Amazon Picking Challenge Stowage Task

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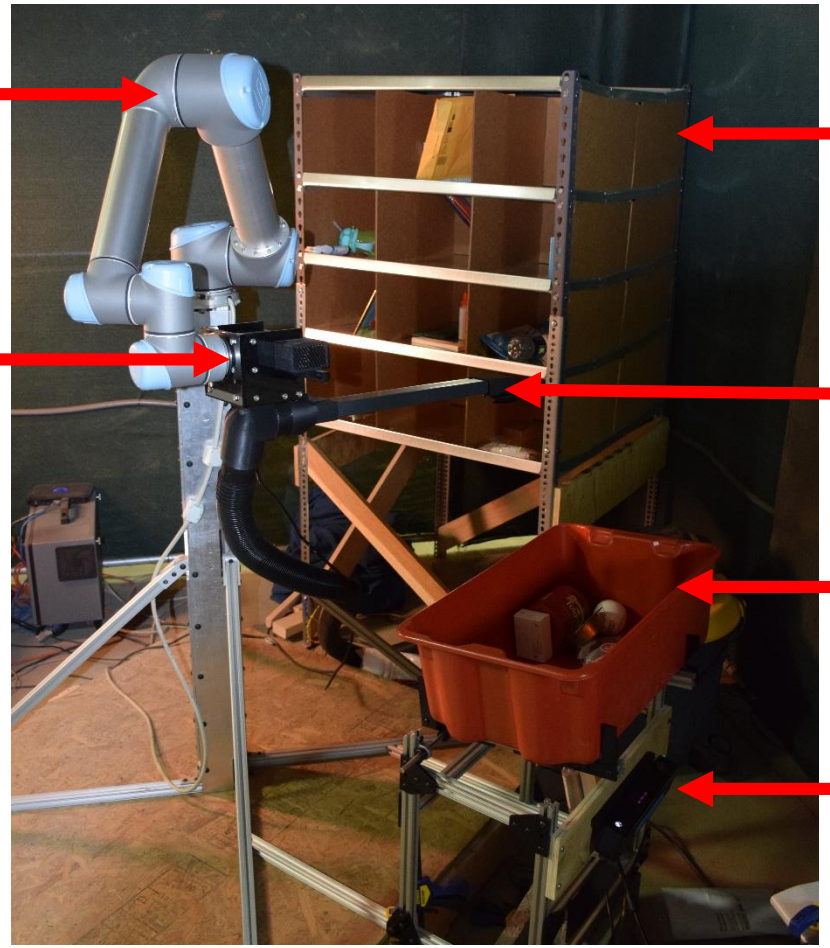
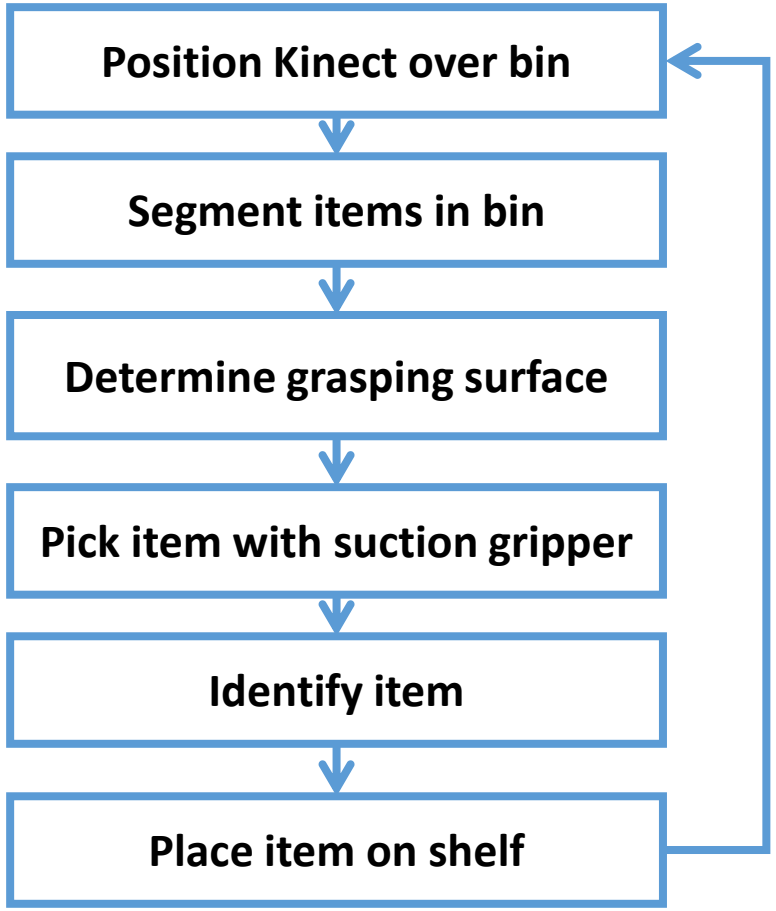
Introduction

