Refining Object Recognition, Localization, and Grasping with Tactile Feedback

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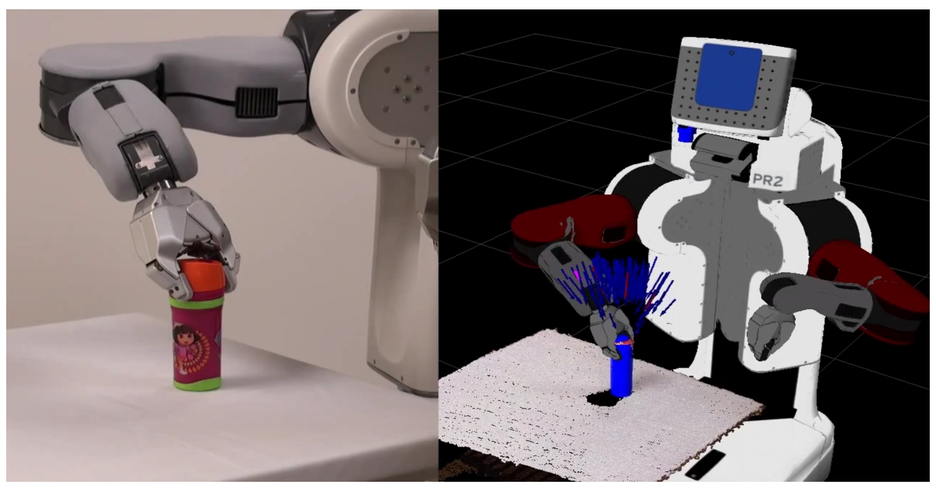
Overview

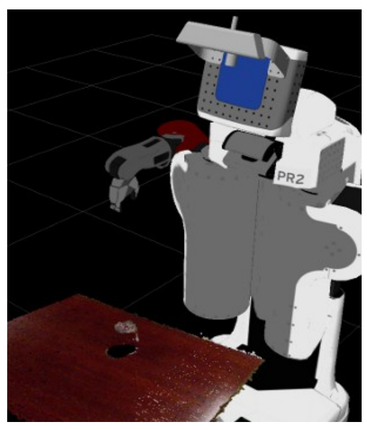
- Vision-based object recognition results in uncertain object shape and location
- Using tactile feedback, the robot can reduce the uncertainty while grasping
- Grasp planning takes the current object pose and location uncertainty into account



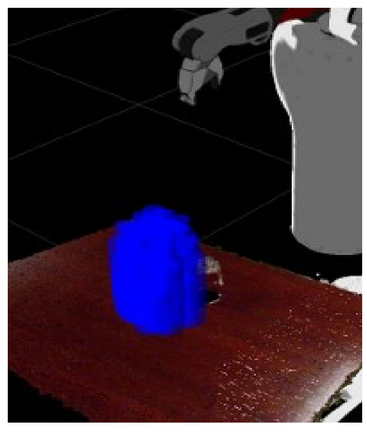
Approach

- Use **vision** to get some hypotheses about object **shape and pose**.
- **Choose a grasp** likely to work, given all of the hypotheses.
- **Start executing** a grasp; abort if we sense an unexpected contact.
- **Update** the belief distribution using **tactile and proprioceptive** information.
- Repeat steps 2-4 until we know the object's position and shape well enough that we are certain we have executed a good grasp.

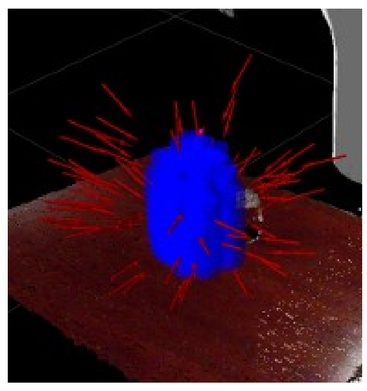
Object on table (as seen by Kinect point cloud) has uncertain shape/identity and pose.



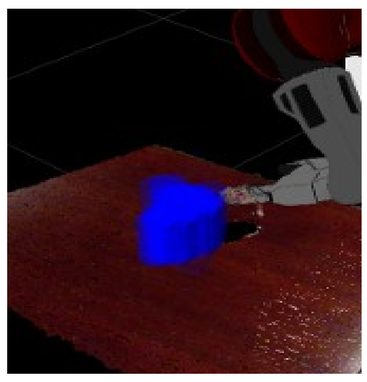
Robot uses visual object recognition to get an initial pose and shape distribution for the object.



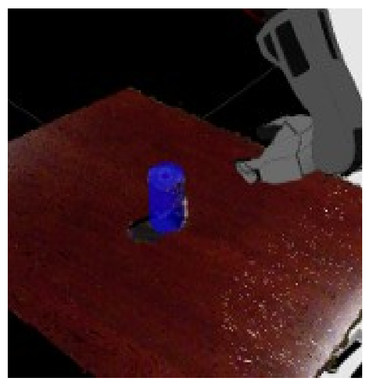
Robot begins executing grasp with highest success probability given object distribution.



No contact is made (object is shorter than expected), so grasp is aborted and a new grasp is planned based on updated object distribution.



Contact is made, and now the pose and shape of the object are quite certain. Robot plans a new grasp once more to do the final pickup.



