机器人操控中的计算机视觉

Computer Vision in Robot Manipulation

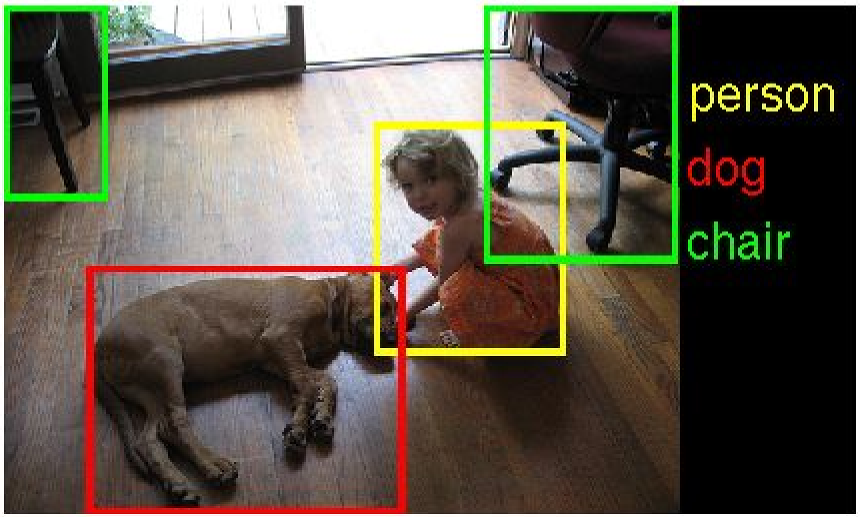
Dorabot Inc. 蓝胖子机器人

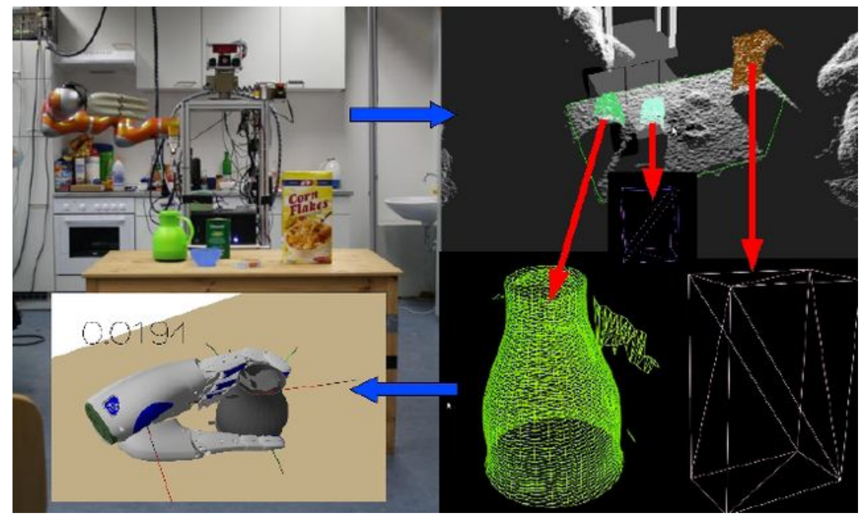
CTO 张浩

Table of Contents

蓝胖子机器人 dorabot

What’s the difference? 2D V.S. 3D

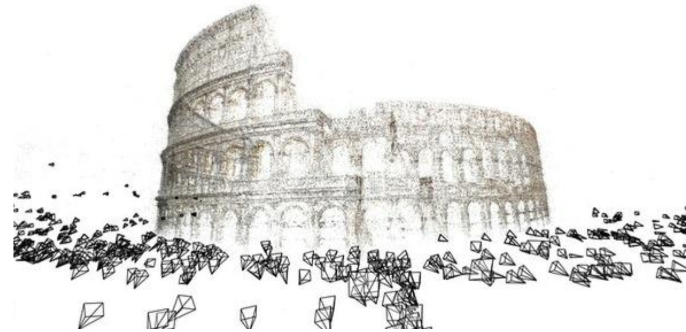


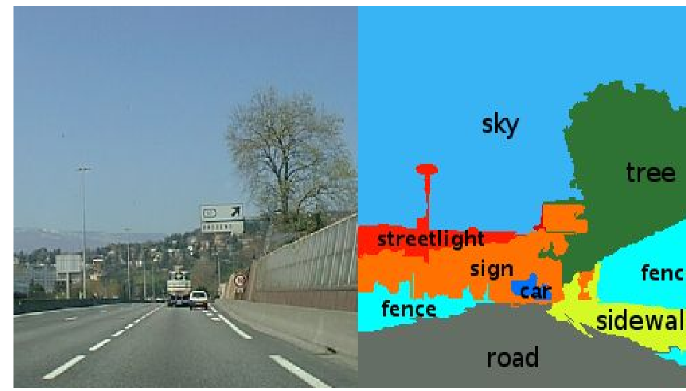


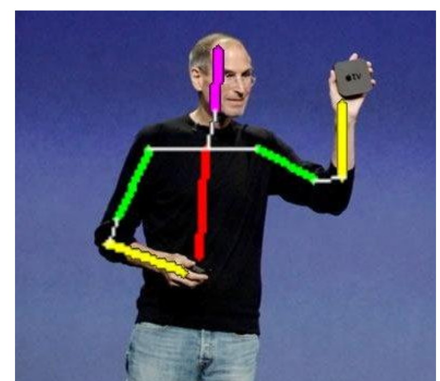
2D V.S. 3D

蓝胖子机器人
dorabot

Task Focus







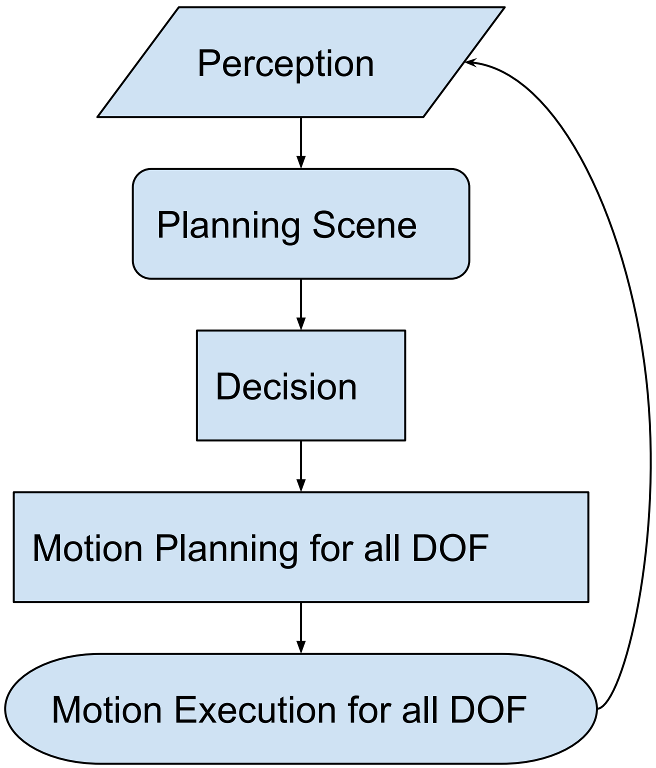
蓝胖子机器人
dorabot

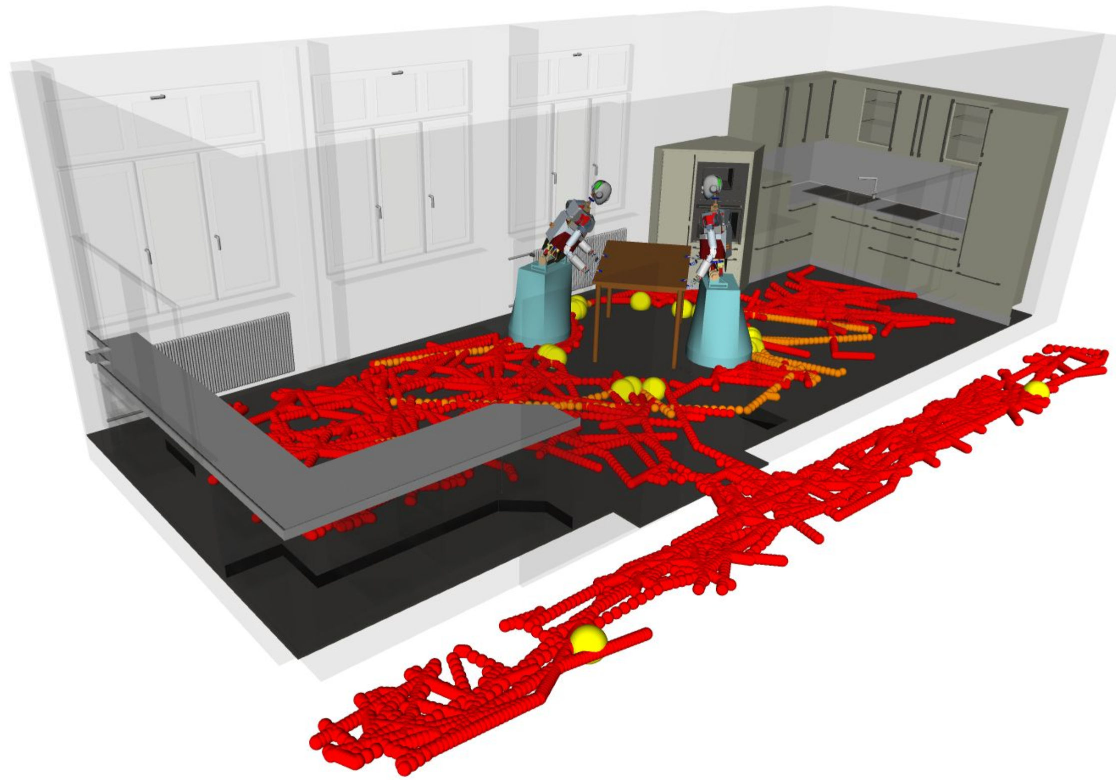
General method v.s. Tailored method

Computer Vision tries to solve problems in its most general form.

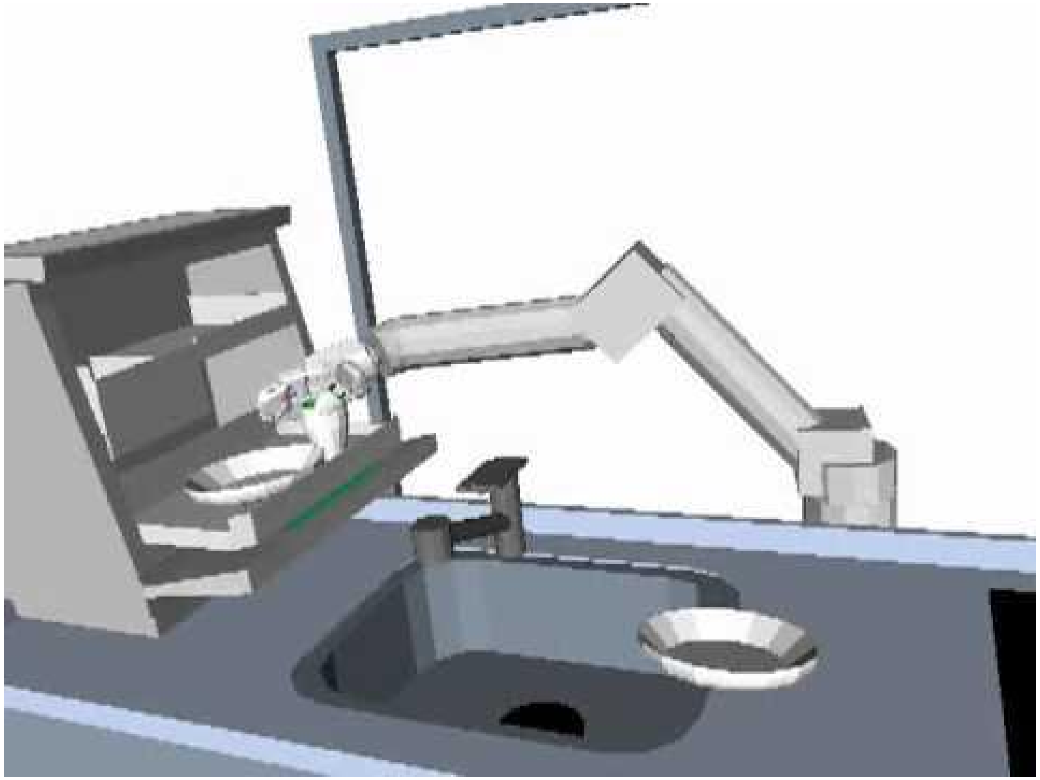
Different robot manipulation tasks have different assumptions that suit for different combinations of CV methods, most probably with some small innovations here and there. A tailored solution is usually required.

How does robot interact with the physical world?





Planning Scene



Typical Vision Tasks in Robot Manipulation

Environment reconstruction: build planning scene

Self-localization: localize robot in such scene

Object pose estimation: supply information in scene

Visual servoing: cope with error in vision & tasks require real-time reaction

RGBD-SLAM

Mapping and localizing do not have to happen simultaneously, but they have to be 3D.

