CVPR 2021

Fully Convolutional Networks for Panoptic Segmentation

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Zeming Li, Jian Sun, Jiaya Jia

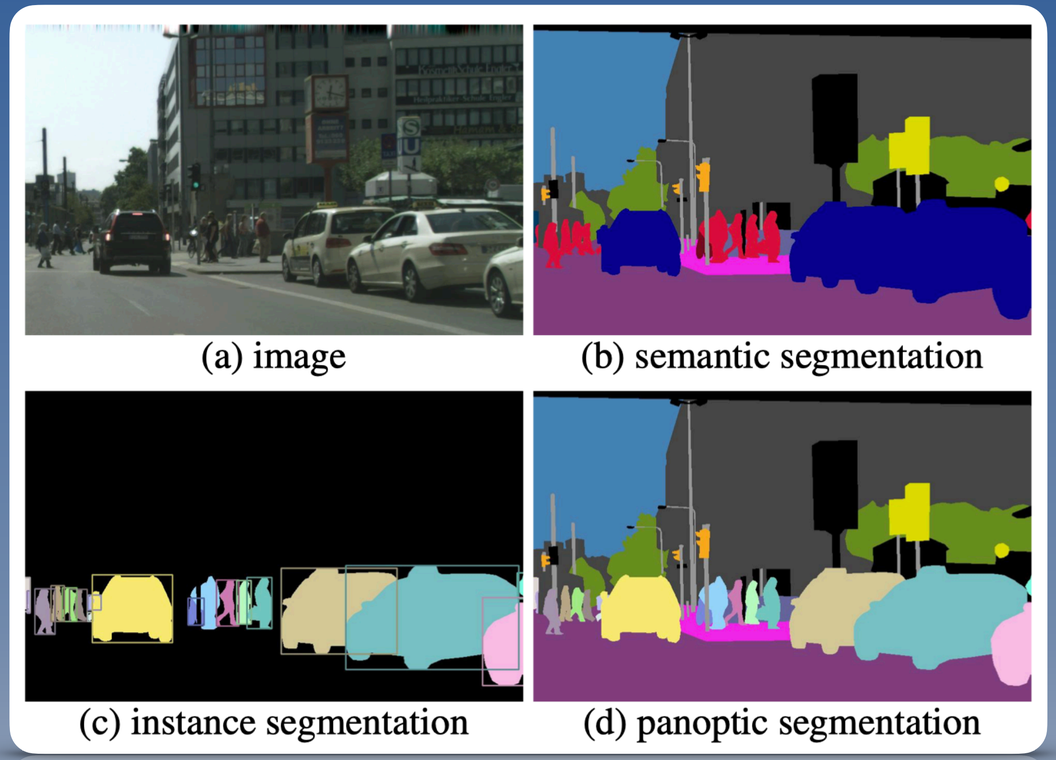
Introduction

Definition of Panoptic Segmentation

Assign each pixel with a semantic label and unique identity to Things and Stuff.

Difficulties in Panoptic Segmentation

- Conflicting properties of Things and Stuff. Things rely on instance-aware features, while Stuff need semantic-consistent characters.
- How to encode things and stuff in a unified representation?
- How to model the relationship among things, and between things and stuff?



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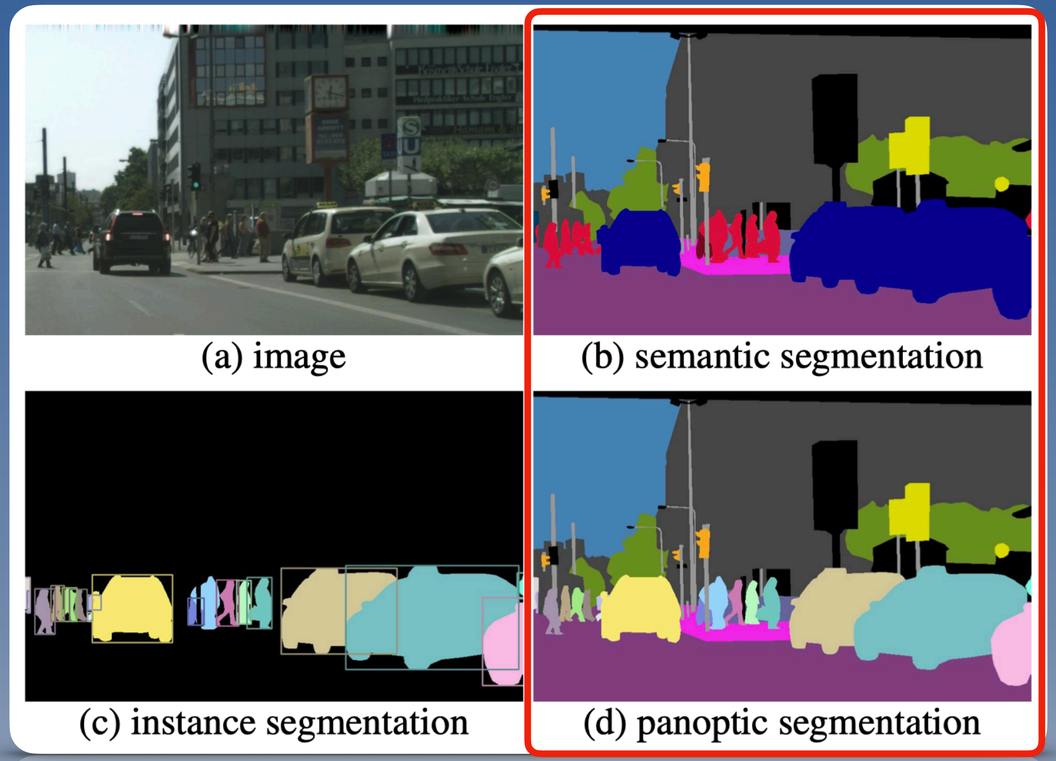

