Panoptic Segmentation
J. Yuan
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Panoptic Segmentation on aerial Images in urban Area

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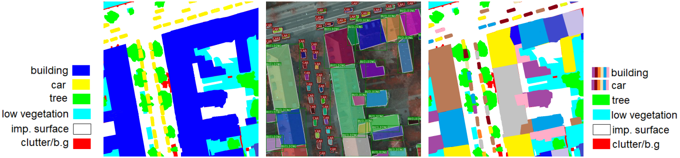
Panoptic Segmentation

What is Panoptic Segmentation?



semantic　　instance　　panoptic

- countatble things vs. uncountable stuff.
- panoptic - including everything visible in one view.
- a unified framework combining instance segmentation & semantic segmentation.
- applications on automatic building map updating.
- lacking of datasets on aerial images.

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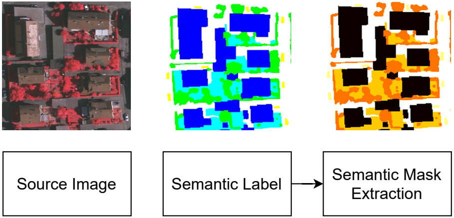
Dataset Annotation

From Semantic to Instance



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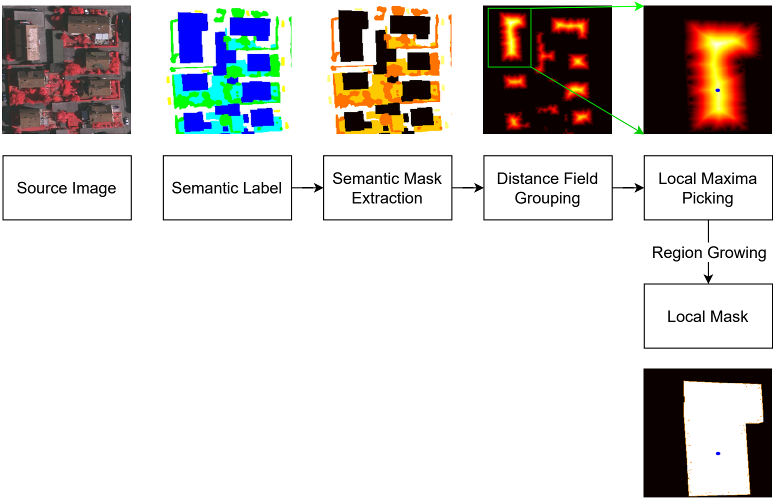

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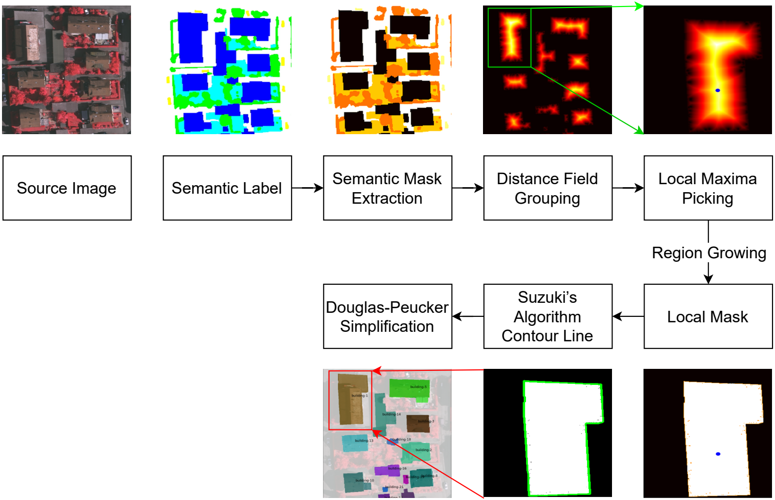

