SemanticPaint

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Outline

Introduction

Introduction

State of the Art

Acquisition and Reconstruction

Scene Understanding

Pipeline

Voxel Oriented Patch features

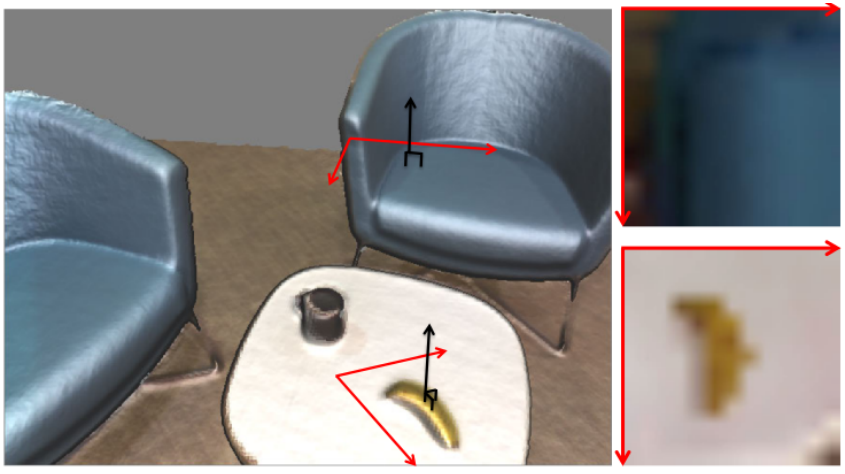


Figure: Colours shown in RGB for illustration purposes.

$(\mathbf{p} - \mathbf{p}_i) \cdot (n)_i = 0$

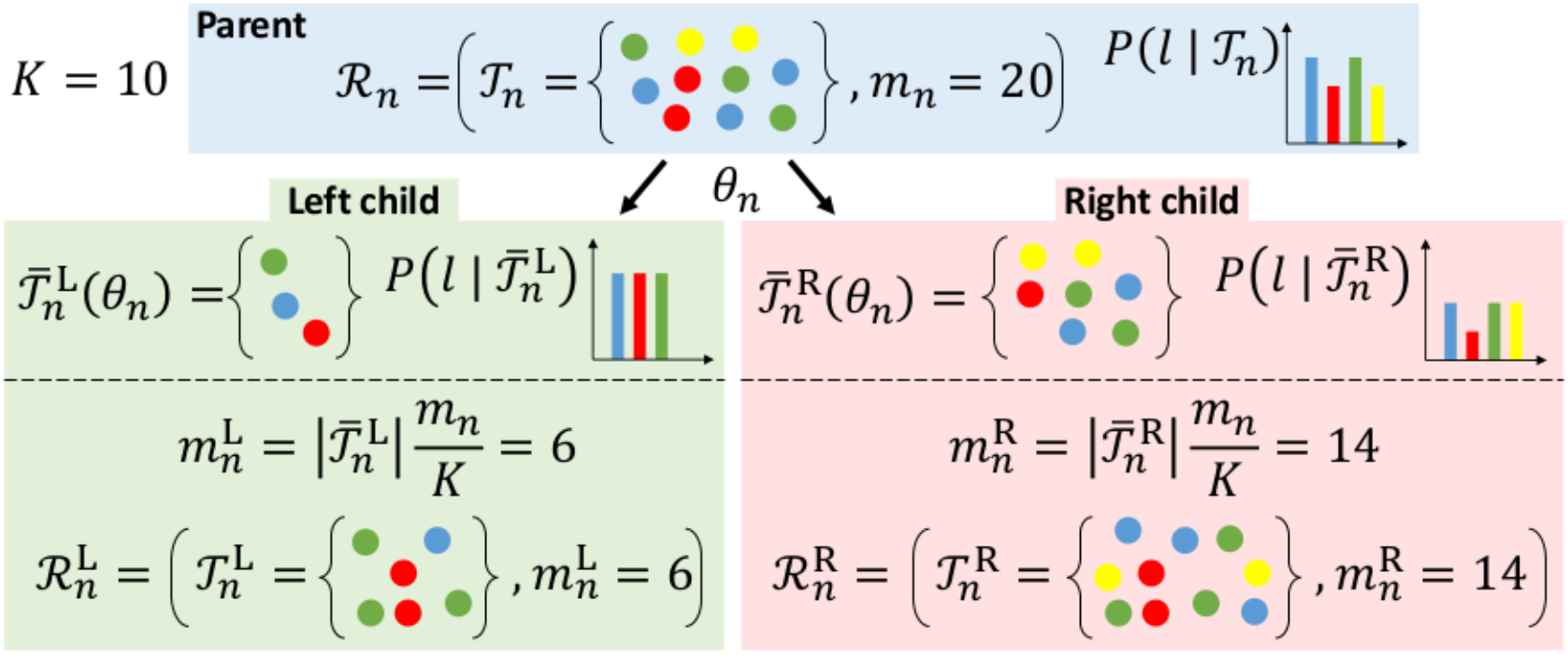
$r \times r$, $r = 13px$ with $10 \frac{mm}{pixel}$

