# Object Category Pick and Place

Marcus Gualtieri, Andreas ten Pas, and Robert Platt
College of Computer and Information Science, Northeastern University
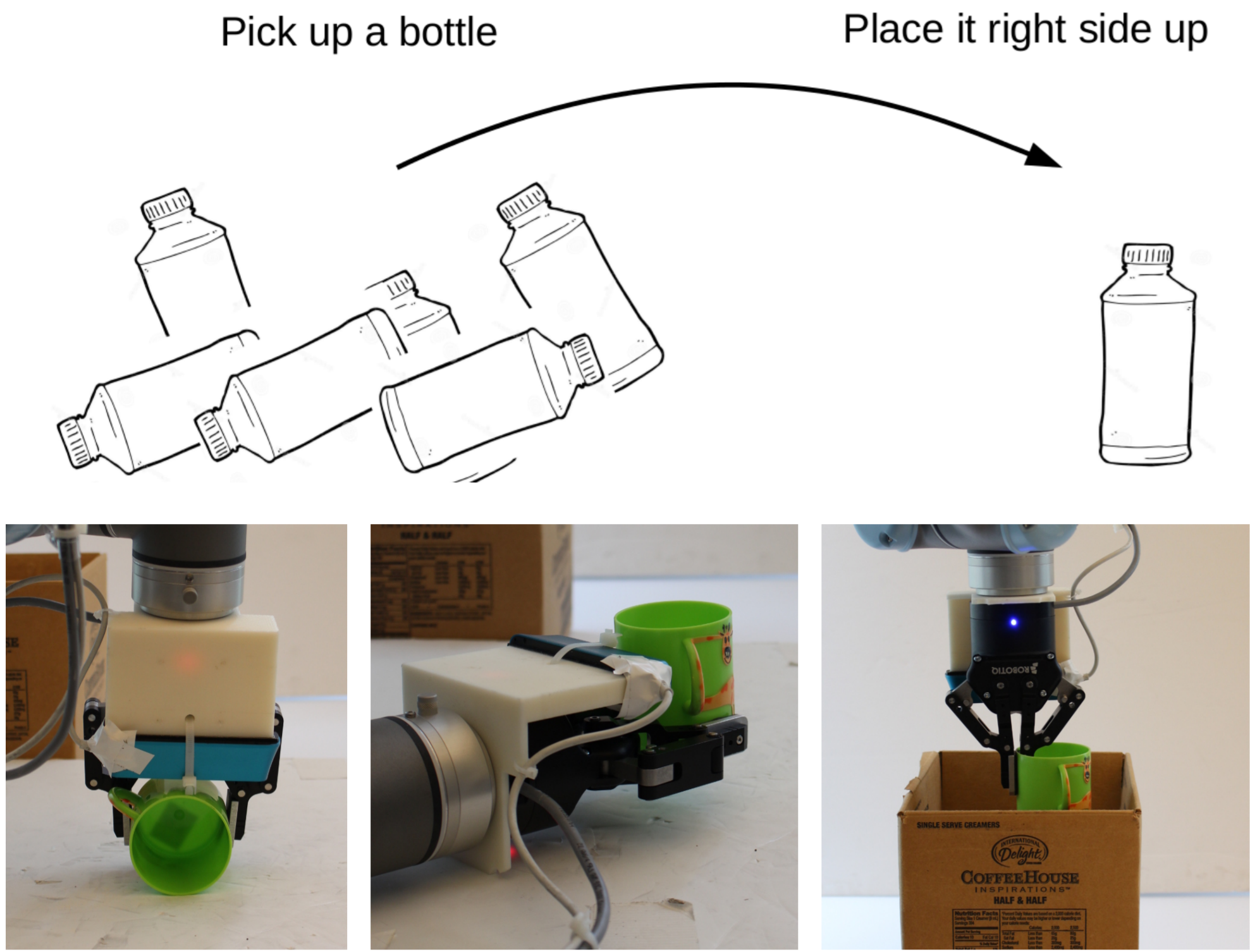
## Problem Definition

- Pick and place at object category level
- Category is known, but not the object instance