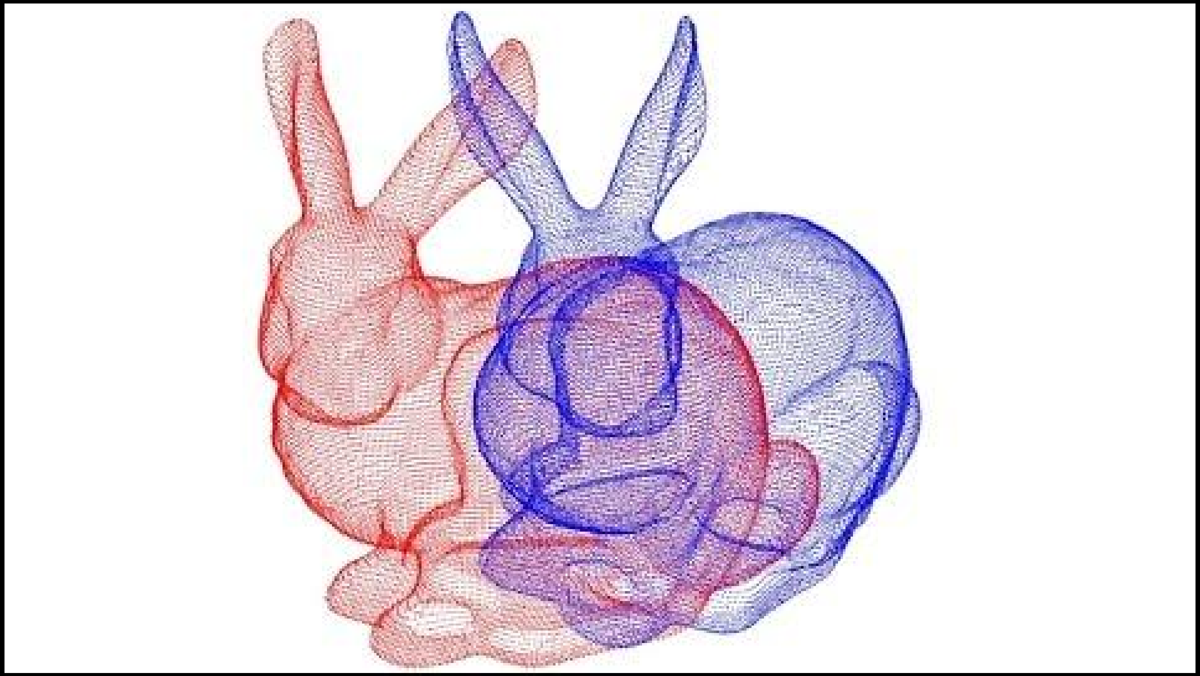
Object Pose Estimation

Goal: Full 6D object pose

Approach 1 : Align 3D CAD model to 3D point cloud. ICP(iterative closest point) is frequently used.

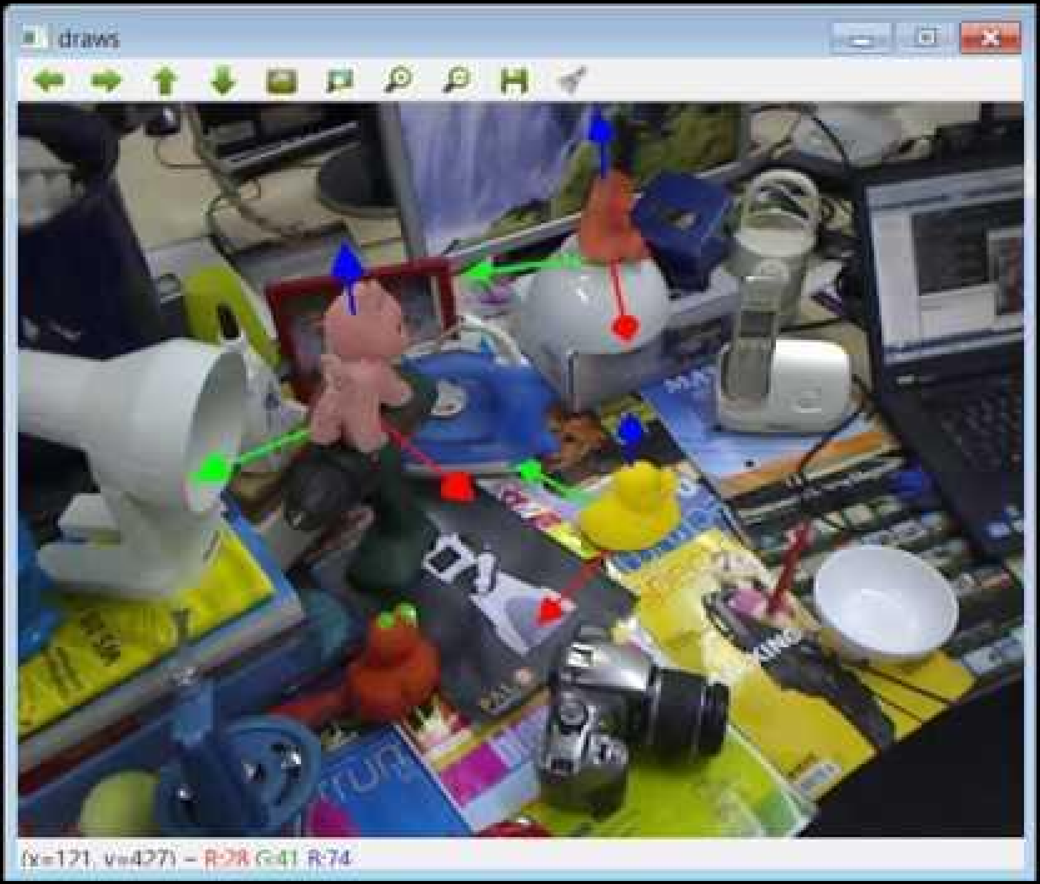
Approach 2: 2D descriptors (SIFT, SURF etc.) , 3D descriptors (FPFH), or simpler 2D or 3D features (color gradient, edge, normal) based correspondences. MOPED, LINEMOD roughly falls into this category.

ICP



MOPED

LINEMOD



LINEMOD

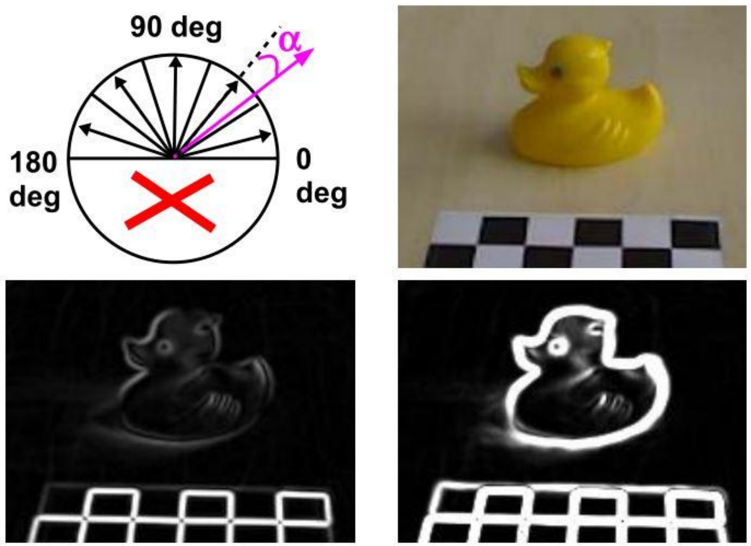


Fig. 3: **Upper Left:** Quantizing the gradient orientations: the pink orientation is closest to the second bin. **Upper right:** A toy duck with a calibration pattern. **Lower Left:** The gradient image computed on a gray value image. The object contour is hardly visible. **Lower right:** Gradients computed with our method. Details of the object contours are clearly visible.