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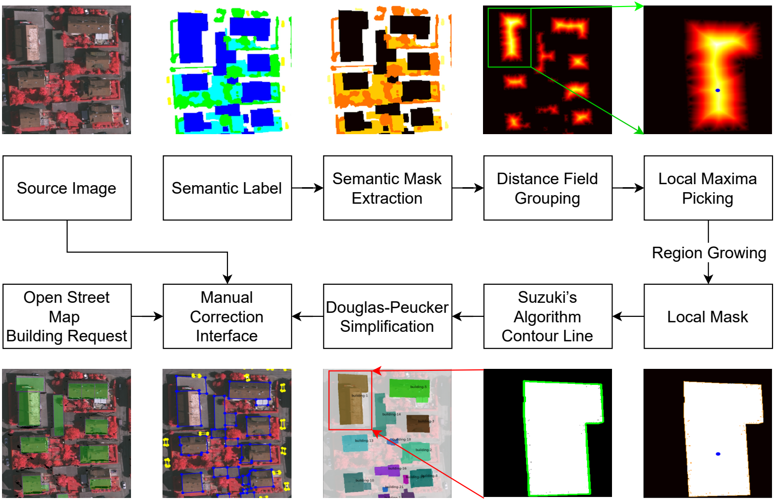

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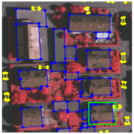
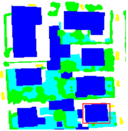
Dataset Annotation

From Instance/Semantic to Panoptic



Instance Annotation



Semantic Labeling

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Dataset Annotation

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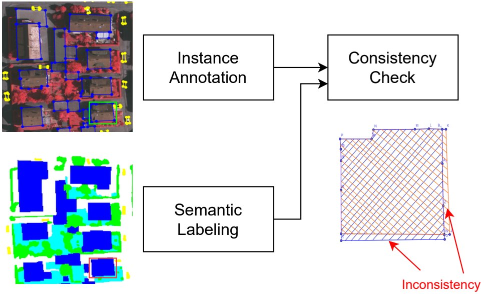
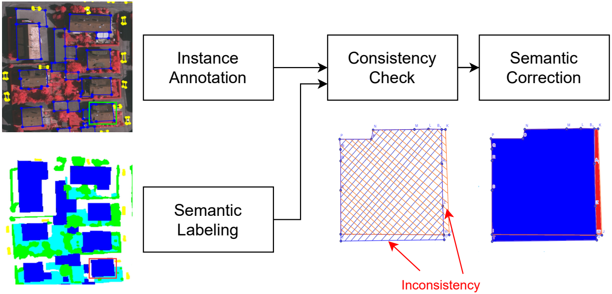


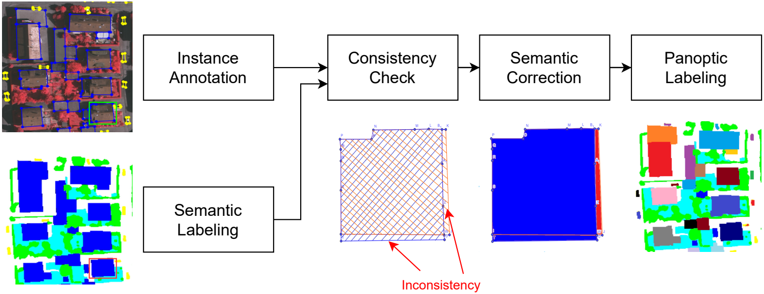
Dataset Annotation

From Instance/Semantic to Panoptic



Dataset Annotation

From Instance/Semantic to Panoptic



PanUrban Dataset

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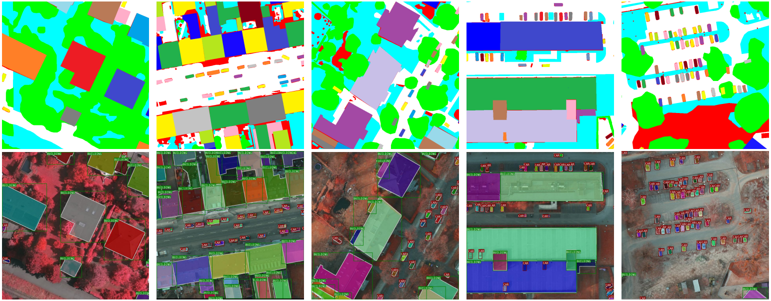


apartment innercity residual factory parking

- Subsets: Potsdam, Vaihingen, MA.
- Bounding boxes axis-aligned(ABB) or rotated(RBB).
- Compatibility with multiple tasks