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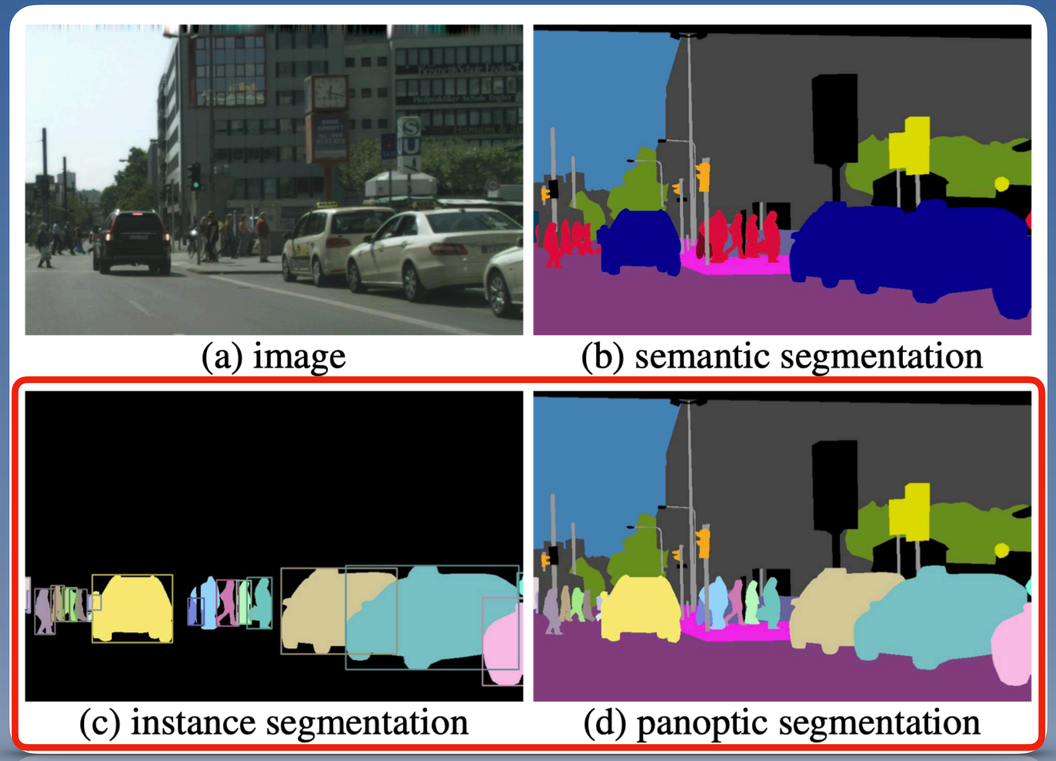

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Panoptic FCN

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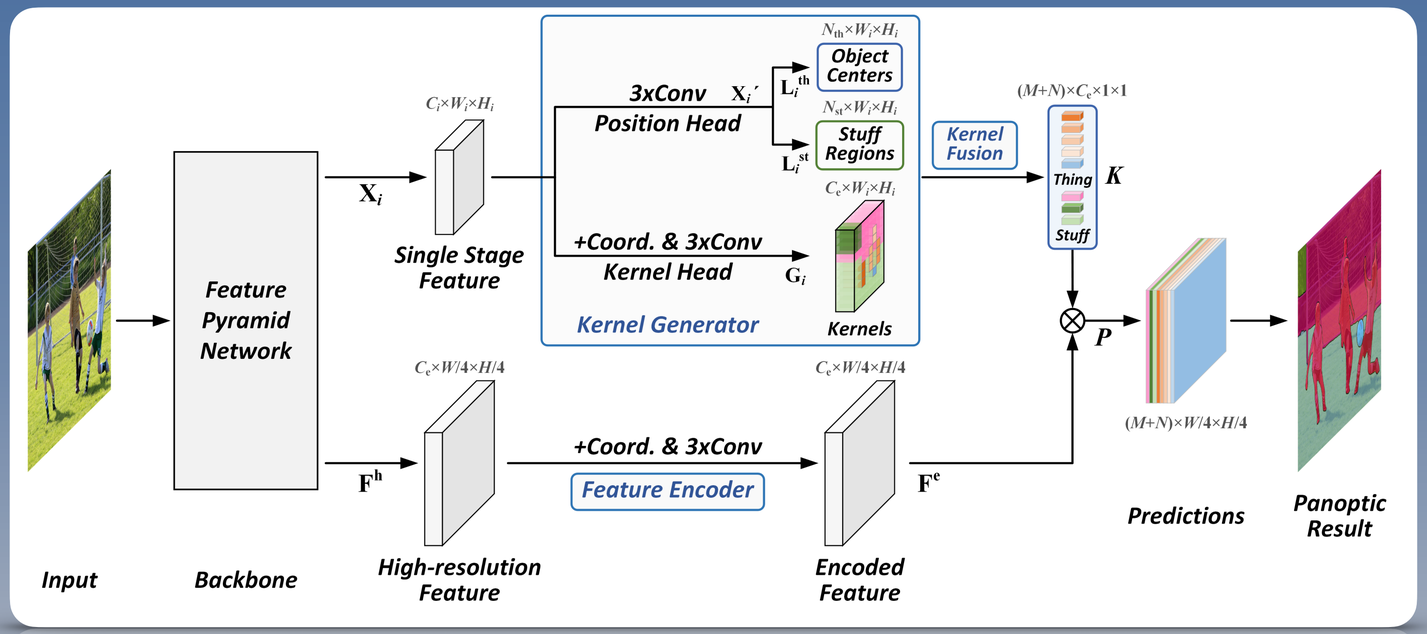
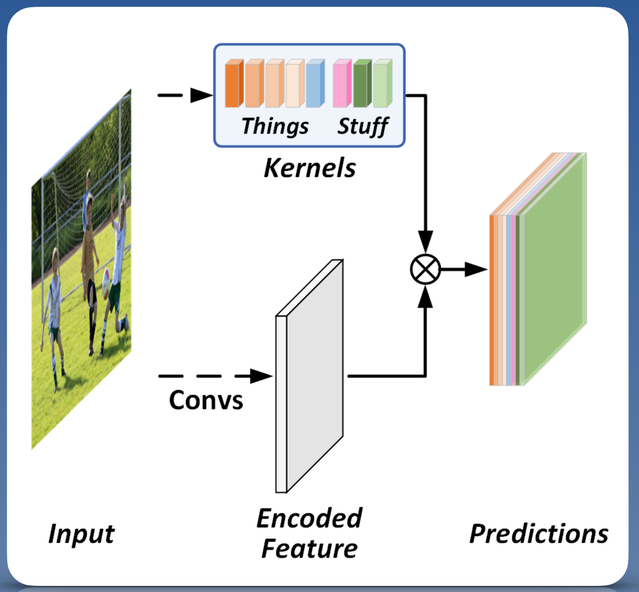
Panoptic FCN represent them uniformly

- It encodes each instance into a specific kernel and generates the prediction by convolutions directly.
- Instance-awareness for things: each thing has unique kernel.
- Semantic-consistency for stuff: identical stuff has same kernel.



Framework of Panoptic FCN.