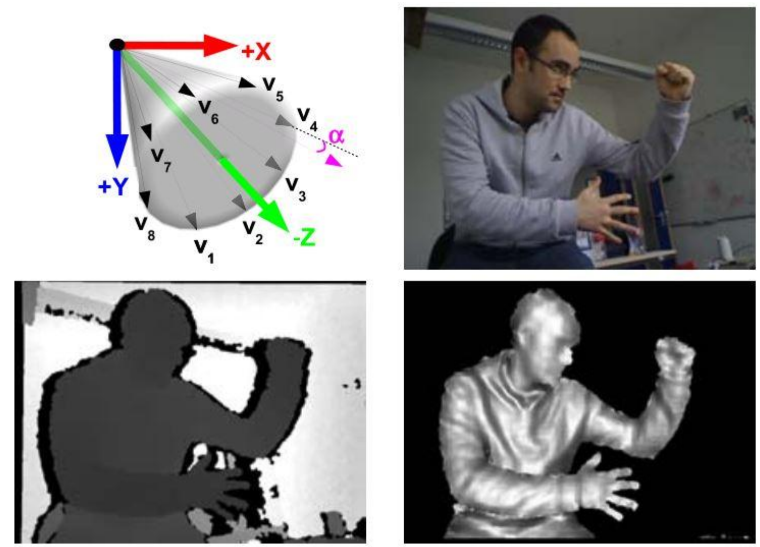


Fig. 8: **Upper Left:** Quantizing the surface normals: the pink surface normal is closest to the precomputed surface normal v_4. It is therefore put into the same bin as v_4. **Upper right:** A person standing in an office room. **Lower Left:** The corresponding depth image. **Lower right:** Surface normals computed with our approach. Details are clearly visible and depth discontinuities are well handled. We removed the background for visibility reasons.

LINEMOD

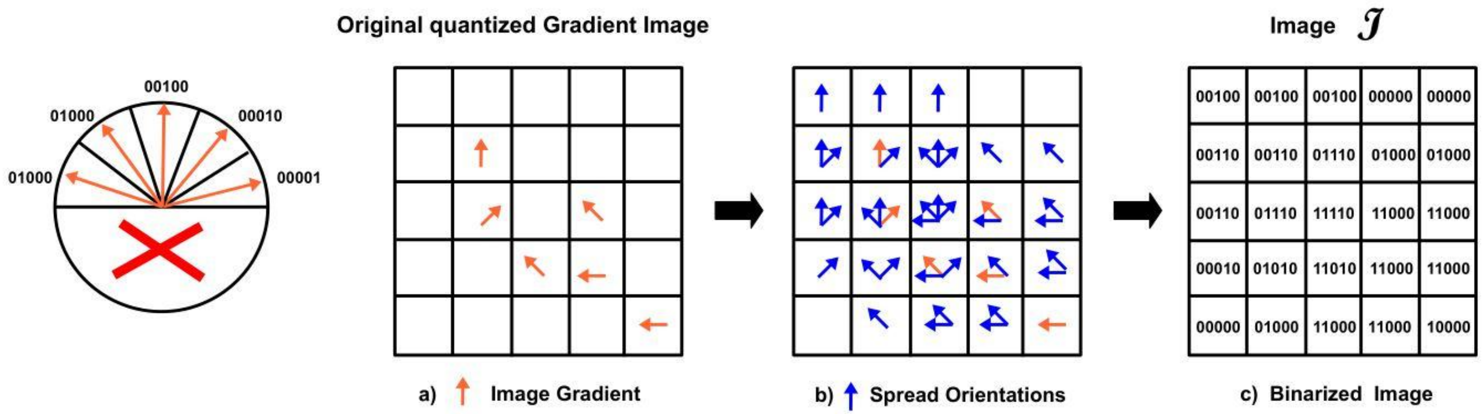


Fig. 4: Spreading the gradient orientations. **Left:** The gradient orientations and their binary code. We do not consider the direction of the gradients. **a)** The gradient orientations in the input image, shown in orange, are first extracted and quantized. **b)** Then, the locations around each orientation are also labeled with this orientation, as shown by the blue arrows. This allows our similarity measure to be robust to small translations and deformations. **c)** $\mathcal{J}$ is an efficient representation of the orientations after this operation, and can be computed very quickly. For this figure, $T = 3$ and $n_o = 5$. In practice, we use $T = 8$ and $n_o = 8$.

LINEMOD

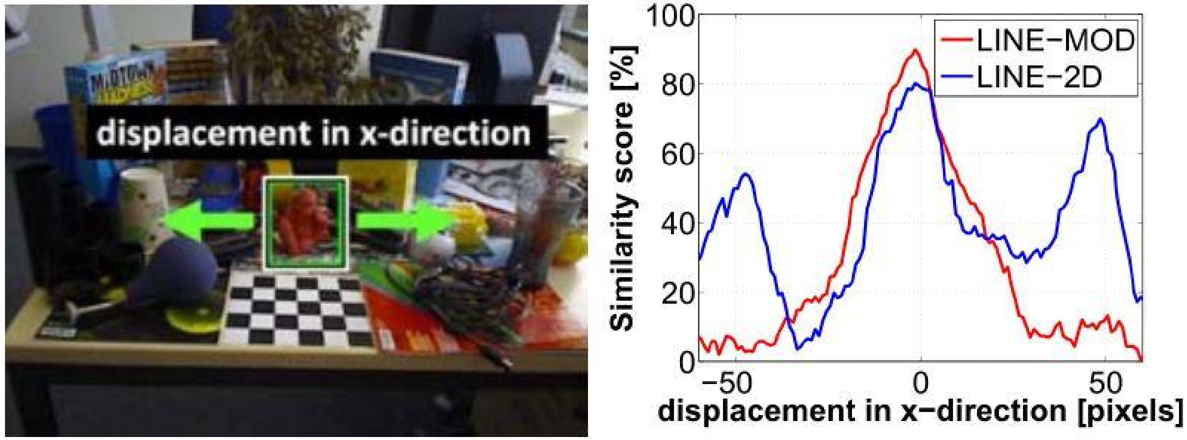


Fig. 9: Combining many modalities results in a more discriminative response function. Here we compare LINE-MOD against LINE-2D on the shown image. We plot the response function of both methods with respect to the true location of the monkey. One can see that the response of LINE-MOD exhibits a single and discriminative peak whereas LINE-2D has several peaks which are of comparable height. This is one explanation why LINE-MOD works better and produces fewer false positives.

None of the methods are universal!

