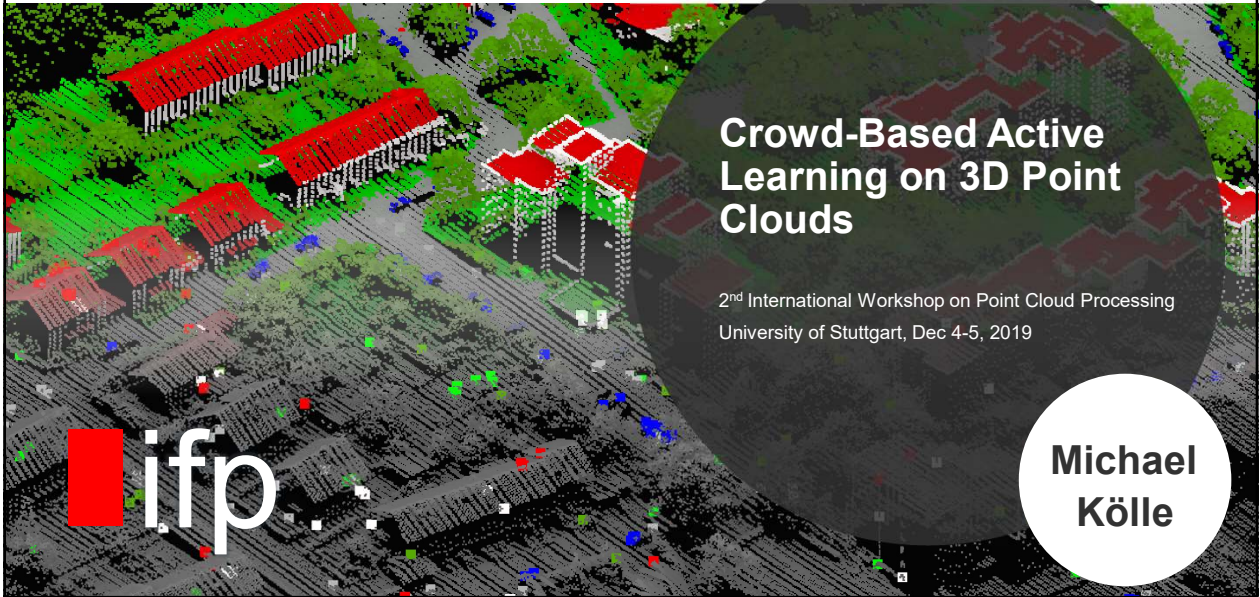




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Crowd-Based Active Learning on 3D Point Clouds

2nd International Workshop on Point Cloud Processing
University of Stuttgart, Dec 4-5, 2019

Michael
Kölle

Motivation



Where to get labels from?



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Motivation



vs.

microWorkers
work & earn or offer a micro job



Outsourcing of tasks to crowd → (Paid) Crowdsourcing



Inhomogeneity of received data



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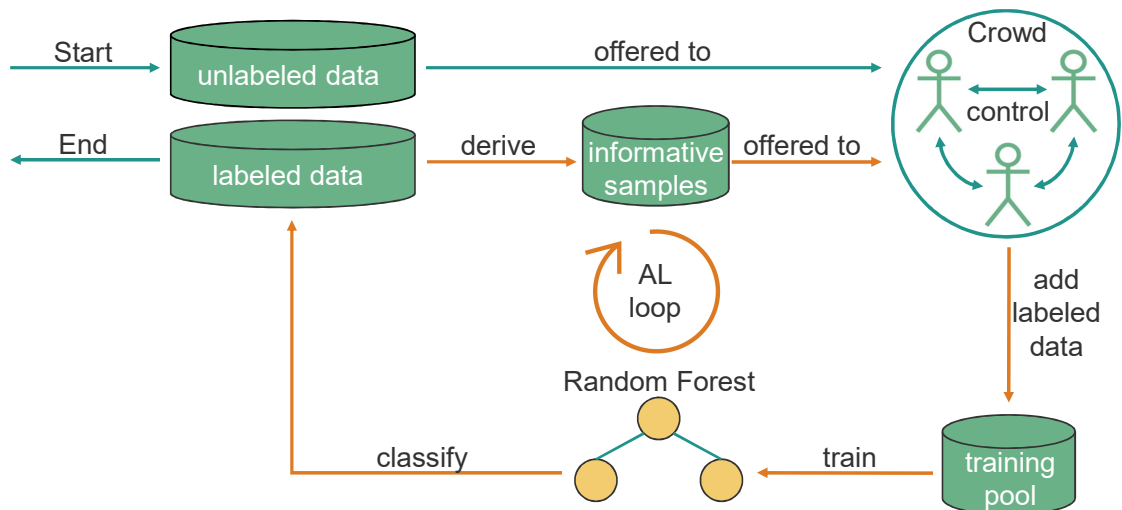
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Crowd-Based Active Learning on 3D Point Clouds



