Georgia Institute of Technology

The Role of Haptics in Affordances

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Robotics@GT & Intelligent Machines

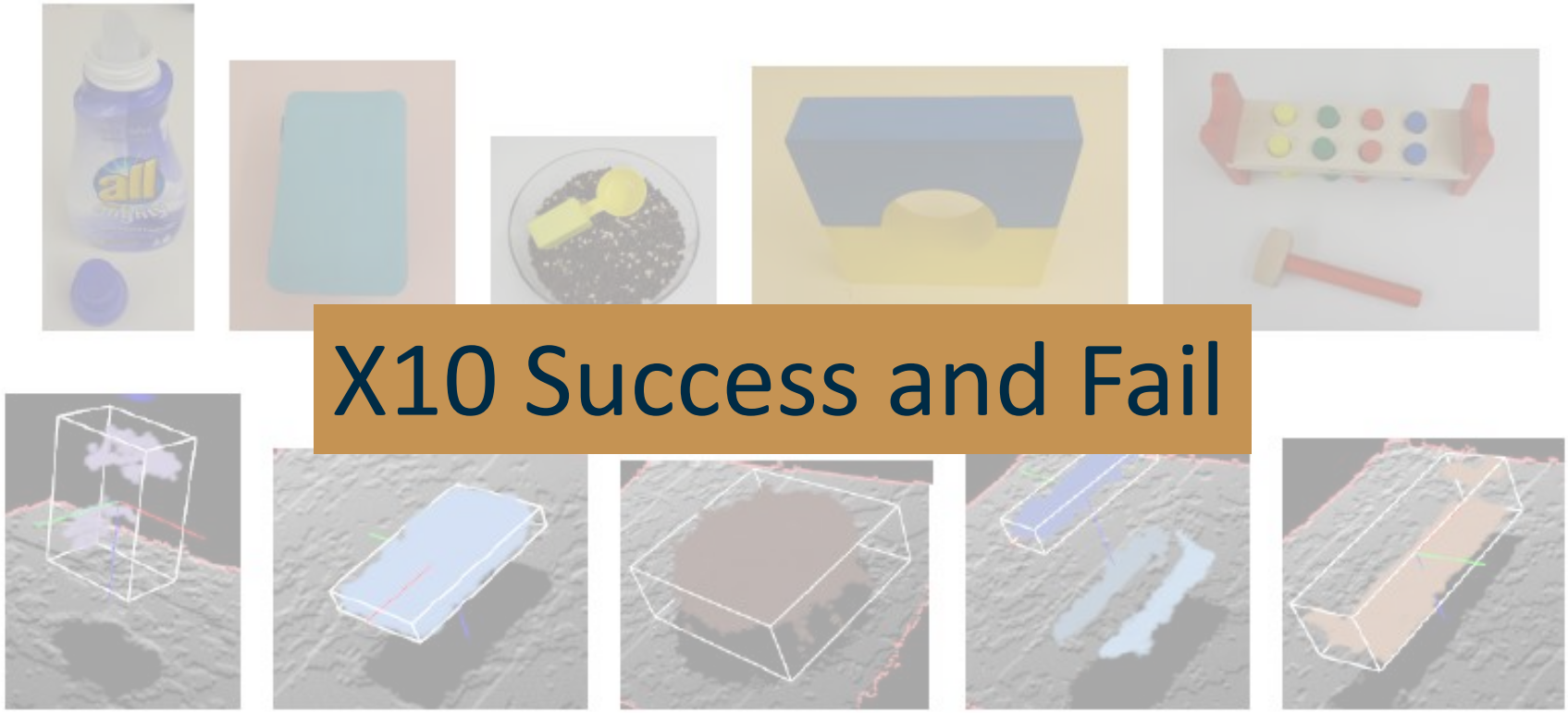
J.J. Gibson (1977) – “action possibilities” that appear between environment and the agent

Problem

- Model manipulation affordances using tactile data

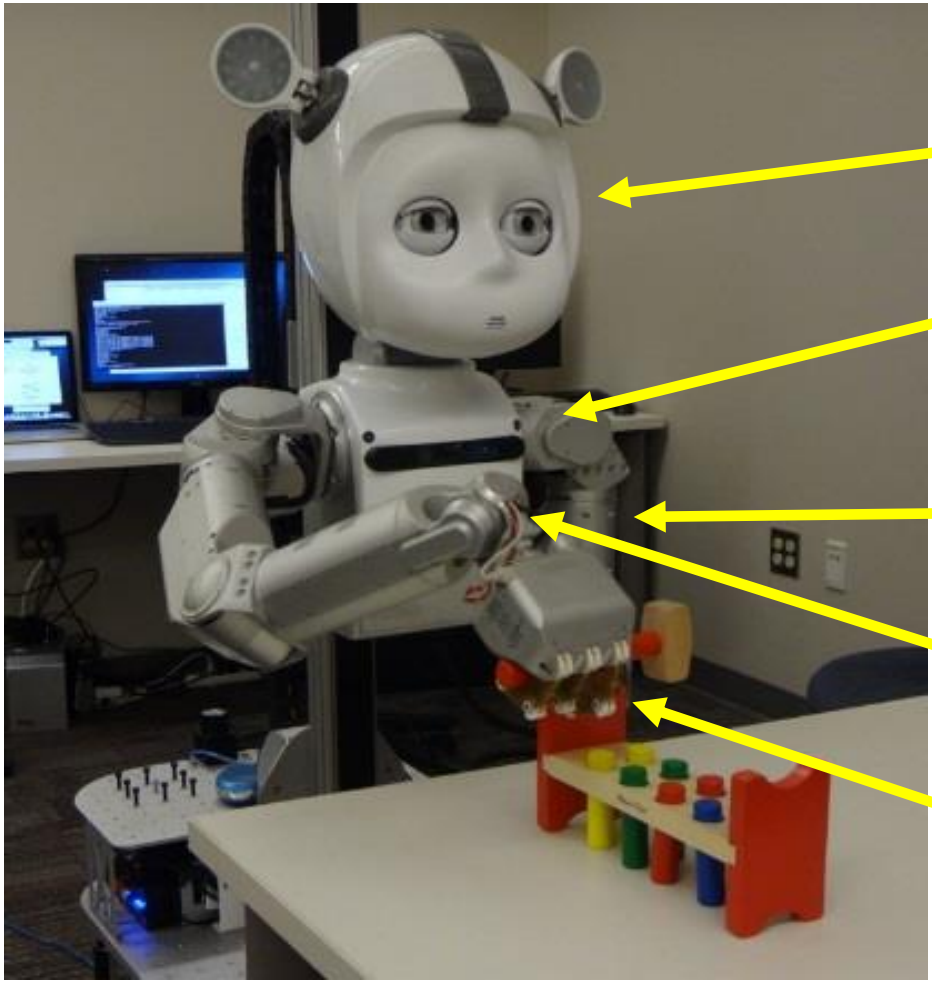
- How can this be learned from a human partner?