Good Toy Problems: Robot Competitions

Amazon Picking Challenge : Fully autonomous, focus on pick & place

DARPA Robotic Challenge : Remote control with unstable network connection

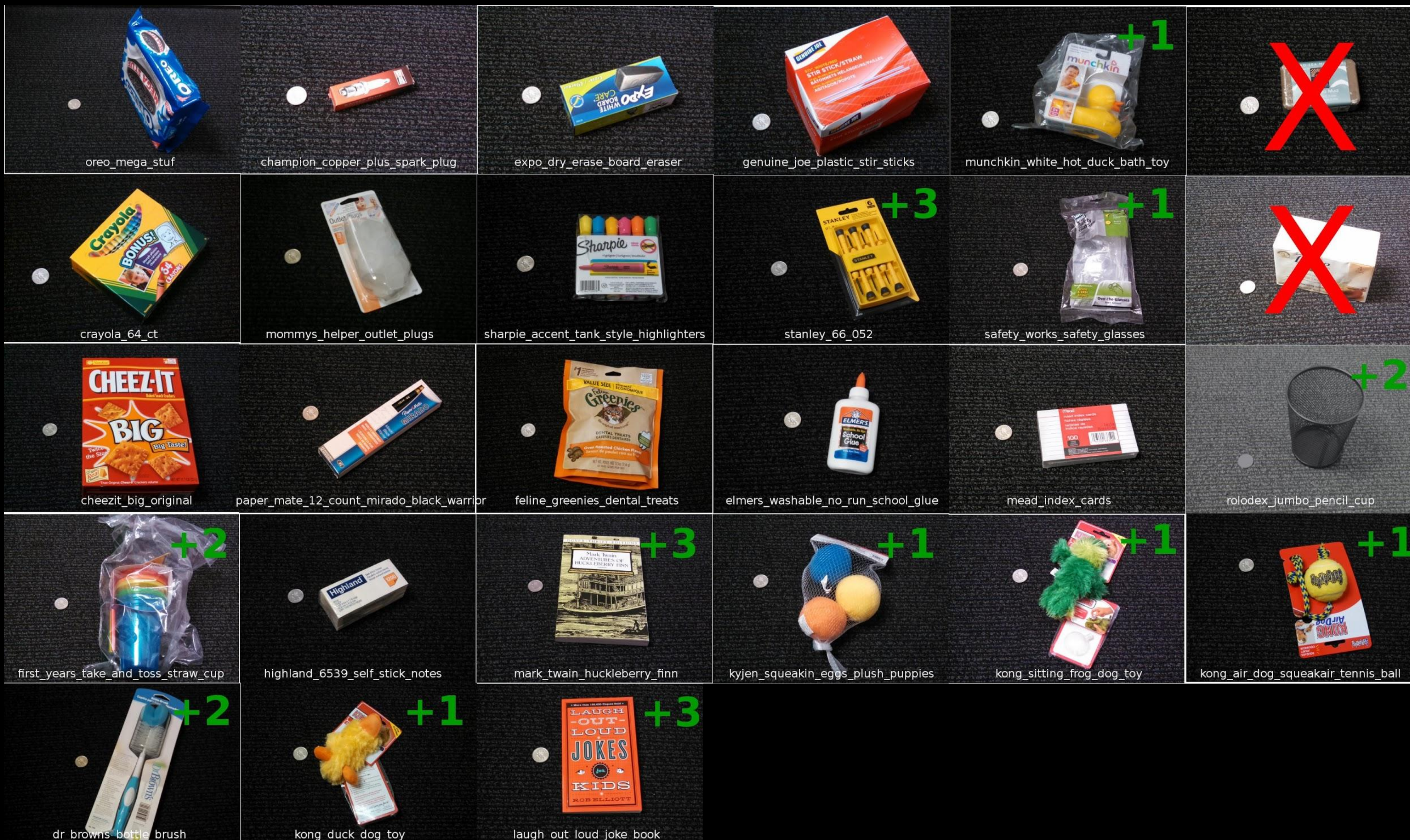
Robocup@Home : Fully autonomous, with various kinds of tasks including manipulation

Robocup@Work : Fully autonomous, focus on mobile manipulation of simple shaped workpieces

Robotic Grasping and Manipulation Competition : Different tracks with different automation level, focusing on manipulation capability of robotic hand

