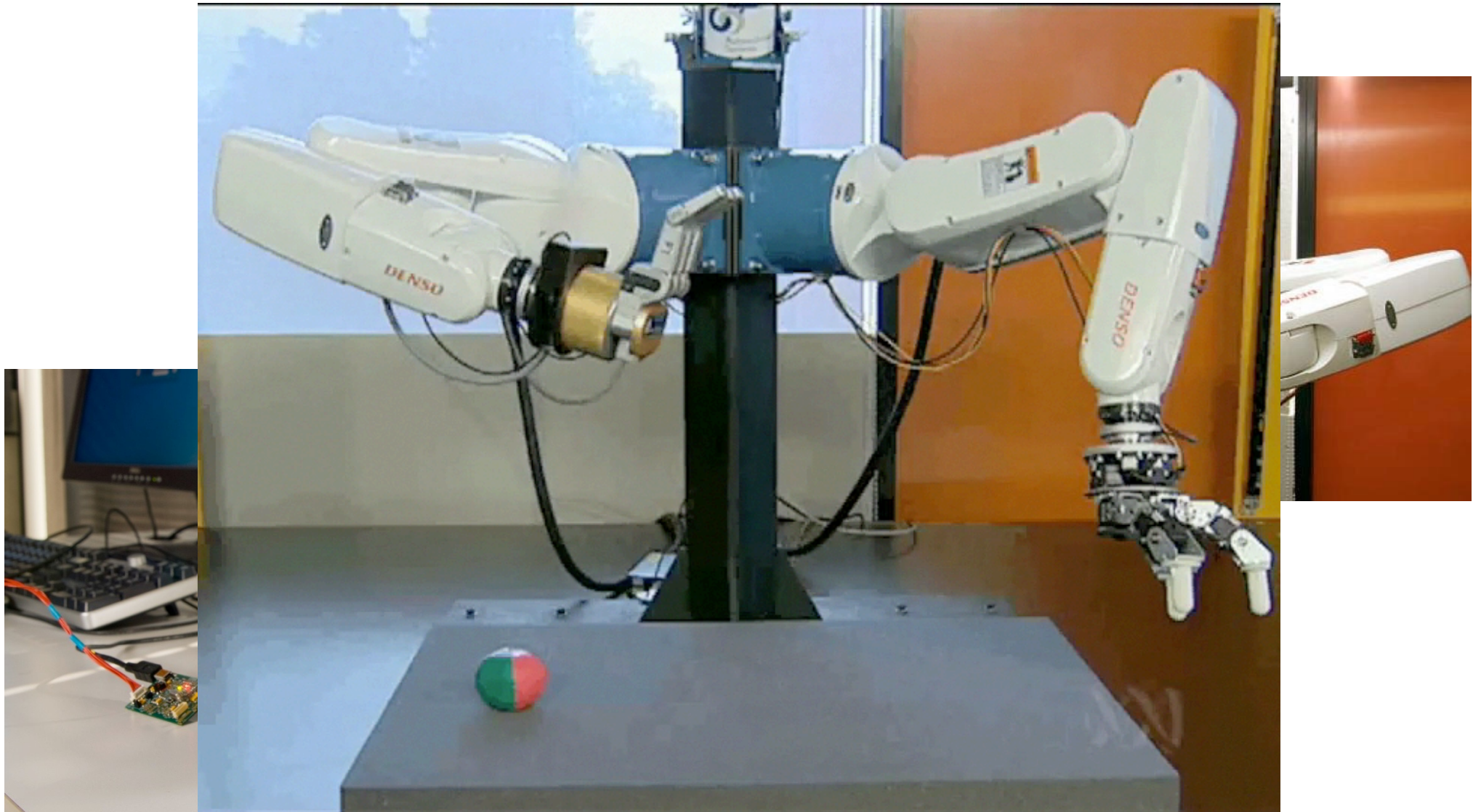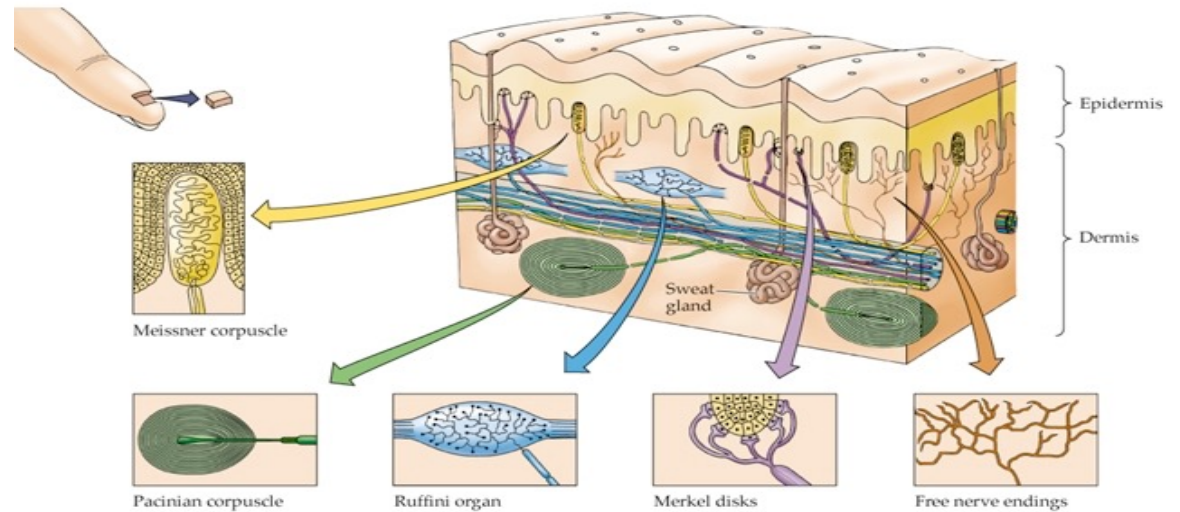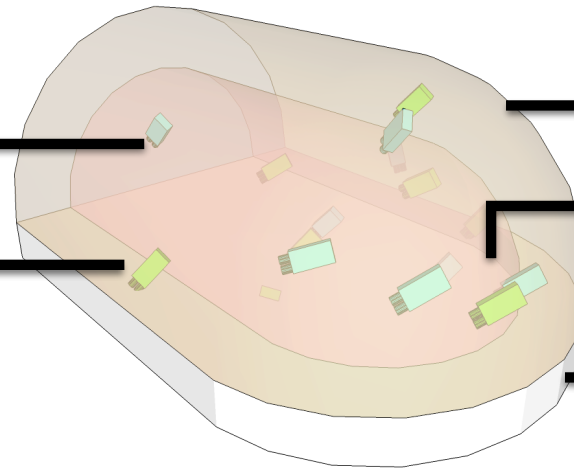# Tactile Sensing

