A Dataset for Improved RGBD-based Object Detection and Pose Estimation for Warehouse Pick-and-Place

*Colin Rennie, *Rahul Shome, †Alberto Ferreira De Souza, *Kostas Bekris

* Rutgers, the State University of New Jersey † Federal University of Espirito Santo, Brazil

Motivation

- Provide a dataset for the task of robotic grasping and manipulation in a typical constrained warehouse environment
- A difficult environment:
  - Inconsistent and indirect lighting conditions induce noise in sensors
  - Objects are often partially occluded by other objects or the shelving unit
  - Narrow bins allow only very limited robotic mobility
- However, the task is of great importance to industrial applications
- Developing high accuracy pose estimation algorithms is of utmost importance
- **Objective:** provide a representative dataset that *allows researchers to determine effects of specific environmental variables on pose estimation algorithms*

Amazon Picking Challenge (APC)

Figure: The 25 APC objects categorized by broad object class

- Shelf-picking challenge simulating a warehouse environment
- Tight, cluttered workspaces bins within the shelving unit
- 25 target objects stocked in 12 bins, 1-4 objects per bin
- Target items show variety of forms and traits

Data Collection

Figure: Our data collection hardware and environment

- Collection performed on Motoman Dual-arm SDA10F humanoid robot using Kinect v1 RGBD camera
- Camera located on wrist of robot, position calibrated prior to data collection
- 10,368 RGBD images collected involving 24 target objects, each shown in:
  - 12 different bin locations
  - 3 clutter states per bin (1, 2, 3 items)
  - 3 viewpoints per clutter state
  - 4 frames per viewpoint
- 6D Ground truth annotated by hand, including all transformations between object, camera, and robot base

Dataset Features

- Large dataset covering wide variety of objects with 6D ground truth object pose annotatations
- Good sample coverage of probable object poses within the shelves
- Provides researchers the ability to determine the effects of immediate clutter on pose estimation
  - Same ground truth target object pose is given with varying degrees of clutter within the bin
- Allows opportunity to analyze accuracy based on the camera's viewpoint
  - For each shelf configuration, samples are generated from 3 different viewing positions
- Provides the ability to determine the effects of slight sensor noise on deterministic algorithms
  - For each shelf configuration at each viewpoint 4 samples are generated

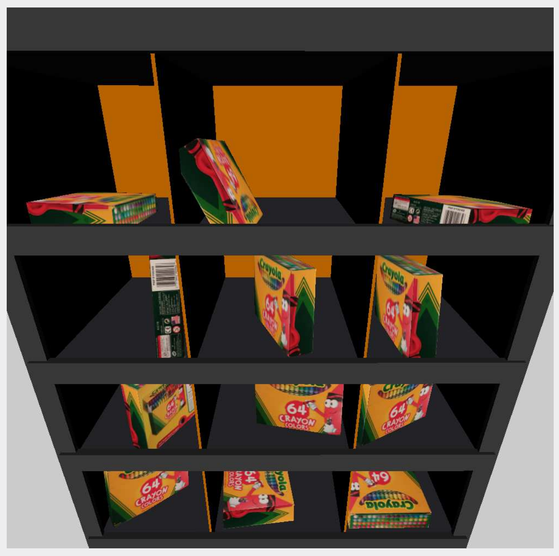

Figure: Variety of coverage in our dataset of ground truth poses for a single object

Figure: Examples from our dataset showing the same target object pose (the "duck") in varying degrees of clutter within the bin

Pose Estimation Evaluation

- Dataset is readily used to compare pose estimation algorithms for this difficult task
- Acceptable accuracy thresholds are at the discretion of the user
- May use the metrics provided by the dataset to determine a series of improvements in order to deal with difficulties of the task

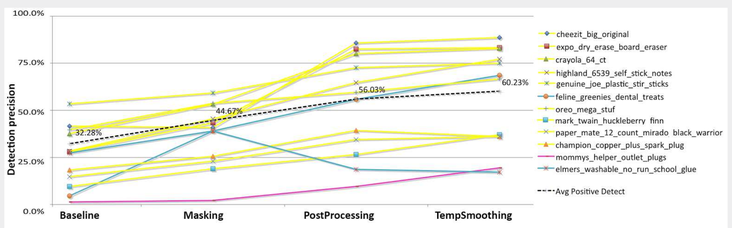

Figure: Evaluation made possible several improvements to an example pose estimation algorithm