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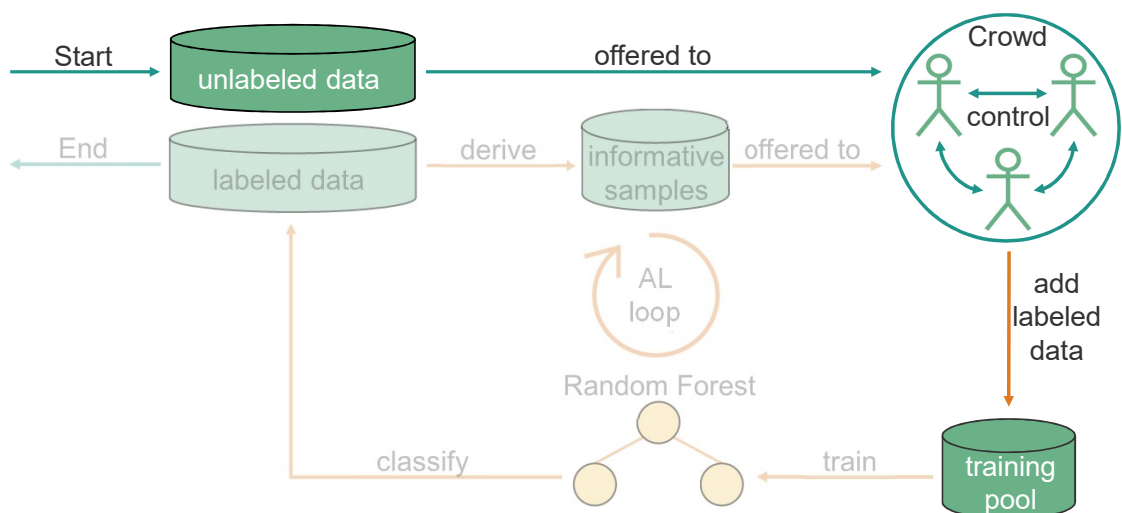
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Crowd-Based Active Learning on 3D Point Clouds



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Point Picking

Reset view
Viewing Mode
Picking Mode



Need some examples?
See our [Reference guide](#).

Ground

- Grassland ✓ ✗
- Street ✓ ✗

Vegetation

- Fence/Hedge ✓ ✗
- Bush ✓ ✗
- Tree ✓ ✗

House

- Powerline ✓ ✗
- Roof ✓ ✗
- Façade ✓ ✗

Other Man-Made Objects

- Car ✓ ✗

Submit classes



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Control Picking

Reset view



3/13 done

Example:



Street:
Paved ground.

Is this a Street ?

