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RGB-D at the Robotics and State Estimation Lab

Kevin Lai

Collaborators: Dieter Fox, Liefeng Bo, Marc Deisenroth, Peter Henry, Evan Herbst, Michael Krainin, Jinna Lei, Cynthia Matuszek, Xiaofeng Ren

RGB-D Mapping

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Henry, Krainin, Herbst, Ren, Fox (ISER '10)

Object Modelling

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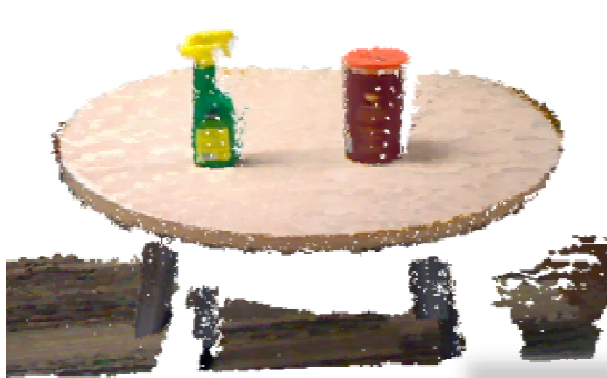


Krainin, Henry, Ren, Fox (IJRR '11)

Krainin, Curless, Fox (ICRA '11)

Object Discovery

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Herbst, Henry, Ren, Fox (ICRA '11)

Game Playing Robot

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Gambit: An Autonomous Chess-Playing Robotic System

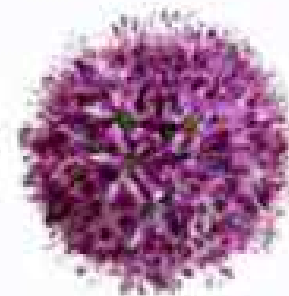
C. Matuszek, B. Mayton, R. Aimi, M. P. Deisenroth, L. Bo,
R. Chu, M. Kung, L. LeGrand, J. R. Smith, D. Fox