Figure: An example detection of the "duck" from our dataset

Dataset Comparison

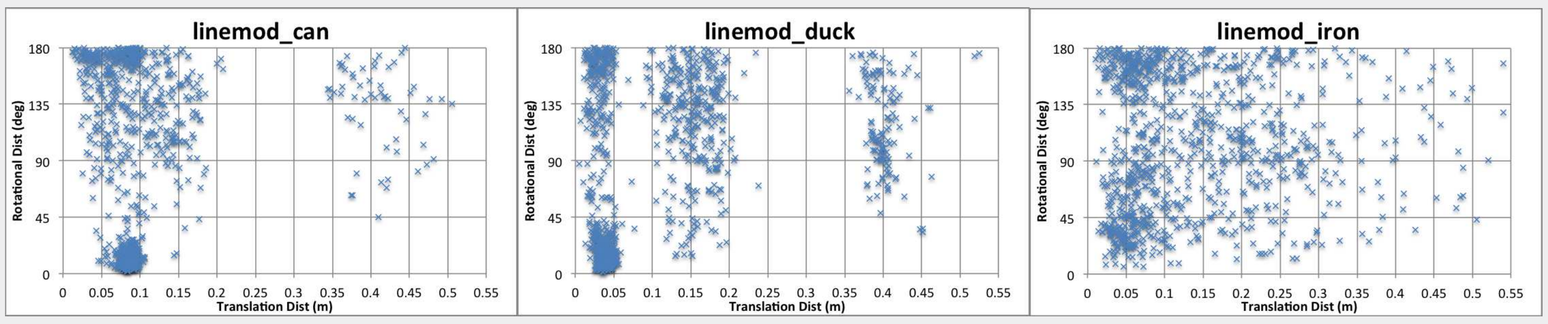

Figure: Example objects from LINEMOD dataset evaluated using our example algorithm

- LINEMOD dataset of 10,000+ RGBD images with ground truth 6D pose
- Shows target items on an AR board, in a heavily cluttered environment
- Samples generated from a variety of viewpoints around and above the object
- Can evaluate rotational, translational accuracy using the provided object models

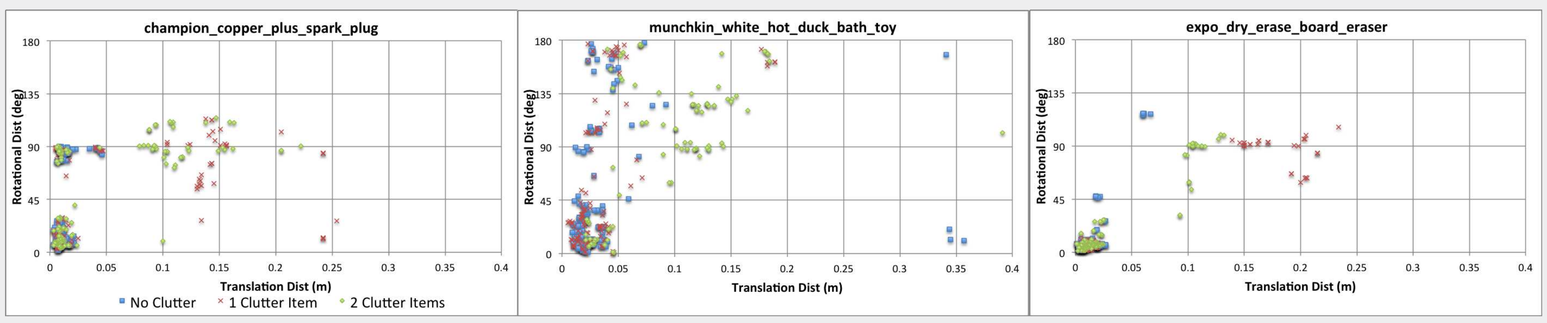

Figure: Objects from our dataset evaluated using the same algorithm; Colors indicate clutter conditions

- Our similar setup: object models provided, 10,000+ RGBD images
- Able to extract effects of immediate clutter on accuracy
- Can also determine robustness to noise in the sensor samples
- Evaluation with our dataset allows researchers to identify certain weak points in pose estimation algorithms on this difficult task

http://www.pracsyslab.org/rutgers_apc_rgbd_dataset {colin.rennie, rahul.shome, kostas.bekris}@cs.rutgers.edu, alberto@lcad.inf.ufes.br