Grasping in ROS:
The Good, the Bad and the Research

Matei Ciocarlie

Joint work with: Kaijen Hsiao, Sachin Chitta, Gil Jones, Adam Leeper, IoanSucan, Mehmet Dogar, Peter Brook, David Gossow, and the entire Willow Garage team.
This Talk

- Overview of available capabilities in ROS
  - pointers to package names → www.ros.org
  - pointers to publications
- Overview of recent research results
- Not a step-by-step tutorial...
Outline

• The Basics...
  ◦ Semantic Perception
  ◦ Grasp Planning
  ◦ Grasping Pipeline and Execution

• ... and Beyond!
  ◦ Grasping in uncertainty and clutter
  ◦ Tiered Human-in-the-Loop grasping
  ◦ Interactive Manipulation
  ◦ Robots for Humanity
Semantic Perception
Semantic Perception

Grasp this...

...glass, CAD model #9776.
...glass-like object.
...blob.
...well, anything
Semantic Perception

*tabletop_object_detector* package

- plane segmentation
- Cartesian clustering
- 2D ICP-based fitting and recognition
  - rotationally symmetrical objects
Semantic Perception

**object_recognition stack**

- Textured Object Detector (TOD)

[Rublee, Rabaud, Konolidge, Bradski – ICCV 2011]
Semantic Perception

Grasp this...

...glass, CAD model #9776.  ...glass-like object.  ...blob.  ...well, anything
Household Objects Database

- Real-life objects from major retailers
  - Target / IKEA / common household
  - graspable with one or two hands

IKEA / Target

Household
Household Objects Database

- Real-life objects from major retailers
- Triangular meshes
  - surfaces of rotation
  - 3DSOM shape from silhouettes
  - TOD model construction
Household Objects Database

- Real-life objects from major retailers
- Triangular meshes
- Metadata
  - maker and model name (where available)
  - barcode (where available)
  - category tag and description

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<th>ID</th>
<th>Type</th>
<th>Brand</th>
<th>Code</th>
<th>Maker</th>
<th>Description</th>
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</table>
Household Objects Database

- Grasp points for the PR2 and other grippers
- Computed in simulation
  - simulated annealing search
  - align gripper pads to object surface
- 4 hours / object
  - approx. 600 grasps / object
Household Objects Database

- Live demo!
  - *Grasptl!* simulator from `graspit_simulator` stack
  - visualization of database grasps
  - generation of database grasps
    (not yet released and documented...)
Grasp this...

...glass, CAD model #9776.
...glass-like object.
...blob.
...well, anything
Grasp Planning for Novel Objects

- pr2_gripper_grasp_planner_cluster
- Plan grasps based on segmented point cloud

[Hsiao, Chitta, Ciocarlie, Jones, IROS’10]

VIDEO!
Grasp Planning Recap

- Grasp planning nodes in packages:
  - `household_objects_database`
  - `pr2_gripper_grasp_planner_cluster`
- Grasp planning service:
  - `object_manipulation_msgs/GraspPlanning.srv`
The ROS Grasping Pipeline

[Ciocarlie, Hsiao, Jones, Chitta, Rusu, Sucan – ISER 2010]
The ROS Grasping Pipeline
The ROS Grasping Pipeline

Motion planning

Sampling-based planning

Interpolated IK
Grasp Execution

**object_manipulator**
- check pre-grasp
- compute Int. IK to grasp
  - allows coll. w. object
- compute Int. IK to lift
  - allows coll. w. support
- motion plan to pre-grasp
- execute!

**object_manipulation_msgs/Pickup.action**
Place Execution

object_manipulator

- check pre-place
- compute Int. IK to place
  - allows coll. w. support
- compute Int. IK to retreat
  - allows coll. w. object
- motion plan to pre-place
- execute!

object_manipulation_msgs/Place.action

VIDEO!
Recent Research Directions

- How do we go from here ...

... to here?

