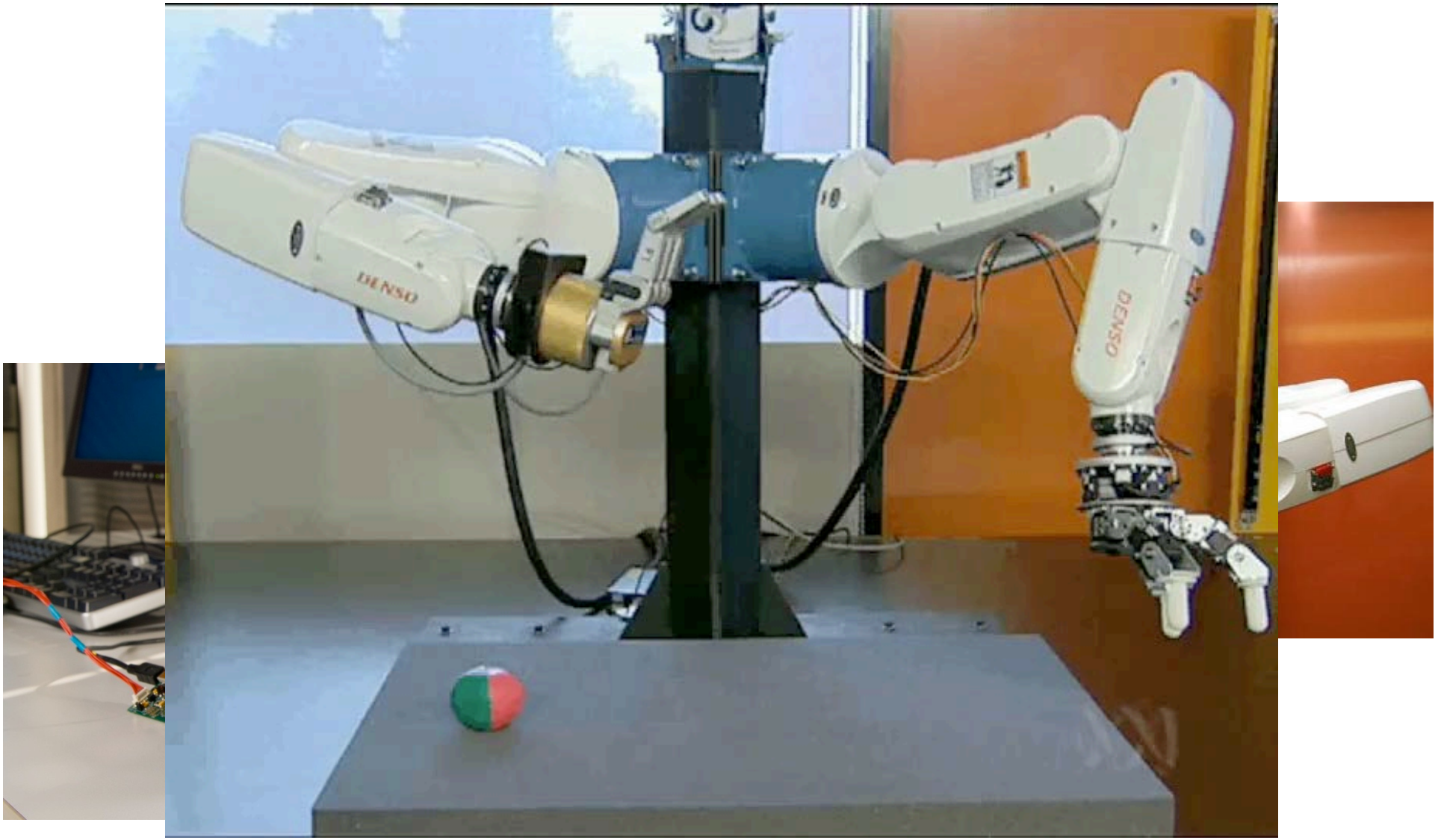
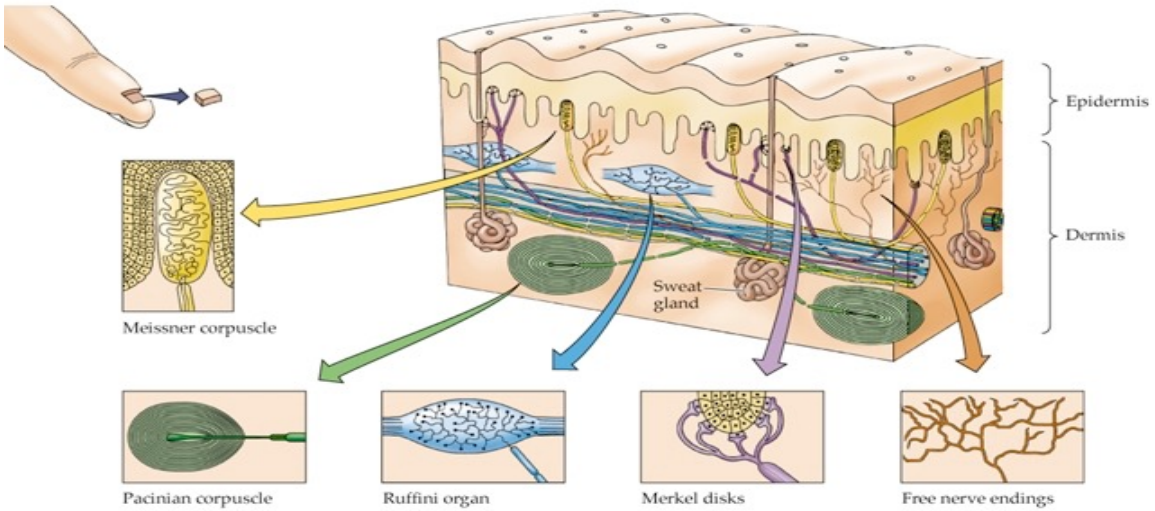
Tactile Sensing