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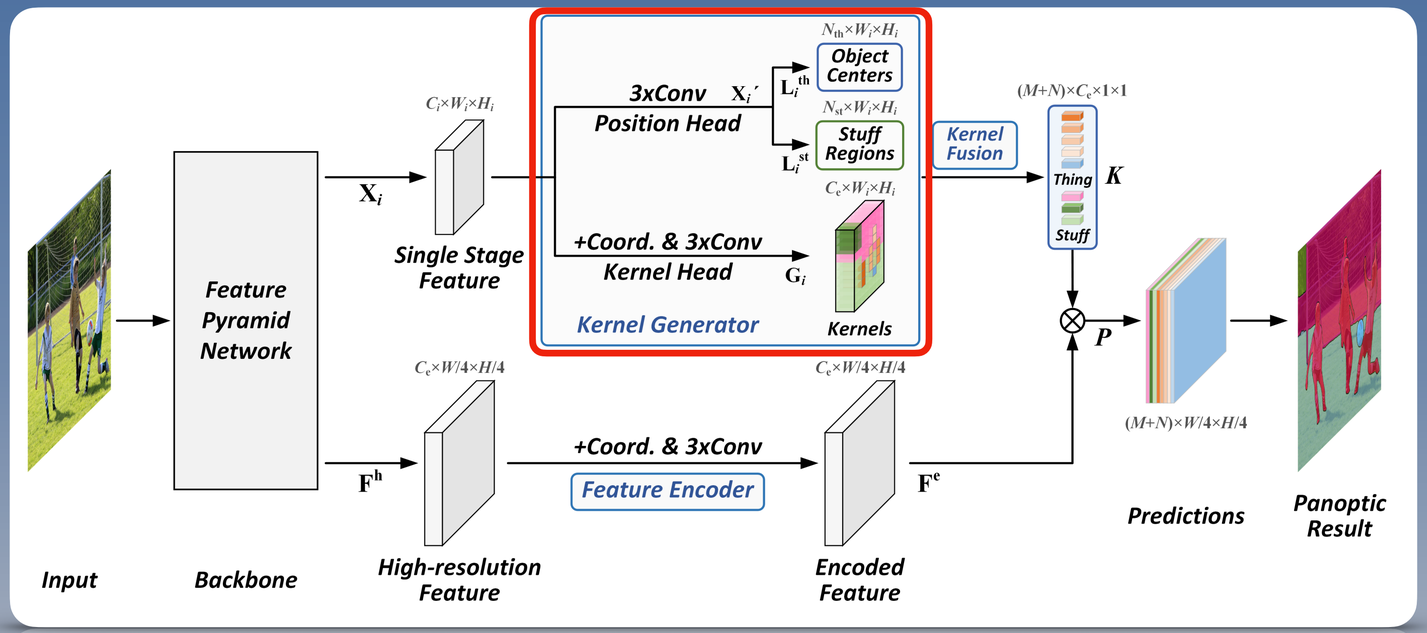

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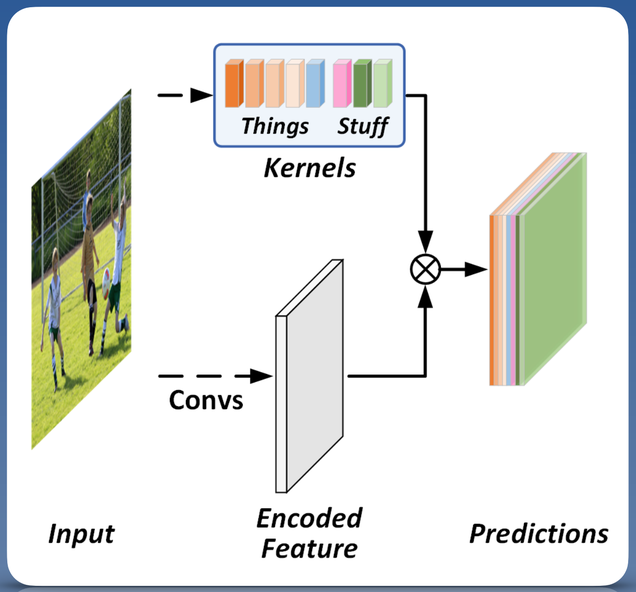

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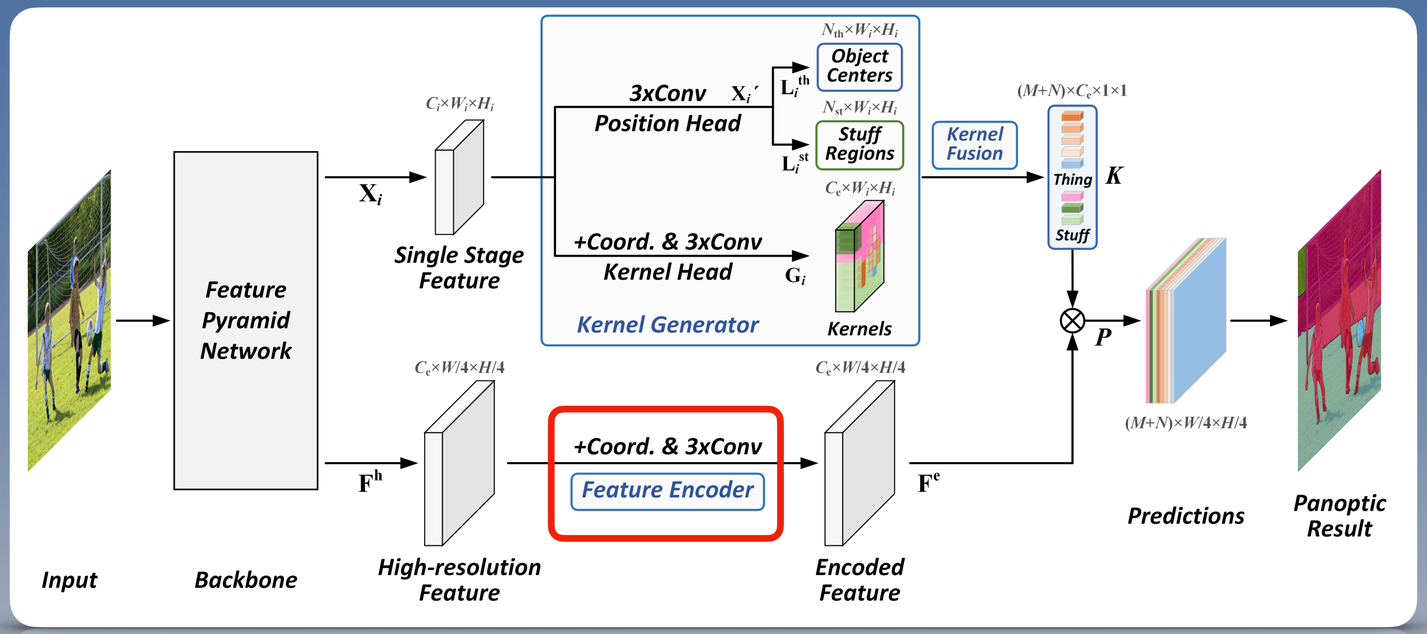

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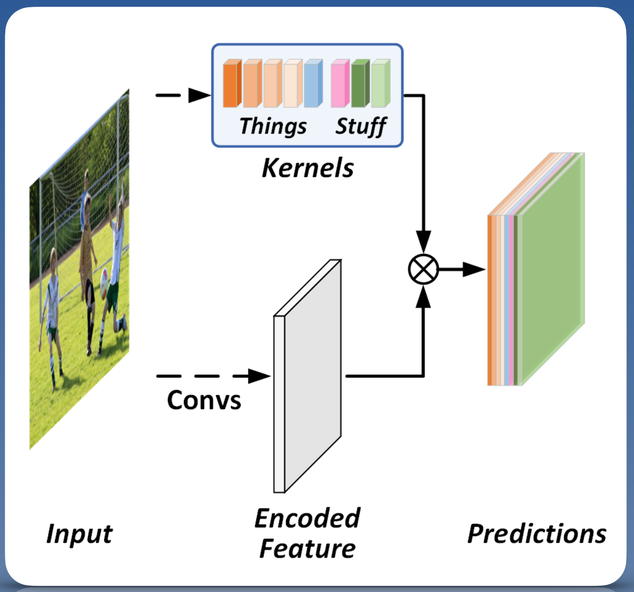

