Robotic Grasping for Daily-Living Manipulation Tasks

Yu Sun / 孙宇
University of South Florida
Stanford University

USFRPAL
Robot Perception and Action Lab
Robotic Grasping and Manipulation Competition
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http://www.rhgm.org/activities/competition_iros2016/
• 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

- 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

\[
Q_w = \frac{\text{Count}\{O|O \in GWS \cap TWS\}}{\text{Count}\{O|O \in TWS\}}
\]
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!

Evaluation by Barrett Hand
Success Rate of Real Execution

Our approach

Force-closure approach

<table>
<thead>
<tr>
<th>Task</th>
<th>Success Rate of Task Disturbance Based Grasp Planning</th>
<th>Success Rate of non-task oriented Grasp Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Task 2</td>
<td>80%</td>
<td>70%</td>
</tr>
<tr>
<td>Task 3</td>
<td>70%</td>
<td>20%</td>
</tr>
<tr>
<td>Overall</td>
<td>70%</td>
<td>43.3%</td>
</tr>
</tbody>
</table>

A haptic device is used to demonstrate a task.
Grasp Measure Based-on Manipulator Efficiency in Task

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

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

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.
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
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
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, “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
- 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
References

2. Sun, Y., Yun Lin, and Yongqiang Huang (2016) Robotic Grasping for Instrument Manipulations, URAI, 1-3
Thank You!