University of Washington



Intel Labs Seattle

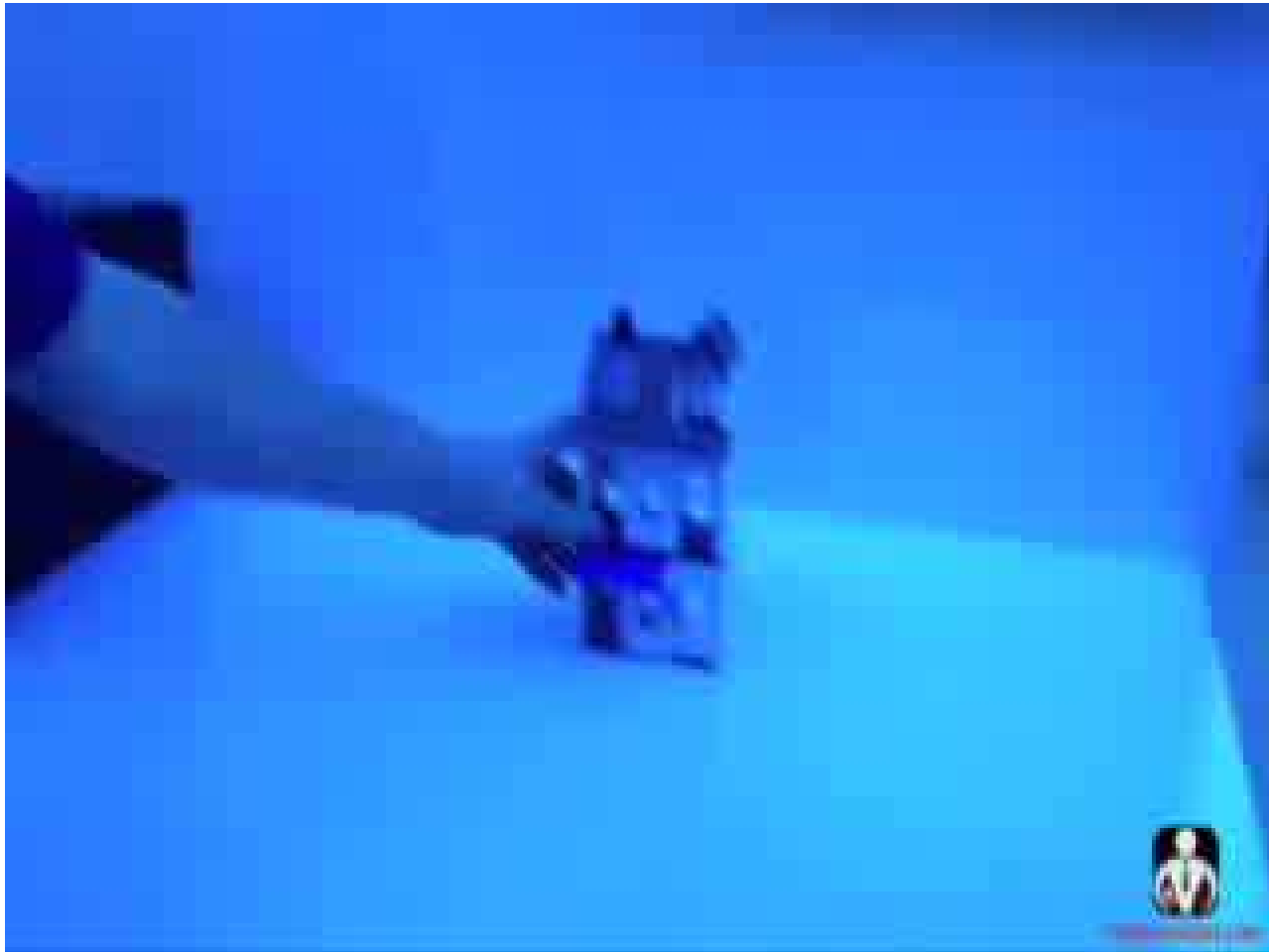


Allium Labs

Matuszek, Mayton, Aimi, Deisenroth, Bo, Chu, Kung, LeGrand, Smith, Fox (ICRA '11)

RGB-D Object and Pose Recognition

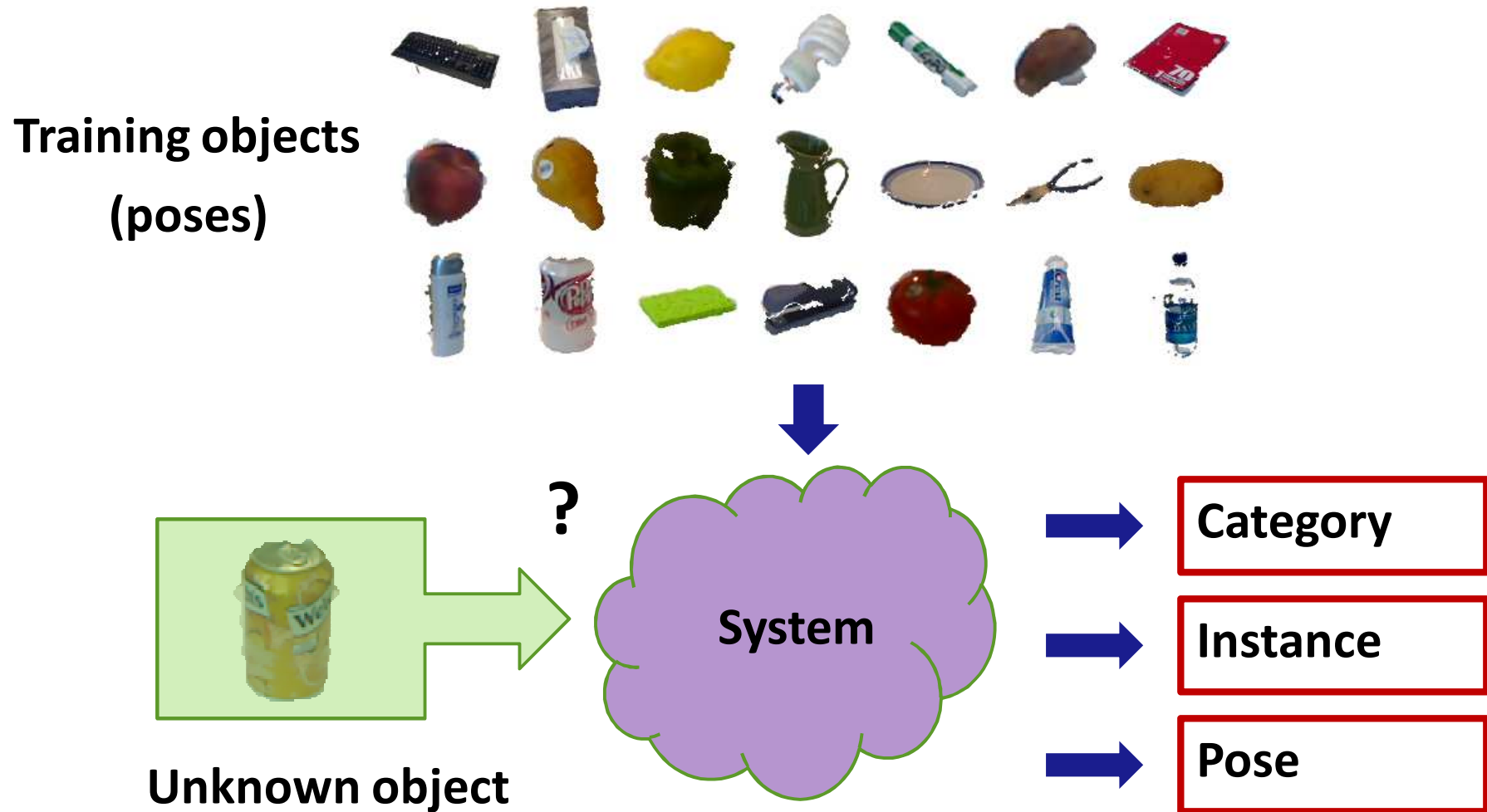
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L. Bo, D. Fox, B. Harrison, K. Lai, J. Lei, P. Powledge, X. Ren, S. Grampurohit, R. Ziola

