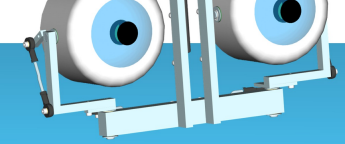


Towards Object Part Detection with a Range Camera

Stefan Gächter and Roland Siegwart

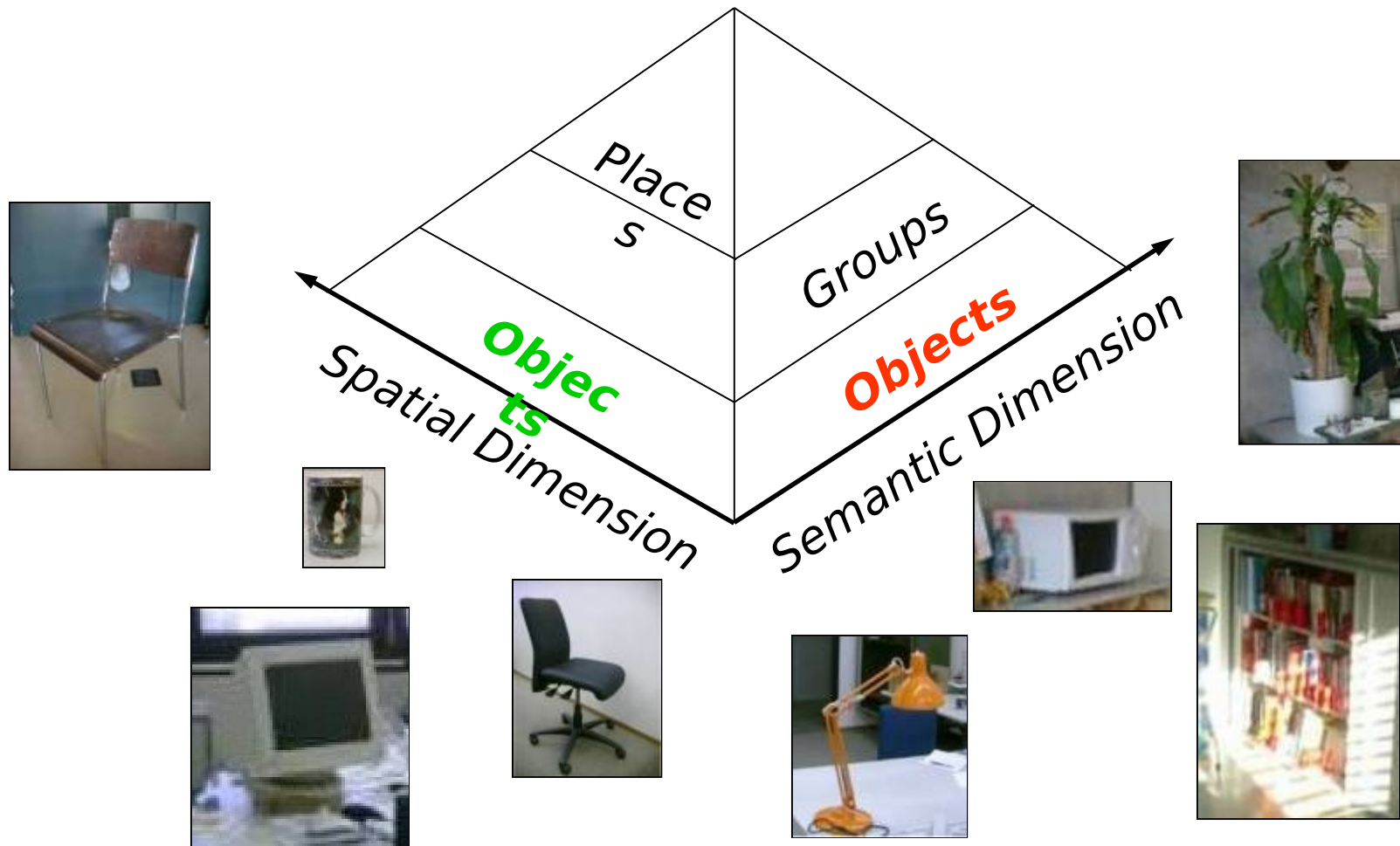
ETHZ-ASL

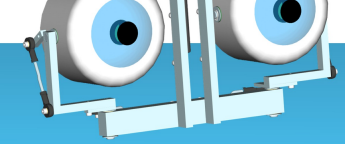
Robots@Home, May 2007



Motivation

Object Based Representation

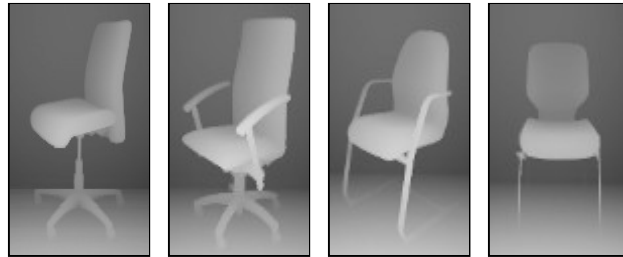




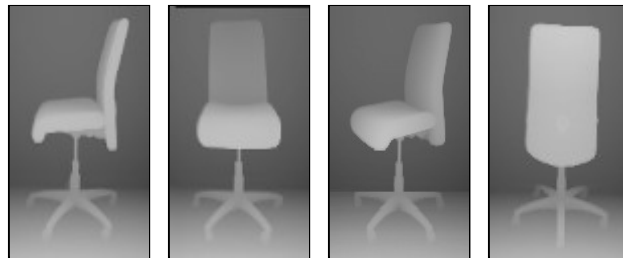
Motivation

Object Classification

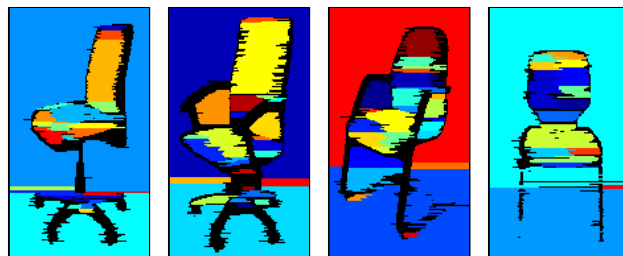
Challenges in Real World Environment



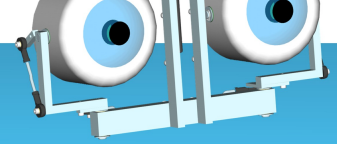
Variation in the Object Class



Different Views of Same Object



Uncertainty of Sensory Data and Preprocessing Errors



Motivation

Object Classification

- **Object's Functionality for Representation**

Object class is generalizable by object's functionality (affordance).

Example: Chair is a chair because it is a "sittable" object.