Building a Tactile Sensor

Human Receptors

- Two major layers

- Two main types

  - Fast Adapting: Pacinian and Meissner corpuscles

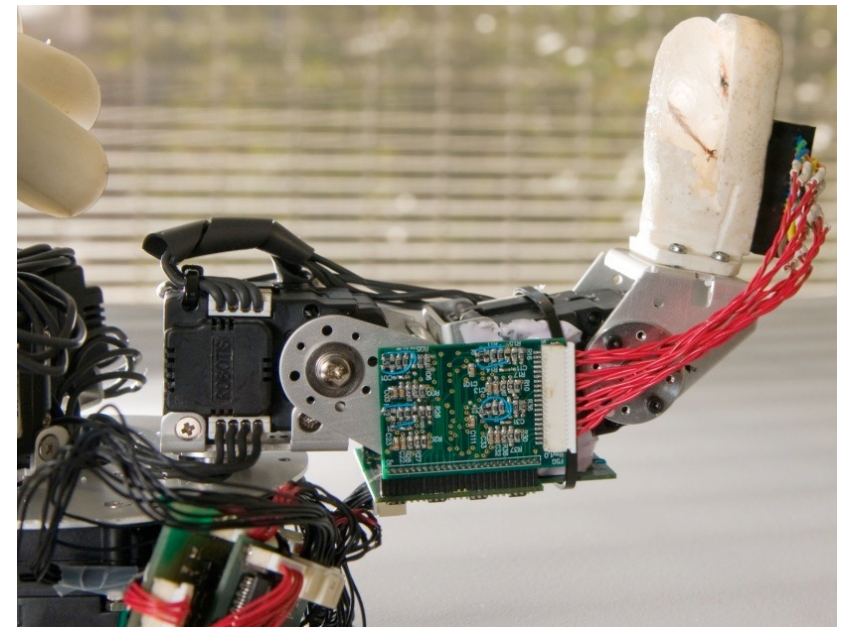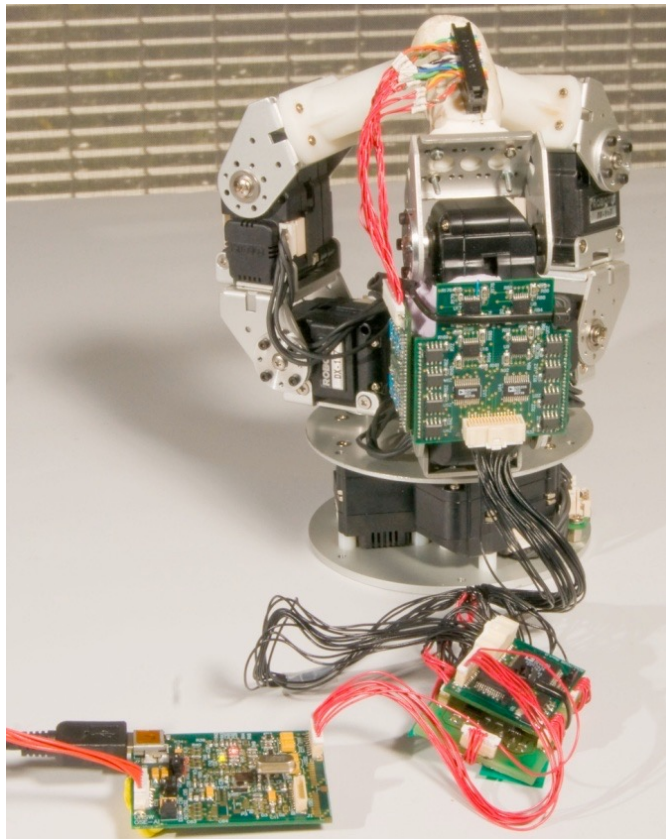 - Slow Adapting: Merkel disk, Ruffini organ

Artificial Finger

Randomly placed sensors
Strain Gauges
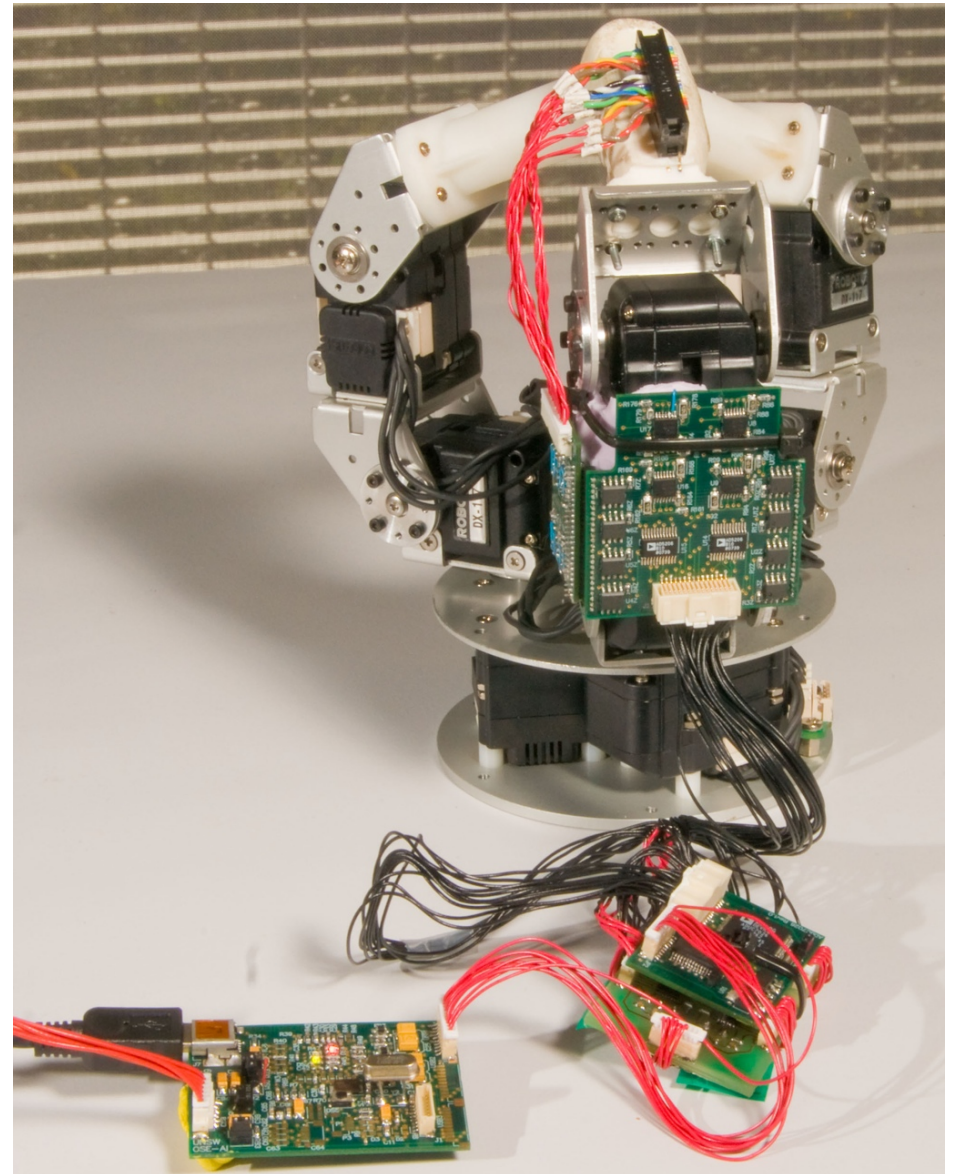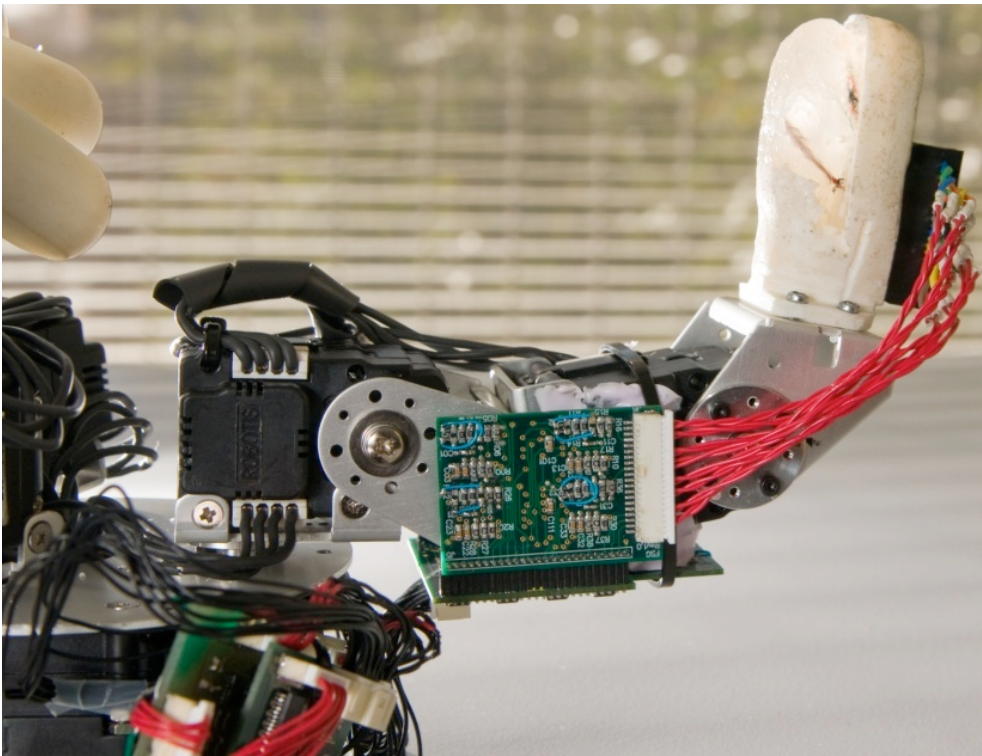Polyvinylidene Fluoride
Two Layers