### Example

Pick up a bottle          Place it right side up



## Approach

- Formulate as Markov decision process
- Deep CNN to approximate Q-function
- Train in simulation

### Markov Decision Process



### Representation: 12 channels image



### Neural Network for Q-Function Approximation



## Simulation Results

### Setup

- Training in simulation (OpenRAVE) over 60k episodes
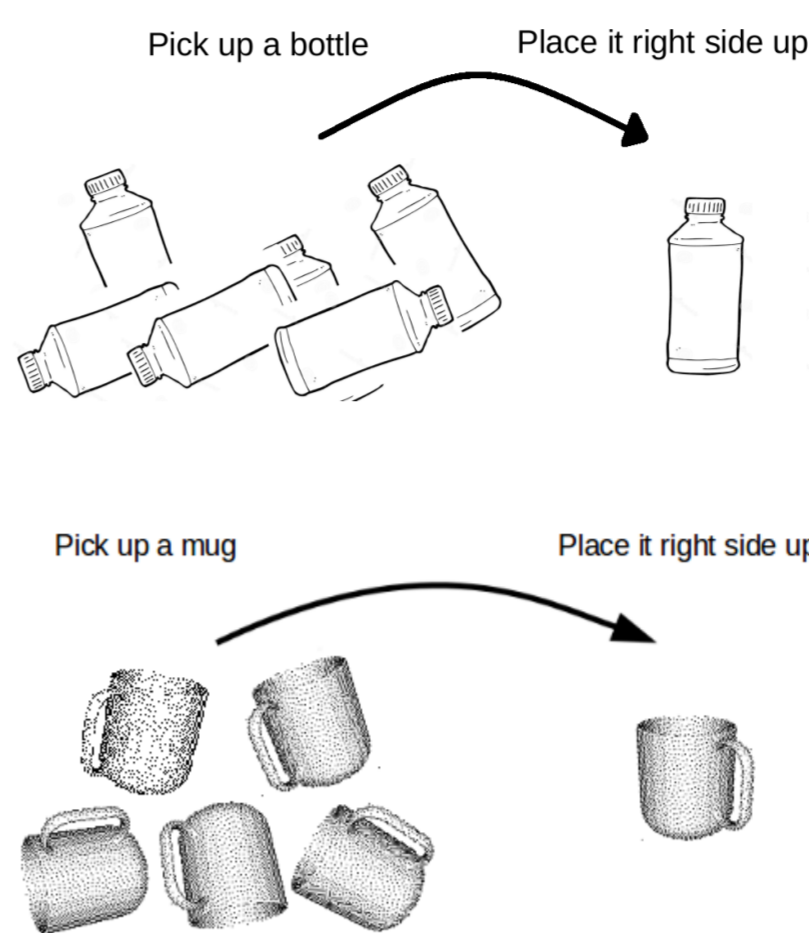- Scenarios: single object, clutter, re-grasping

### Pick and Place WO Re-grasping

Pick up a bottle      Place it right side up

Table: Avg correct placements over 300 episodes.

| Method / # Bottles | 1 (Test) | 7 (Test) |
|---|---|---|
| 1 Bottle | **1.00** | 0.67 |
| 7 Bottles | 0.78 | **0.87** |
| Cylinders | 0.43 | 0.24 |
| Random | 0.02 | 0.02 |

Pick up a mug      Place it right side up

Table: Avg correct placements over 300 episodes.

| Method / # Mugs | 1 (Test) | 7 (Test) |
|---|---|---|
| 1 Mug | 0.84 | 0.60 |
| 7 Mugs | 0.74 | **0.75** |
| Cylinders | 0.08 | 0.12 |
| Random | 0.02 | 0.02 |

### Re-Grasping Results: Single Mugs

Pick up a mug   Place it in a temporary configuration   Place it in a final configuration
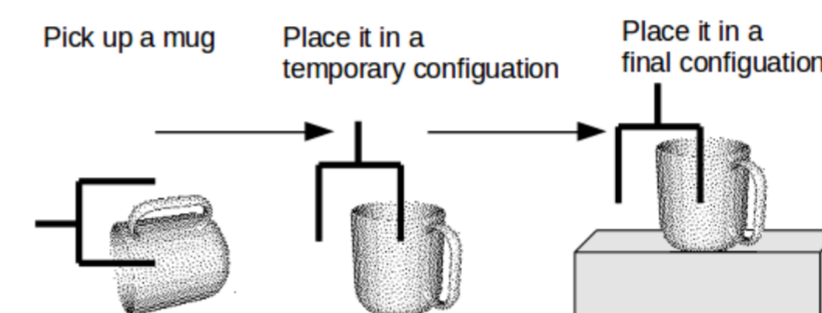
Table: Avg results over 300 episodes.

