

Analyse eines Forschungsthemas

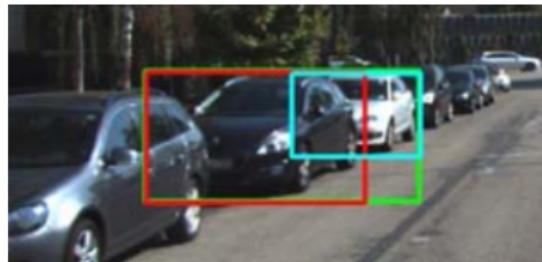
a detection and two pose estimation algorithms deal with occlusion

Josef Schulz

April 20, 2016

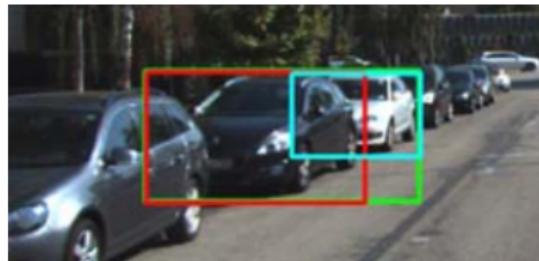
Example Problems

Example Problems

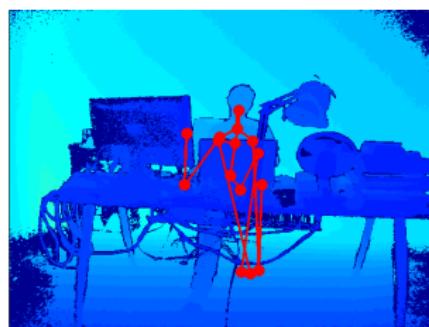


DPM: classification and localisation

Example Problems

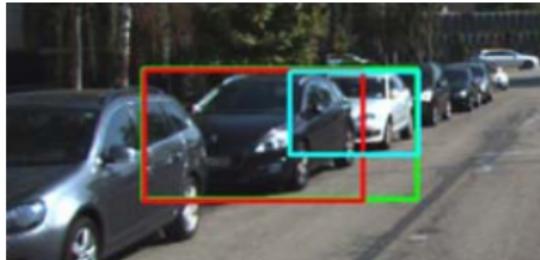


DPM: classification and localisation

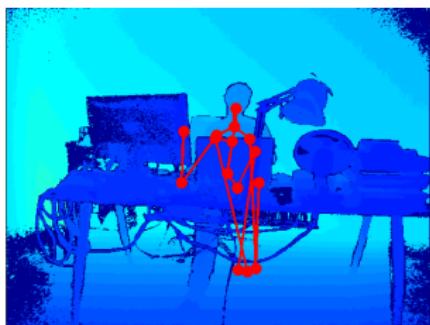


joint pose estimation with Kinect2
SDK

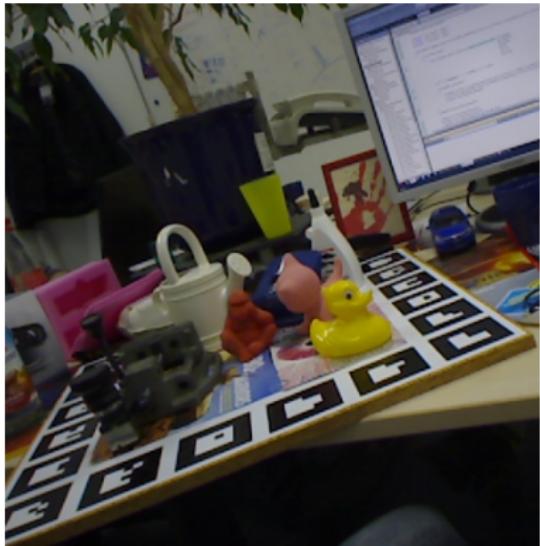
Example Problems



DPM: classification and localisation



joint pose estimation with Kinect2
SDK



pose estimation with occlusion

Content

1 Examples

2 Algorithms

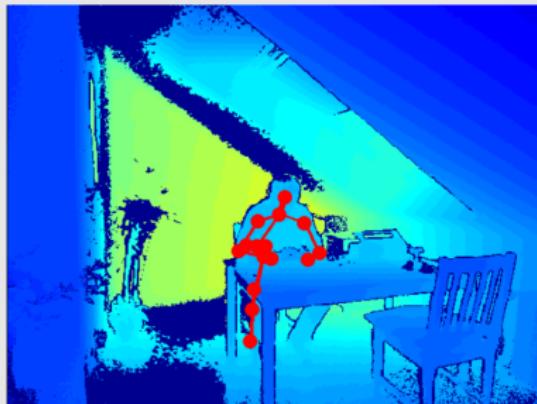
- Semantic Occlusion Model
- Occlusion Patterns
- Robust Instance Recognition