Building a Tactile Sensor

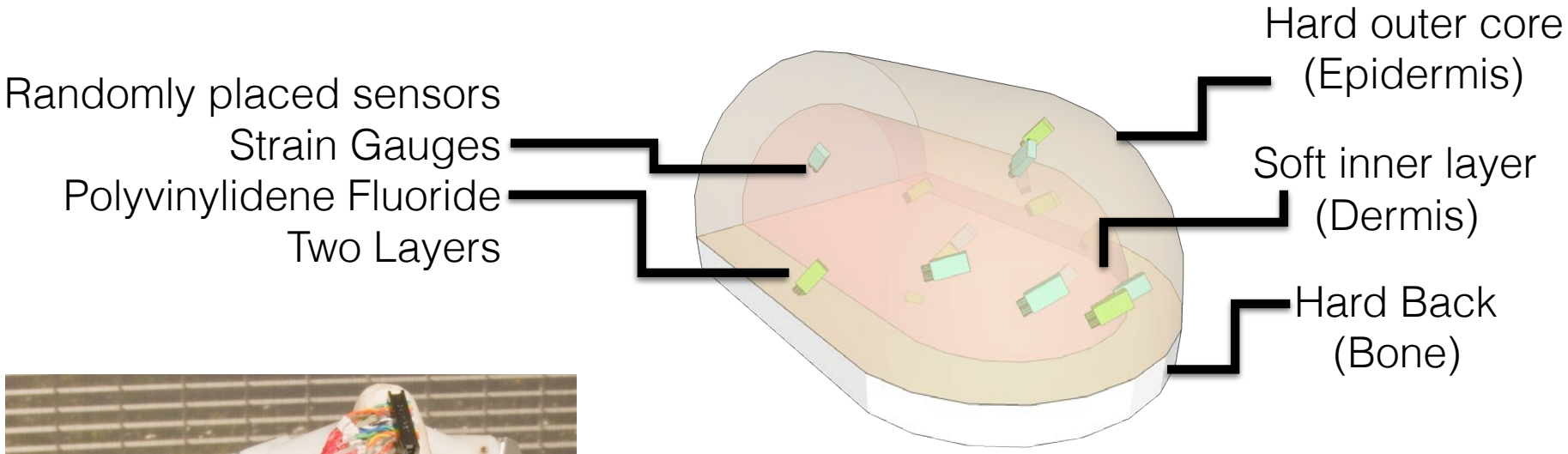


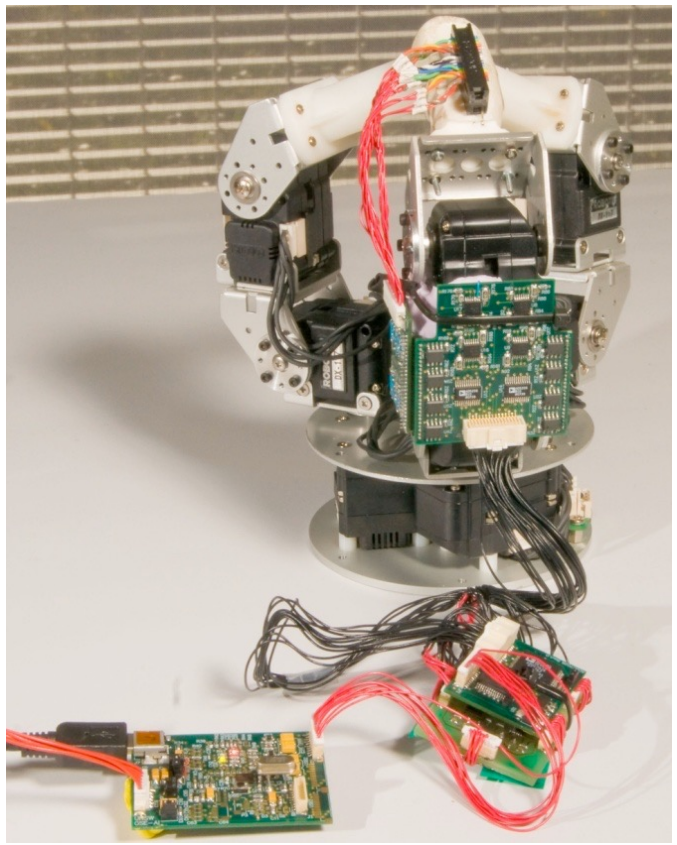
Human Receptors

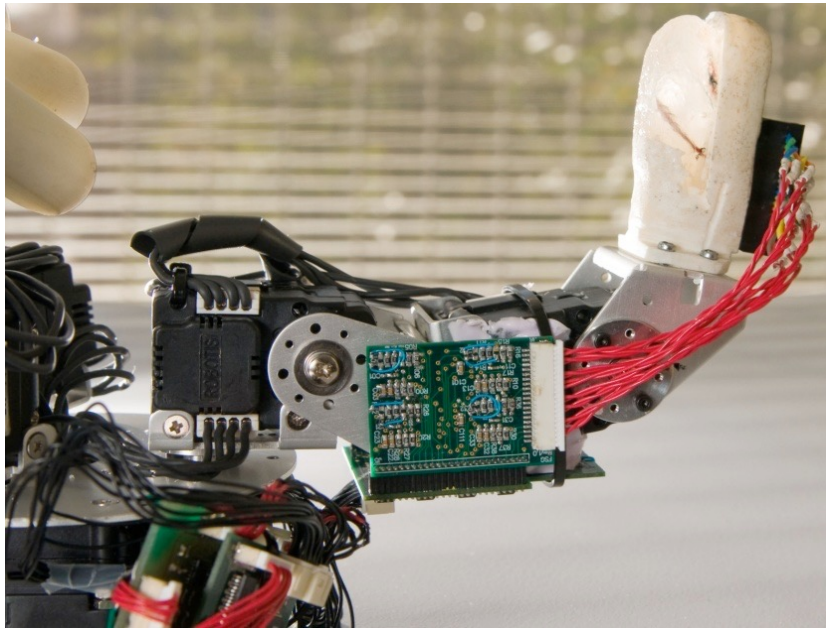


- Two major layers
- Two main types
    - Fast Adapting: Pacinian and Meissner corpuscles
    - Slow Adapting: Merkel disk, Ruffini organ