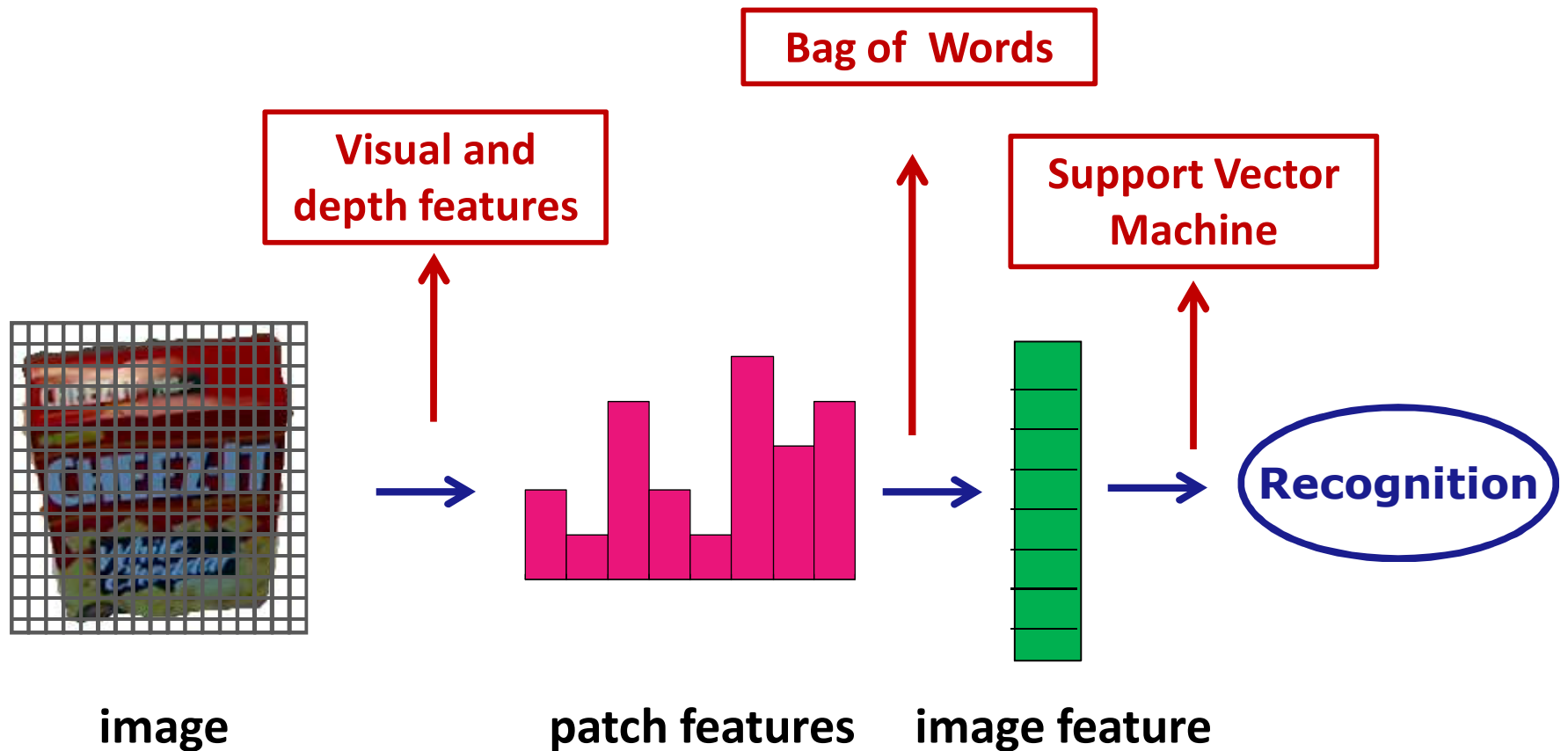
Object Recognition and Pose Estimation System

