
# Recognizing Affective Touch for Social Robots


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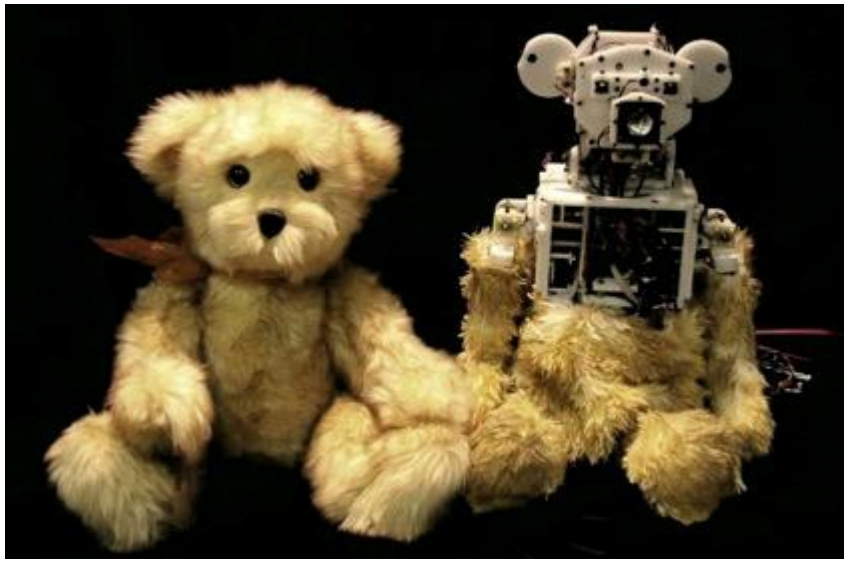
# Introduction

- Touch is a principal modality when humans interact with their pets
- Pets can sense their owner's emotional state
  - We would like pet robots to do the same
- It is essential to design pet robots that respond to touch
  - and infer emotional state of the user via touch

# Pet robot examples

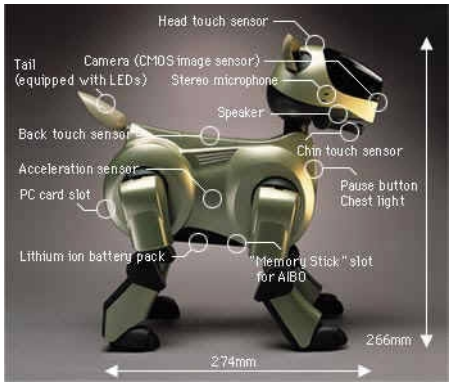


Huggable (2006)
MIT Media Lab

PARO (1996)
AIST, Japan

# Pet robot examples

Probo (2008)
VU Brussel




AIBO (2001)
Sony

# Pet robot examples

Haptic Creature (2008)
The University of British Columbia

# Problem definition

- Affect recognition through touch
- Touch is more common in human-pet interaction than in human-human interactions
- We use the Haptic Creature as the robot platform

# Haptic Creature

- Interaction is limited to touch only
  - breathing
  - purring
  - modulating ear stiffness
- force sensing resistors (FSR) and accelerometer to sense touch

# Affect space

- Nine emotion words were used in the experiments
- Arranged in a 3x3 grid structure
  - arousal-valence space
  - horizontal axis: valence
    - negative to positive
  - vertical axis: arousal
    - low to high

| | | |
|---|---|---|
| $e_1$ distressed (stresli) | $e_2$ aroused (uyanık) | $e_3$ excited (heyecanlı) |
| $e_4$ miserable (zavallı) | $e_5$ neutral (nötr) | $e_6$ pleased (memnun) |
| $e_7$ depressed (depresif) | $e_8$ sleepy (uykulu) | $e_9$ relaxed (rahatlamış) |

# Experiment

- 31 participants presented with emotion labels
- For each label, participants evaluated the likelihood of performing 30 different hand gestures (1: Very unlikely, 5: Very likely)
- If they responded 4 or 5, they were asked to perform the gesture on the robot
- FSR and accelerometer signals were recorded