Hard outer core
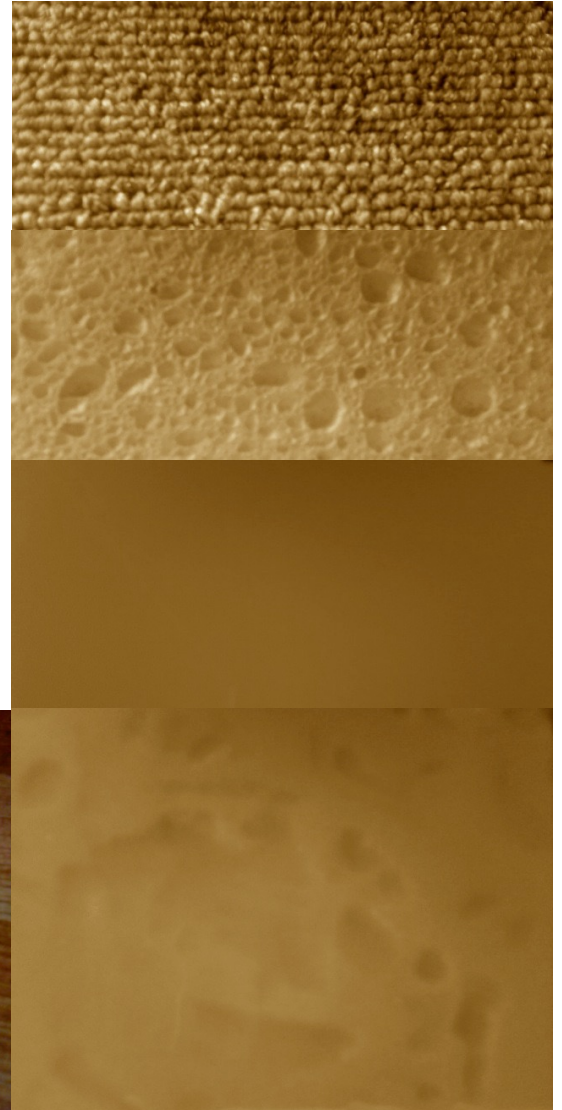(Epidermis)

