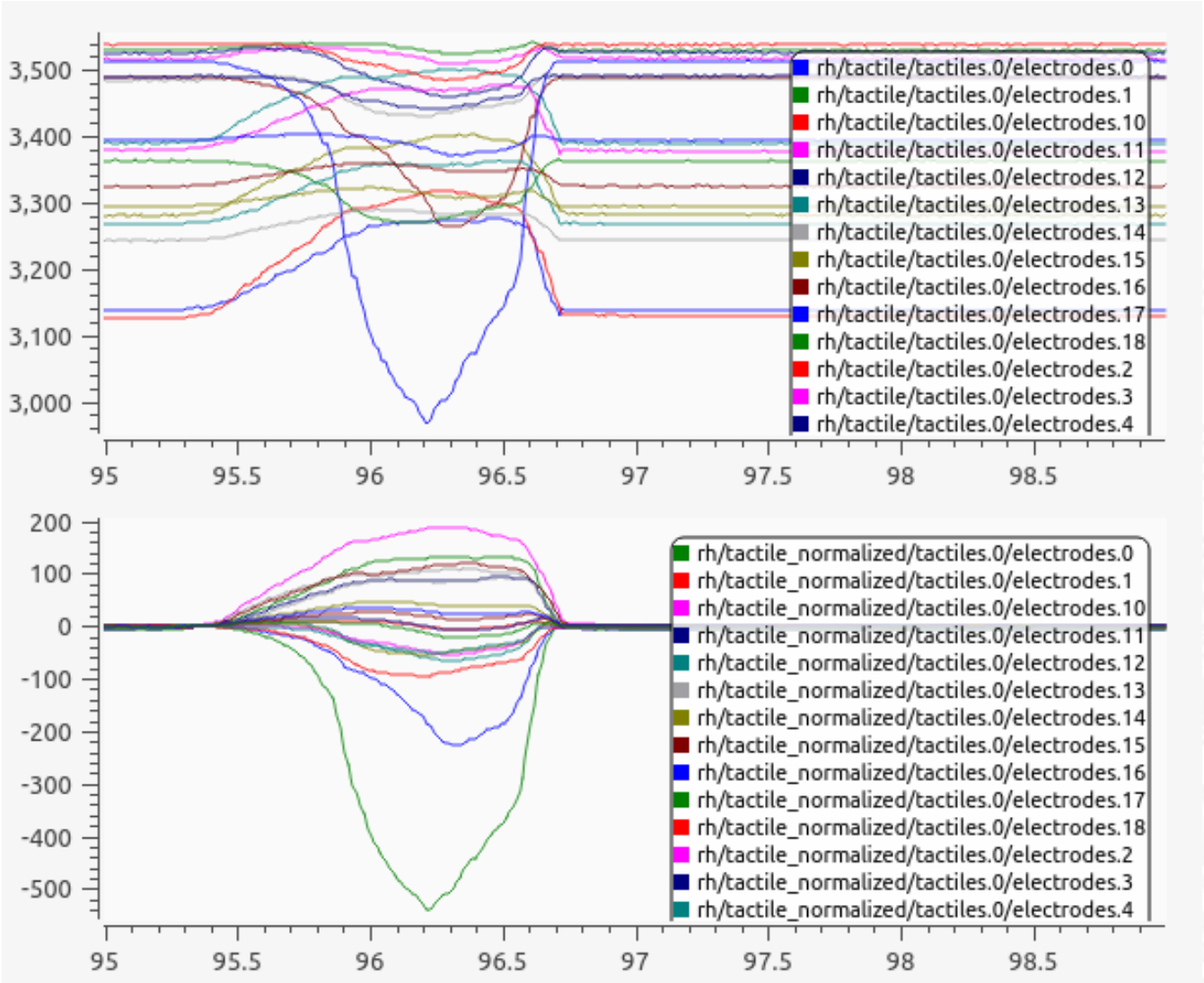
[3] https://www.syntouchinc.com/wp-content/uploads/2017/01/BioTac_Product_Manual.pdf

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

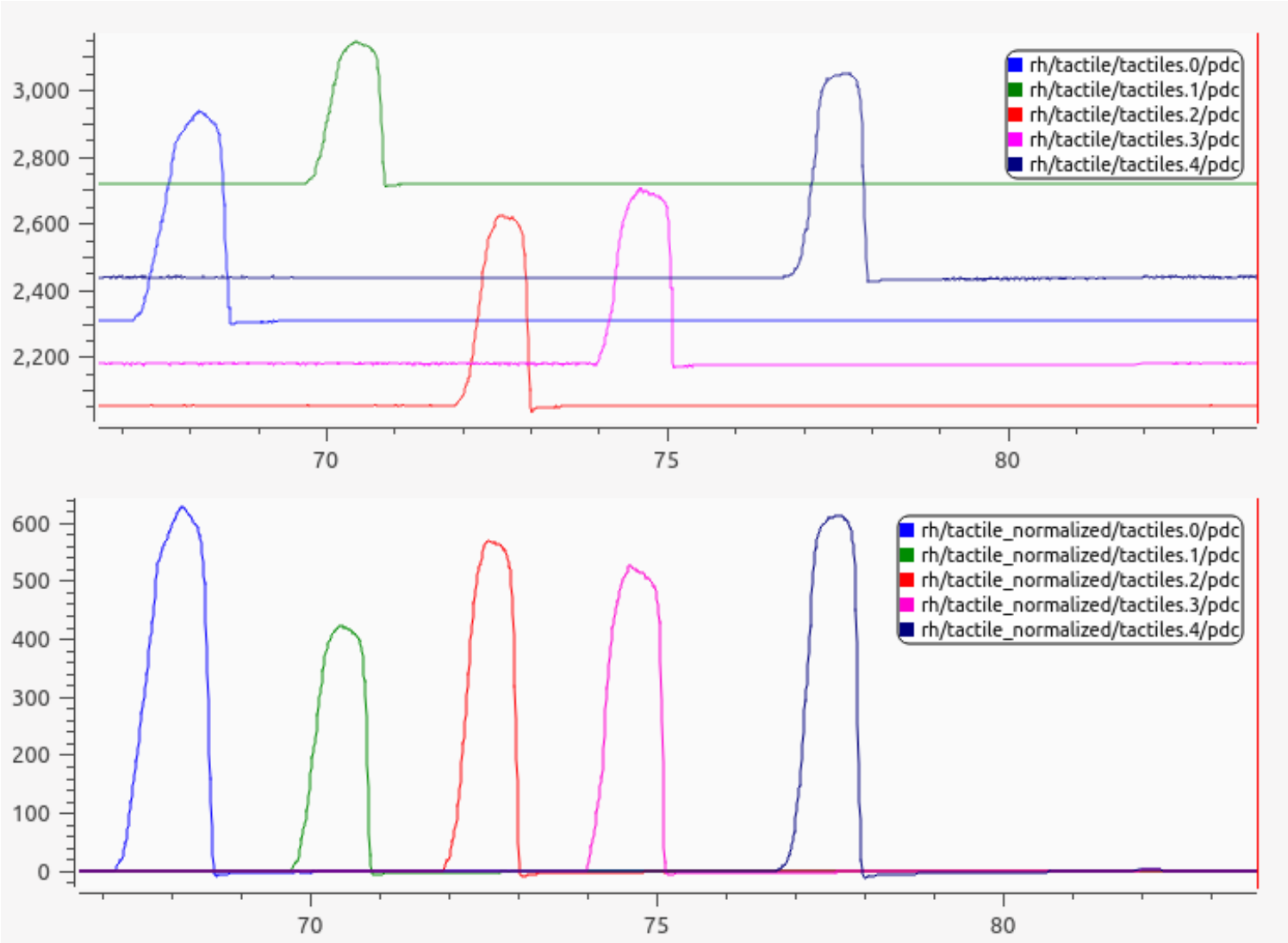
All incoming values from 0 to 4095

Electrode Voltages (E1 - E19) - Impedance



Top: raw data; Bottom: filtered and normalized

DC Pressure (Pdc)



