Robotic Grasping for Daily-Living Manipulation Tasks

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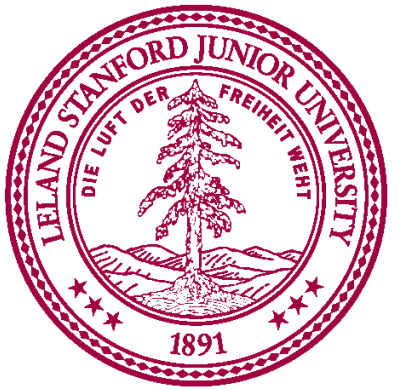
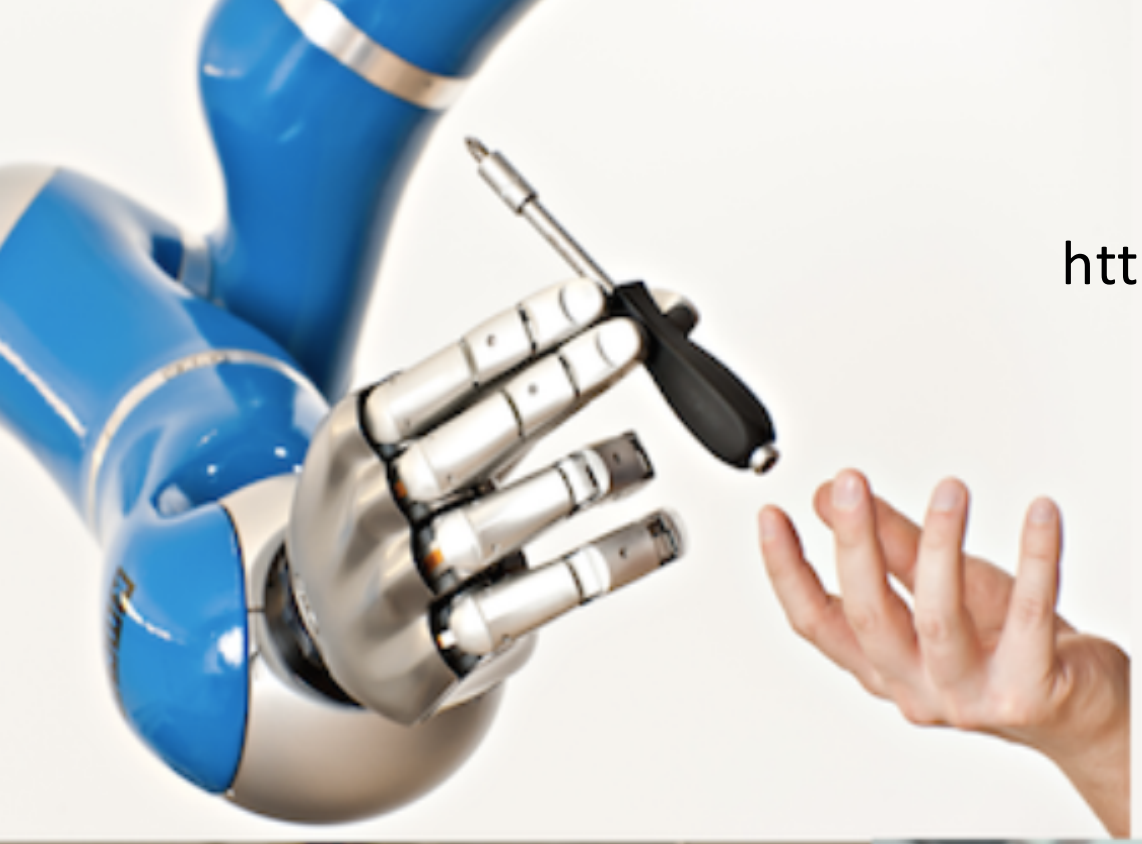
USFRPAL

Robot Perception and Action Lab



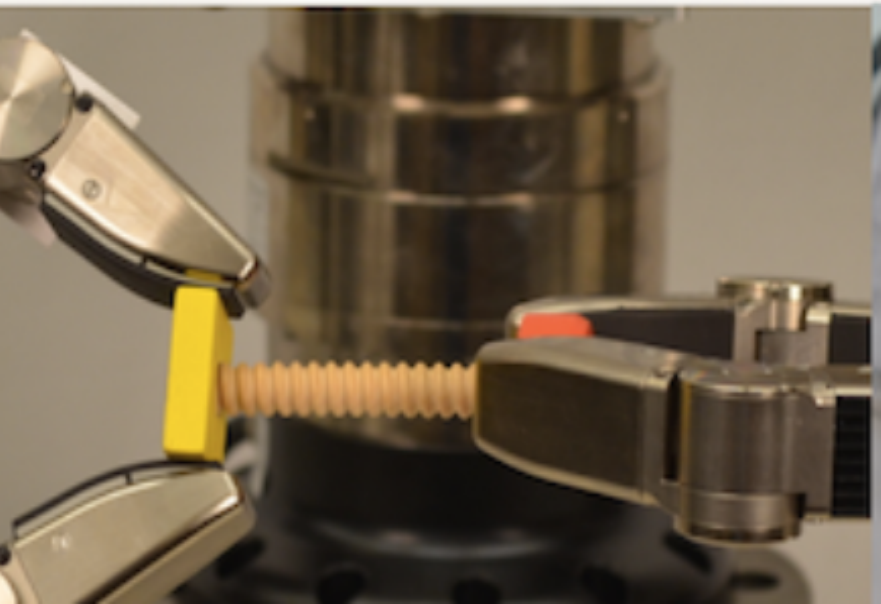


HOME CFP FORMAT RULES SUPPORT DEADLINES PEOPLE

http://www.rhgm.org/activities/competition_iros2016/

Robotic Grasping and Manipulation Competition

@ IROS 2016 (Oct. 10-12, 2016) in Daejeon, Korea



- Use a spoon to pick up peas
- Use a spoon to stir water in a cup
- Shake salt shaker
- Plug into a socket
- Hammer a nail
- Transfer straw into a to-go cup with lid
- Putting on or removing bolts from nuts with a nut driver
- Use a saw to saw open a cardboard along a line
- Open a bottle with a locking safety cap

Grasp for Manipulation

- Manipulating an instrument
  - Task wrench: interactive force and torque between the instrument and environment
  - Instrument motion

Task-Based Grasp Quality Measures -- Optimization Goals

Grasp to Facilitate Manipulation

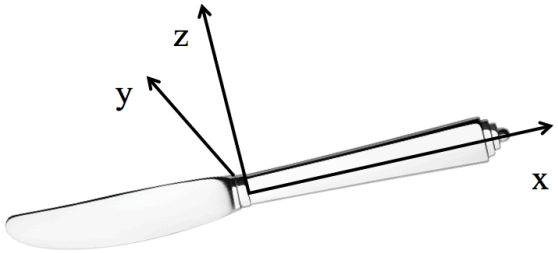
- Maintain a firm grip and withstand and provide necessary interactive wrench on the instrument
- Enable the manipulator to carry out the task most efficiently with little motion effort
- Measure how well a grasp satisfies the objectives