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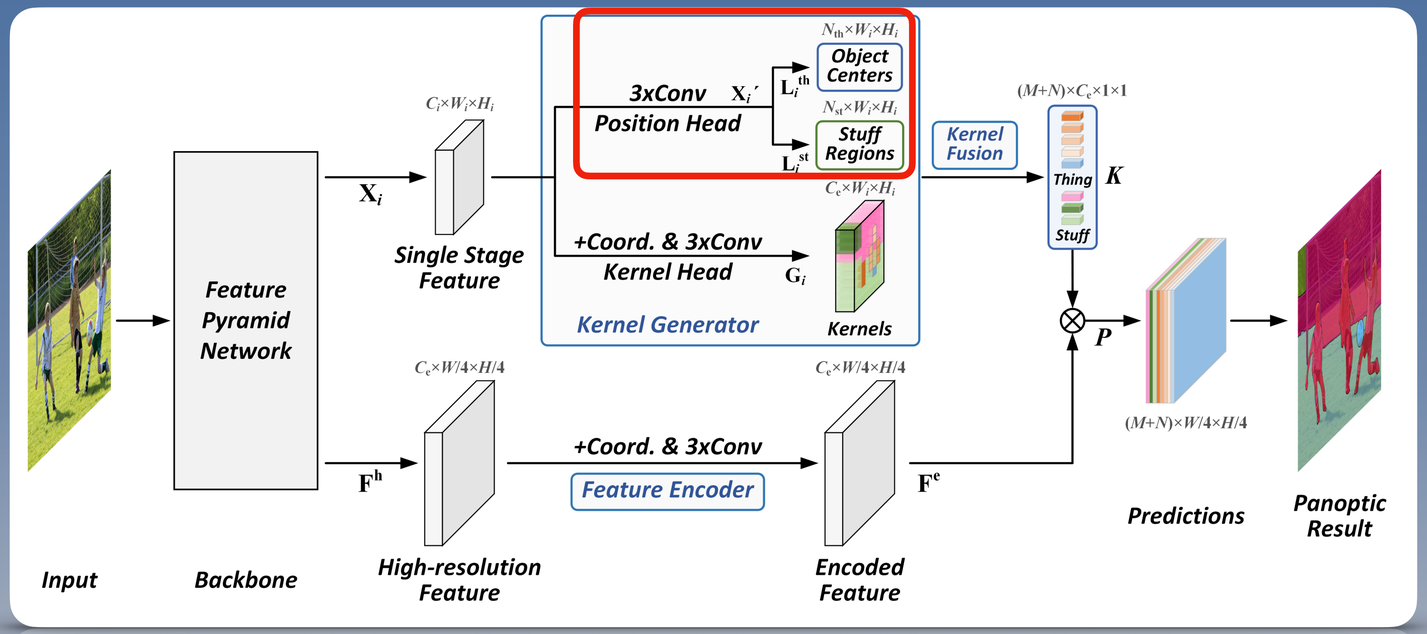

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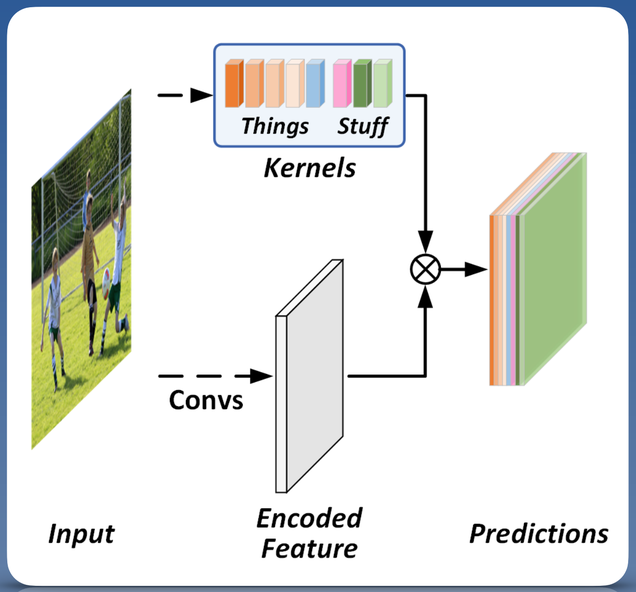

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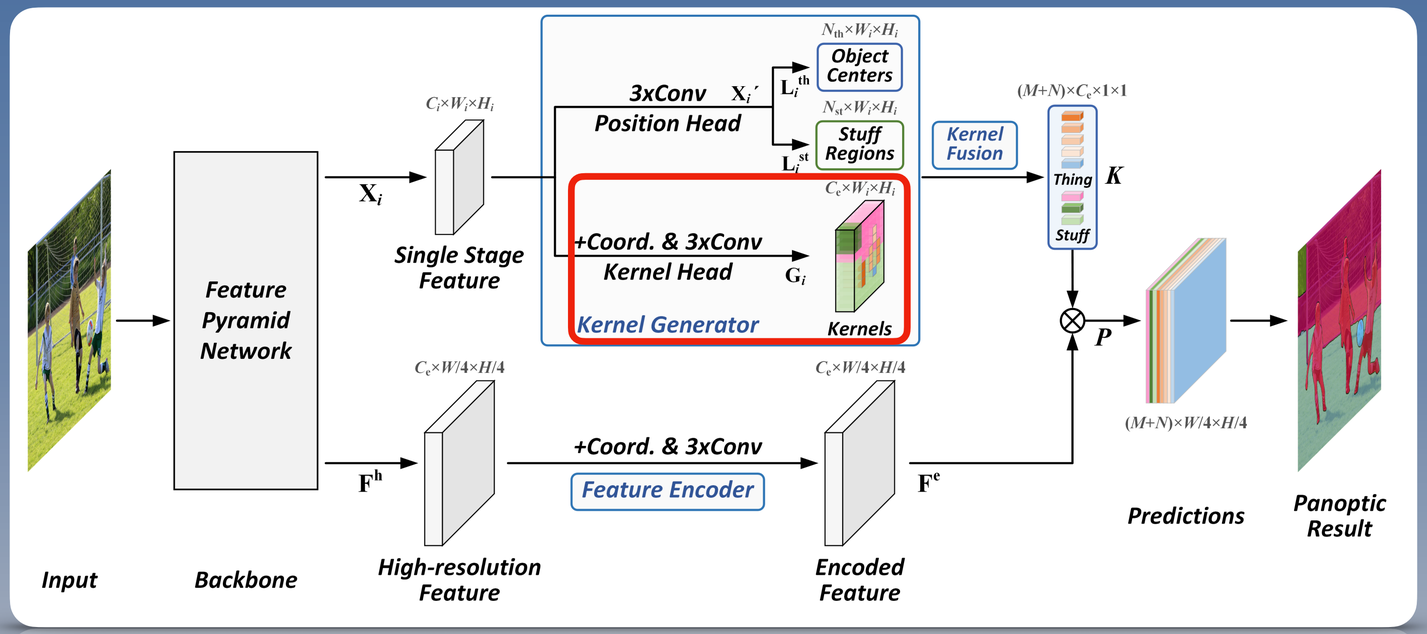