PanUrban Dataset

Statistics

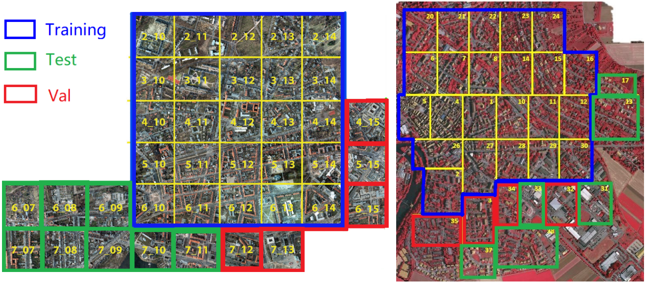
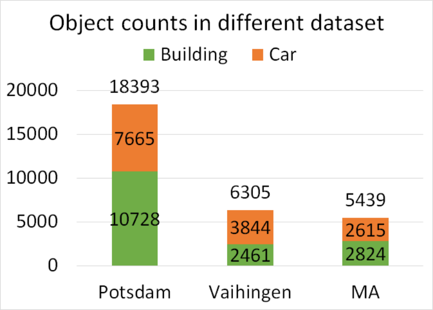


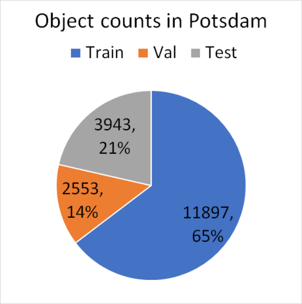
Figure: Dataset split in Potsdam and Vaihingen

- Training is a stitched patch.
- Test and Val are in small image patch.

PanUrban Dataset

Statistics





- Number of objects in datasets: Potsdam > Vaihingen > MA
- Number of objects in Train/Val/Test subsets: Train(65%), Test(21%), Val(14%)

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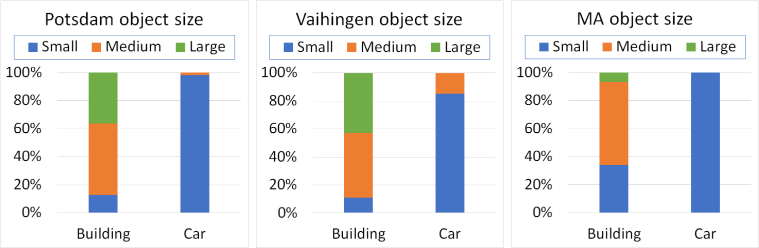

Object size s in pixel:

small:$s \in [0, 32^2)$, medium:$s \in [32^2, 96^2)$, large:$s \in [96^2, \infty)$

- most of buildings belongs to medium and large object
- most of cars belongs to small object.

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Model Division

The model of panoptic segmentation can be divided into 6 parts listed as follows:

- **entry network**
- **region proposal network**
- **instance classification**
- **instance mask segmentation**
- **semantic segmentation**
- **fusion**

Loss functions:

$$\mathcal{L} = \mathcal{L}_{proposal} + \mathcal{L}_{instance} + \mathcal{L}_{semantic}$$

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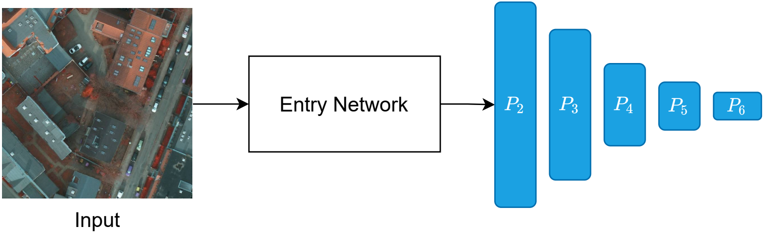
Entry Net

Entry Net Structure



- input: source image
- feature maps P_i with $i \in [2, 6]$ in different scale.

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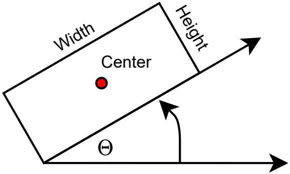
Region Candidates Proposal

Region Proposal Network(RPN)

What is a region? - a bounding box enclosed area.

