Contact-Reactive Grasping of Objects with Partial Shape Information

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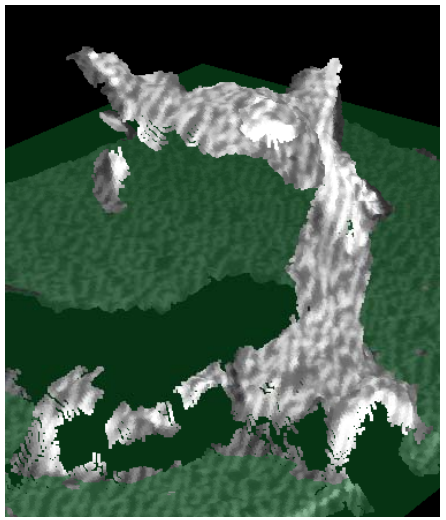
Willow Garage

ICRA 2010 Workshop on Mobile Manipulation

Willow Garage

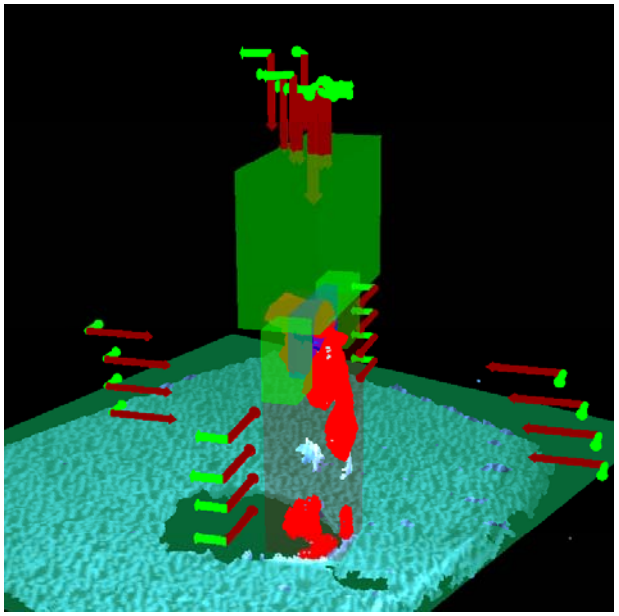
The goal

- Grasping unrecognized objects
- Assumptions
  - Tabletop objects
  - Large separation (3 cm) between objects



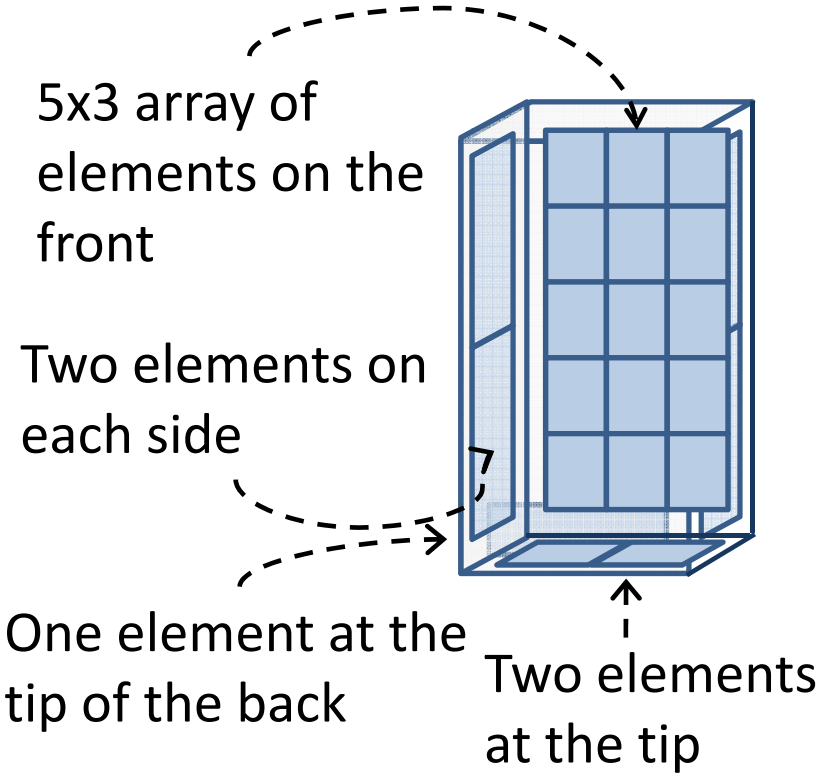
The approach

- Stereo camera with texture projection
- Select grasps orthogonal to principal axes
- Use contact sensors to reactively adjust grasp