☐ Yes
☐ No

Submit current answer



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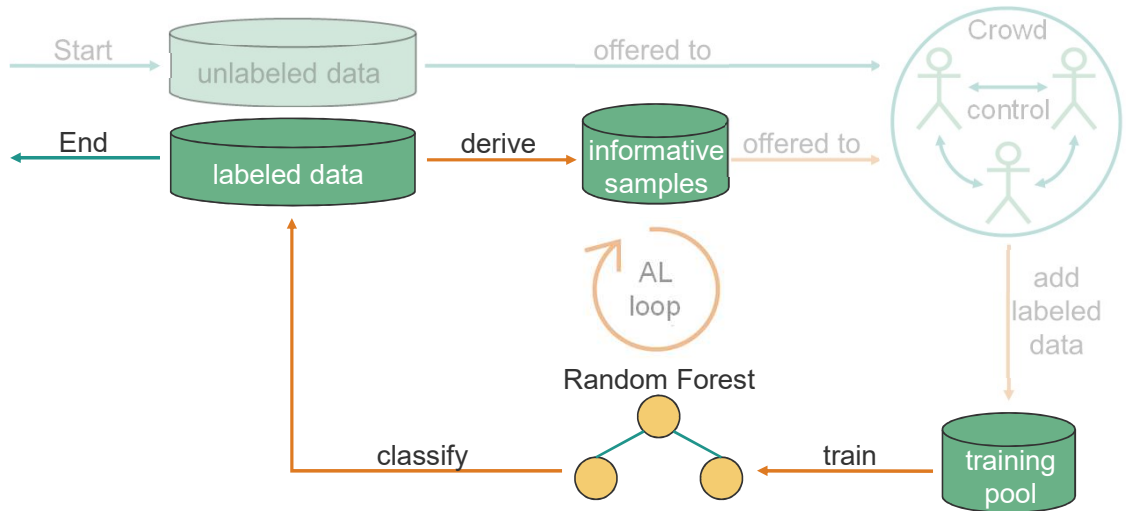
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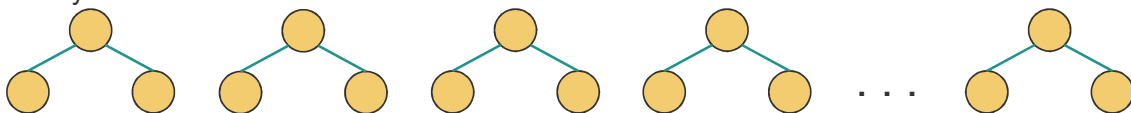


Crowd-Based Active Learning on 3D Point Clouds

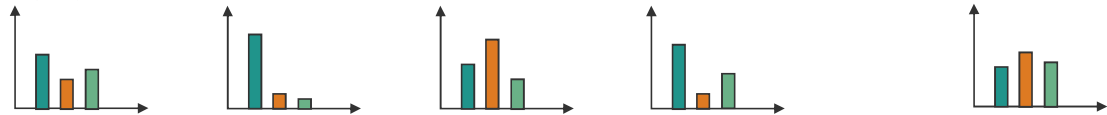


Detection of informative samples via Vote Entropy

Binary Decision Trees:



$P(x|c)$

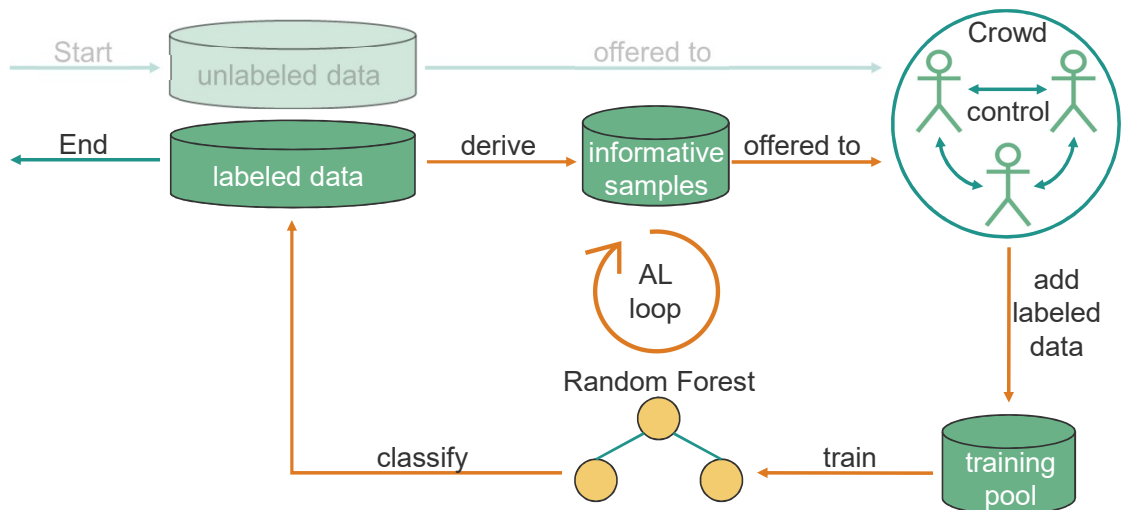


$$VE = - \sum_c \frac{\sum_e D(\mathbf{P}_e, c)}{N_e} \cdot \log \frac{\sum_e D(\mathbf{P}_e, c)}{N_e}$$

$$\text{where } D(a, c) = \begin{cases} 1, & \text{if } \operatorname{argmax}(a) = c \\ 0, & \text{otherwise} \end{cases}$$