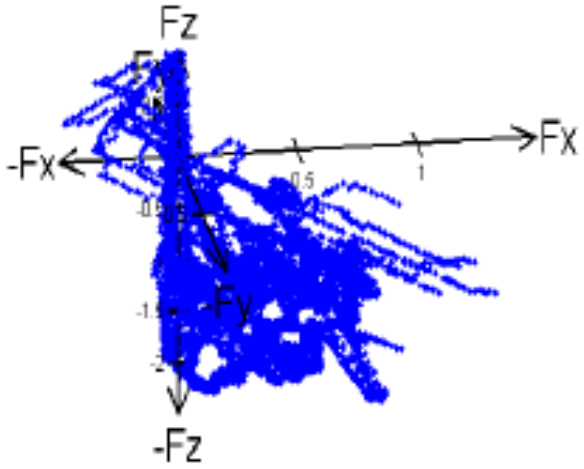
Use a Knife

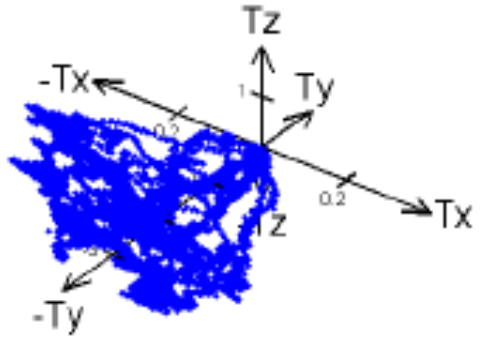
From WikiHow

Use a Knife

Task 1: cutting

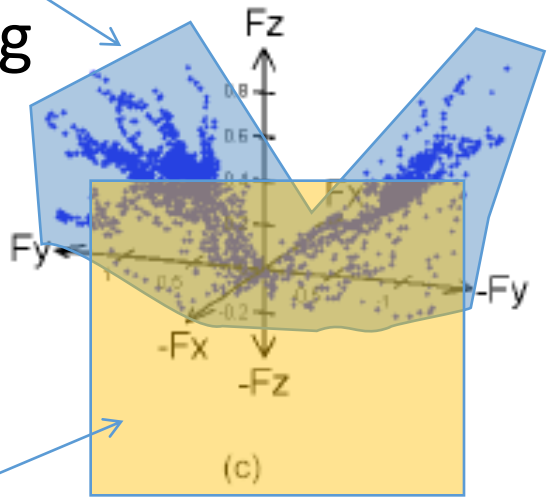


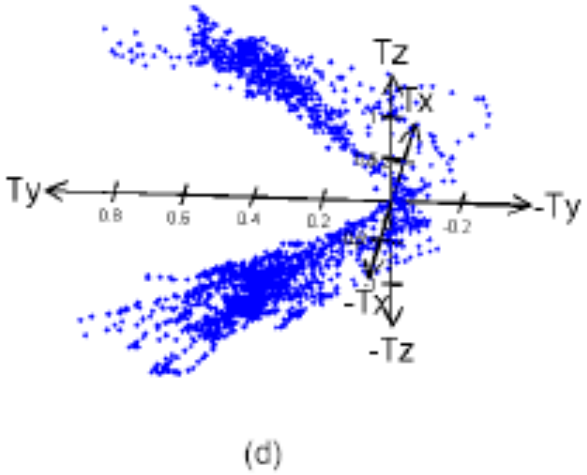




Task Coverage

Task 2: butter spreading





Force closure

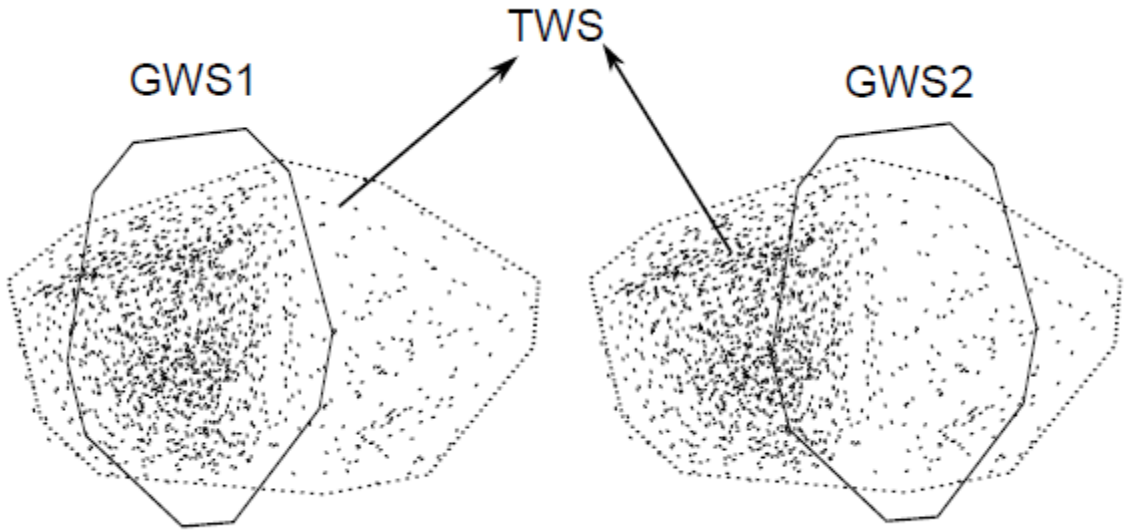
Task-Oriented Grasping

- Z. Li and S. S. Sastry. Task-oriented optimal grasping by multifingered robot hands. *IEEE Journal of Robotics and Automation*, 4(1):32–44, feb 1988.
- Nancy Pollard
- Jeff Trinkle, Zexiang Li
- Gerd Hirzinger
- Danica Kragic
- Many others
- Approximate the task wrench space with geometry shapes

Quality Measure: Task Wrench Coverage

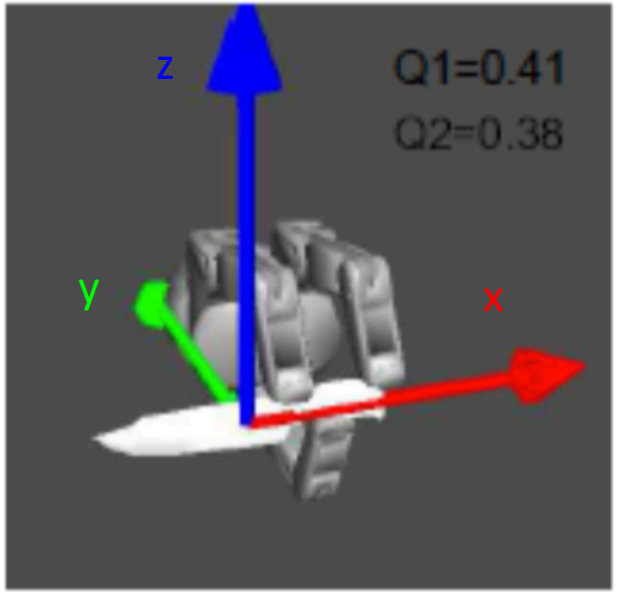
- Random in task: density of the task wrench samples
- The count of task wrench observations in the TWS that are covered by GWS
- The count of the total task wrench observations in the TWS

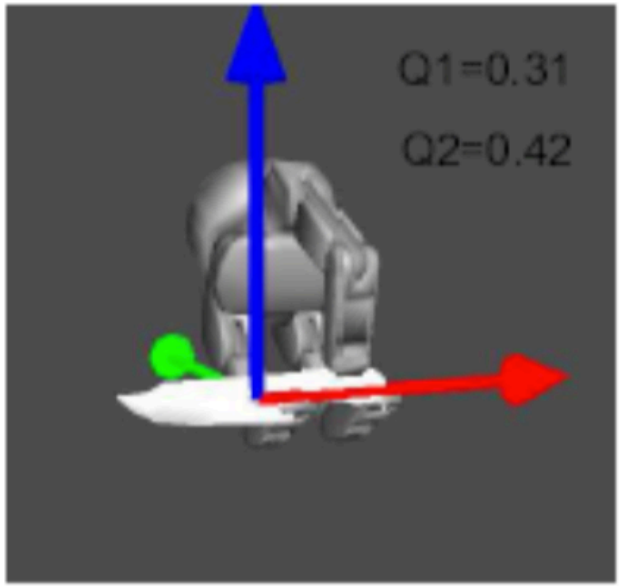
$$Q_w = \frac{Count\{\mathrm{O}|O \in \mathrm{GWS} \cap \mathrm{TWS}\}}{Count\{\mathrm{O}|O \in \mathrm{TWS}\}}$$