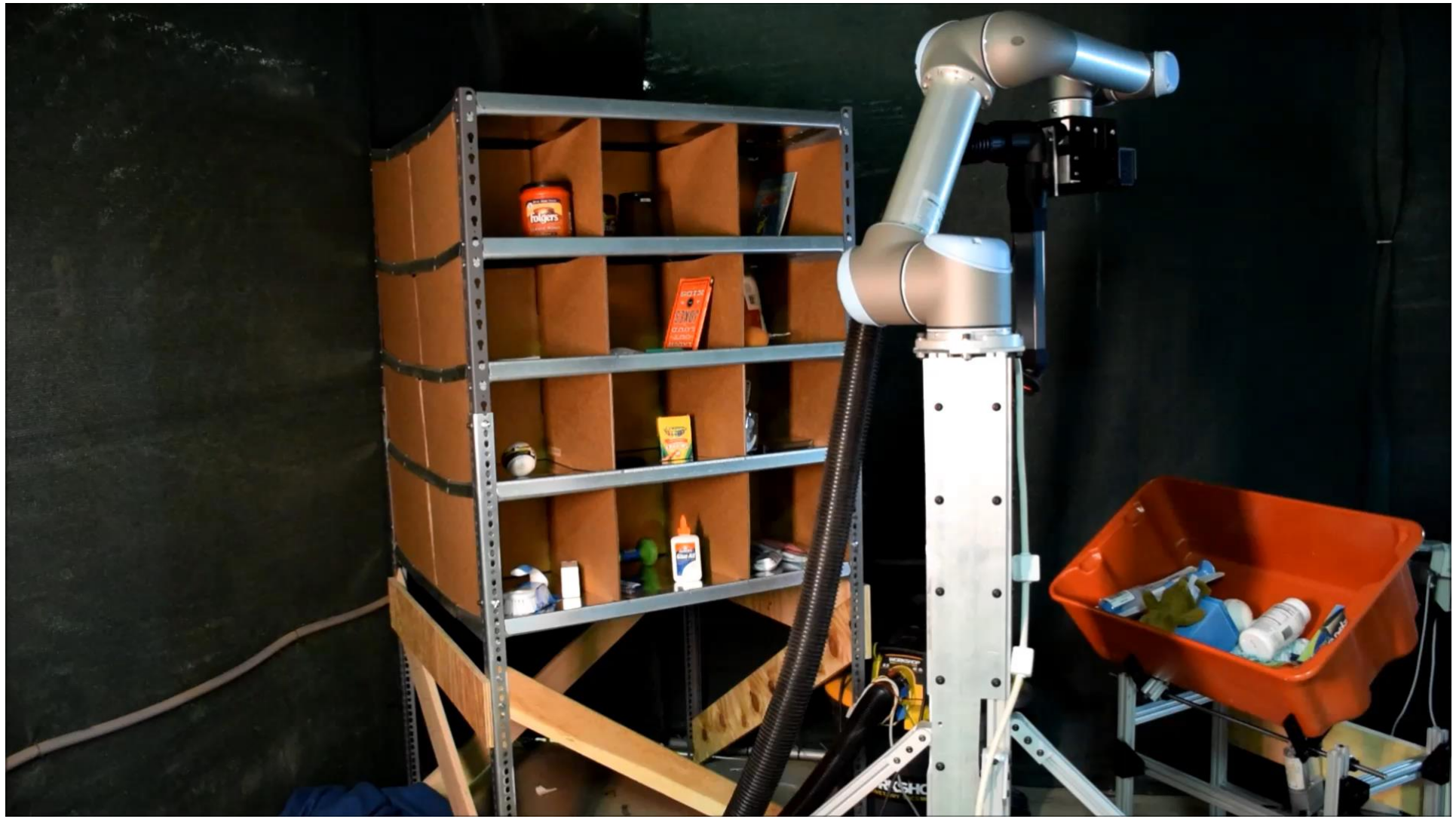
- Designed robotic system for stocking warehouse shelves
- Task
  - Retrieve items out of an unstructured bin
  - Identification of each item
  - Place item onto the shelf without damage
- Competing in the 2016 Amazon Picking Challenge