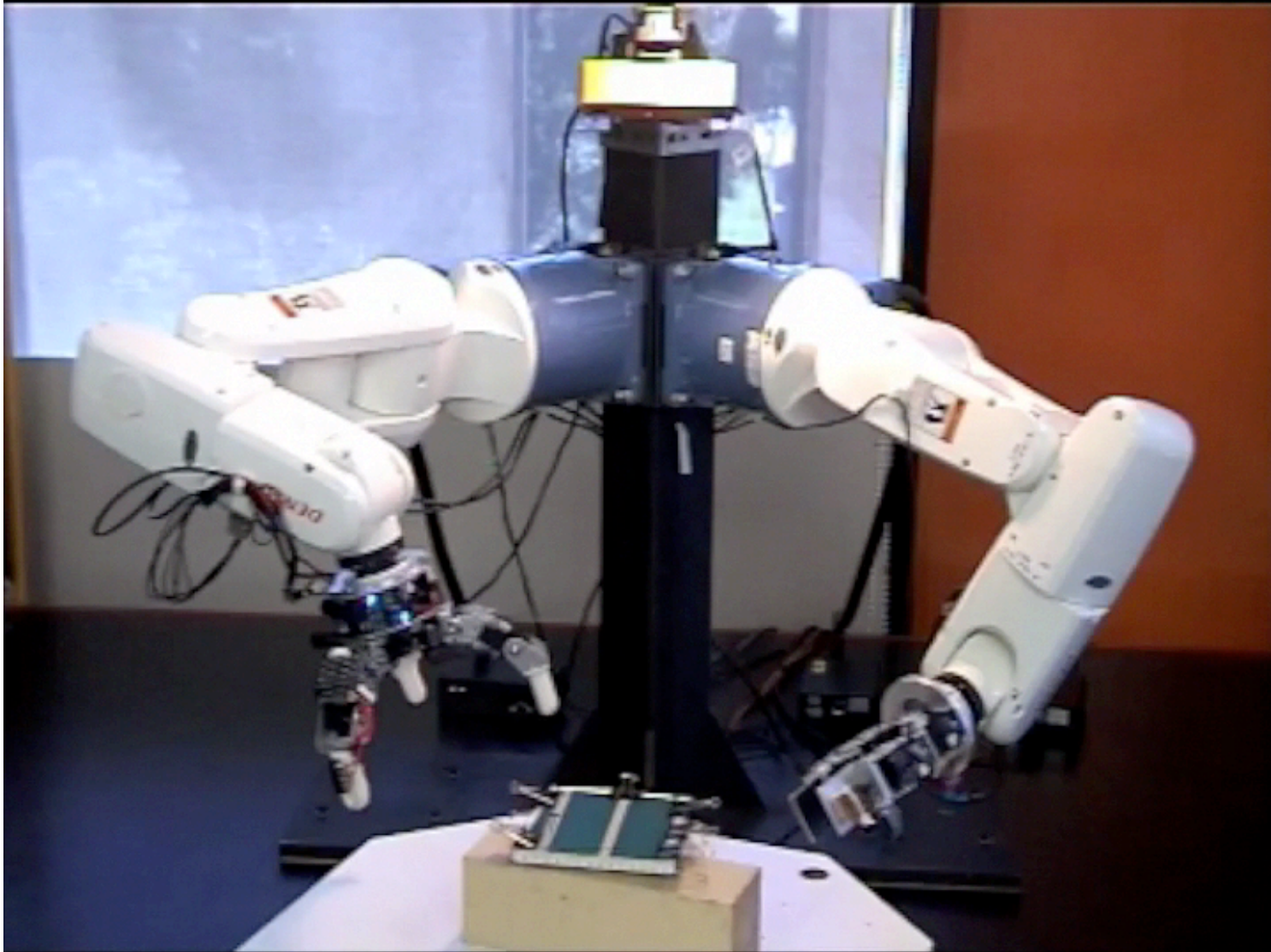Soft inner layer
(Dermis)

Hard Back
(Bone)

Designed In-house

Distinguishing Natural Textures

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