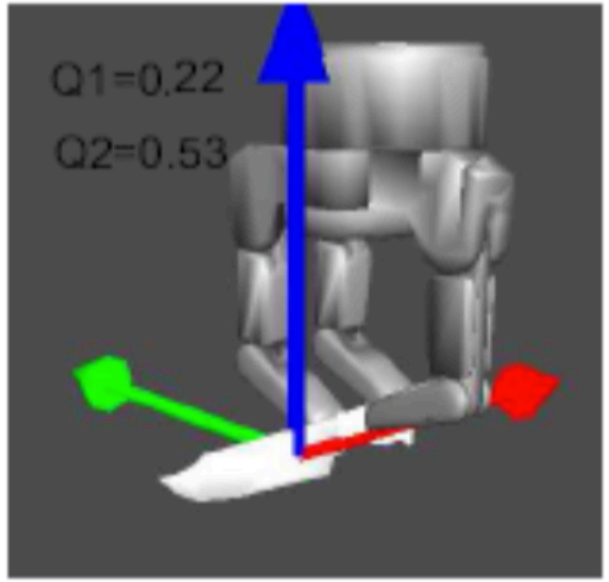


Task 1

Task 2



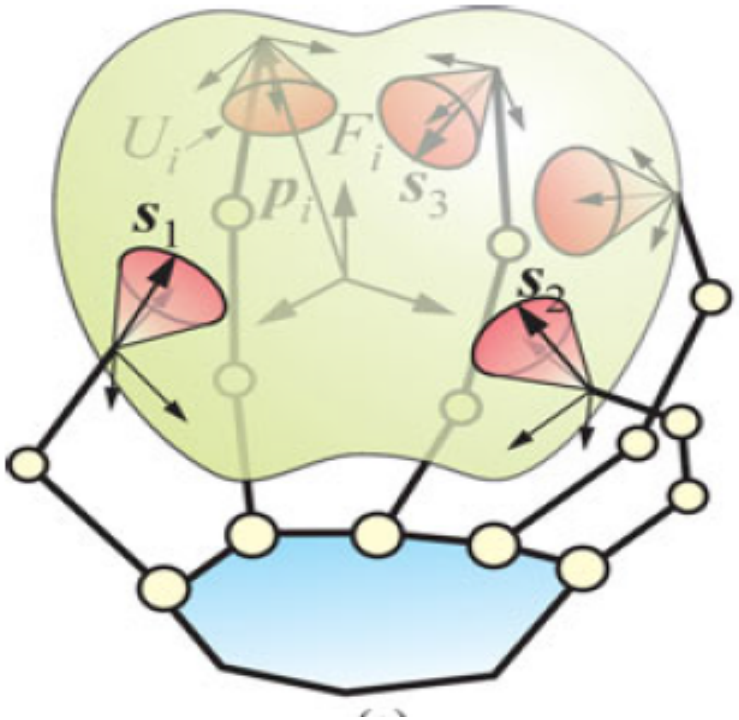




Grasp Definition

- Grasp can be defined by
  - Hand posture G(p, w)

    Where p is a vector of joint angles; w is a 6-d vector of wrist position and orientations
- Grasp capability is decided by
  - Contact points
    - Hand posture



Thumb Placement
-- Reduce search space

- Measure

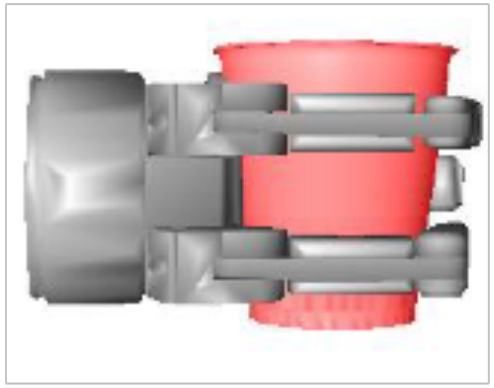
✓ Learn human grasping strategies

? Robotic hands are different from human hands

✓ Extract general strategy based on the common mechanical structure -- Thumb placement