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Object Recognition Pipeline

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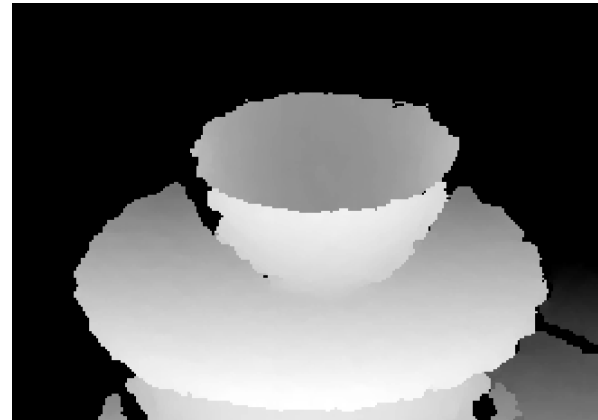
Outline

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- ◆ RGB-D Object Dataset
- ◆ Object Recognition and Detection
- ◆ Ongoing work: Object-Pose Tree

RGB-D Object Dataset

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- ◆ 300 objects in 51 categories
- ◆ 250,000 640x480 RGB-Depth frames total
- ◆ 8 natural scenes (offices, kitchens, meeting rooms)

K. Lai, L. Bo, X. Ren and D. Fox (ICRA '11)

<http://www.cs.washington.edu/rgb-d-dataset>

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RGB-D Object Dataset

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[Software](#)

[Demos](#)

[Publications](#)

Download RGB-D Object Dataset

The RGB-D Object Dataset provided here is for non-commercial research/educational use only. For commercial use, please [contact us](#) for more information.

To obtain the RGB-D Object Dataset, please click the "Send Email" link below and enter your full name, email, and affiliation (in the message portion). We ask for this information only to keep track of who is using the dataset. We will not give this to third parties or publish it publicly anywhere. Once your information has been verified, we will send you a link to the dataset via the email address that you entered.

[Send Email](#)

RGB-D Object Dataset Evaluation Procedure

We will add details about the evaluation procedure for object recognition and object detection here in the near future. In the meantime, please see our [paper](#) for a description.