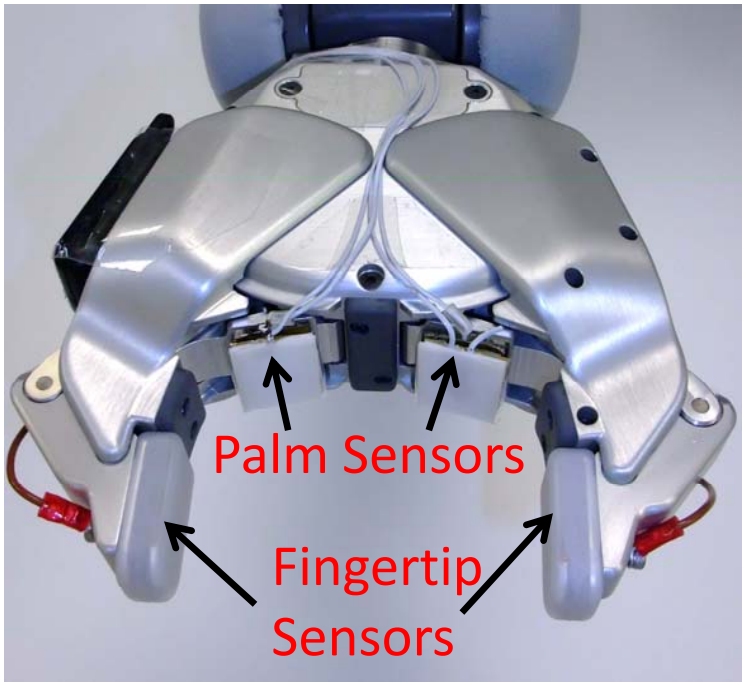


Hardware platform

Willow Garage PR2



Fingertip tactile sensor arrays



Parallel-jaw gripper

Outline

- Grasp selection
- Reactive grasping
- Experiments

Outline

- Grasp selection
  - Find table and object clusters
  - Find cluster bounding box
  - Find set of possible grasps
  - Rank grasps
  - Test feasiblity
- Reactive grasping
- Experiments

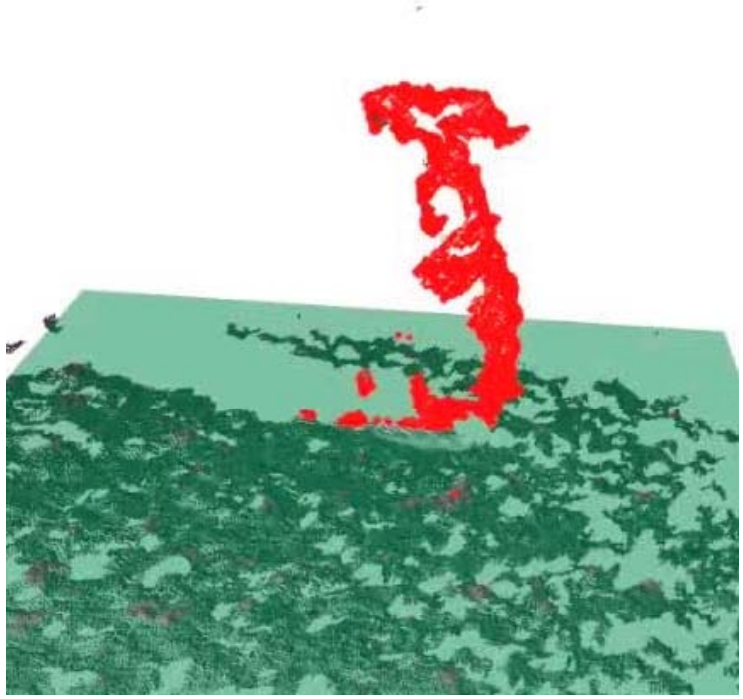
Finding object point cloud and axes

- Table detection:

  largest plane
- Cluster detection:

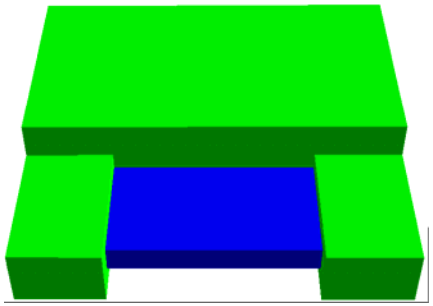
  blobs projected on table
- Object principal axes:

  PCA

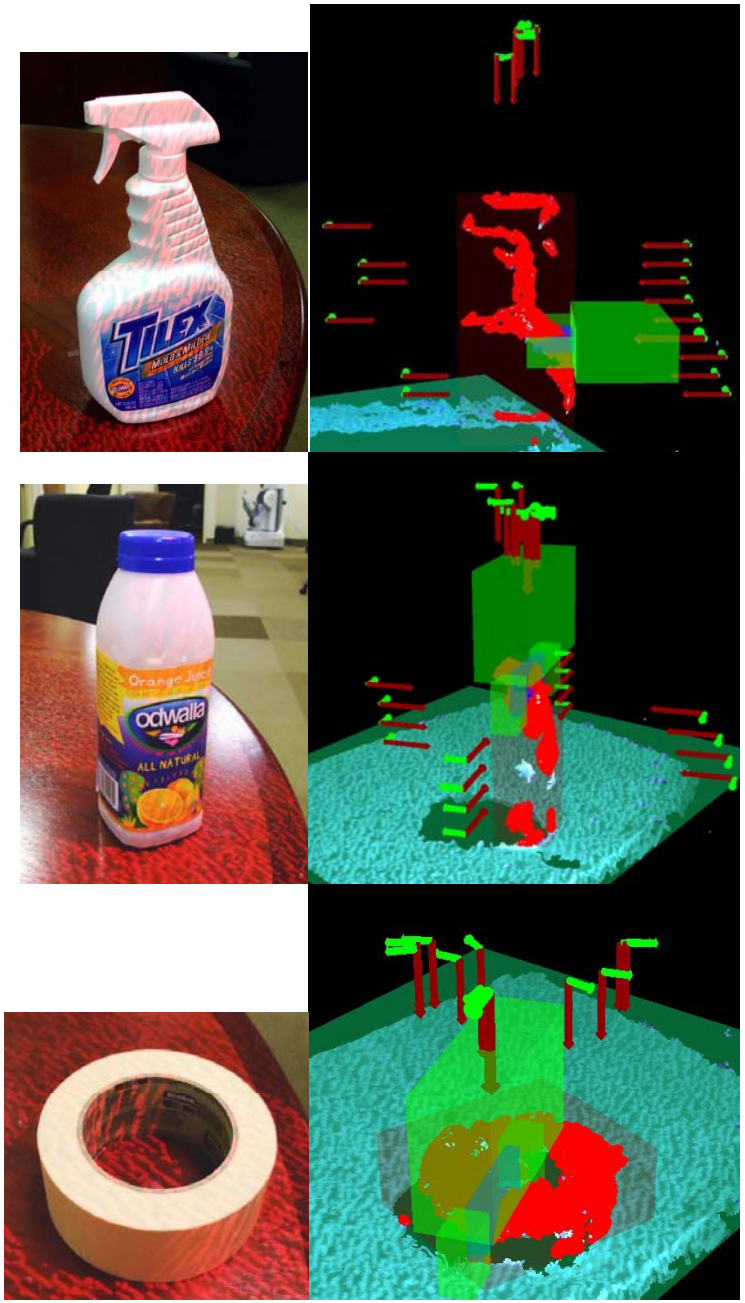


Finding possible grasps

- Simple gripper model

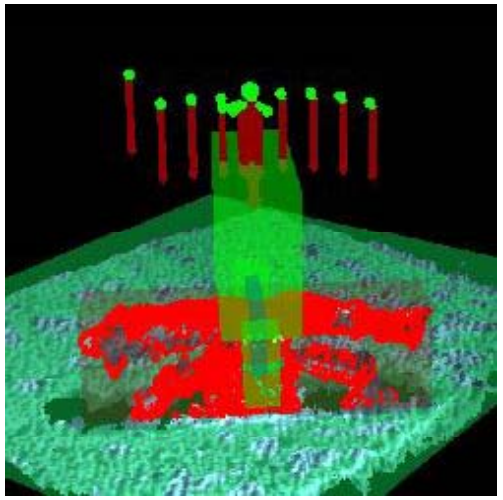


- Top grasps:
  - Gripper aligned with x, y axes
  - High point grasps with gripper oriented toward box center
- Side grasps:
  - Front, back, both sides
  - Search up and down (along z)