CIELab

Rotated to dominant gradient direction

Streaming Random Forest

SRF - Reservoir Splitting



Dynamic Conditional Random Field

$$P(\mathbf{x}|\mathbf{D}) = \prod_{i \in \mathcal{V}} \left(\psi_i(x_i) \prod_{j \in \mathcal{E}_i} \psi_{ij}(x_i, x_j) \right) \tag{1}$$

$$E_t(\mathbf{x}) = \sum_{i \in \mathcal{V}} \left(\phi_i(x_i) + \sum_{j \in \mathcal{E}_i} \phi_{ij}(x_i, x_j) \right) + K \tag{2}$$

CRF - User Interactions

Touching:

$$\phi_i(l) = \begin{cases} 0 & \text{if } l = l_S \\ \infty & \text{otherwise} \end{cases} \tag{3}$$

Encircling:

$$\phi_i(l) = \begin{cases} \log P_E(fg|\mathbf{a}_i) & \text{if } l = \text{fg} \\ \log(1 - P_E(fg|\mathbf{a}_i)) & \text{if } l = \text{bg} \end{cases} \tag{4}$$

CRF - Predictions and Smoothnes

Predictions:

$$\phi_i(l) = -\log P_F(x_i = l|\mathbf{D}) \tag{5}$$

Smoothnes:

$$\phi_{ij}(x_i, x_j) = \theta_p e^{-||\mathbf{p}_i - \mathbf{p}_j||} + \theta_a e^{-||\mathbf{a}_i - \mathbf{a}_j||} + \theta_n e^{-||\mathbf{n}_i - \mathbf{n}_j||} \tag{6}$$

Mean-Field Inference

$P(\mathbf{x})$ approximated by $Q(\mathbf{x})$ under $KL(Q||P)$:

$$Q_i^t(l) = \frac{1}{Z_i} e^{M_i(l)}, \; t = 1, \ldots, T \tag{7}$$

$$M_i(l) = \phi_i(l) + \sum_{l' \in \mathcal{L}} \sum_{j \in \mathcal{N}(i)} Q_j^{t-1}(l') \phi_{ij}(l, l') \tag{8}$$

Frame at time t initialized with:

$$\widetilde{Q}_i^t(x_i) = \gamma Q_i^{t-1}(x_i) + (1 - \gamma) P_F^{t-1}(x_i = l|\mathbf{D}), \; \gamma \in [0, 1] \tag{9}$$

Results

Segmentation

Table: Segmentation Results

Component	LivingRoom	Bedroom	Kitchen	Desk	Average
User Interaction	99.35%	97.61%	96.09%	97.73%	97.7%
Forest Prediction	94.57%	88.31%	82.58%	90.29%	88.94%
Final Inference	96.26%	95.19%	90.69%	95.55%	94.42%

Features

Table: Feature Comparison

Feature	LivingRoom	Bedroom	Kitchen	Desk	Average
VOP	**94.57%**	**88.31%**	82.58%	**90.29%**	**88.94%**
Δ RGB mean	80%	71.84%	76.29%	73.42%	75.39%
Depth Probe	77.54%	61.79%	**84.9%**	68.9%	73.06%
Color Probe	56.39%	65.68%	60.77%	60.74%	60.9%
SURF	43.74%	67.12%	57%	58.13%	56.5%
SPIN	58.77%	43.22%	48.41%	36.1%	46.63%

Streaming Random Forest

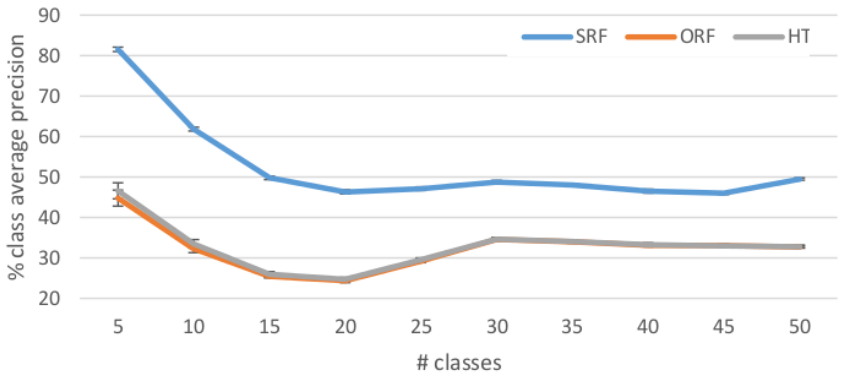


Figure: Average Precision

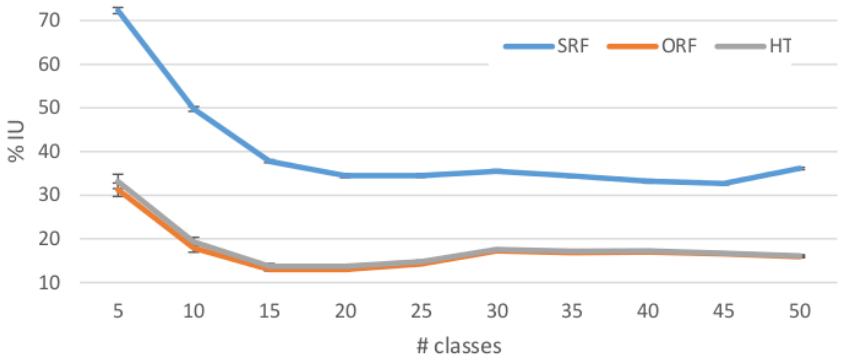


Figure: Intersection/Union

Data:
300 objects
51 classes
full revolution
3 points of view

SRF - Streaming Random Forest
ORF - Online Random Forest
HT - Hoeffding Tree

Discussion and Outlook

Summary

- customized models of 3D enviornments
- fully interactive
- online and real time
- no pretraining