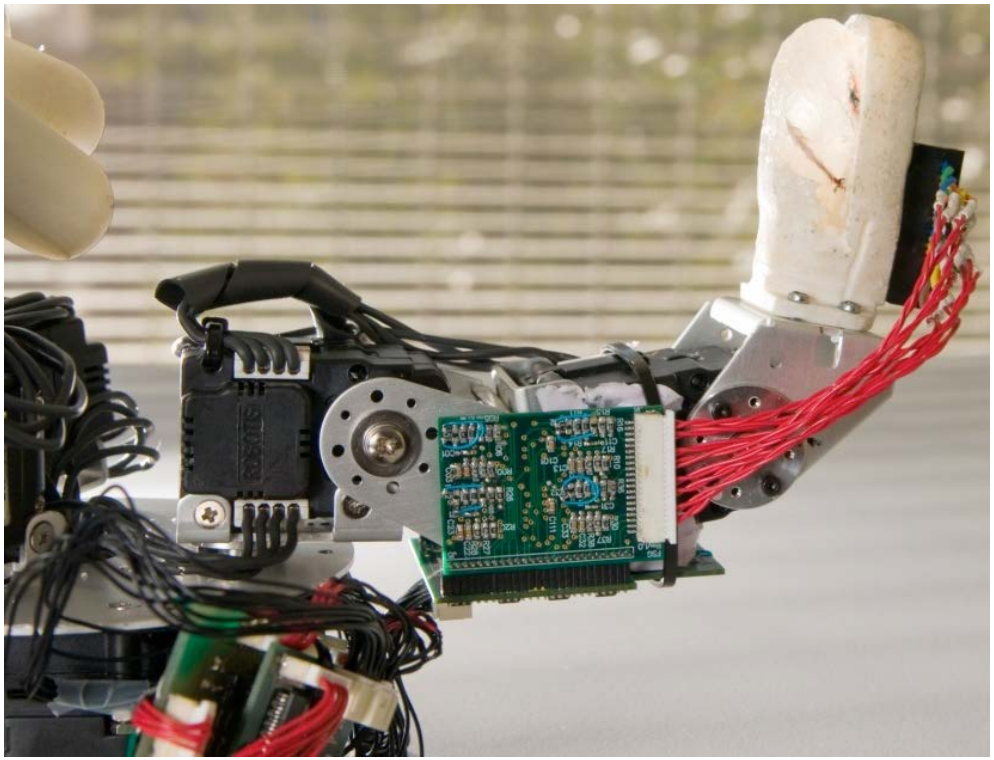
Artificial Finger

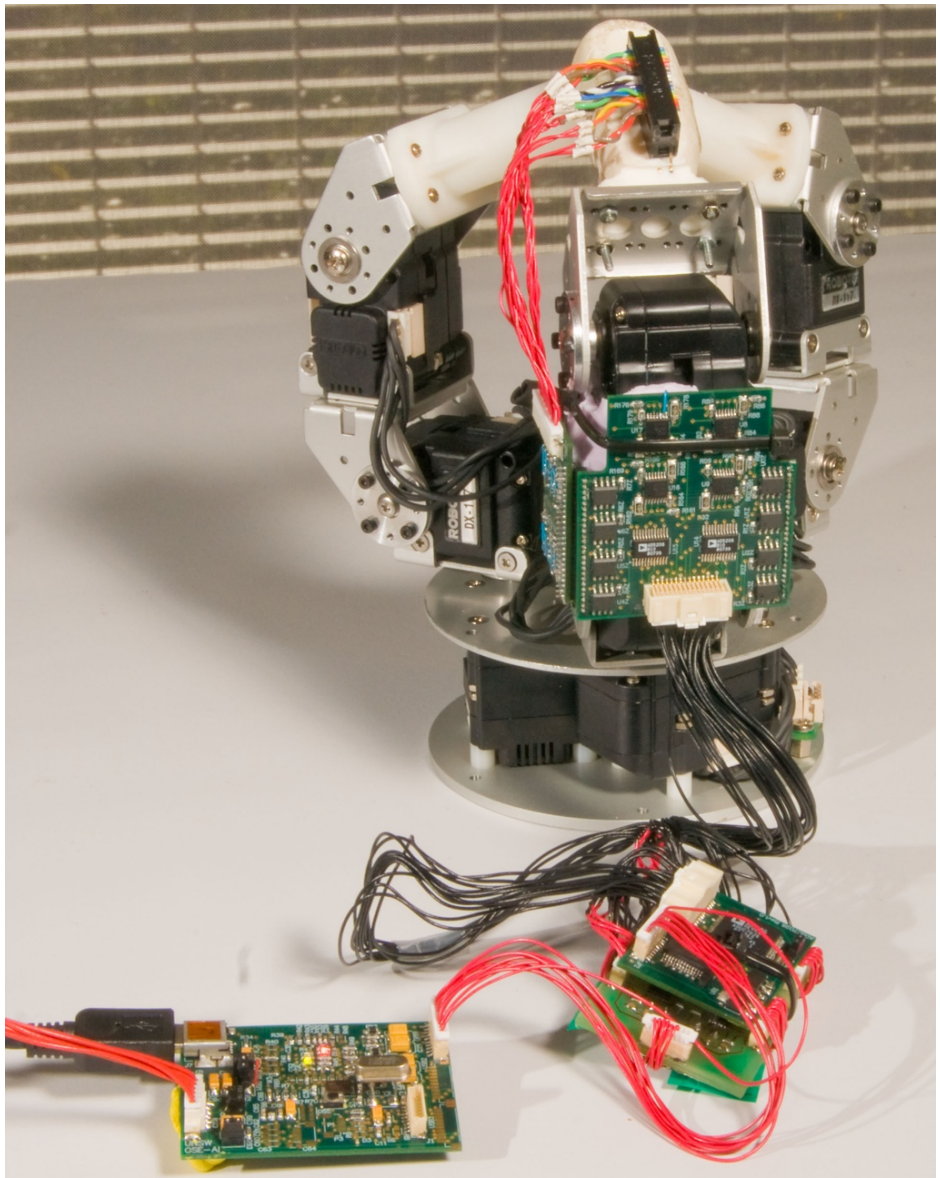






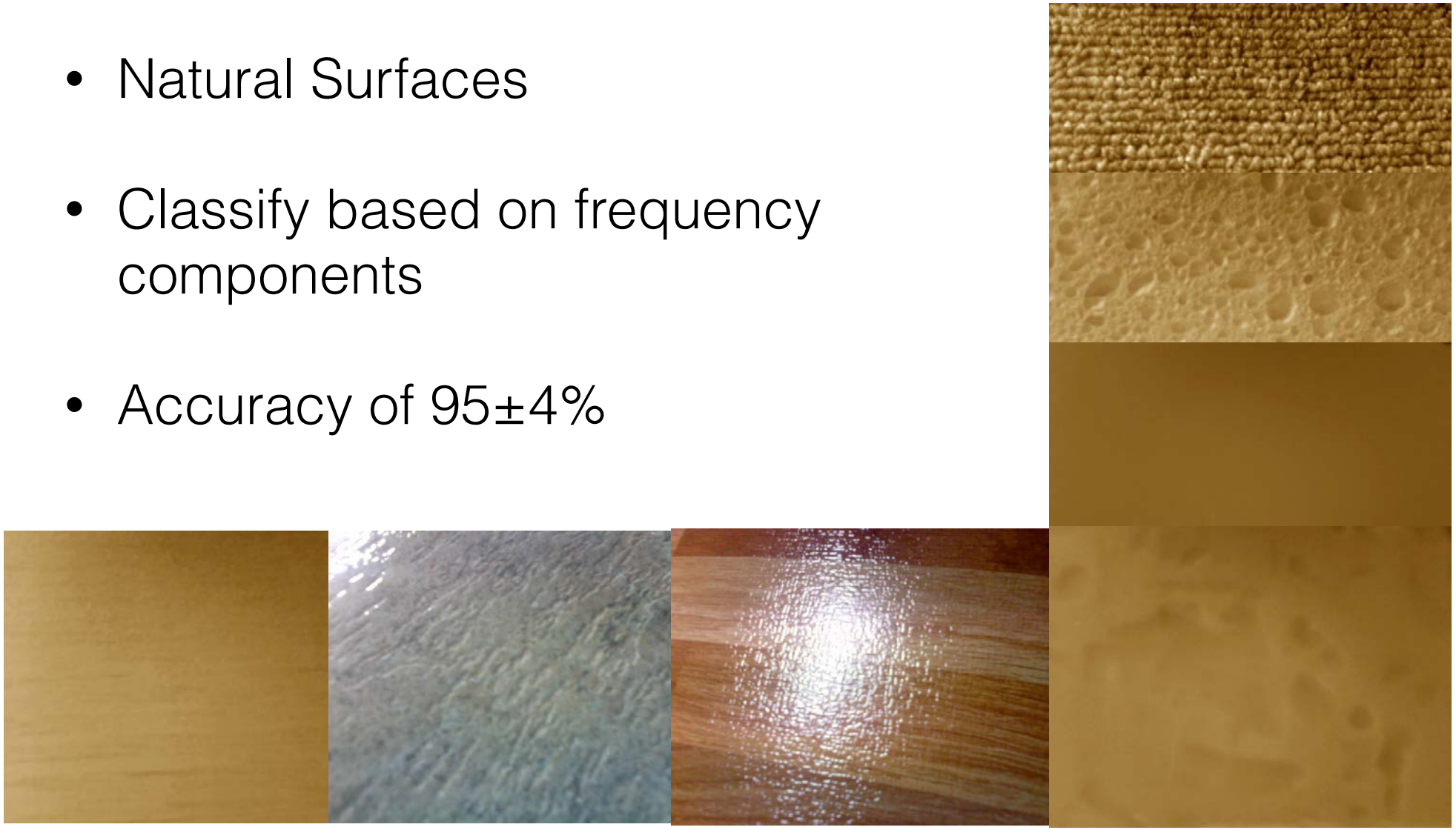
Designed In-house