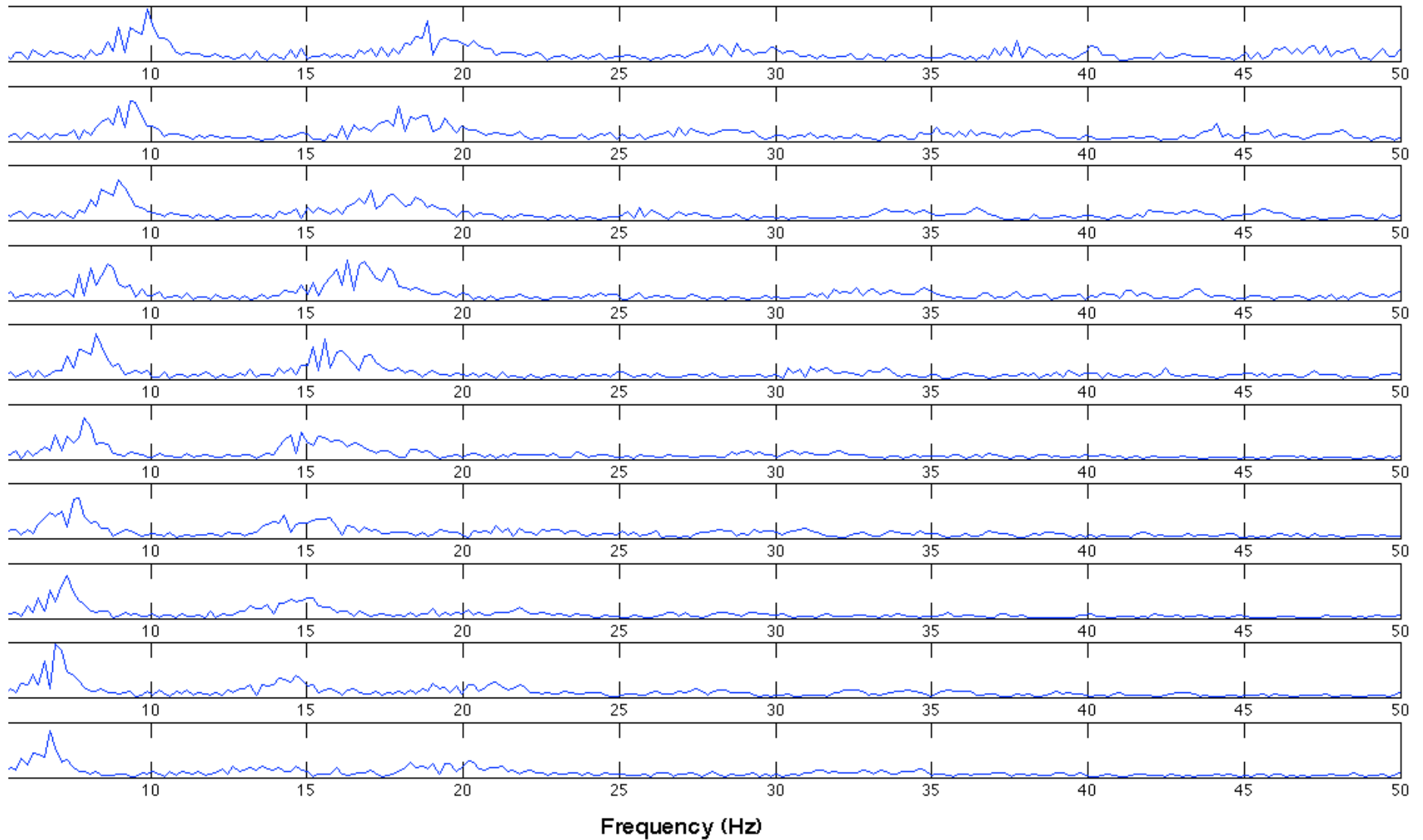
- Classify based on frequency components
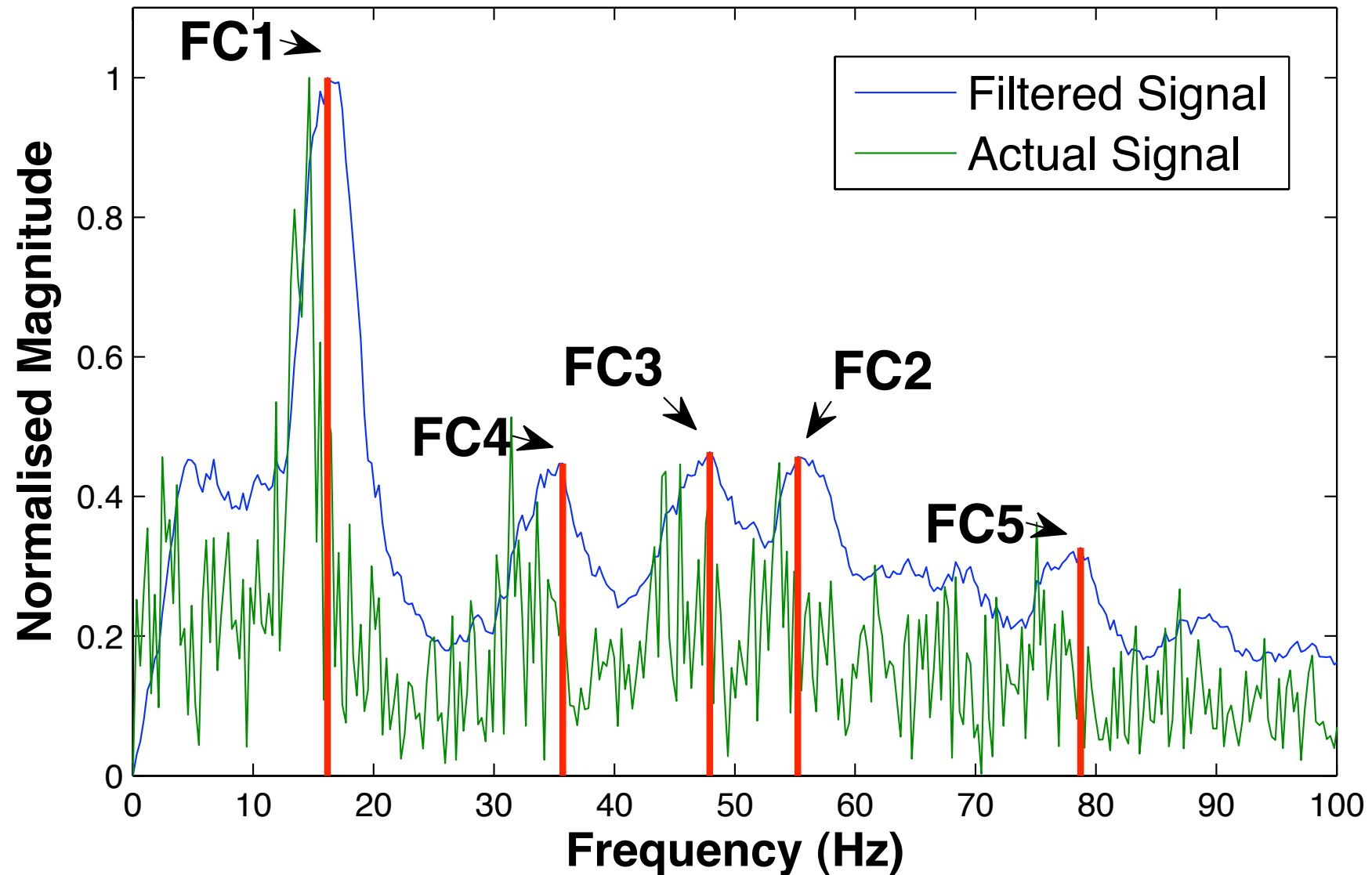
- Accuracy of 95±4%