Failures

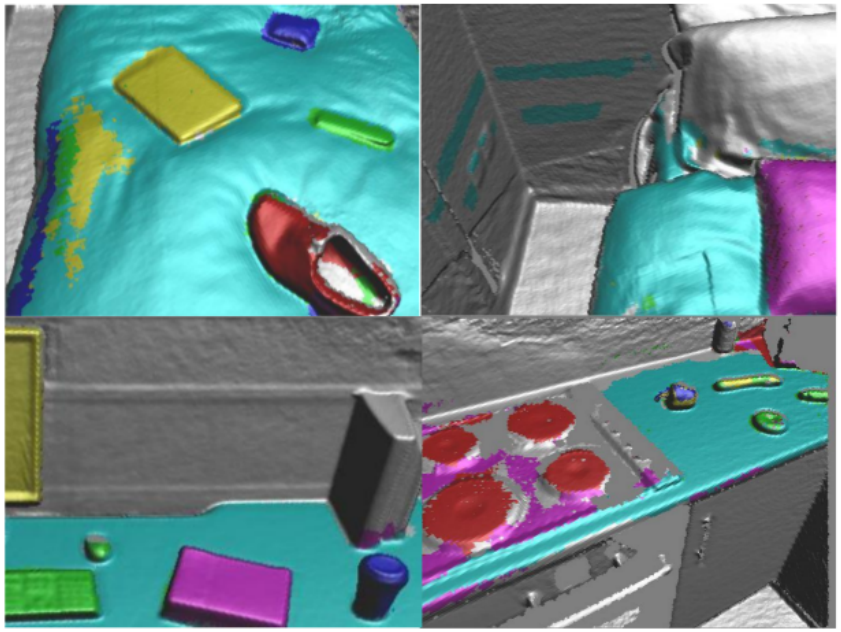


Figure: Failure cases.

- bleeding
- illumination change
- viewpoint change

Future Work

- class priors for different enviornments
- priors for class properties (vertical walls)
- discriminative geometrical features
- outdoor enviornments
- better scalability

References

- Roberts, L. G. 1963. Machine perception of three-dimensional solids. Ph.D. thesis, Massachusetts Institute of Technology.
- Kim, B.-S. et. al. 2013. 3D scene understanding by voxel-CRF. In Proc. ICCV.
- Pradeep, V. et. al. 2013. Monofusion: Real-time 3D reconstruction of small scenes with a single web camera. In Proc. ISMAR.
- Herbst, E. et.al. 2014. Toward online 3-d object segmentation and mapping. In IEEE International Conference on Robotics and Automation (ICRA).
- Valentin, J. P. et. al. 2013. Mesh based semantic modelling for indoor and outdoor scenes. In Proc. CVPR.
- Levoy , M. et. al. 2000. The digital Michelangelo project: 3D scanning of large statues. In Proc. SIGGRAPH. ACM.
- Newcombe , R. A. et. al. 2011. KinectFusion: Real-time dense surface mapping and tracking. In Proc. ISMAR.
- Curless , B. et. al. 1996. A volumetric method for building complex models from range images. In Proceedings of the 23rd annual conference on Computer graphics and interactive techniques. ACM, 303312.
- Niessner , M. et. al. 2013. Real-time 3D reconstruction at scale using voxel hashing. ACM TOG 32, 6

References cont'd

- Saffari , A. et. al. 2009. On-line random forests. In IEEE ICCV Workshop.
- Vitter , J. S. 1985. Random sampling with a reservoir. ACM TOMS 11, 1.
- Lower , D. G. 1999. Object recognition from local scale-invariant features. In Proc. ICCV.
- Lafferty , J. et. al. 2001. Conditional random fields: Probabilistic models for segmenting and labeling sequence data.
- Ktahenbl, P. et. al. 2011. Efficient inference in fully connected CRFs with Gaussian edge potentials. In NIPS.
- Koller , D. et.al , N. 2009. Probabilistic Graphical Models: Principles and Techniques. MIT Press
- Domingos, P. et. al. 2000. Mining high-speed data streams. In Proc. SIGKDD.
- Lai, K. et. al. 2011. A large-scale hierarchical multi-view rgb-d object dataset. In Proc. ICRA.
- Valentin, J. et. al. 2015. SemanticPaint: Interactive 3D Labeling and Learning at your Fingertips. SIGGRAPH.