3 Conclusions

4 Discussion

5 References

A Semantic Occlusion Model For Human Pose Estimation



Kinect2 SDK

Input : single Depth-Image

Output : estimated poses of all parts

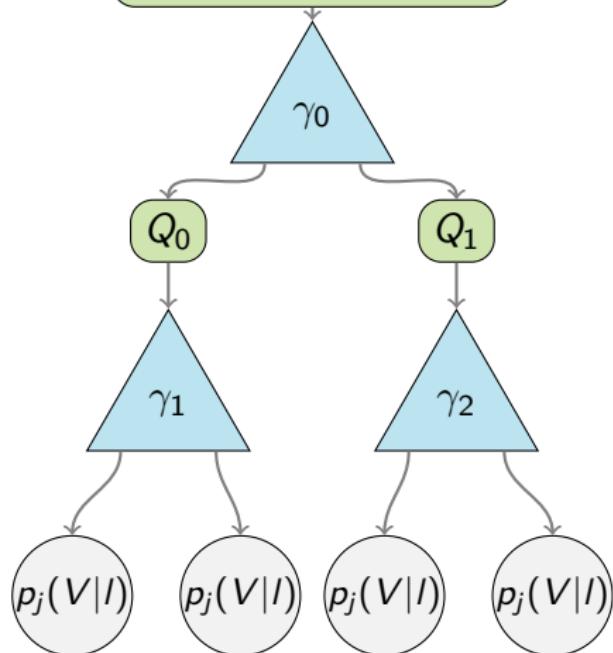
Regression Forest

Training Set

$$Q = \{(q, D, c, \{V_j\}), \dots\}$$

- q pixel location
- D reference depth image
- c class label corresponding to limbs
- $\{V_j\}$ is set of 3D offset vectors between q and the joint position q_j :
$$V_j = q_j - q$$

$$Q = \{(q, D, c, \{V_j\})\}$$



Split Node

$$\gamma = (\textcolor{blue}{u}, \textcolor{blue}{v}, \tau)$$

$$\Phi_{\gamma}(q, D) \mapsto \{0, 1\}$$

$$\Phi_{\gamma}(q, D) = \begin{cases} 1 & \text{if } D(q + \frac{\textcolor{blue}{u}}{D(q)}) - D(q + \frac{\textcolor{blue}{v}}{D(q)}) > \tau \\ 0 & \text{else} \end{cases}$$

$\textcolor{blue}{u}, \textcolor{blue}{v}$ - offset vectors

τ - threshold

$D(q)$ - depth value

Evaluating The Splitting Functions Information Gain

$$\Phi^* = \arg \max_{\Phi} g(\Phi)$$

$$g(\Phi) = H(Q) - \sum_{s \in \{0,1\}} \frac{|Q_s(\Phi)|}{|Q|} H(Q_s(\Phi))$$

$$H(Q) = - \sum_c p(c|Q) \log(p(c|Q))$$

$H(Q)$ - Shannon entropy

$g(\Phi)$ - information gain

Leaf Node

a leaf node stores:

- ▶ class c
- ▶ two cluster centers V_{ljk} for each joint
- ▶ two support values w_{ljk} for each cluster
- ▶ probabilities over V_j :

$$p_j(V|I) \propto \sum_{k \in K} w_{ljk} \cdot \exp\left(-\left\|\frac{V - V_{ljk}}{b}\right\|_2^2\right)$$

K - cluster

w_{ljk} - is determined by offset vectors ended in the cluster
 $k, k \in K$

V_{ljk} - cluster center

Pose Estimation

$$p_j(x|D) \propto \sum_{(x_j, w_j) \in X_j} w_j \cdot \exp\left(-\left\|\frac{x - x_j}{b_j}\right\|_2^2\right)$$

$$X_j = \{(x_j, w_j)\}$$

x_j - absolute joint position, $x_j = q + V_{ljk}$

w_j - confidence value, $w_j = w_{ljk} \cdot D^2(q)$

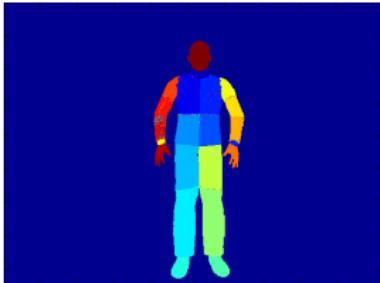
The cluster with the highest summed weights w_j are used for prediction.

Occlusion Aware Regression Forests

idea: Add new class labels which does not correspond to the body.
The assumption is that if a person interact with a specific object,
some joint position could be predicted.

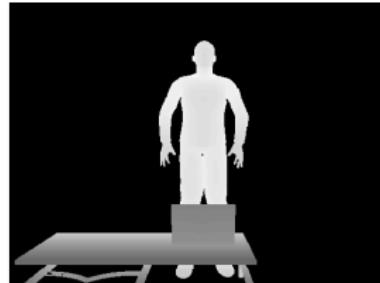
$$Q = Q \cup \{(q_{occ}, D, C_{occ}, \{v_{jocc}\})\}$$

without Semantics

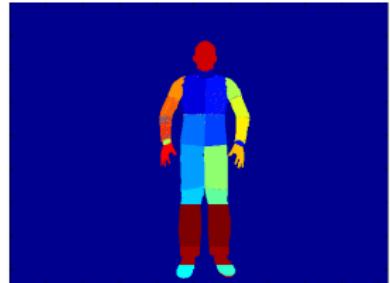


$$C_{occ} = \{c_{occ}\}$$

with Semantics



$$C_{occ} = \{c_{obj1}, c_{obj2}, \dots\}$$



Training Data

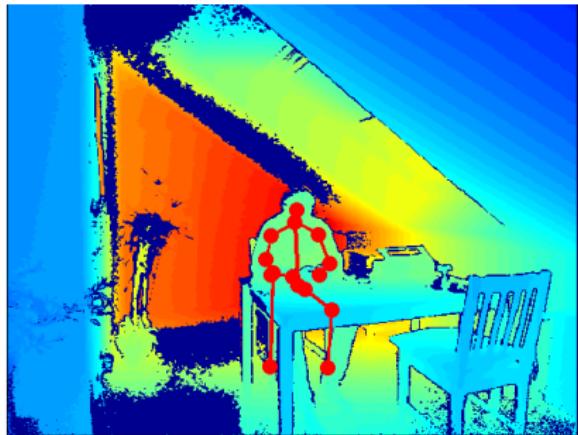
Synthetic Data (552 images)