✓ Search for optimal grasp to maximize a task-based grasp quality measure

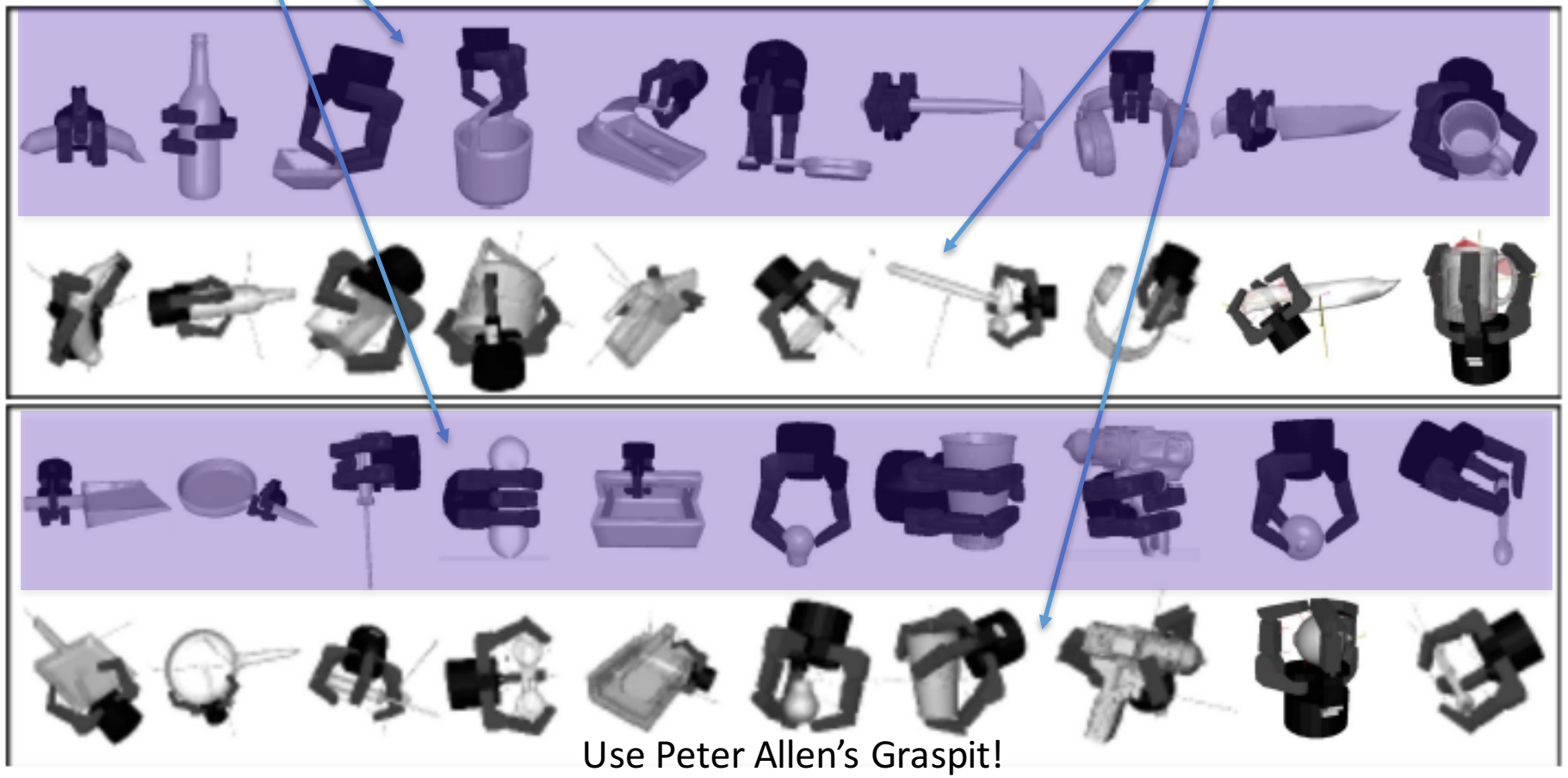
Thumb Placement



Evaluation Using Barrett Hand

With thumb placement constraints

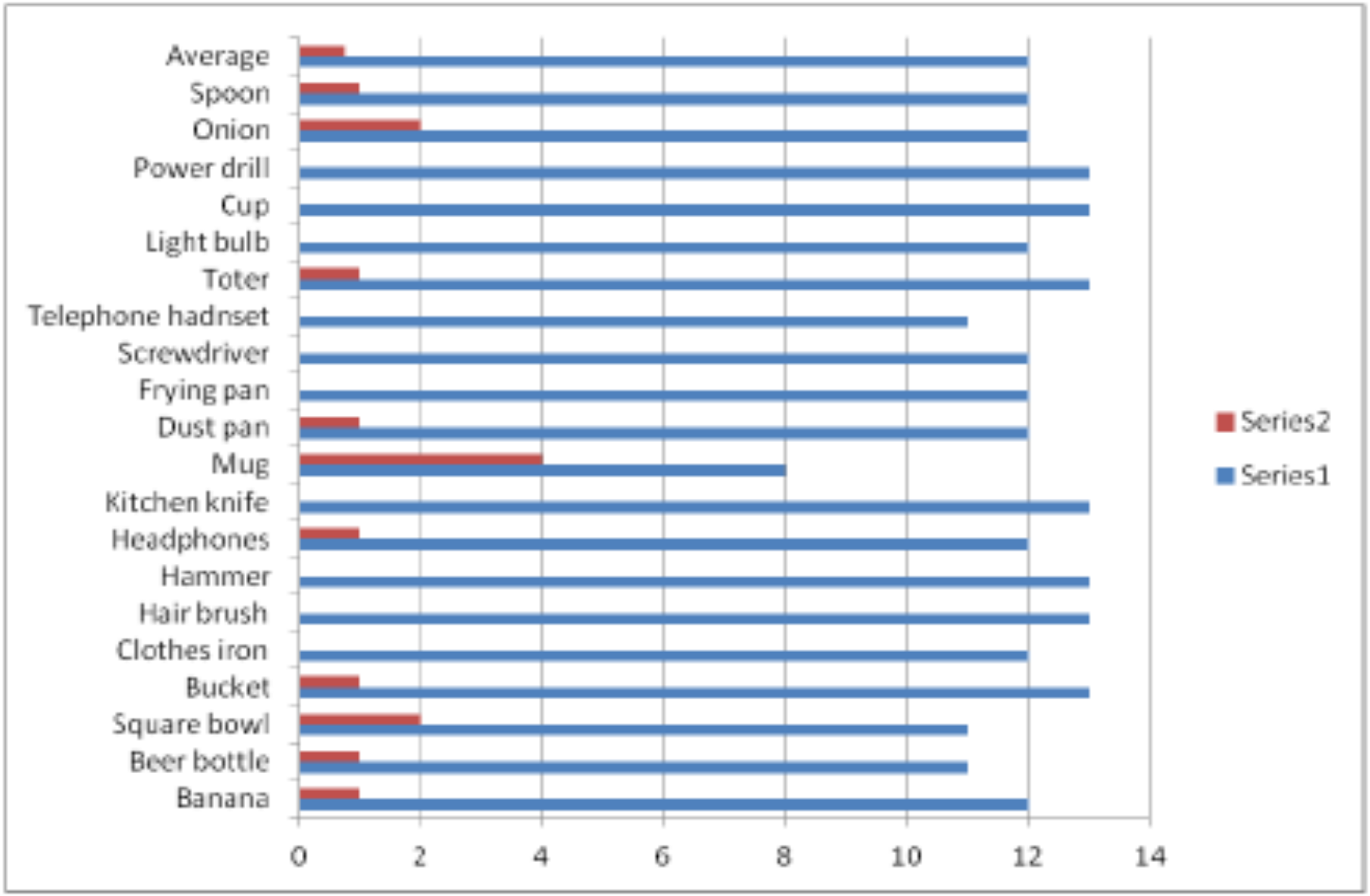
Without thumb placement constraints



Use Peter Allen's Graspit!

Lin, and Sun (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.

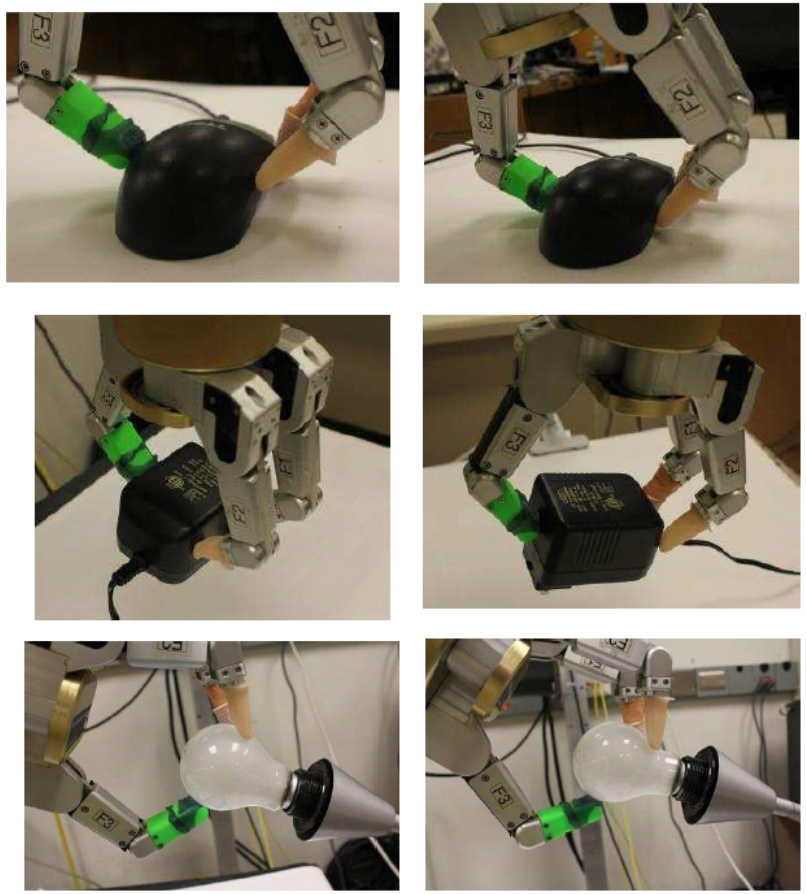
Evaluation by Barrett Hand



Success Rate of Real Execution

Our approach

Force-closure approach

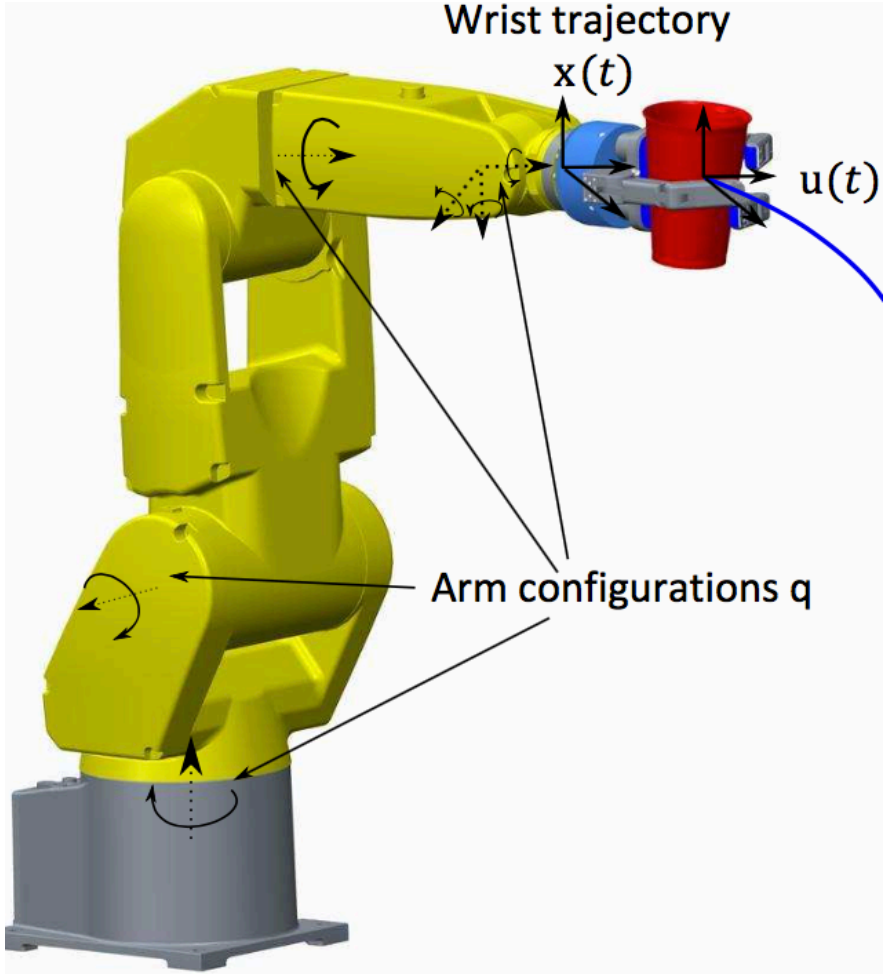


Task	Success Rate of Task Disturbance Based Grasp Planning	Success Rate of non-task oriented Grasp Planning
Task 1	60%	40%
Task 2	80%	70%
Task 3	70%	20%
Overall	70%	43.3%

Lin, Y. and Sun, Y., (2015) Grasp Planning to Maximize Task Coverage, Intl. Journal of Robotics Research, pp. 1-16


A haptic device is used to
demonstrate a task.