System Overview





System Demo: Part 1



Bin Actuation

- Linear actuator tilts bin to increase accessible space
- Robot is able to pick up items against the walls

Motion Planning

- MoveIt! software package manages arm kinematics and path planning
- OMPL motion planner implements RRT*Connect algorithm to find optimal, minimal distance paths
- Base, end effector, and shelf modeled as collision objects

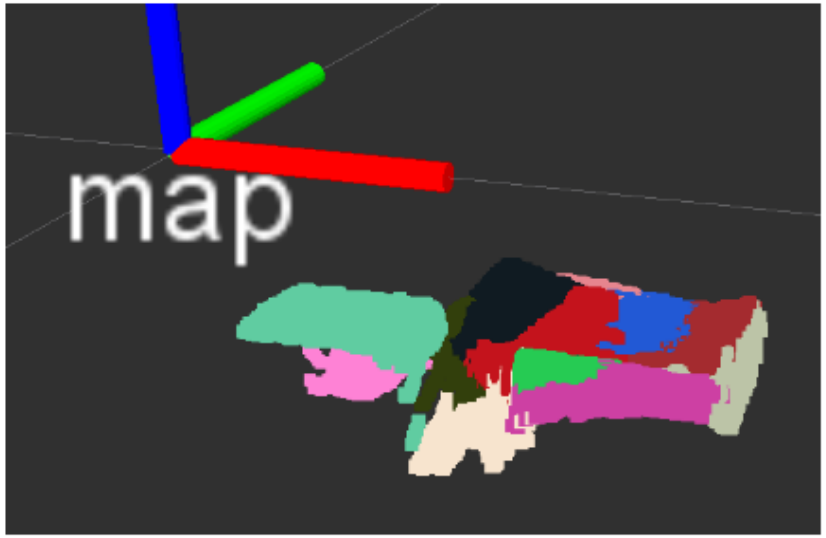
Suction Grasping

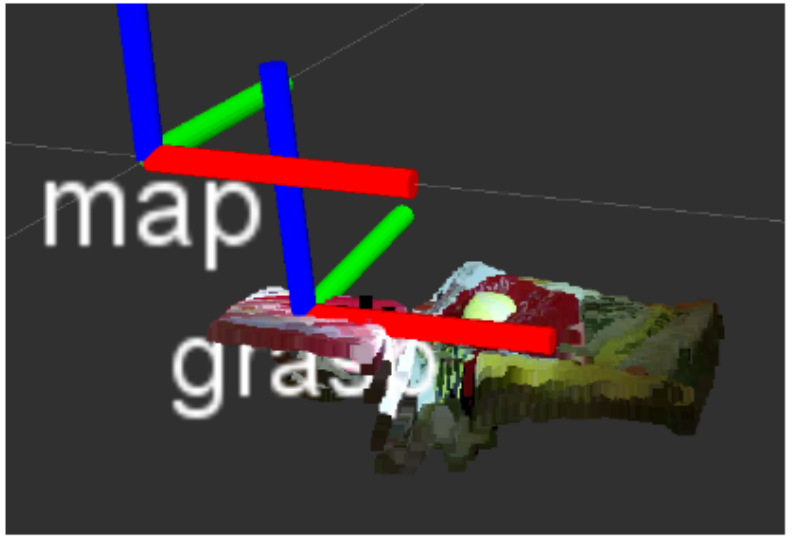
- High flow low pressure vacuum system
  - Shop-Vac impeller provides 200 CFM and 40 kPA
- Custom suction cup mounted to UR5 wrist
- Capable of acquiring 36 / 38 items from the 2016 APC item list

Grasp Planning

1) Region Growing Segmentation
    - Select points with minimum curvature values as cluster centers
    - Find nearest neighbors of the selected points to generate clusters

2) Clusters are scored based on…
    - Maximum number of points
    - Height of each cluster
    - Area of the horizontal surface of each cluster (x-y axis)
    - Direction of normal