Experiment



Platform

ASUS Xtion Pro Live RGB-D Camera



Socially Expressive Head

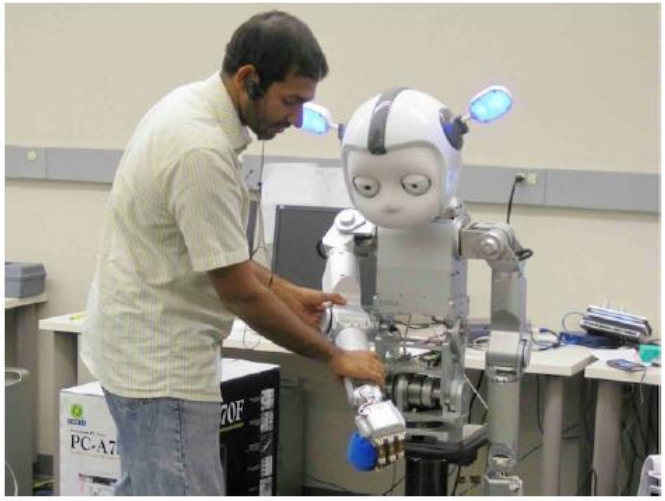
Stereo Microphone Array
ASUS RGB-D Camera

Two 7 DOF Arms

ATI Mini40 F/T Plates

Two under actuated 4 DOF hands

Exploration



Akgun, Baris, et al. 2012 "Keyframe-based learning from demonstration."

Thomaz and Cakmak, 2009
"Learning about objects with human teachers."

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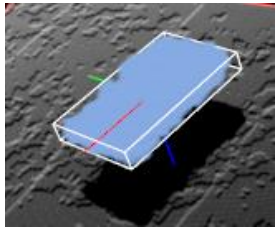
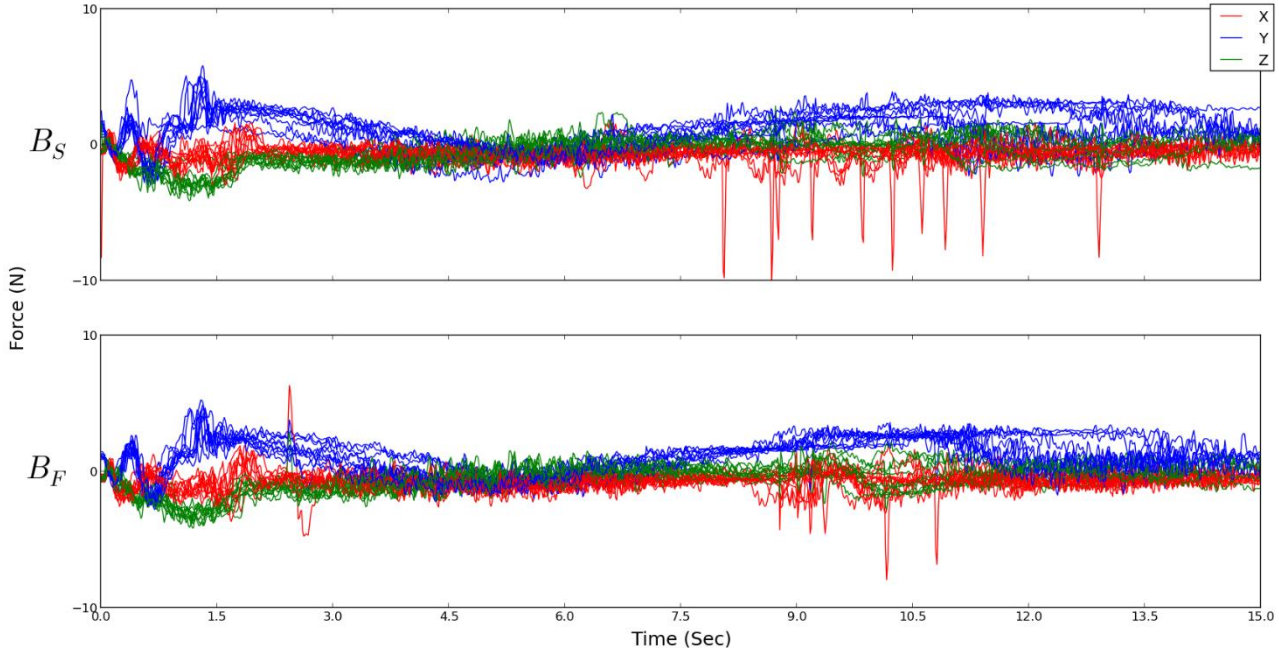
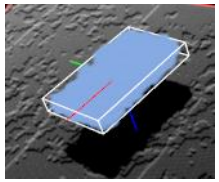
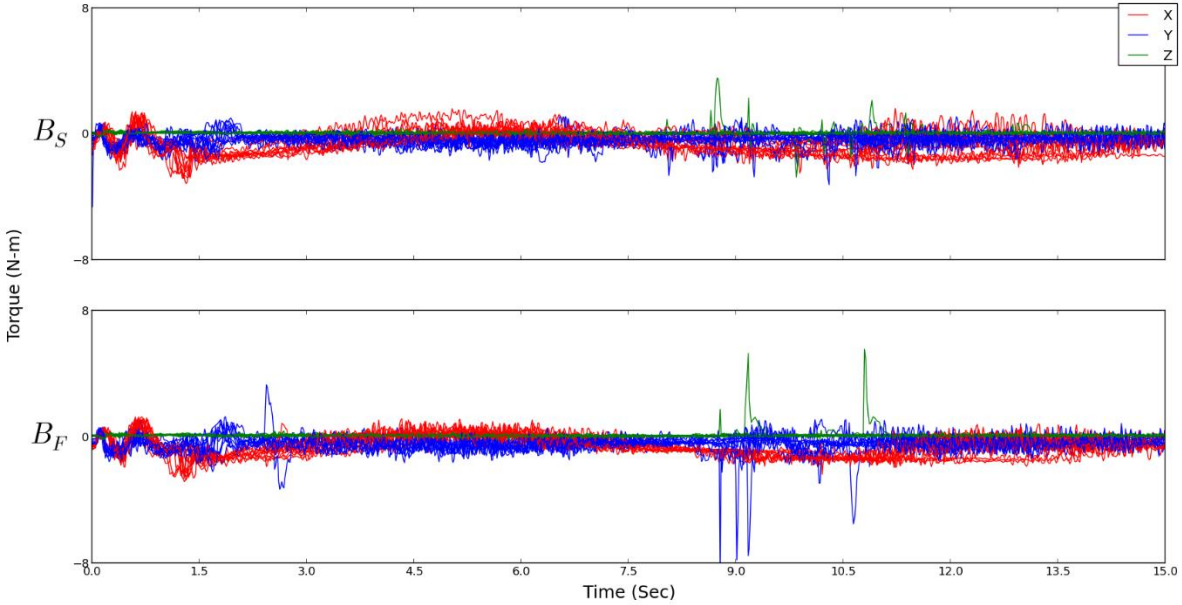
Curi closing a box