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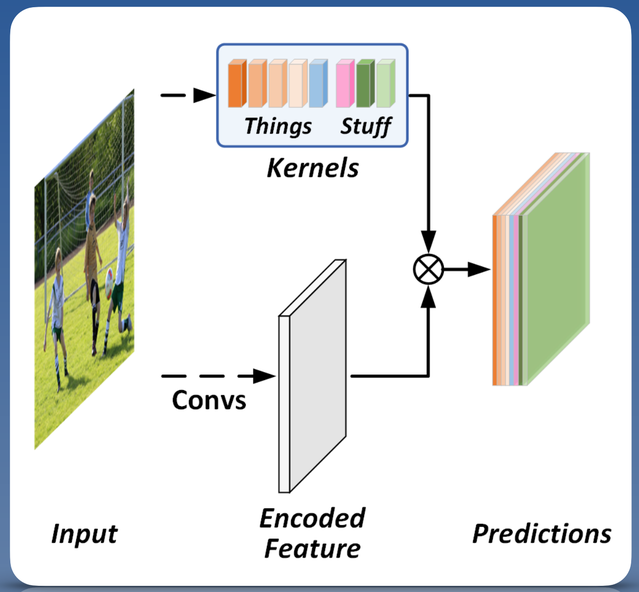

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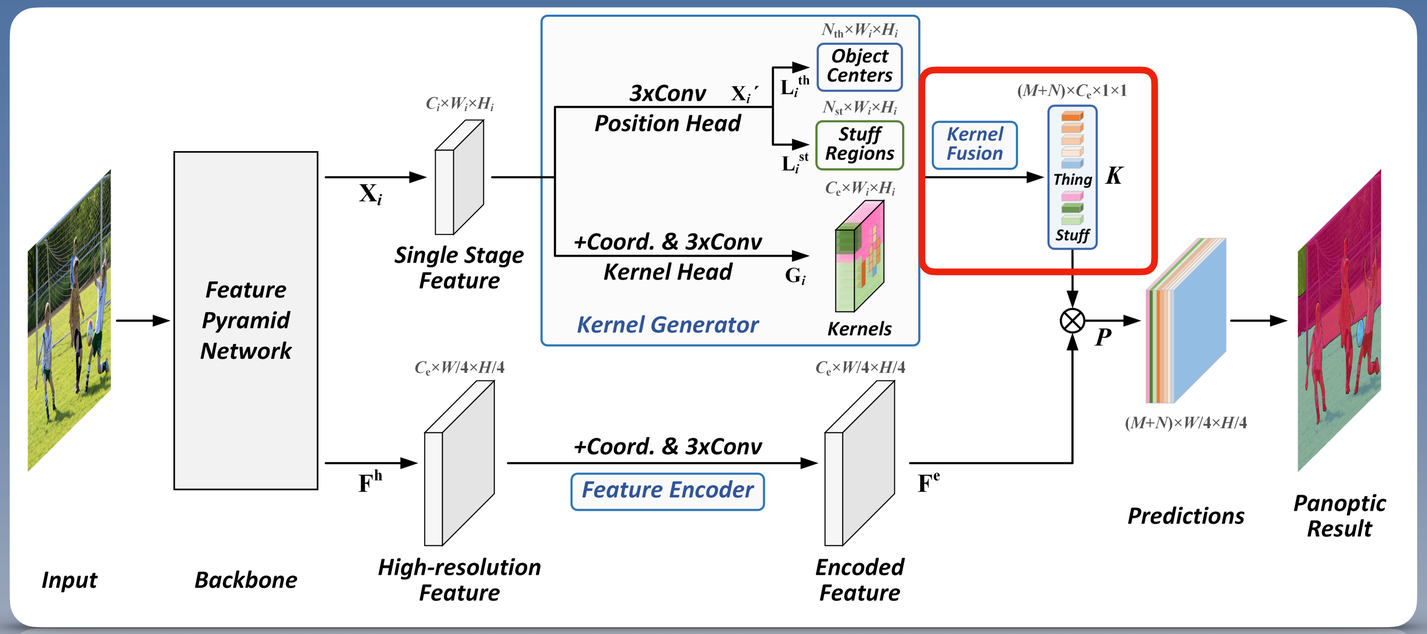

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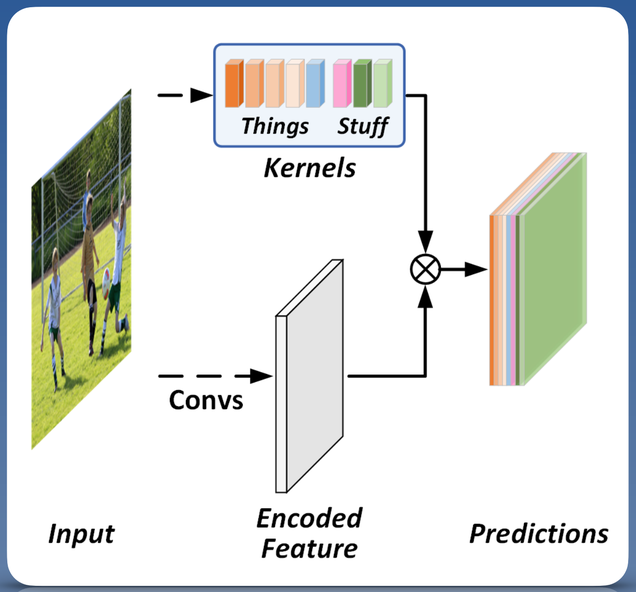


Unified representation.

Unified loss function in Panoptic FCN

- Loss function for position localization

$$\mathscr{L}_{\text{pos}}^{\text{th}} = \sum_i \text{FL}(\mathbf{L}_i^{\text{th}}, \mathbf{Y}_i^{\text{th}})/N_{\text{th}}$$

$$\mathscr{L}_{\text{pos}}^{\text{st}} = \sum_i \text{FL}(\mathbf{L}_i^{\text{st}}, \mathbf{Y}_i^{\text{st}})/W_i H_i$$

