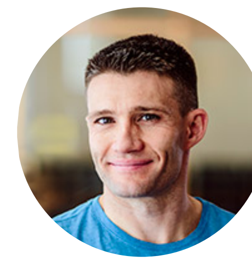
Panoptic Segmentation: Unifying Semantic and Instance Segmentation







Alex Kirillov   Carsten Rother   Kaiming He   Ross Girshick   Piotr Dollár

UNIVERSITÄT HEIDELBERG

FACEBOOK AI RESEARCH

Unifying Semantic and Instance Segmentation

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Semantic Segmentation

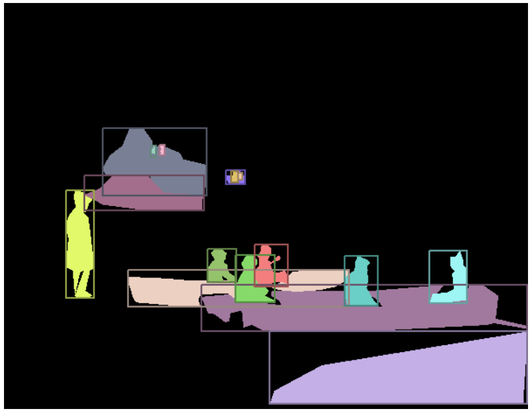
Unifying Semantic and Instance Segmentation

Semantic Segmentation

Object Detection

Unifying Semantic and Instance Segmentation

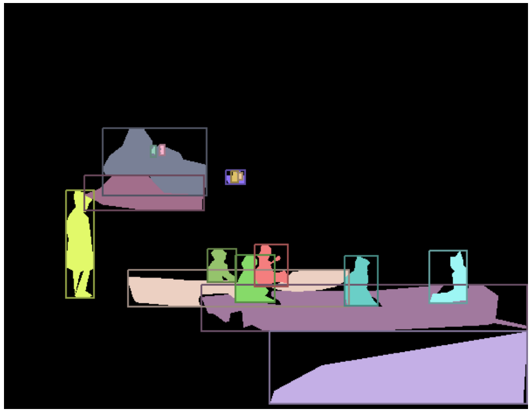
Semantic Segmentation



Object Detection/Seg

Unifying Semantic and Instance Segmentation

Semantic Segmentation



Object Detection/Seg

- per-pixel annotation
- simple accuracy measure
- instances indistinguishable

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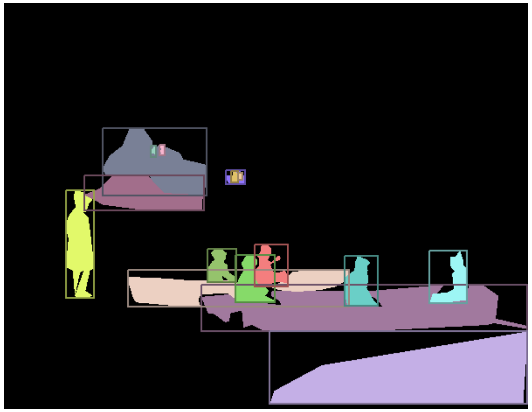

Object Detection/Seg

- each object detected and segmented separately
- "stuff" is not segmented

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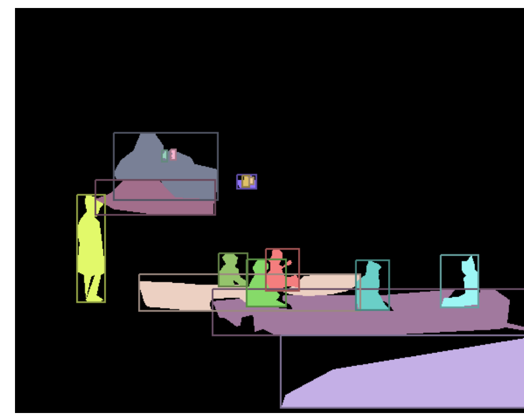

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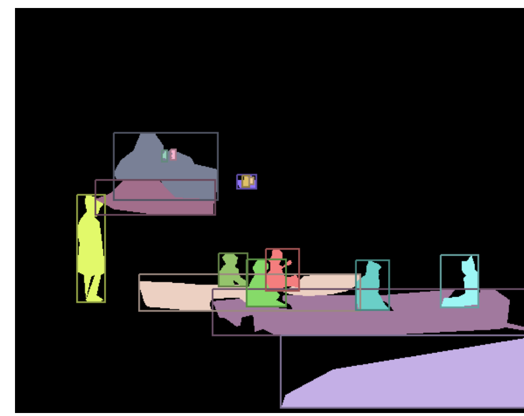
Panoptic Segmentation



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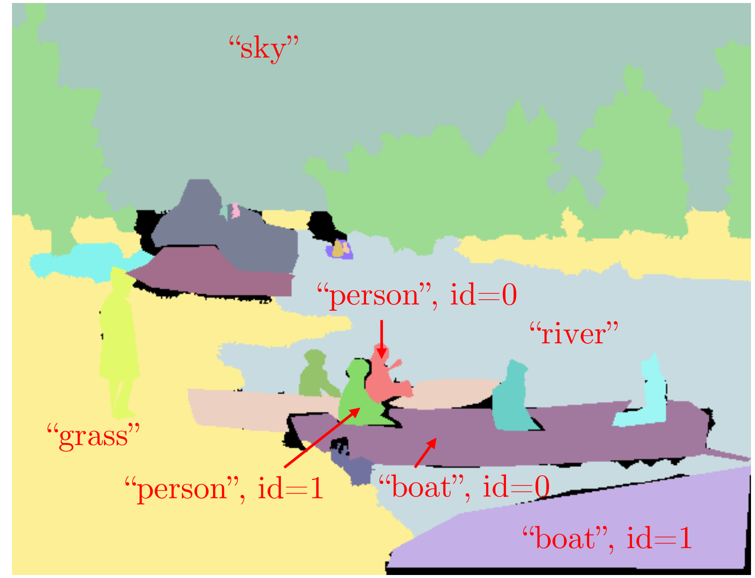
Outline

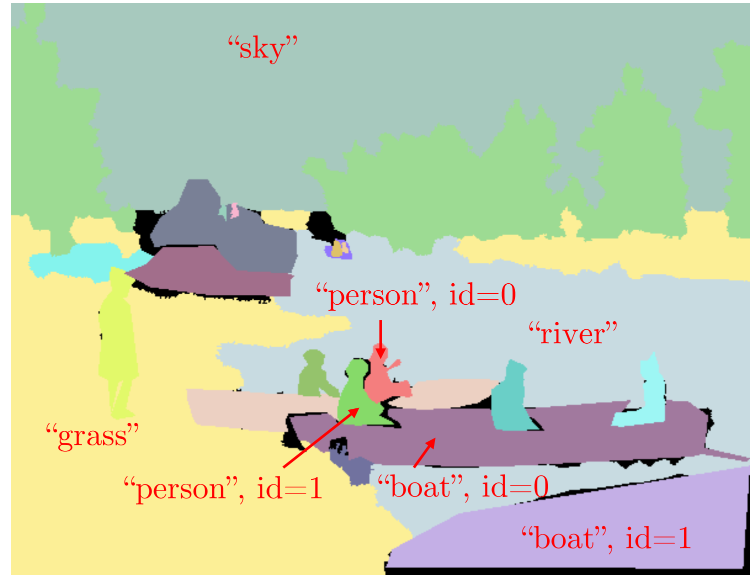
- ➢Motivation
- ➢**Problem Definition**
- ➢Quality Evaluation
- ➢Human Performance
- ➢Humans vs Computers
- ➢Perspectives