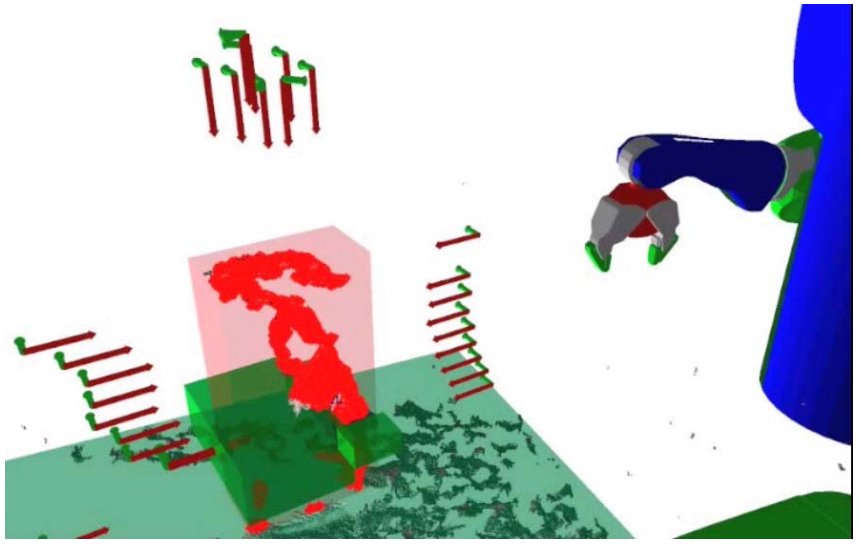
Grasp ranking

- Two separate categories:
  - "Preferred": grasps centered on the z-axis (top or side)
  - "Fall-back": off-center grasps, high-point grasps
- Within-category ranking by sum of empirically weighted features such as:
  - Number of points within gripper
  - Are there valid grasps on both sides?
  - Does the bounding box fit within the gripper?

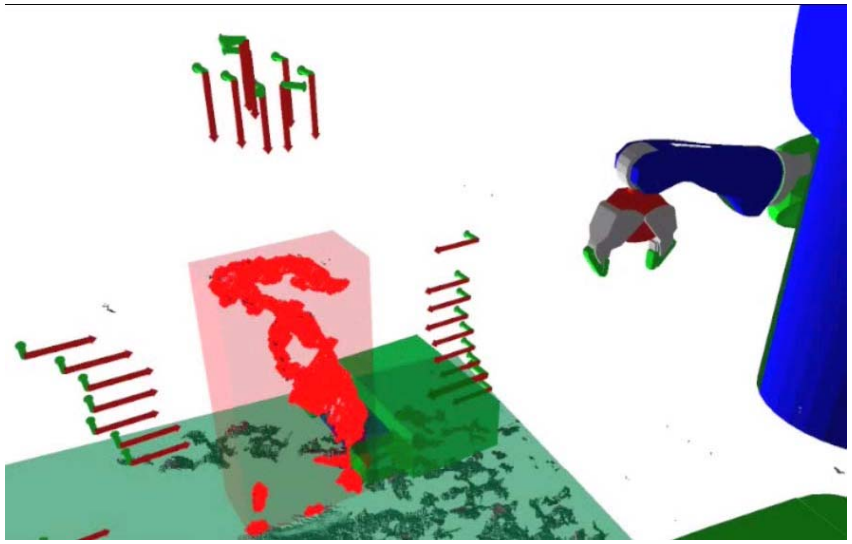


Feasibility testing

- Approach pose 10 cm back from grasp pose
- Collision-free joint-angle path to approach
- Collision-free/reachable/consistent interpolated-IK path from approach to grasp



