Efficient Surface and Feature Estimation in RGBD

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RGB-D Workshop on 3D Perception in Robotics
at the European Robotics Forum
Västerås, April 2011

Intelligent Autonomous Systems

Introduction

Motivation:

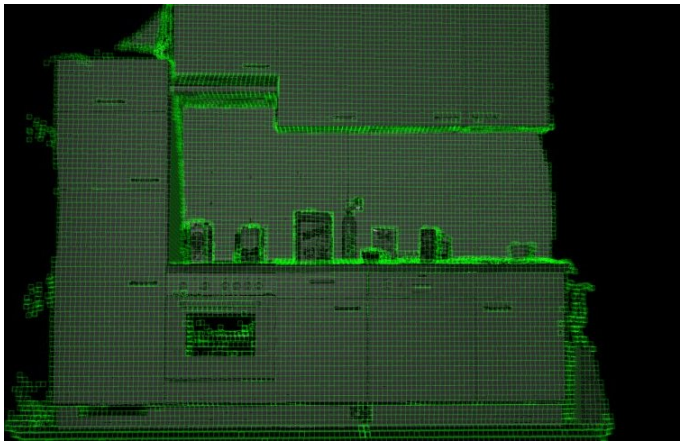
- High frame-rate and RGB-D allow multi-view classification or dynamic scenes even if processing methods are fast
- Vision has a long history, but there is no standard geometric feature
- Used 3D is often an image feature on the depth image

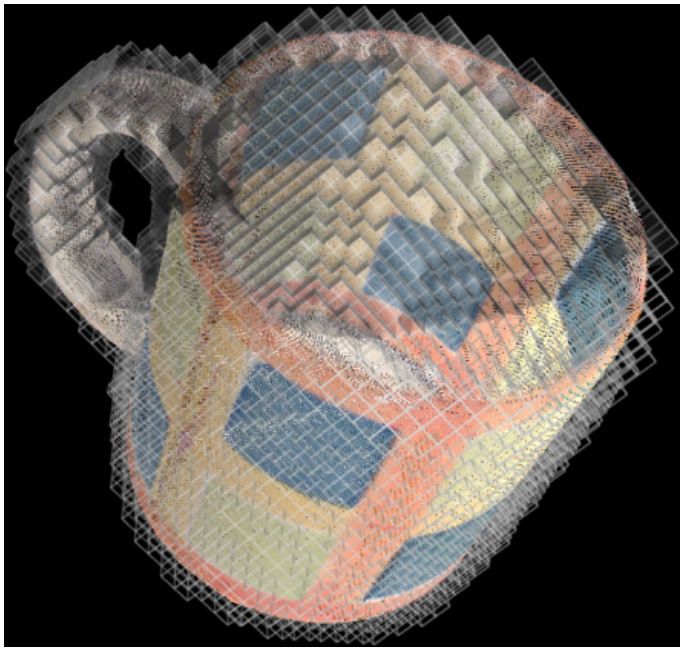
Goal:

- We are interested in geometry, not points, and in a compact way (PFH versions for example are high-dimensional)
- Reuse as much as possible: voxelization, smooth surface reconstruction, etc.
- Combination with color that is very integrated and allows part based detection