Panoptic Segmentation



For each pixel i predict semantic label l **and instance id** $\boldsymbol{z}$

Panoptic Segmentation



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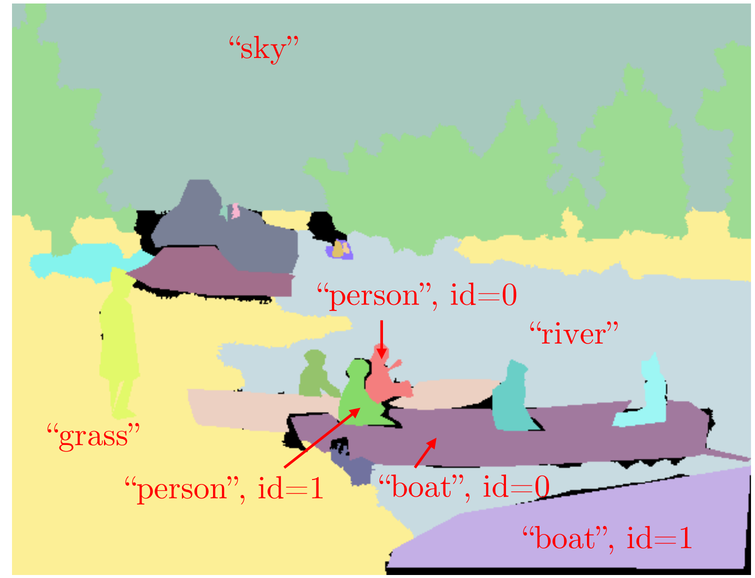
- no overlaps between segments

Panoptic Segmentation

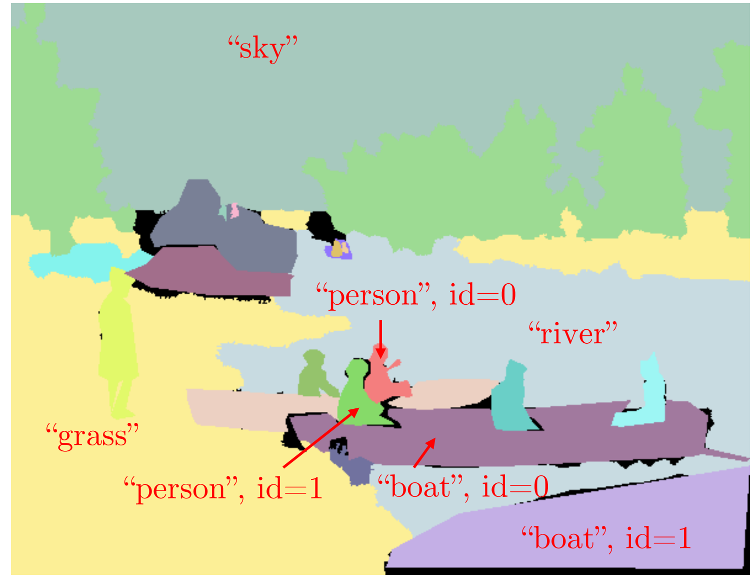


For each pixel i predict semantic label l **and instance id** $\boldsymbol{z}$

- ➢ no overlaps between segments

- Popular datasets can be used
- We introduce simple, intuitive metric
- Drive novel algorithmic ideas

Popular datasets can be used



For each pixel i predict semantic label l **and instance id z**

Datasets	Instance Segmentation	Semantic Segmentation
COCO*	+	+
ADE20k/Places	+	+
CityScapes	+	+
Mapillary Vistas	+	+

*COCO has overlaps (no depth order)

Outline

- ➢Motivation
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- ➢**Quality Evaluation**
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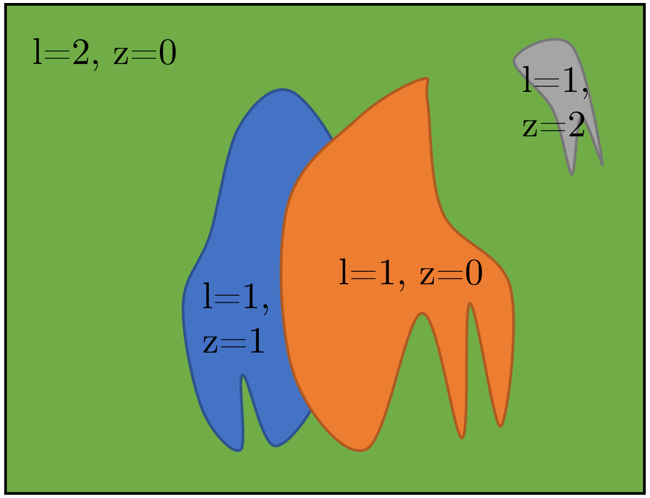
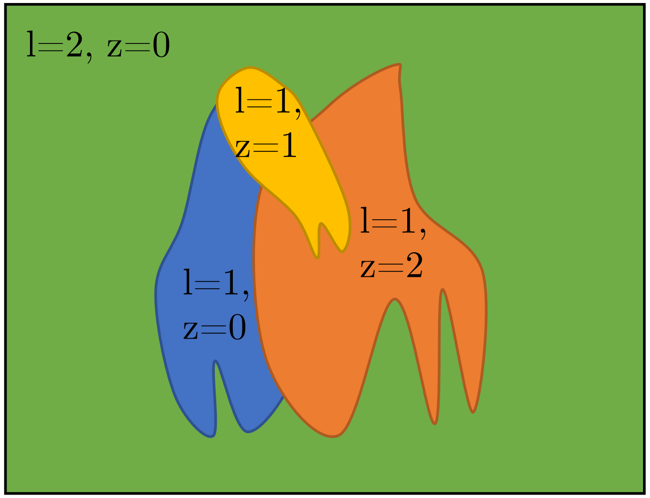
Quality Evaluation

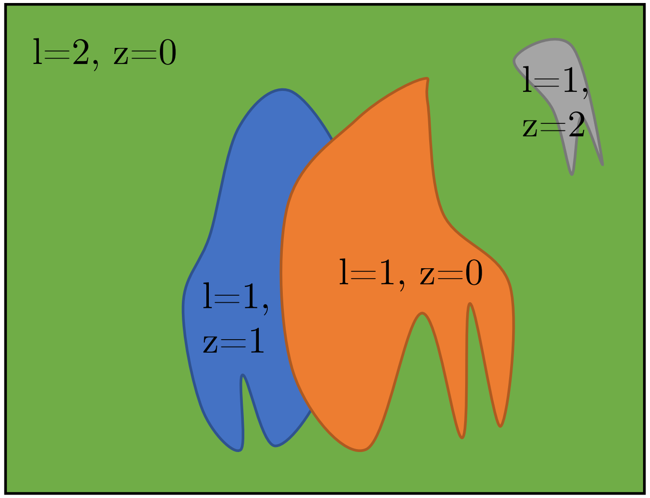


Ground Truth



Prediction

Quality Evaluation



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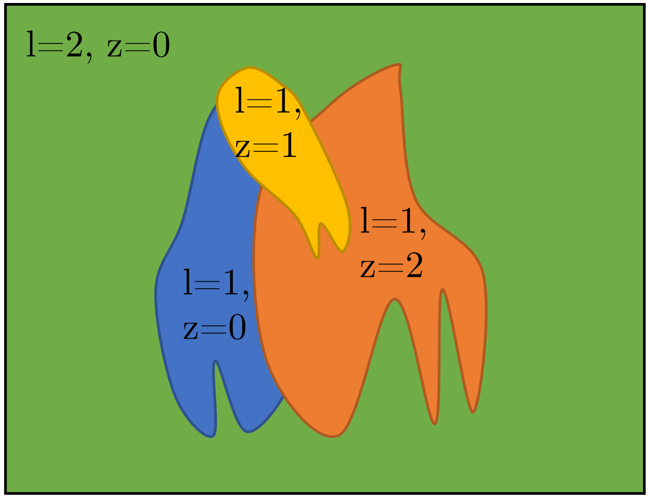
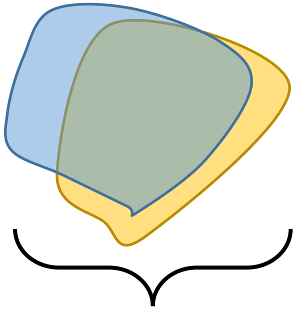


Prediction

Theorem: Matching is unique if overlapping threshold **>** 0.5 IoU and both ground truth and prediction have no overlaps.

