



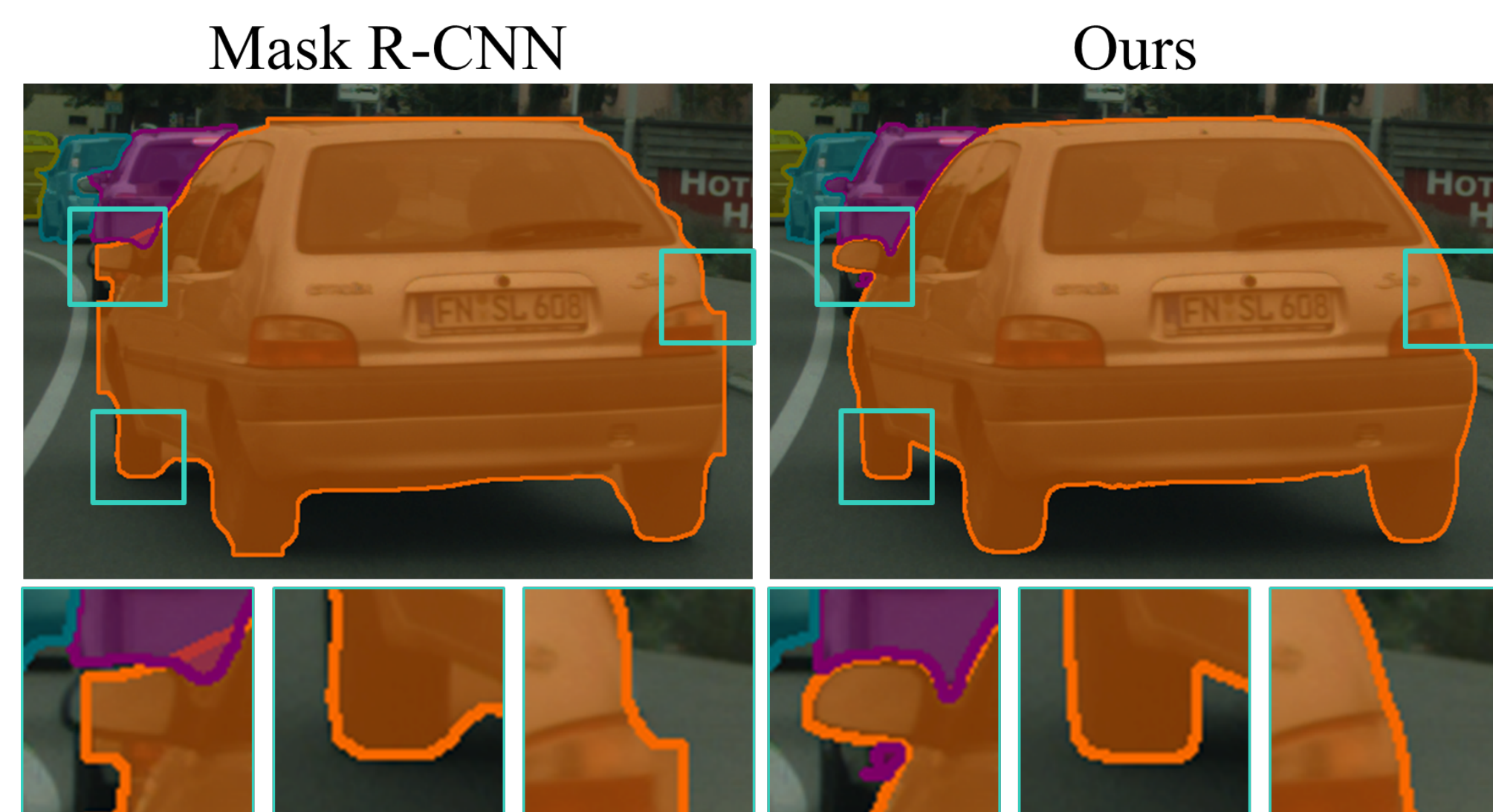
Look Closer to Segment Better: Boundary Patch Refinement for Instance Segmentation

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Summary

- **Problem:** the boundaries of predicted instance masks are usually **coarse and imprecise**.
- **Contribution:** we propose a conceptually simple yet effective *post-processing* framework, termed **BPR**, to improve the boundary quality of any instance segmentation results.
- **Results:** we reached **1st place** on the *Cityscapes* leaderboard ($AP_{test} = 42.7\%$).