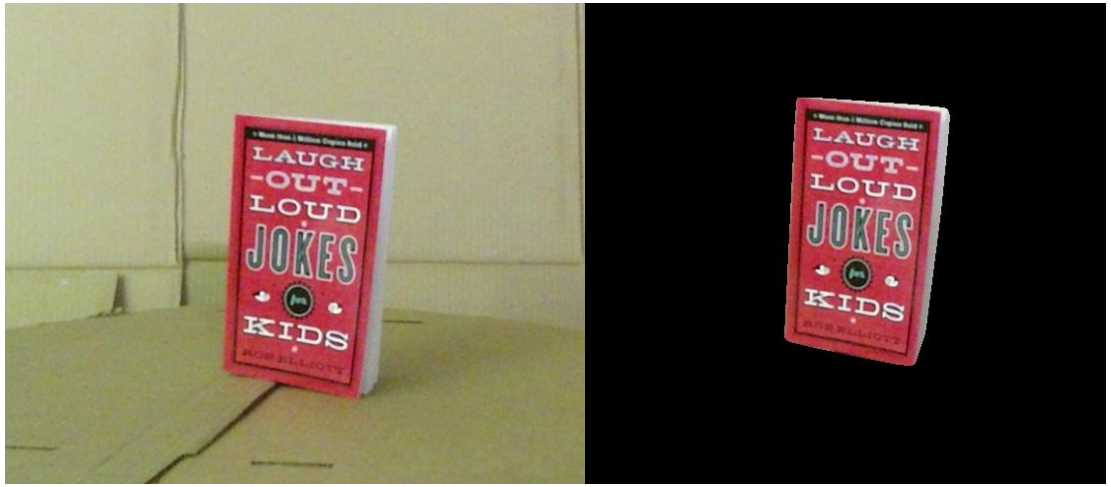


Item Identification

- Capture kinect2 RGBD data
- Mask image based on depth data
- Segment image using SLIC algorithm
- Classify superpixels using Caffe and Alexnet CNN architecture
- Make prediction based on

Dataset Generation

- Automatic image capture using actuated turntable
- HSV color based segmentation
- Convex hull approximation
- Collected 100 images for all 38 items



Item Segmentation

- Fixed location of the end-effector above the ID Kinect.
- Depth based thresholding
- Geometries of all the objects are known, horizontal thresholding.

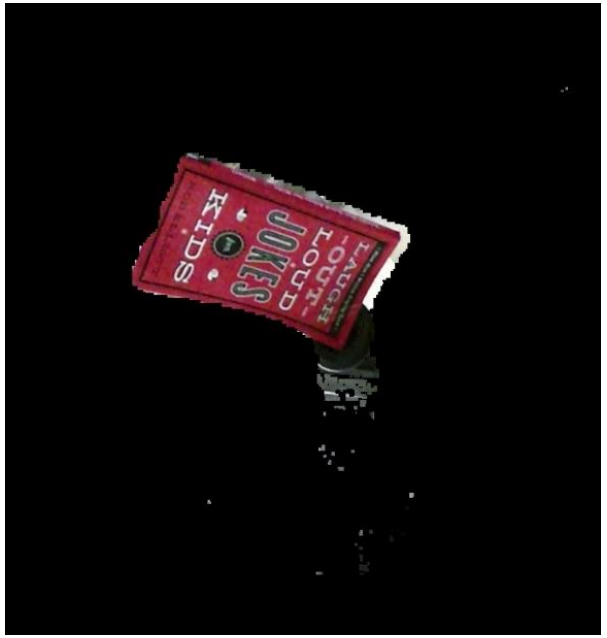
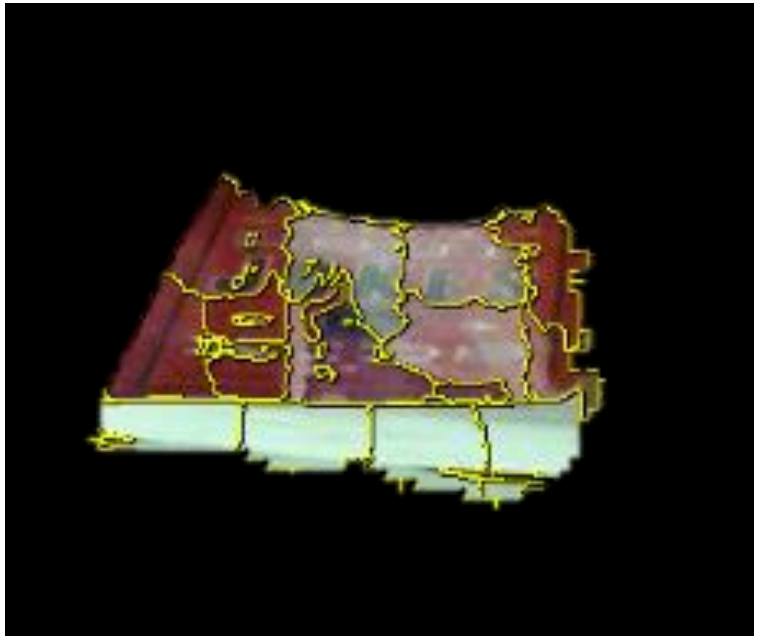