Amazon Picking Challenge

Amazon Picking Challenge



Amazon Picking Challenge

Cluttered environment: multiple objects in narrow spaces

Occlusion: Limited camera position

Missing data: reflective/transparent/meshed surfaces

Small objects: Few data points

Deformable objects: model alignment doesn’t work

Speed: Time limit for overall task

Uncontrolled lighting

蓝胖子机器人 dorabot

Probabilistic Multi-Class Segmentation

Probabilistic Multi-Class Segmentation

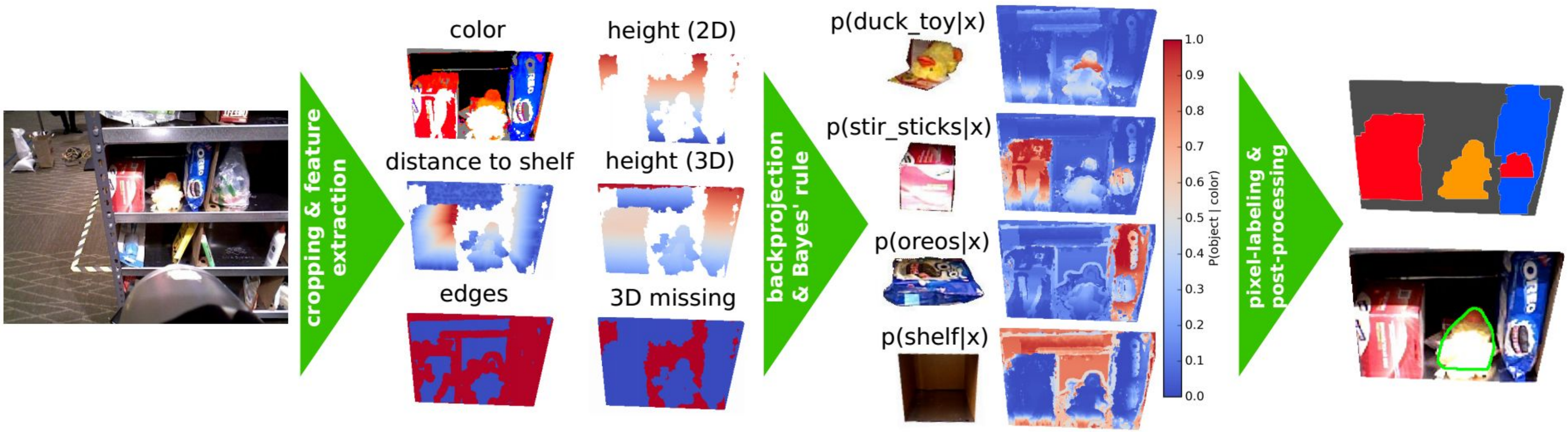


Fig. 2. Overview of the multi-class segmentation phase of our approach

蓝胖子机器人 dorabot

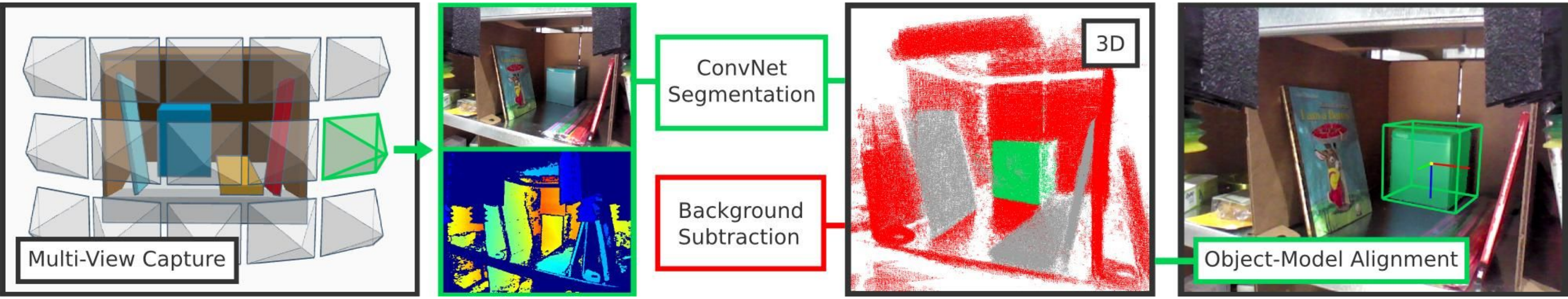
Jonschkowski, R., Eppner, C., Höfer, S., Martín-Martín, R., & Brock, O. (2016). Probabilistic Multi-Class Segmentation for the Amazon Picking Challenge. In IEEE/RSJ International Conference on Intelligent Robots and Systems.

Probabilistic Multi-Class Segmentation

Fig. 3. Segmentation results during the APC run; the green line outlines the segments returned by our method; all segments lie on the correct objects; mean precision: 91%, mean recall: 73%, $F_{0.5}$ score: 0.864

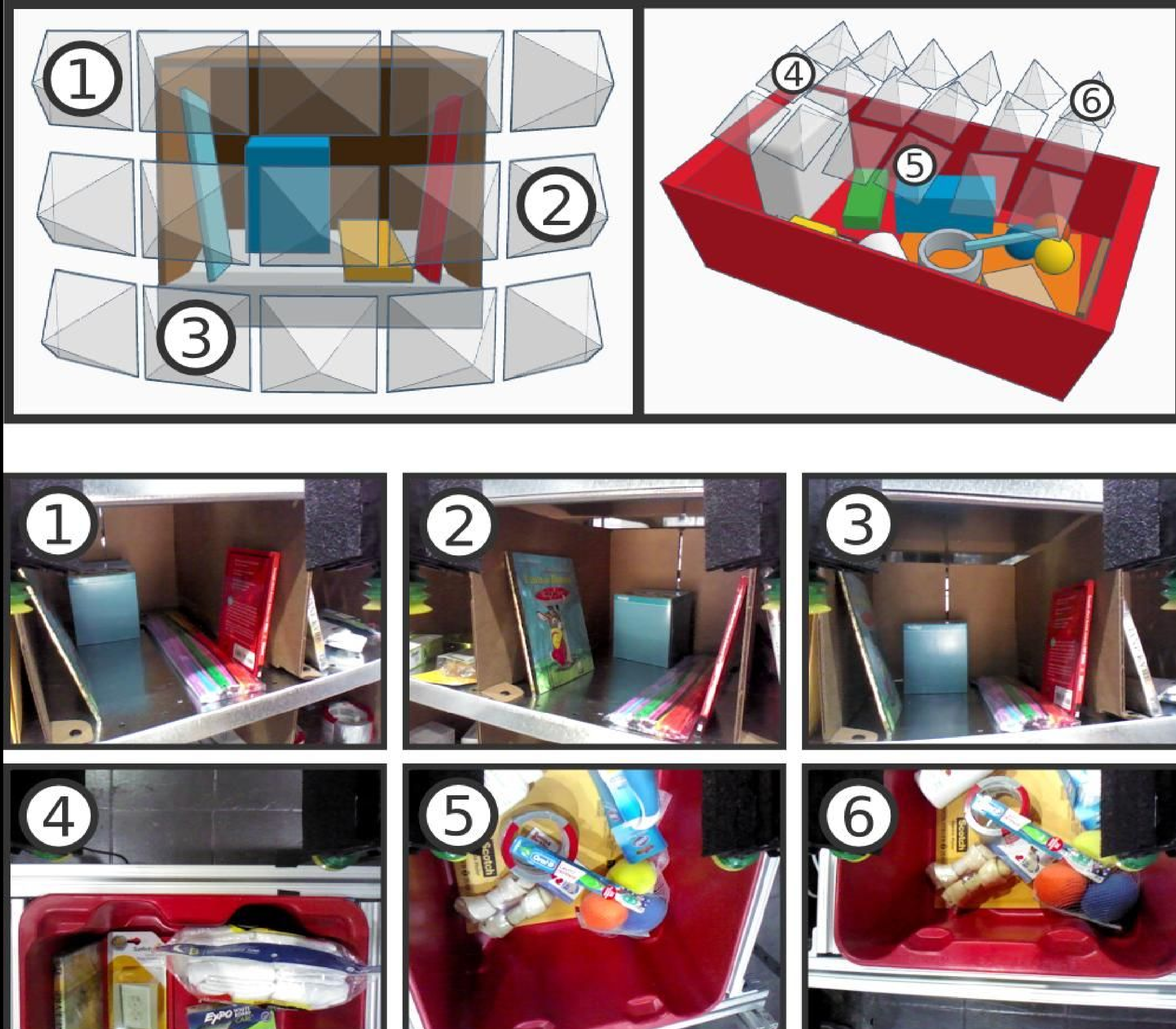
Multi-view Self-supervised Deep Learning for 6D Pose Estimation