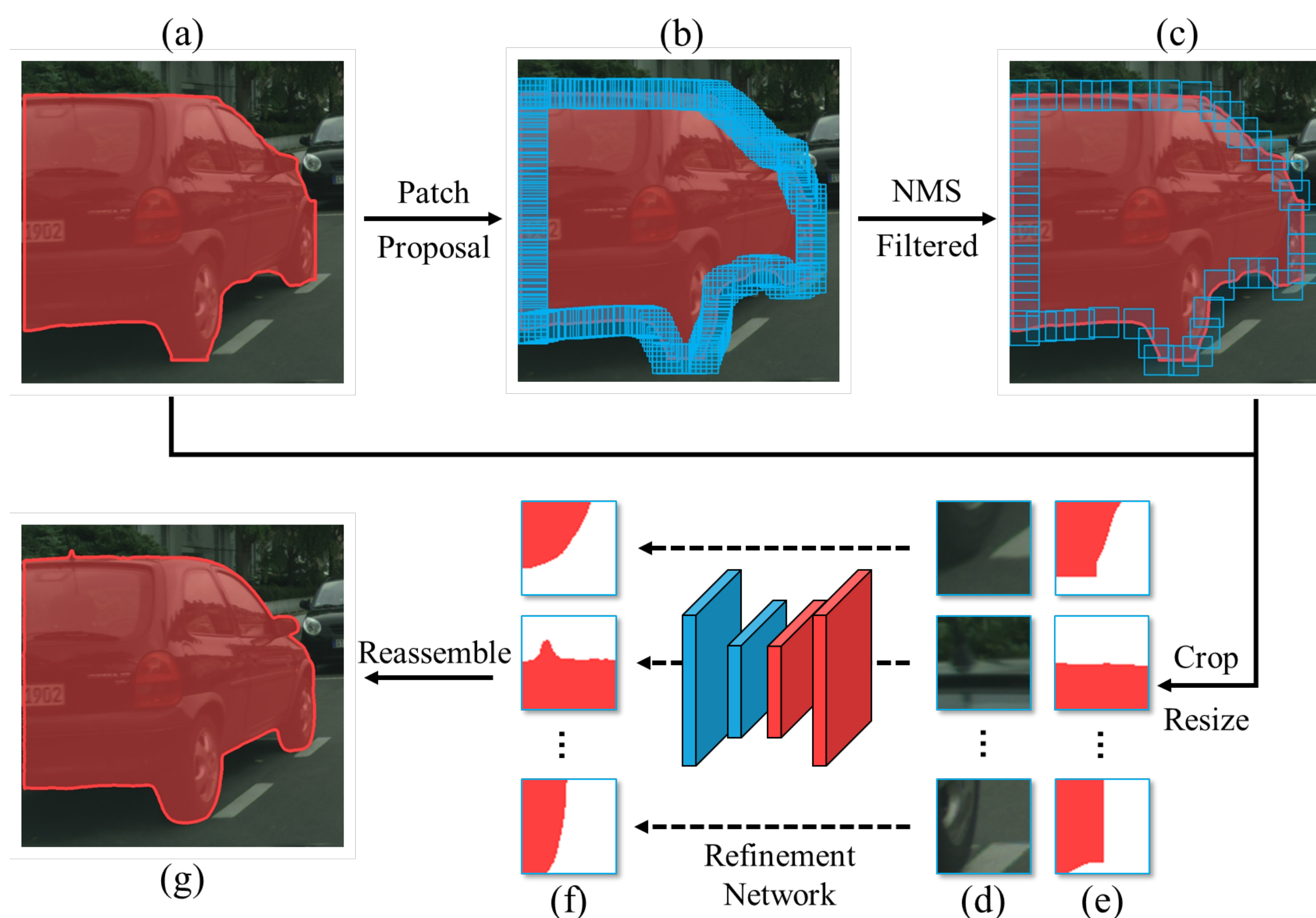
Motivation

- **Issues leading to low-quality boundaries:**
 - low spatial resolution of the output (e.g. 28x28)
 - extremely low proportion of boundary pixels
- **Importance of boundary pixels:** correcting the error pixels near object boundaries can improve the mask quality a lot.