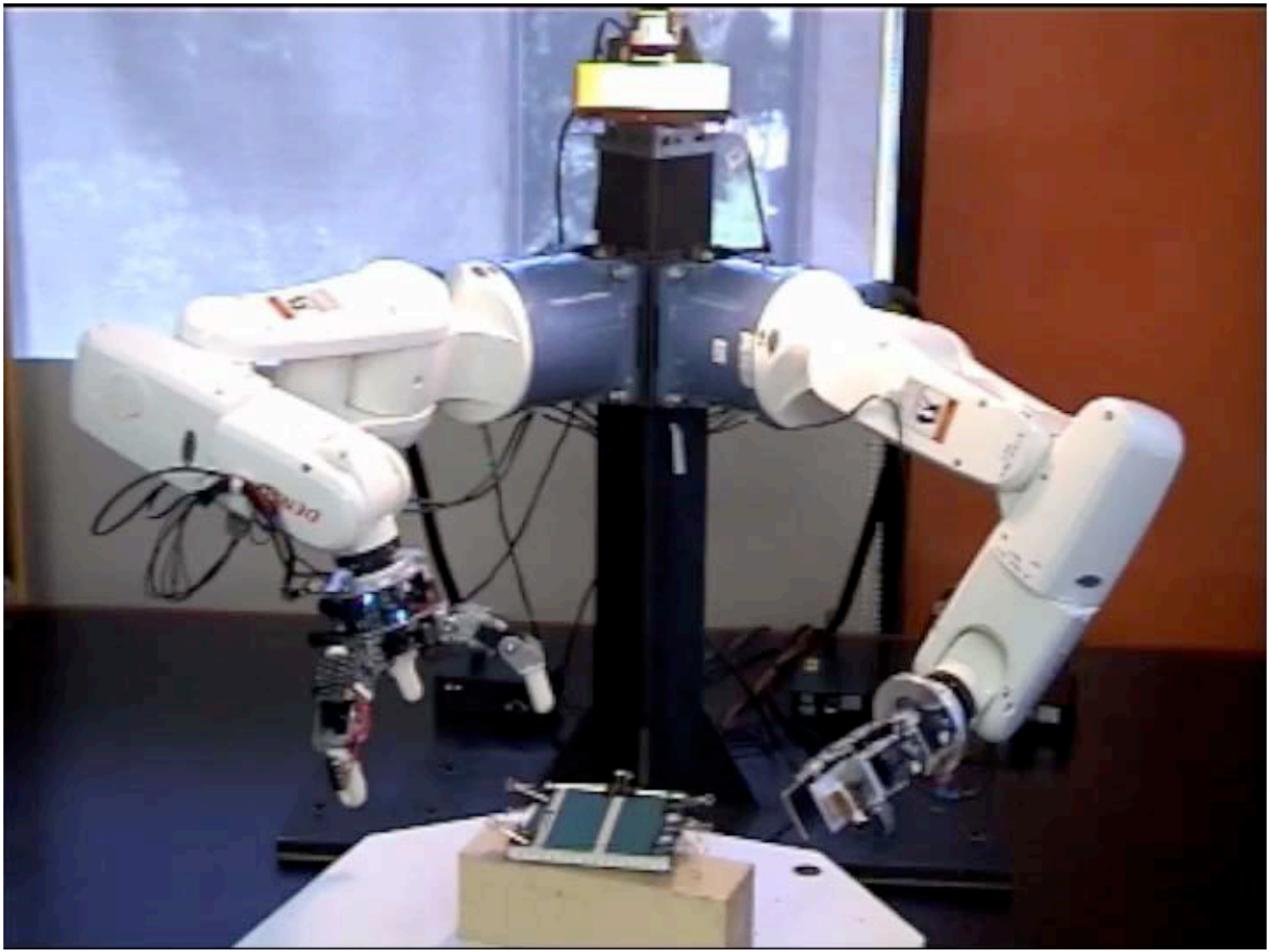


Distinguishing Natural Textures

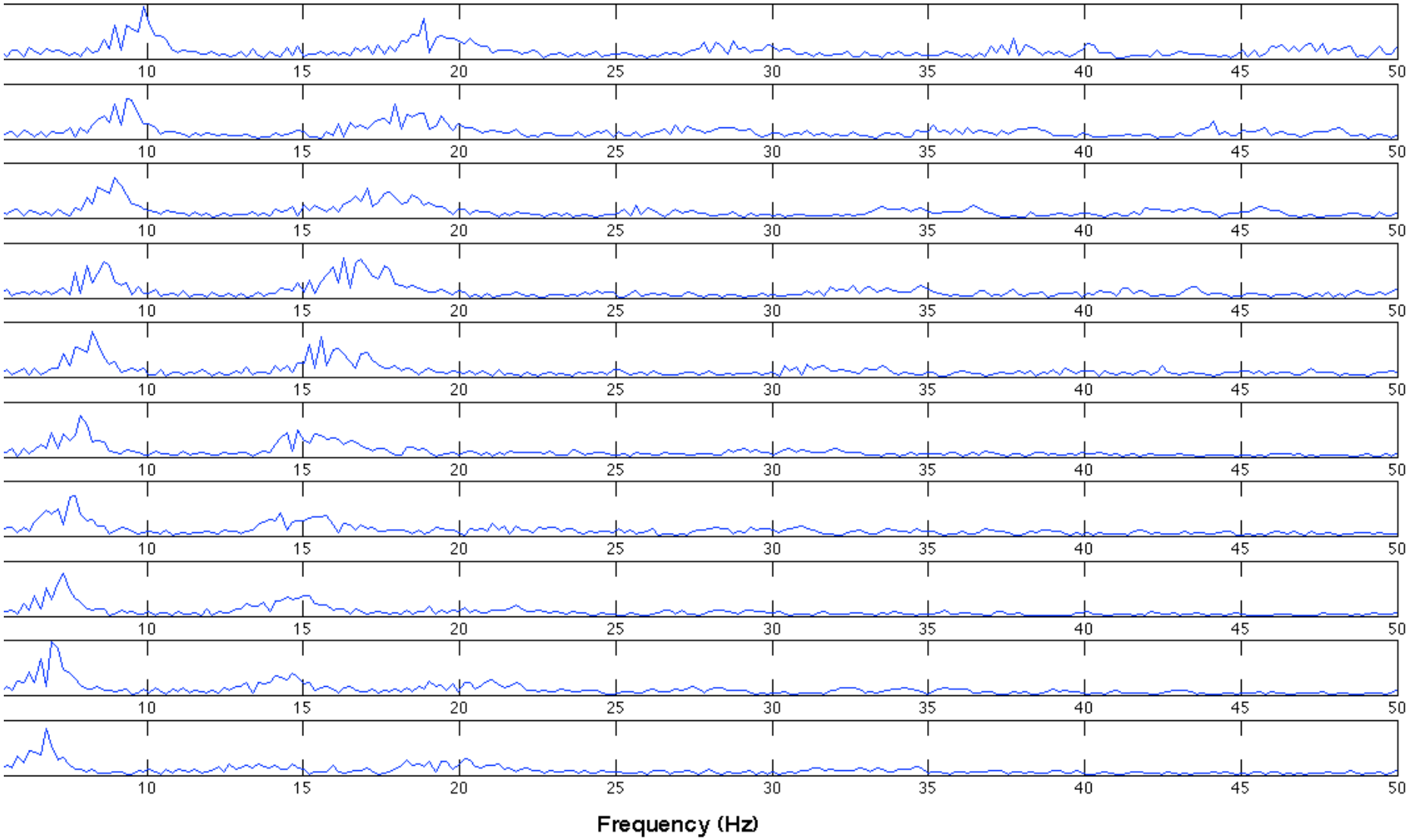
- Natural Surfaces
- Classify based on frequency components
- Accuracy of 95±4%



