A Probabilistic Approach to Grasp Planning

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What is grasp planning?

Given an object:

- Find a suitable pose for the gripper - 6D search space
- Find a suitable configuration of the hand joints - nD search space
Why is Grasp Planning Easy for Humans?

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Why is Grasp Planning Hard for Robots?

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Uncertainty in grasp planning

Grasp planning requires knowledge of:
- a gripper
- an object

These are observed via sensors
Uncertainty in grasp planning

Real scene

Sensed scene
Uncertainty in grasp planning

Is incomplete or noisy world information a problem?
Uncertainty in grasp planning

Yes.

Sensed scene

Object detection error

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ROS Grasping Pipeline

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ROS Grasping Pipeline

- **Motivation**
- **Planner Overview**
- **Evaluation**
- **Conclusion**

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- **3D Perception**
- **Scene Interpretor**
- **Object Model Registration**
- **Collision Map Generation**

- **Object Model Database**

- **Grasp Planning for known objects**
- **Grasp Planning for unknown objects**

- **Grasp Selection**
- **Motion Planning**

- **Grasp Execution**
- **Tactile Feedback**
ROS Grasping Pipeline

- **3D Perception**
  - Collision Map Generation
  - Scene Interpreter
  - Object Model Registration
- **Object Model Database**
- **Grasp Planning**
  - for unknown objects
  - for known objects
- **Grasp Selection**
- **Motion Planning**
  - Grasp Execution
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Handling Object Detection Uncertainty

Key Points

- Every guess about the object is a representation
- Choose grasps which work well on available representations

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How do we Know if a Grasp is Good?

▶ **evaluate** grasp on all representations
How do we Know if a Grasp is Good?

- evaluate grasp on all representations

For point cluster grasps:

- Heuristic quality measures
How do we Know if a Grasp is Good?

- **evaluate** grasp on all representations
  - For point cluster grasps:
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  - For database objects:
    - Evaluate grasp in simulation (expensive)
How do we Know if a Grasp is Good?

- **evaluate grasp** on all representations
  - For point cluster grasps:
    - Heuristic quality measures
  - For database objects:
    - Evaluate grasp in simulation (expensive)
    - Use **data-driven regression** for evaluation
Gripper Pose Uncertainty

Bonus: regression helps with gripper pose uncertainty
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Reasoning About Uncertainty Helps

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Reasoning About Uncertainty Helps

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Percentage of ‘Good’ Grasps

Planner-Estimated Probability

Naive Planner

Naive Planner (leave-one-out)

Probabilistic Planner

Probabilistic Planner (leave-one-out)
## Experimental Success Results

<table>
<thead>
<tr>
<th></th>
<th>prob. planner</th>
<th>naive planner</th>
</tr>
</thead>
<tbody>
<tr>
<td>leave-one-out</td>
<td>22/25</td>
<td>18/25</td>
</tr>
<tr>
<td>regular detection</td>
<td>22/25</td>
<td>21/25</td>
</tr>
</tbody>
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**Table:** Number of objects successfully grasped and lifted on the PR2 robot.
Potential for Extension

- More representations
  - Primitives (spheres, cylinders, boxes, etc.)
  - Primitive hierarchies

- More detectors (recognition pipeline)
  - Don’t hide the uncertainty
  - Detector feedback: similar objects should be grasped similarly

- More objects
  - Few objects: no generalization
  - 50 objects: some generalization
  - 1000s of objects: complete generalization?
Can we Trust Our Sensors?

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Online Tuning

Motivation

Planner Overview

Evaluation

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Code Availability

- **Planner code:** `probabilistic_grasp_planner`
- **Documentation:**
  

- **Integrated with trunk of grasping pipeline**

- **Will be released with the 0.3 release of**
  
  `object_manipulation`
Thanks!

Matei and Kaijen are awesome!
Questions?