Proof sketch:

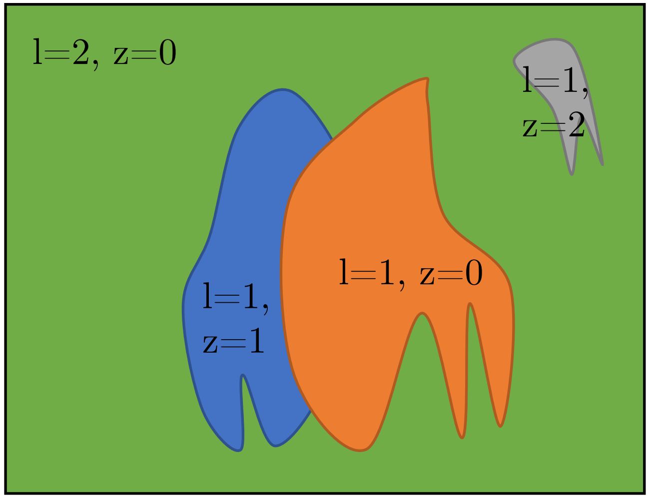
if



$\text{IoU} > 0.5$

then there is no other non overlapping object that has IoU $>$ 0.5.

Quality Evaluation



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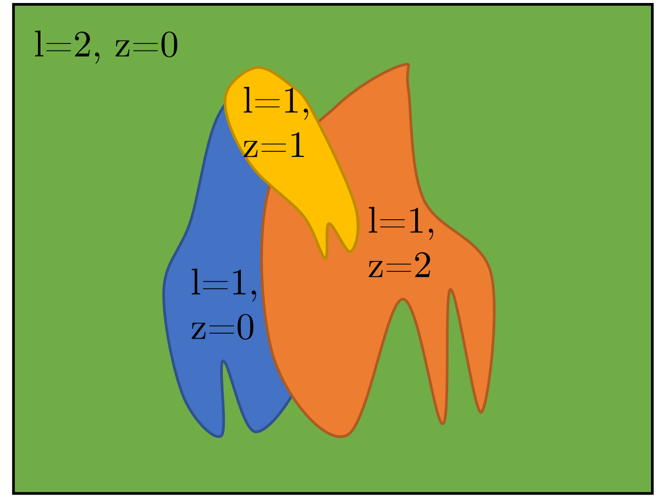
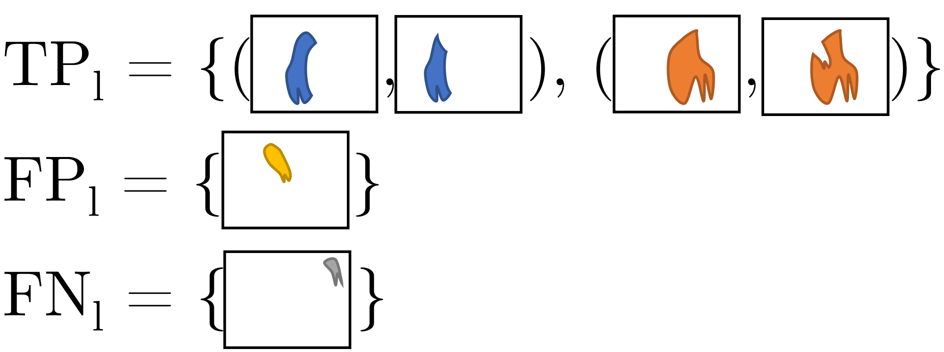
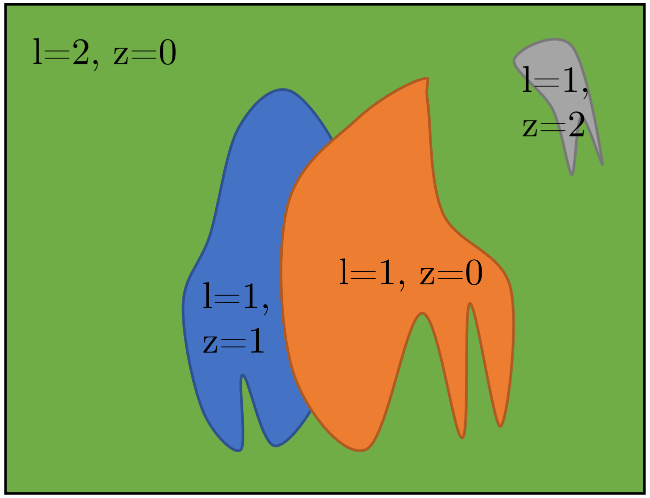