Crowd-Based Active Learning on 3D Point Clouds



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Dataset: ISPRS Vaihingen 3D Semantic Labeling Contest



- Point density: 4-8 Pts/m²
- LiDAR (Aug 21, 2008), Imagery (Aug 6, 2008)



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Performance of the Crowd in initialization

Crowd-predicted Label \ True Label	Powerline	Low Vegetation	Impervious Surface	Car	Fence/Hedge	Roof	Façade	Shrub	Tree
Powerl.	.84	.03	.05	.02	.04	.14	.24	.23	.09
Low Veg.	0	.59	.01	0	0	.01	.03	.09	.05
Imp. Surf.	0	.01	.58	.06	0	.01	0	0	0
Car	0	.01	.29	.90	0	.01	0	.11	0
Fence	.11	.23	.03	.02	.62	.05	.05	.19	.05
Roof	0	0	0	0	0	.60	0	0	0
Façade	.05	.08	.03	0	.04	.14	.65	.16	.04
Shrub	0	.05	.01	0	.29	.02	.02	.21	.30
Tree	0	0	0	0	0	.02	.02	.02	.46

OA = 56.44 %

Crowd-predicted Label \ True Label	Powerline	Low Vegetation	Impervious Surface	Car	Fence/Hedge	Roof	Façade	Shrub	Tree
Powerl.	1	.04	0	0	0	.03	.11	.12	0
Low Veg.	0	.71	0	0	0	0	0	.12	.03
Imp. Surf.	0	0	.97	.09	0	0	0	0	0
Car	0	0	0	.91	0	0	0	0	0
Fence	0	.17	0	0	.80	.03	0	.50	.03
Roof	0	0	0	0	0	.79	0	0	0
Façade	0	.04	.03	0	.10	.14	.78	0	0
Shrub	0	.04	0	0	.10	0	.11	.12	.24
Tree	0	0	0	0	0	0	0	.12	.70

OA = 74.67 %



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Performance of the Crowd

Crowd-predicted Label \ True Label	Low Vegetation	Impervious Surface	Car	Roof	Façade	Mid- & High Vegetation
Low Veg.	.90	.16	0	0	0	.04
Imp. Surf.	.06	.82	.01	0	0	.02
Car	0	0	.96	0	0	.03
Roof	0	0	0	.94	.07	.01
Façade	.02	.01	.02	.04	.88	.06
Mid- & High Veg.	.02	.01	.01	.02	.05	.84

• Merging of classes:

- *Roof and Powerline*
- *Tree, Shrub and Fence*

OA = 88.87 %



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Performance of the Crowd

Crowd-predicted Label	True Label					
	Low Vegetation	Impervious Surface	Car	Roof	Façade	Mid- & High Vegetation
Low Veg.	.90	.16	0	0	0	.04
Imp. Surf.	.06	.82	.01	0	0	.02
Car	0	0	.96	0	0	.03
Roof	0	0	0	.94	.07	.01
Façade	.02	.01	.02	.04	.88	.06
Mid- & High Veg.	.02	.01	.01	.02	.05	.84

