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AI未来之光

第一届北京高校人工智能学术论坛

2019 Beijing Universities Academic Forum of Artificial Intelligence

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Deep Fitting Degree Scoring Network for Monocular 3D Object Detection

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清華大學 Tsinghua University
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01 Problem

Monocular 3D Object Detection

"Perception is our best guess as to what is in the world given our current sensory input and our prior experience"

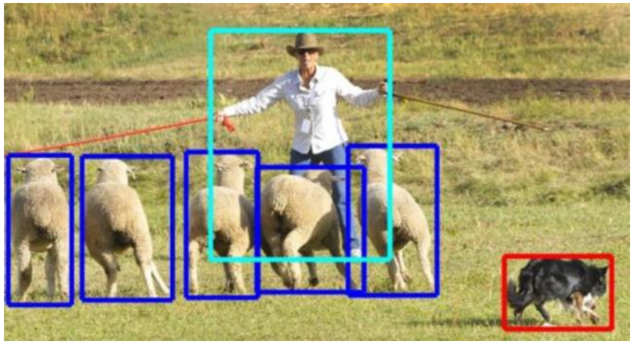
- Helmholtz (1866)

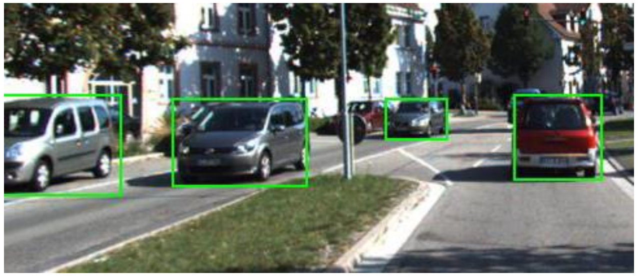
Problem Setting: Monocular 3D Object Detection

- Input: A single RGB image & camera intrinsic
- Solve: 9 DoF, including orientation, dimension, location
- Cue: Appearance (sensory input) & Projection Law (prior experience)

Why 3D perception

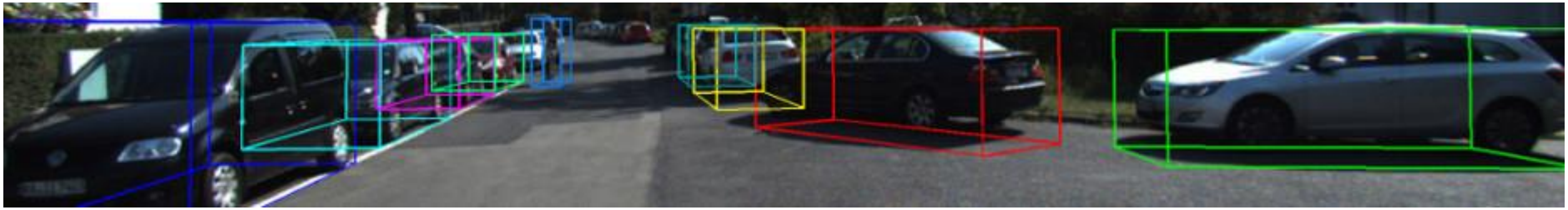
- 3D perception is the key to human intelligence
- Autonomous driving & Robotic grasping





Challenges in Location Estimation

- Dimension and orientation estimation are easier than location estimation
- Ambiguities arising from 2D-3D mapping
- Real 3D information unavailable
- Occlusions, Truncation, Scale variation……



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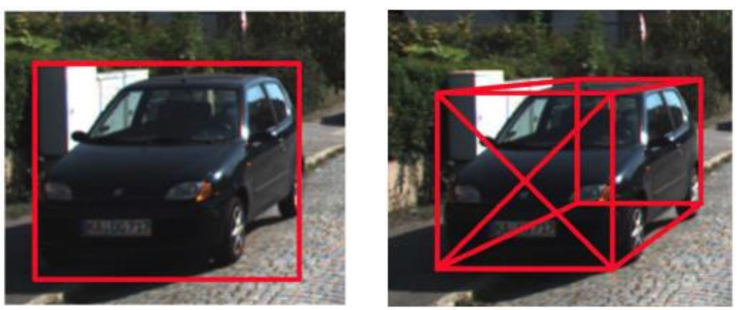
02

Motivation

How we come up with our idea

Previous Methods

- Tight Constraints （CVPR17）
- Solves the location by placing the 3D proposal in the 2D bounding box compactly.