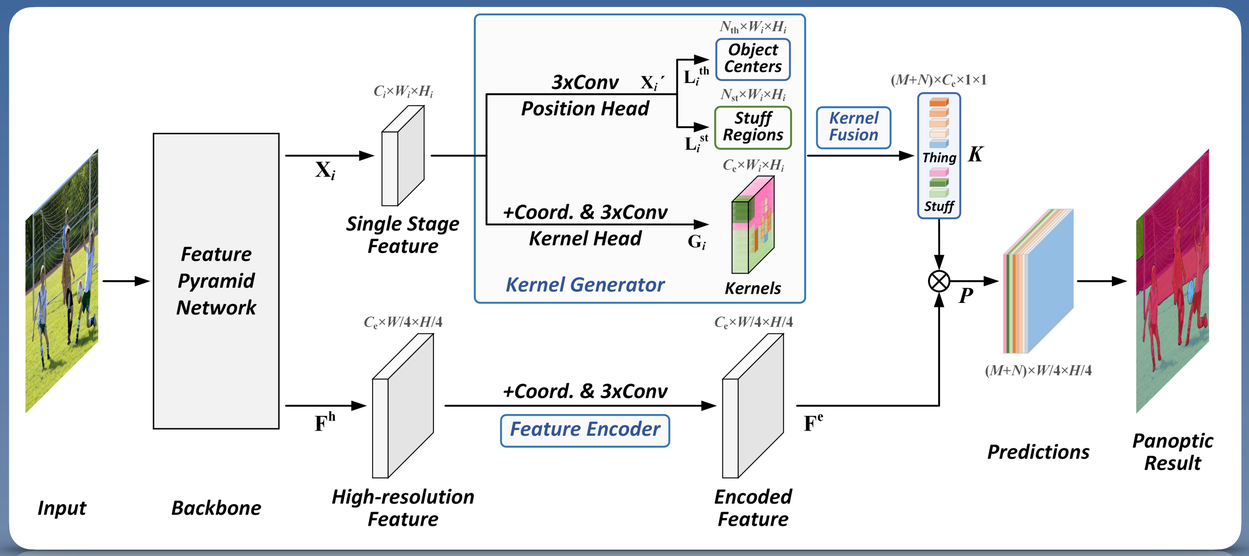
$$\mathscr{L}_{\text{pos}} = \mathscr{L}_{\text{pos}}^{\text{th}} + \mathscr{L}_{\text{pos}}^{\text{st}}$$

- Loss function for segmentation

$$\text{WDice}(\mathbf{P}_j, \mathbf{Y}_j^{\text{seg}}) = \sum_k w_k \text{Dice}(\mathbf{P}_{j,k}, \mathbf{Y}_j^{\text{seg}})$$

$$\mathscr{L}_{\text{seg}} = \sum_j \text{WDice}(\mathbf{P}_j, \mathbf{Y}_j^{\text{seg}})/(M+N)$$

$$\mathscr{L} = \lambda_{\text{pos}} \mathscr{L}_{\text{pos}} + \lambda_{\text{seg}} \mathscr{L}_{\text{seg}}$$



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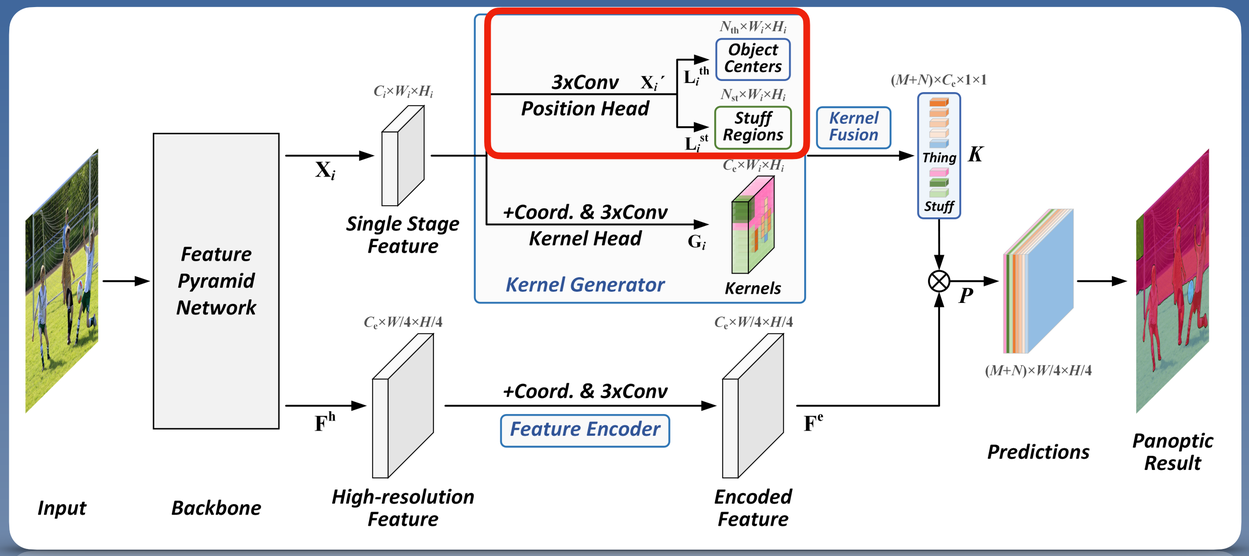

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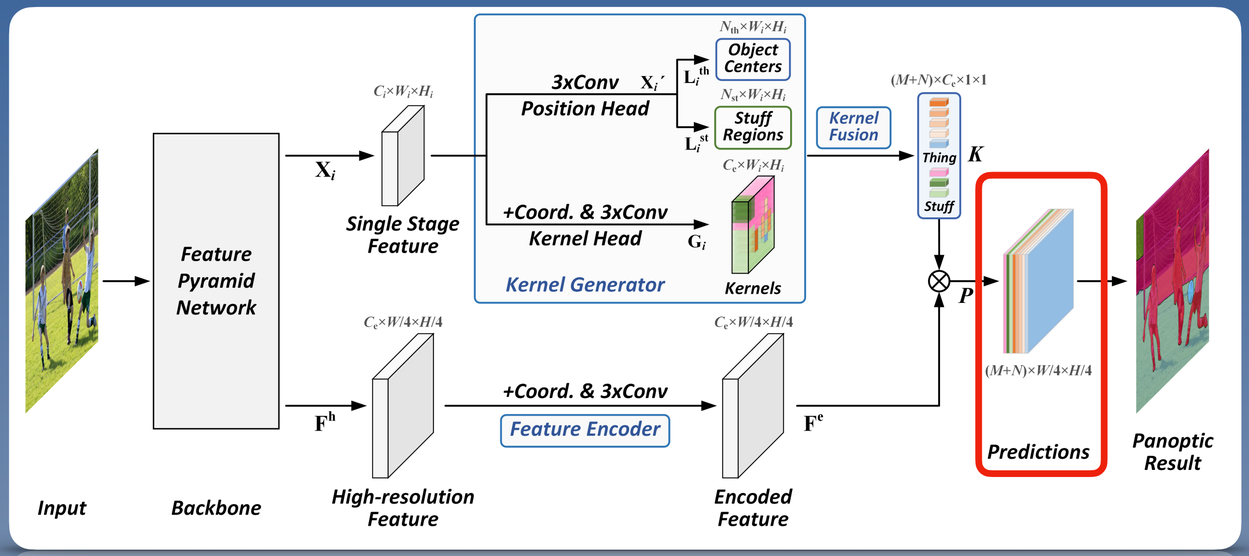


Framework of Panoptic FCN.