ABB vs.RBB



parameterization of RBB

- axis-aligned bounding box(ABB) vs. rotated bounding box(RBB)
- parameterization: (x_c, y_c, w, h).vs. (x_c, y_c, w, h, θ)
- compact alignment with rotated bounding box.

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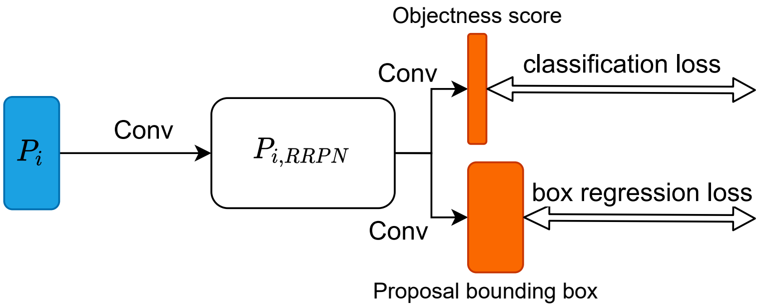
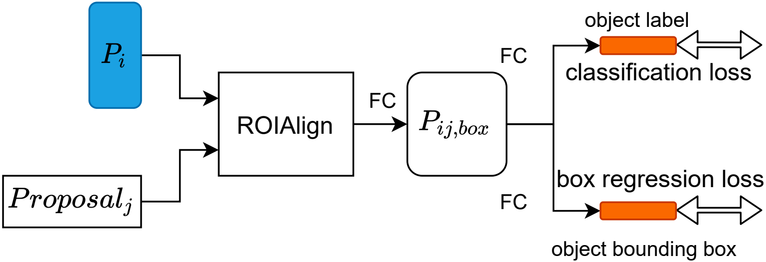
Region Candidates Proposal

Region Proposal Network(RPN) Structure



- Input: feature map from entry network P_i
- Output: objectness score & object bounds
- Loss: $\mathcal{L}_{proposal}^{cls}$ and $\mathcal{L}_{proposal}^{box}$

Object Classification



- Input: P_i, $Proposal_j$
- Output: classified object region
- Loss: $\mathcal{L}^{box}_{instance}$ and $\mathcal{L}^{cls}_{instance}$

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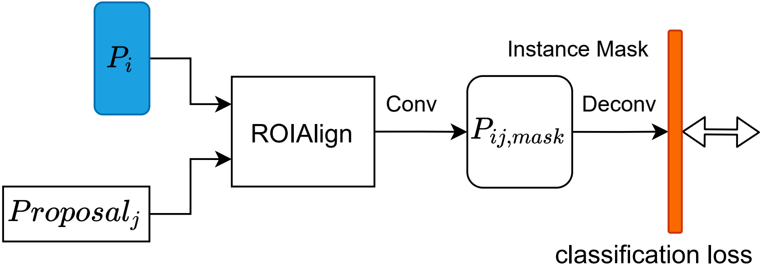
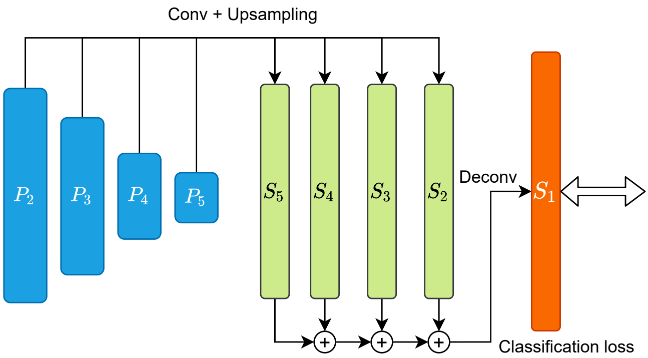
Mask Segmentation



- Input: P_i, $Proposal_j$.
- Output: classified object region
- Loss: $\mathcal{L}_{instance}^{mask}$