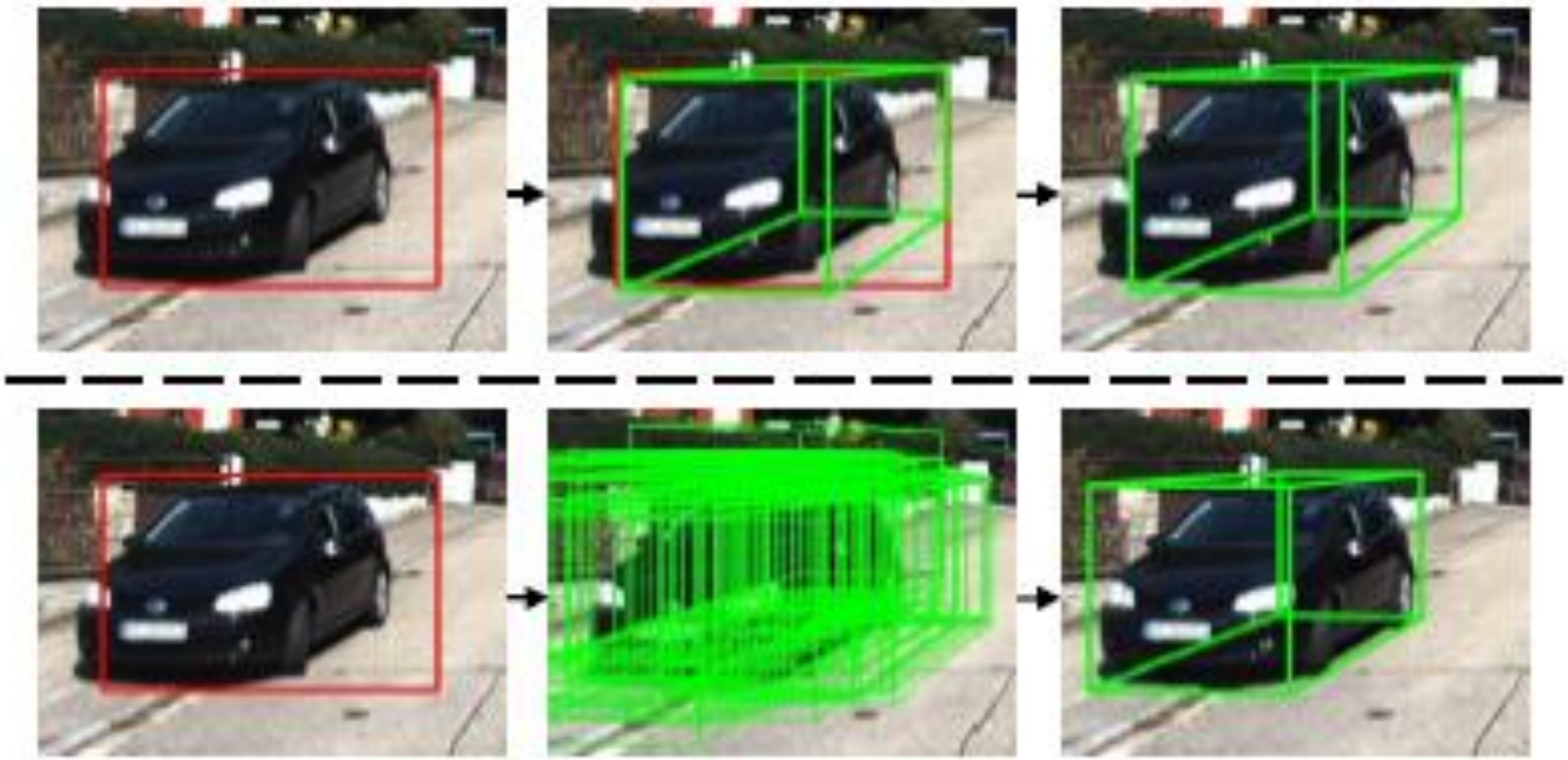
Drawbacks:

1) Image appearance clue is not used

2) Performance highly depends on the 2D detection accuracy

How do human do?