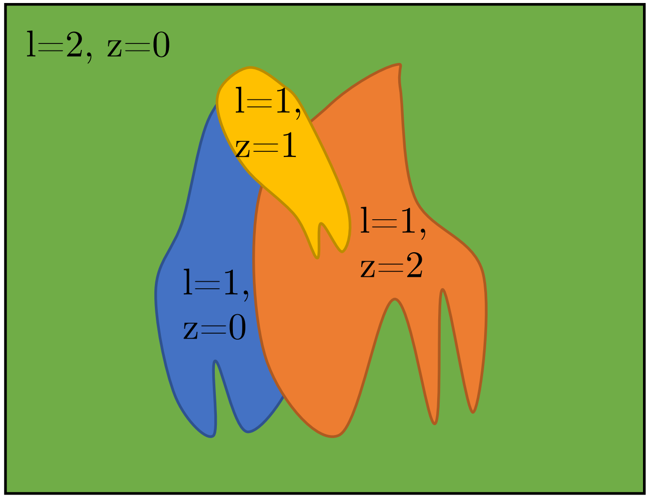
Prediction



Quality Evaluation



Ground Truth



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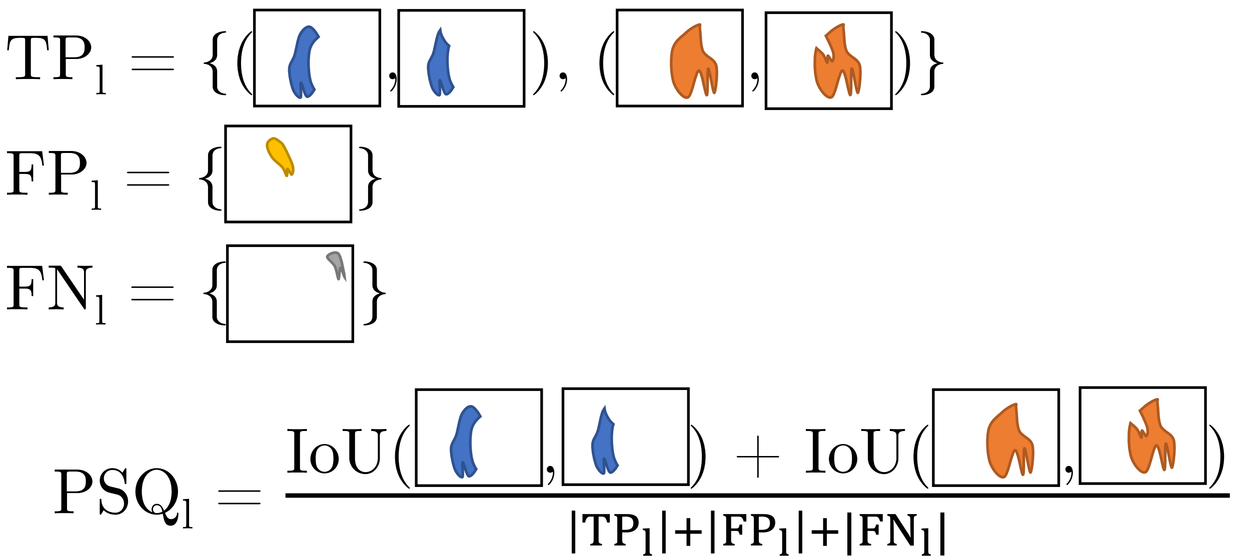
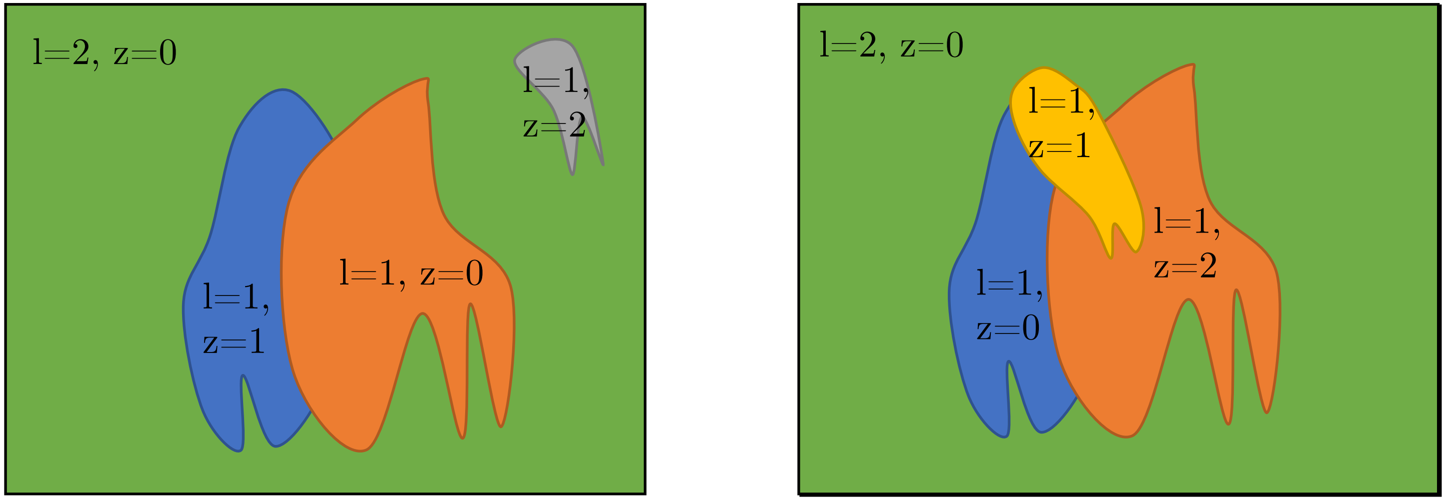


$$= \frac{\sum_{(g,p)\in TP_l} \mathrm{IoU}(g,p)}{|TP_l|+|FP_l|+|FN_l|}$$

Quality Evaluation



$$\mathrm{PSQ}_l = \frac{\sum_{(g,p)\in TP_l} \mathrm{IoU}(g,p)}{|TP_l|+|FP_l|+|FN_l|} = \underbrace{\frac{\sum_{(g,p)\in TP_l} \mathrm{IoU}(g,p)}{|TP_l|}}_{\text{Segmentation Quality}} \cdot \underbrace{\frac{|TP_l|}{|TP_l|+|FP_l|+|FN_l|}}_{\text{Detection Quality}}$$

Outline

- Motivation
- Problem Definition
- Quality Evaluation
- **Human Performance**
- Humans vs Computers
- Perspectives

Panoptic Segmentation Quality (PSQ)

$$\mathrm{PSQ_l} = \frac{\sum_{(g,p)\in \mathrm{TP_l}} \mathrm{IoU}(g,p)}{|\mathrm{TP_l}|+|\mathrm{FP_l}|+|\mathrm{FN_l}|} = \underbrace{\frac{\sum_{(g,p)\in \mathrm{TP_l}} \mathrm{IoU}(g,p)}{|\mathrm{TP_l}|}}_{\text{Seg Quality}} \cdot \underbrace{\frac{|\mathrm{TP_{l=1}}|}{|\mathrm{TP_l}|+|\mathrm{FP_l}|+|\mathrm{FN_l}|}}_{\text{Det Quality}}$$

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no confidence scores

$\Downarrow$

human performance can be measured

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CityScapes: 30 images were annotated independently twice.

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no confidence scores
⇩
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CityScapes: 30 images were annotated independently twice.

class	PSQ	Seg Quality	Det Quality
car	66.6%	87.5%	76.2%
person	61.8%	80.8%	76.4%
motorcycle	51.8%	77.8%	66.7%
pole	46.9%	70.3%	66.7%
road	98.0%	98.0%	100.0%
traffic sign	67.1%	79.5%	84.4%
average	**62.6%**	**83.9%**	**73.43%**

All Objects

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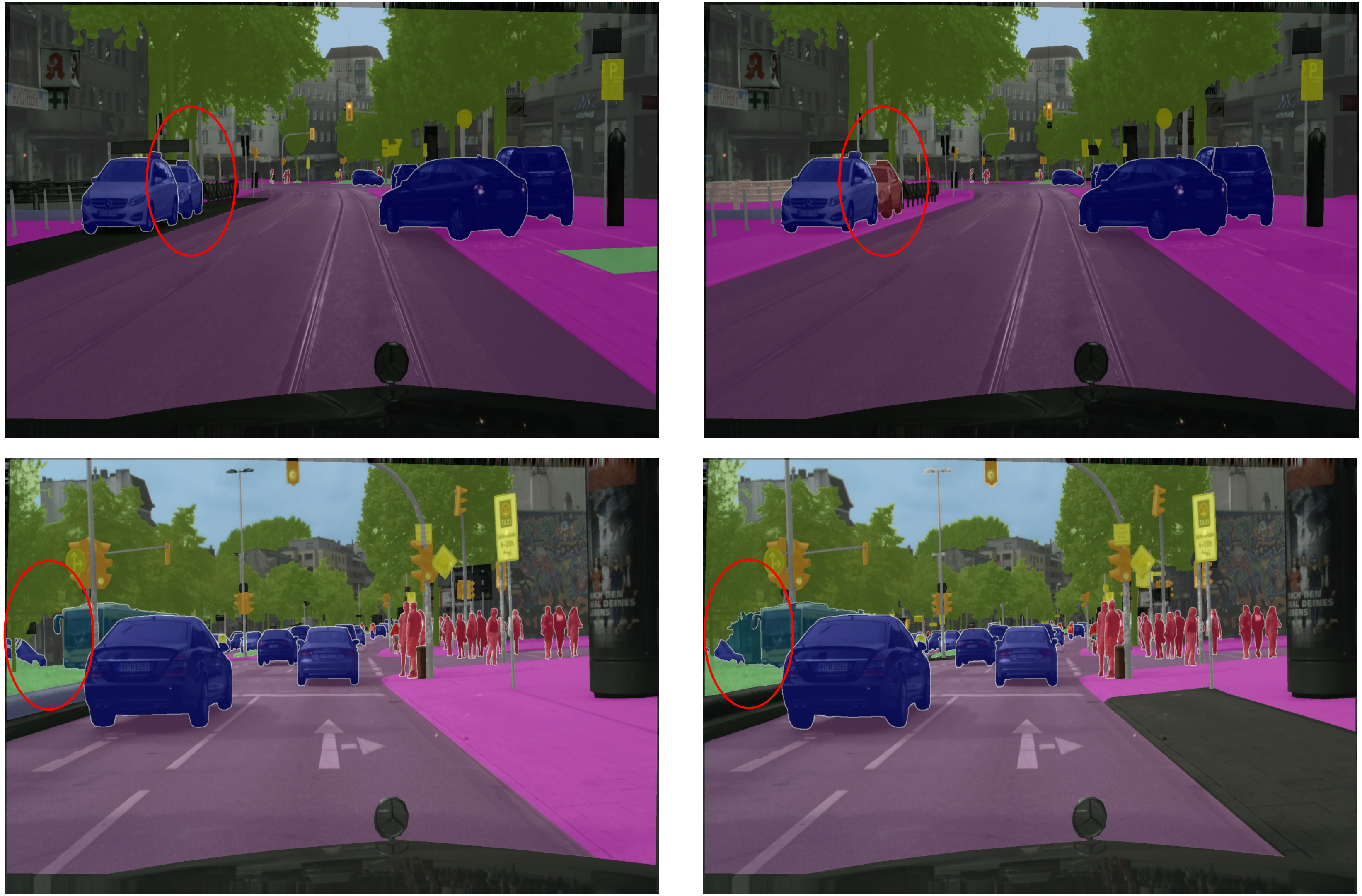
CityScapes: 30 images were annotated independently twice.