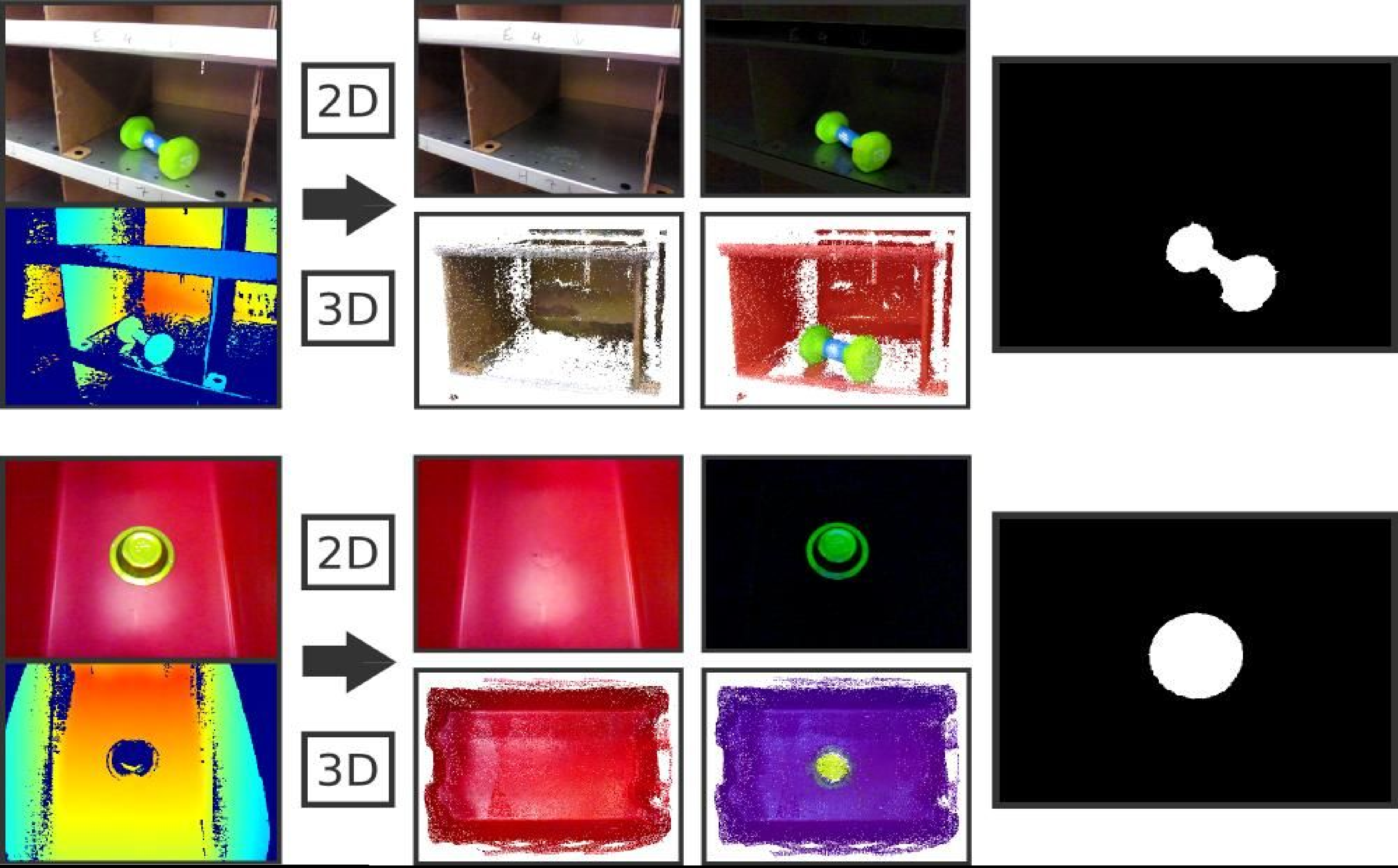
Multi-view Self-supervised Deep Learning for 6D Pose Estimation



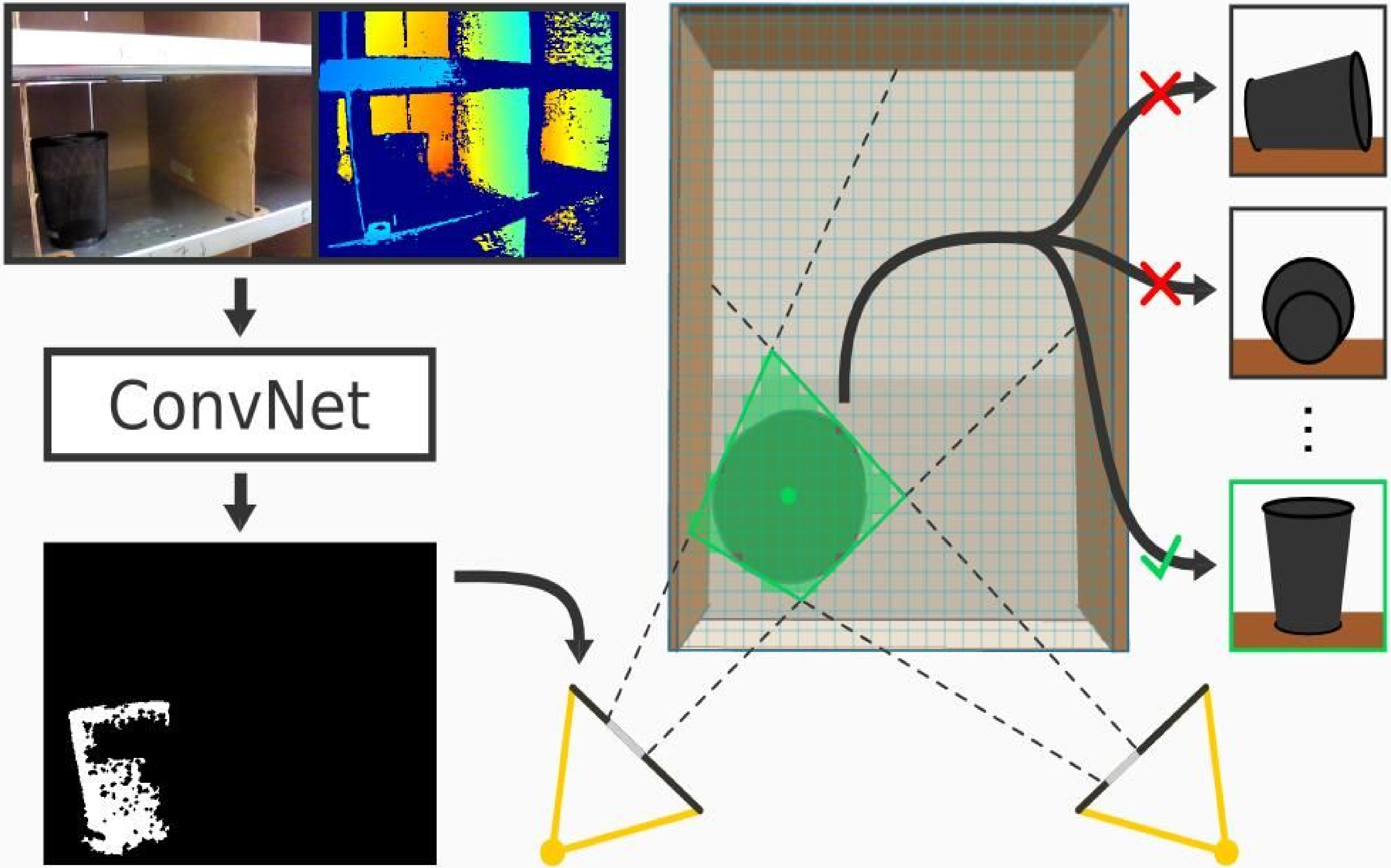
蓝胖子机器人 dorabot

Zeng, A., Yu, K.-T., Song, S., Suo, D., Walker, E., Rodriguez, A., & Xiao, J. (2016). Multi-view Self-supervised Deep Learning for 6D Pose Estimation in the Amazon Picking Challenge. Retrieved from http://arxiv.org/abs/1609.09475