**Table 4** Mean likelihood touch gestures would be used to communicate given emotions

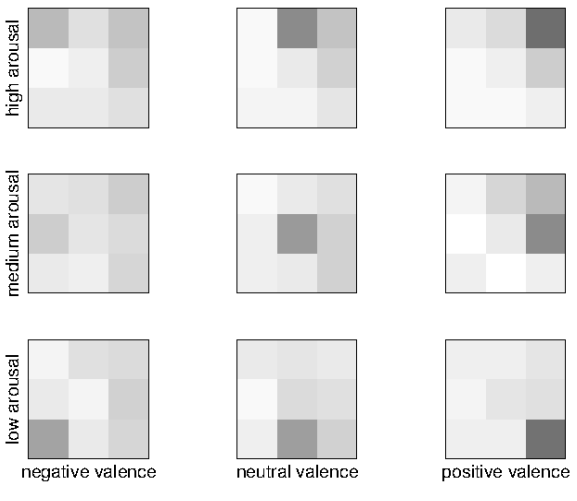
| Gesture | Emotion | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Distressed | Aroused | Excited | Miserable | Neutral | Pleased | Depressed | Sleepy | Relaxed | Total |
| **Stroke** | 2.97 | 3.50 | 3.40 | 3.07 | 3.93 | 4.13 | 3.47 | 3.73 | 4.33 | 32.53 |
| **Contact** | 2.90 | 2.37 | 2.00 | 3.70 | 4.57 | 3.10 | 4.40 | 4.60 | 4.63 | 32.27 |
| **Hug** | 2.77 | 3.60 | 3.87 | 3.37 | 3.00 | 4.30 | 3.63 | 3.57 | 3.47 | 31.58 |
| **Hold** | 3.13 | 3.00 | 3.37 | 3.37 | 3.83 | 3.80 | 3.53 | 3.60 | 3.80 | 31.43 |
| **Rub** | 2.67 | 3.70 | 3.80 | 3.07 | 3.47 | 3.97 | 3.03 | 3.03 | 3.70 | 30.44 |
| **Pat** | 2.80 | 3.50 | 3.37 | 2.63 | 3.73 | 3.87 | 3.07 | 3.10 | 3.83 | 29.90 |
| **Cradle** | 2.77 | 2.80 | 2.60 | 3.10 | 3.23 | 3.70 | 3.53 | 3.80 | 3.93 | 29.46 |
| **Massage** | 2.43 | 3.53 | 3.27 | 2.47 | 3.27 | 3.43 | 2.73 | 3.17 | 4.03 | 28.33 |
| **Scratch** | 2.80 | 3.33 | 3.50 | 2.80 | 3.27 | 3.40 | 2.63 | 2.63 | 3.67 | 28.03 |
| **Finger Idly** | 2.67 | 2.70 | 2.33 | 2.73 | 3.80 | 2.90 | 3.30 | 3.07 | 3.73 | 27.23 |
| **Rock** | 2.47 | 2.97 | 2.80 | 2.70 | 2.83 | 3.10 | 2.90 | 3.00 | 2.90 | 25.67 |
| **Nuzzle** | 2.00 | 2.93 | 3.37 | 2.50 | 2.67 | 3.50 | 2.67 | 2.93 | 2.87 | 25.44 |
| **Tickle** | 1.57 | 3.20 | 3.80 | 1.80 | 2.77 | 3.87 | 2.03 | 2.63 | 3.33 | 25.00 |
| **Squeeze** | 2.77 | 3.00 | 3.60 | 2.57 | 2.33 | 2.67 | 2.43 | 2.27 | 2.33 | 23.97 |
| **Lift** | 2.00 | 3.13 | 4.00 | 1.67 | 2.53 | 3.37 | 1.60 | 1.53 | 2.43 | 22.26 |
| Pull | 2.67 | 2.83 | 2.77 | 2.53 | 2.07 | 2.37 | 2.23 | 2.27 | 2.07 | 21.81 |
| Press | 2.87 | 2.53 | 2.57 | 2.43 | 2.57 | 2.33 | 2.23 | 2.13 | 2.13 | 21.79 |
| **Kiss** | 1.47 | 2.93 | 2.87 | 1.80 | 2.10 | 3.37 | 2.10 | 2.40 | 2.73 | 21.77 |
| **Swing** | 1.90 | 2.83 | 3.73 | 1.80 | 2.07 | 3.00 | 1.73 | 1.73 | 2.10 | 20.89 |
| Tap | 2.70 | 2.47 | 2.90 | 1.90 | 2.63 | 2.20 | 2.00 | 1.93 | 2.00 | 20.73 |
| Pick | 2.70 | 2.37 | 2.47 | 2.23 | 2.33 | 2.20 | 2.33 | 1.73 | 2.10 | 20.46 |
| Push | 2.83 | 1.63 | 1.63 | 2.93 | 1.83 | 1.80 | 2.30 | 2.07 | 1.53 | 18.55 |
| Poke | 2.07 | 2.50 | 2.67 | 2.10 | 1.97 | 1.80 | 1.90 | 1.60 | 1.43 | 18.04 |
| **Toss** | 1.67 | 2.60 | 3.30 | 1.73 | 1.97 | 2.27 | 1.37 | 1.23 | 1.80 | 17.94 |
| Tremble | 2.67 | 2.27 | 2.30 | 2.50 | 1.53 | 1.50 | 2.30 | 1.37 | 1.37 | 17.81 |
| Grab | 2.47 | 2.50 | 2.97 | 2.00 | 1.70 | 1.83 | 1.70 | 1.30 | 1.30 | 17.77 |
| Pinch | 2.43 | 2.07 | 2.10 | 2.17 | 1.83 | 1.80 | 1.83 | 1.53 | 1.53 | 17.29 |
| Shake | 2.47 | 2.07 | 2.80 | 1.80 | 1.23 | 1.40 | 1.50 | 1.17 | 1.40 | 15.84 |
| Slap | 1.90 | 1.40 | 1.47 | 1.87 | 1.37 | 1.30 | 1.50 | 1.17 | 1.17 | 13.15 |
| Hit | 1.77 | 1.27 | 1.40 | 1.70 | 1.23 | 1.10 | 1.33 | 1.03 | 1.03 | 11.86 |