Top: raw data; Bottom: filtered and normalized

Preprocessing

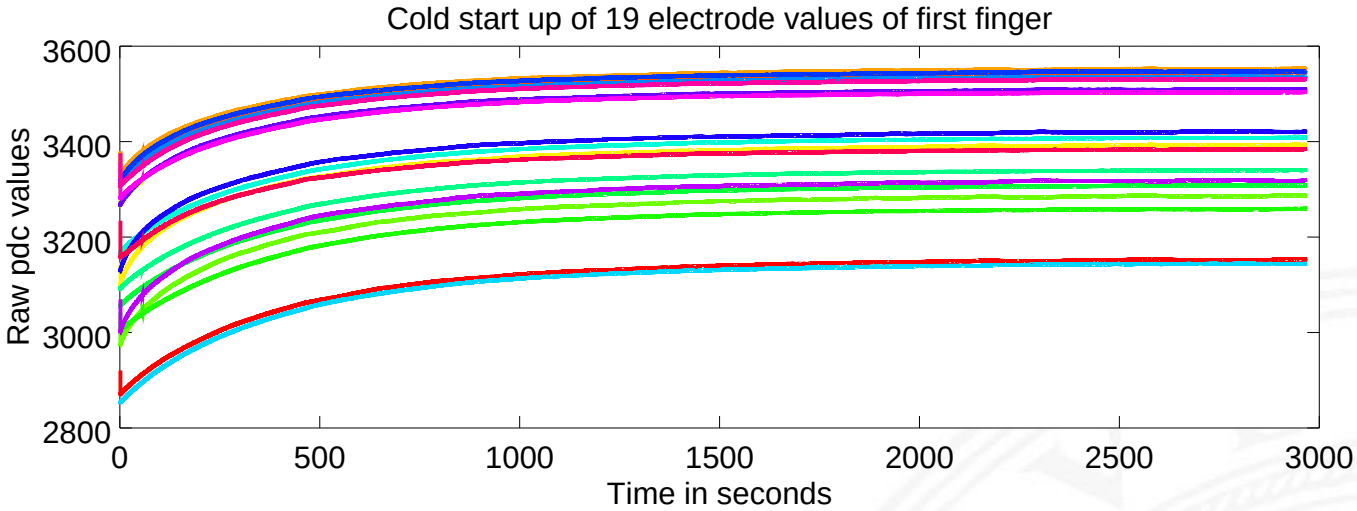
Goal

Get information which are useful for grasping.

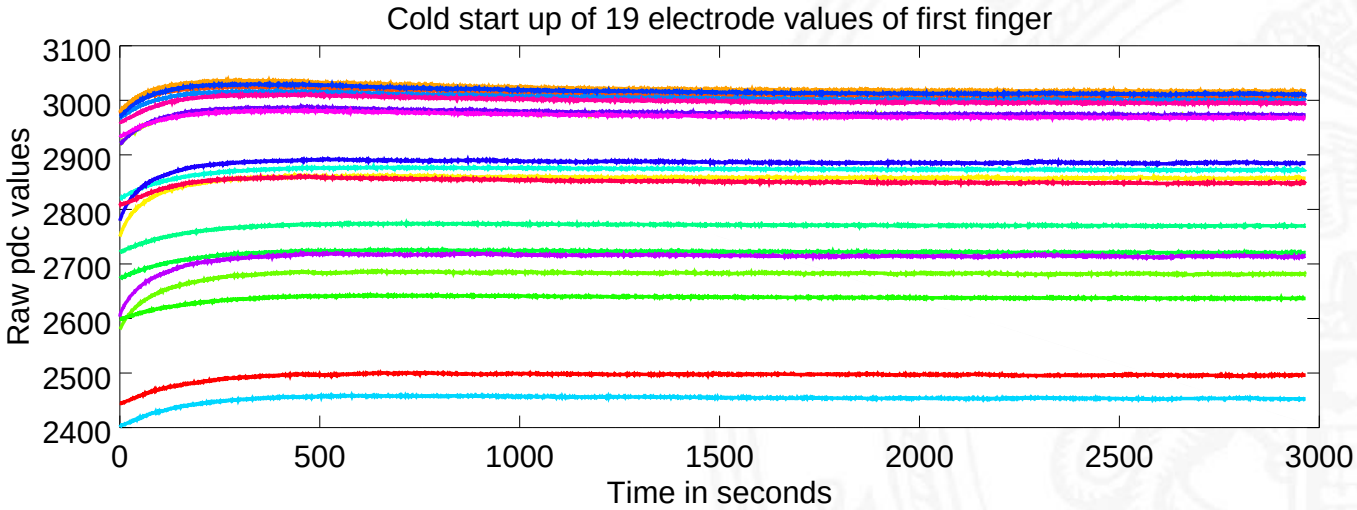
E.g.: Point of contact, contact force

To calculate these informations the data is preprocessed:

Preprocessing
Temperature Compensation



Raw electrode data



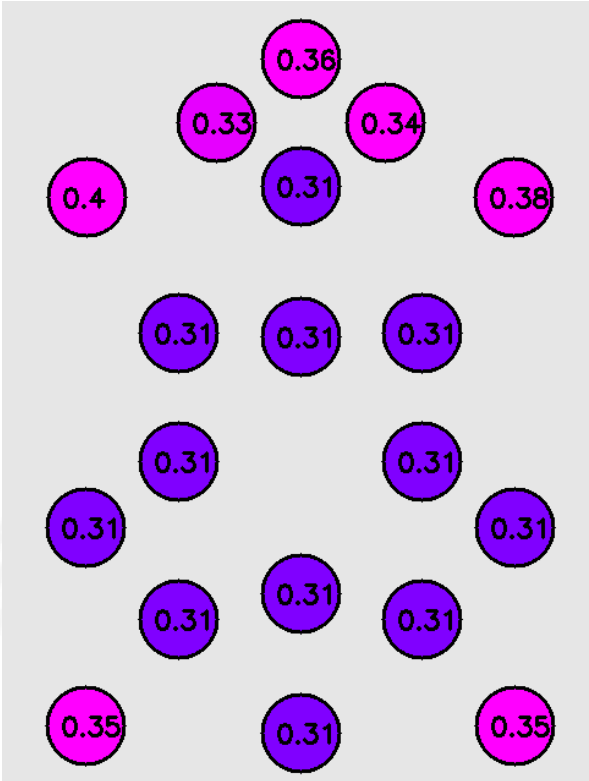
Electrode data with compensated electrode

Preprocessing
Temperature Compensation

$$temp\_e_i' = e_i - tdc \cdot \alpha_i$$

With:

- e_i: Raw electrode value
- tdc: Raw temperature value
- α_i: Compensation constant