- Hypothesize-and-Verify



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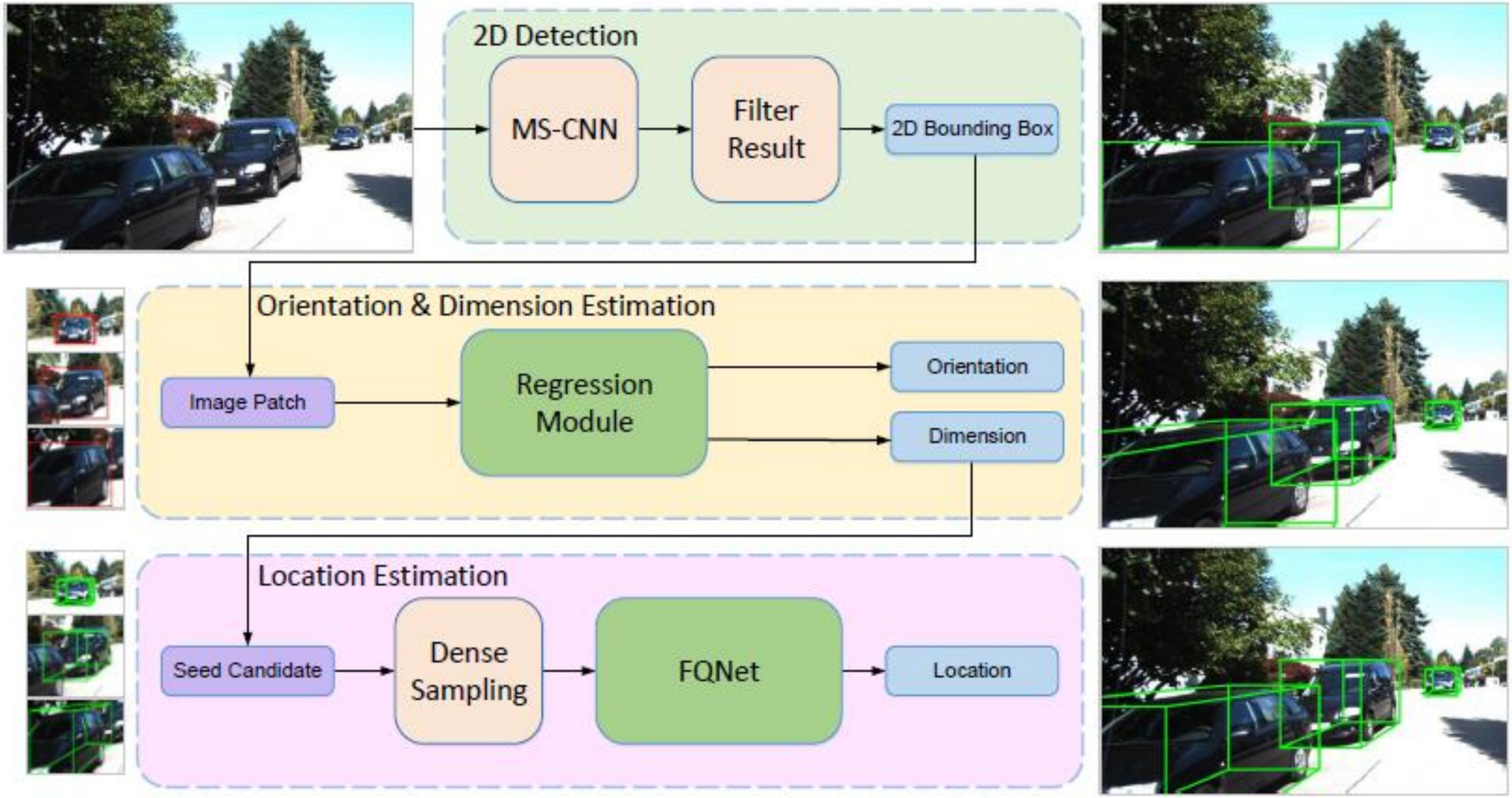
03 Approach