- ▶ Human Poses from CMU-Database [9]
- ▶ body part labels for each pixel

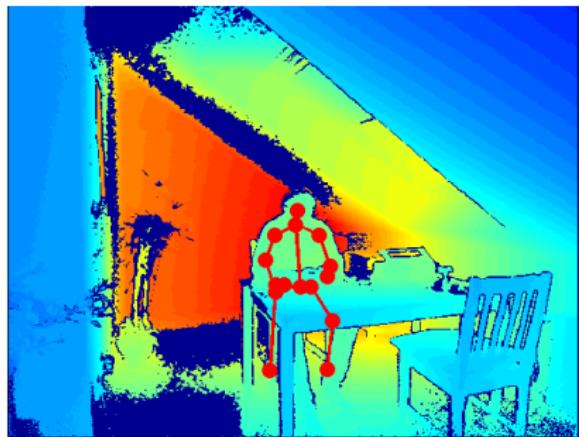
Real Data (552 images)

- ▶ Kinect2 SDK, all fails are discarded

With And Without Semantics

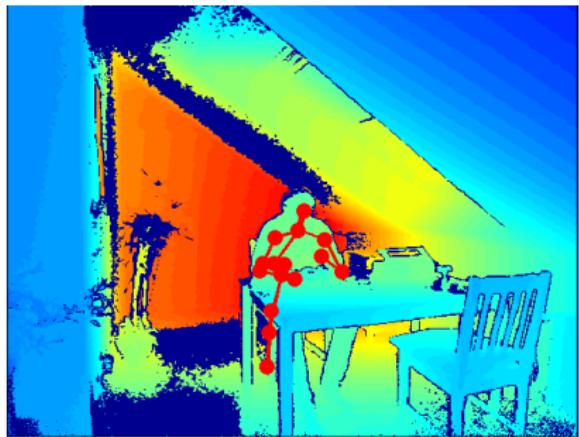


without semantics: the joint at
the hip is not good estimated

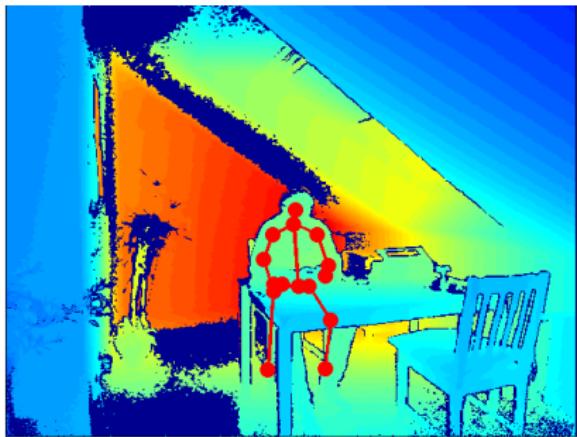


with semantics

OARF vs. Kinect2 SDK



Kinect2 SDK



OARF with semantics

Results

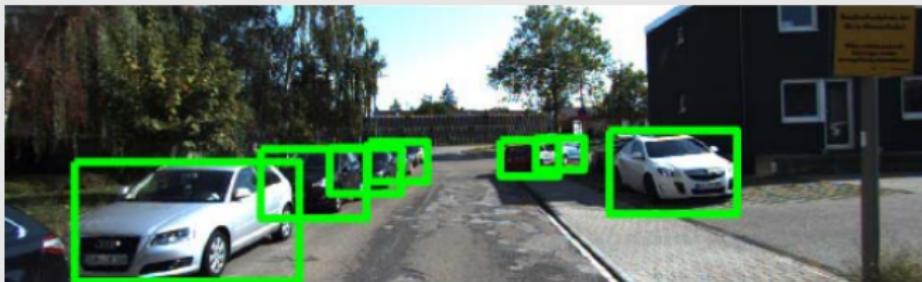
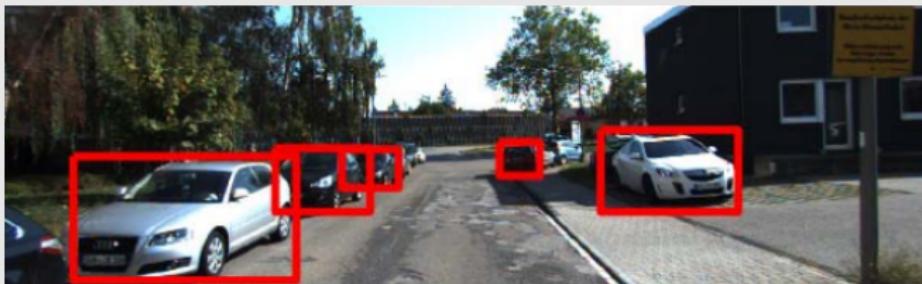
	Occluded Joints	Non Occluded Joints	All Joints
OARF W/O	32.60	55.50	50.66
OARF W	35.77	56.01	51.72
Kinect2 SDK	18.13	66.36	56.94

in %

Testset: real + synthetic data

- ▶ real data was taken with the Kinect
- ▶ synthetic data is generated by rendered scenes