α values for first finger

Noise filtering with the Exponentially Weighted Moving Average (EMA)

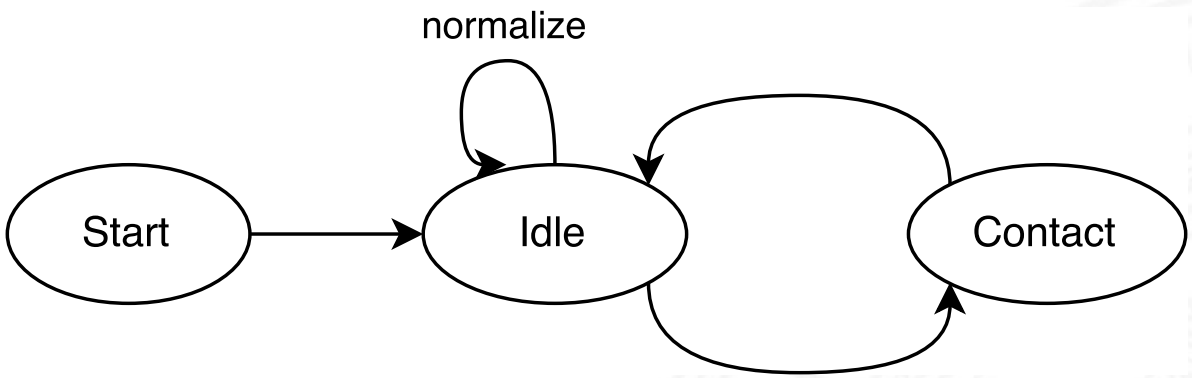
$EMA_n = \alpha \cdot x_n + (1 - \alpha) \cdot EMA_{n-1}$
With:

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

Preprocessing
normalization

Idea

Pdc, pac and electrode values should be 0 in an idle state



Normalization state diagram

Contact

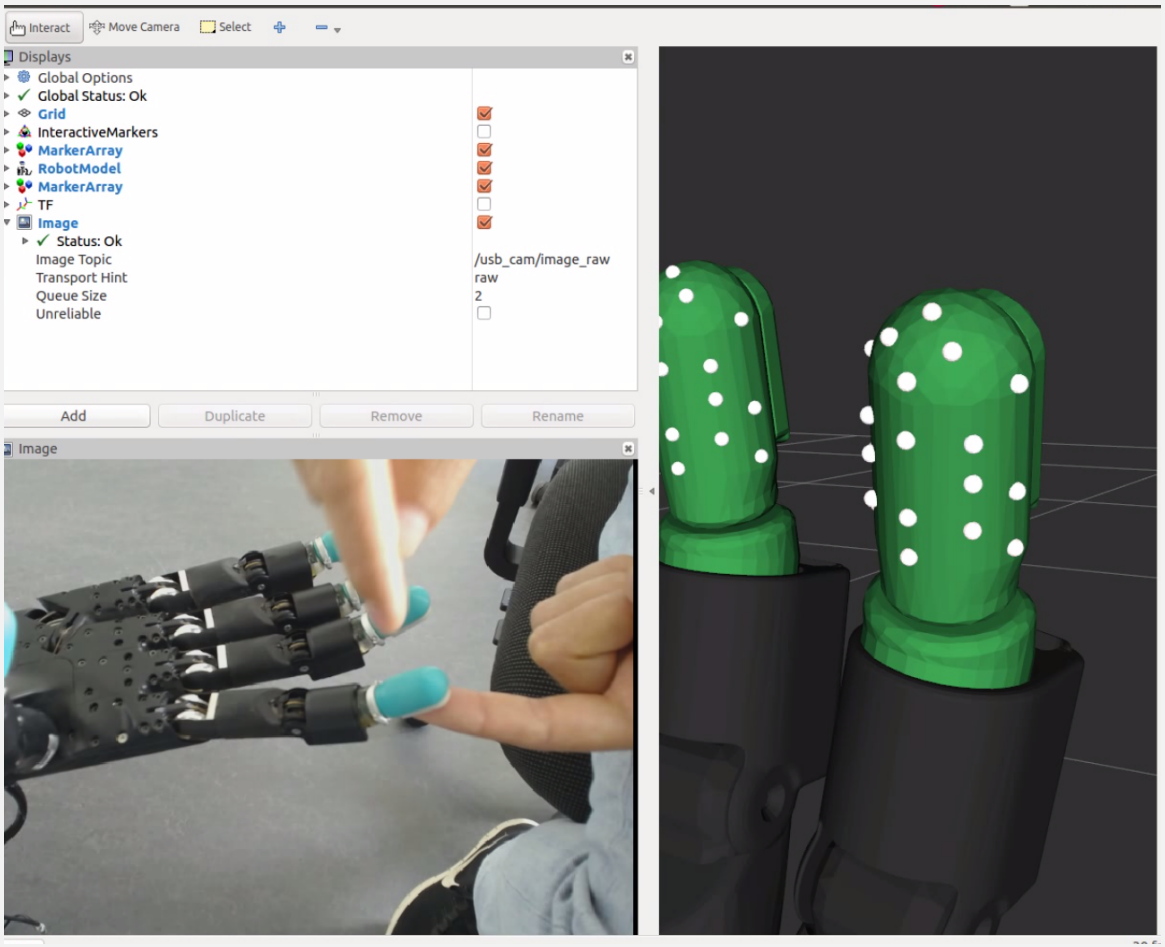
Most important properties of a contact:

- Point of contact
- Normal force

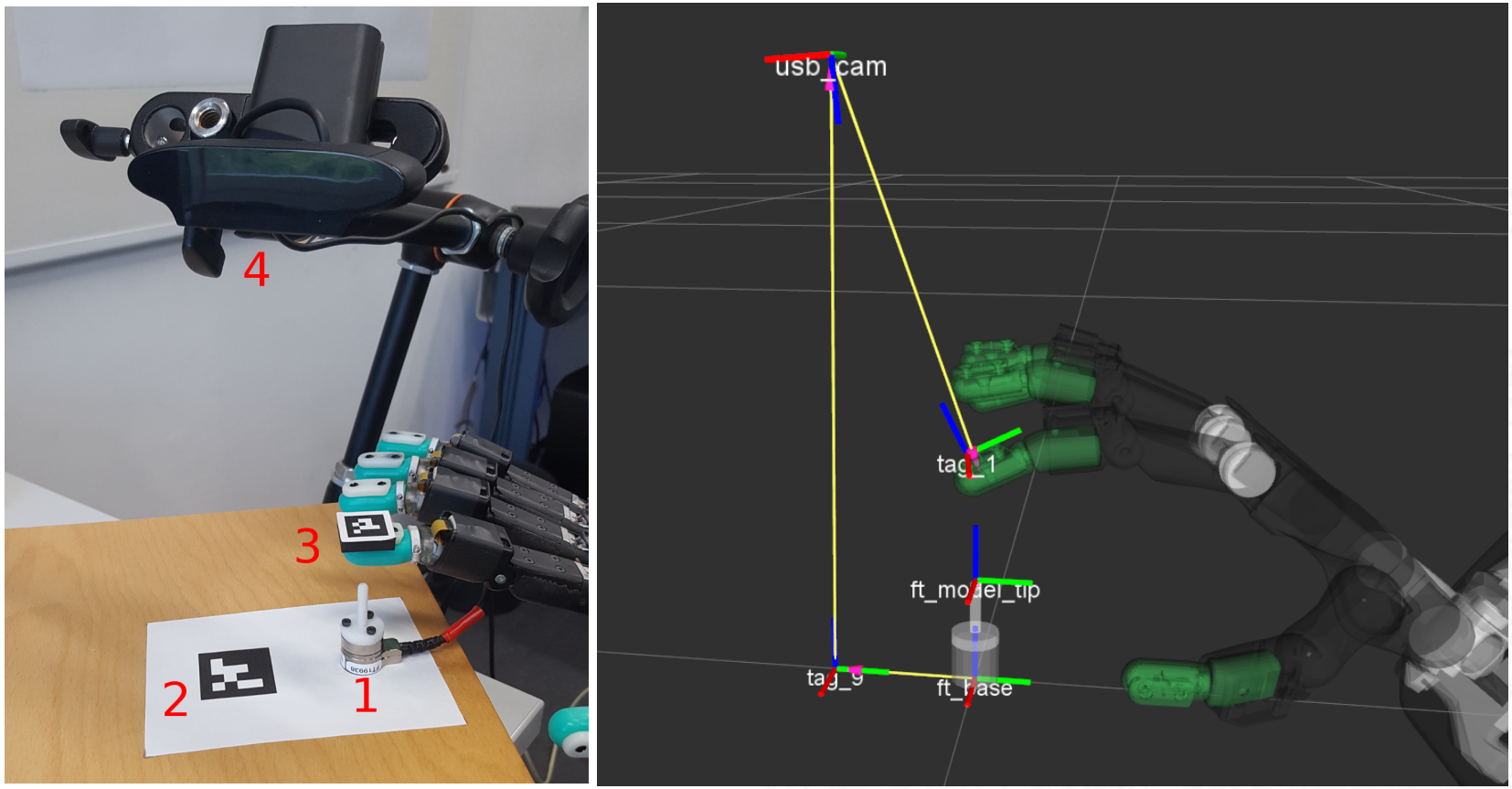
Other properties which will not be regarded:

- Contact Area
- Tangential forces
- ...

Video


Interact
Move Camera
Select
Displays
Global Options
Global Status: Ok
Grid
InteractiveMarkers
MarkerArray
RobotModel
MarkerArray
TF
Image
Status: Ok
Image Topic
/usb_cam/image_raw
Transport Hint
raw
Queue Size
2
Unreliable
Add
Duplicate
Remove
Rename
Image

Contact
Ground truth



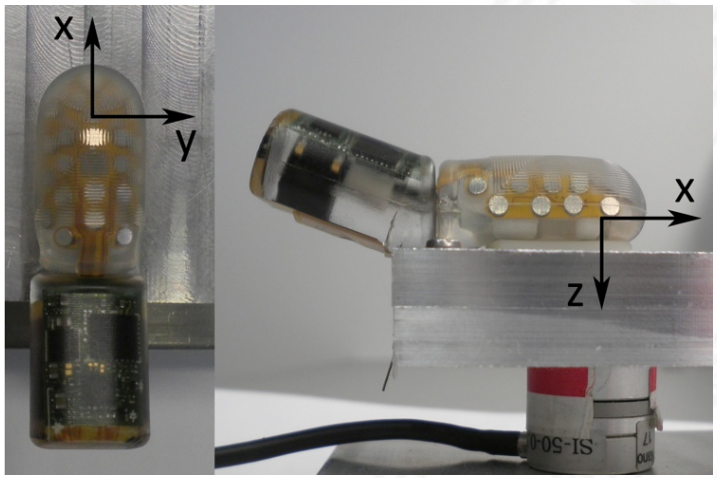
Ground truth setup

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



BioTac origin [4]

[4] https://www.syntouchinc.com/wp-content/uploads/2016/12/2013_Lin_Analytical-1.pdf

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

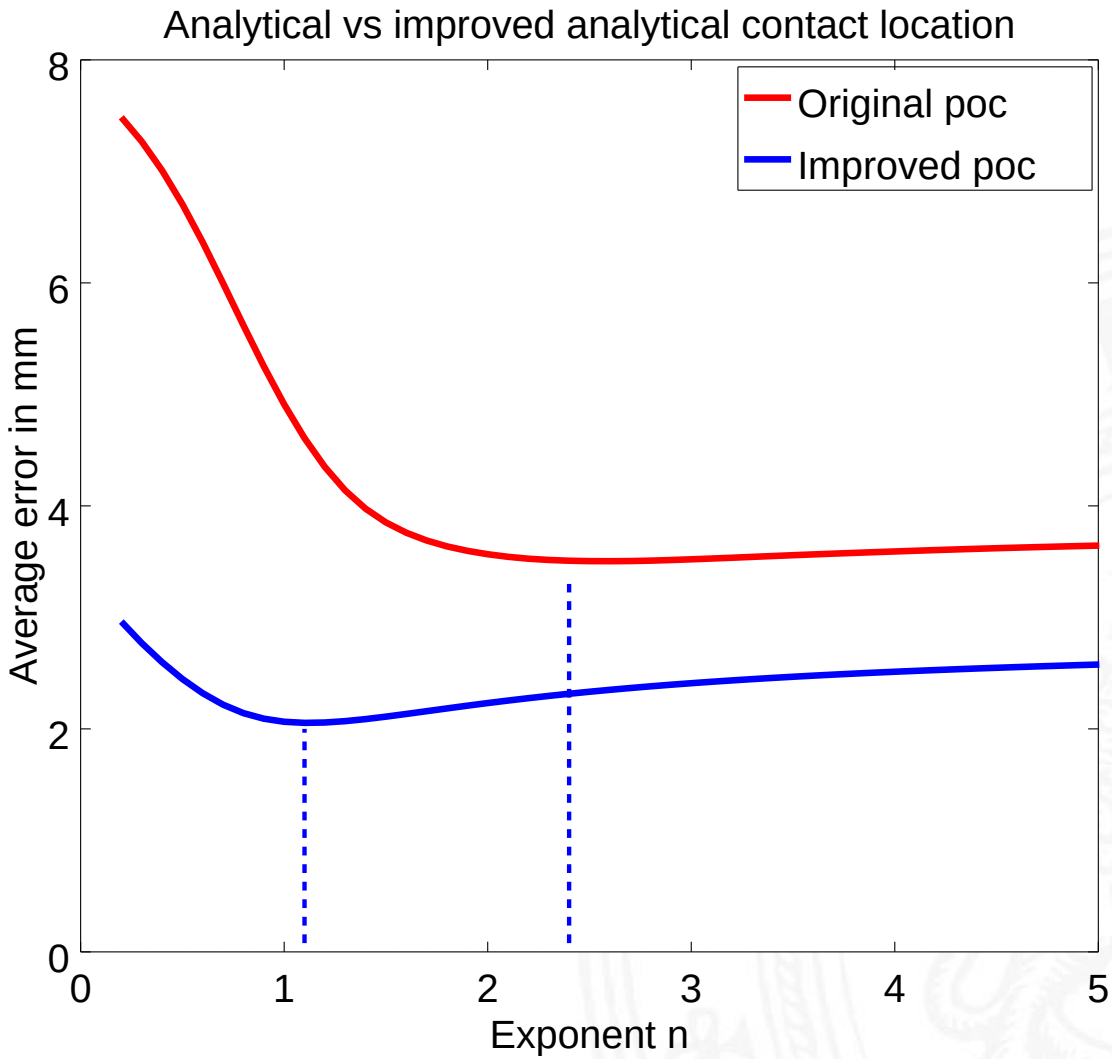
n: Impect of the single electrode

Point of contact
Improved analytical approach

Considering only negative electrode values

$$\langle x_c, y_c, z_c \rangle = \frac{\sum_{i=1}^{19}(|e_{i*}|^n \langle x_i, y_i, z_i \rangle)}{\sum_{i=1}^{19}(|e_{i*}|^n)} \quad with \quad e_{i*} = \begin{cases} e_{i*} & for \ e_{i*} < 0 \\ 0 & for \ e_{i*} > 0 \end{cases}$$