Some details

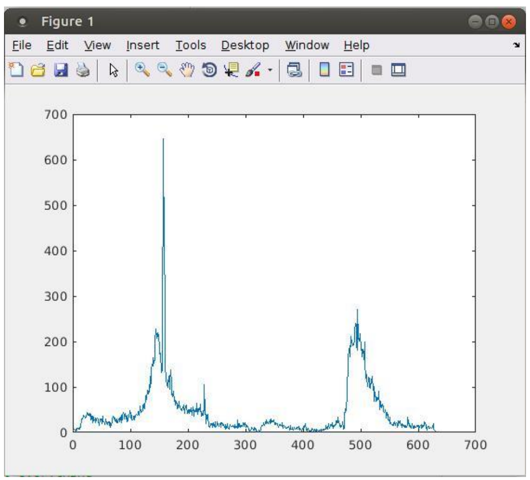
Overall framework

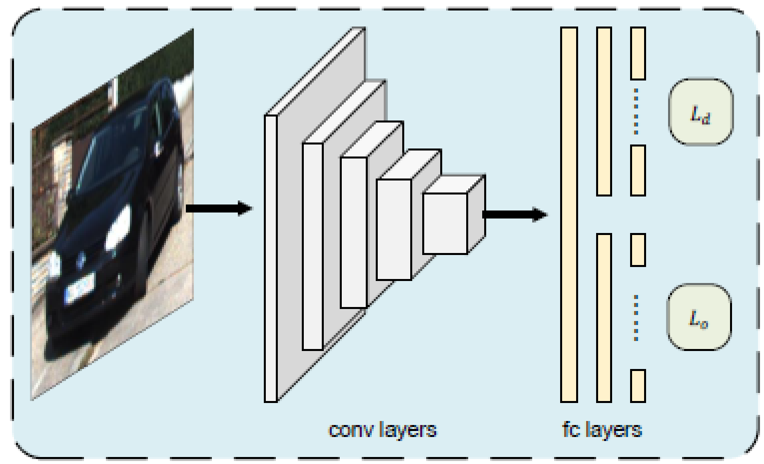
- Three-stage



Regression Module

- Anchor cuboid & Anchor angle



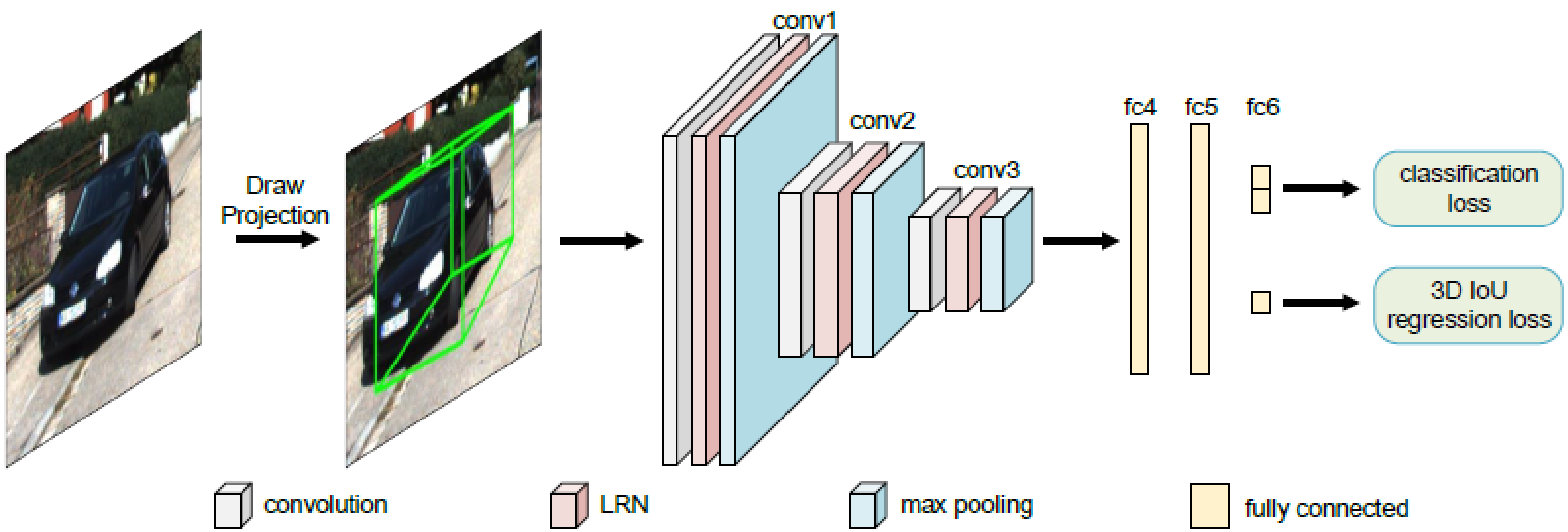


$$L_d = -\log\sigma(c_{i^\star}) + [1 - IoU(\boldsymbol{A}_{i^\star} + [\Delta w_{i^\star}, \Delta h_{i^\star}, \Delta l_{i^\star}], \boldsymbol{G})]$$

$$L_o = -\log\sigma(c_{i^\star}) + [1 - \cos(\Theta_{i^\star} + \Delta\theta_{i^\star} - \theta_G)]$$

Location Estimation

- Dense sampling
- FQNet



$$\Theta^{\star} = \arg\min_{\Theta} ||\mathcal{F}(\boldsymbol{I}, \boldsymbol{S}_i|\Theta) - IoU(\boldsymbol{I}, \boldsymbol{S}_i)||$$

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04 Experiments

Some demonstration

Experimental Results on KITTI dataset

➢ Orientation & Dimension

Table 1. Comparisons of the Average Orientation Similarity (AOS) with the state-of-the-art methods on the KITTI dataset.