X
Y
Z
B_S
B_F
Force (N)
Time (Sec)




X
Y
Z
B_S
B_F
Torque (N-m)
Time (Sec)

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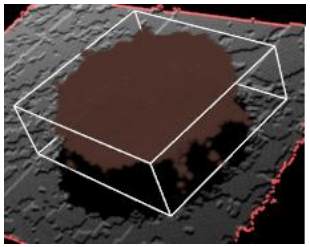
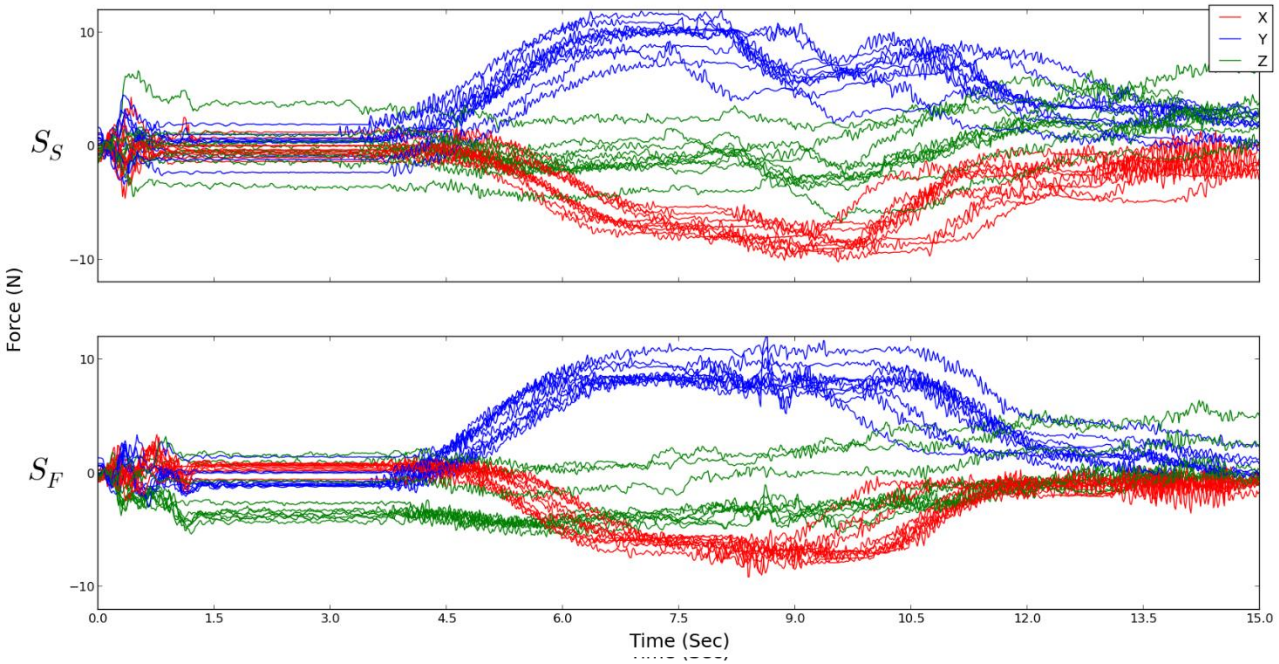
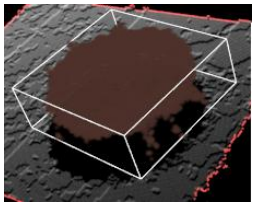
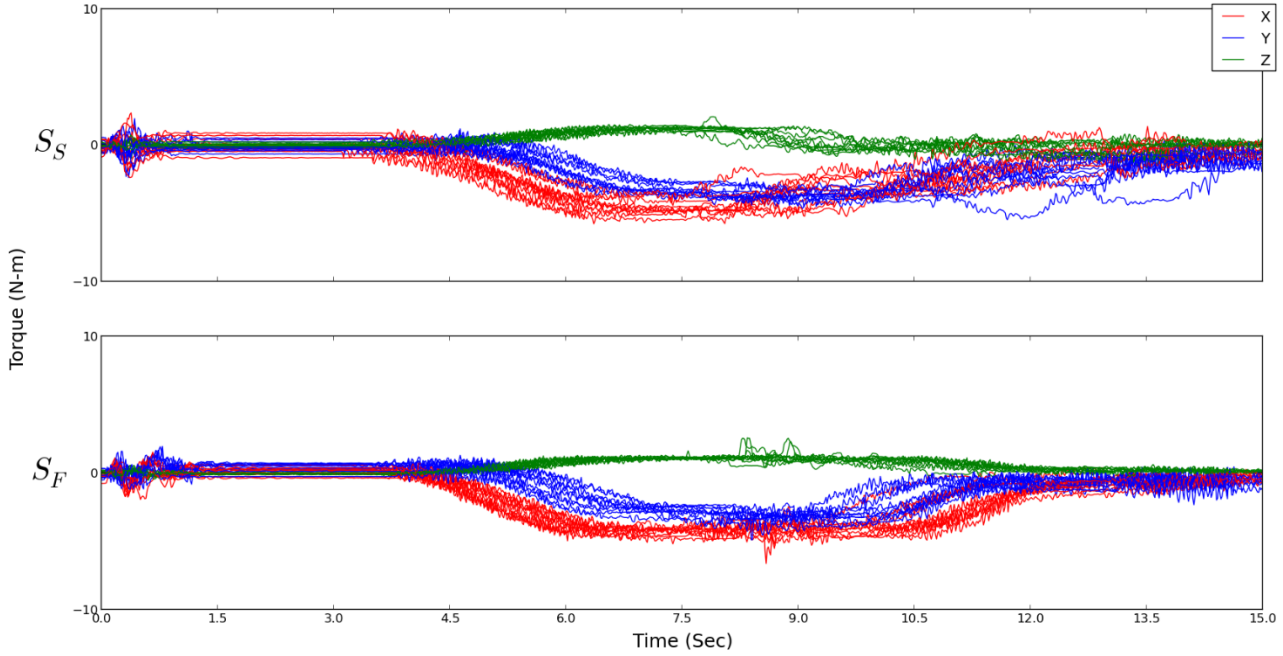
Scooping Beans