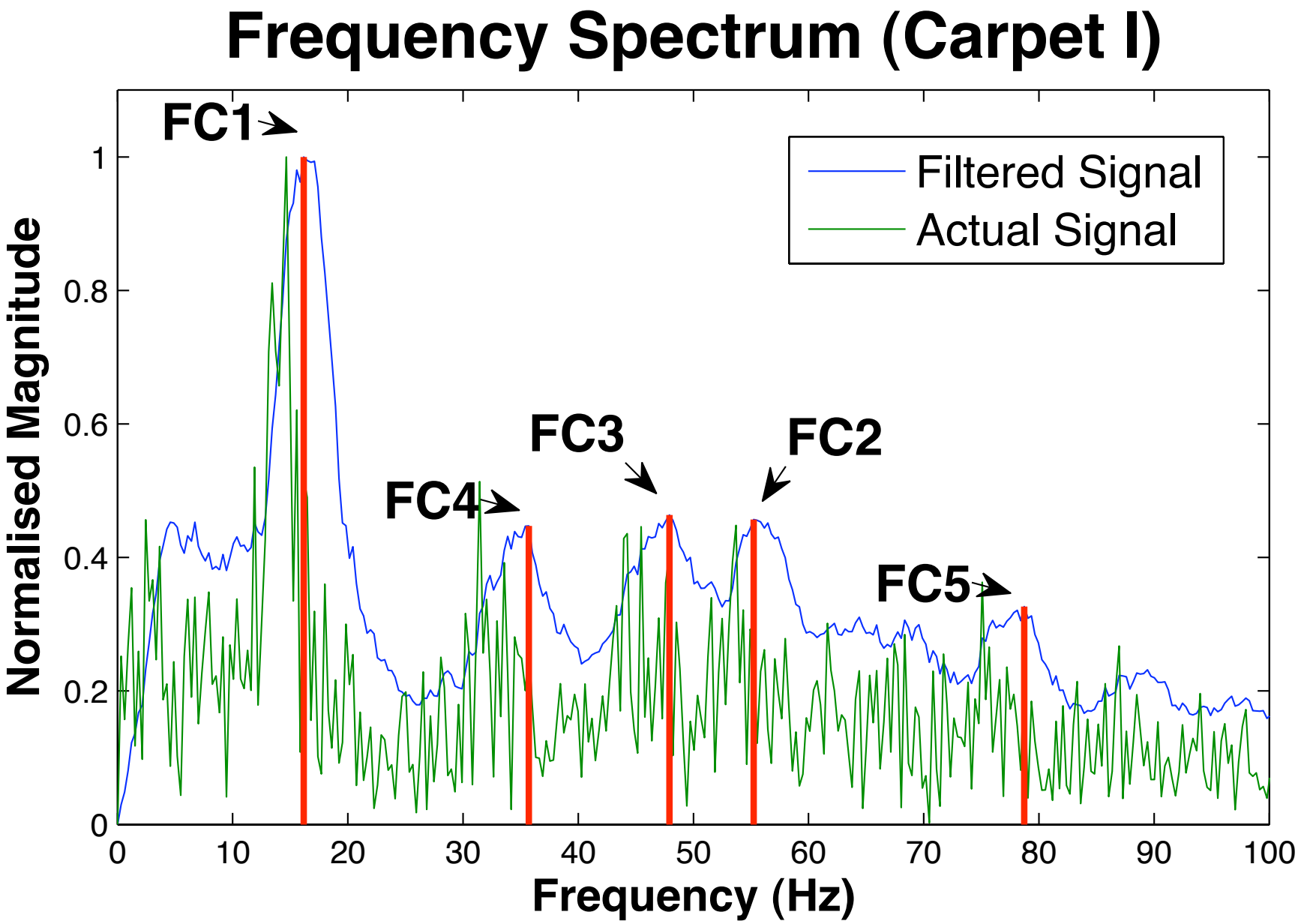
Experimental Setup



Training



Typical Frequency Response



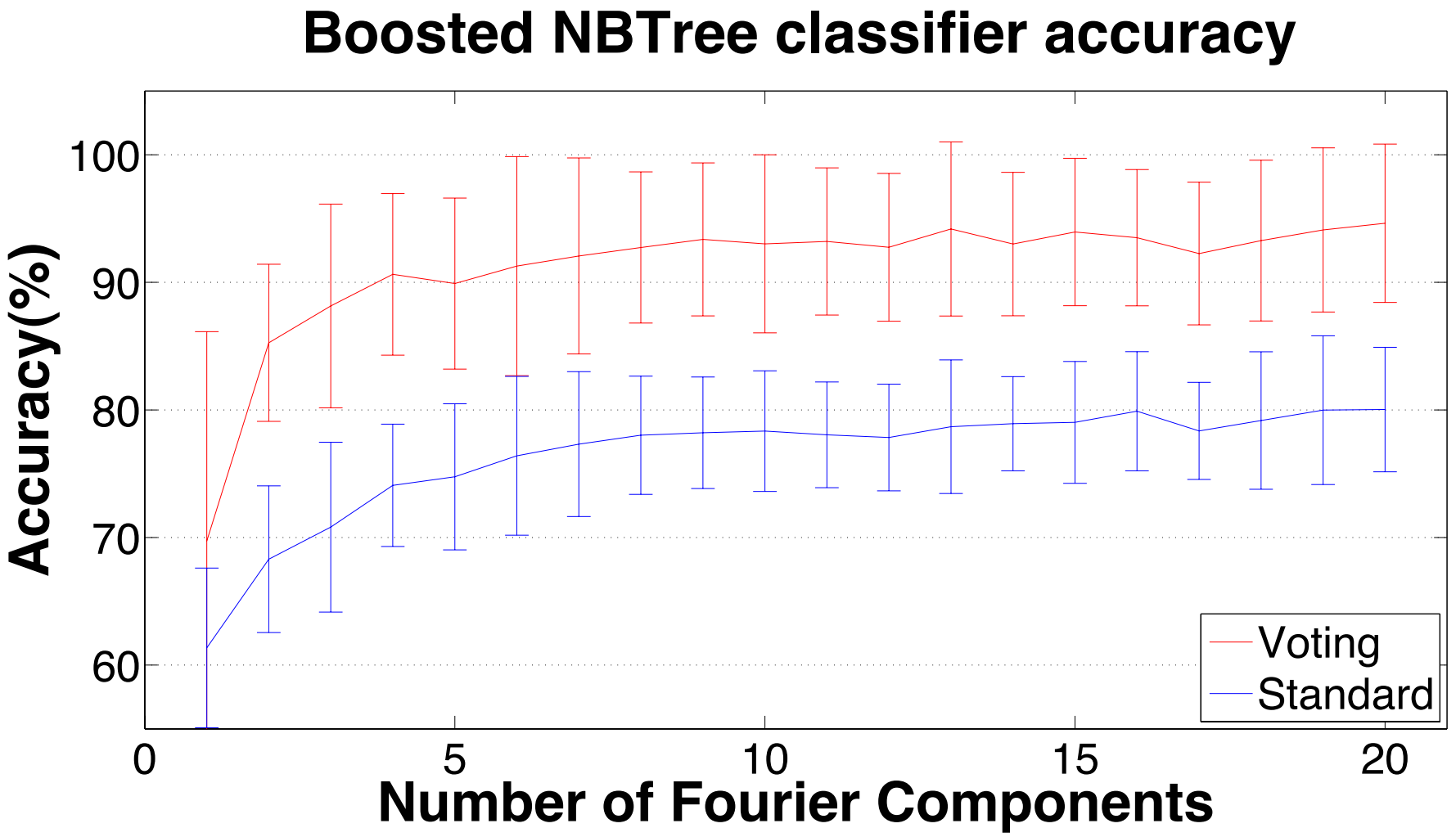
Sample Classifier Output

$(\mathbf{PVDF_1^1}, \mathbf{PVDF_1^2}, \mathbf{PVDF_1^3}, \mathbf{PVDF_2^1}, \mathbf{PVDF_2^2}, \mathbf{PVDF_2^3},$
$\mathbf{PVDF_3^1}, \mathbf{PVDF_3^2}, \mathbf{PVDF_3^3}, \mathbf{PVDF_4^1}, \mathbf{PVDF_4^2}, \mathbf{PVDF_4^3},$
$\mathbf{SG\_AVG_1}, \mathbf{SG\_AVG_2}, \mathbf{SG\_AVG_3}, \mathbf{SG\_AVG_4},$