Getting Local Neighborhoods

Advantages of Voxelization



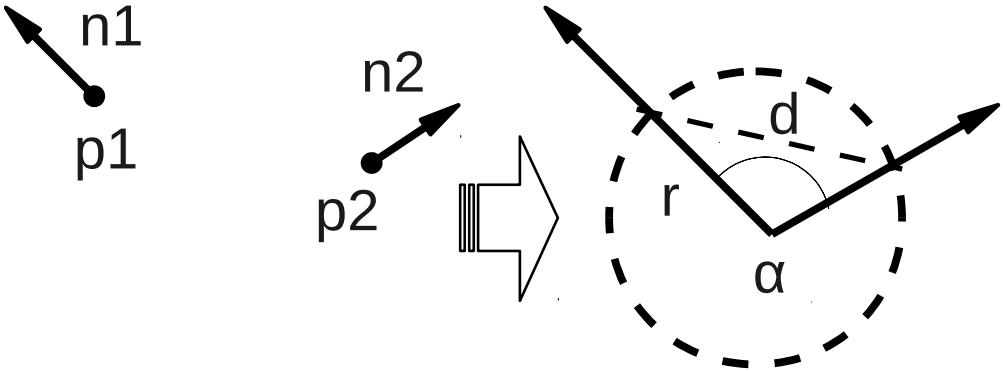


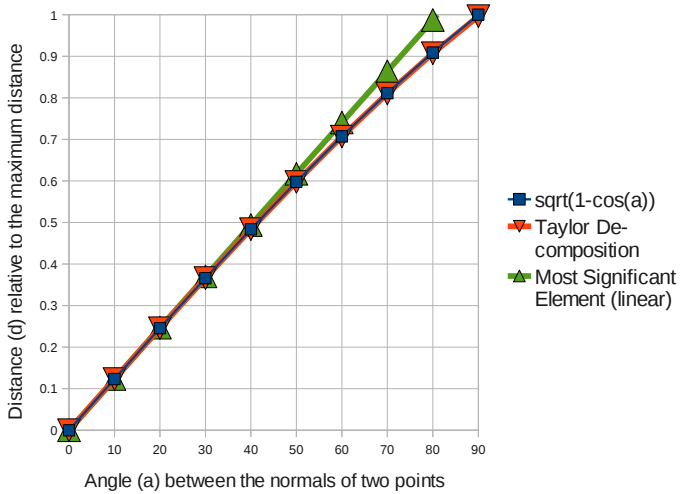
- Pixel window is good, but voxelization assures spacial closeness
- Supports e.g. occupancy labels: mapping, collision avoidance, visibility checks
- Speeding up model fitting
- PCL: added way to retrieve points of a cell and its neighbors to downsampling
- Point-wise features can be parallelized but voxel-wise is even faster

Radius-based Suface Descriptor (RSD)

Theory and Approximation

- Estimate minimum and maximum curvature radius from angle/distance pairs:





Near-linear relation between distance and angle: the radius [m]

$$d_{(\alpha)} = \sqrt{2}r\sqrt{1 - cos(\alpha)} \Rightarrow d_{(\alpha)} = r\alpha + \frac{r\alpha^3}{24} + O(\alpha^5) \Rightarrow d = r \cdot \alpha$$

[IROS2010:] Marton et al., General 3D Modelling of Novel Objects from a Single View

Radius-based Surface Descriptor (RSD)

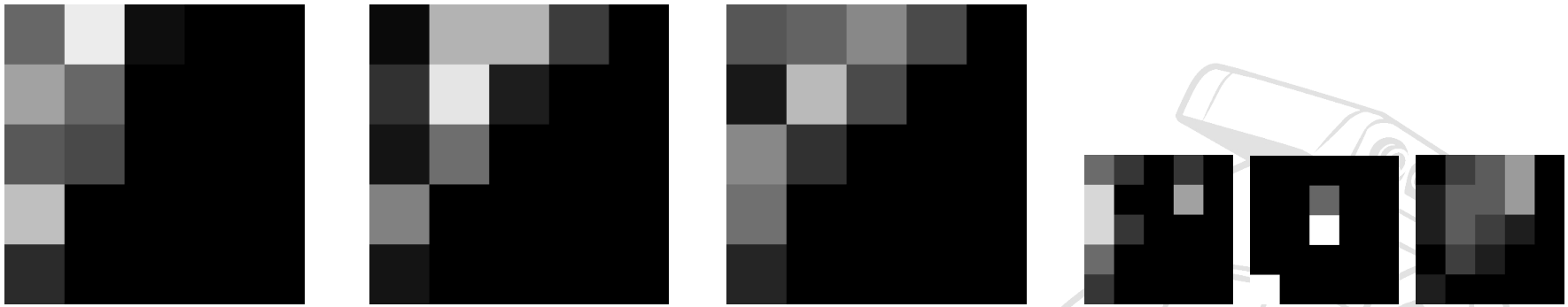
Principle Radii

- Local variation of normal angles by distance (similar to PFH and “spin images with normals”):