X
Y
Z
S_S
S_F
Force (N)
10
0
−10
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)




X
Y
Z
S_S
S_F
Torque (N-m)
10
0
−10
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)

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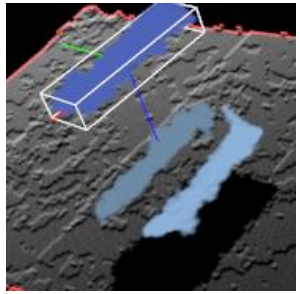
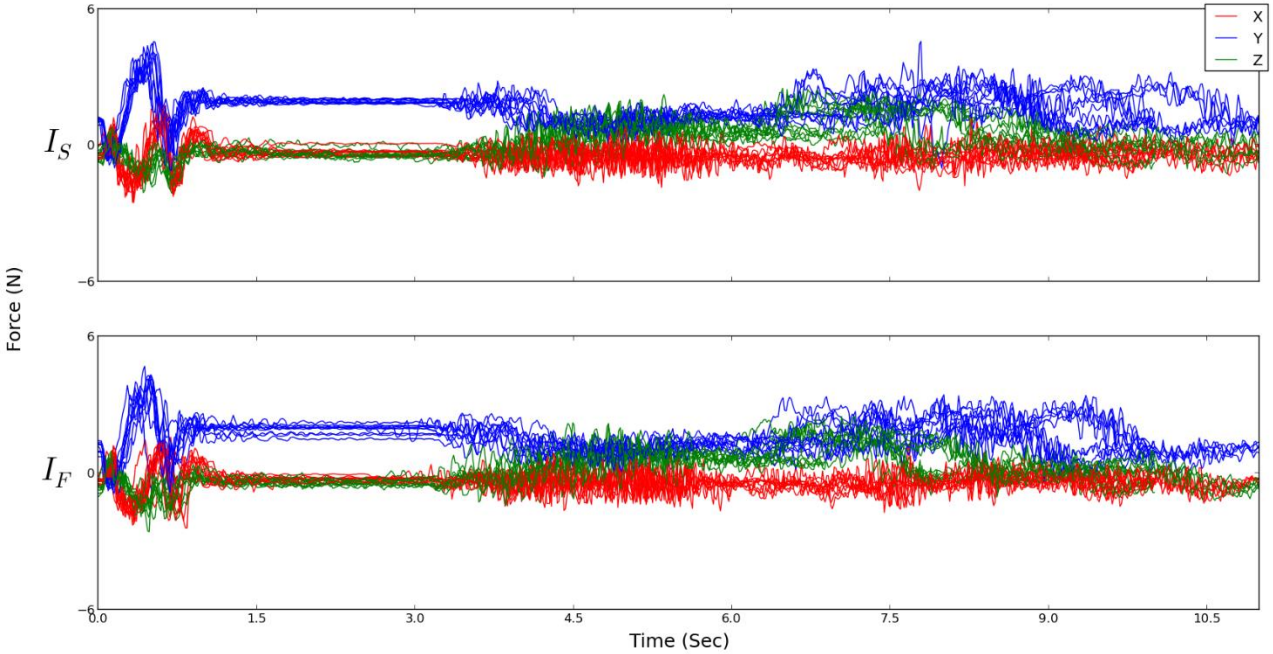
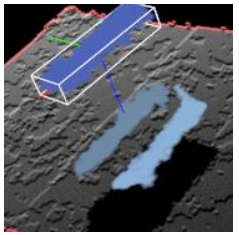
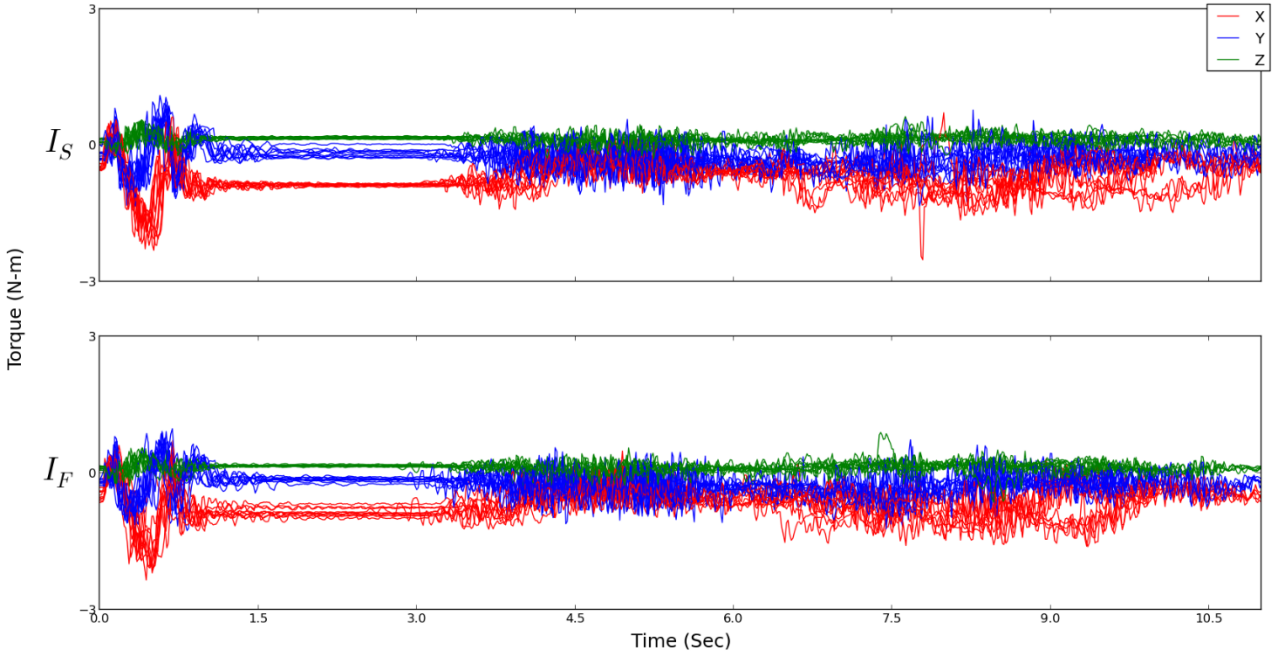
Insertion Task