1
2
3
4
5
6
1
2
3
4
5
6



2D
3D
2D
3D


ConvNet

DoraPicker

DoraPicker

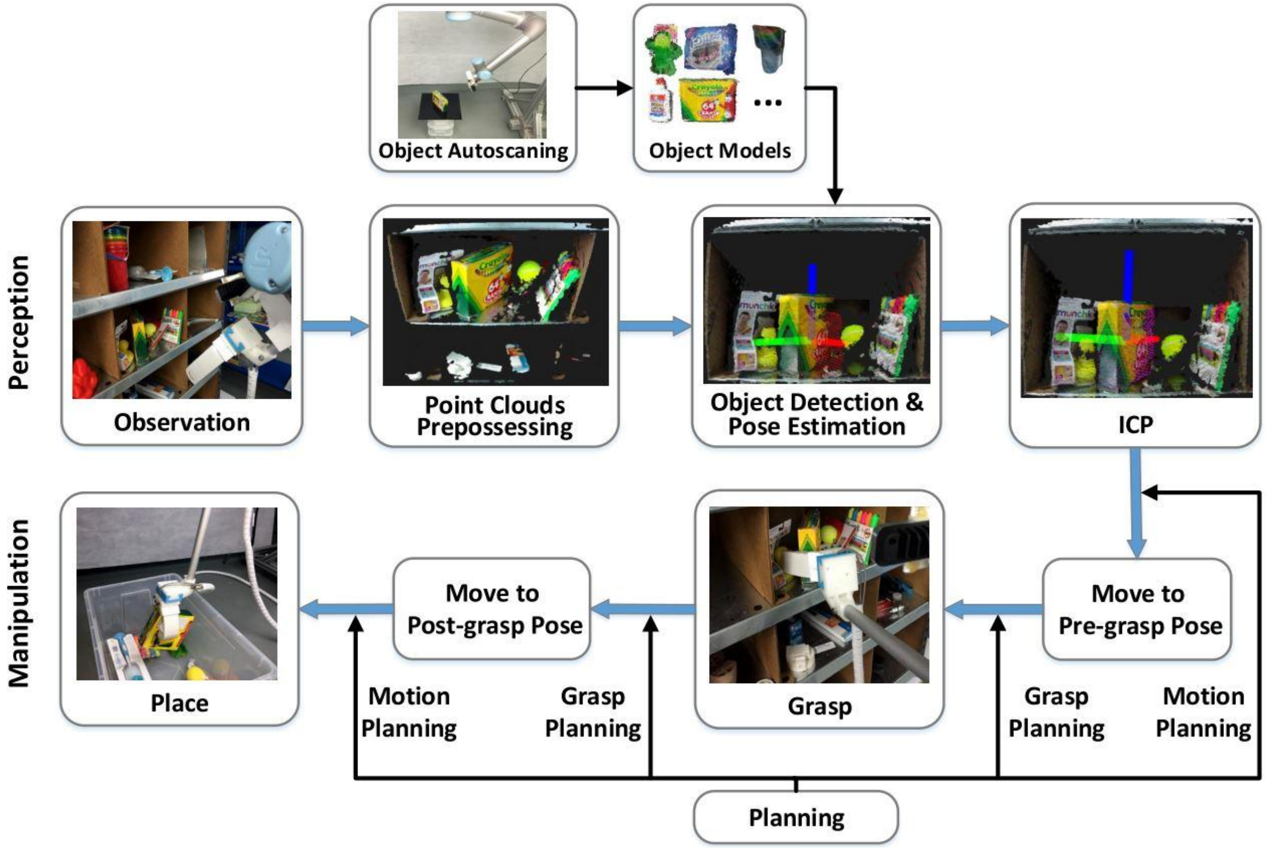
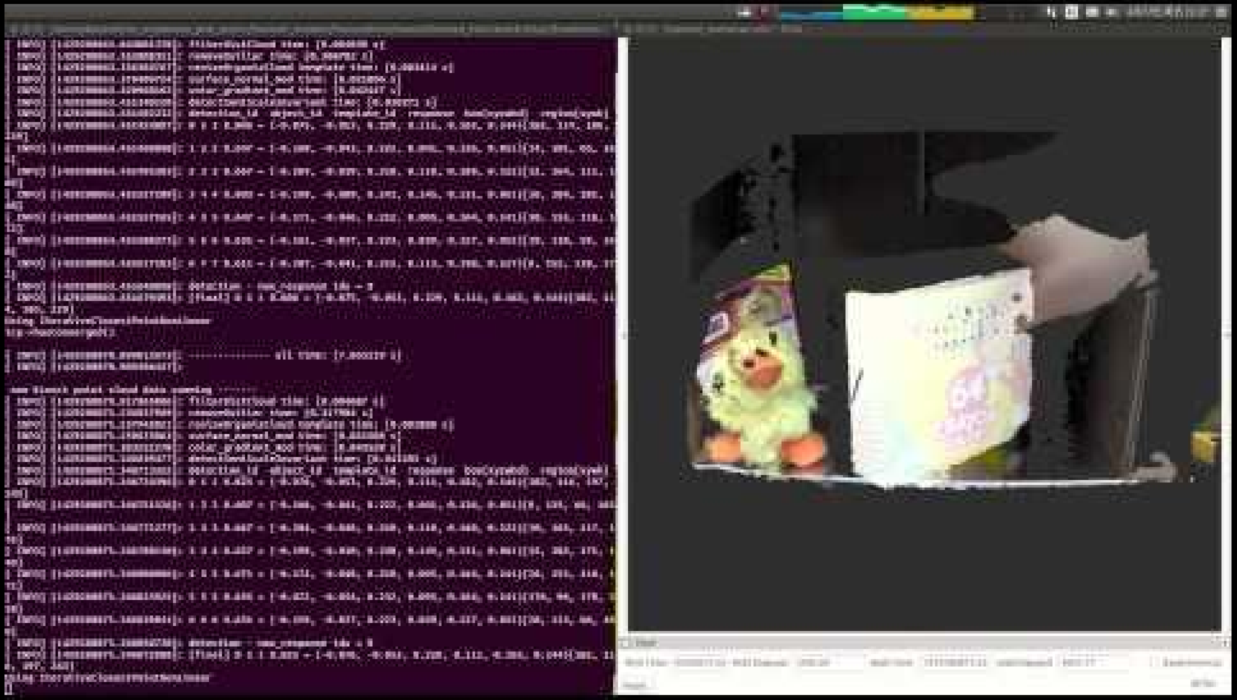


Fig. 3. The software architecture of DoraPicker.

Zhang, H., Long, P., Zhou, D., Qian, Z., Wang, Z., Wan, W., … Pan, J. (2016). DoraPicker: An Autonomous Picking System for General Objects, 10. http://doi.org/10.1109/COASE.2016.7743473

DoraPicker (LINEMOD+ICP)



Robotic Grasping and Manipulation Competition

Book in preparation: Robotic Grasping and Manipulation Competition, Springer, 2017.

DataSets

http://rll.berkeley.edu/bigbird/

http://www.pracsyslab.org/rutgers_apc_rgbd_dataset

http://www.cs.princeton.edu/~andyz/apc2016

Enough toy problem, how about real-world problem?

Dorabot Mobile Manipulator: Warehouse demo

Looking for challenges?

Join us to work on real-world problems!

dream@dorabot.com

关注蓝胖子公众账号

Thank You!

联系方式 Contact: info@dorabot.com

网站 Website: http://www.dorabot.com