infeasible



feasible

Video of grasp selection

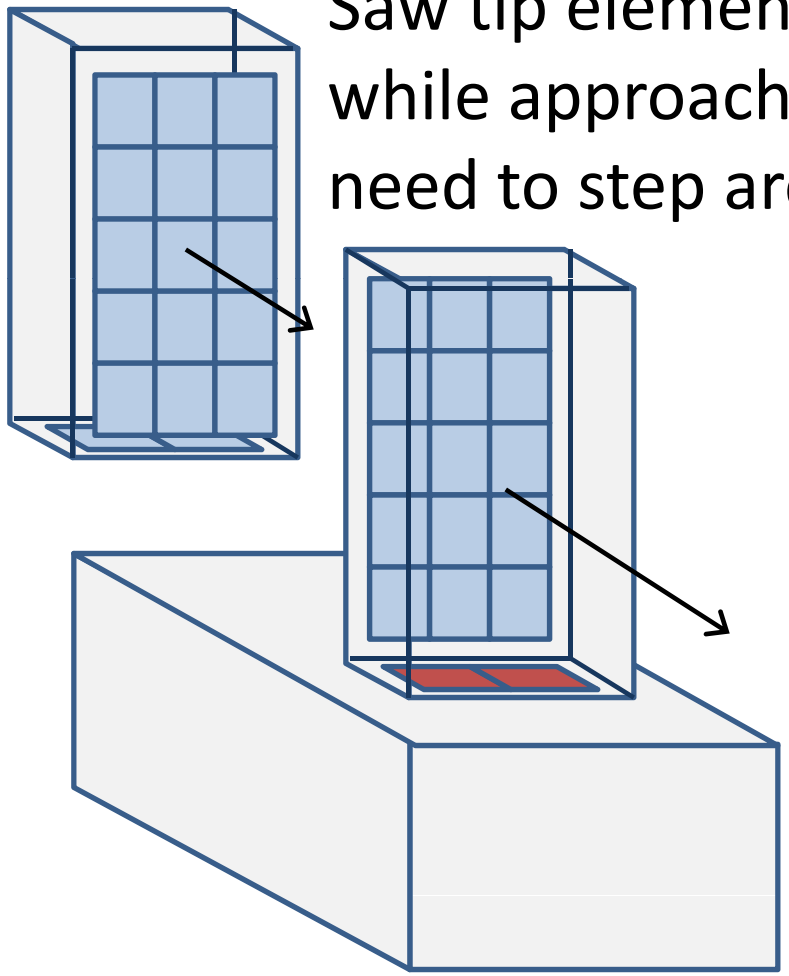
Outline

- Grasp selection
- Reactive grasping
  - Reactive approach
  - Compliant close
  - Grasp adjustment
- Experiments

Reactive approach

Unexpected contact when moving from approach to goal

Saw tip elements while approaching: need to step around



Compliant close

First contact made: switch Cartesian controller to fingertip frame

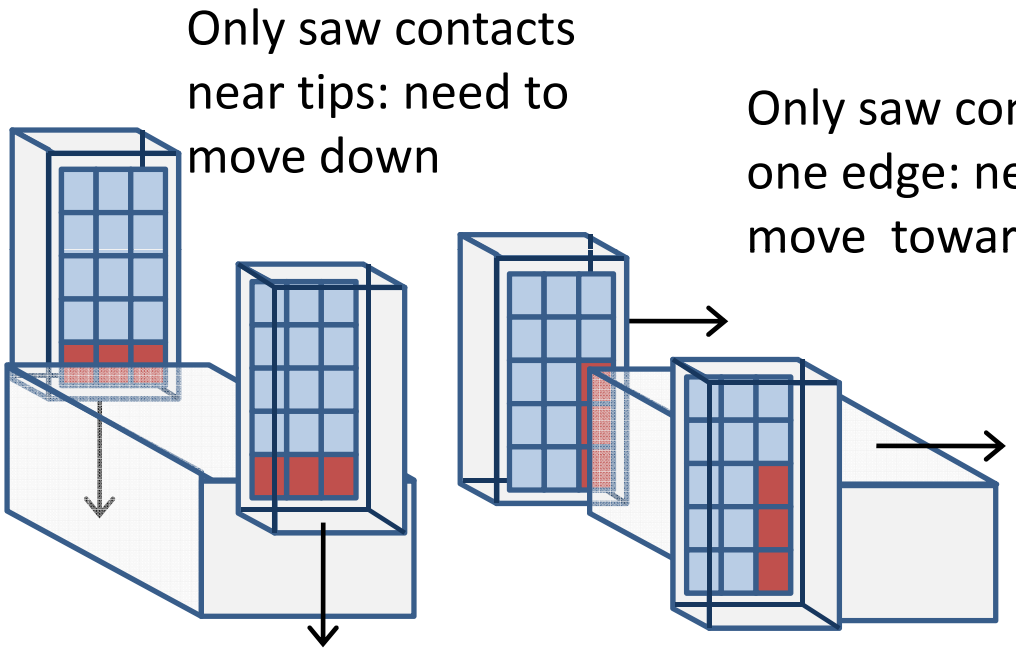
This fingertip remains in place while the gripper closes

Wrist frame (normal Cartesian controller frame)

This fingertip continues to move toward the object to make contact

Prevents unnecessary movement of object while closing

Grasp adjustment



- If grasp looks unstable, try to move to a more stable position
- If fingers close all the way, move forward more and try approach again

Video of reactive grasping

Outline

- Grasp selection
- Reactive grasping
- Experiments
  - Reactive grasping of can
  - Complete system