class	PSQ	Seg Quality	Det Quality
car	89.4%	91.3%	97.9%
person	82.0%	78.1%	94.1%
motorcycle	68.8%	79.4%	86.7%
pole	48.2%	70.3%	68.6%
road	98.0%	98.0%	100.0%
traffic sign	74.0%	79.5%	93.1%
average	**68.7%**	**85.1%**	**80.1%**

Objects $> 32^2$

Human Annotation Flaws



Classification Flaws

Human Annotation Flaws

Segmentation Flaws

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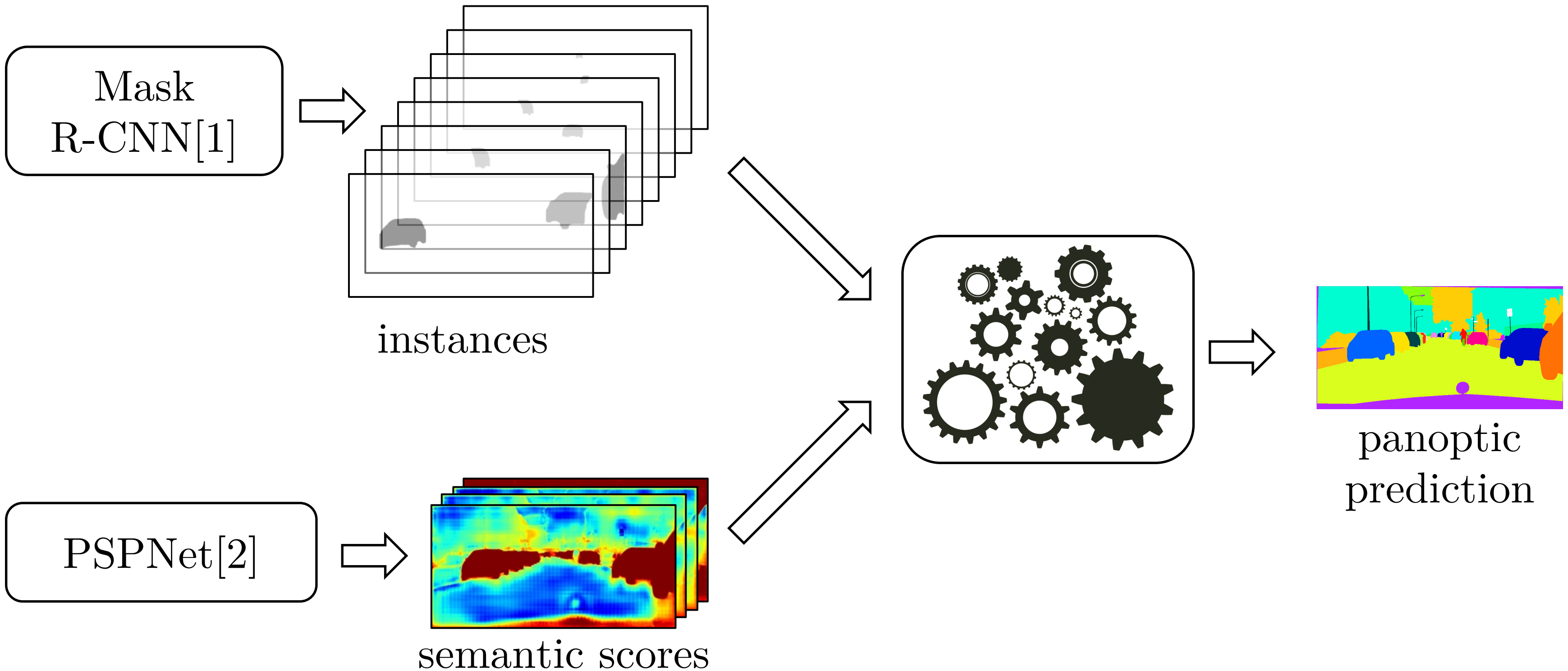
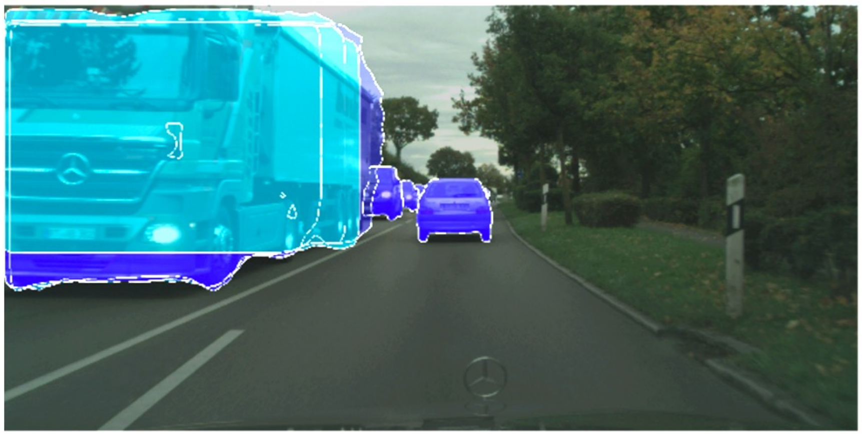
Mask R-CNN + PSPNet Combination Heuristic

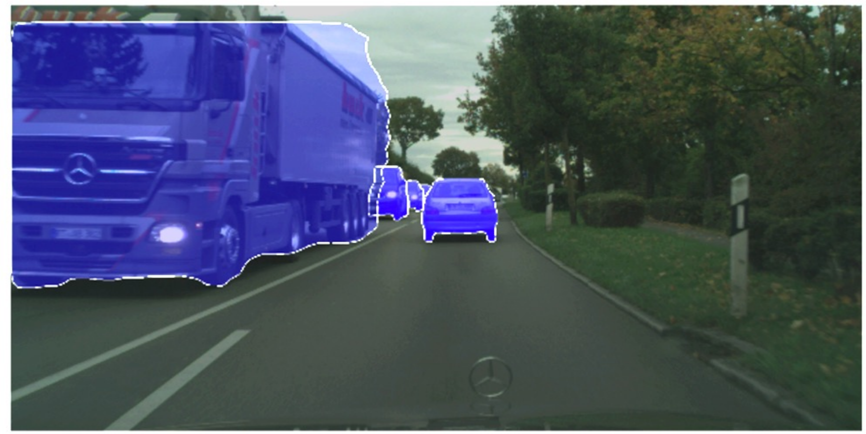


[1] He, K., Gkioxari, G., Dollár, P., & Girshick, R. Mask R-CNN. ICCV 2017.
[2] Zhao, H., Shi, J., Qi, X., Wang, X., & Jia, J. Pyramid scene parsing network. CVPR 2017.