Occlusion Patterns for Object Class Detection

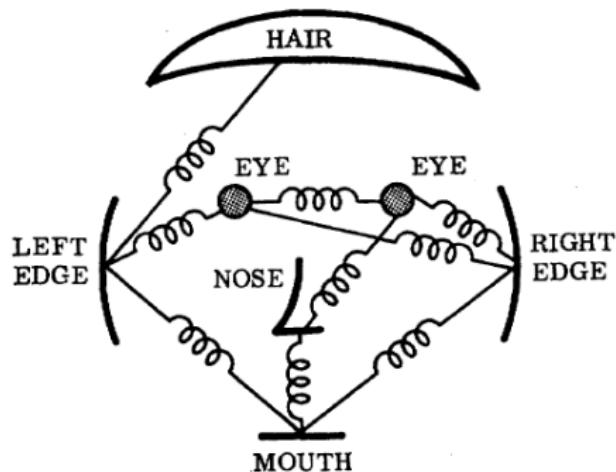


Input : Single RGB-Image

Output : Object-Bounding-Boxes

Deformable Models Approach

- ▶ Consider each object as a deformed version of a template
- ▶ Compact representation



Pictorial Structure Model [8]

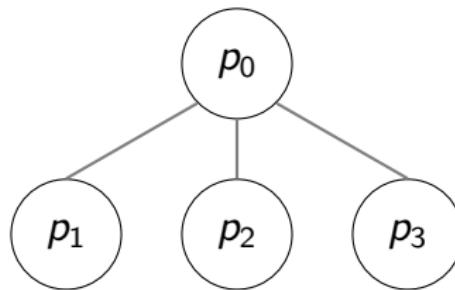
Matching model to image involves joint optimization of part locations "stretch and fit"

Model

Model is represented by a Graph

- ▶ $p = \{p_0, \dots, p_M\}$ are the parts
- ▶ p_i is parameterized through their bounding box (l_i, r_i, t_i, b_i)

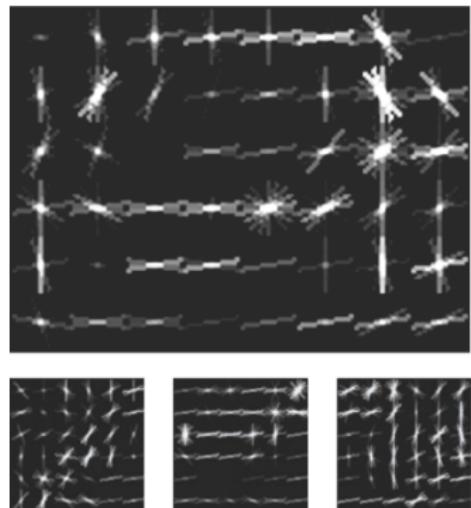
E_c - is the Energy function



$$E_c(p; I) = \underbrace{\sum_{i=0}^M \langle v_i^c, \Phi(p_i; I) \rangle}_{\text{placing cost}} + \underbrace{\sum_{i=1}^M \langle w_i^c, \Phi(p_0, p_i) \rangle}_{\text{deformation cost}}$$

Filter

- ▶ images with bounding boxes
- ▶ histograms of oriented gradients (HOG) for placement
- ▶ twice the resolution for every level
- ▶ Gaussians for deformation



KITTI Data Set

KITTI contains 7481 images

	#objects	#occluded objects	%
Car	28521	15231	53.4
Pedest.	4445	1805	40.6
Cycles	1612	772	44.5

Parts:

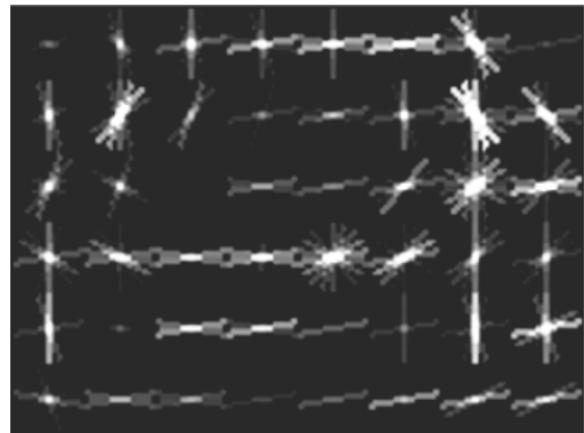
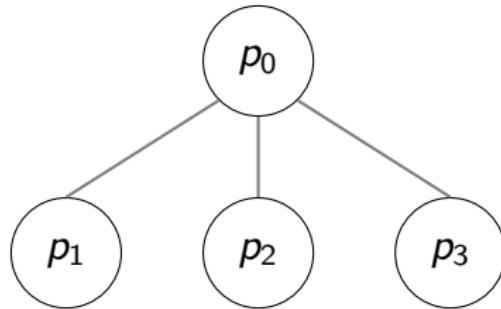
visible 6

occluded 16 – 15

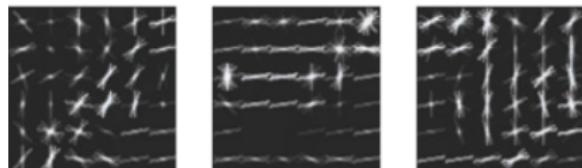
Single-Object Occlusion Patterns - OC-DPM

Learn class from object instances with distinctive appearances of occlusion.