Experimental Setup

Training

Frequency (Hz)

Typical Frequency Response

Frequency Spectrum (Carpet I)

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
| PVDF₁² ≤ 58.89
| | PVDF₁¹ ≤ 50.96
| | | PVDF₁¹ ≤ 14.34: NB 3
| | | PVDF₁¹ > 14.34
| | | | PVDF₂¹ ≤ 51.57: NB 4
| | | | PVDF₂¹ > 51.57: NB 5
| | PVDF₁¹ > 50.96
| | | PVDF₁¹ ≤ 62.25: NB 6
| | | PVDF₁¹ > 62.25: NB 7
| PVDF₁² > 58.89: NB 13
```
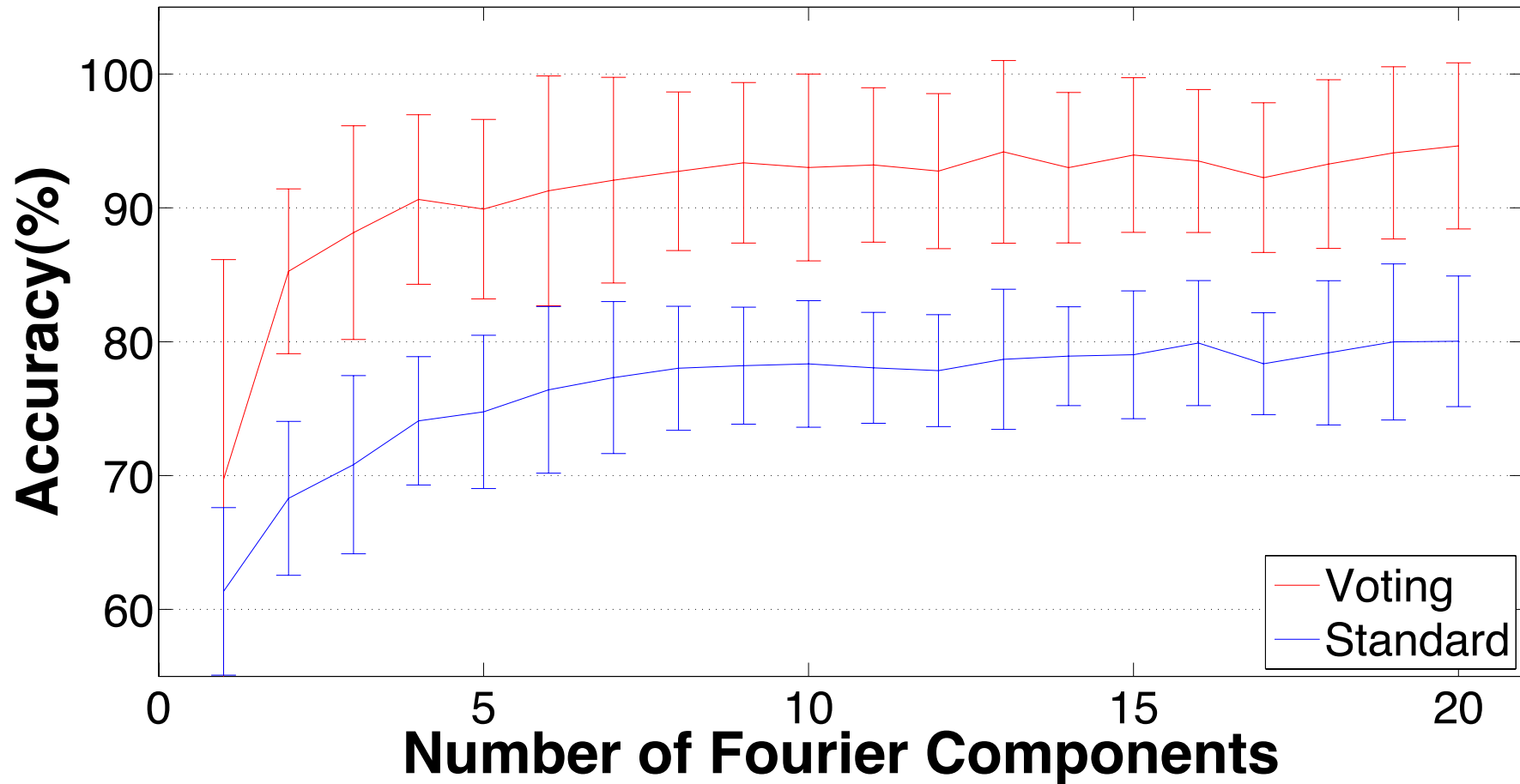
$\text{SPEED} = 20$: NB 1

$\text{SPEED} = 25$: NB 2

$\text{SPEED} = 30$

| $\text{PVDF}_1^2 \leq 58.89$

| | $\text{PVDF}_1^1 \leq 50.96$