Results & Analysis

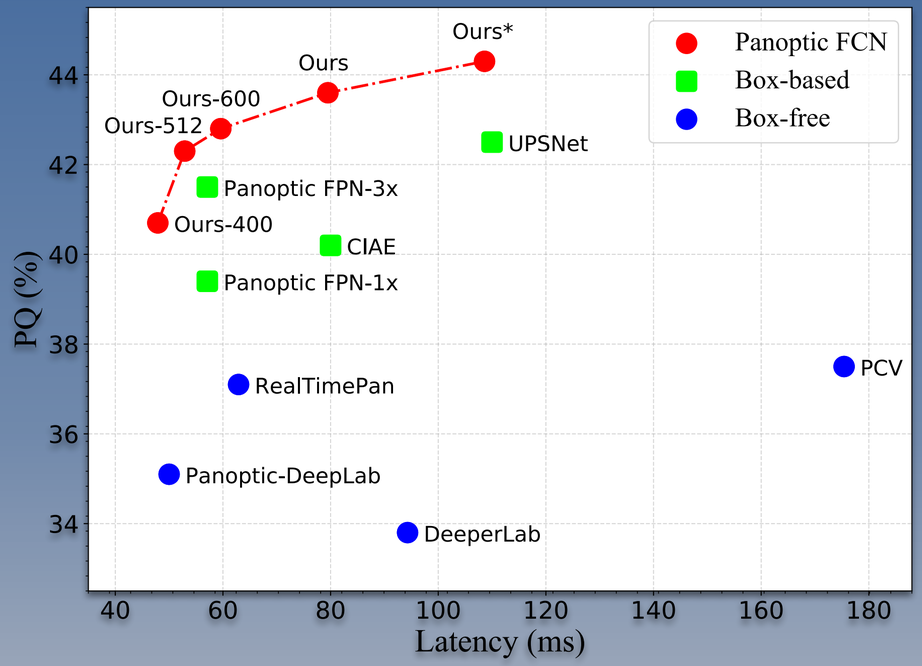
Component-wise Analysis in Panoptic FCN

Ablation studies on upper-bound and speed-accuracy.
More detailed ablations please refer to the paper.

Upper-bound analysis on the COCO val set. gt position and gt class denote utilizing ground-truth position and class for kernel generation, respectively.

gt position	gt class	PQ	PQ^{th}	PQ^{st}	AP	mIoU
○	✓	43.6	49.3	35.0	34.5	43.8
✓	○	49.8	52.2	46.1	38.2	54.6
✓	✓	**65.9**	**64.1**	**68.7**	**45.4**	**86.6**
		+22.3	*+14.8*	*+33.7*	*+11.0*	*+42.8*

Speed-accuracy trade-off curve on the COCO val set. The latency is measured end-to-end from single input to panoptic result.



Results of Panoptic FCN

It surpasses previous box-based and box-free methods with efficiency.

Comparisons with previous methods on the COCO val set. Panoptic FCN-400, 512, and 600 denotes utilizing smaller input instead of the default setting. All of our results are achieved with single input and no flipping.

Method	*Backbone*	PQ	SQ	RQ	PQ^{th}	SQ^{th}	RQ^{th}	PQ^{st}	SQ^{st}	RQ^{st}	Device	FPS
box-based												
Panoptic FPN-1x	Res50-FPN	39.4	77.8	48.3	45.9	80.9	55.3	29.6	73.3	37.7	V100	17.5
Panoptic FPN-3x	Res50-FPN	41.5	79.1	50.5	48.3	82.2	57.9	31.2	74.4	39.5	V100	17.5
CIAE	Res50-FPN	40.2	-	-	45.3	-	-	32.3	-	-	2080Ti	12.5
UPSNet	Res50-FPN	42.5	78.0	52.5	48.6	79.4	**59.6**	33.4	75.9	41.7	V100	9.1
Unifying	Res50-FPN	43.4	79.6	53.0	48.6	-	-	35.5	-	-	-	-
box-free												
DeeperLab	Xception-71	33.8	-	-	-	-	-	-	-	-	V100	10.6
Panoptic-DeepLab	Res50	35.1	-	-	-	-	-	-	-	-	V100	20
AdaptIS	Res50	35.9	-	-	40.3	-	-	29.3	-	-	-	-
PCV	Res50-FPN	37.5	77.7	47.2	40.0	78.4	50.0	33.7	76.5	42.9	1080Ti	5.7
SOLO V2	Res50-FPN	42.1	-	-	49.6	-	-	30.7	-	-	-	-
ours												
Panoptic FCN-400	Res50-FPN	40.7	80.5	49.3	44.9	82.0	54	34.3	78.1	42.1	V100	**20.9**
Panoptic FCN-512	Res50-FPN	42.3	**80.9**	51.2	47.4	82.1	56.9	34.7	**79.1**	42.7	V100	18.9
Panoptic FCN-600	Res50-FPN	42.8	80.6	51.6	47.9	82.6	57.2	35.1	77.4	43.1	V100	16.8
Panoptic FCN	Res50-FPN	43.6	80.6	52.6	49.3	82.6	58.9	35.0	77.6	42.9	V100	12.5
Panoptic FCN*	Res50-FPN	**44.3**	80.7	**53.0**	**50.0**	**83.4**	59.3	**35.6**	76.7	**43.5**	V100	9.2

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Results of Panoptic FCN

It surpasses previous box-based and box-free methods with efficiency.

Experiments on the COCO test-dev set.

Method	Backbone	PQ	PQ^{th}	PQ^{st}
box-based				
Panoptic FPN	Res101-FPN	40.9	48.3	29.7
CIAE	DCN101-FPN	44.5	49.7	36.8
AUNet	ResNeXt152-FPN	46.5	**55.8**	32.5
UPSNet	DCN101-FPN	46.6	53.2	36.7
Unifying^	DCN101-FPN	47.2	53.5	37.7
box-free				
DeeperLab	Xception-71	34.3	37.5	29.6
SSAP	Res101-FPN	36.9	40.1	32.0
Panoptic-DeepLab	Xception-71	39.7	43.9	33.2
AdaptIS	ResNeXt101	42.8	53.2	36.7
Axial-DeepLab	Axial-ResNet-L	43.6	48.9	35.6
ours				
Panoptic FCN	Res101-FPN	45.5	51.4	36.4
Panoptic FCN	DCN101-FPN	47.0	53.0	37.8
Panoptic FCN*	DCN101-FPN	47.1	53.2	37.8
Panoptic FCN*^	DCN101-FPN	**47.5**	53.7	**38.2**

Experiments on the Cityscapes val set.

Method	Backbone	PQ	PQ^{th}	PQ^{st}
box-based				
Panoptic FPN	Res101-FPN	58.1	52.0	62.5
AUNet	Res101-FPN	59.0	54.8	62.1
UPSNet	Res50-FPN	59.3	54.6	62.7
Seamless	Res50-FPN	60.2	55.6	63.6
Unifying	Res50-FPN	61.4	54.7	66.3
box-free				
PCV	Res50-FPN	54.2	47.8	58.9
DeeperLab	Xception-71	56.5	-	-
SSAP	Res50-FPN	58.4	50.6	-
AdaptIS	Res50	59.0	**55.8**	61.3
Panoptic-DeepLab	Res50	59.7	-	-
ours				
Panoptic FCN	Res50-FPN	59.6	52.1	65.1
Panoptic FCN*	Res50-FPN	**61.4**	54.8	**66.6**

Experiments on the Mapillary Vistas val set.