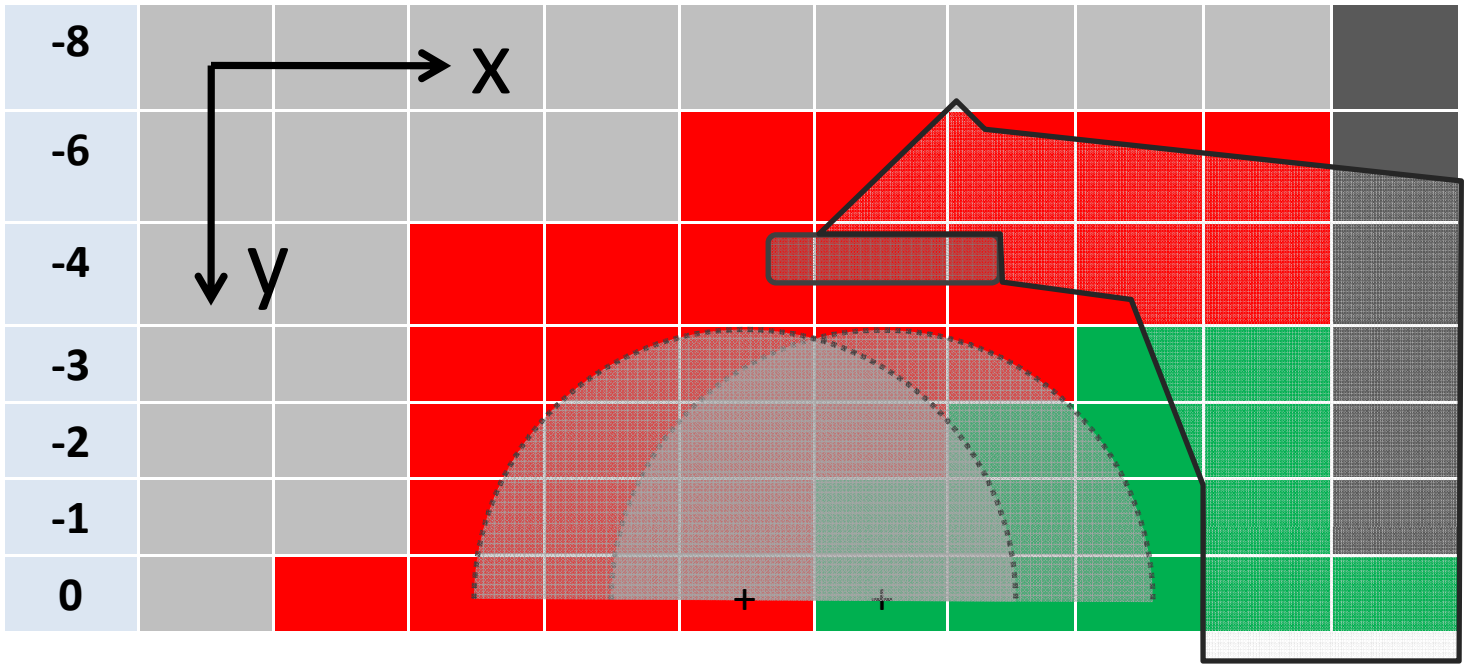
Reactive grasp of can: Side

Both succeed

Reactive succeeds, Open loop fails

Neither succeeds

Can in collision with gripper



Reactive grasp of can: Top