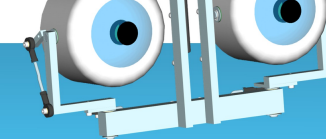
Gibson, J.J., The Theory of Affordances, in: Shaw, R. and Bransford, J. (ed.), Perceiving, Acting, and Knowing: Toward an Ecological Psychology, Lawrence Erlbaum Associates, Hillsdale, New Jersey, pp. 67-82, 1977.

- **Functionality for Classification**

Semantic attached to *structural elements*.

Property inferred from *action*.

Chaigneau, S.E. and Barsalou, L.W., The Role of Function in Categories, Theoria et Historia Scientiarum, Reprinted in the Polish Journal, Kognitywistyka i Media w Edukacji / Cognitive Science and Media in Education, (in press).



Motivation

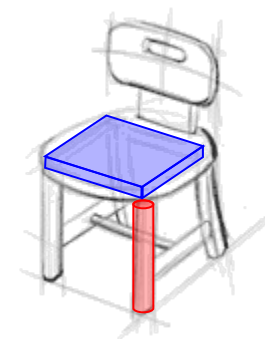
Function Based Approaches

Generic Object Recognition using Form and

Stark L. and Bower K., **Generic Object Recognition using Form & Function**, Series in Machine Perception and Artificial Intelligence, World Scientific Publishing, 1996.