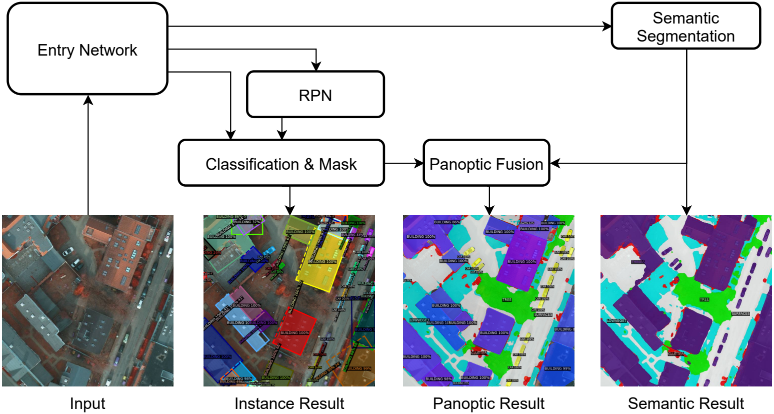
Semantic Segmentation



- input: Multi-scale feature map $P_2 - P_5$
- output: predicted semantic label
- loss: $\mathcal{L}_{semantic}$

Panoptic Segmentation

Full model



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Task Metrics

Panoptic Quality

$$PQ = \frac{\sum_{p,q \in TP} IoU(p,q)}{|TP| + \frac{1}{2}|FP| + \frac{1}{2}|FN|} = \underbrace{\frac{\sum_{p,q \in TP} IoU(p,q)}{|TP|}}_{\text{segmentation quality(SQ)}} \times \underbrace{\frac{|TP|}{|TP| + \frac{1}{2}|FP| + \frac{1}{2}|FN|}}_{\text{recongnition quality(RQ)}}$$

where:

p, q = prediction and groundtruth of matched **segments.**

TP = true positive segment, which has $IoU(p, q) > 0.5$

$|*|$ = count of **segments**, **not pixels.**

SQ = average IoU of **matched segments**

RQ = F1 score of segments.

Experimental Setting

Content of experiment:

1. influence of pretraining on semantic branch.
2. performance comparison on ABB and RBB.
3. inference cross different datasets.

Additional experiment can be found in the thesis:

1. full range augmentation performance.
2. pretraining on RPN.
3. ablation study.
4. parameter study.

Pretraining on Semantic Branch

Pretrained weight is applied on the entry net.

Pretraining\IoU	mIoU	$IoU_{clutter}$	$IoU_{l.veg}$	$IoU_{imp.surf.}$	IoU_{thing}	IoU_{tree}
$COCO_{weight}$	**60.2**	8.9	68.1	**77.2**	**82.9**	**63.8**
$ImageNet_{weight}$	60.1	**13.6**	**68.6**	75.9	79.9	62.5
None	50.6	4.8	56.6	67.4	62.5	61.5
$COCO^{full}_{weight}$	64.1	22.3	69.4	78.6	84.1	66.0

Table: Semantic Metrics w.r.t Pretraining: mIoU denotes averaged Intersection over Union over all classes, subscript hints class name

Result from Semantic Branch:

- Comparison on $COCO_{weight}$ vs. $ImageNet_{weight}$ and None Pretraining.
- Comparison on semantic categories.
- Comparison with fully trained model, inferring the influence of instance branch.

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Full range augmentation

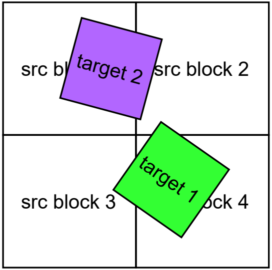

Figure: Example of Full range augmentation on source block 1-4

Features:

- random location
- random orientation
- random small scale difference.
- extract features across source blocks.