X
Y
Z
I_S
I_F
Force (N)
Time (Sec)




X
Y
Z
I_S
I_F
Torque (N-m)
Time (Sec)

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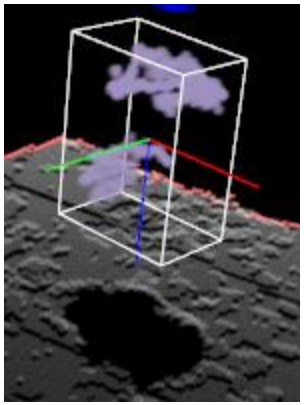
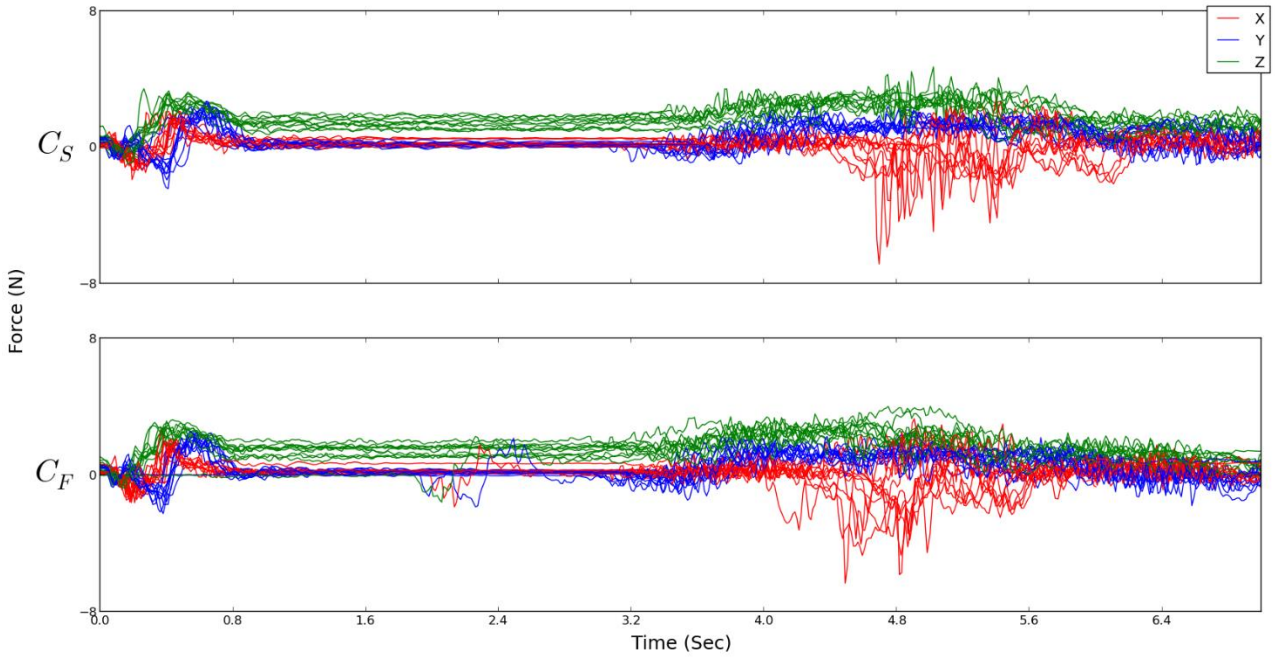
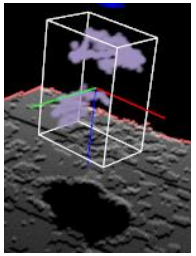
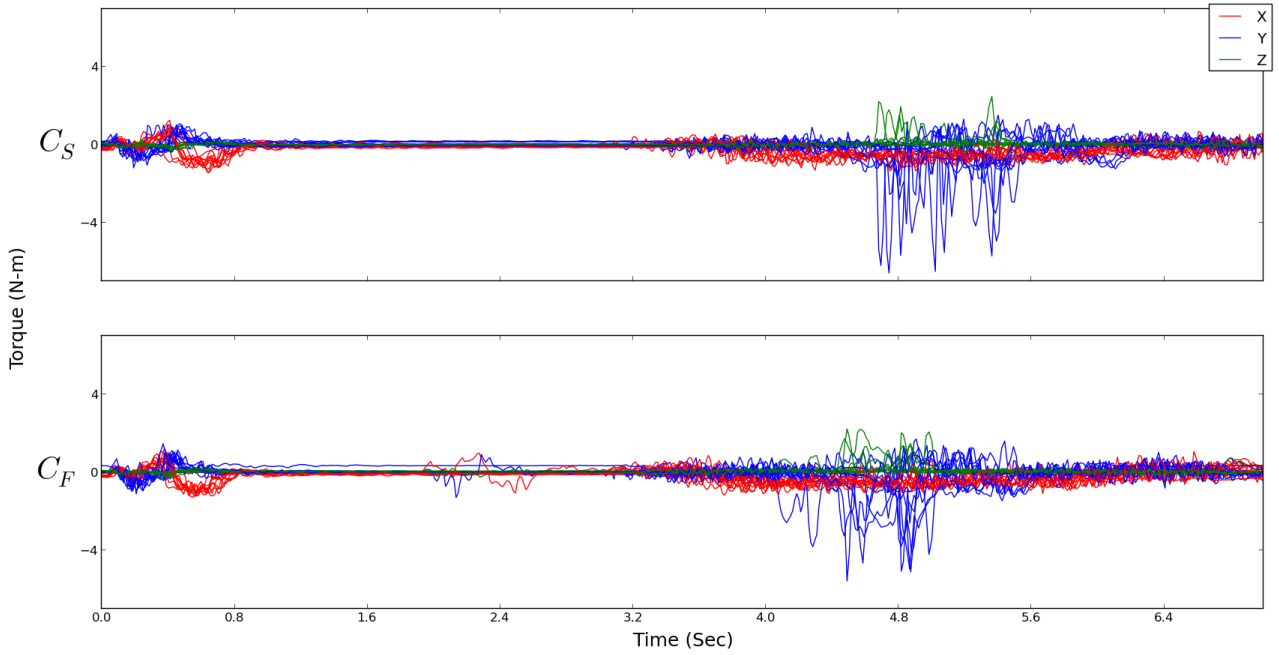
Cap the Bottle




X
Y
Z
C_S
C_F
Force (N)
8
0
−8
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
Time (Sec)