$\mathbf{SPEED}, \mathbf{Material\ Class})$

SPEED = 20: NB 1
SPEED = 25: NB 2
SPEED = 30
| $PVDF_1^2 \leq 58.89$
| | $PVDF_1^1 \leq 50.96$
| | | $PVDF_1^1 \leq 14.34$: NB 3
| | | $PVDF_1^1 > 14.34$
| | | | $PVDF_2^1 \leq 51.57$: NB 4
| | | | $PVDF_2^1 > 51.57$: NB 5
| | $PVDF_1^1 > 50.96$
| | | $PVDF_1^1 \leq 62.25$: NB 6
| | | $PVDF_1^1 > 62.25$: NB 7
| $PVDF_1^2 > 58.89$: NB 13

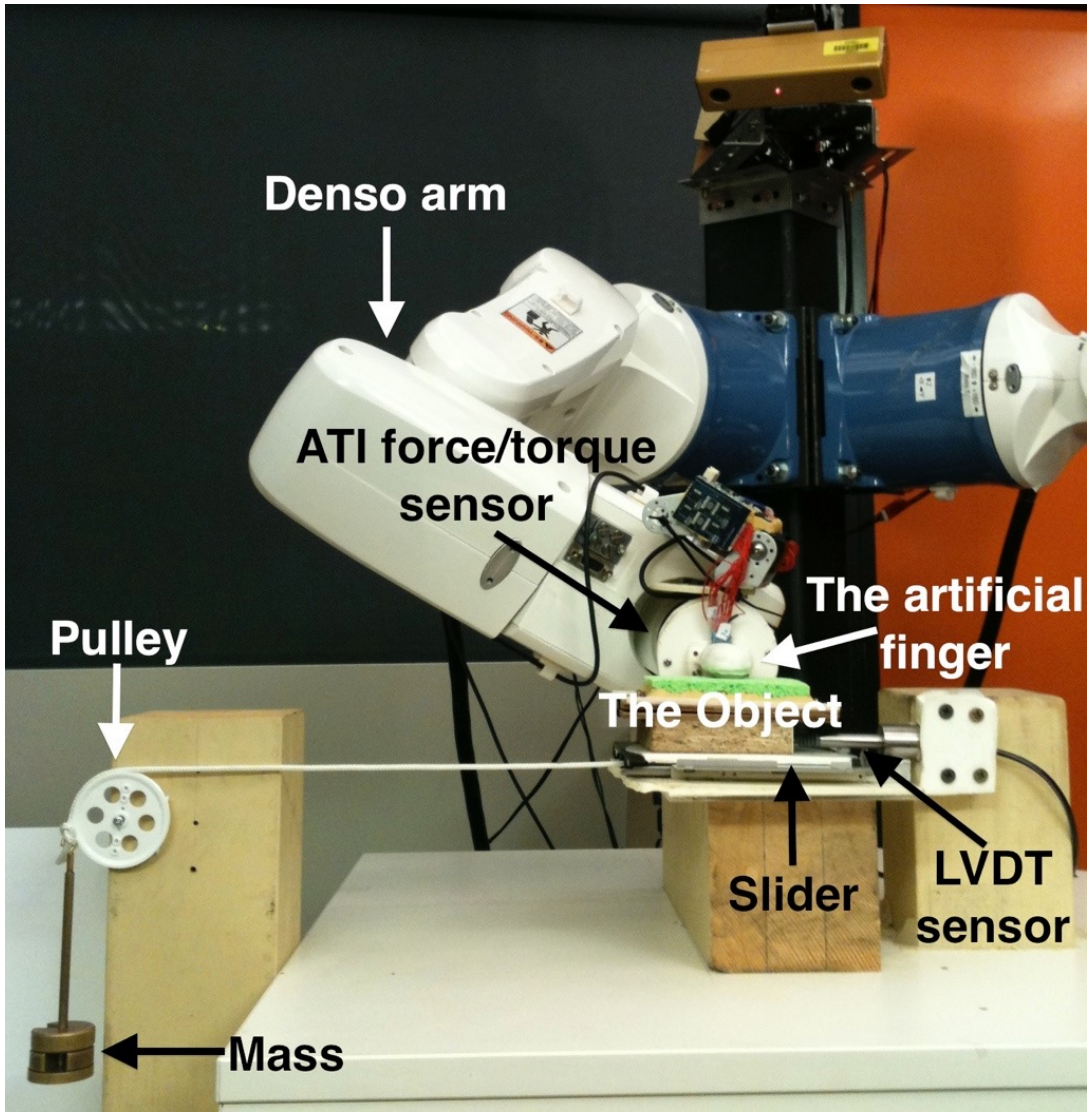
PVDF Fourier components
Strain Gauge average