Grasp Measure Based-on Manipulator Efficiency in Task



Instrument trajectory vs. Wrist trajectory

When instrument trajectory is fixed, different grasps will need different wrist trajectories.

Different wrist trajectories needs completely different arm motions.

Grasp => arm motion

Best Grasp Requests Less Arm Motion

M-joint vector of torques from the actuator

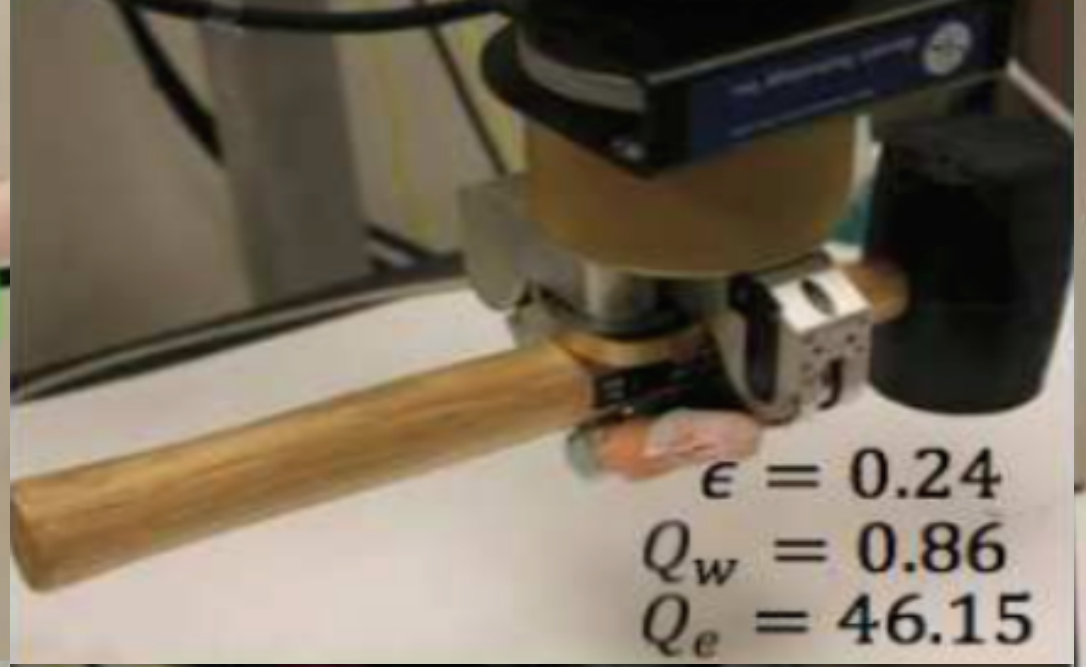
$$\tau = M(\mathbf{q})\ddot{\mathbf{q}} + C(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}} + F(\dot{\mathbf{q}}) + G(\mathbf{q}) + J(\mathbf{q})\mathbf{f}$$

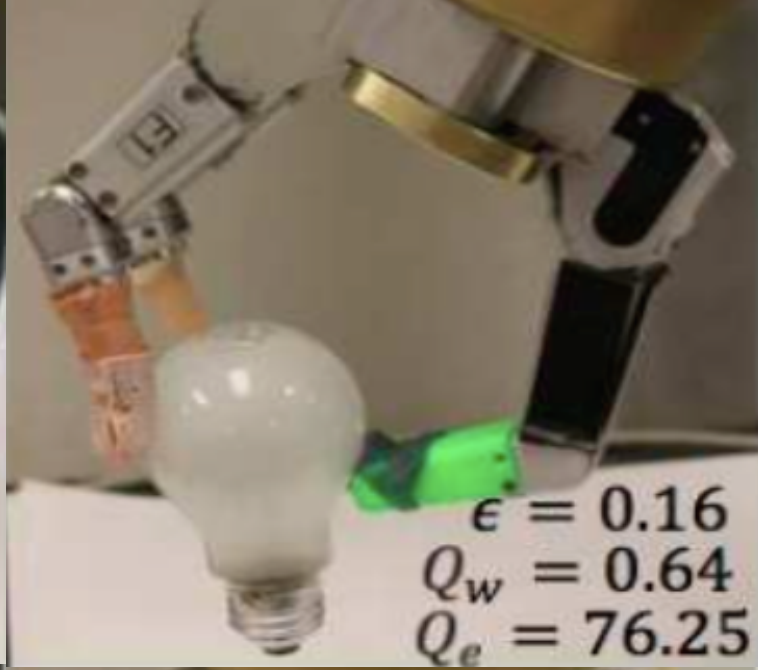
Manipulator's motion effort over time

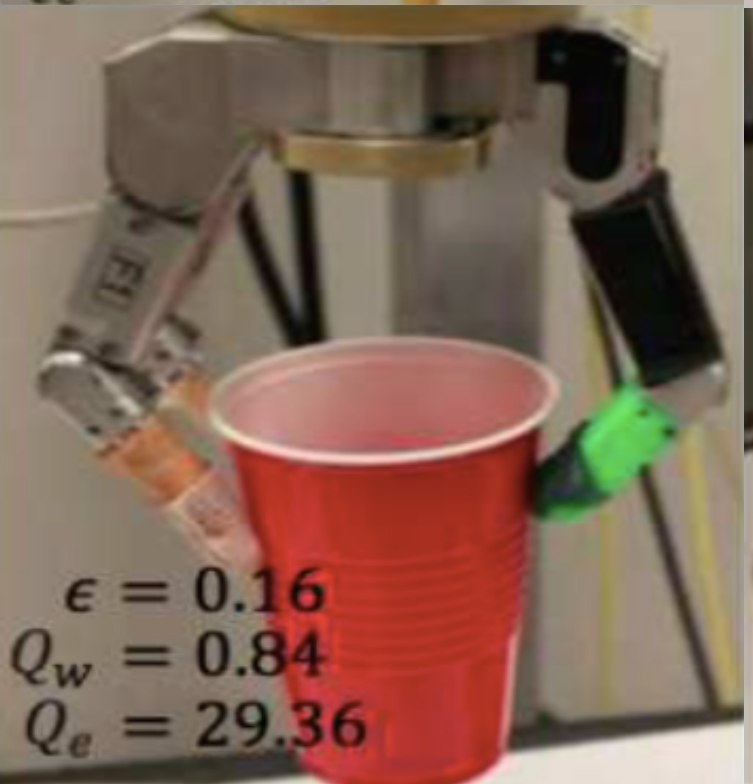
$$Q_e = \int_{t_0}^{t_n} \tau(t)^T \tau(t) dt$$

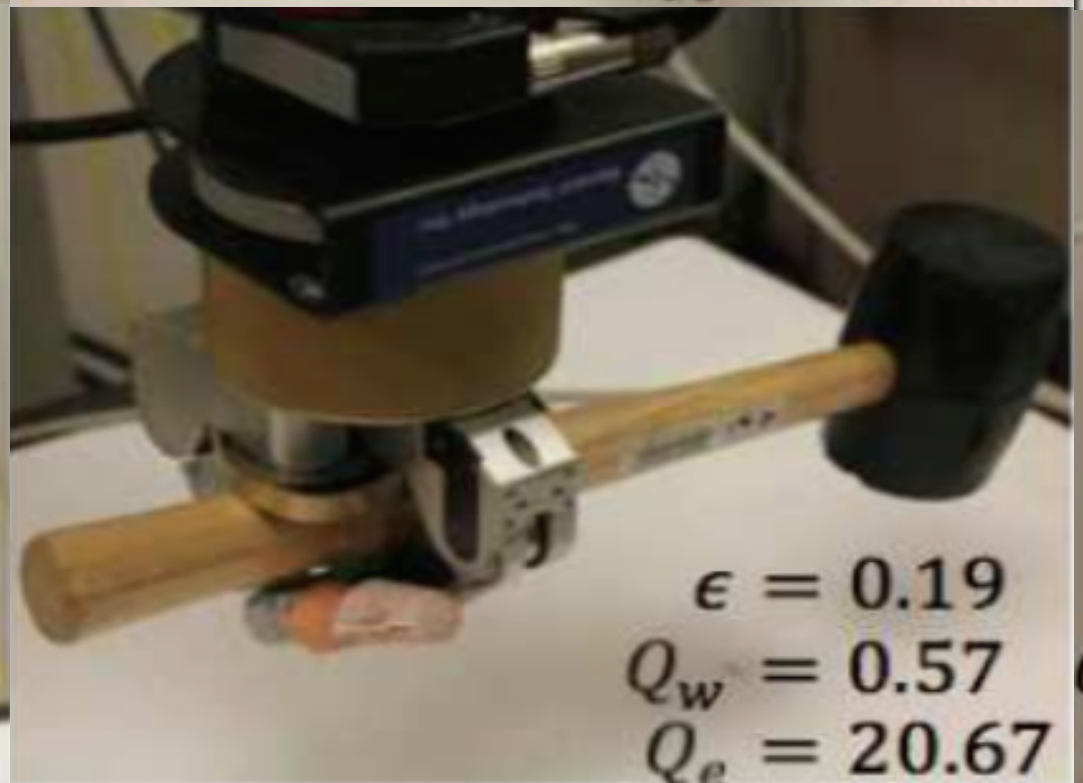
An example of task demonstration. Motion and disturbance distribution are captured.