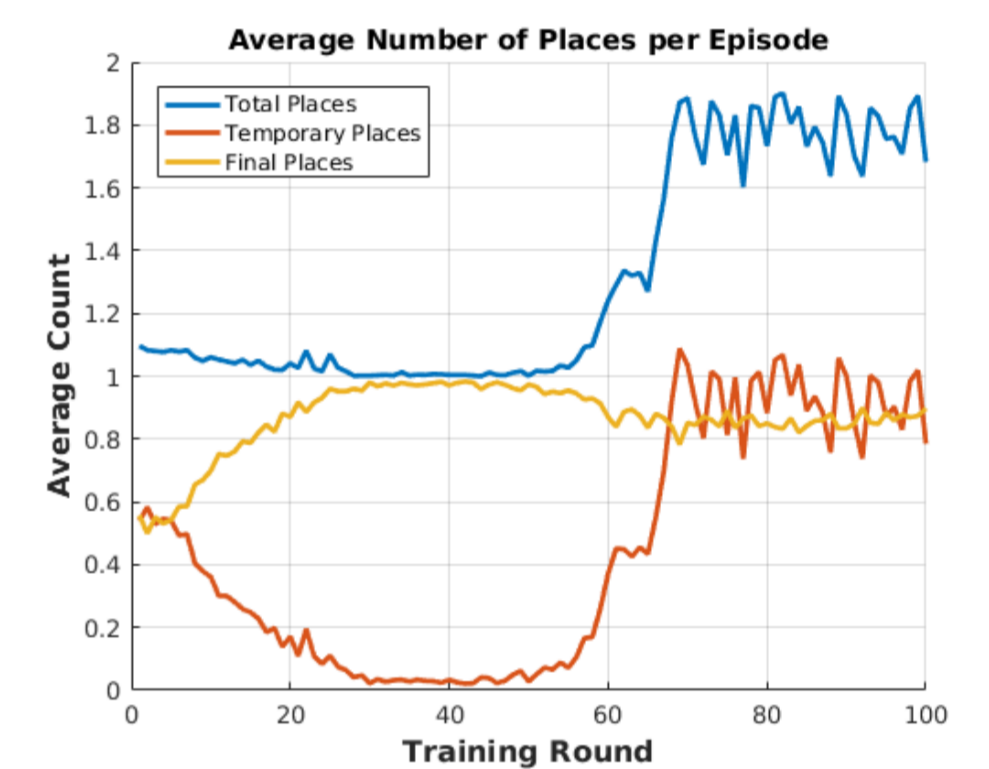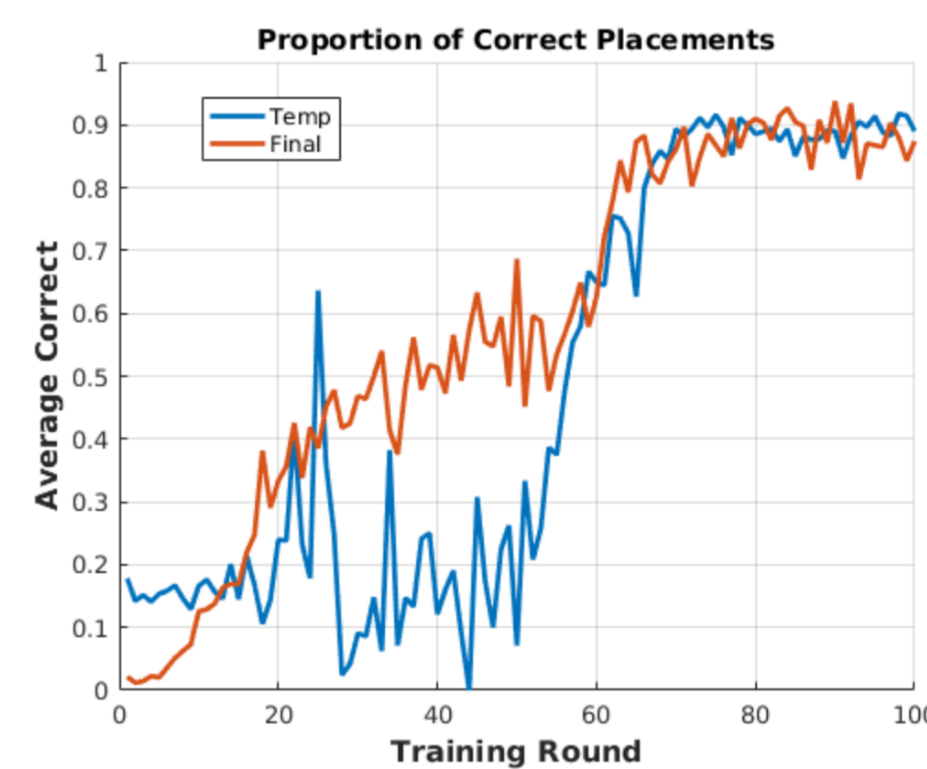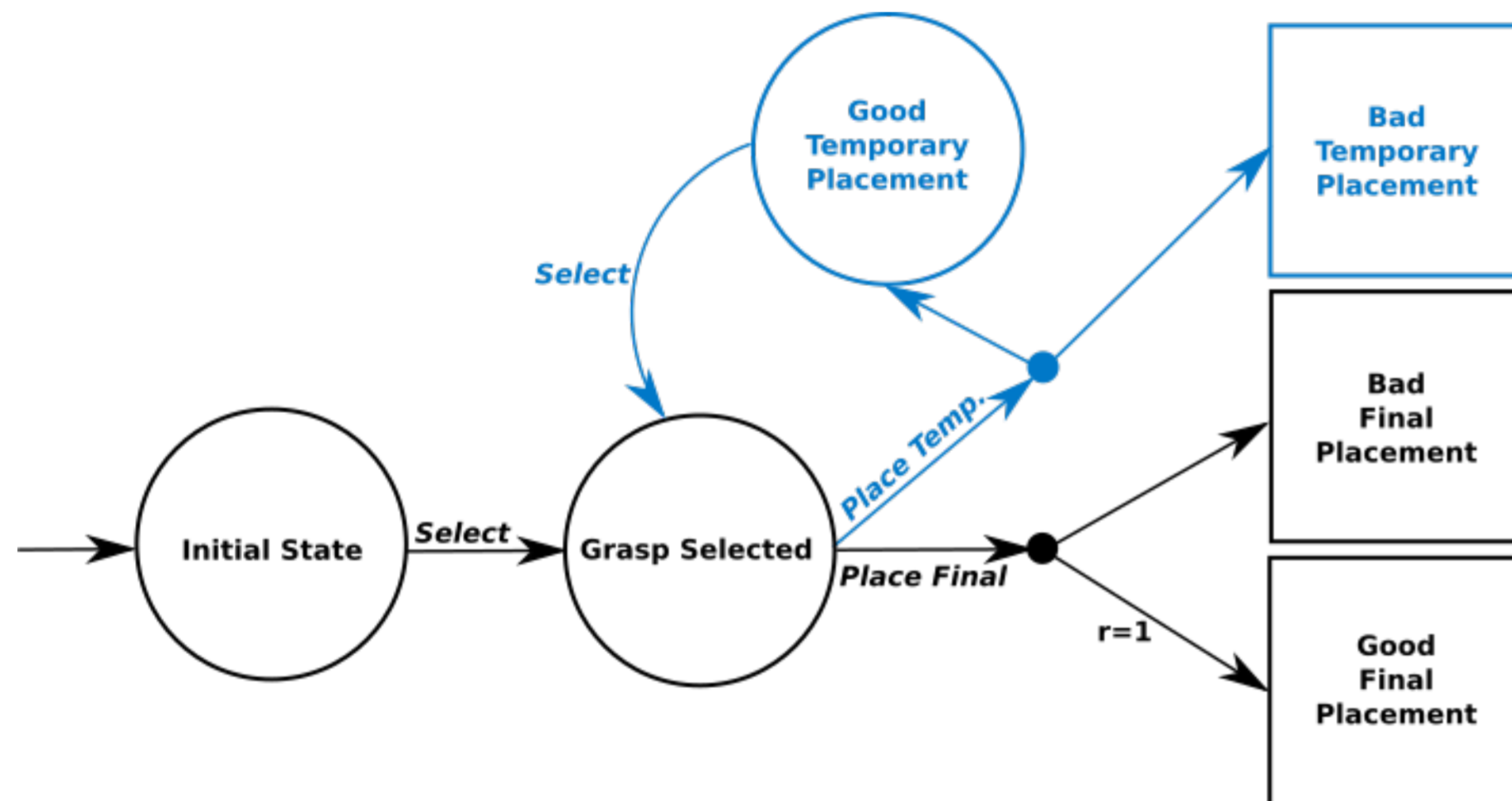| Metric / Tested With | 1 Mug (Test) |
|---|---|
| % Correct Placements | 0.84 |
| # Placements / Episode | 1.85 |