X
Y
Z
C_S
C_F
Torque (N-m)
4
0
−4
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
Time (Sec)

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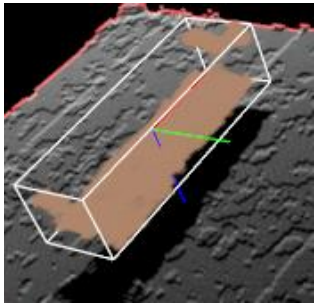
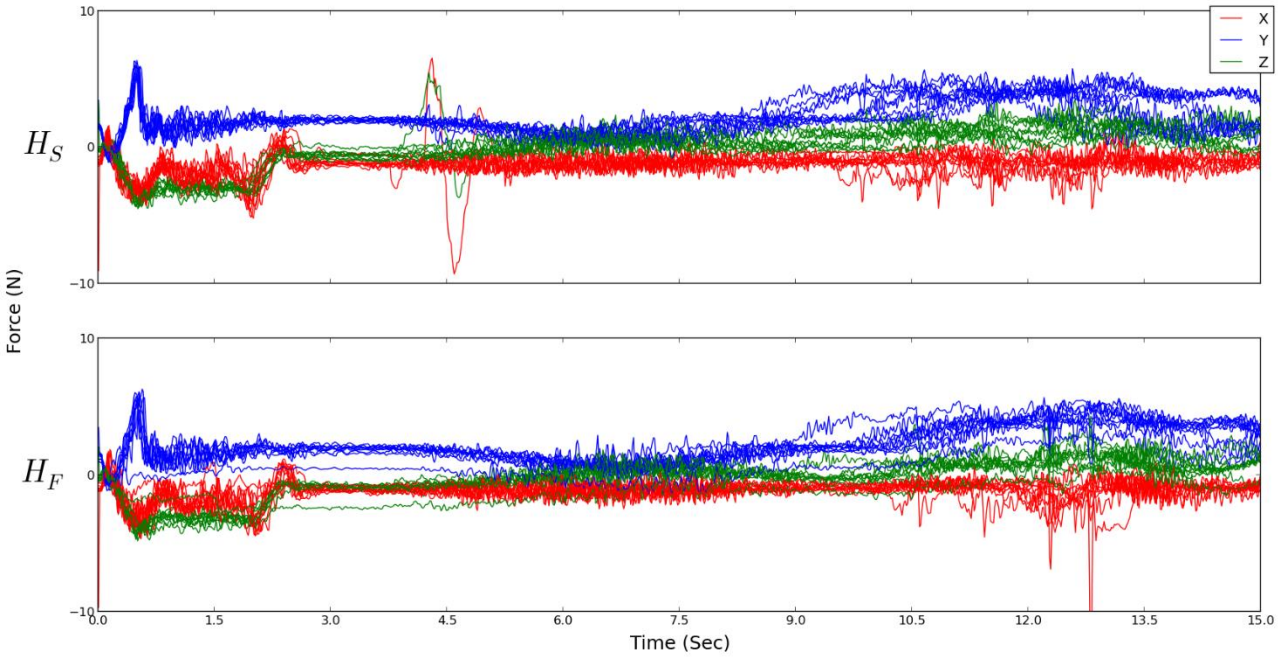
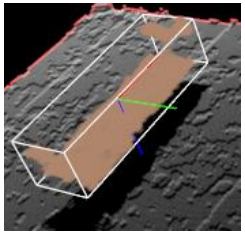
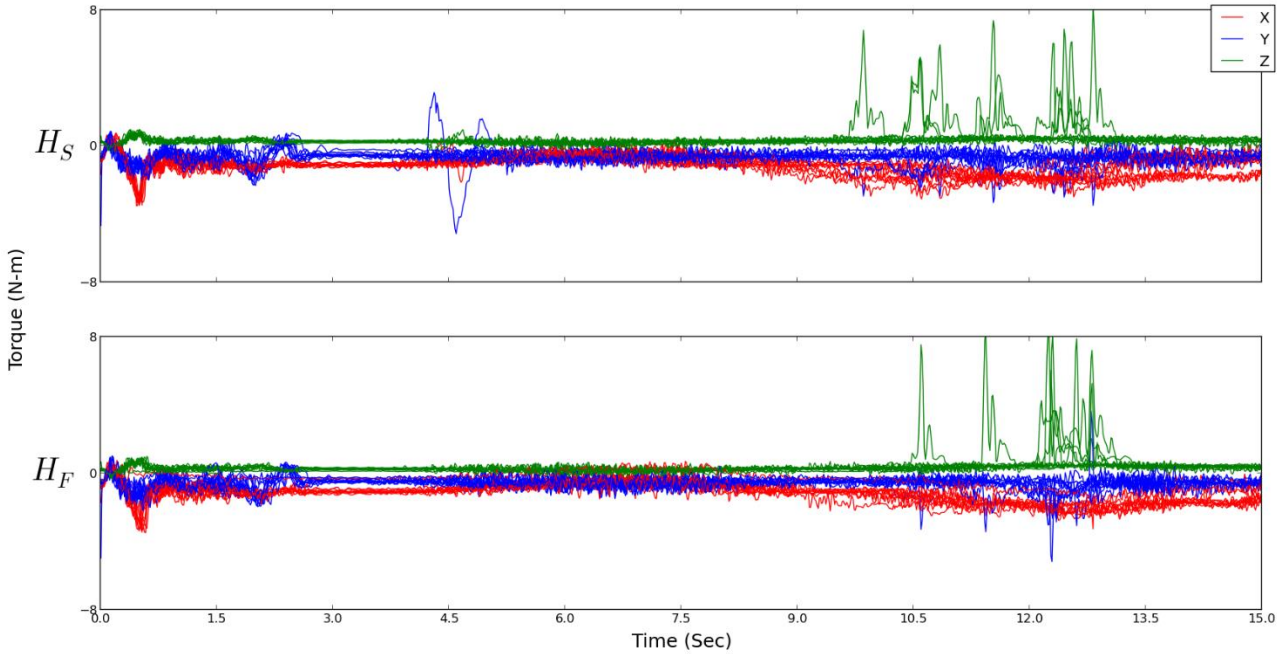
Curi hammering




X
Y
Z
H_S
H_F
Force (N)
10
0
−10
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)




X
Y
Z
H_S
H_F
Torque (N-m)
8
0
−8
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)

Modeling

- Hidden Markov Model (HMM)
- Feature Space
  - FT: 6 values (Fx,Fy,Fz,Tx,Ty,Tz)
  - Pose: 3 values (x,y,theta)
- Model “success” and “near-miss” for each task