Probabilistic Geometric Grammars for Object

Aycina M. A., **Probabilistic Geometric Grammars for Object Recognition**, Master Thesis, Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, September 2005.

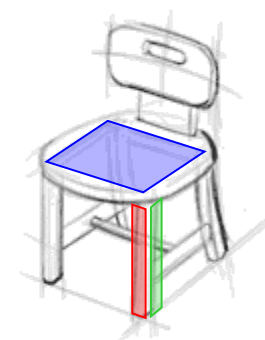


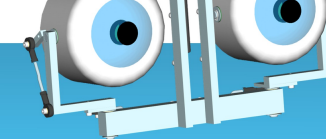
Object Classification by Functional Parts

Froimovich, G.; Rivlin, E. and Shimshoni, I., **Object Classification by Functional Parts**, Proceedings of the First Symposium on 3D Data, Processing, Visualization and Transmission , pp. 648-655 , 2002.

Function-Based Classification from 3D Data via Generic and Symbolic Models

Pechuk, M.; Soldea, O. and Rivlin, E., **Function-Based Classification from 3D Data via Generic and Symbolic Models**, Twentieth National Conference on Artificial Intelligence, AAAI-05, Pittsburgh, Pennsylvania, USA, July 9-13, 2005.



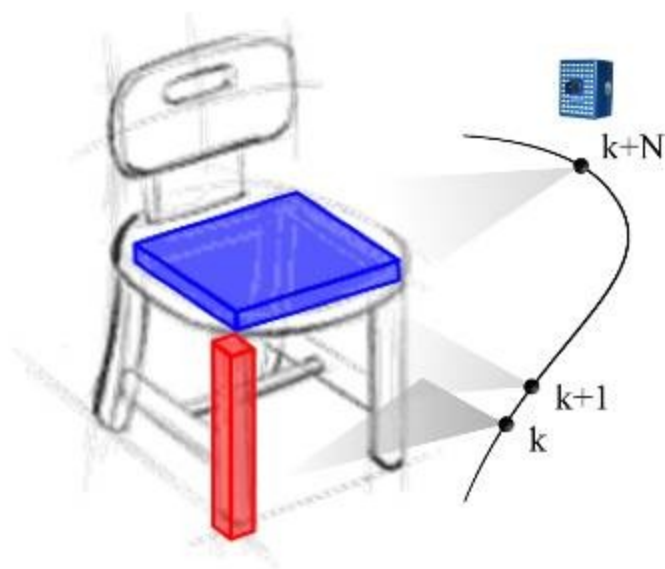


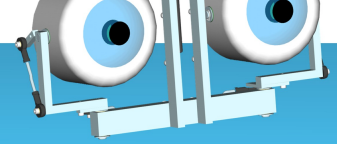
Approach

Object Part Detection

Function-based object classification is here structure-based object classification, function guides the segmentation of the object's structure.

- Object parts have to be detected.
- Object structure has to be verified.