Segmented Objects

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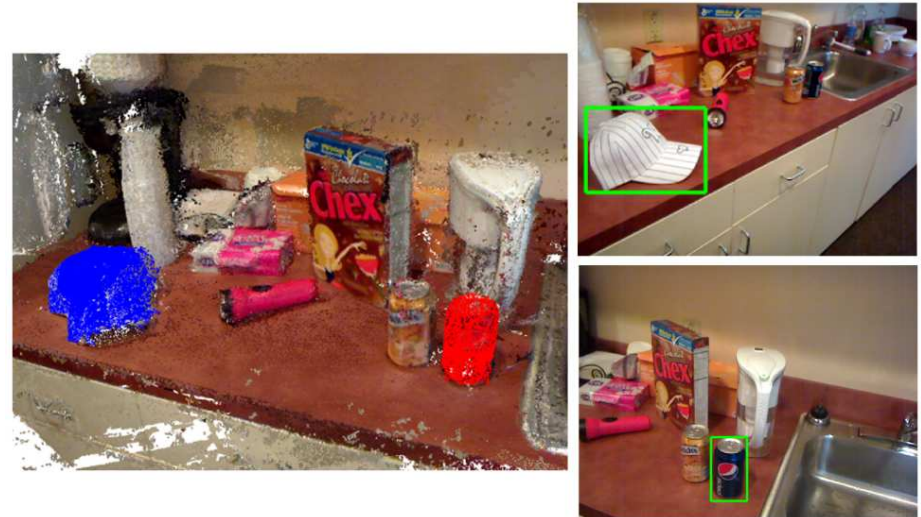
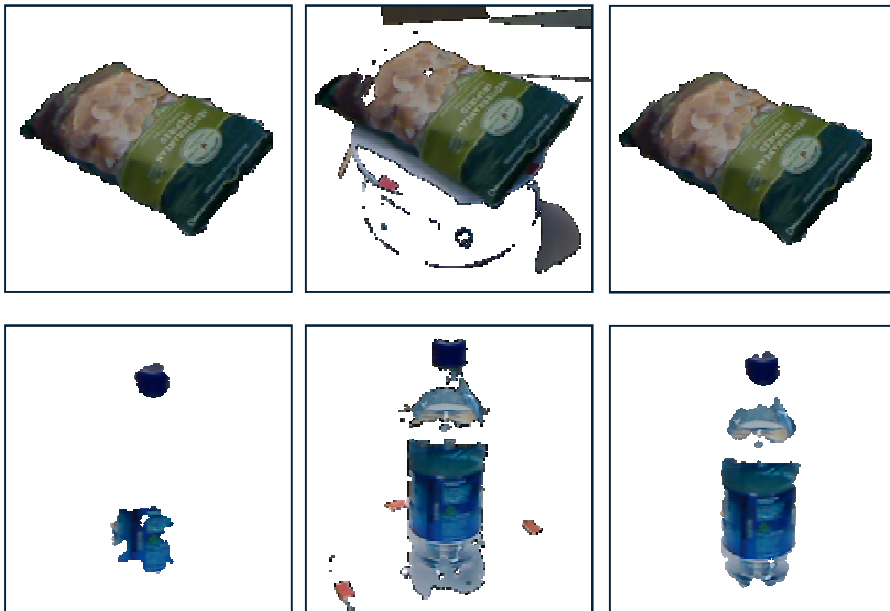
Natural Scenes

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Segmentation and Labeling

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Outline

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- ◆ RGB-D Object Dataset
- ◆ Object Recognition and Detection
- ◆ Ongoing work: Object-Pose Tree

Instance and Category Recognition

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Query **Instance Recognition**



Category Recognition



Features

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Feature Set

Dense SIFT features(RGB)
Color histograms(RGB)
Texon histograms (RGB)
Spin image features (Depth)
3D bounding box (Depth)

KDES + Pyramid EMK

gradient kernel descriptor(RGB)
shape kernel descriptor(RGB)
color kernel descriptor(RGB)
gradient kernel descriptor(Depth)
shape kernel descriptor(Depth)

L. Bo, X. Ren and D. Fox, NIPS '10.

Results on RGB-D Object Dataset

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Classifier: linear SVM

Category	Depth	RGB	RGB+Depth
Feature Set	51.7%	72.7%	81.9%
KDES + Pyramid EMK	72.7%	76.3%	85.6%

Instance	Depth	RGB	RGB+Depth
Feature Set	42.3%	59.3%	73.9%
KDES + Pyramid EMK	49.7%	74.9%	82.5%

Results on RGB-D Object Dataset

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Classifier: linear SVM

Category	Depth	RGB	RGB+Depth
Feature Set	51.7%	72.7%	81.9%
KDES + Pyramid EMK	72.7%	76.3%	85.6%

Instance	Depth	RGB	RGB+Depth
Feature Set	42.3%	59.3%	73.9%
KDES + Pyramid EMK	49.7%	74.9%	82.5%