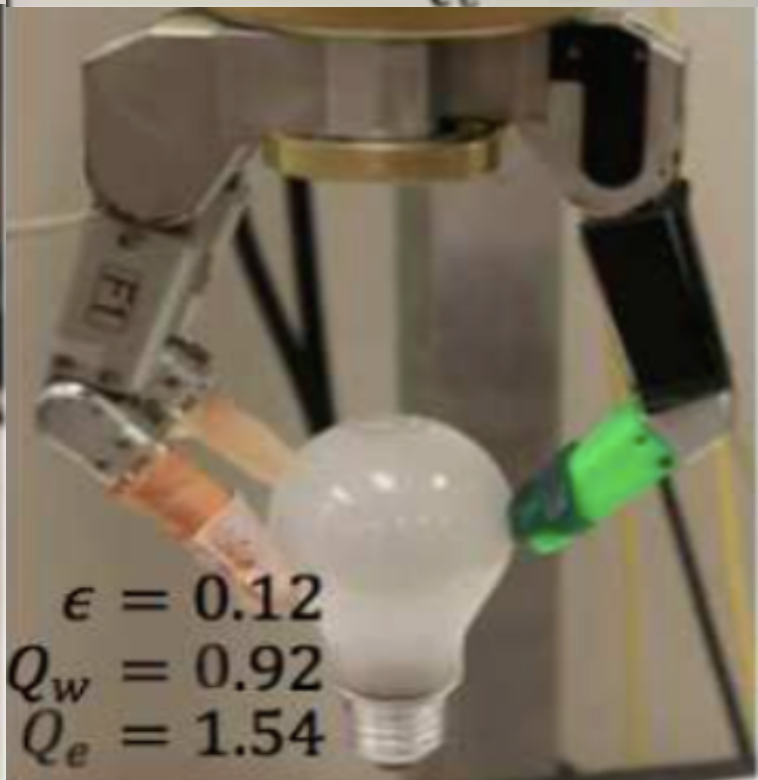

$\epsilon = 0.28$
$Q_w = 0.95$
$Q_e = 13.43$

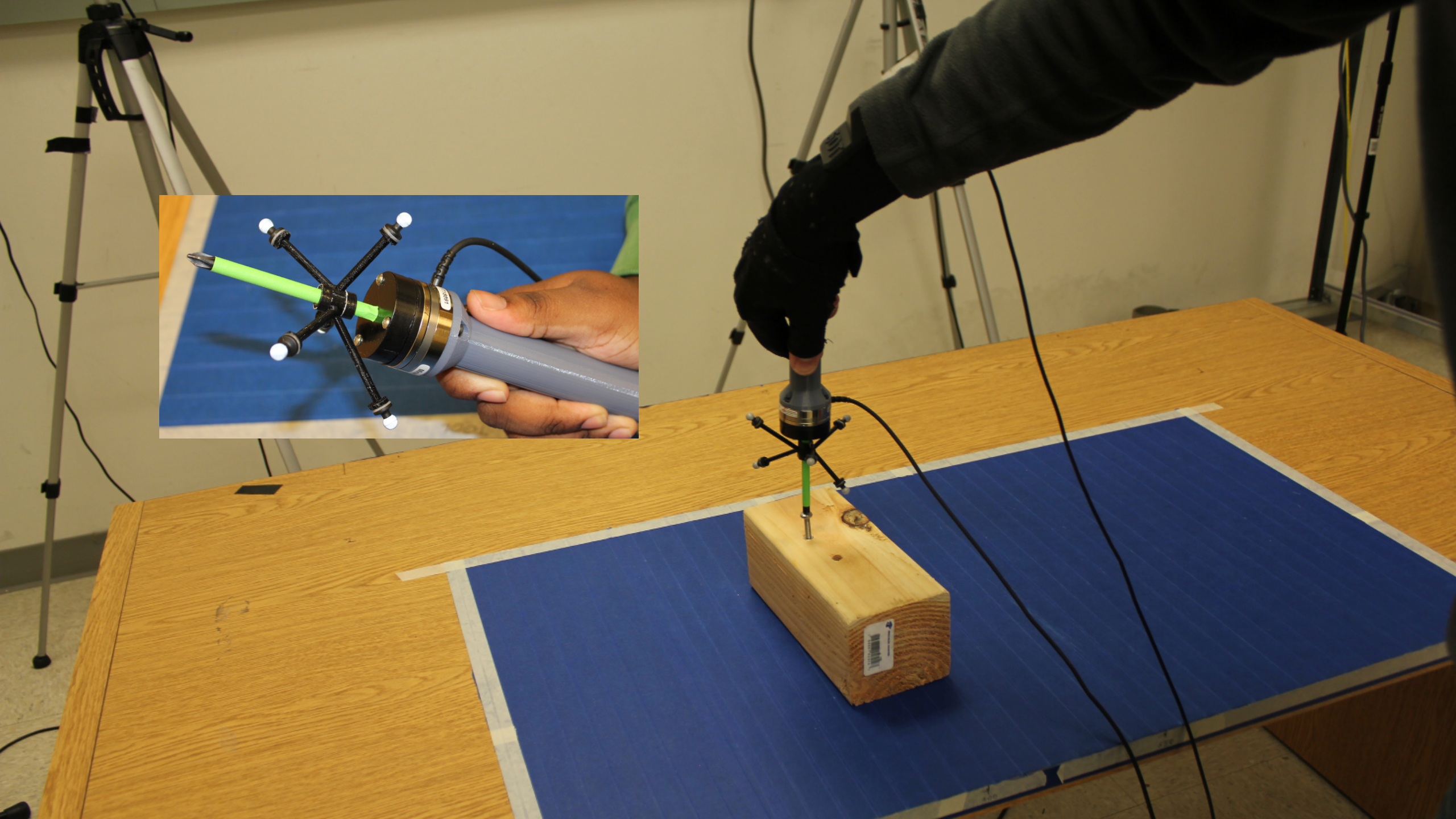

$\epsilon = 0.24$
$Q_w = 0.86$
$Q_e = 46.15$


$\epsilon = 0.16$
$Q_w = 0.64$
$Q_e = 76.25$


$\epsilon = 0.16$
$Q_w = 0.84$
$Q_e = 29.36$


$\epsilon = 0.19$
$Q_w = 0.57$
$Q_e = 20.67$


$\epsilon = 0.12$
$Q_w = 0.92$
$Q_e = 1.54$



Equipment and Modalities

- Motion tracking
  - NaturalPoint OptiTrack MoCap
  - 100 Hz
- RGBD sensor
  - Primesense
  - RGBD, 25 ftp
- Force/torque sensor
  - ATI Nano17 and Mini40
  - XYZ force and torque, 1000 Hz.
- Dataglove
  - 5DT dataglove
  - 14 DOF, 60 Hz