Object Detection

- Tabletop Object Detector (ICP on segmented point clusters)
- TOD (Textured Object Detector)
- Object detectors provide object shape and pose hypotheses, with associated quality scores
- Naive Bayes for estimating the initial probabilities of different shape/pose hypotheses

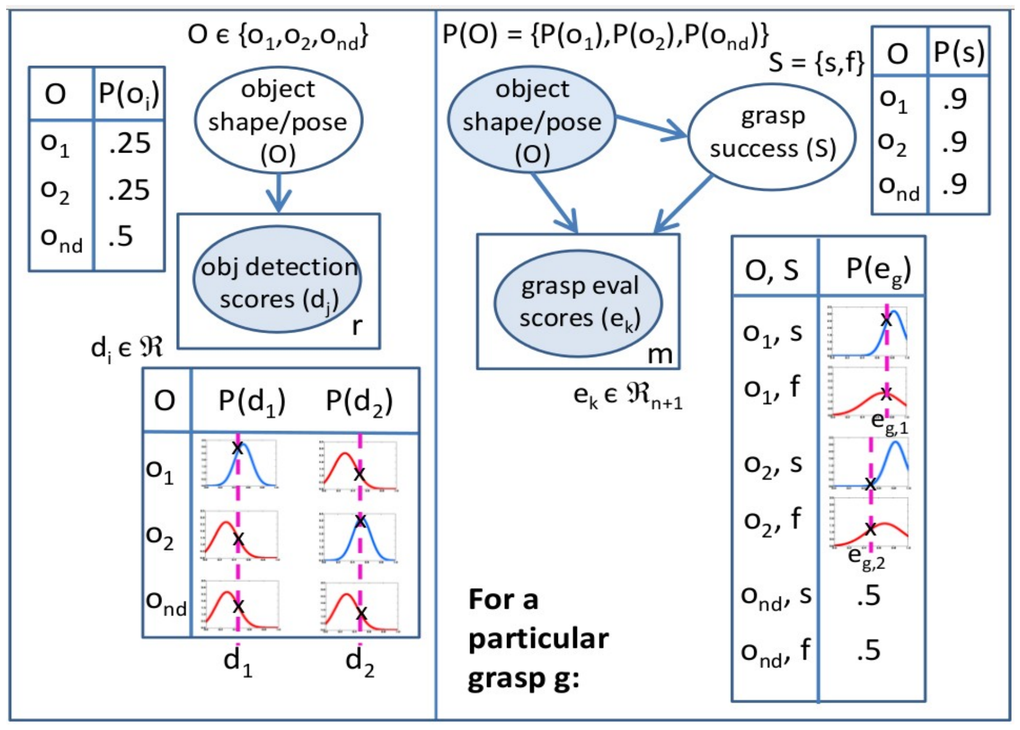
Bayesian Grasp Planner

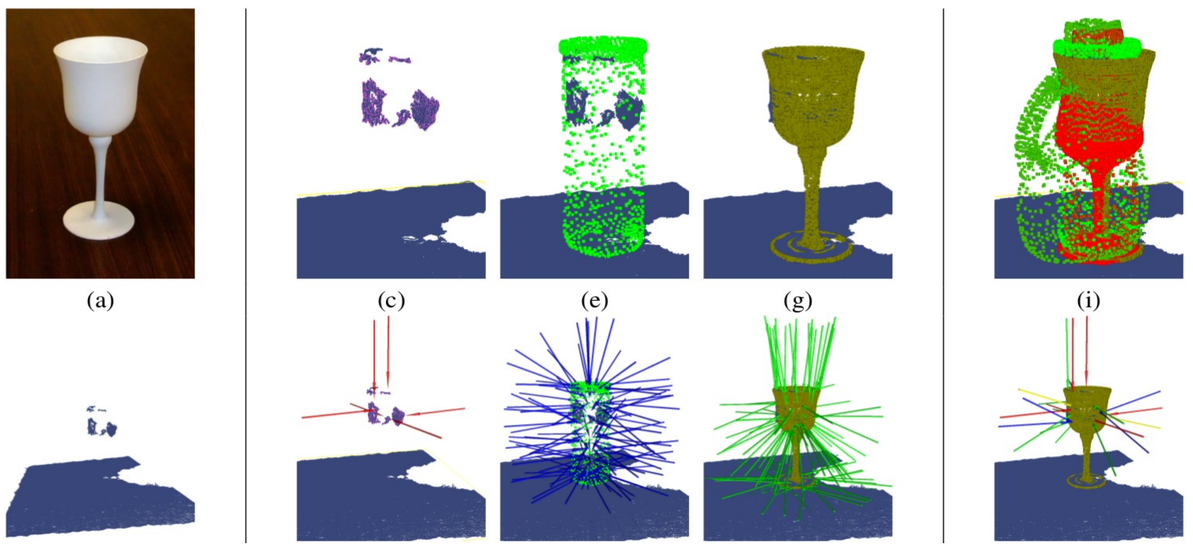
- Select grasps that maximize probability of success over entire set of object shape/pose hypotheses
- Grasp generator: Pulls grasps for an object from a database with pre-planned grasps
- Grasp evaluator: Regression-based grasp evaluator based on stored grasps with associated qualities
- Probability of grasp success for a particular grasp based on object detection scores and grasp evaluation scores (marginalize over shape/pose hypotheses):

$$P(s|E,D) = \sum_{o \in O} P(o|D)\,P(s|E,o)$$

s = grasp success
E = grasp evaluation scores
D = object detection scores

o = object shape/pose hypothesis





Belief Update

- Belief state is set of weighted particles
- Each particle has a specific object shape and pose
- Update based on tactile and proprioceptive data:

$$P(o|D,T) \propto p(o|D) \prod_{\tau \in T} P(\tau|o)$$

o = object shape/pose hypothesis
D = object detection scores

τ = positive or negative tactile / proprioceptive measurement

Tactile Sensor / Proprioceptive Model

- Likelihood of a positive measurement
  - Gaussian on the distance to the nearest surface
- Likelihood of a negative measurement
  - If inside: Gaussian on the distance to the nearest surface
  - If outside: Constant