Category: 3% higher than feature set

Results on RGB-D Object Dataset

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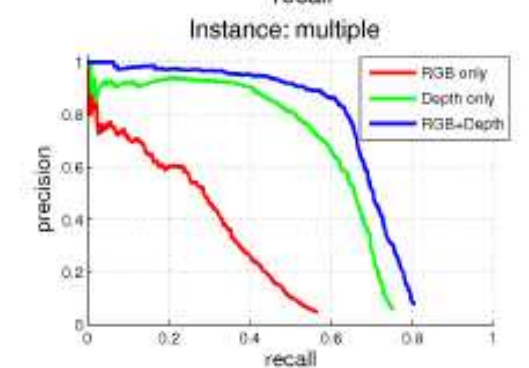
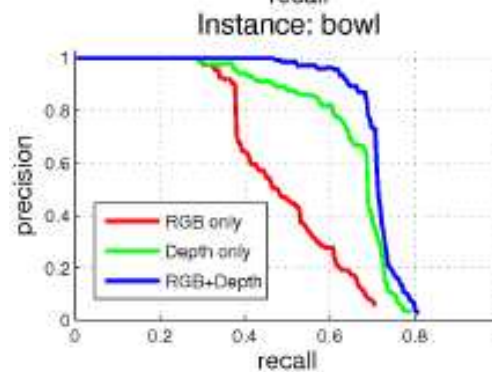
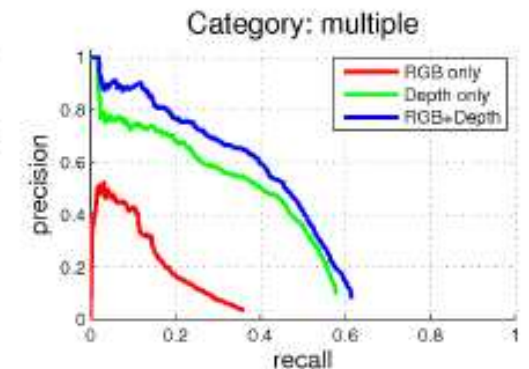
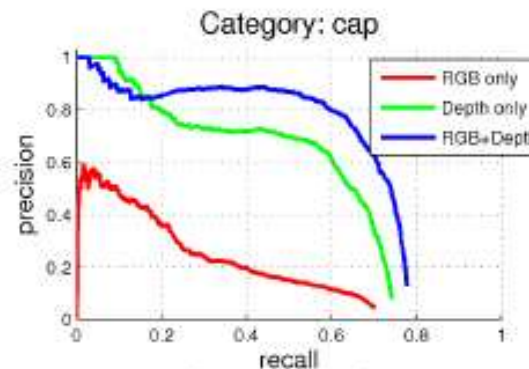
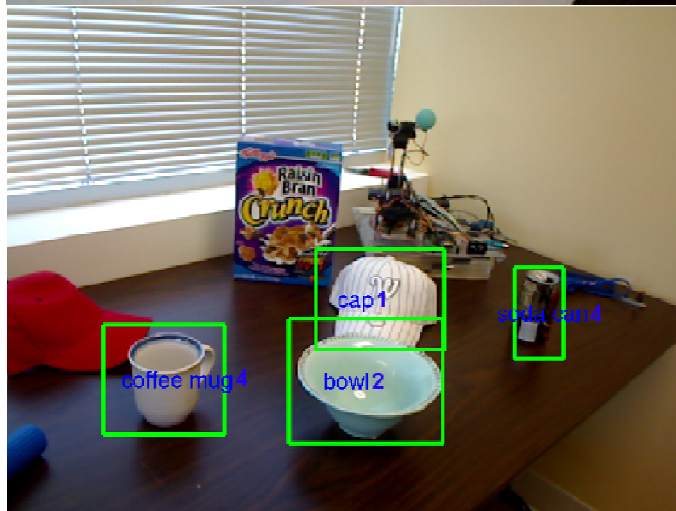
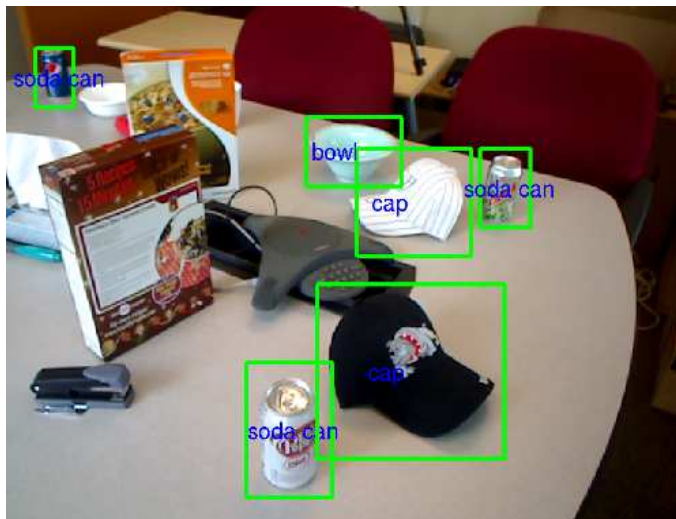
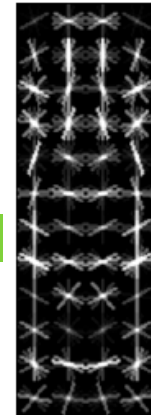
Classifier: linear SVM