# Results

| | $e_1$ | $e_2$ | $e_3$ | $e_4$ | $e_5$ | $e_6$ | $e_7$ | $e_8$ | $e_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $e_1$ | 51 | 22 | 44 | 5 | 13 | 36 | 15 | 15 | 22 |
| $e_2$ | 9 | 118 | 58 | 6 | 21 | 46 | 10 | 12 | 28 |
| $e_3$ | 22 | 39 | 164 | 6 | 16 | 54 | 9 | 8 | 19 |
| $e_4$ | 19 | 21 | 35 | 36 | 18 | 26 | 14 | 12 | 29 |
| $e_5$ | 6 | 20 | 27 | 14 | 92 | 42 | 13 | 21 | 40 |
| $e_6$ | 16 | 46 | 80 | 5 | 24 | 137 | 18 | 5 | 22 |
| $e_7$ | 9 | 23 | 26 | 15 | 10 | 35 | 72 | 17 | 30 |
| $e_8$ | 15 | 21 | 17 | 5 | 26 | 25 | 14 | 76 | 34 |
| $e_9$ | 14 | 15 | 25 | 11 | 26 | 31 | 16 | 18 | 142 |

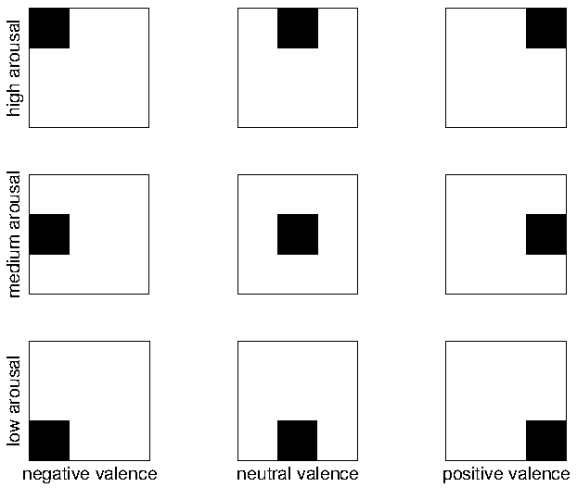
- Classification using Random Forests
- Success rate: 36%
- Many “near misses” in the affect space
  - Need to measure the degree of misclassifications