Method	Easy			Moderate			Hard		
	train/val 1	train/val 2	test	train/val 1	train/val 2	test	train/val 1	train/val 2	test
3DOP [9]	91.58	-	91.44	85.80	-	86.10	76.80	-	76.52
Mono3D [8]	91.90	-	91.01	86.28	-	86.62	77.09	-	76.84
3DVP [42]	-	78.99	86.92	-	65.73	74.59	-	54.67	64.11
SubCNN [43]	-	94.55	90.67	-	85.03	88.62	-	72.21	78.68
Deep3DBox [31]	-	97.50	**92.90**	-	96.30	88.75	-	80.40	76.76
3D-RCNN [23]	90.70	**97.70**	89.98	89.10	96.50	**89.25**	**79.50**	**80.70**	**80.07**
Our Method	**97.28**	97.57	92.58	**93.70**	**96.70**	88.72	79.25	80.45	76.85

Method	train/val 1	train/val 2
3DOP [9]	0.3527	-
Mono3D [8]	0.4251	-
Deep3DBox [31]	-	0.1934
Our Method	**0.1698**	**0.1465**

Experimental Results on KITTI dataset

➢ Location

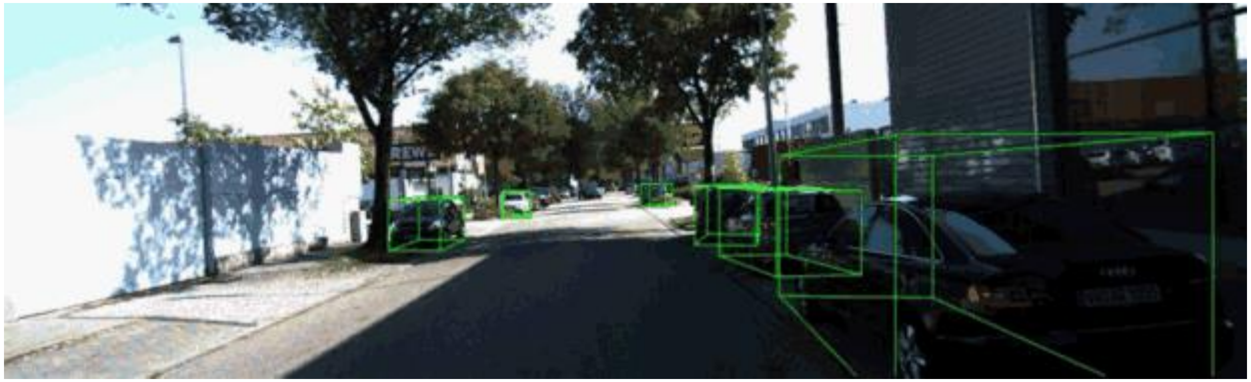
Table 2. Comparisons of the 2D AP with the state-of-the-art methods on the KITTI Birds Eyed View validation dataset.