Implementation

Range Camera

- **Advantages**

- Range as well as reflectance images

- Resolution of 124×160 pixels

- Frame rate of about 20Hz

- Small size

- **Disadvantages**

- Limited emitter radiation power

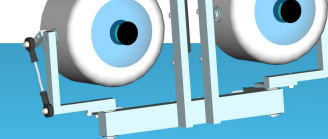
- Limited measurement range

- Interdependent measurement parameters /

- Limited calibration accuracy



SR 3000



Implementation

Limitations

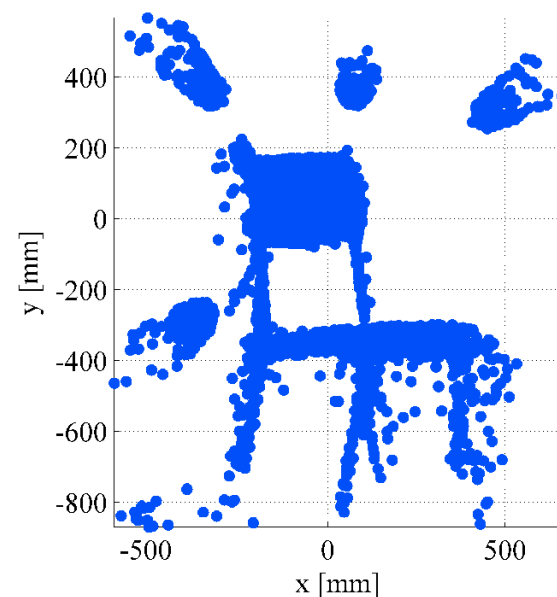
- **Calibration Limitations**

Calibration Limitations

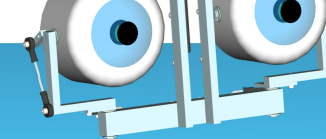
Noise of at least $\sigma = 1.5\text{cm}$

Outliers at depth
discontinuities

Distortion caused by
non-uniform illumination



3D Points
Cloud



Implementation

Experimental Setup

- **Sphere as Artificial Feature**

Gradient angle image.

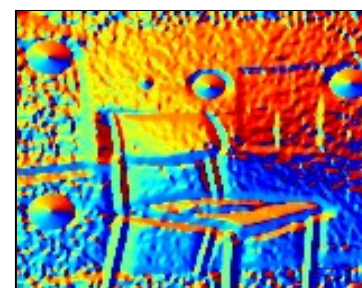
Template matching.

Sphere position tracking.

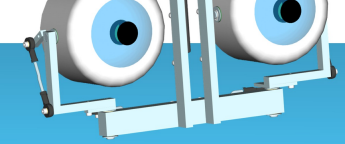
3D coordinate of sphere center.