- Grasping in uncertainty and clutter
- Tiered Human-in-the-Loop grasping
- Interactive Manipulation
- Robots for Humanity
Grasping Under Unc

- Objects are observed via noisy sensors
- Recognition methods are not 100% accurate
Grasping Under Uncertainty

- Objects are observed via noisy sensors
- Recognition methods are not 100% accurate
Grasping Under Uncertainty

First approach: [Brook, Ciocarlie, Hsiao – ICRA 2011]
Bayesian framework: [Hsiao, Ciocarlie, Brook – ICRA 2011 Wksh.]
## Probabilistic Grasping - Results

<table>
<thead>
<tr>
<th></th>
<th>Collaborative Planner</th>
<th>Naïve Planner</th>
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<tbody>
<tr>
<td>Novel objects</td>
<td>22/25</td>
<td>18/25</td>
</tr>
<tr>
<td>Database objects</td>
<td>22/25</td>
<td>21/25</td>
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</tbody>
</table>

- Single object on table
- Success = lift and move to side without dropping
Grasping in Clutter

Example scene

Place the hand on the target with direction $a$ and offset $l$.

Back-up out of contact

Find $d$ to grasp the target

Verify with rest of the clutter

[Dogar, Hsiao, Ciocarlie, Srinivasa – RSS 2012]
Grasping in Clutter

Planner success (100 scenes of 6 objects)

- Clutter-Grasp
- Push-Grasp
- Kinematic-Grasp

# of successful grasps

Scene complexity:
- Easy
- Medium
- Hard
Tiered Human-in-the-Loop Grasping

- 4 grasping strategies, different levels of autonomy
- 3 environments: from moderate to extreme clutter

[Leeper, Hsiao, Ciocarlie, Takayama, Gossow – HRI 2012]
Tiered Human-in-the-Loop Grasping

Number of Objects Grasped with Each Strategy in Each Environment

- Environment 1
- Environment 2
- Environment 3

Number of Major Collisions with Each Strategy in Each Environment

- Strategy 1
- Strategy 2
- Strategy 3
- Strategy 4
Strategies for HitL Grasping

- Autonomy helps (yay!)
  - motion planning for non-anthropomorphic kinematics
  - motion planning for collision avoidance
- Autonomy does not have to be perfect
- Trust and communication are key
  - autonomous component must communicate what it can or can not do
Human-in-the-Loop Robotics

- Accelerate deployment of robots in homes or offices
- Learn about what is hard in the context of complete tasks
  - progress towards full autonomy
- Enable applications in the near-term
  - remote operation
  - call center for robots
  - help people with disabilities: “Robots for Humanity”
Interactive Manipulation

pr2_interactive_manipulation

VIDEOS!
“Robots for Humanity”

● Collaborative project:
  ◦ Willow Garage
  ◦ Georgia Tech (Prof. Charlie Kemp)
  ◦ Oregon State University (Prof. William Smart)
  ◦ Henry and Jane Evans

● Goal: enable people with motor impairments to interact with their environment through mobile manipulators
Interactive Manipulation for Assistive Robotics

VIDEO!

[Chen et al. – IROS 2012] – WeGVT4.4
[Ciocarlie, Hsiao, Leeper, Gossow – IROS 2012] – WeGT7.2
Keynote at Assistance and Service Robotics Workshop - Friday
Grasping in ROS - Foundation

• Semantic Perception
  ◦ simple scenes: \texttt{tabletop\_object\_detector}
  ◦ \texttt{object\_recognition}

• Grasp Planning
  ◦ known objects: \texttt{household\_objects\_database}
  ◦ new: \texttt{pr2\_gripper\_grasp\_planner\_cluster}

• Grasping Pipeline and Execution
  ◦ Integration with sensing and Motion Planning
  ◦ Pickup and Place actions: \texttt{object\_manipulator}
Grasping in ROS - Research

- Grasping in Uncertainty and Clutter
  - `probabilistic_grasp_planner`
  - `push_grasp_planner`

- Interactive Manipulation
  - `pr2_interactive_manipulation`
Grasping and Manipulation in ROS

- Check out our Internship Program:
  - [www.willowgarage.com](http://www.willowgarage.com)
    - Jobs → Internship Opportunities → Grasping & Manipulation
  - Resume / code samples / recommendations