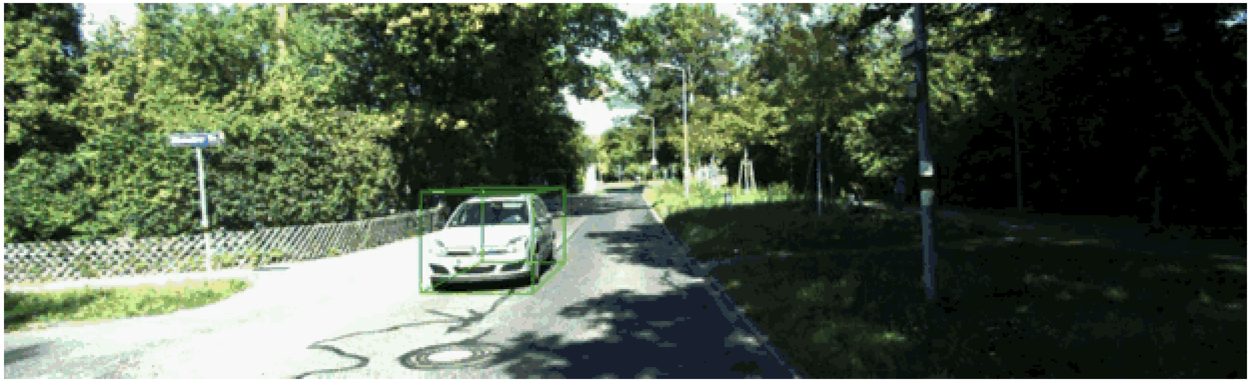
Method	IoU = 0.5						IoU = 0.7					
	Easy		Moderate		Hard		Easy		Moderate		Hard	
	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2
3DOP [9]	55.04	-	41.25	-	34.55	-	12.63	-	9.49	-	7.59	-
Mono3D [8]	30.50	-	22.39	-	19.16	-	5.22	-	5.19	-	4.13	-
Deep3DBox [31]	-	30.02	-	23.77	-	18.83	-	9.99	-	7.71	-	5.30
Our Method	32.57	33.37	24.60	26.29	21.25	21.57	9.50	10.45	8.02	8.59	7.71	7.43

Table 4. Comparisons of the 3D AP with the state-of-the-art methods on the KITTI 3D Object validation dataset.

Method	IoU = 0.5						IoU = 0.7					
	Easy		Moderate		Hard		Easy		Moderate		Hard	
	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2	t/v 1	t/v 2
3DOP [9]	46.04	-	34.63	-	30.09	-	6.55	-	5.07	-	4.10	-
Mono3D [8]	25.19	-	18.20	-	15.52	-	2.53	-	2.31	-	2.31	-
Deep3DBox [31]	-	27.04	-	20.55	-	15.88	-	5.85	-	4.10	-	3.84
Our Method	28.16	28.98	21.02	20.71	19.91	18.59	5.98	5.45	5.50	5.11	4.75	4.45