Chair Setup

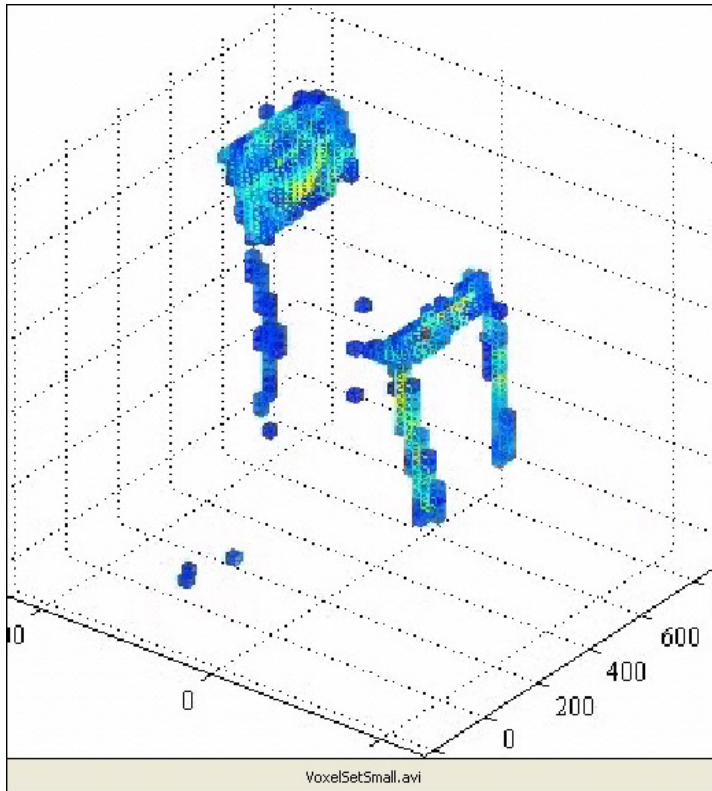


Gradient Angle
Image

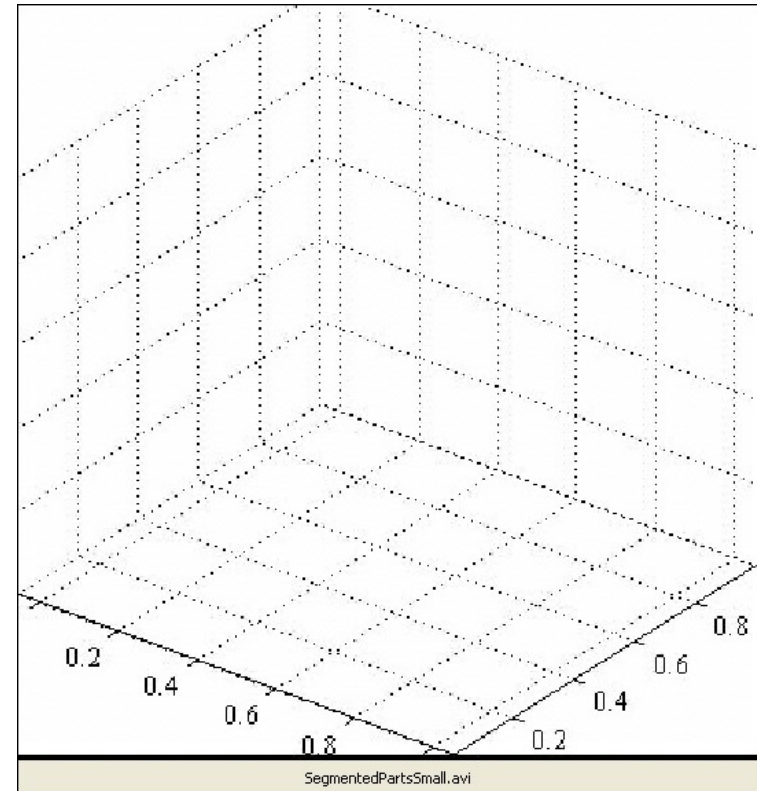


Implementation

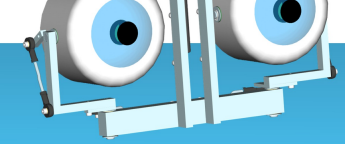
Registration and Segmentation



Voxel Set

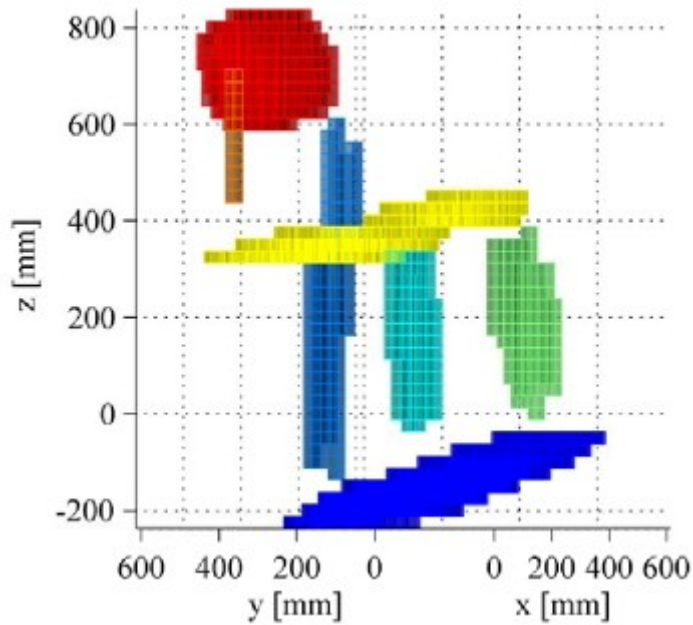


Part Segmentation

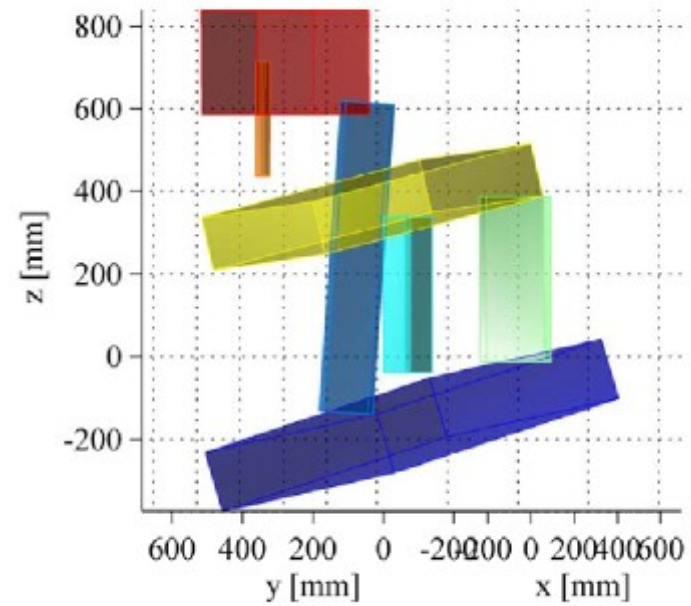


Implementation

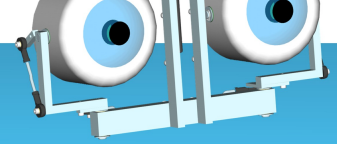
Registration and Segmentation Error



Segmented