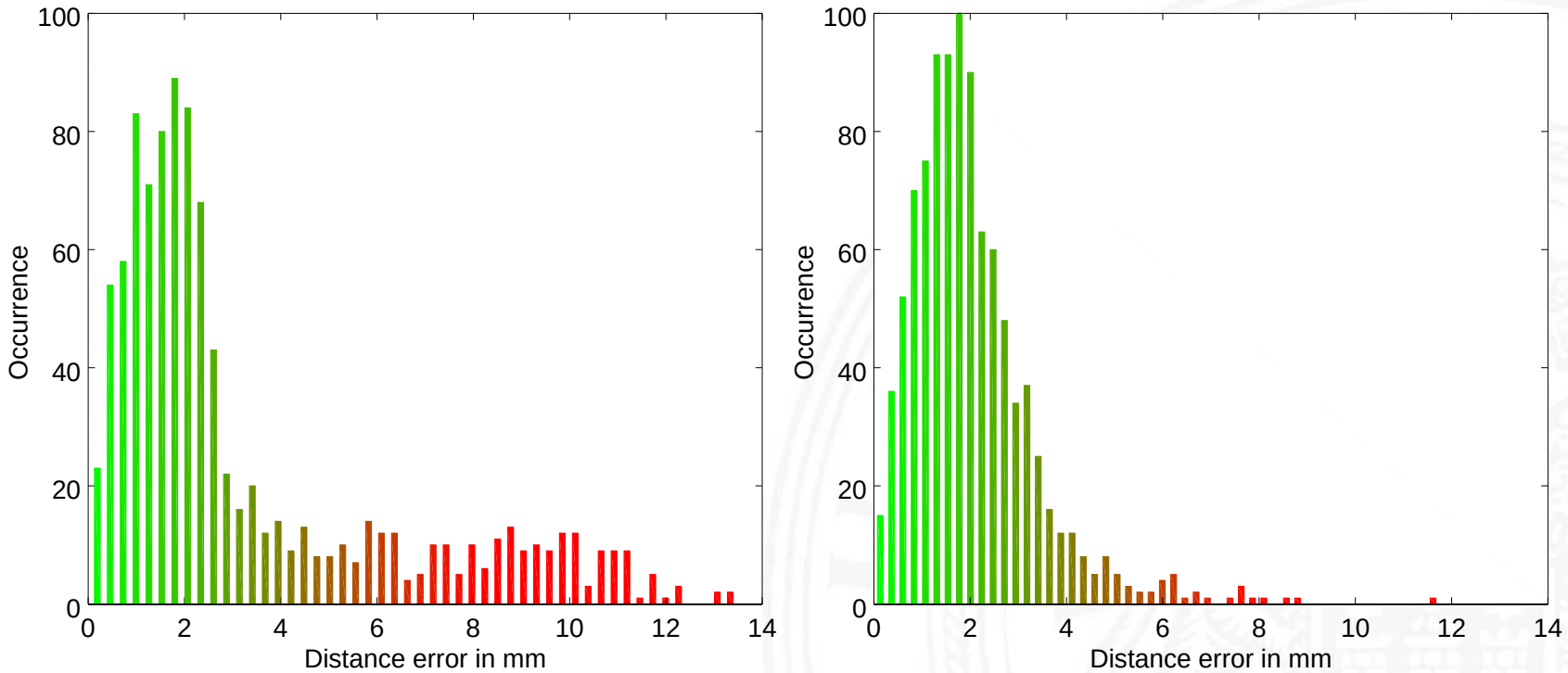
Point of contact
Evaluation



Point of contact
Evaluation

Average error:

- Original: 3.42 mm
- Improved: 2.01 mm



Distance error distribution

Point of contact
Calibration of electrodes

Goal

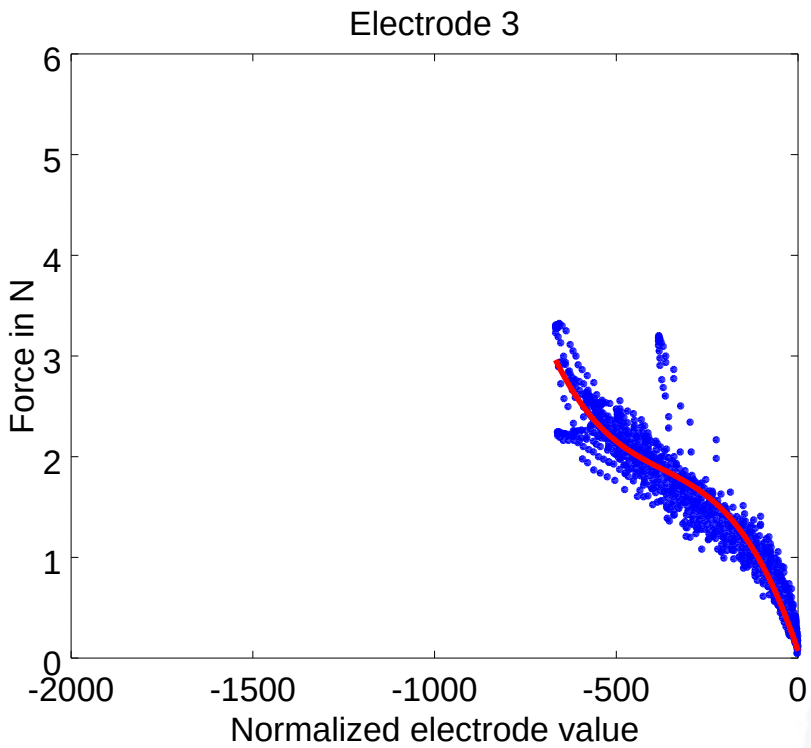
Improve point of contact accuracy by calibrating the electrode values