Training and Evaluation

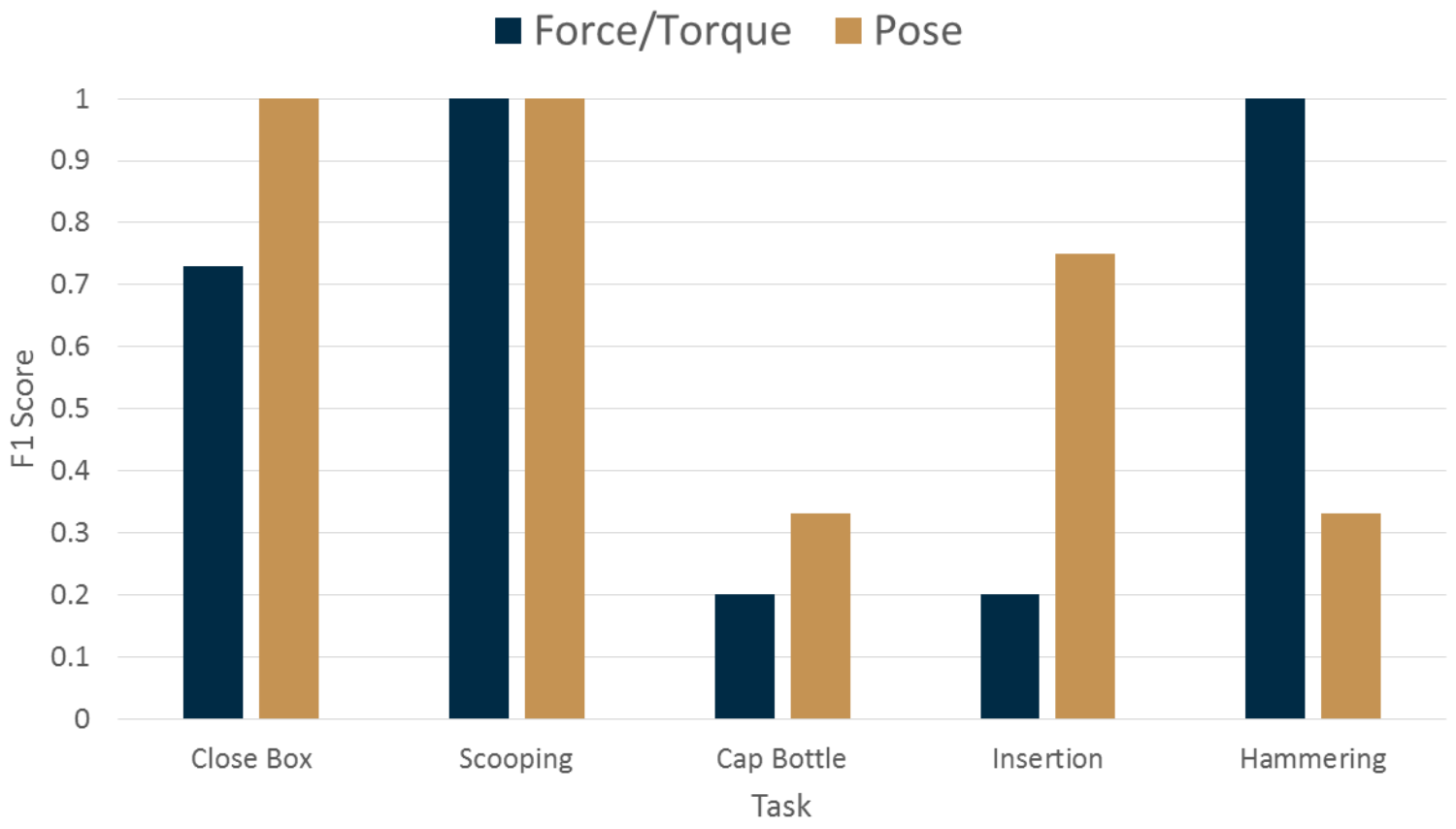
- Train: 16 examples
  - 8 success, 8 fail
- Test: 4 examples
  - 2 success, 2 fail
- Leave-one-out cross validation

Evaluate each using F1 Metric:

Precision	Recall	F_1
$\frac{tp}{tp+fp}$	$\frac{tp}{tp+fn}$	$2 \cdot \frac{precision \cdot recall}{precision + recall}$

tp: true positive
fp: false positive
tn: false negative

Classification Results



Future Questions

- How do we go from monitoring to planning?
- How to incorporate with visual affordances?
- How to leverage human partners and how good exactly are the models generated rather than using exhaustive exploration?