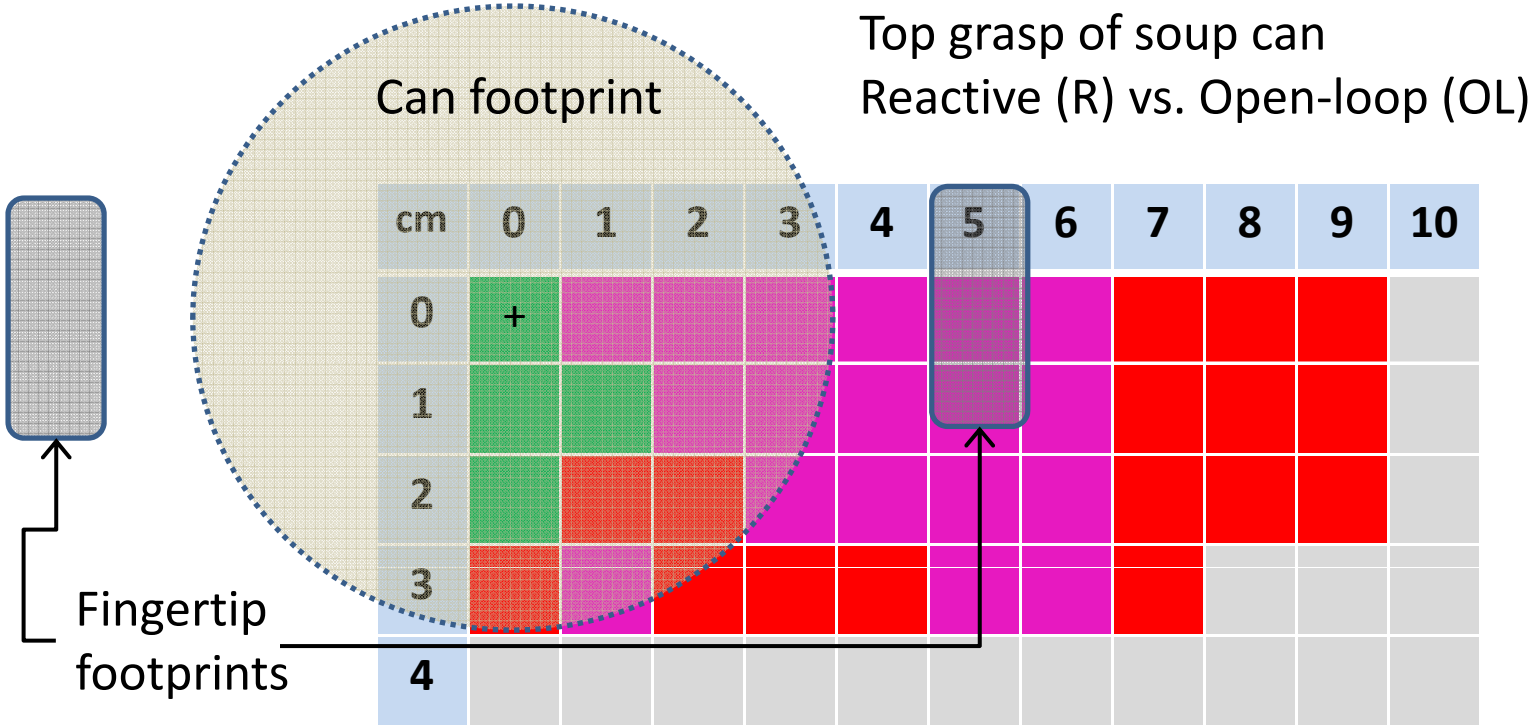
Both succeed

R succeeds, OL grasps rim

R succeeds, OL fails

Neither succeeds

Top grasp of soup can
Reactive (R) vs. Open-loop (OL)