Category	Depth	RGB	RGB+Depth
Feature Set	51.7%	72.7%	81.9%
KDES + Pyramid EMK	72.7%	76.3%	85.6%
Instance	Depth	RGB	RGB+Depth
Feature Set	42.3%	59.3%	73.9%
KDES + Pyramid EMK	49.7%	74.9%	82.5%

Instance: 10% higher than feature set

RGB-D Object Detection

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Outline

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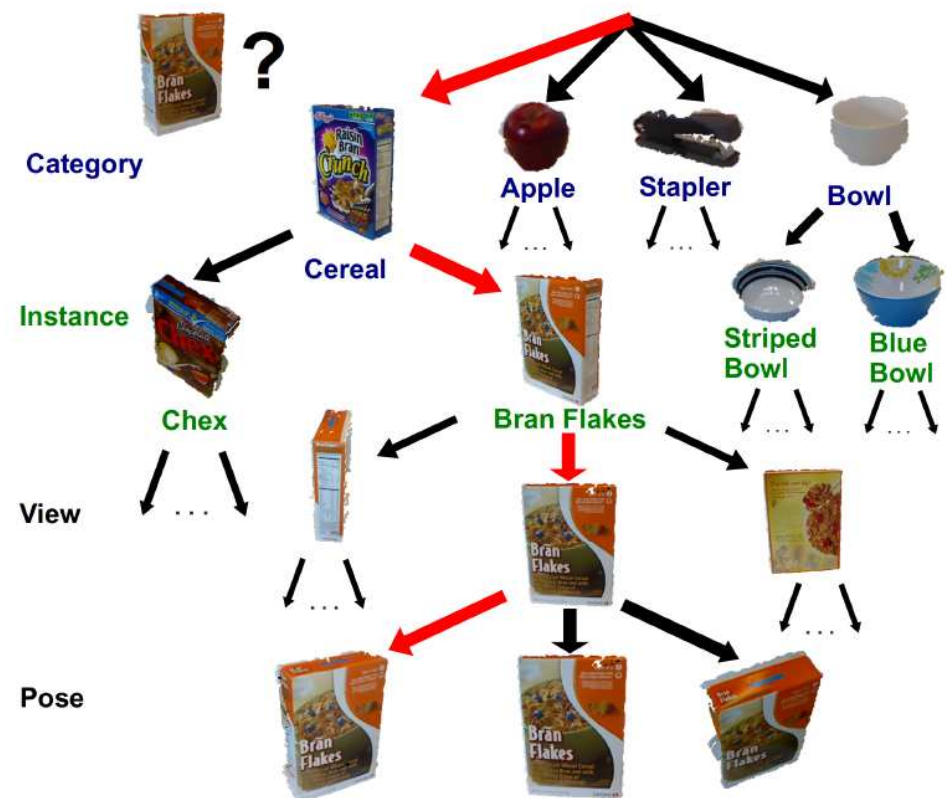
- ◆ RGB-D Object Dataset
- ◆ Object Recognition and Detection
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Object-Pose Tree

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The goal: recognize objects and their poses jointly

Joint optimization of parameters of the entire tree based on loss function introduced by Bengio et al. NIPS '10.



Preliminary Results

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Summary

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- ◆ RGB-D Object Dataset: a large scale, publicly available dataset of objects and natural scenes with RGB+depth videos
- ◆ Depth is a very useful cue for object recognition and pose estimation!
- ◆ Kernel descriptors are a powerful feature for extracting gradient, shape, and color information from RGB and depth images.
- ◆ Our approach has been applied to an interactive LEGO playing scenario that was shown live at CES 2011

Questions?
Thanks for your attention!

RGB-D Recognition: Demo

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Category recognition

RGB-D Recognition: Demo

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Online Learning

RGB-D Recognition: Demo

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Category recognition

Object Hierarchy (WordNet/ImageNet)

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