Texture Classification Results

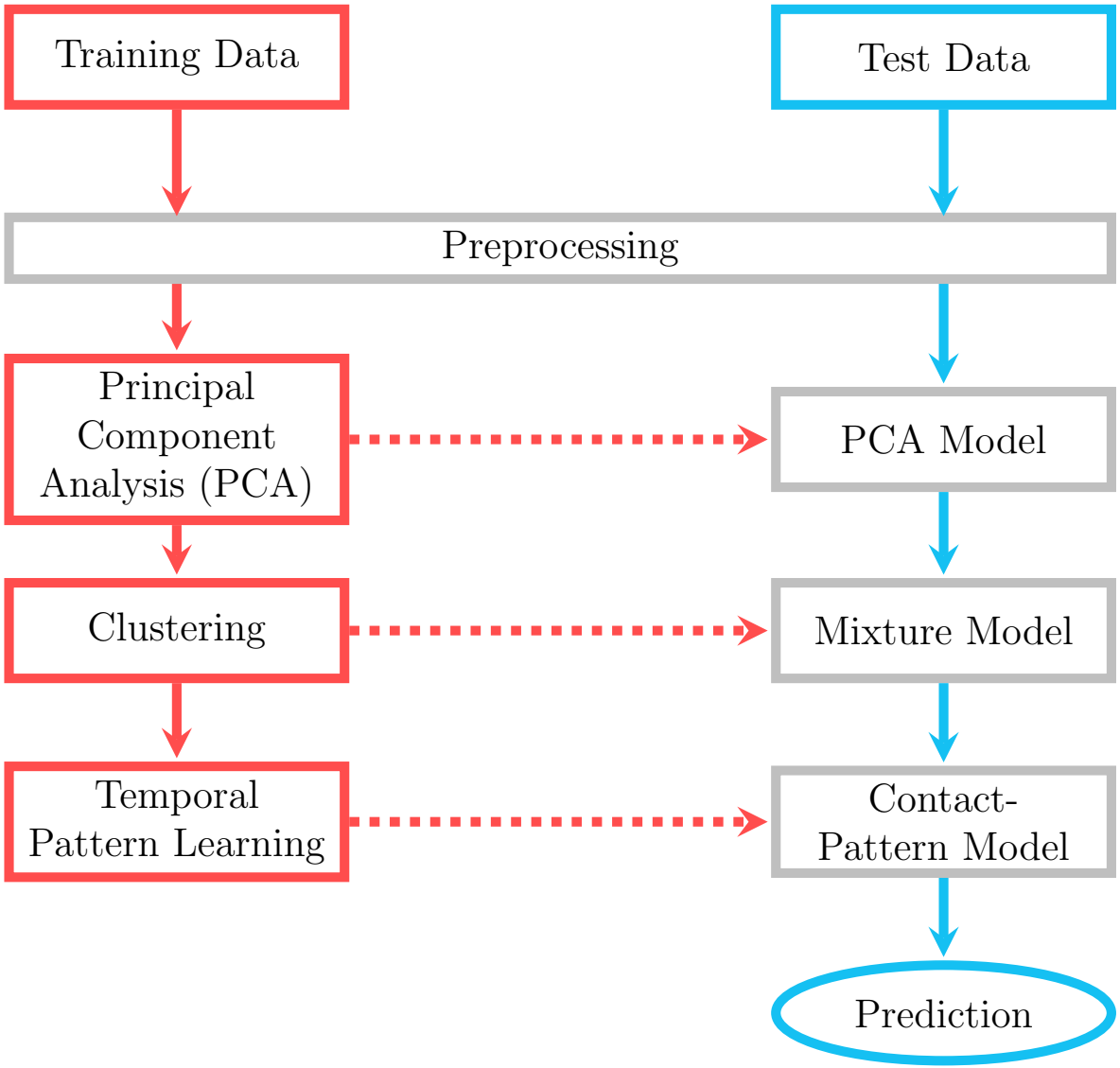


Slip Prediction

- Perform time-domain analysis to predict slip
- Seven objects
- Predict slip at least 100ms before it happens with 96% accuracy