Method	Backbone	PQ	PQ^{th}	PQ^{st}
box-based				
BGRNet	Res50-FPN	31.8	**34.1**	27.3
TASCNet	Res50-FPN	32.6	31.1	34.4
Seamless	Res50-FPN	36.2	33.6	40.0
box-free				
DeeperLab	Xception-71	32.0	-	-
AdaptIS	Res50	32.0	26.6	39.1
Panoptic-DeepLab	Res50	33.3	-	-
ours				
Panoptic FCN	Res50-FPN	34.8	30.6	40.5
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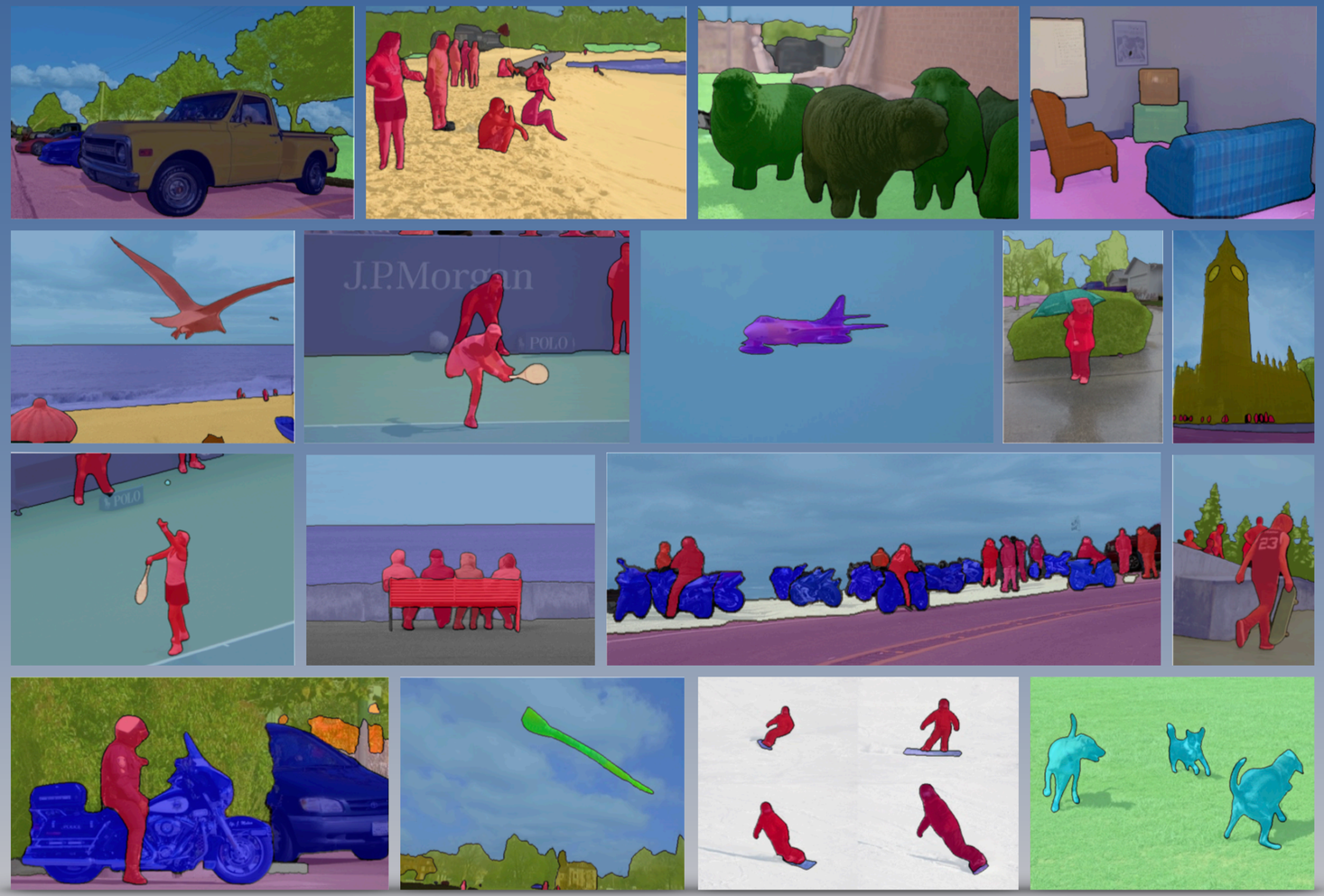
Visualization of Panoptic FCN

It achieve fine results on common context and traffic-related scenarios.

Visualization of panoptic results on the COCO val set.



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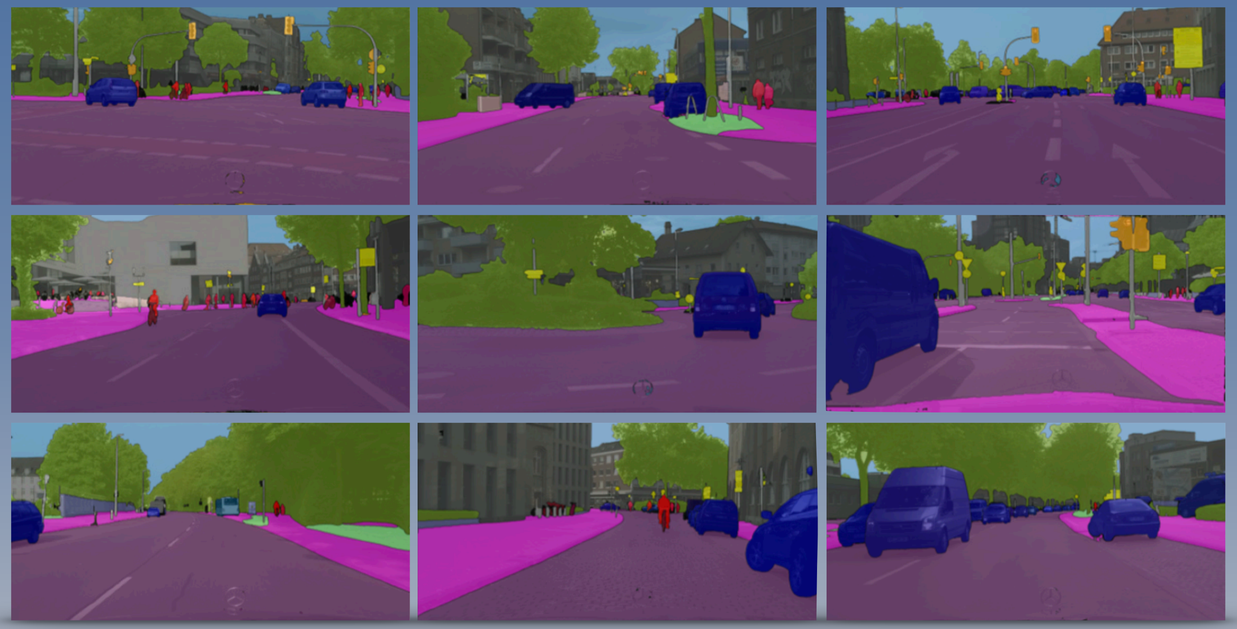

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Thanks

For more questions, please contact

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Paper

Code