# Confusion matrix visualization




between-subject


within-subject

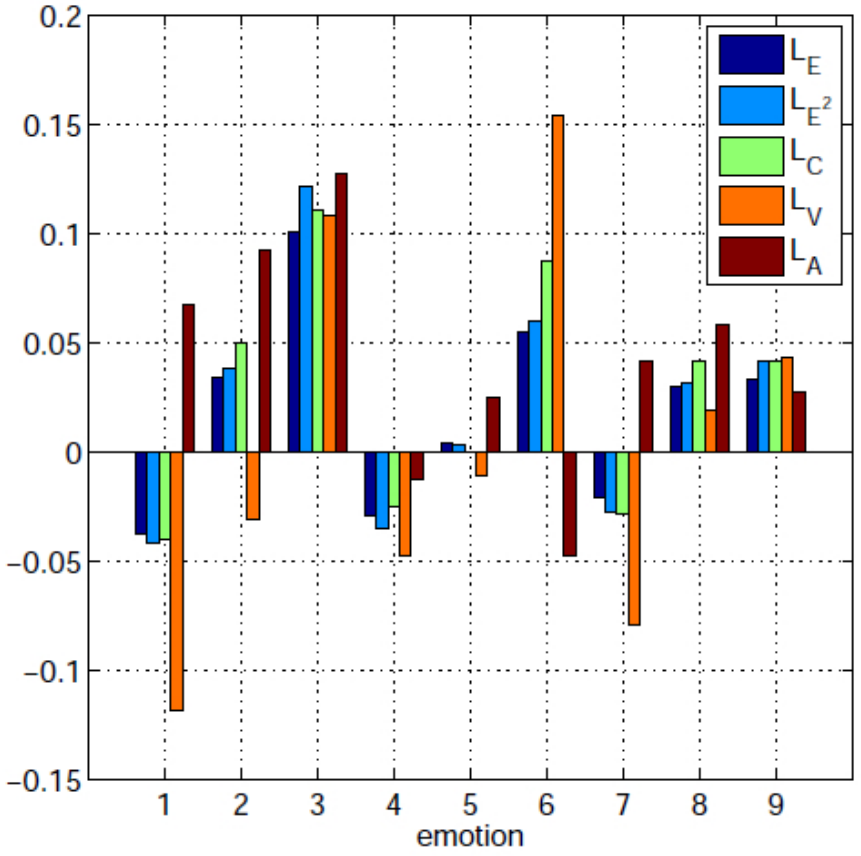


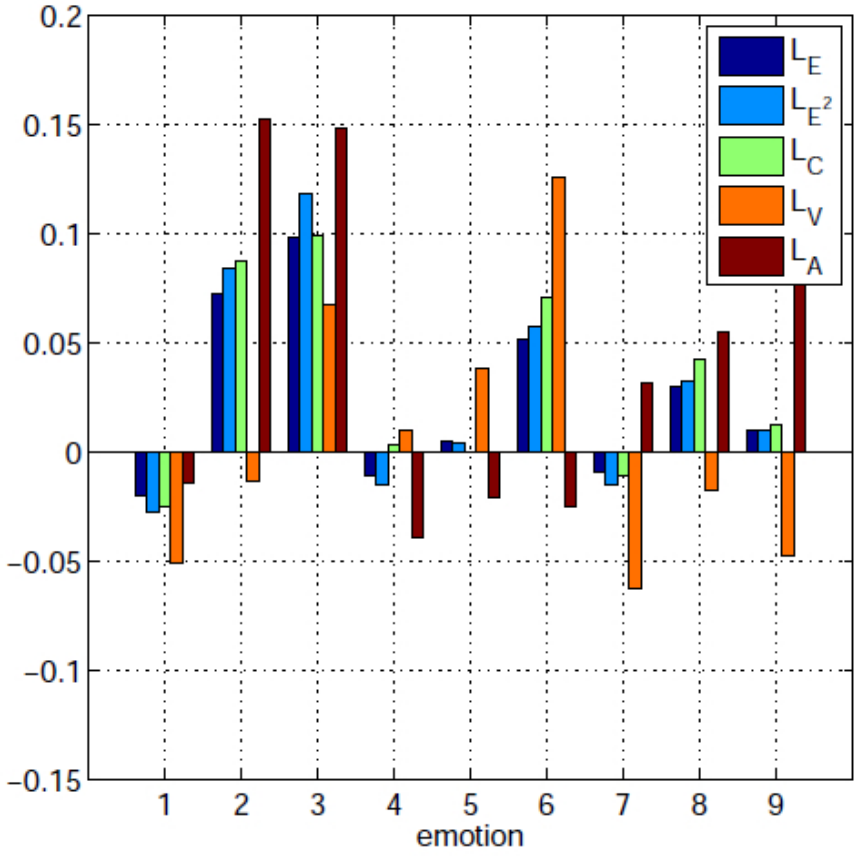

hypothetical perfect classification

# Distance functions

- We defined distance functions to evaluate the degree of misclassification
  - Discrete distance (correct: 0, wrong: 1)
  - Euclidean distance
  - Euclidean distance squared
    - Does not satisfy the triangle inequality; not a “proper” distance in the mathematical sense
  - Valence loss
    - disregards valence, focuses on arousal
  - Arousal loss
    - disregards arousal, focuses on valence

# Results


0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
1
2
3
4
5
6
7
8
9
emotion
$L_E$
$L_{E^2}$
$L_C$
$L_V$
$L_A$