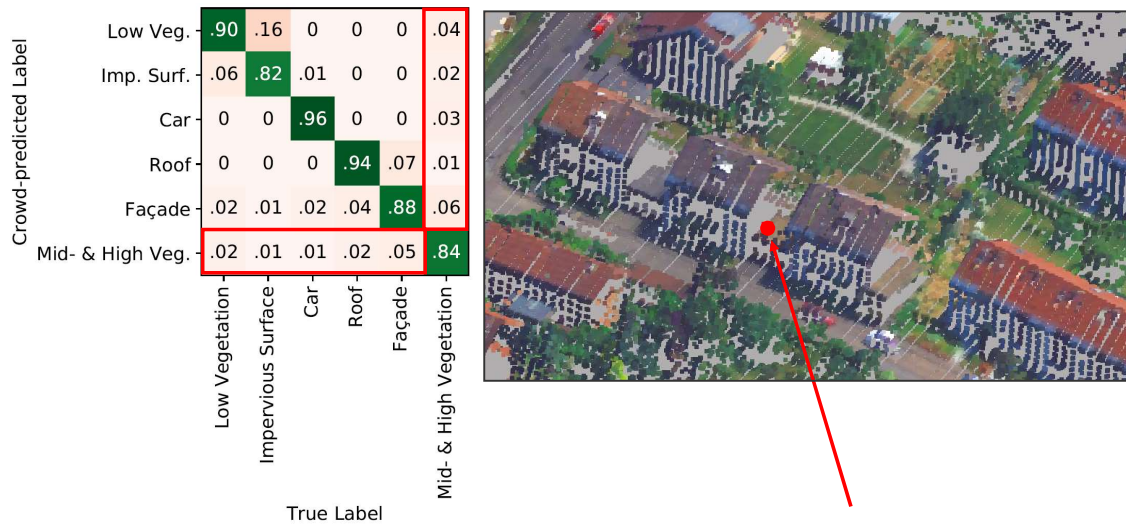


Performance of the Crowd

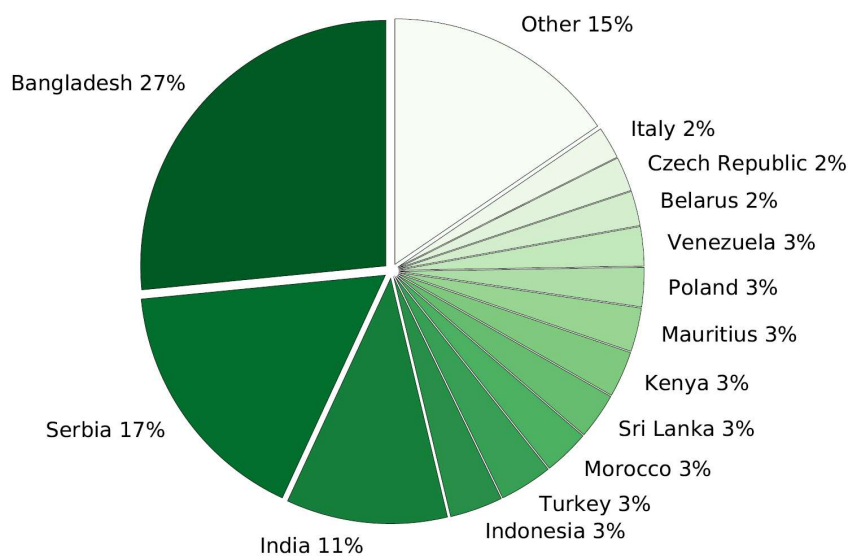
Crowd-predicted Label	True Label					
	Low Vegetation	Impervious Surface	Car	Roof	Façade	Mid- & High Vegetation
Low Veg.	.90	.16	0	0	0	.04
Imp. Surf.	.06	.82	.01	0	0	.02
Car	0	0	.96	0	0	.03
Roof	0	0	0	.94	.07	.01
Façade	.02	.01	.02	.04	.88	.06
Mid- & High Veg.	.02	.01	.01	.02	.05	.84