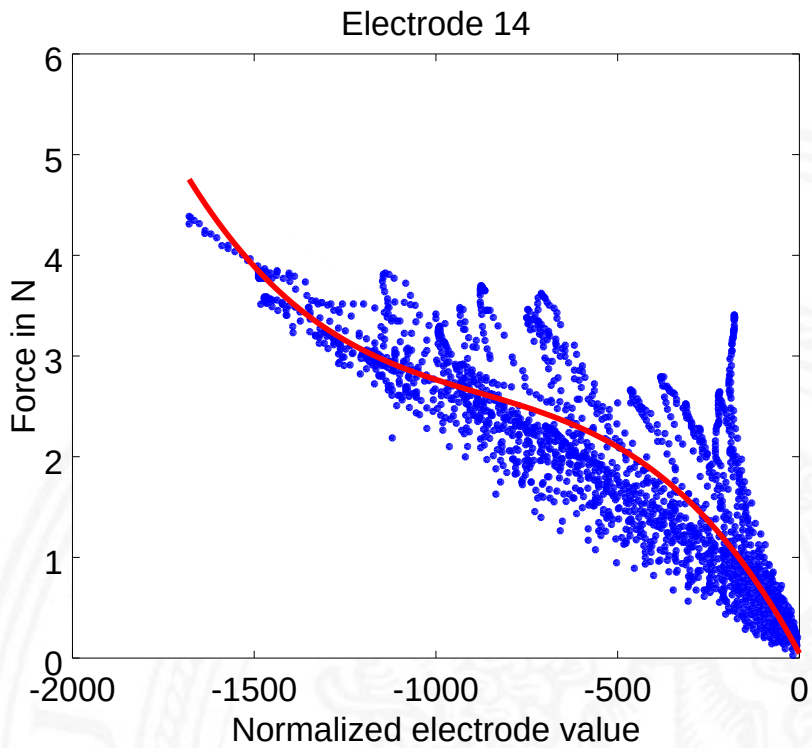
Problem: Electrodes react differently to the same amount of force

Calibration approaches:

1. Generate transfer function for each electrode with ground truth force
2. Normalize electrode values between -1 and 1 with minimum and maximum

Transfer functions for electrode 3 and electrode 14



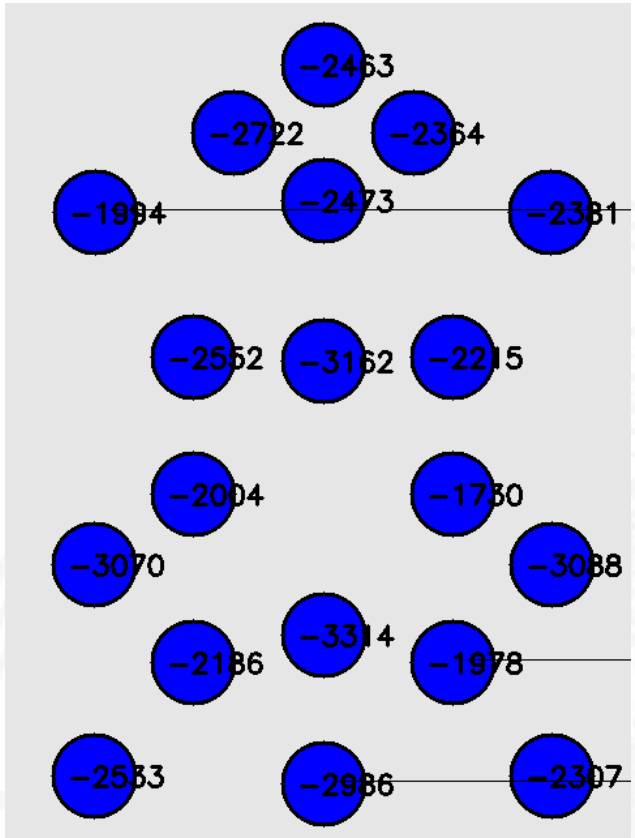


Point of contact
Calibration of electrodes

$$e_{i\_norm} = \frac{e^*_i}{e^*_{i\_min}}$$

With:

- e^*_i: Preprocessed electrode value
- $e^*_{i\_min}$: Minimum value at electrode i

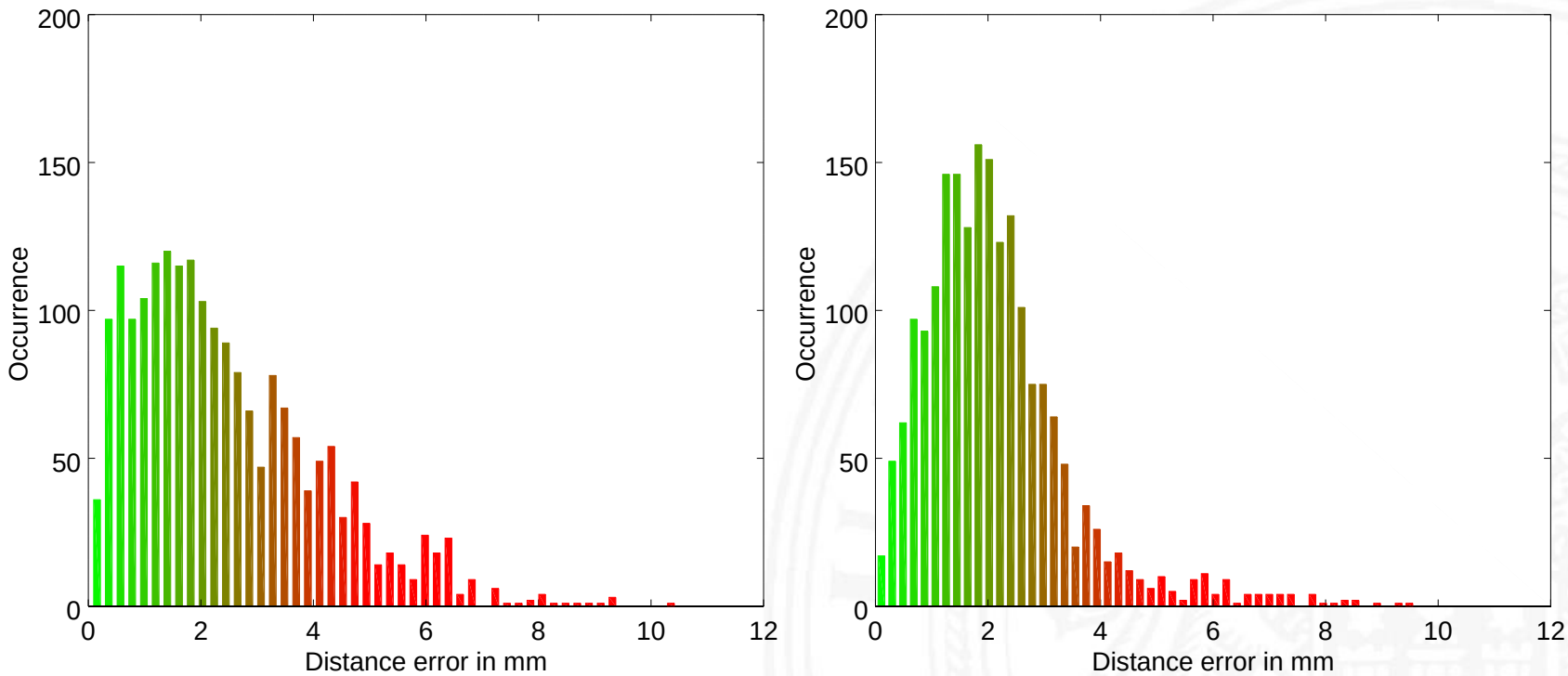


Minimum values

Point of contact
Evaluation

Average error:

- Ground truth force: 2.44 mm
- -1 to 1 normalization: 2.04 mm



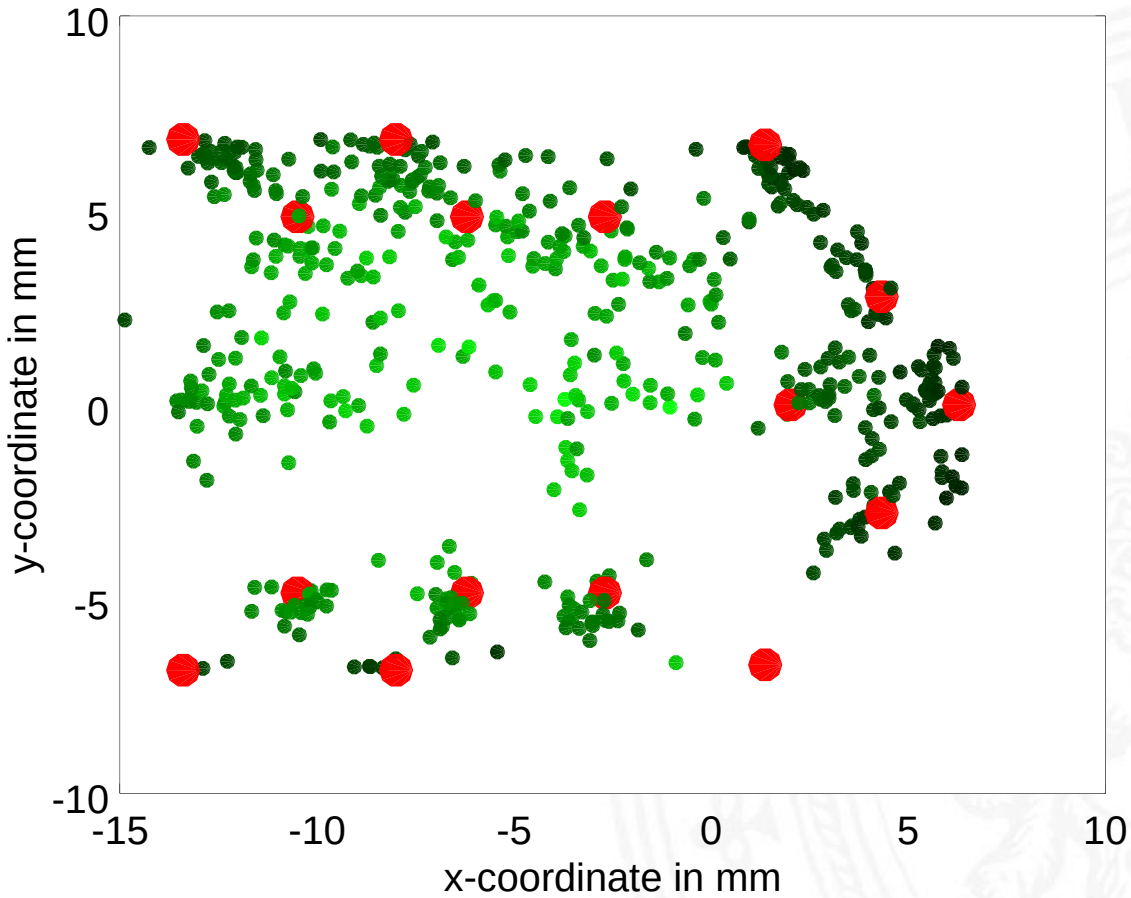
Distance error distribution

Normal force estimation

Idea

Generate transfer function between pdc and force

Problem: Relation between force and pdc depends on contact point

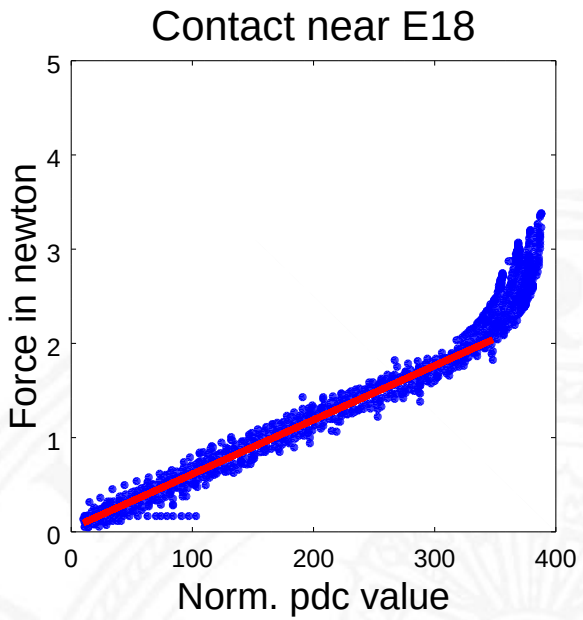


Normal force estimation

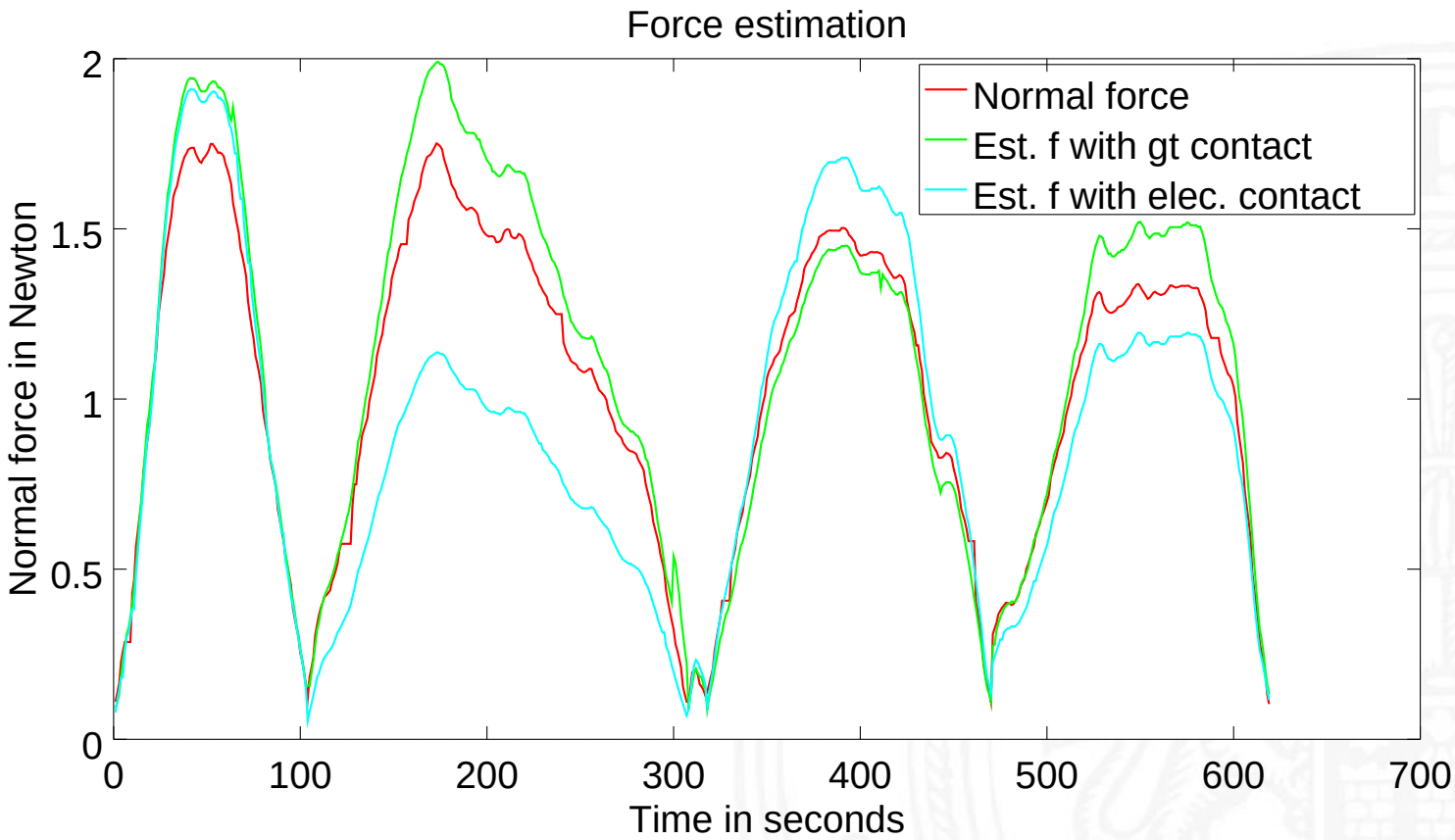
Transfer functions

Generate 19 transfer functions at electrode positions and interpolate between them with distance-based interpolation