Image Segmentation and Identification

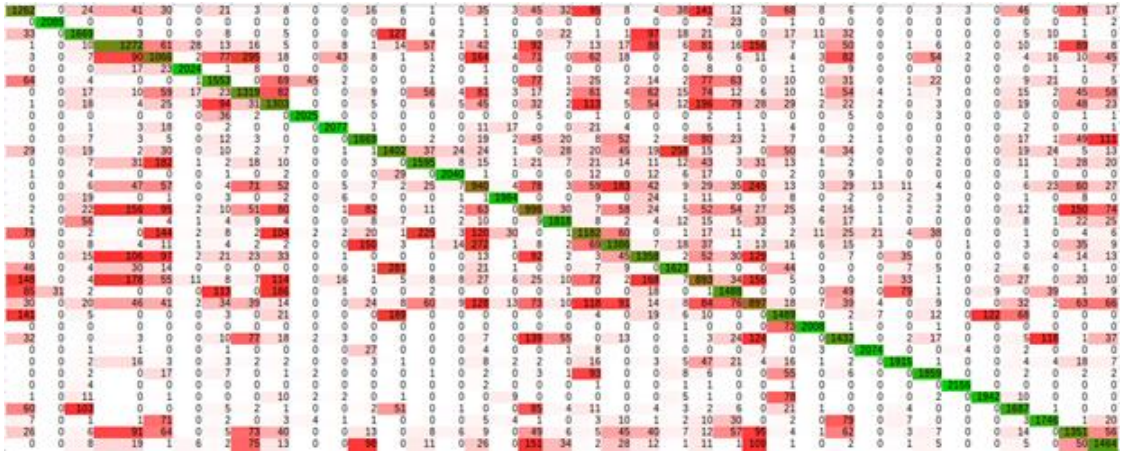
- Segment image using SLIC superpixel algorithm
- AlexNet CNN is used for item identification
  - Trained for 8 hours on over 400,000 segments using Nvidia Titan GPU
  - Predictions are computed in < 1 second
- 38 predictions are generated for every super pixel



Global Prediction

- Average predictions for each class
- Identify item that has the highest confidence prediction
- Renormalize predictions
- Repeat until all 12 items are identified

- 75% accuracy on over 10,000 simulated permutations of acquired images



System Demo: Part 2

Future Work

2 months to improve system before the competition at Robocup on June 31st

Grasping from bin

- Use improved clustering to improve first pass pickup rate

Item Identification

- Further supplement training data with real images
- Place items in ‘confusion set’ in the same bin to reduce the chance of mis-associations
- Refine global prediction algorithm to maximize accuracy

Item placement on shelf

- Develop pose estimation method for large items
- Develop place strategy for large items of known pose

Questions

[1] Amazon picking challenge rules: http://amazonpickingchallenge.org/APC_2016_Official_Rules.pdf
[2] Amazon picking challenge submission video: https://youtu.be/oGq05wN7mmg
[3] PCL Region Growing Segmentation: http://pointclouds.org/documentation/tutorials/region_growing_rgb_segmentation.php
[4] MoveIt: http://moveit.ros.org/
[5] Open Motion Planning Library: http://ompl.kavrakilab.org/
[6] AlexNet: http://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf
[7] Caffe Deep Learning: http://caffe.berkeleyvision.org/
[8] Berkeley APC Dataset: http://rll.berkeley.edu/amazon_picking_challenge/