Performance of the Crowd



Crowd Statistics



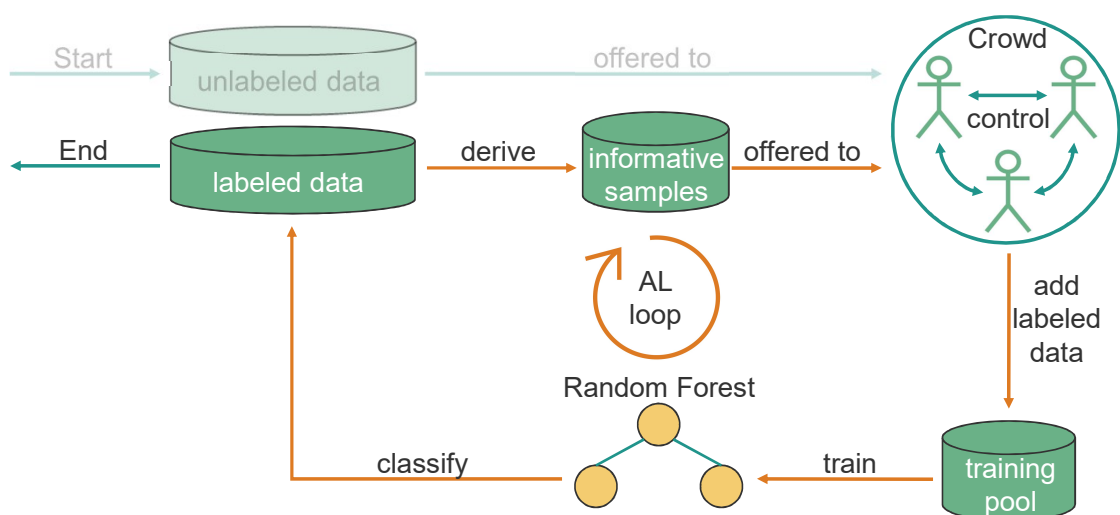
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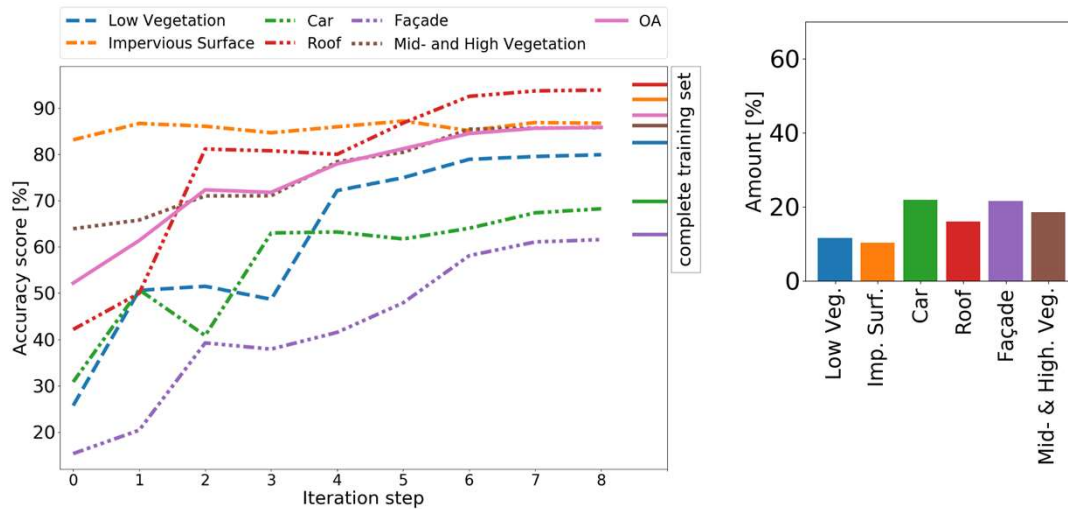


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Monitoring the AL Pipeline

F1-scores and OA [%]



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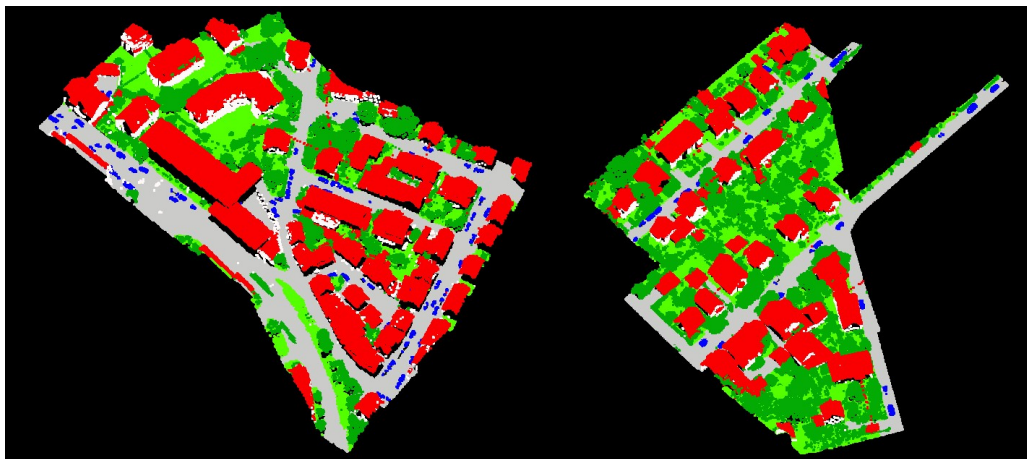
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Results of Crowd-based AL Pipeline