| | | $\text{PVDF}_1^1 \leq 14.34$: NB 3

| | | $\text{PVDF}_1^1 > 14.34$

| | | | $\text{PVDF}_2^1 \leq 51.57$: NB 4

| | | | $\text{PVDF}_2^1 > 51.57$: NB 5

| | $\text{PVDF}_1^1 > 50.96$

| | | $\text{PVDF}_1^1 \leq 62.25$: NB 6

| | | $\text{PVDF}_1^1 > 62.25$: NB 7

| $\text{PVDF}_1^2 > 58.89$: NB 13

PVDF Fourier components
Strain Gauge average
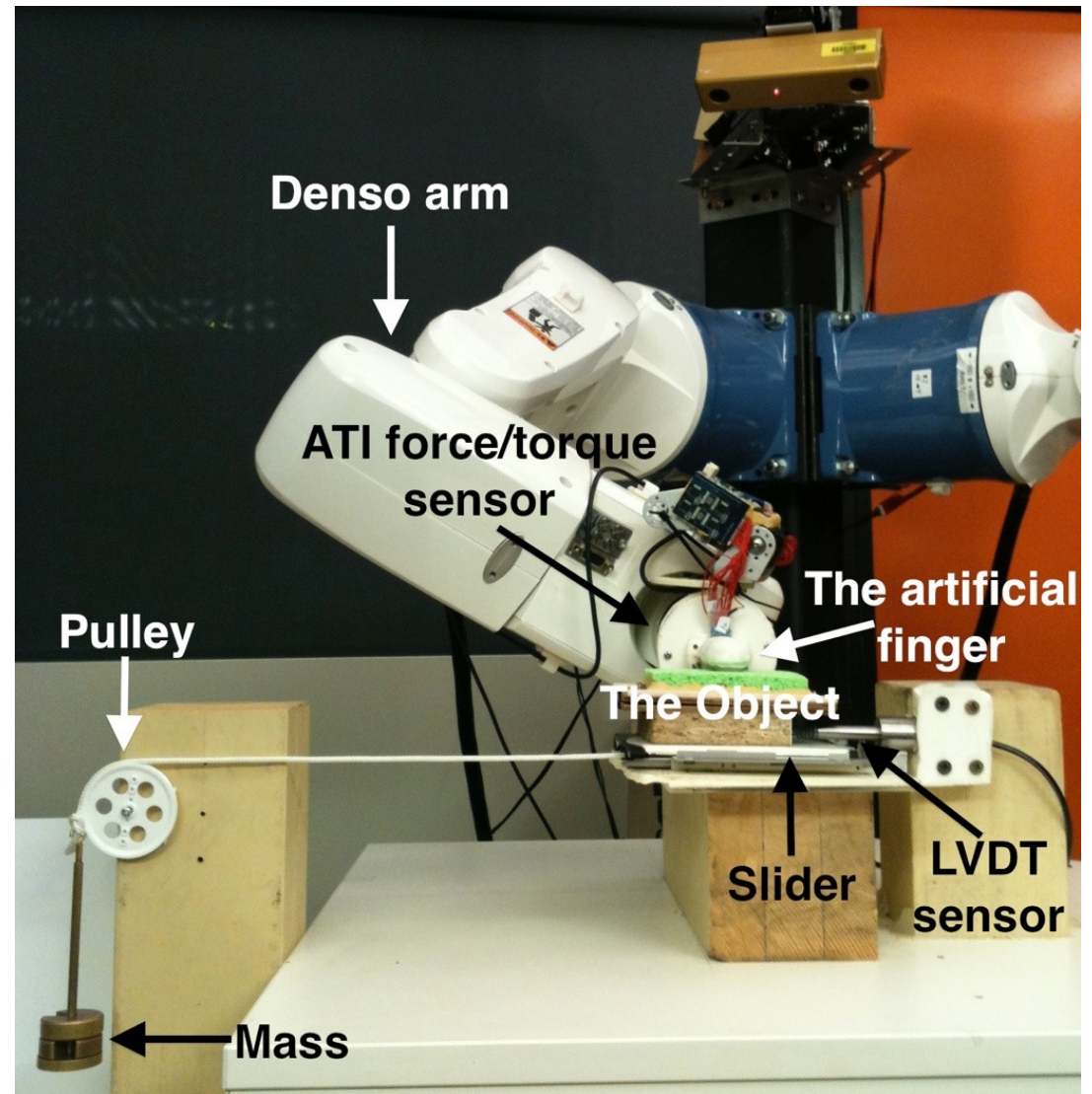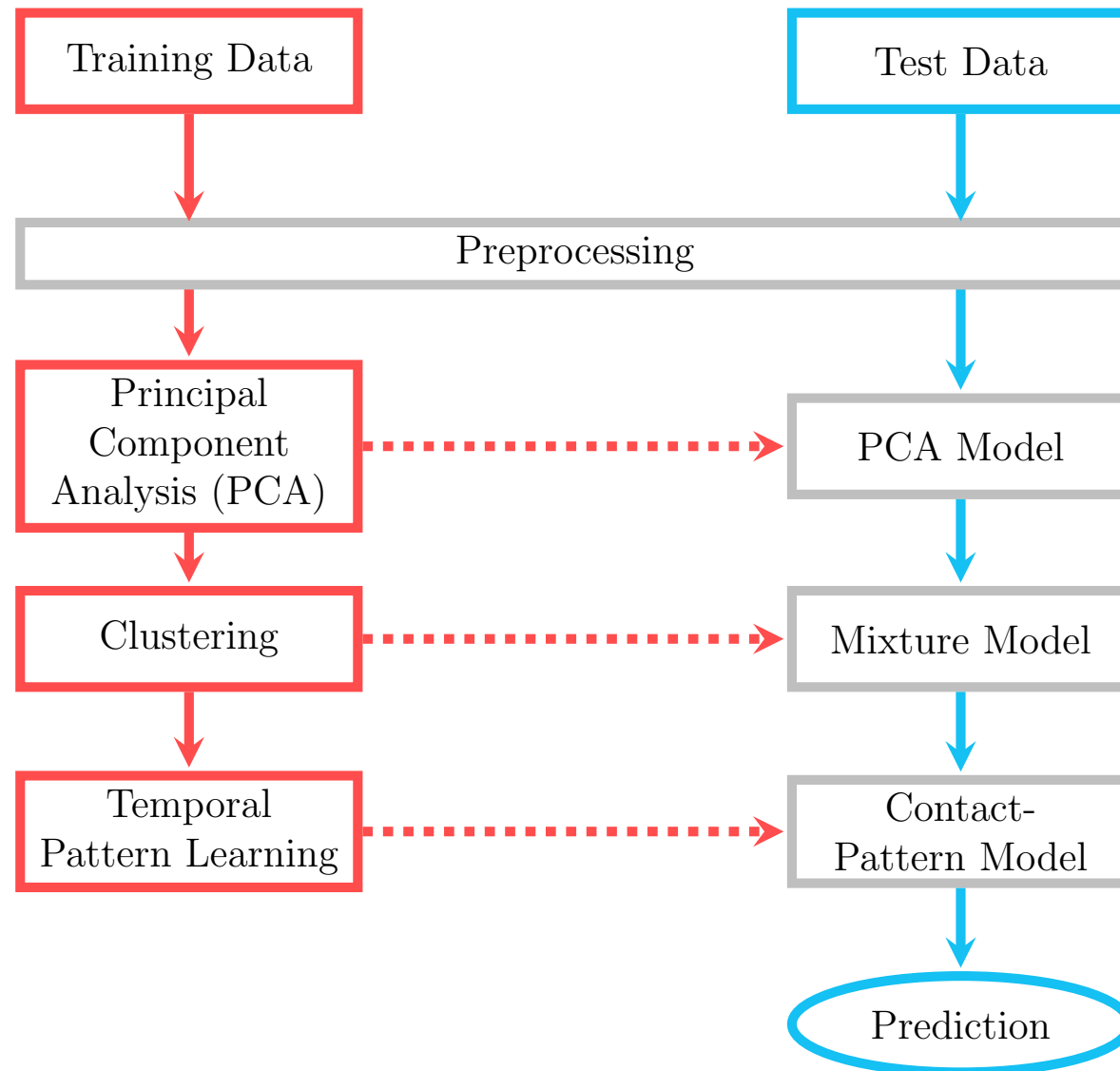
Texture Classification Results

Slip Prediction

- Perform time-domain analysis to predict slip

- Seven objects