Synthetic Data

plane *sphere* *sphere side* *corner* *cylinder* *cylinder top* *cylinder side* *edge* *handle*

Real Data

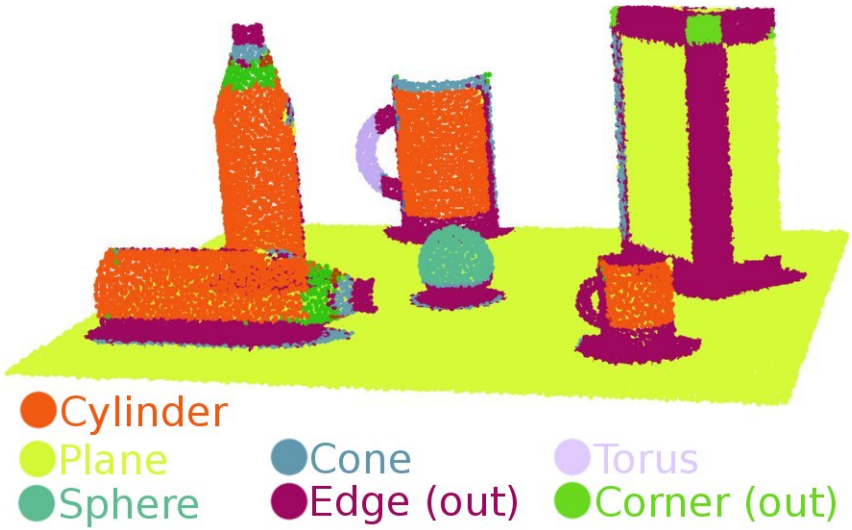


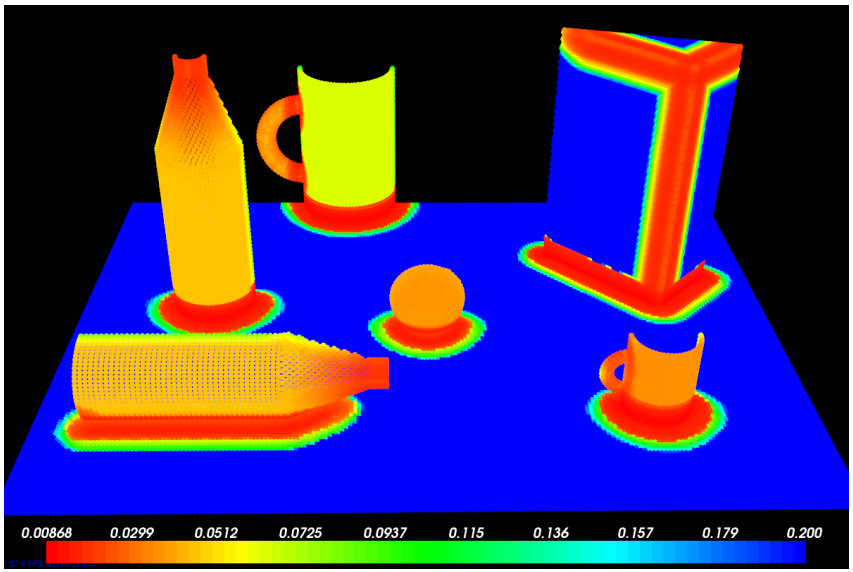
small cylinder *medium cylinder* *big cylinder* *handle1* *handle2* *handle3*

The tilt angles of the lines starting from bottom left corner correspond to the physical radii: smallest tilt that still covers occupied cells to the min. radius, while the biggest to the max.