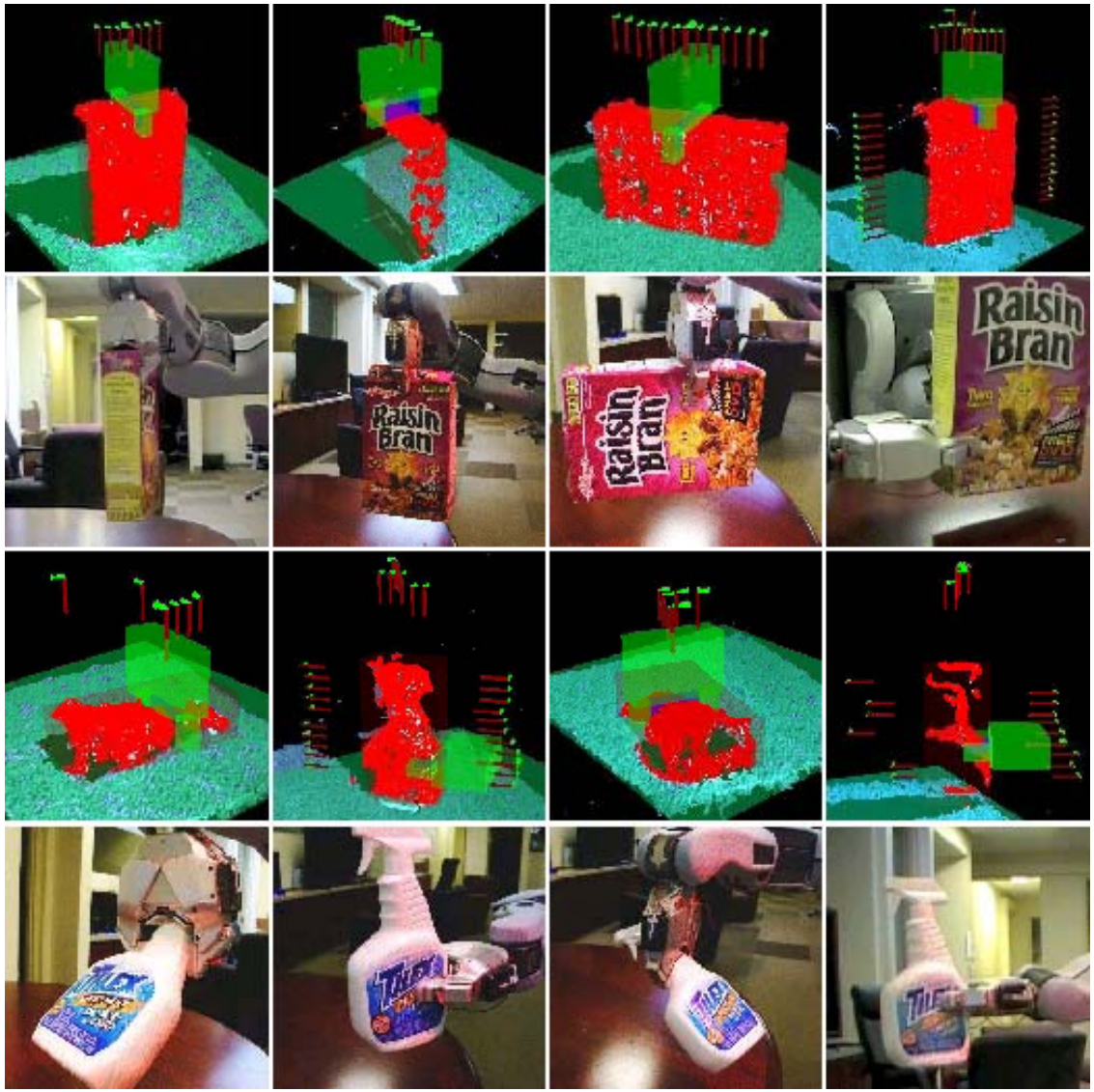


Grasp Experiments

- 30 objects x 2 poses each x {reactive, not reactive}

Grasp experiments (extra poses)

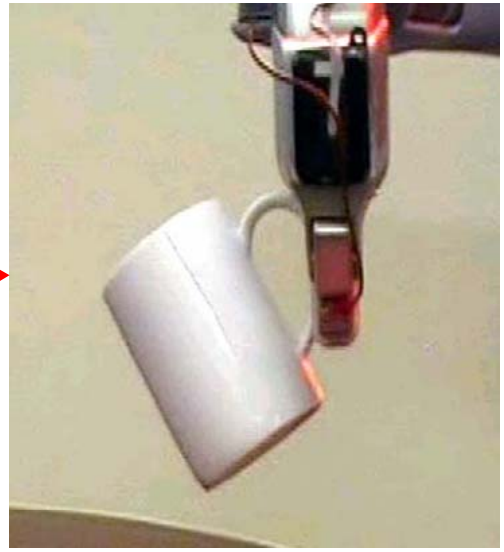
- 4 extra poses of Raisin Bran box and Tilex bottle



Grasp experiment results

- Reactive grasping: 66/68 Failures:





- Open-loop grasping: 60/68 Failures:





(x2)

Video of grasp experiments

When doesn't this work?

- Objects that:
  - Are too large to fit within gripper
  - Are too flat/wide to grasp without sliding off table
  - Are too light to sense with tactile sensors
  - Are hard to see/segment with textured stereo (transparent, shiny, small/flat objects, clutter)
  - Require specific/finicky/off-axis grasps (handles, highly constrained situations)
  - Require grasps that look marginal to fingertips
- Bad lighting conditions (bright sunlight)

Related Work

- Grasp selection from vision/point clouds using features with learned weights (Saxena et al. 2008)
- Model-free reactive grasping with tactile sensors (Natale and Torres-Jara 2006, Platt et al. 2002, Dollar et al. 2010)
- Grasp selection from point clouds + reactive grasping (Jain and Kemp 2010)

Conclusions

- Simple heuristics can select stable grasps for many objects using only partial object scans
- Local reactive behaviors using tactile sensing can significantly increase grasping success rate
- “Simple is not incapable!” [Charlie Kemp]
- Grasping pipeline released as a ROS stack for the PR2 soon

Booth demo