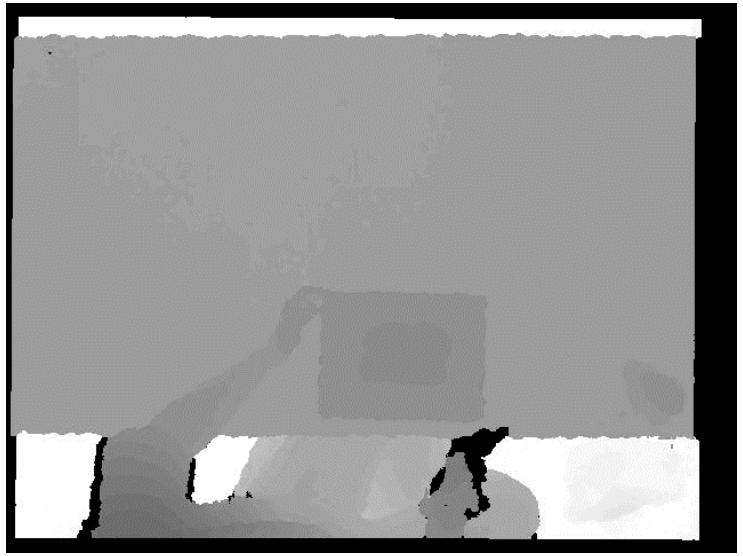

SECURITY
STANLEY

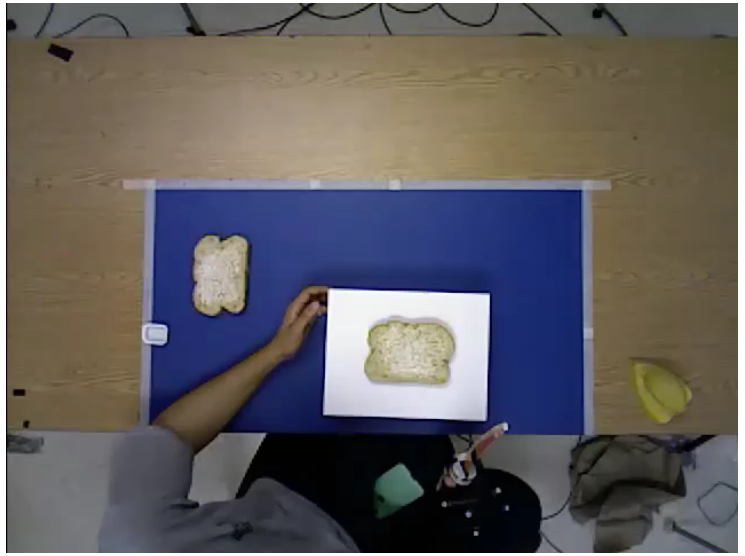
Nine Initial Tasks

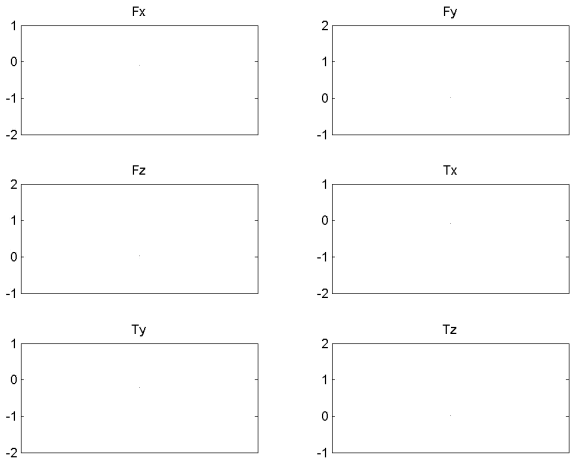
- Developmental skills for a five-year-old child
- Cutting across pretend clay pieces such as pancakes with a plastic knife
- Spreading butter or frosting on crackers with a plastic knife
- Poking or examining objects with a stick
- Putting a key into a keyhole and turning it
- Using small crayons to draw squares and triangles
- Using a spoon to stir water in a cup
- Using a spoon to pick up peas
- Screwing and unscrewing a jar lid
- Putting on or removing bolts from nuts with a screw driver.

Instrumental ADLs

- Food preparation
- Basic house maintenance
- Basic housework
- Personal hygiene
- Total: 36 manipulation tasks



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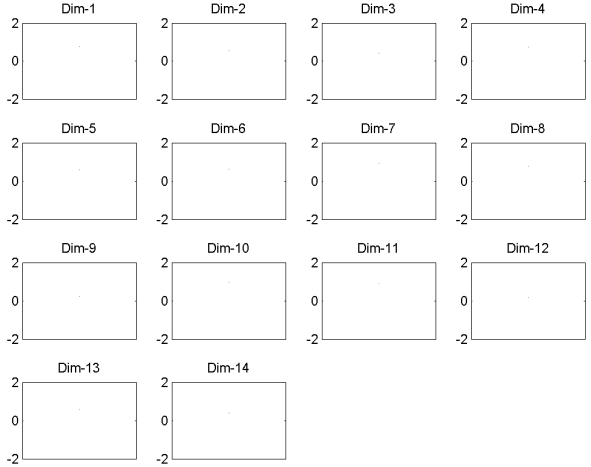
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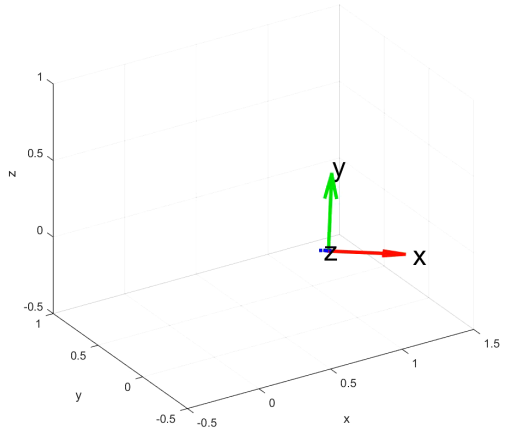
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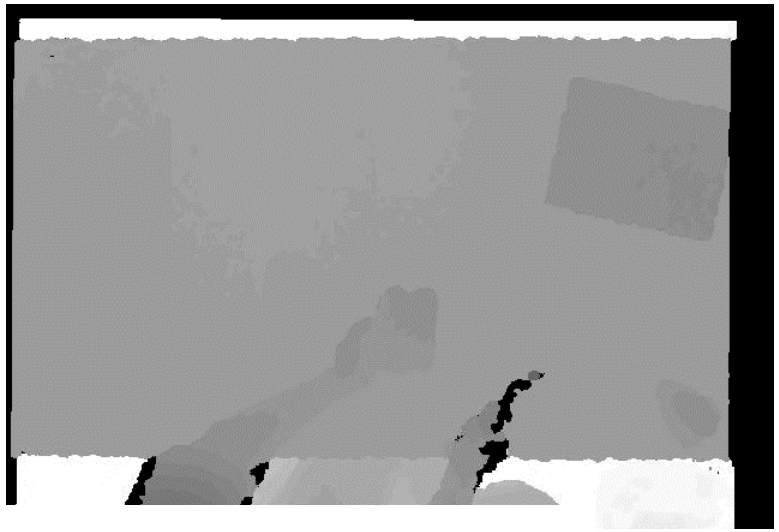

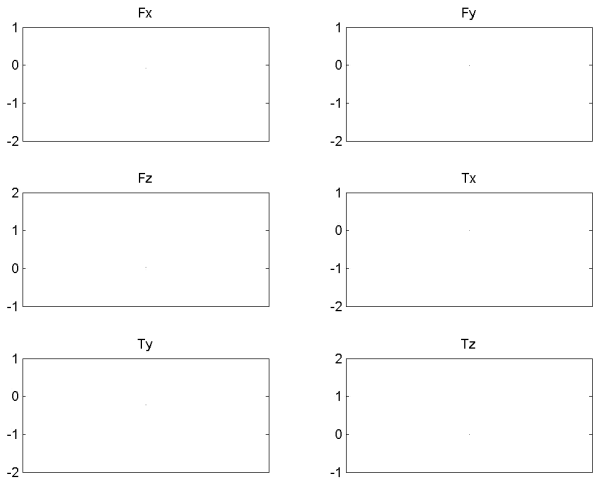
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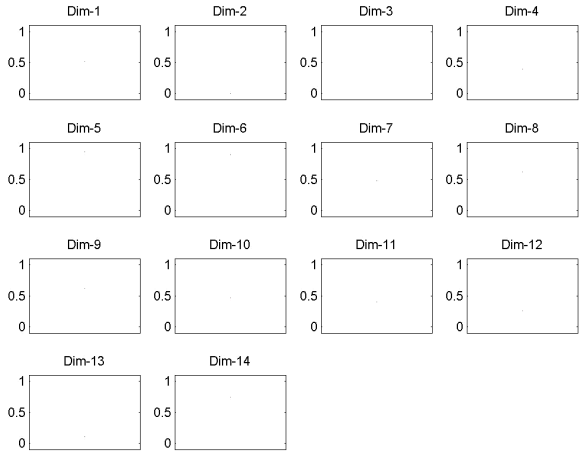
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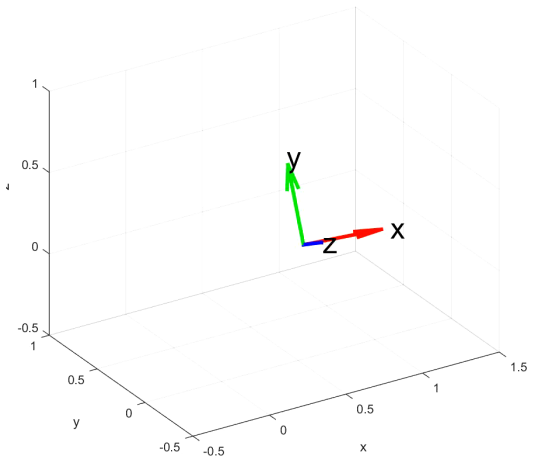
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Dataset