$$C = \{1, \dots, C_{visible}\} \cup C_{invisible}$$



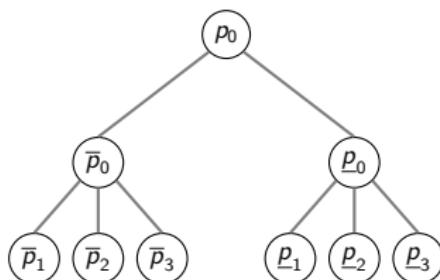
- ▶ like standard DPM
- ▶ trained with occlusion
- ▶ C are components



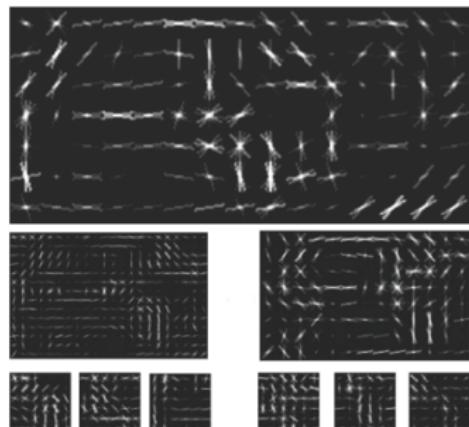
Double-Objects With Joint Root - SYM-DPM

Represent occluder and occludee at once and combine them with a root joint.

$$E'_c(p; I) = \langle v^c, \Phi(p_0; I) \rangle + \langle \bar{w}^c, \Phi(p_0, \bar{p}_0) \rangle + \langle \underline{w}^c, \Phi(p_0, \underline{p}_0) \rangle \\ + E_c(\bar{p}_0; I) + E_c(\underline{p}_0; I)$$

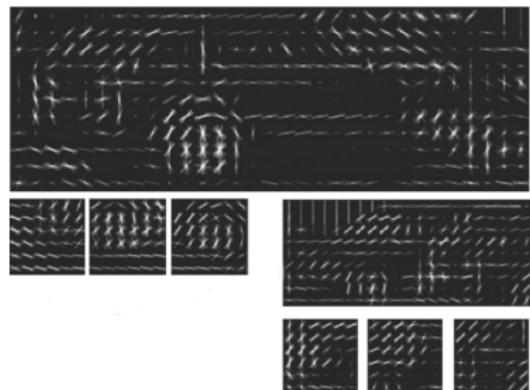
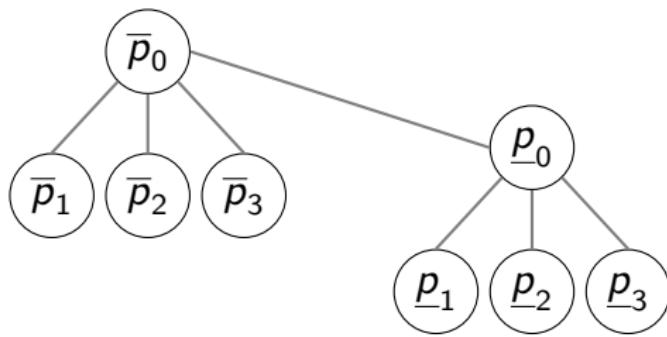


- ▶ one root part
- ▶ occluder \bar{p}_0 root part
- ▶ occludee p_0 root part



Double-Objects Without Joint Root - ASYM-DPM

Both objects are combined to one, based on the intuition that the occluder can be trusted more.



- ▶ occluder left, occludee right
- ▶ tree structure
- ▶ no extra terms

Mining Training Data

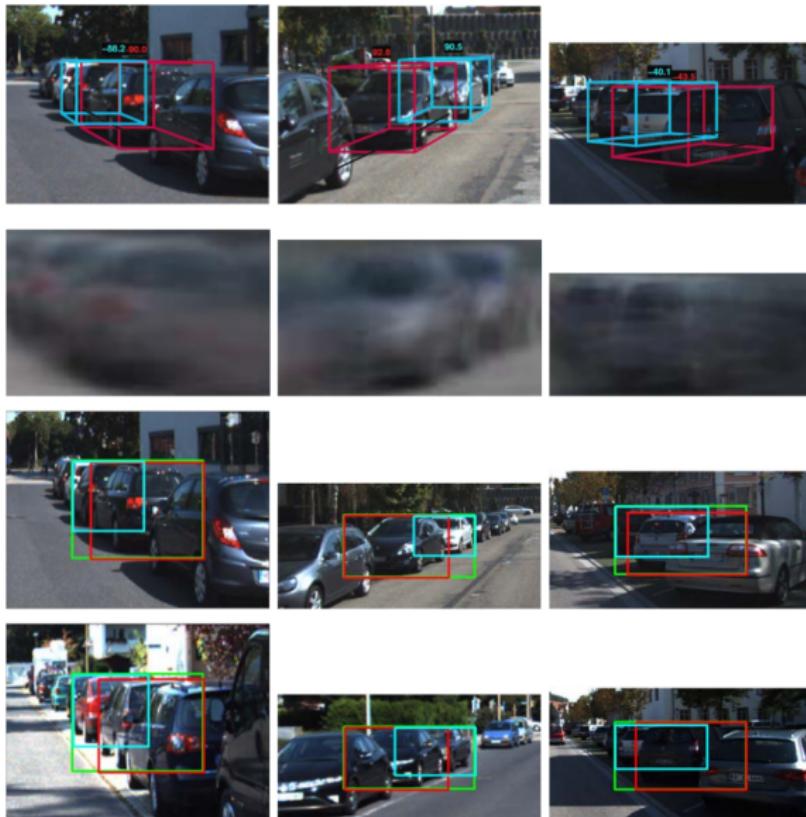
Feature Space:

- i occluder left/right of occludee
- ii orientation of occluder/occludee
- iii occluder is/is not occluded
- iv degree of occlusion of occludee

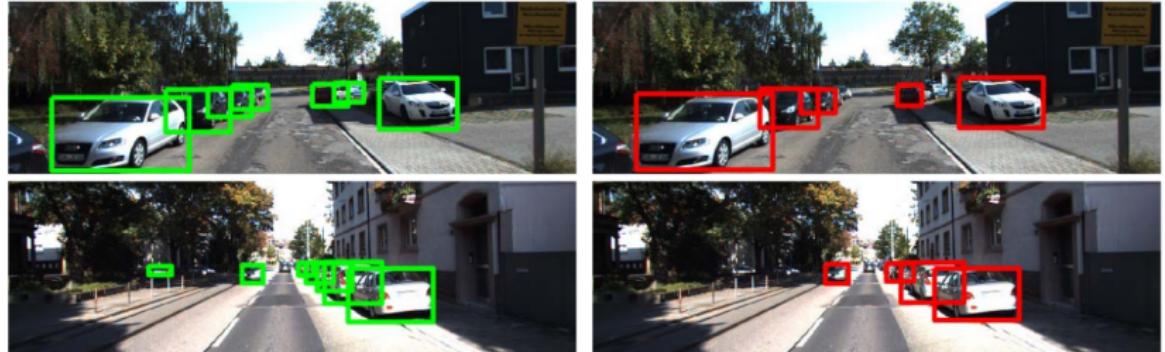
Rule-based clustering

- repeatedly splitting the training data
- according to the viewing angle of the occluder

Mining Training Data



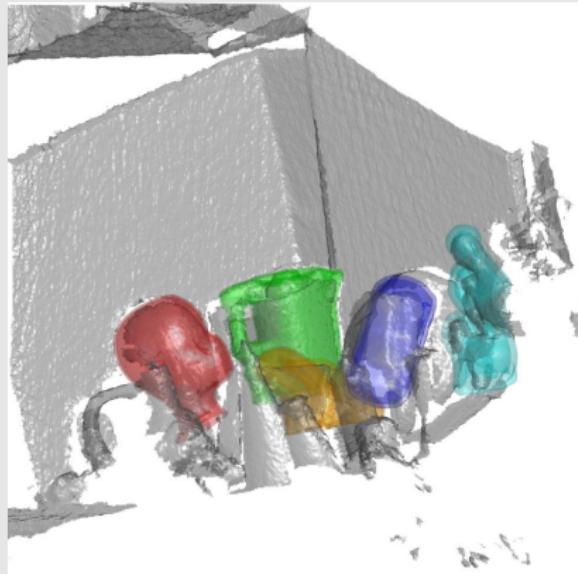
Results



OC-DPM	DPM	OC-DPM	SYM-DPM	ASYM-DPM	DPM
full dataset	62.8	64.4	53.7	52.3	
Pedestrian	36.2	37.2	31.4	29.4	

in %

Robust Instance Recognition in Presence of Occlusion and Clutter



Input : 5-10 consecutive frames as one Pointcloud

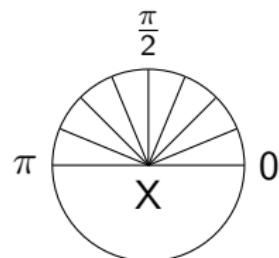
Output : 6D-Object-Pose

Introduction

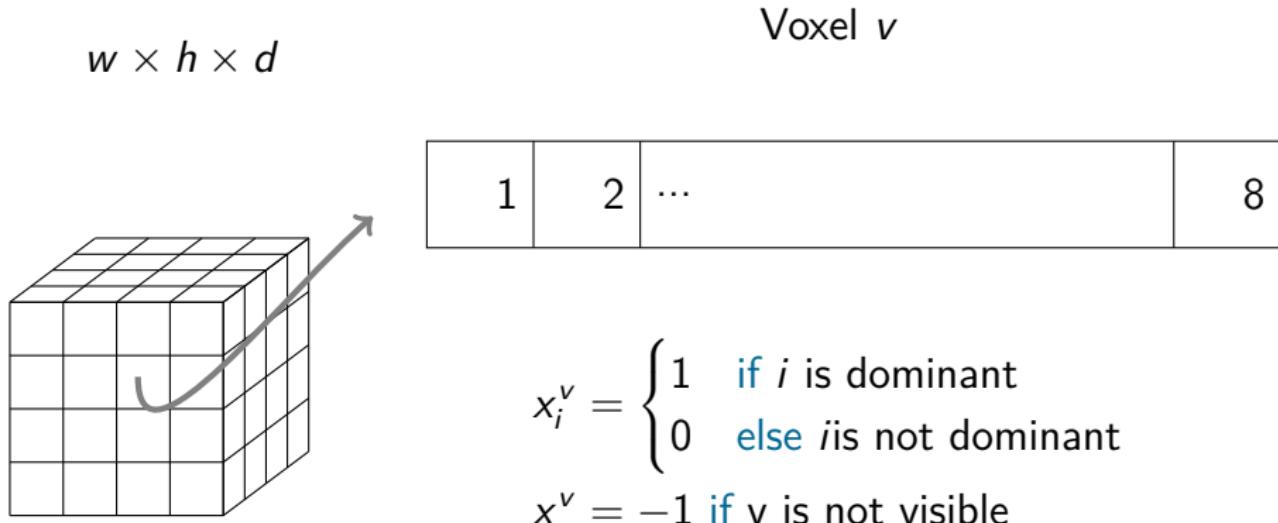
- object shape is invariant to changes in illumination or texture
- Kinect sensors generates cheap depth data
- it is easy to synthesize pointcloud data