Reference



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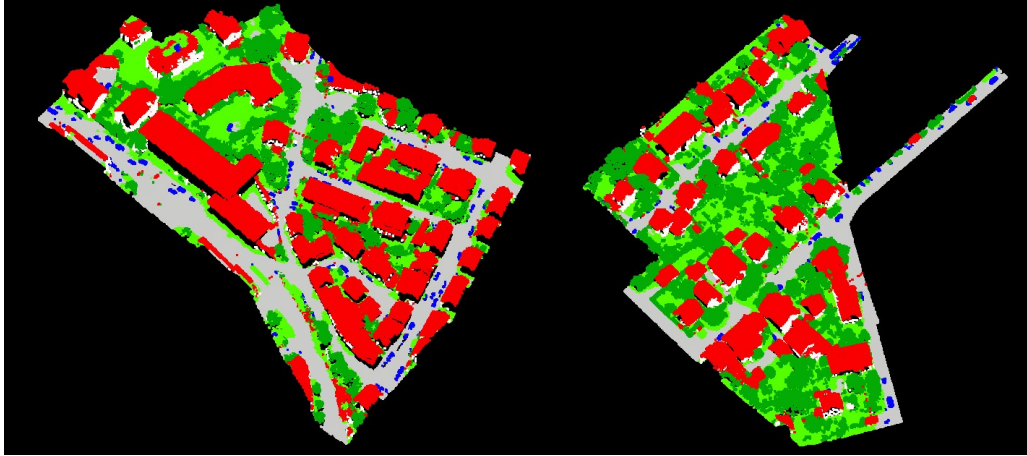
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Results of Crowd-based AL Pipeline

Automated labeling based on training data from crowd



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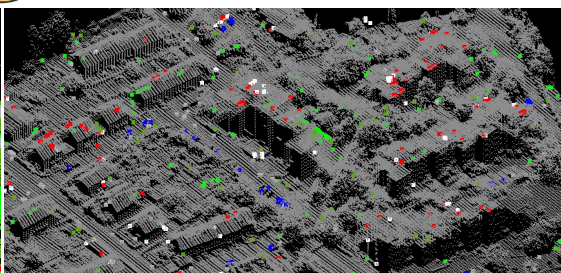
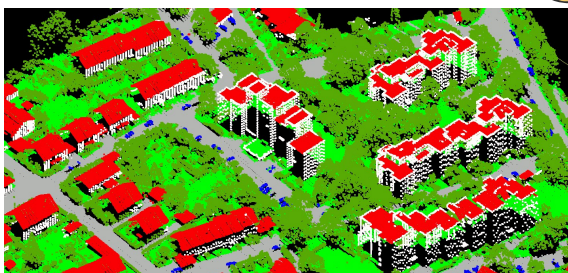


Dense vs. sparse training dataset

dense training set from expert

VS.

sparse training set from crowd



- 100 % of points labeled
- OA = 88.42 %
- Costs = ???
- Expert(s) actively involved in labeling

- 0.4 % of points labeled
- OA = 85.82 %
- Costs < 145 \$
- Only providing data and wages



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Conclusion

• Performance of the Crowd:

- Crowd achieves an OA of 88.87 % for annotation of 3D points
- Crowd cannot label all kinds of classes (at once)

→ *Controlling mechanisms*

• Performance of AL Pipeline:

- Labeling effort can be reduced to labeling only 0.4 % of points
- Extracted training pool can be used for classification of unknown dataset (OA = 85.82 %)

→ *Fully automated pipeline for efficiently extracting highly informative training pool*



Thank you very much for your attention



<https://www.quantamagazine.org/machines-beat-humans-on-a-reading-test-but-do-they-understand-20191017/>



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