Dist.	-	1px	2px	3px	∞
AP	36.4	45.8	50.6	54.2	70.4

- **Human annotation behavior:** coarse-to-fine

Framework

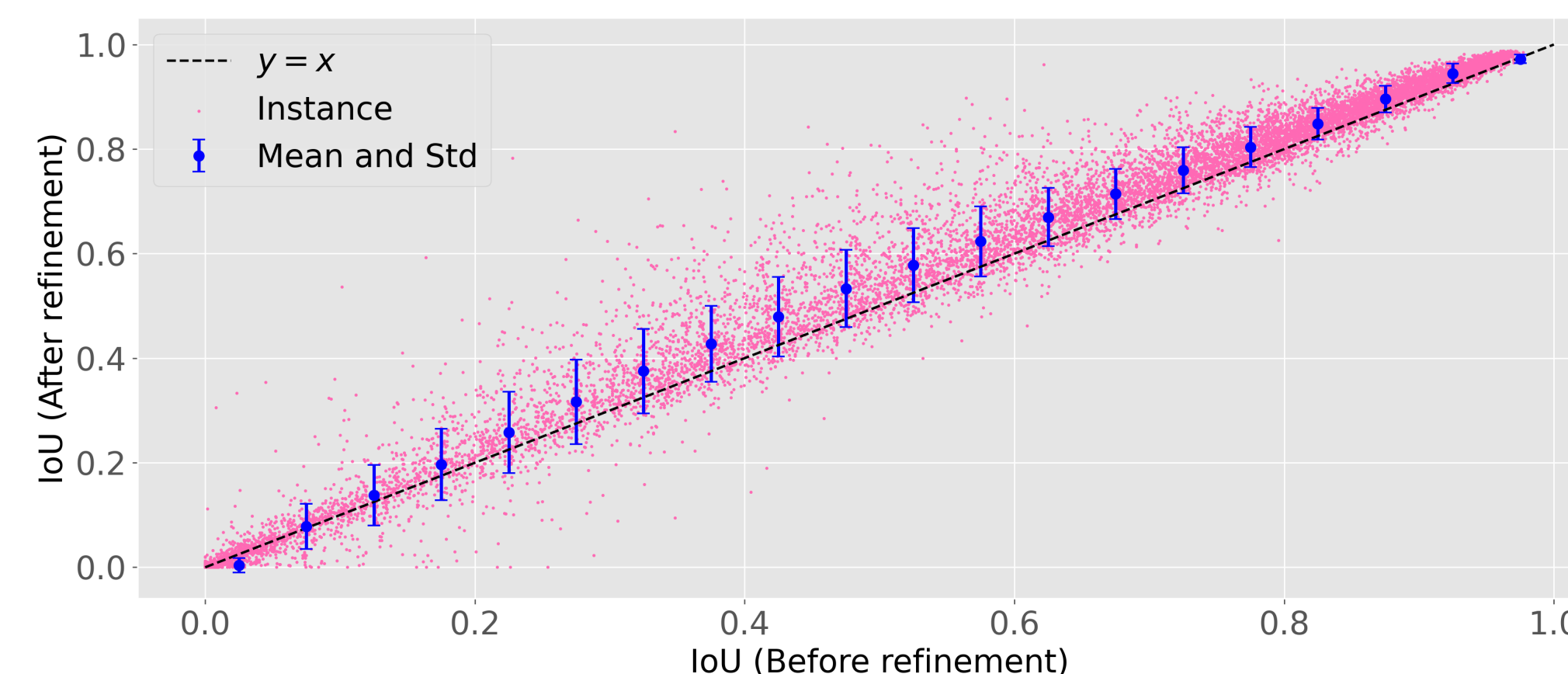


- **Boundary Patch Extraction:** a *sliding-window style* algorithm to extract a series of patches along the predicted instance boundaries.
- **Boundary Patch Refinement:** the *image patch* and *mask patch* are concatenated together and fed into a binary segmentation network (e.g. HRNet).
- **Reassembling:** the refined boundary patches are reassembled into a compact instance-level mask by *replacing* their previous predictions.

Results on Cityscapes

	training data	AP_{val}	AP	AP_{50}
Mask R-CNN [13]	fine	31.5	26.2	49.9
BMask R-CNN [7]	fine	35.0	29.4	54.7
PANet [24]	fine	36.5	31.8	57.1
SSAP [11]	fine	37.3	32.7	51.8
UPSNNet [42]	fine + COCO	37.8	33.0	59.7
PANet [24]	fine + COCO	41.4	36.4	63.1
Mask R-CNN* [13]	fine + COCO	36.8	32.6	59.2
+ SegFix* [46]		38.2	33.3	57.8
+ BPR		41.1	36.9	61.0
+ SegFix + BPR		40.9	36.8	59.8
PolyTransform [21]	fine + COCO	44.6	40.1	65.9
+ SegFix [46]		-	41.2	66.1
+ BPR*		46.9	42.4	66.6
+ SegFix + BPR*		-	42.7	66.5

- Established the new **state-of-the-art** on *Cityscapes val* and *test* sets.
- Effectively improved the mask IoU for most of predicted instances.



Ablation Study

- **Mask patch:** without the mask patch's guide, the model yields terrible results.

w/ mask	AP	AP_{50}	AF	AP_S	AP_M	AP_L
-	36.4	60.8	54.9	11.1	32.4	57.3
✗	20.1	42.2	57.2	4.0	14.7	36.3
✓	39.8	62.0	66.8	12.7	35.9	62.2



- **Different patch extraction schemes:**

scheme	size	AP	AP_{50}	AF
-	-	36.4	60.8	54.9
dense sampling + NMS	64	39.8	62.0	66.8
pre-defined grid	32	39.3	61.8	65.8
pre-defined grid	64	39.1	61.9	65.6
pre-defined grid	96	38.8	61.6	63.7
instance-level patch	256	37.5	61.1	61.5
instance-level patch	512	38.7	61.6	63.8

- **Transferability:** the trained BPR model can be transferred to refine any instance segmentation results.

	AP	AP_{50}	AF
PointRend [19]	35.6	60.6	58.0
w/ BPR [†]	38.6	62.4	66.5
Mask R-CNN + SegFix [50]	38.2	63.4	63.2
w/ BPR [†]	40.0	63.4	67.0