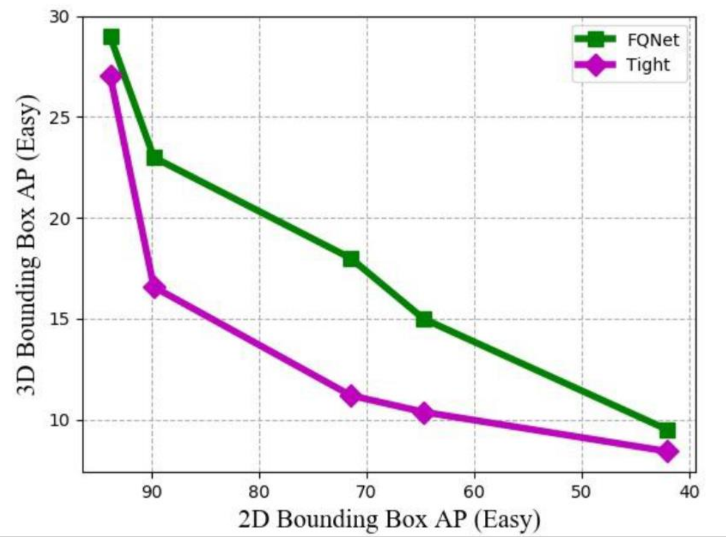
Qualitative Results

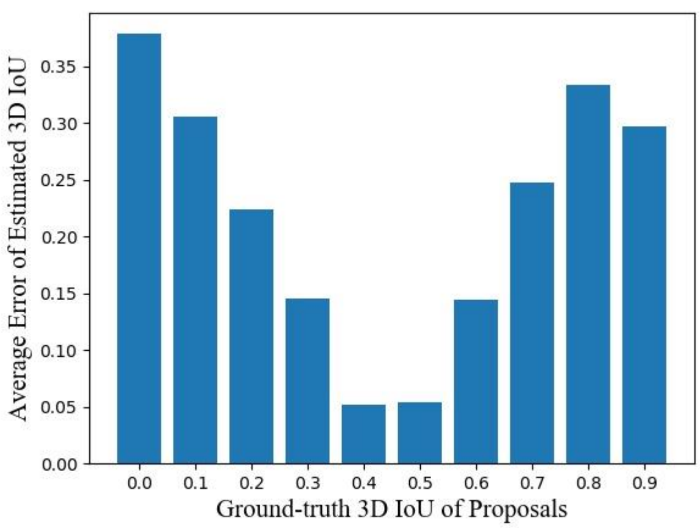




Effectiveness

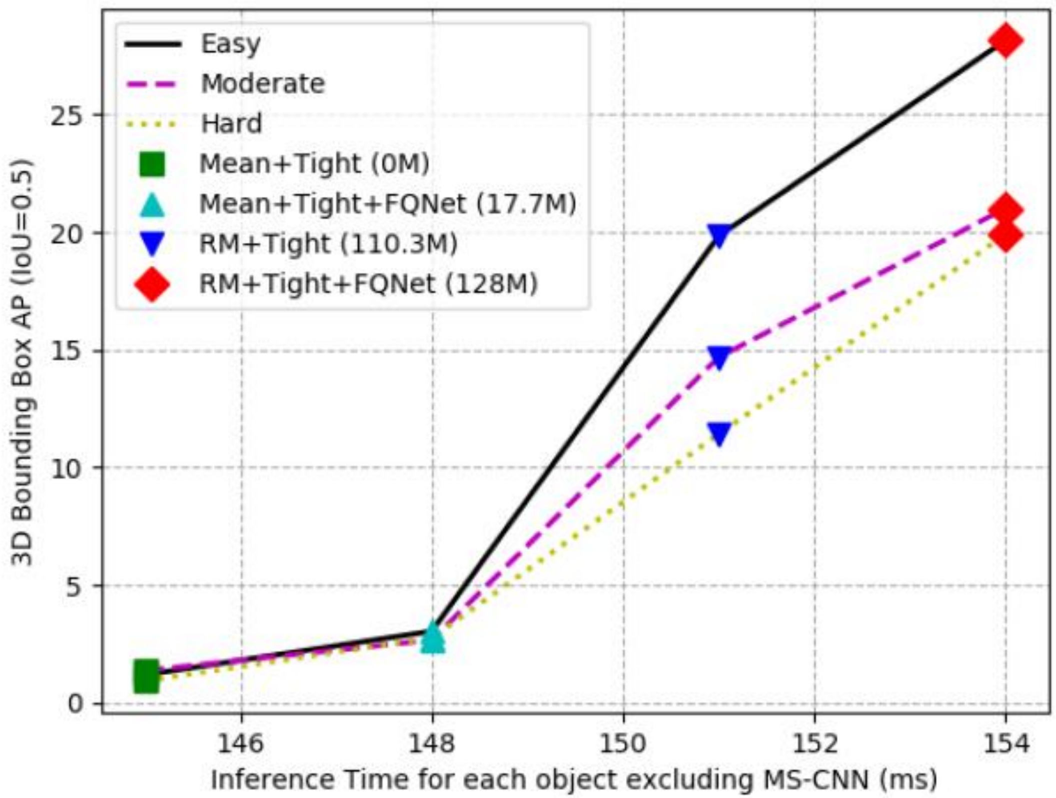
- Not sensitive to 2D detection precision
- 3D IoU regression





Accuracy vs Speed

- Ablation study
- Efficiency



THANK YOU

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