Edgelet

- ▶ N points per Pointcloud j
- ▶ **FOR ALL** $i \in \{1, \dots, N\}$
 - ▶ calc λ_1 and λ_2
 - ▶ $r = \frac{\lambda_1}{\lambda_2}$
 - ▶ $r \rightarrow \text{curvatureMap}$
- ▶ hysteresisThesholding(`curvatureMap`);
- ▶ nonmaximalSuppression(`curvatureMap`);
- ▶ hysteresisThesholding(`depthMap`);
- ▶ projectToPointcloud(`curvatureMap`, `depthMap`);
- ▶ RANSAC line fitting
- ▶ orientation to 8 bins // (direction % π)



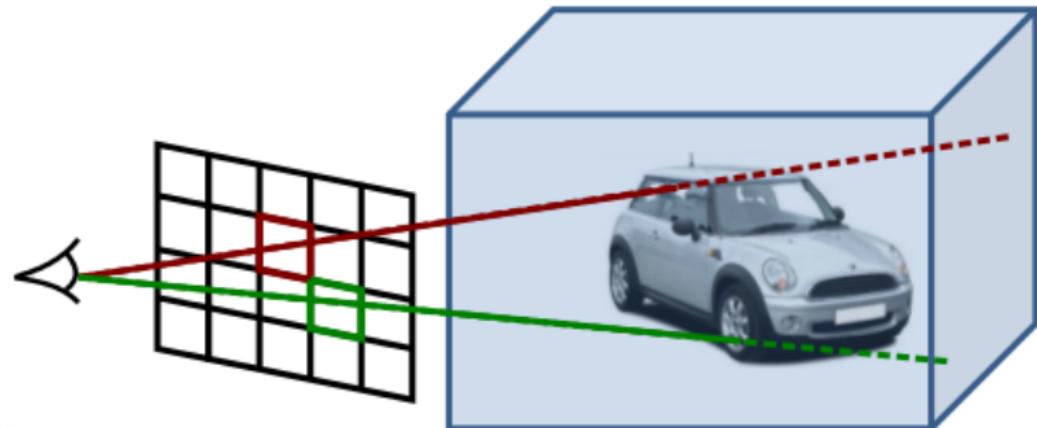
Feature Vector



The resulting feature vector is the concatenation of all voxels:

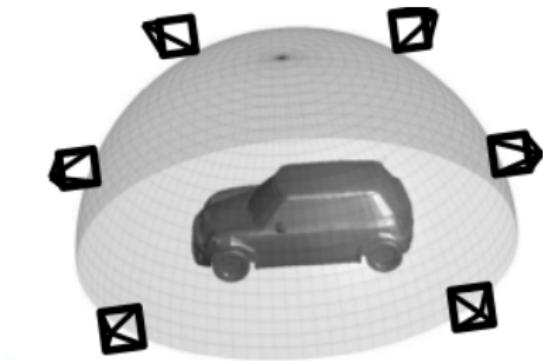
$$w \times h \times d \times 8$$

Box Model For Occluder



- ▶ occluder are rectangular
- ▶ occluders are restricted to start from the ground plane

Soft Label Random Forest



- ▶ 16 pose classes
- ▶ +1 class = $\begin{cases} 1 & \text{if bg} \\ 0 & \text{else} \end{cases}$
- ▶ $d_j^i = \|I - R_j^i\|_F$