Parts



Bounding Boxes



Implementation

Detection

Recursive Bayesian estimation for incremental detection of object parts.

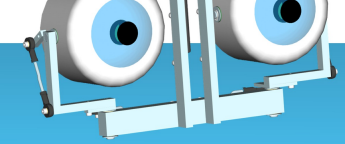
$$P(R_k = r | \mathbf{z}_{1:k}) = \int_V p(R_k = r, \mathbf{x}_k | \mathbf{z}_{1:k}) d\mathbf{x}_k,$$

R_k : Number object parts

(Part type will be integrated in future)

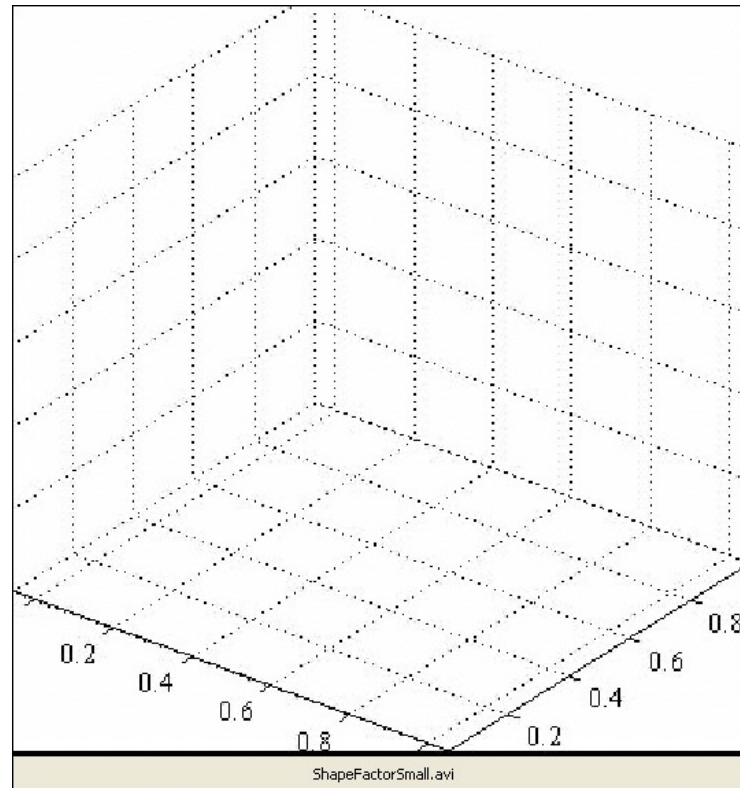
\mathbf{x}_k : Position and size of an object part