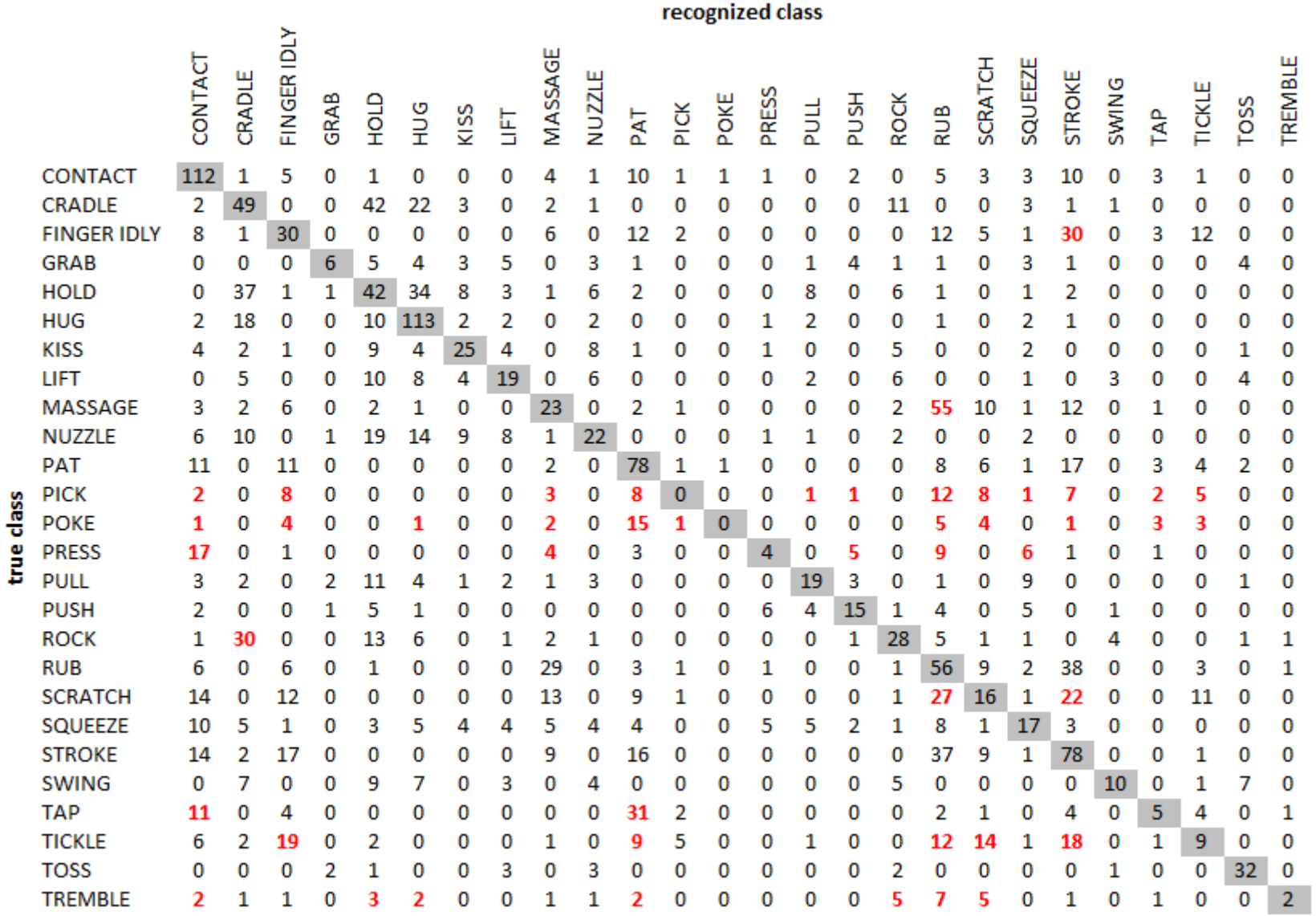

0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
1
2
3
4
5
6
7
8
9
emotion
$L_E$
$L_{E^2}$
$L_C$
$L_V$
$L_A$

# Results

- “Near misses” in arousal are more likely in high arousal region
- “Near misses” in valence are more likely in positive valence region

| | | |
|---|---|---|
| $e_1$ distressed (stresli) | $e_2$ aroused (uyanık) | $e_3$ excited (heyecanlı) |
| $e_4$ miserable (zavallı) | $e_5$ neutral (nötr) | $e_6$ pleased (memnun) |
| $e_7$ depressed (depresif) | $e_8$ sleepy (uykulu) | $e_9$ relaxed (rahatlamış) |