$$l_j^i = \exp(-d_j^{i2}), i \in \{1, \dots, 16\}$$

IF fg THEN $1 = \sum_{i=1}^{16} l_j^i$ ELSE 0

Occlusion Queries

$$x_j \in \{-1, 0, 1\}$$

(> -1) - visible versus occluded voxel

(> 0) - dominant or not

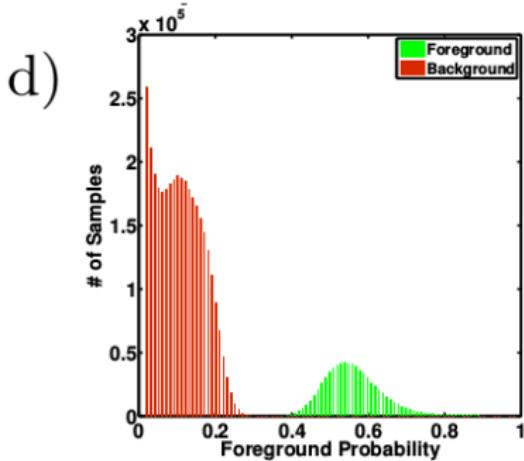
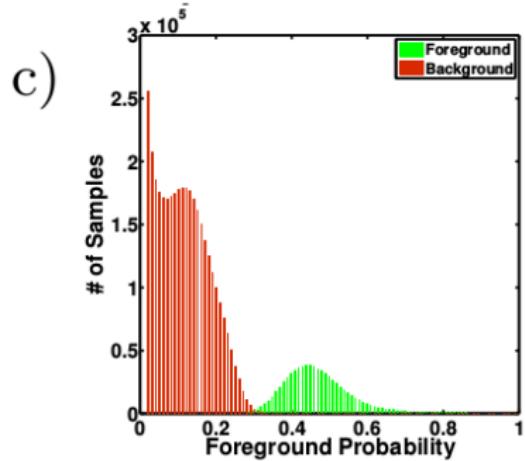
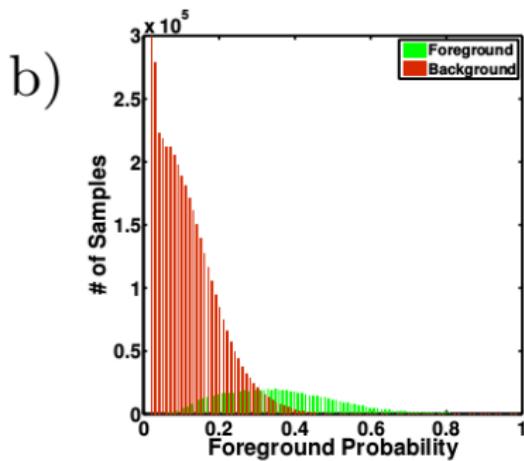
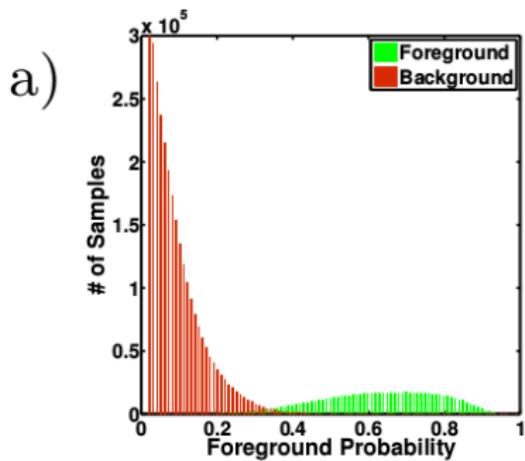
- split questions in the topmost nodes ($\approx 5 - 10$) are restricted to the second type

training scheme for sLRF

Input: $X = \{x_j, l_j\}$, (≈ 27000) examples

Output: Learnt sLRF classifier

1. $X_s \subset X$, $|X_s| = |X|/20$
2. Train sLRF with X_s , compute p_{fg} with X
3. add borderline positive (low p_{fg}) and borderline negative (high p_{fg})
4. add confusing samples
5. compute d_L for all positive samples, add samples with high d_L
6. repeat 2-5 till p_{fg} for all positive data is greater than p_{fg} for all negative data.



Results

	D-DPM	LineMod	S-Iterative (Edges)	S-Iterative (Occlusion)
L	40.50	30.15	70.70	81.89
L+P	23.72	13.17	52.62	62.11

in %

L - location

P - pose estimation

Robustness Against Occlusion - Conclusion

- ▶ semantic (scene understanding)
- ▶ mixture models
- ▶ multiple representation for one object class
- ▶ good feature representation
- ▶ training with occlusion

Discussion





Ujwal Bonde, Vijay Badrinarayanan, and Roberto Cipolla.
“Computer Vision – ECCV 2014: 13th European Conference,
Zurich, Switzerland, September 6-12, 2014, Proceedings, Part
II”. In: ed. by David Fleet et al. Cham: Springer International
Publishing, 2014. Chap. Robust Instance Recognition in
Presence of Occlusion and Clutter, pp. 520–535. ISBN:
978-3-319-10605-2. DOI: 10.1007/978-3-319-10605-2_34.
URL:
http://dx.doi.org/10.1007/978-3-319-10605-2_34.



Andreas Geiger. “Are We Ready for Autonomous Driving?
The KITTI Vision Benchmark Suite”. In: *Proceedings of the
2012 IEEE Conference on Computer Vision and Pattern
Recognition (CVPR)*. CVPR '12. Washington, DC, USA:
IEEE Computer Society, 2012, pp. 3354–3361. ISBN:
978-1-4673-1226-4. URL: <http://dl.acm.org/citation.cfm?id=2354409.2354978>.

-  Andreas Geiger et al. "Vision meets Robotics: The KITTI Dataset". In: *International Journal of Robotics Research (IJRR)* (2013).
-  Stefan Hinterstoisser et al. "Multimodal templates for real-time detection of texture-less objects in heavily cluttered scenes." In: *ICCV*. Ed. by Dimitris N. Metaxas et al. IEEE Computer Society, 2011, pp. 858–865. ISBN: 978-1-4577-1101-5. URL: <http://dblp.uni-trier.de/db/conf/iccv/iccv2011.html#HinterstoisserHCKNL11>.
-  Alexander Krull et al. "6-DOF Model Based Tracking via Object Coordinate Regression." In: *ACCV (4)*. Ed. by Daniel Cremers et al. Vol. 9006. Lecture Notes in Computer Science. Springer, 2014, pp. 384–399. ISBN: 978-3-319-16816-6. URL: <http://dblp.uni-trier.de/db/conf/accv/accv2014-4.html#KrullMBGIR14>.

-  Bojan Pepik et al. "Occlusion Patterns for Object Class Detection." In: *CVPR*. IEEE, 2013, pp. 3286–3293. URL: <http://dblp.uni-trier.de/db/conf/cvpr/cvpr2013.html#PepikSGS13>.
-  Umer Rafi, Juergen Gall, and Bastian Leibe. "A Semantic Occlusion Model for Human Pose Estimation From a Single Depth Image". In: *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*. June 2015.
-  unknown. *Pictorial Structure Model*. [Online; accessed April 17, 2016]. unknown. URL: <http://kenschutte.com/thesis/fischler.png>.
-  unkown. *CMU Mocap*. [Online; accessed April 17, 2016]. unkown. URL: <http://mocap.cs.cmu.edu/>.