Panoptic Segmentation

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ABB vs. RBB

Comparison on bounding box format

Metrics	All classes			Things			Stuff		
	PQ_{all}	SQ_{all}	RQ_{all}	PQ_{th}	SQ_{th}	RQ_{th}	PQ_{st}	SQ_{st}	RQ_{st}
$Potsdam_R$	**54.4**	**74.2**	**72.7**	**70.0**	83.3	**84.2**	**46.6**	**69.6**	**67.0**
$Potsdam_A$	53.9	74.1	72.1	69.4	**84.2**	82.8	46.2	69.1	66.8
$Vaihingen_R$	53.6	63.2	**71.0**	63.9	82.5	77.8	**48.5**	53.6	**67.6**
$Vaihingen_A$	**53.8**	**63.7**	70.8	**64.7**	**82.8**	**78.6**	48.4	**54.1**	67.0

Table: PQ.RQ,SQ in axis-aligned box(ABB) and rotated bounding box(RBB) in dataset Potsdam and Vaihingen, with full range augmentation

- Comparison on Box formats: subscript H and R.
- Comparison on things and stuff.

Metircs	PQ_{all}	SQ_{all}	RQ_{all}	PQ_{th}	SQ_{th}	RQ_{th}	PQ_{st}	SQ_{st}	RQ_{st}
MA_R	**40.1**	**58.1**	**56.9**	**47.1**	**74.4**	**62.7**	**36.6**	**49.9**	**54.0**
MA_A	31.5	54.0	48.4	38.3	73.8	51.5	28.1	44.2	46.9

Table: PQ.RQ,SQ on axis-aligned box and rotated box in dataset MA, with rotational augmentation

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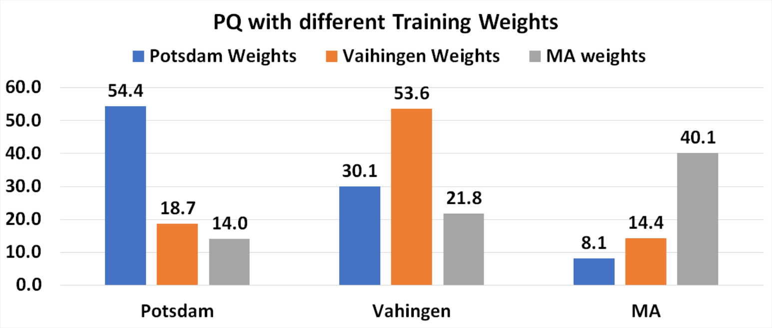
Cross Dataset Performance

This experiment applies training on a dataset and inference on other datasets.



- Model tend to overfit the training data.

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Conclusions and Outlook

Conclusions:

- PanUrban dataset is developed with a semi-automatic workflow, which can be applied in multiple aerial image tasks.
- Training a panoptic segmentation model has achieved a plausible result which can be set as a baseline in future development.

Future work:

- Limited generalization ability requires techniques to limit overfitting on training data, applying different normalization layers or add regularization terms.

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- Alexander Kirillov et al. “Panoptic feature pyramid networks”. In: *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2019, pp. 6399–6408.
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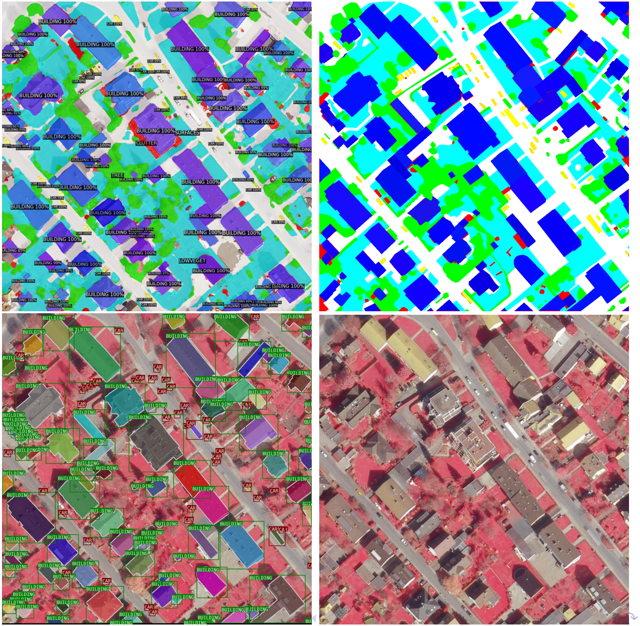
References II

Shaoqing Ren et al. "Faster r-cnn: Towards real-time object detection with region proposal networks". In: *arXiv preprint arXiv:1506.01497* (2015).

Prediction Samples - MA



Prediction Samples - Potsdam