# Hand gesture recognition

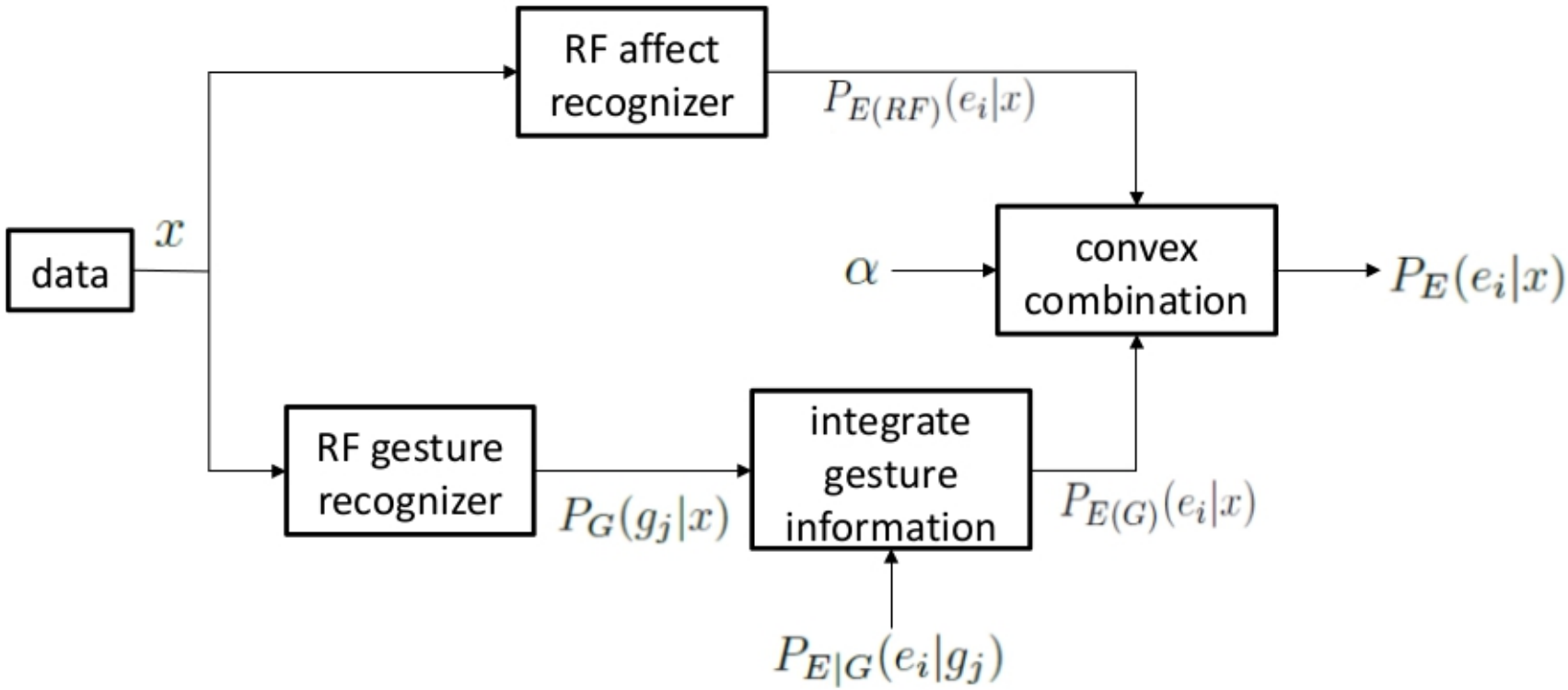


| true class \ recognized class | CONTACT | CRADLE | FINGER IDLY | GRAB | HOLD | HUG | KISS | LIFT | MASSAGE | NUZZLE | PAT | PICK | POKE | PRESS | PULL | PUSH | ROCK | RUB | SCRATCH | SQUEEZE | STROKE | SWING | TAP | TICKLE | TOSS | TREMBLE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONTACT | 112 | 1 | 5 | 0 | 1 | 0 | 0 | 0 | 4 | 1 | 10 | 1 | 1 | 1 | 0 | 2 | 0 | 5 | 3 | 3 | 10 | 0 | 3 | 1 | 0 | 0 |
| CRADLE | 2 | 49 | 0 | 0 | 42 | 22 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| FINGER IDLY | 8 | 1 | 30 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 12 | 5 | 1 | 30 | 0 | 3 | 12 | 0 | 0 |
| GRAB | 0 | 0 | 0 | 6 | 5 | 4 | 3 | 5 | 0 | 3 | 1 | 0 | 0 | 0 | 1 | 4 | 1 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 4 | 0 |
| HOLD | 0 | 37 | 1 | 1 | 42 | 34 | 8 | 3 | 1 | 6 | 2 | 0 | 0 | 0 | 8 | 0 | 6 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| HUG | 2 | 18 | 0 | 0 | 10 | 113 | 2 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| KISS | 4 | 2 | 1 | 0 | 9 | 4 | 25 | 4 | 0 | 8 | 1 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| LIFT | 0 | 5 | 0 | 0 | 10 | 8 | 4 | 19 | 0 | 6 | 0 | 0 | 0 | 0 | 2 | 0 | 6 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 4 | 0 |
| MASSAGE | 3 | 2 | 6 | 0 | 2 | 1 | 0 | 0 | 23 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 55 | 10 | 1 | 12 | 0 | 1 | 0 | 0 | 0 |
| NUZZLE | 6 | 10 | 0 | 1 | 19 | 14 | 9 | 8 | 1 | 22 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| PAT | 11 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 78 | 1 | 1 | 0 | 0 | 0 | 0 | 8 | 6 | 1 | 17 | 0 | 3 | 4 | 2 | 0 |
| PICK | 2 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 8 | 0 | 0 | 0 | 1 | 1 | 0 | 12 | 8 | 1 | 7 | 0 | 2 | 5 | 0 | 0 |