$\mathbf{z}_{1:k}$: Observation over a range image
sequence

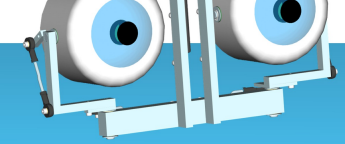


Implementation

Shape Factor

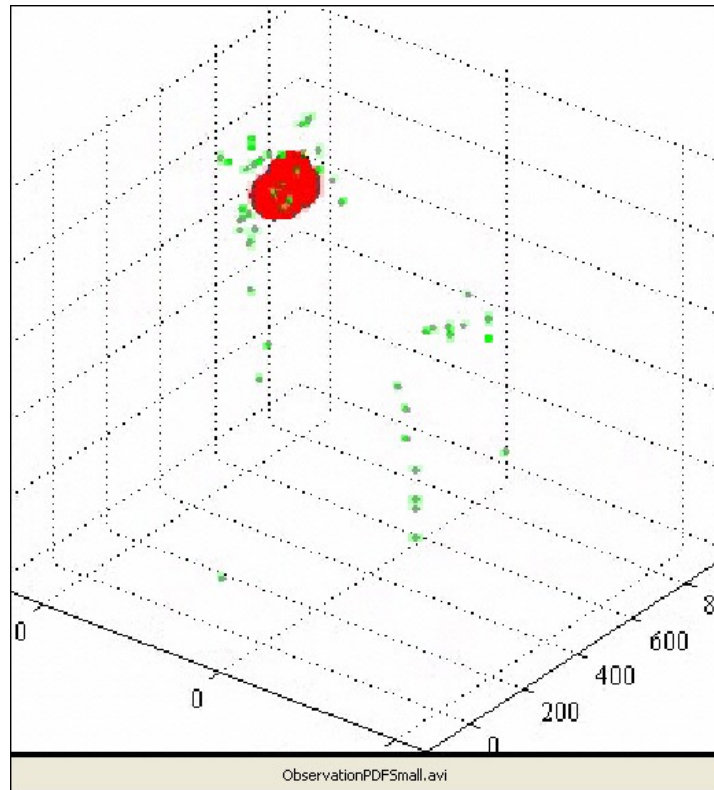


Shape Factor

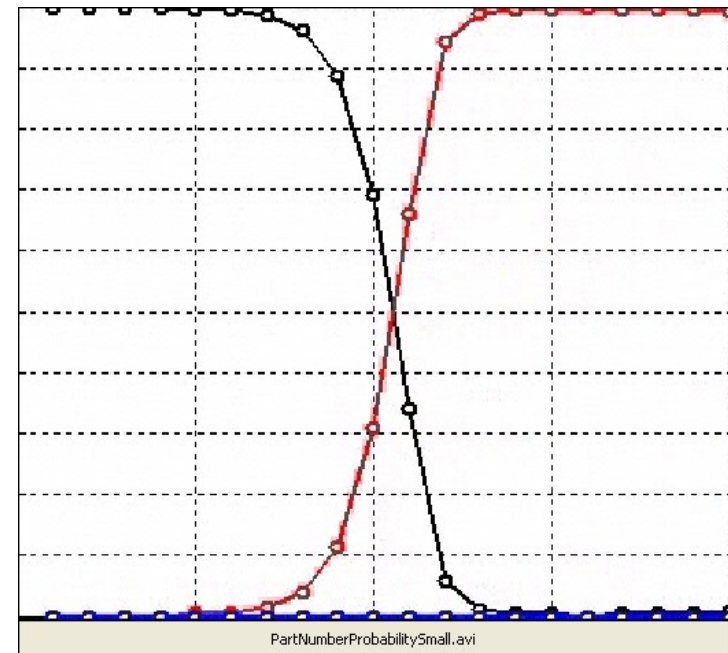


Implementation

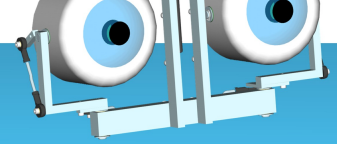
Particle Filter



Observation



Part Presence



Conclusion

- Function-based comes to structure-based object classification.
- Known registration techniques cannot be applied ad-hoc to range camera data.
- Conceptually, object part detection works.
- Particle filter implementation needs further improvement for a working solution.