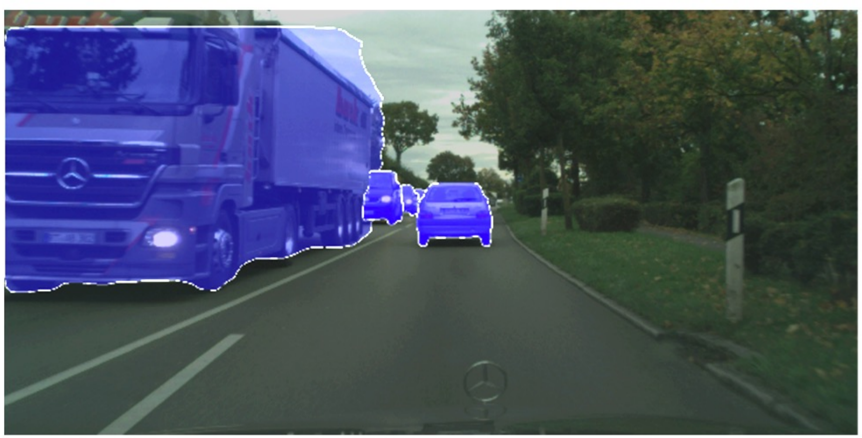
Mask R-CNN Non-overlapping Instances



Mask R-CNN output



Mask R-CNN filtered



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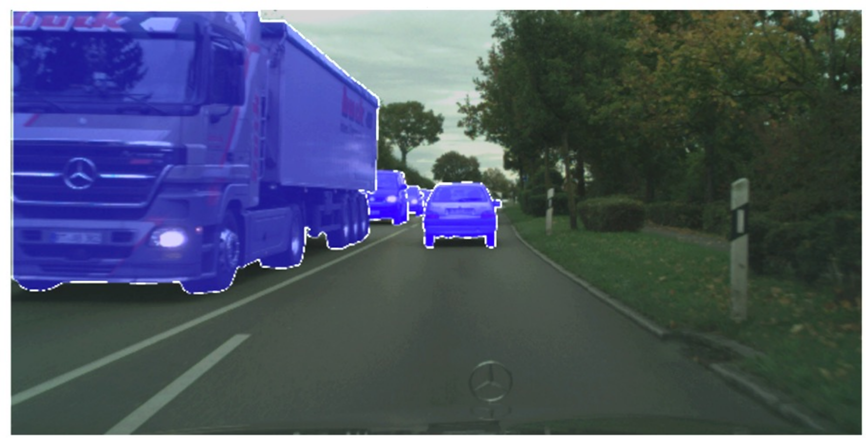

Ground Truth

PSQ – Humans vs Computers

	PSQ avg.	Seg Quality avg.	Det Quality avg.
Humans	**62.6%**	**83.9%**	**73.43%**
Mask R-CNN + PSPNet	**51.7%**	**81.0%**	**62.01%**

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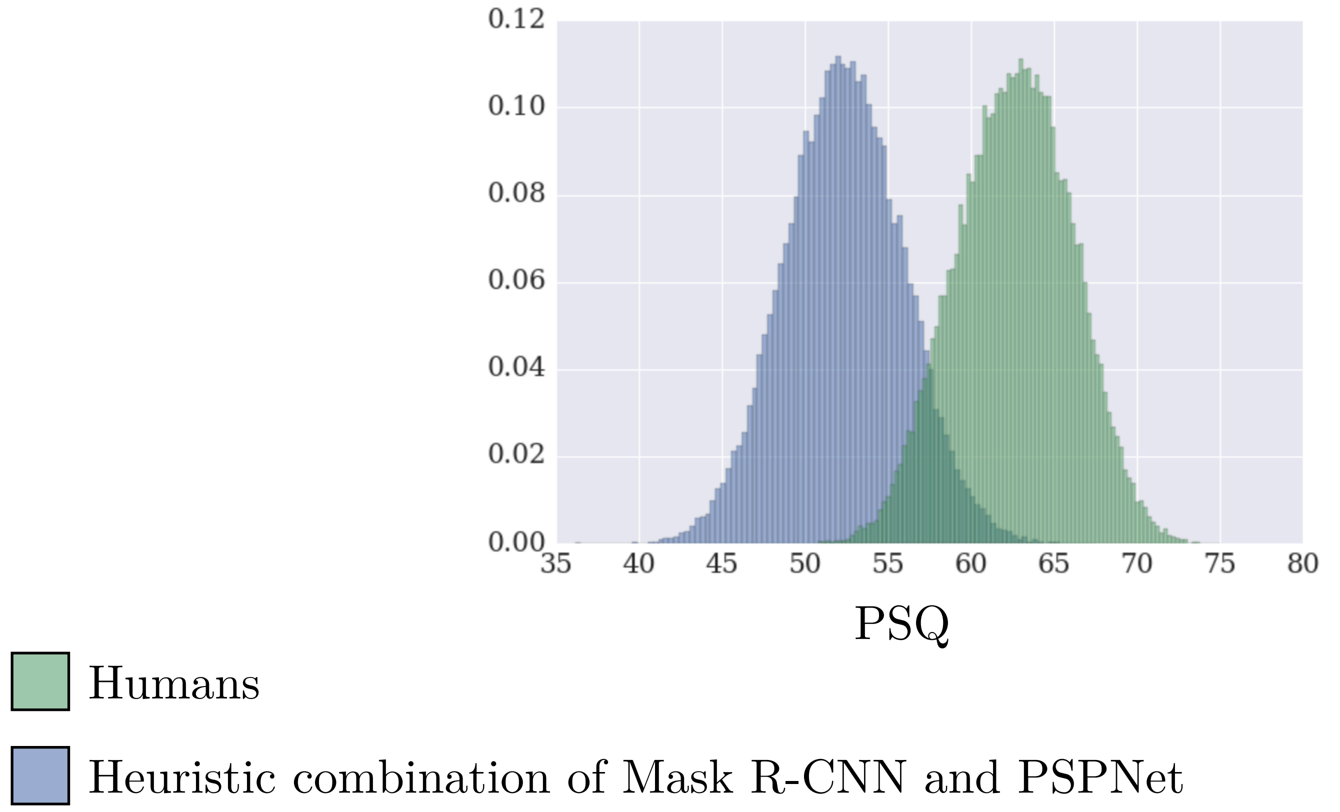