| POKE | 1 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 15 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 0 | 1 | 0 | 3 | 3 | 0 | 0 |
| PRESS | 17 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 3 | 0 | 0 | 4 | 0 | 5 | 0 | 9 | 0 | 6 | 1 | 0 | 1 | 0 | 0 | 0 |
| PULL | 3 | 2 | 0 | 2 | 11 | 4 | 1 | 2 | 1 | 3 | 0 | 0 | 0 | 0 | 19 | 3 | 0 | 1 | 0 | 9 | 0 | 0 | 0 | 0 | 1 | 0 |
| PUSH | 2 | 0 | 0 | 1 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 4 | 15 | 1 | 4 | 0 | 5 | 0 | 1 | 0 | 0 | 0 | 0 |
| ROCK | 1 | 30 | 0 | 0 | 13 | 6 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 28 | 5 | 1 | 1 | 0 | 4 | 0 | 0 | 1 | 1 |
| RUB | 6 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 29 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 1 | 56 | 9 | 2 | 38 | 0 | 0 | 3 | 0 | 1 |
| SCRATCH | 14 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 9 | 1 | 0 | 0 | 0 | 0 | 1 | 27 | 16 | 1 | 22 | 0 | 0 | 11 | 0 | 0 |
| SQUEEZE | 10 | 5 | 1 | 0 | 3 | 5 | 4 | 4 | 5 | 4 | 4 | 0 | 0 | 5 | 5 | 2 | 1 | 8 | 1 | 17 | 3 | 0 | 0 | 0 | 0 | 0 |
| STROKE | 14 | 2 | 17 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 9 | 1 | 78 | 0 | 0 | 1 | 0 | 0 |
| SWING | 0 | 7 | 0 | 0 | 9 | 7 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 10 | 0 | 1 | 7 | 0 |
| TAP | 11 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 4 | 0 | 5 | 4 | 0 | 1 |
| TICKLE | 6 | 2 | 19 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 9 | 5 | 0 | 0 | 1 | 0 | 0 | 12 | 14 | 1 | 18 | 0 | 1 | 9 | 0 | 0 |
| TOSS | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 32 | 0 |
| TREMBLE | 2 | 1 | 1 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 5 | 7 | 5 | 0 | 1 | 0 | 1 | 0 | 0 | 2 |