Radius-based Surface Descriptor

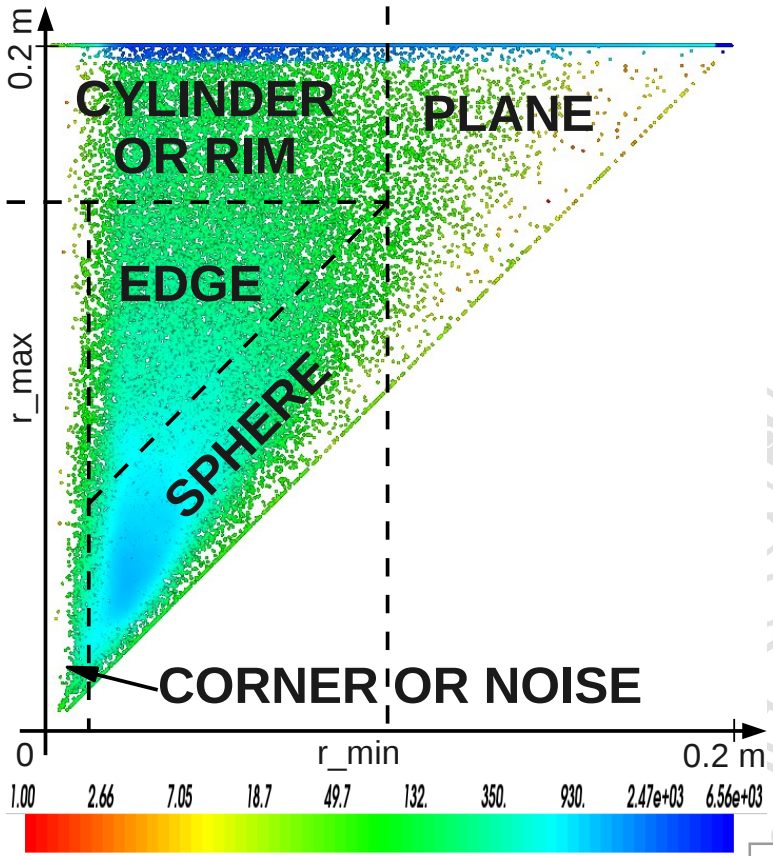
Comparison to (F)PFH





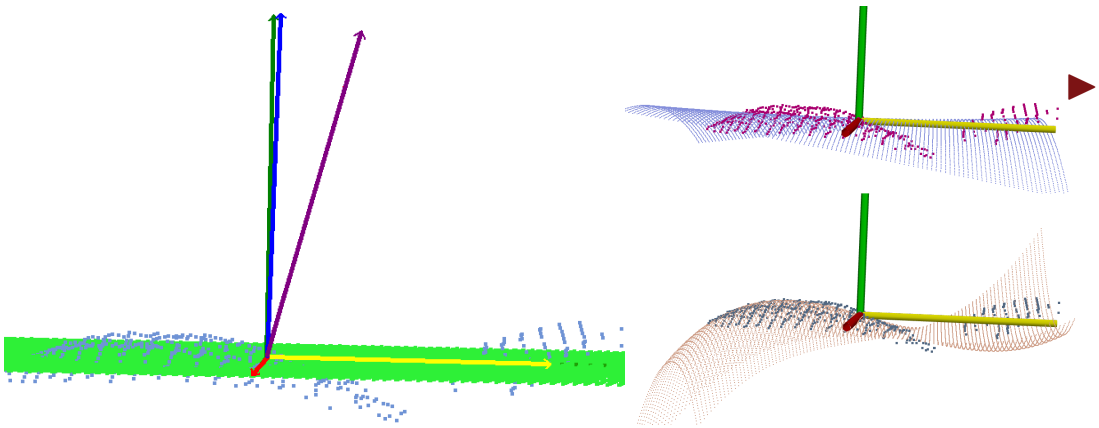
Cheaper and more descriptive with only 2 values

- No learning needed due to physical meaning:



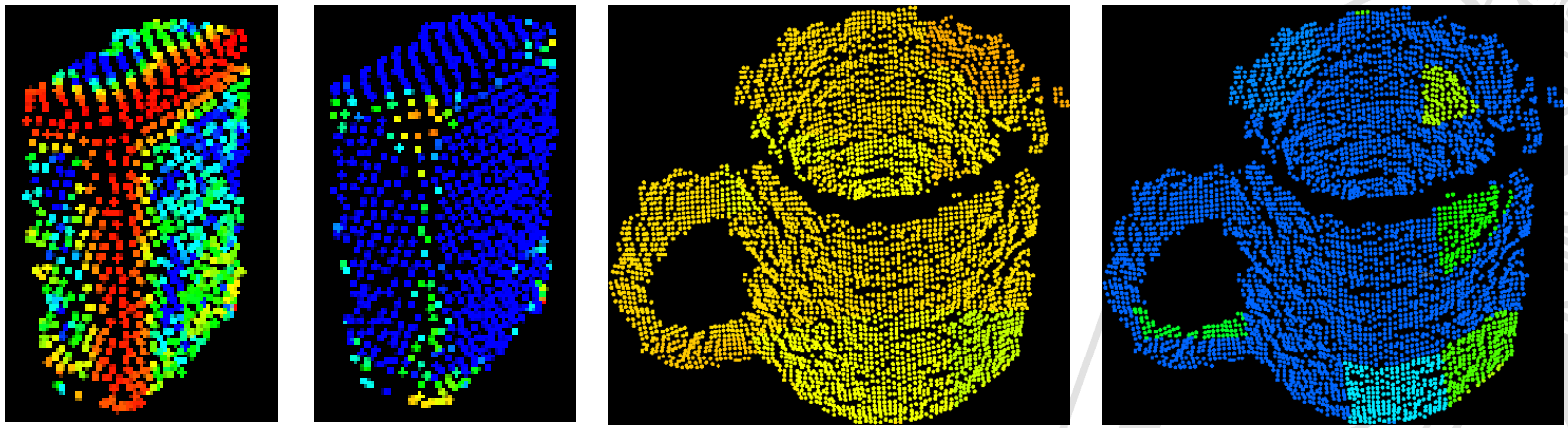
Integrating Computational Steps

Smoothing, Normal Estimation and Surface Radii at once, per Voxel



- Idea: use points in voxels to smooth, downsample, estimate normals and radii at once based on polynomial approximation.

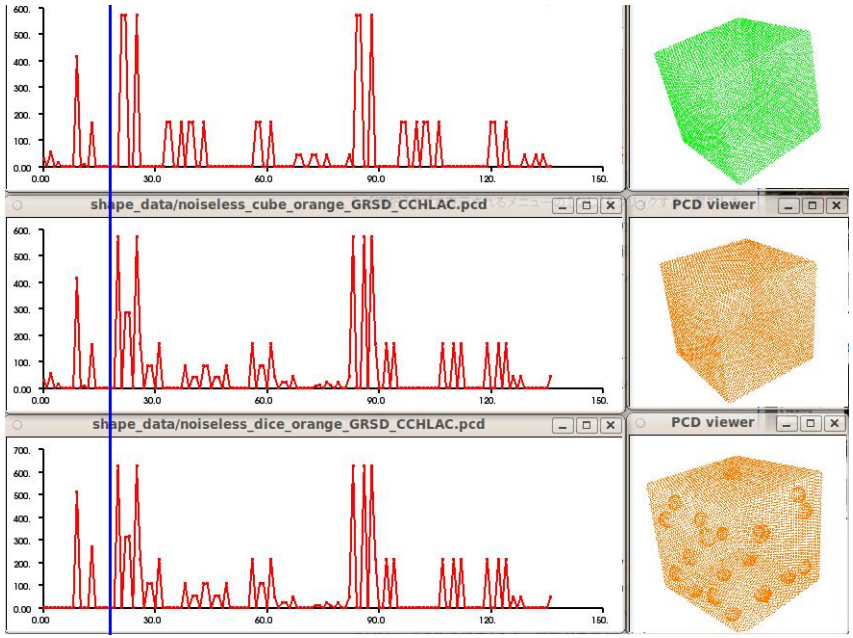
- Results on data coming from Kinect (minimum and maximum radii for a box and a mug):