$$F_N = \begin{cases} \frac{\sum_{i=1}^{3} \frac{1}{d_i} \cdot trans_i(P_{DC})}{\sum_{i=1}^{3} \frac{1}{d_i}} & for\ d_1 > 0 \\ trans_i(P_{DC}) & for\ d_1 = 0 \end{cases}$$



Accuracy of 0.356 N with estimated contact point



Tactile grasping - Proof of Concept

Idea

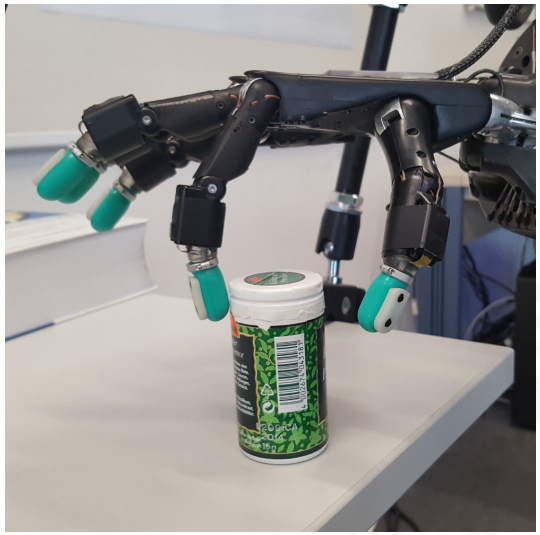
Include tactile feedback in grasping motions

Grasping process:

1. Move both finger to requested position
2. Stop motion of finger on contact
3. Apply requested force when both fingers have a contact

Tactile grasping - Proof of Concept

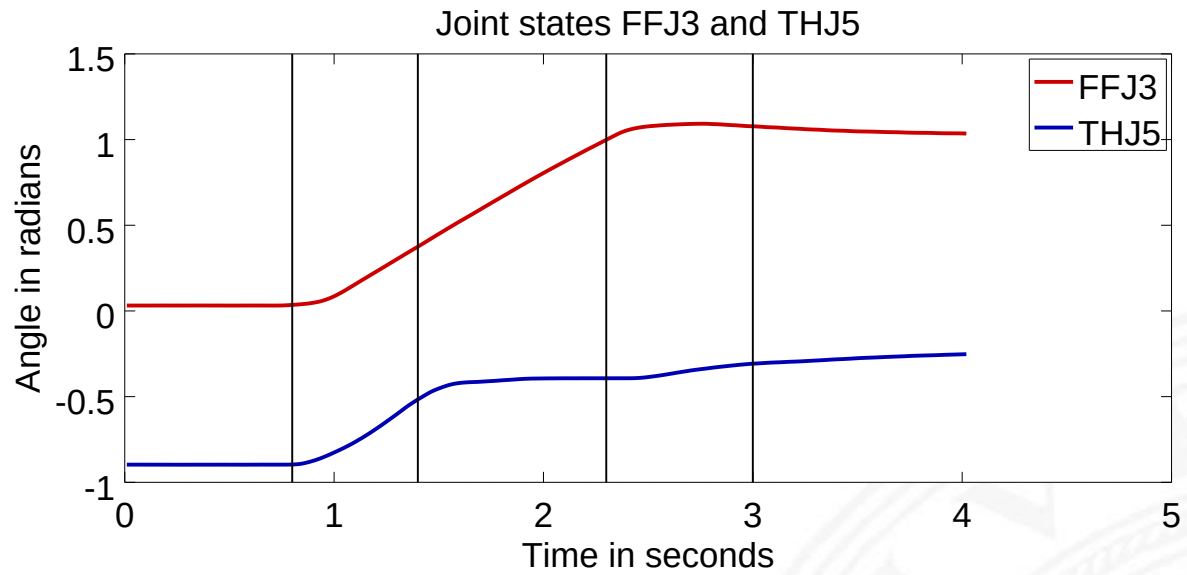
1. Closing

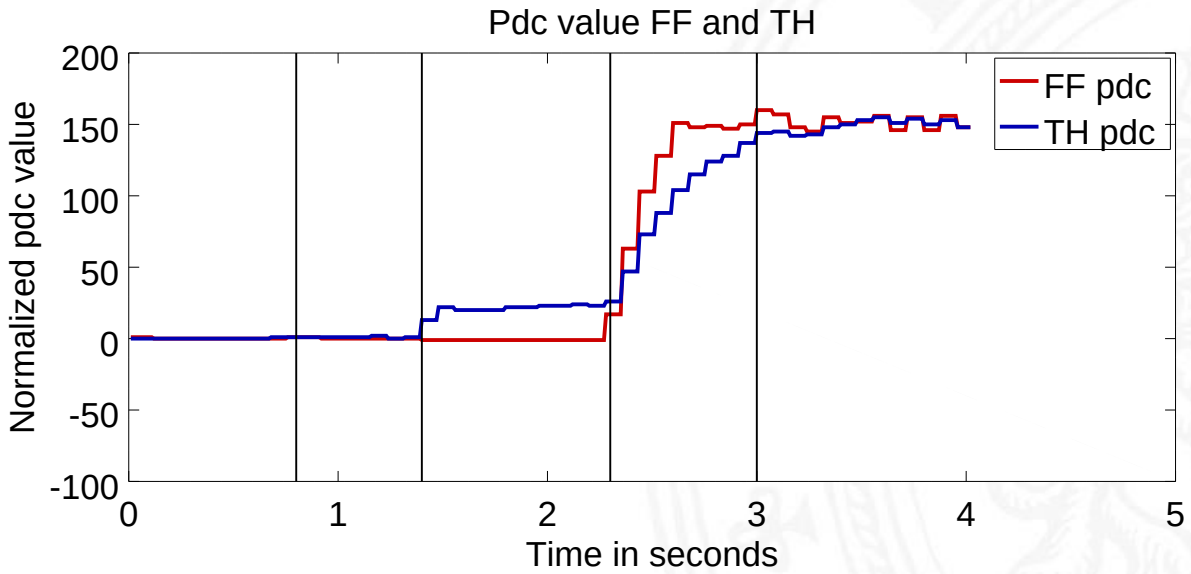


2. First contact

3. Second contact: Apply force

Tactile grasping - Proof of Concept





Conclusion

- Successful grasping an object
- BioTac data is preprocessed and can be used
- Contact point and normal force are estimated for contacts

- Calibration could be improved to increase accuracy

Future work

- Try to learn point of contact and normal force
- Extend controller for more finger
- Integrate grasping with the PR2
- Use preprocessed BioTac data to read braille
- ...