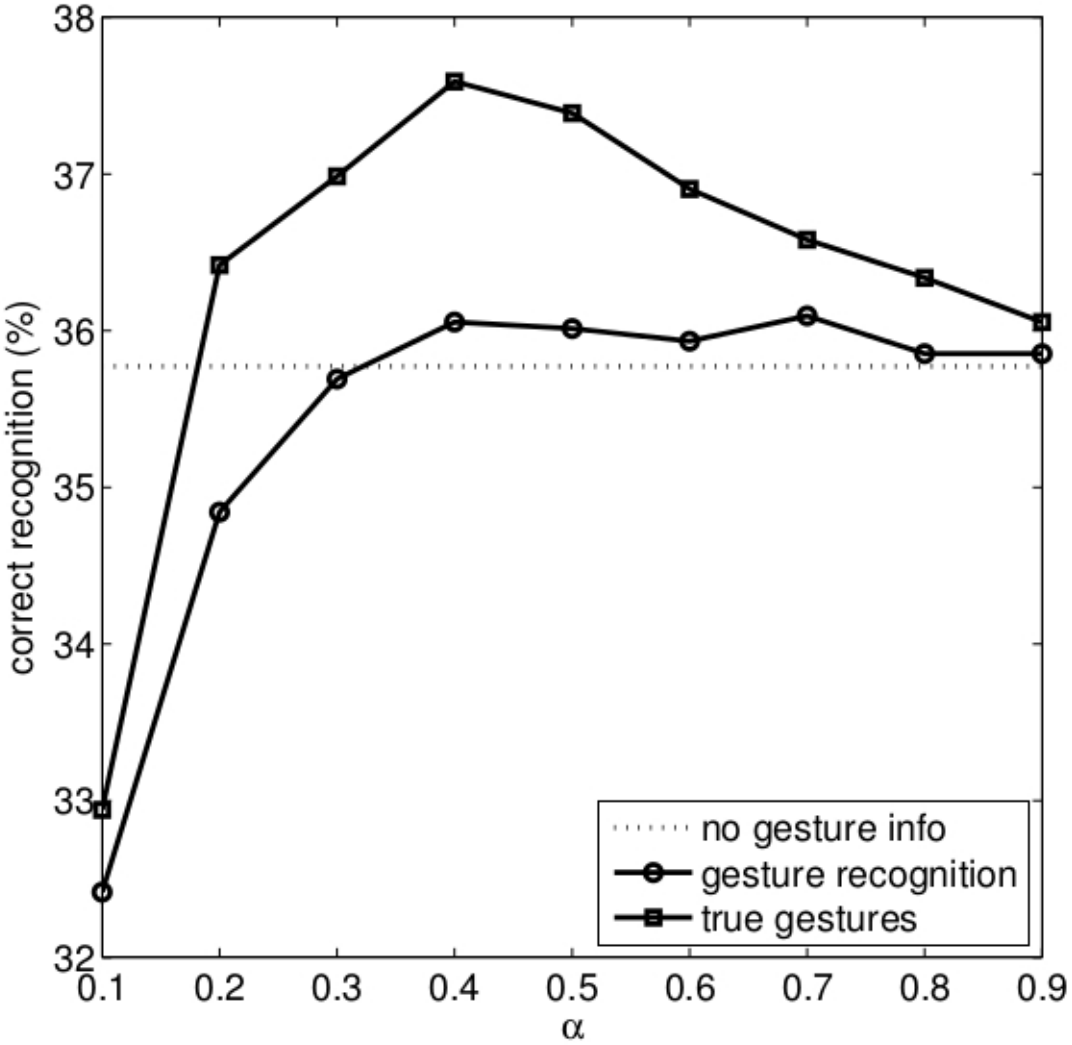
# Hand gestures and affect

- The results of the questionnaire give a relation between hand gestures and affect
  - The numbers can be interpreted as prior probabilities
  - Affect information can be inferred from gesture information and can be fused with direct affect recognition results

# Hand gestures and affect



# Hand gestures and affect



# Results

- 26 hand gestures were classified with 32% correct recognition rate
  - Similar hand gestures were confused (massage and rub, pat and tap, etc.)
- Fusing gesture data did not improve the performance
- Assuming gesture recognition is perfect, the performance increased by 10%  (38%)

# Summary

- Classified 9 different emotional states using touch sensors and accelerometer
  - 35% performance achieved (comparable with human-human touch interaction studies' results)
- “Near misses” in wrong classifications were observed in high arousal and positive valence zones
- Marginal performance increase observed when hand gesture recognition results were fused with direct affect recognition results

# Future work

- Insufficient coverage of FSR sensors
- Need new sensor technologies for this emerging area
  - Cover a compound curved surface
  - Measure touch location, pressure
  - Handle multitouch
  - Able to work when placed on a “rib cage”
  - Pleasant to the touch, or allow placement under fur cover

# Future work

- Need to find most discriminative features
  - Deep learning, unsupervised feature learning approaches
  - Finding most discriminative features would aid sensor design

# Acknowledgments


- Steve Yohanan
- Anna Flagg
- Diane Tam
- UBC CS SPIN Lab

# References


- K. Altun, K. E. MacLean, (accepted for publication) “Recognizing affect in human touch of a robot,” Pattern Recognition Letters, Special Issue on Pattern Recognition in Human-Computer Interaction, 2014.
- S. Yohanan, K. E. MacLean, “The role of affective touch in human-robot interaction: human intent and expectations in touching the Haptic Creature,” International Journal of Social Robotics, 4, 163—180, 2012.