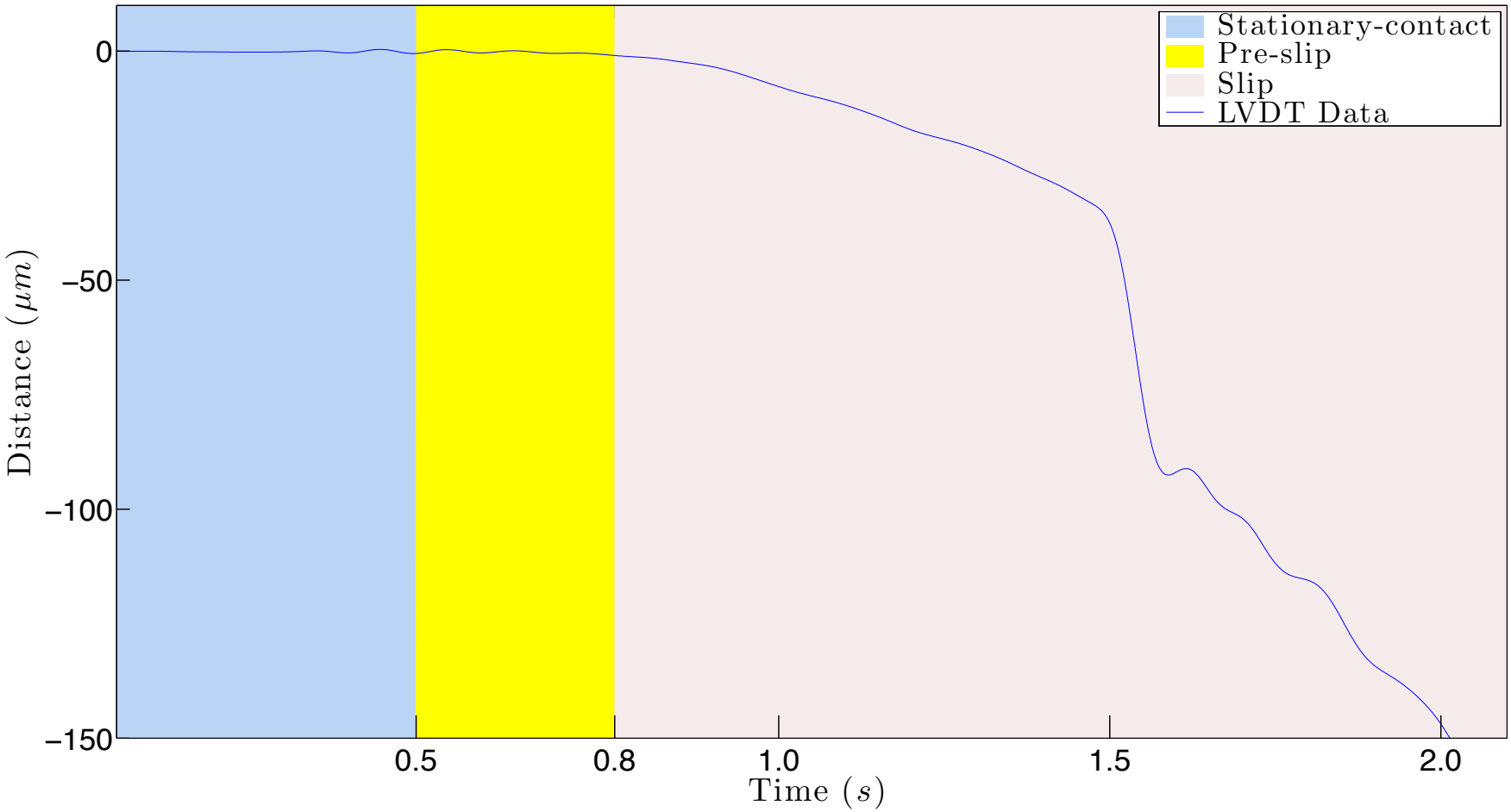


Methodology



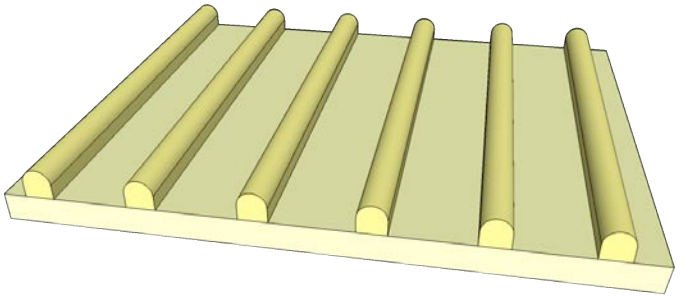
Preprocessing

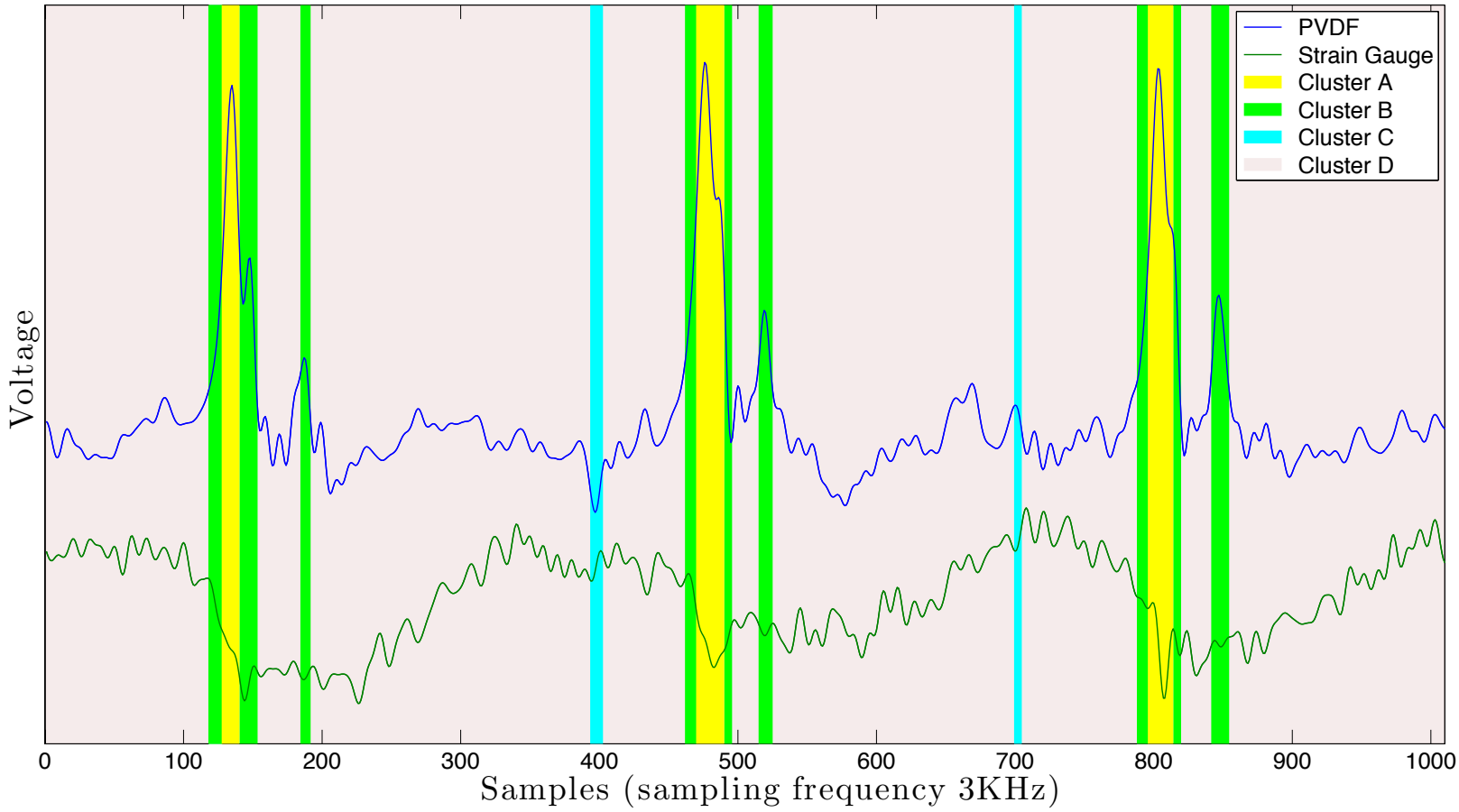
Sequences are labelled using high resolution linear variable differential transformer (LVDT), which is a linear distance sensor.



Dimensionality Reduction

Build Gaussian mixture models using minimum message length as the optimisation criterion

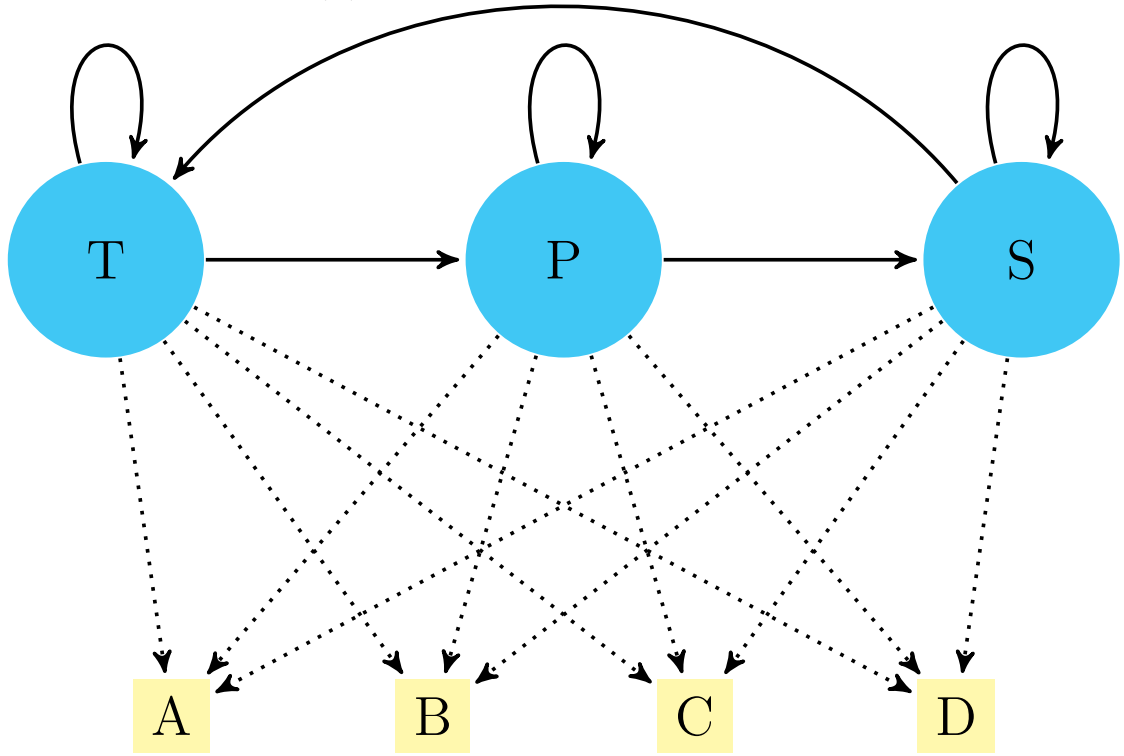




Learning Patterns

$$V_{original} = \{BCCDDCAAAABAABBBB\ldots\}$$

$$V_{labelled} = \Big\{(B,T)(C,T)(C,T)(D,T)(D,T)(C,P)(A,P)(A,P)(A,P)(A,P)(B,S)$$
$$(A,S)(A,S)(B,S)(B,S)(B,S)(B,S)\ldots\Big\}$$



A,B,C and D: membership of a particular cluster

Experimental Setup