Voxel-based RGB-D Object Feature

Advantage of Considering RGB and Depth

- RGB and 3D information are discriminative in different dimensions (see monochrome cube and dice point clouds)
- The question is how to combine them efficiently into the same framework

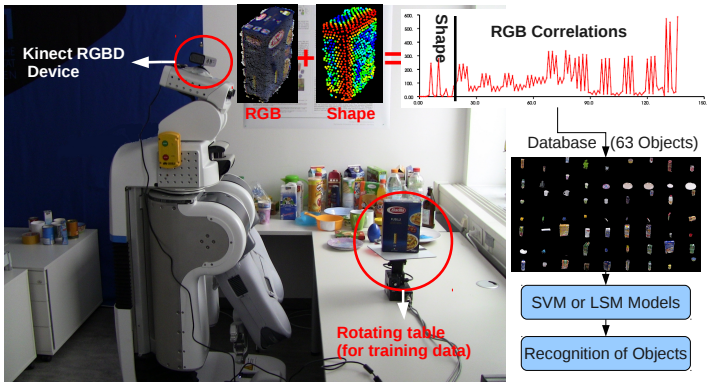


Work done together with Asako Kanezaki.

- Combination of GRSD and $C^3 - HLAC$
- Voxelized point cloud clusters
- Adjacency voxels statistics
- (Normalized) Histogram-based algorithm

Voxel-based RGB-D Object Feature

Setup and Early Results



- The feature is additive, so objects can be recognized based on their parts or using a sliding box
- Feature extraction takes 57 μs per point on a single core
- Initial classification results on 63 objects (many of them of the same type or brand) using SVM: 76.4% (0.05 s per object)
- More training and labeled testing data is needed (thanks Kevin!)
- Better classification: learning views separately but classifying objects ($+12\%$ in similar setup)

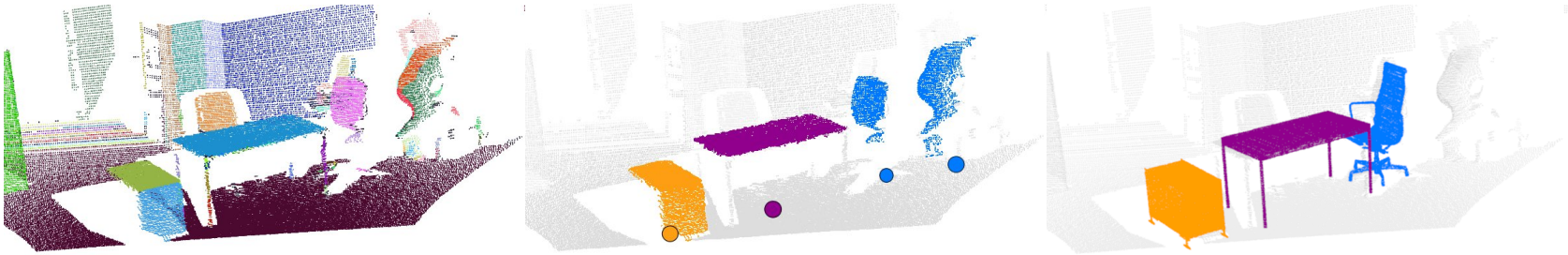
Work done together with Asako Kanezaki.

Conclusions

Advantage of Considering RGB and Informative Depth

Efficient estimation of the physical radius of local surface:

- uses in CAD matching, model fitting and segmentation
- more descriptive features (together with RGB)



Mozos, Marton, Beetz: “Using Web Catalogs to Locate and Categorize Unknown Furniture Pieces in 3D Laser Scans”, Robotics & Automation Magazine (in press)

Integration with RGB to obtain a global feature:

- efficient integration of well matched RGB and 3D features

Futur work:

- deeper integration and improving the geometric part (e.g. including “voxelized“ VFH or others from PCL)
- quantitative comparisons to find strengths and weeknesses

Q&A

Thanks!

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`http://ias.cs.tum.edu`

Point Cloud Library:
`http://pointclouds.org`

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