- Working progress
- RGBD, finger motion, instrument motion and wrench
- 3D models of instruments
- 25 Objects
- 36 manipulation tasks
- Five participants repeat three times
- 60 second each, 10 MB to 50 MB
- 2000 trials

Other Projects

- Functional Object-Oriented Network for Manipulation Learning
- Detect Zika-Vector Habitats with UAVs
- An Automated Pressure Ulcer Monitoring System to Improve Pressure Ulcer Healing Outcomes for Veterans with SCI
- Automated Neonatal Pain Assessment
- Virtually Transparent Epidermal Imagery

Collaborators

- CSE students

Christine Bringes, Khalid Brown-Walker, Anthony Cope, Wei Dai, Sufyan Dawoodjee, Justin Fouts , Lex French, Michael Haubenstock, Yongqiang Huang, Yun Lin, Bingxiong Lin, Roger Milton, Carlos Neninger, David Paulius, William Pence, Shaogang Ren, James Robe, Ivan Shindev, David Richardson

- ECE students

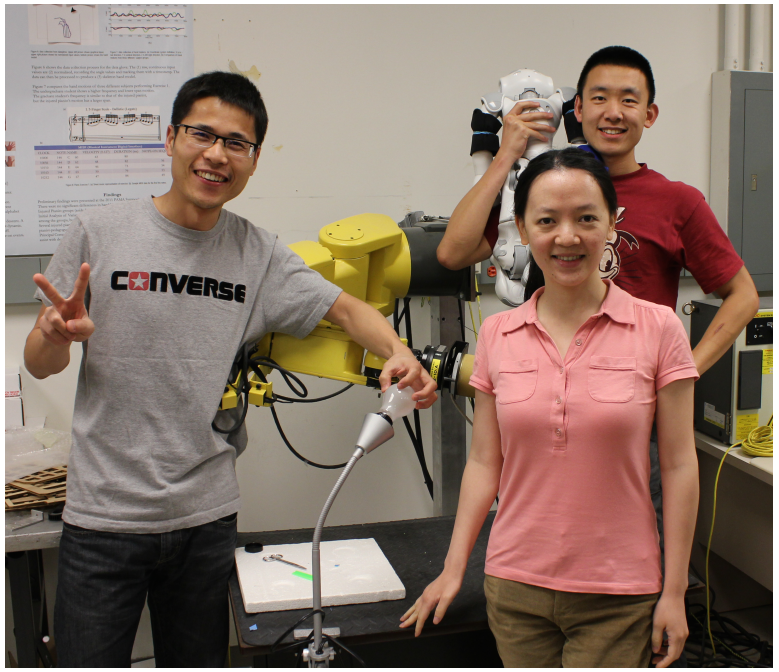
Adrian Johnson

- ME students

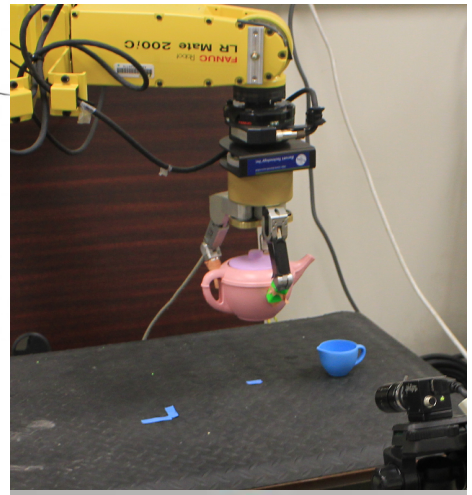
Matthew Clevenger, Louis Melgar

- Faculty
  - CSE: Dmitry Goldgof, Rangachar Kasturi, Sudeep Sarka
  - ECE: Adam Anderson, Richard Gitlin, Xiaoning Qian
  - Music: Sang-Hie Lee
  - Psychology: Michael Coovert
- Physicians and surgeons: Jaime Sanchez, Terri Ashmeade, Thomas McCaffrey

Lab



Ph.D. Students



Toys

Support

- NSF, “EAGER: Characterizing Physical Interaction in Instrument Manipulations,” NSF, 299,887, 3/1/2016-2/28/2018
- NSF, “RI: Small: Functional Object-Oriented Network for Manipulation Learning,” $398,529, 8/15/2014-7/31/2017
- NSF, “REU Site: REU Site on Ubiquitous Sensing,” (International REU), $439,215, 8/1/2016/7/31/2020
- NSF, “REU Site: An REU Site on Ubiquitous Sensing,” $359,367, 1/1/2015-12/31/2017
- ARMY-CDMRP, “An Automated Pressure Ulcer Monitoring System to Improve Pressure Ulcer Healing Outcomes for Veterans with SCI,” Subcontract from VA, $500,000, 10/1/2016-9/30/3019
- USF Health, “Automated Neonatal Pain Assessment,” USF Health, $15,000, 7/1/2016-6/30/2017
- NSF, “CPS: Small: Virtually Transparent Epidermal Imagery, ” $510,945.00, 9/15/2010-8/31/2015
- USF, USF Proposal Enhancement Grant, $25,000, 5/1/2013-4/30/2014
- USF, "Robotics Modeling of Skilled Hand Tasks," USF Neuroscience Collaborative Grant, $100,000, 10/1/2010-9/30/2012

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3. Paulius, D. Huang, Y., Milton, R., Buchanan, W.D., Sam J., and Sun, Y. (2016) Functional Object-Oriented Network for Manipulation Learning, IROS, 3655-3662
4. Huang, Y. and Sun, Y. (2015) Generating Manipulation Trajectories Using Motion Harmonics, IROS, 4949-4954.
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7. Lin, Y., and Sun, Y. (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.
8. Sun, Y., and Y. Lin. Modeling Paired Objects and Their Interaction." In New Development in Robot Vision, pp. 73-87. Springer Berlin Heidelberg, 2015.
9. Sun, Y., Ren, S., and Lin, Y. (2014) Object-Object Interaction Affordance Learning, Robotics and Autonomous Systems, 62(4), 487-496
10. Lin, Y., Sun, Y. (2014) Grasp Planning Based on Grasp Strategy Extraction from Demonstration, IROS, pp. 4458-4463.
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12. Christine Bringes, Yun Lin, Yu Sun, Redwan Alqasemi (2013) Determining the Benefit of Human Input in Human-in-the-Loop Robotic Systems, IEEE ROMAN 2013, pp. 1-8.
13. Ren S., Sun Y. (2013) Human-Object-Object-Interaction Affordance, IEEE Workshop in Robot Vision (WoRV)/Winter Vision Meeting (WVM), pp. 1-6, 2013
14. Lin Y., Sun Y. (2013) Grasp Mapping Using Locality Preserving Projections and KNN Regression, IEEE Intl. Conference on Robotics and Automation, pp 1068-1073
15. Lin Y., Ren S., Clevenger M., and Sun Y. (2012) Learning Grasping Force from Demonstration, IEEE Intl. Conference on Robotics and Automation, pp. 1526-1531.
16. Lin Y, Sun Y (2011) 5-D Force Control System for Fingernail Imaging Calibration, IEEE Intl. Conference on Robotics and Automation, pp. 1374-1379
17. Sun Y (2011) Fingertip Force and Contact Position and Orientation Sensor, IEEE Intl. Conference on Robotics and Automation, pp. 1114-1119

Thank You!