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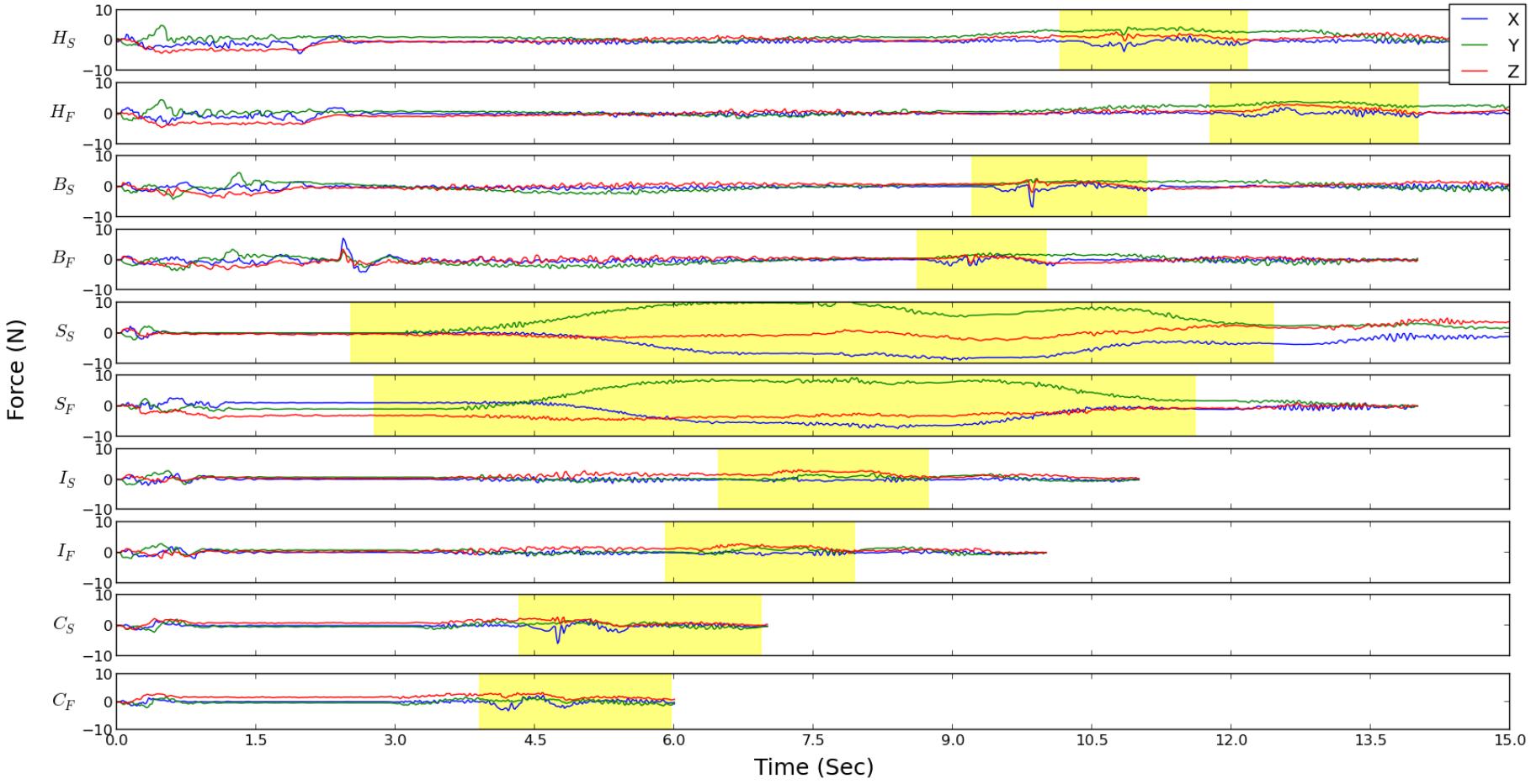
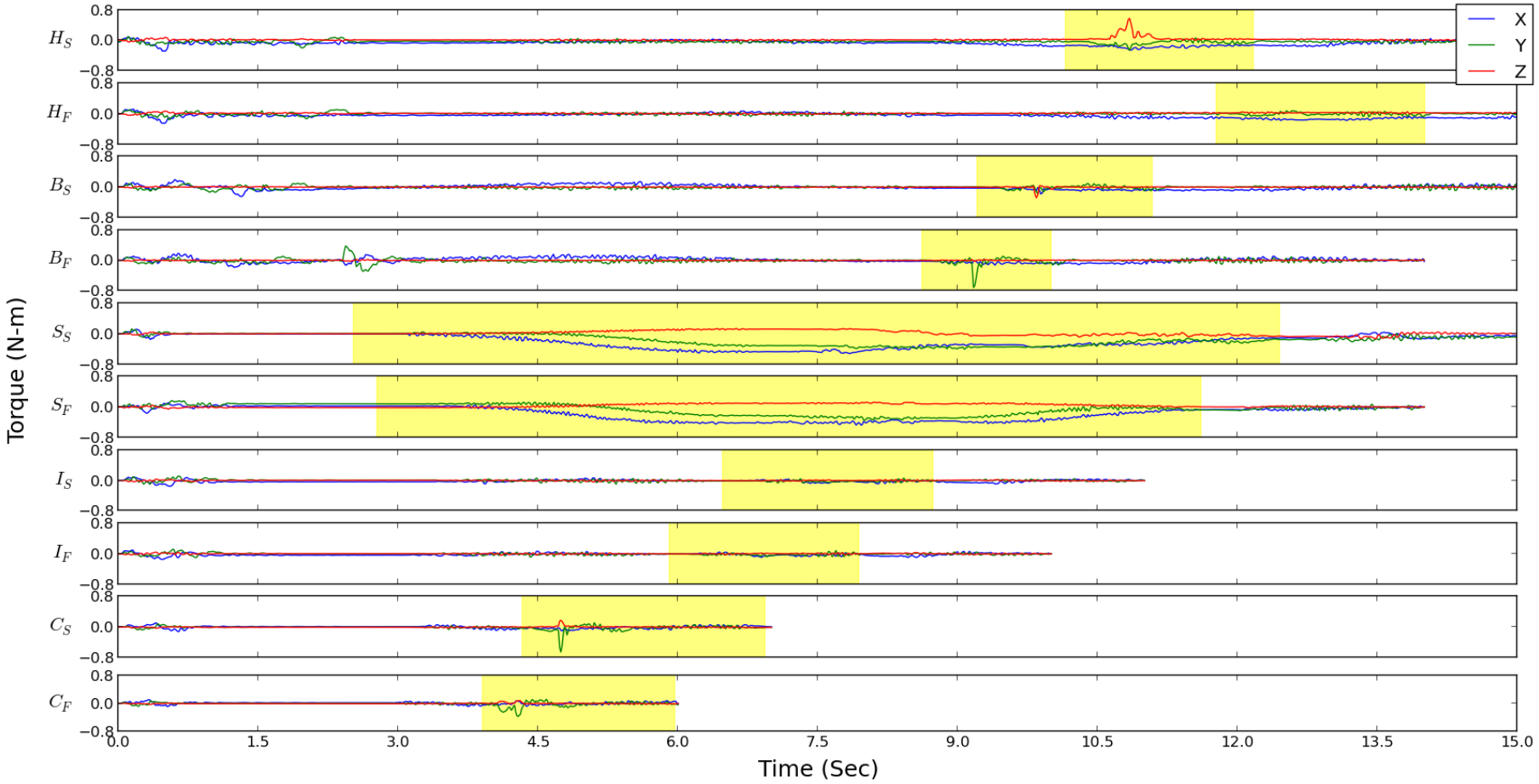
Questions?

Forces


X
Y
Z
H_S
H_F
B_S
B_F
S_S
S_F
I_S
I_F
C_S
C_F
10
0
−10
Force (N)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)

Torques


X
Y
Z
H_S
H_F
B_S
B_F
S_S
S_F
I_S
I_F
C_S
C_F
0.8
0.0
−0.8
Torque (N-m)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Time (Sec)

Initial Results

Force/Torque

Task	Precision	Recall	F1
Box	0.83	0.75	0.73
Scooping	1.0	1.0	1.0
Cap	0.17	0.25	0.2
Insertion	0.17	0.25	0.2
Hammering	1.0	1.0	1.0

Pose

Task	Precision	Recall	F1
Box	1.0	1.0	1.0
Scooping	1.0	1.0	1.0
Cap	0.25	0.5	0.33
Insertion	0.83	0.75	0.75
Hammering	0.25	0.5	0.33