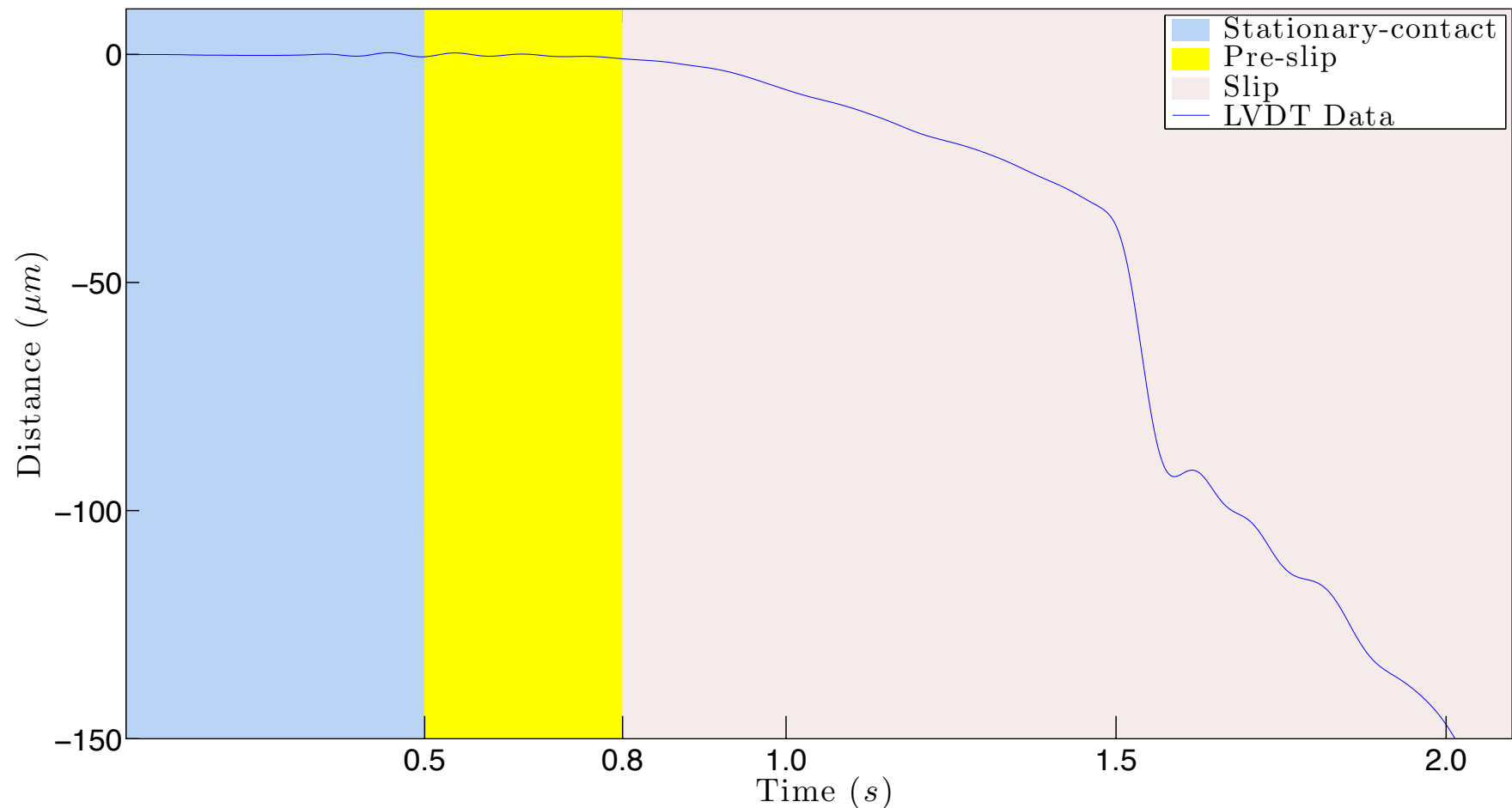- Predict slip at least 100ms before it happens with 96% accuracy
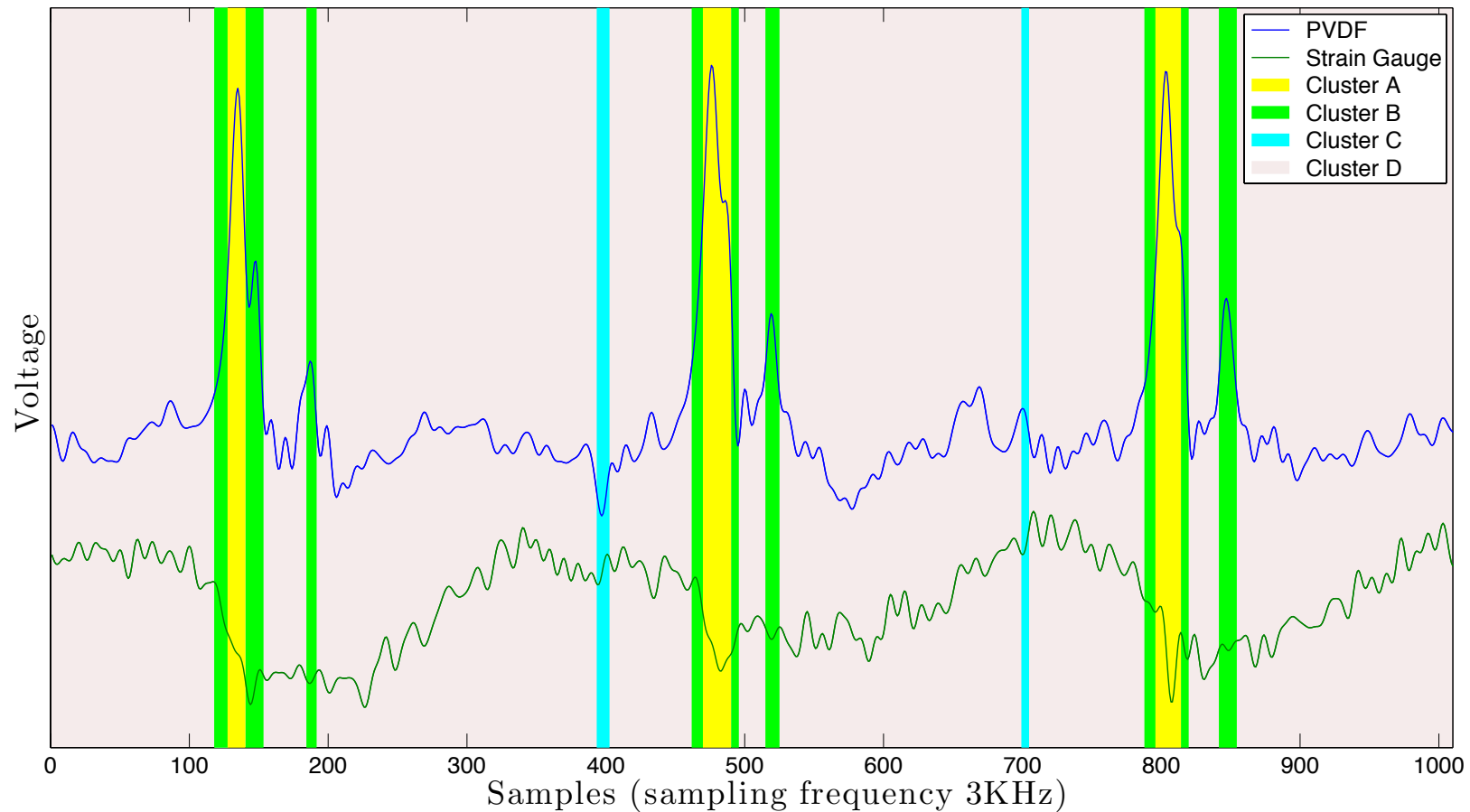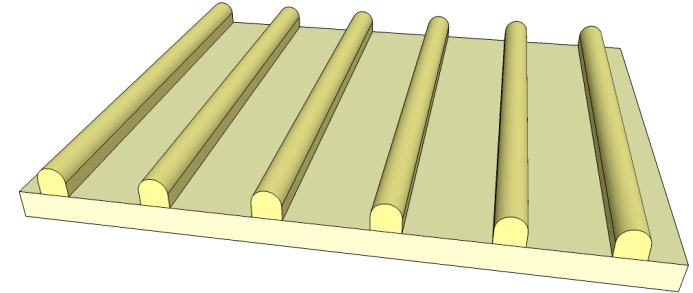
Methodology

Preprocessing

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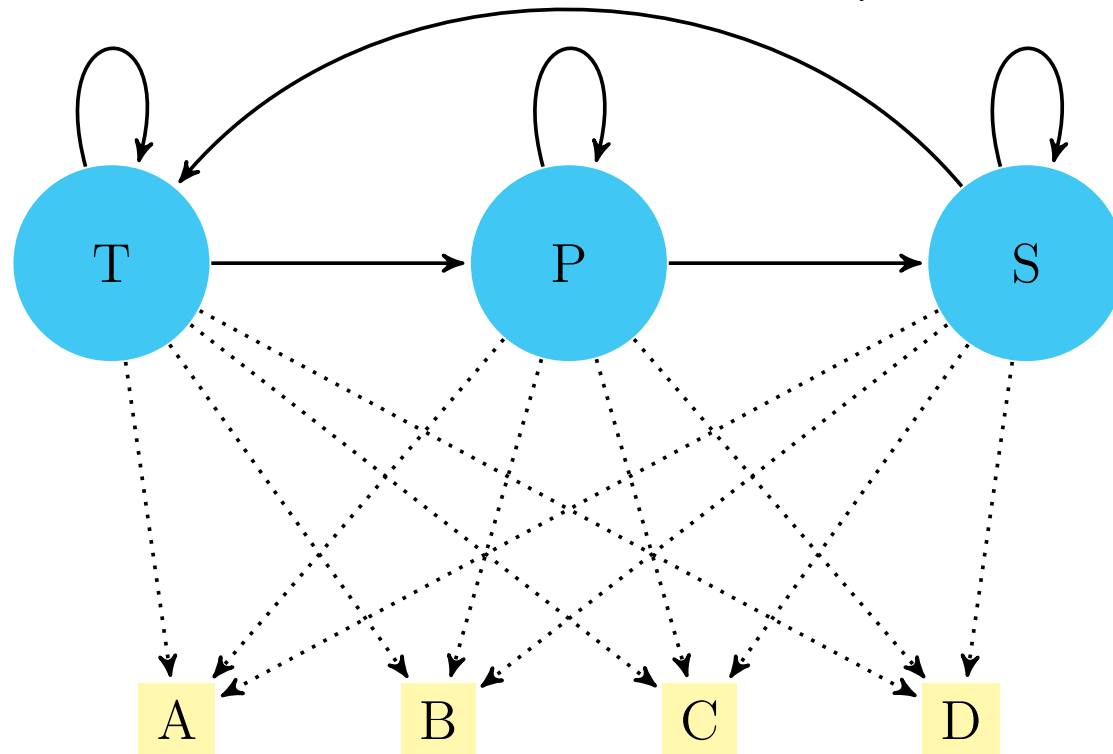
Dimensionality Reduction

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

Learning Patterns

$$V_{original} = \{BCCDDCAAABAABBBB \dots \}$$

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

$$(A,S)(A,S)(B,S)(B,S)(B,S)(B,S) \dots \Big\}$$

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

Experimental Setup