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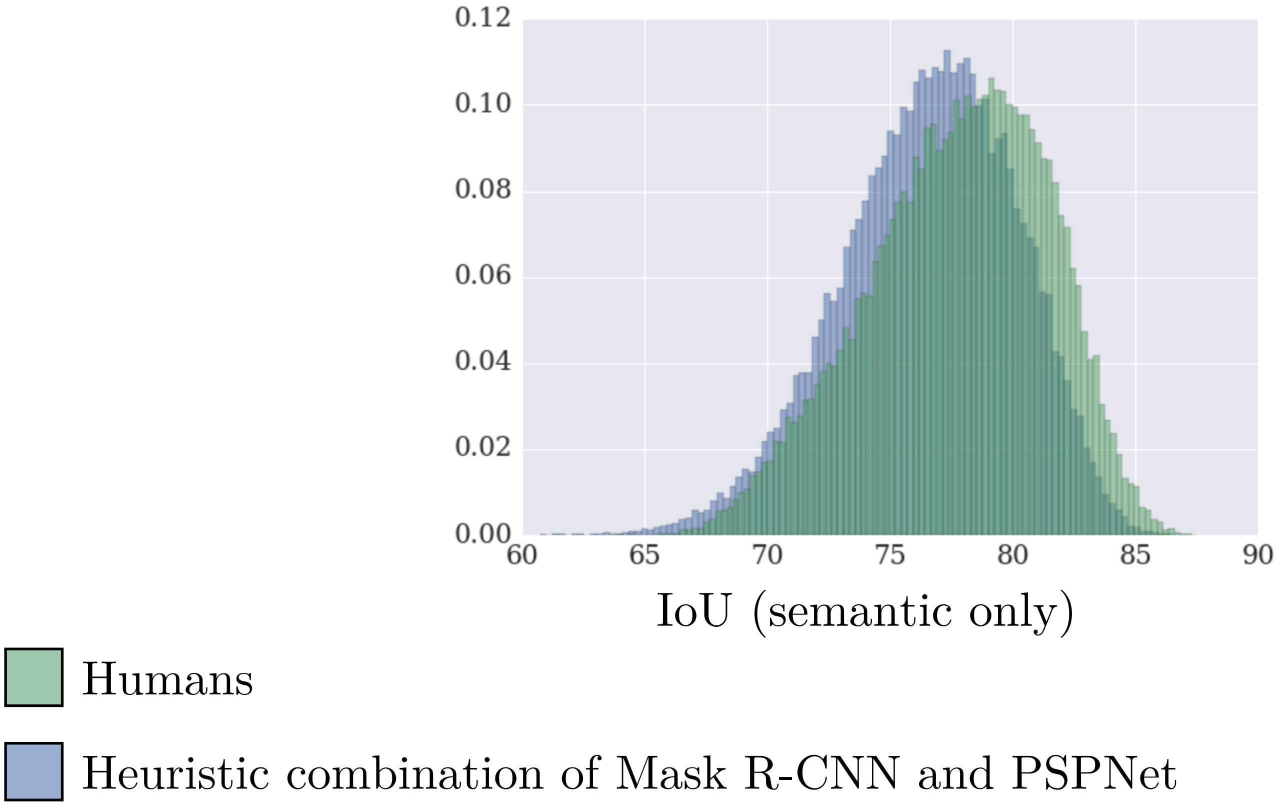

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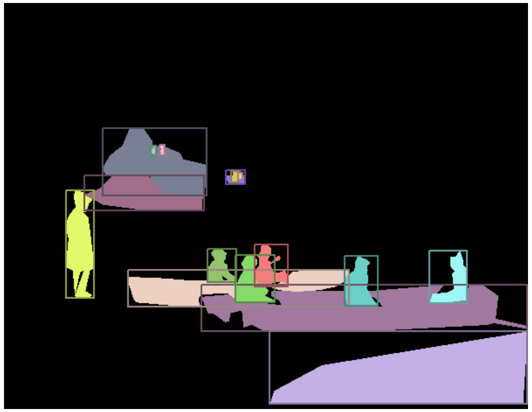
Why solve it?

Semantic Segmentation

- per-pixel annotation
- simple accuracy measure
- instances indistinguishable

Panoptic Segmentation



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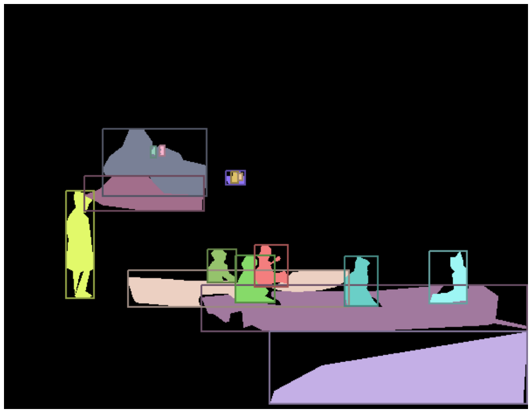
FCN 8s, Dilation8, DeepLab, PSPNet, RefineNet, U-Net, etc.

Panoptic Segmentation

?



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Fast/er R-CNN, DeepMask, SharpMask, Mask R-CNN, FCIS, YOLO, RetinaNet, FPN, etc.

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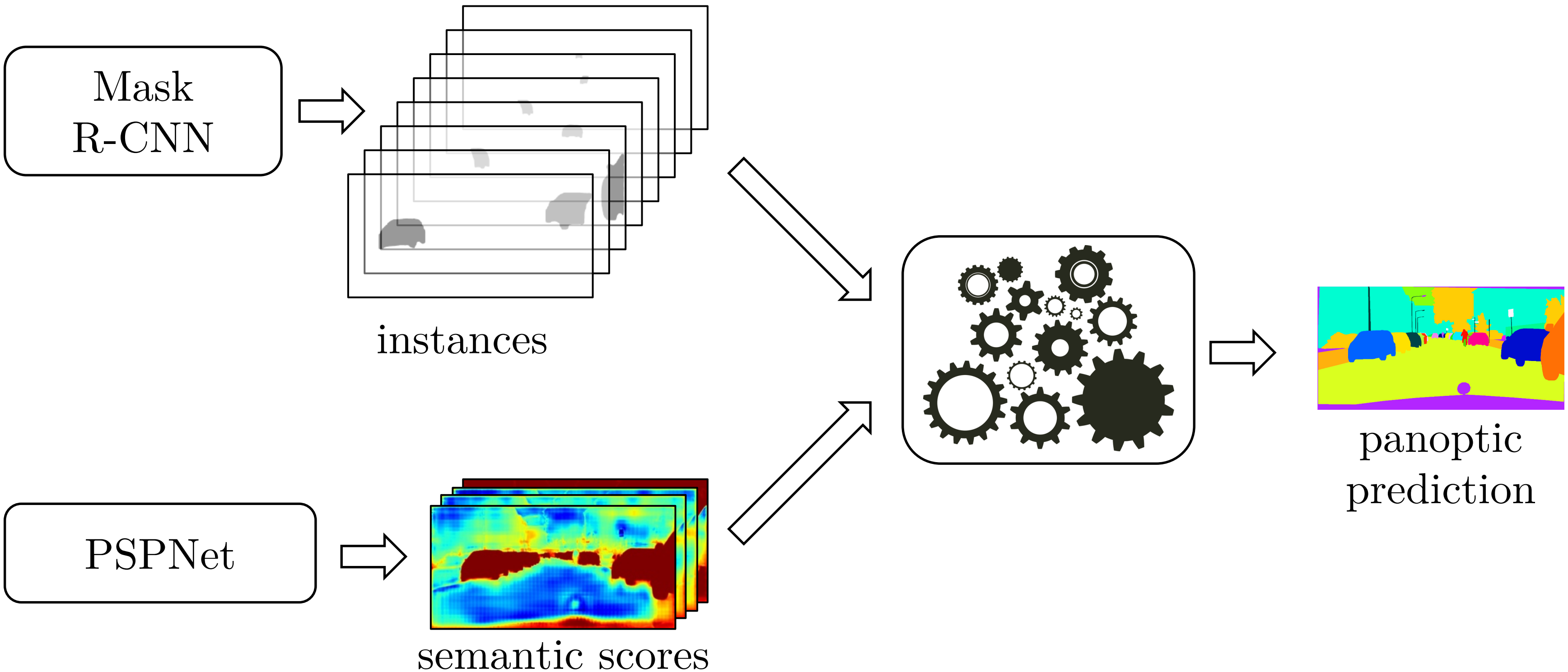
Mask
R-CNN
instances
PSPNet
semantic scores
panoptic
prediction