Figure: (Left) Proportion of correct temporary (blue) and final (red) placements. (Center) Average number of placements (blue), broken up into temporary (red) and final (yellow).
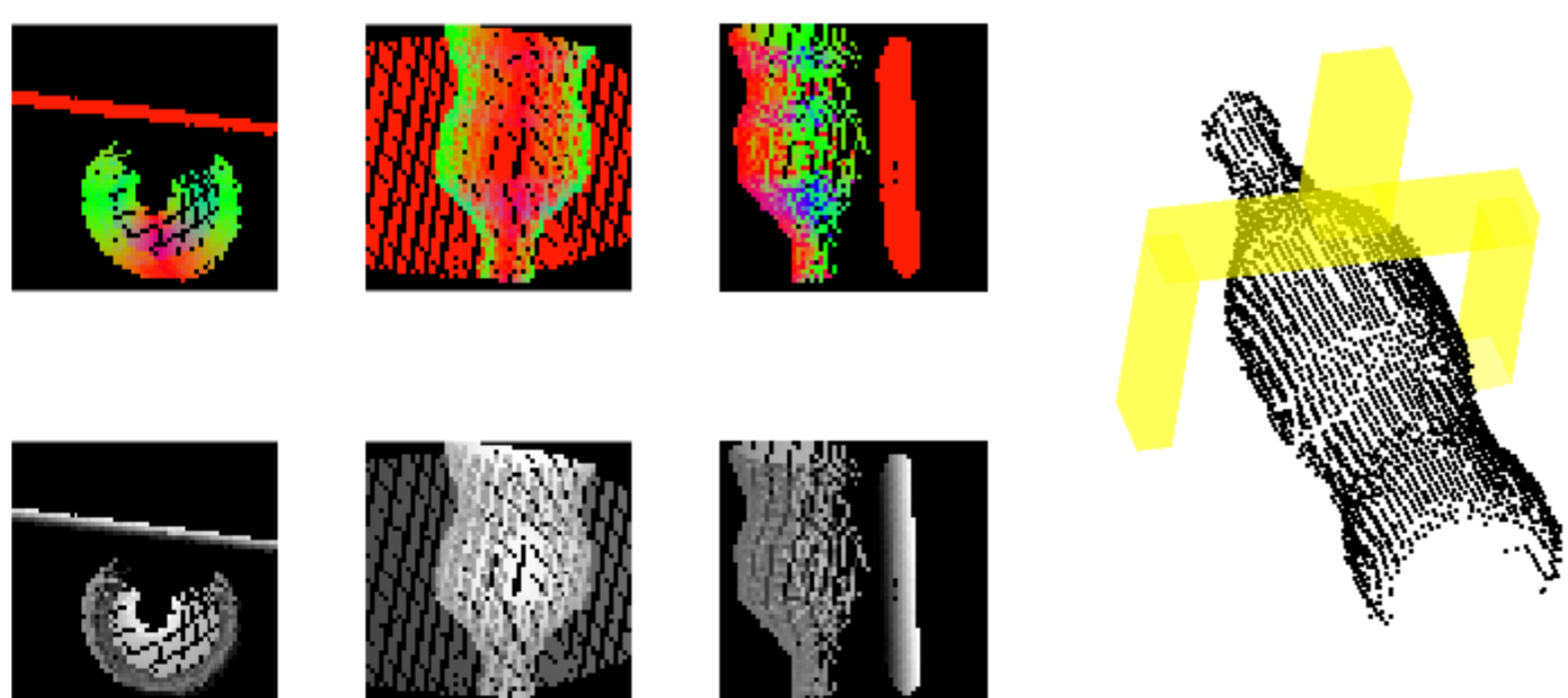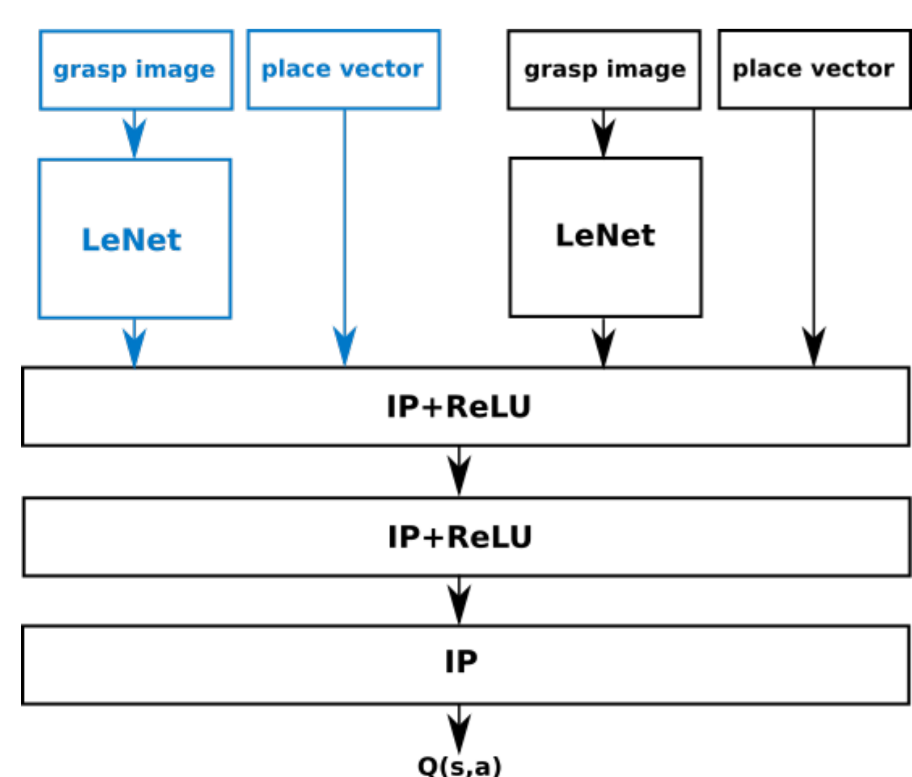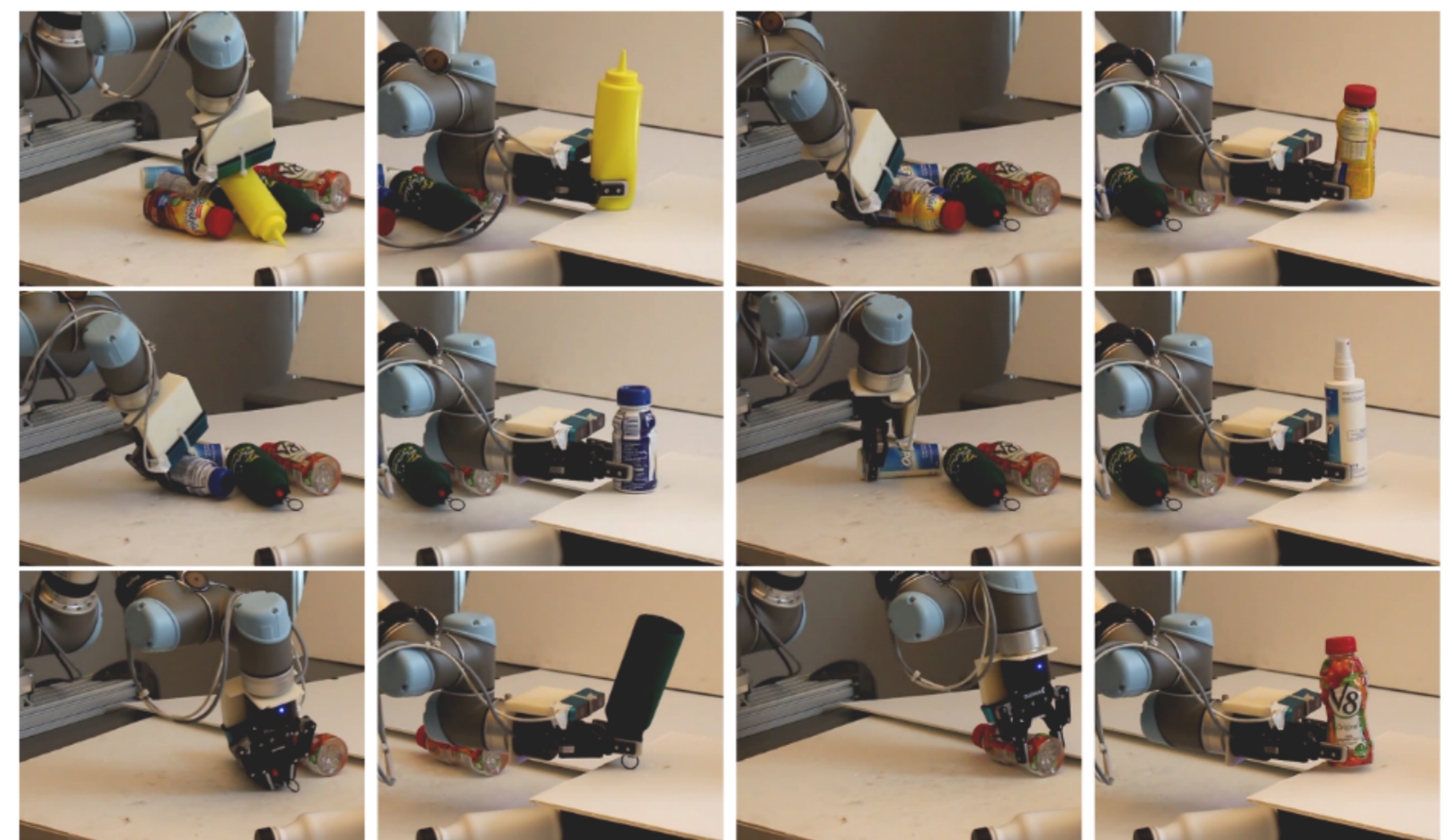
## Robot Experiments

### Setup

- UR 5 robot (6-DOF) and Robotiq 2-finger gripper (1-DOF)
- 2 views from Structure.IO sensor mounted to wrist
- Scenarios: single object, clutter, re-grasp

### Clutter Example



### Results

| | Single Bottle | Clutter Bottles | Single Mug | Clutter Mugs | Re-grasp |
|---|---|---|---|---|---|
| Grasp | 0.96 | 0.97 | 0.88 | 0.80 | 0.97 |
| Final Place | 0.89 | 0.76 | 0.80 | 0.61 | 0.76 |
| Temp. Place | - | - | - | - | 0.77 |
| Entire Task | 0.84 | 0.73 | 0.70 | 0.48 | 0.55 |
| # of Trials | 112 | 97 | 96 | 91 | 72 |
| Upside-down | 5 | 19 | 5 | 4 | 0 |
| Sideways | 0 | 0 | 7 | 18 | 9 |
| Fell Over | 2 | 3 | 1 | 2 | 0 |