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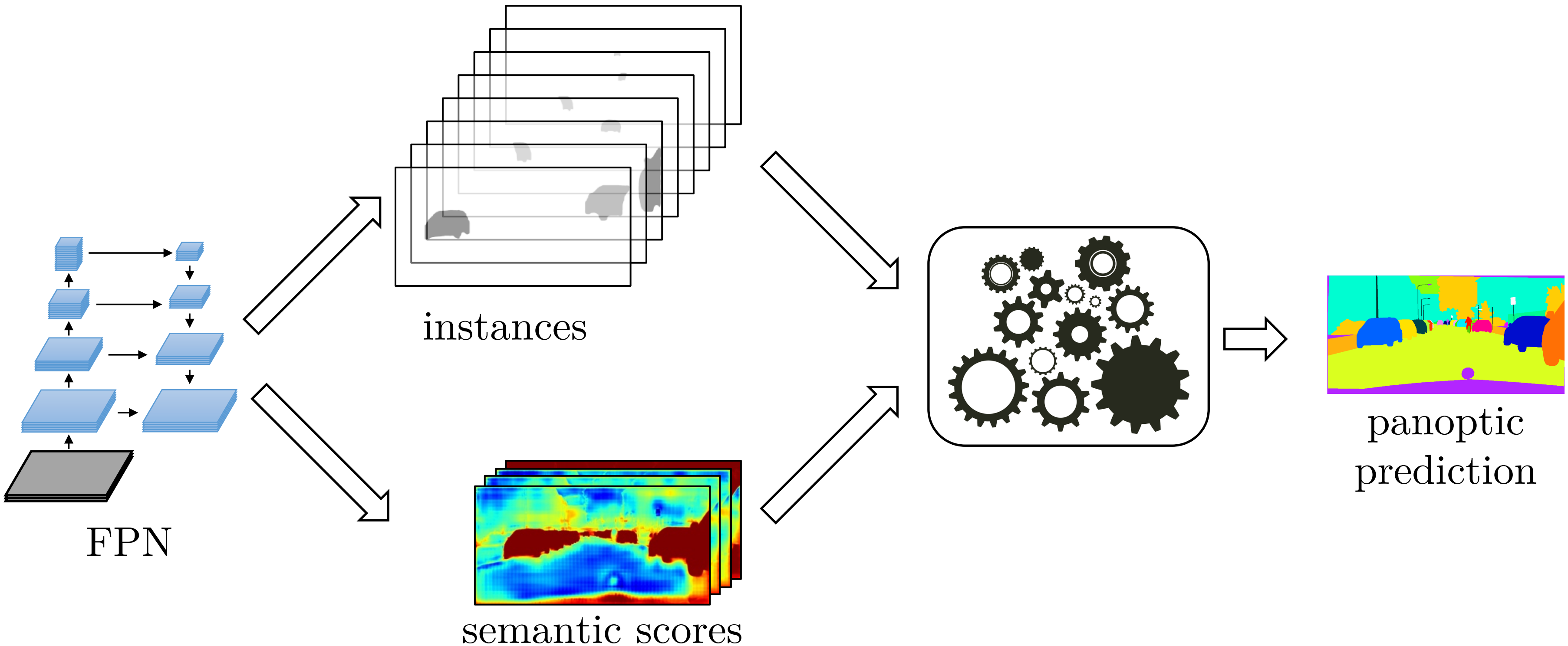

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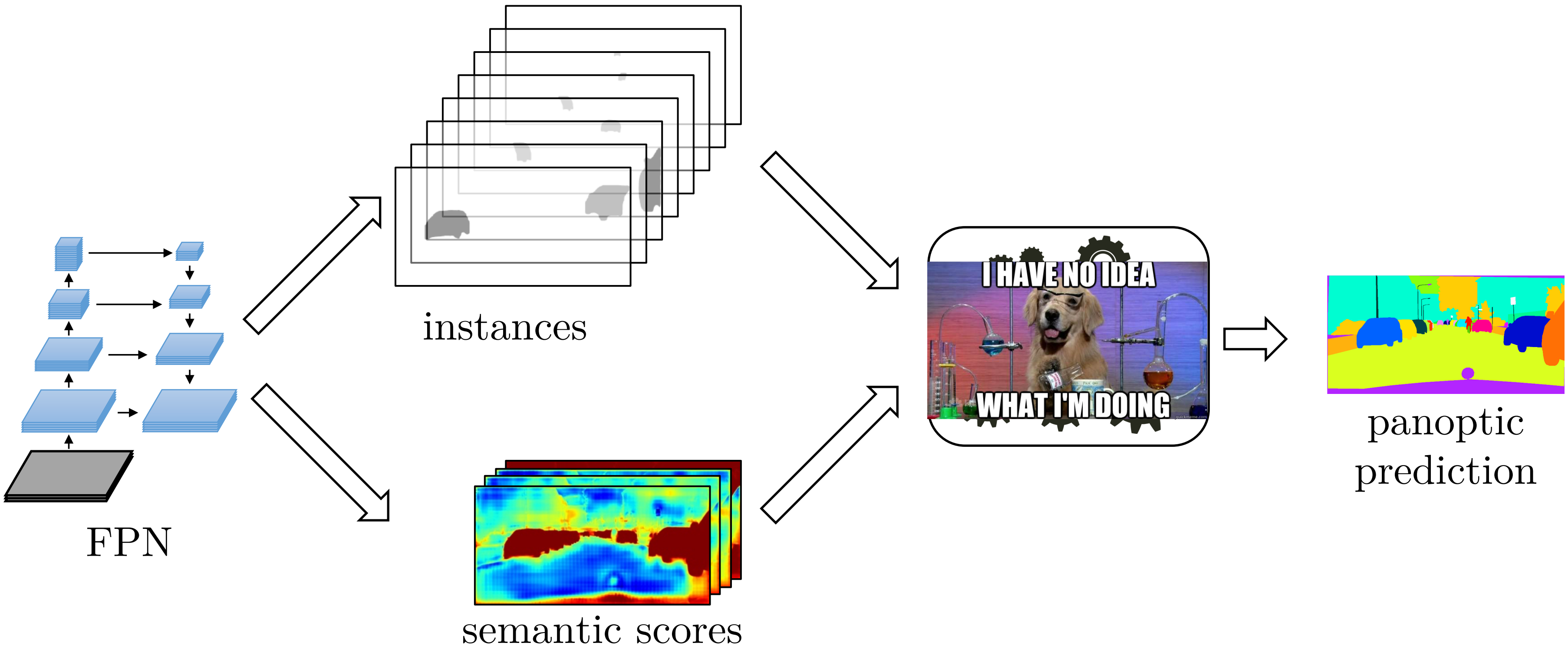
instances
I HAVE NO IDEA
WHAT I'M DOING
FPN
semantic scores
panoptic prediction

Panoptic Segmentation: Future Plans

- Panoptic Segmentation paper on ArXiv
- Efficient evaluation code on GitHub
- Possible competition(s)

Panoptic COCO

Panoptic CityScapes