SAFDNet: A Simple and Effective Network for Fully Sparse 3D Object Detection

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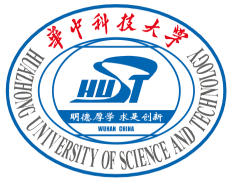

3D Object Detection in Point Clouds

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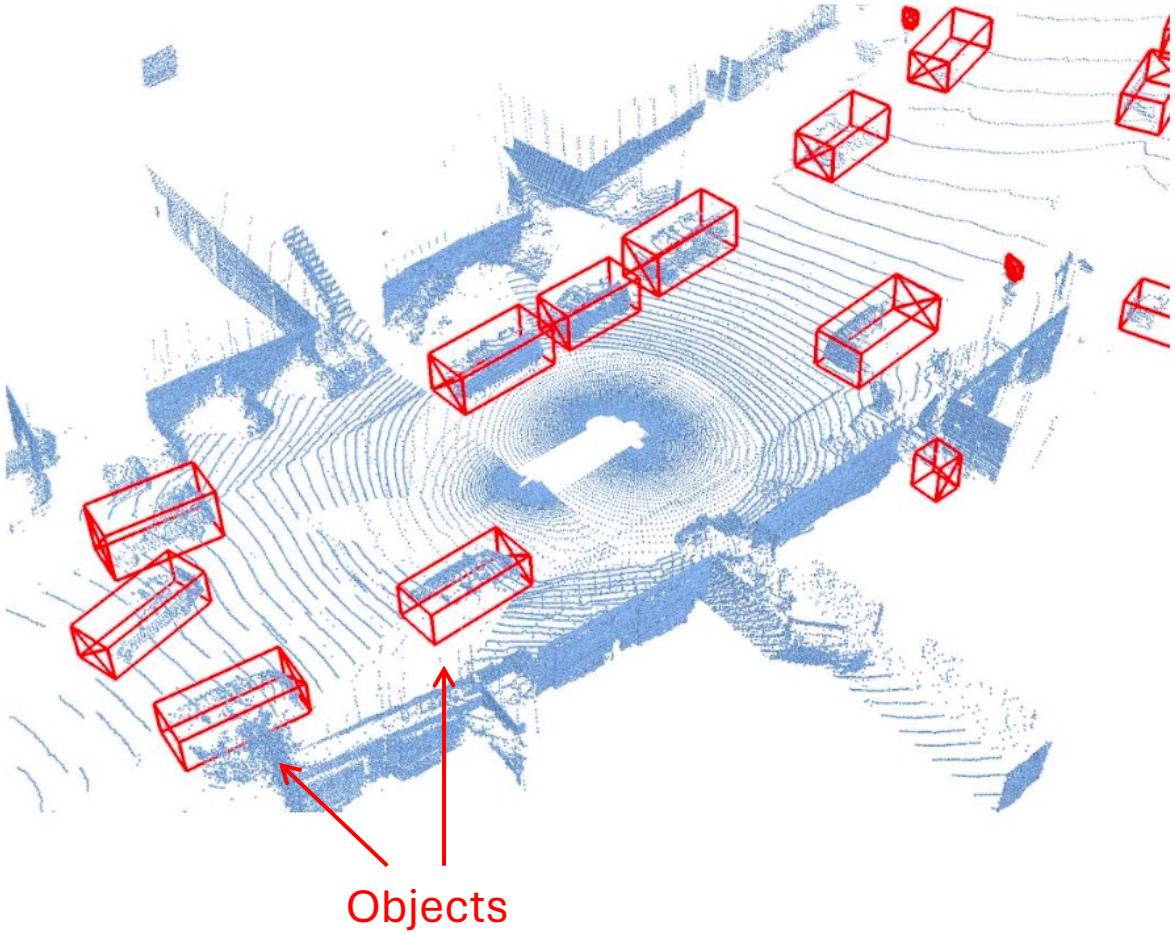

Point clouds

- highly sparse
- distribute on objects' surfaces

3D Object Detection for Autonomous Driving: A Comprehensive Survey. Mao, et al., 2023.

Review 3D Object Detectors in Point Clouds

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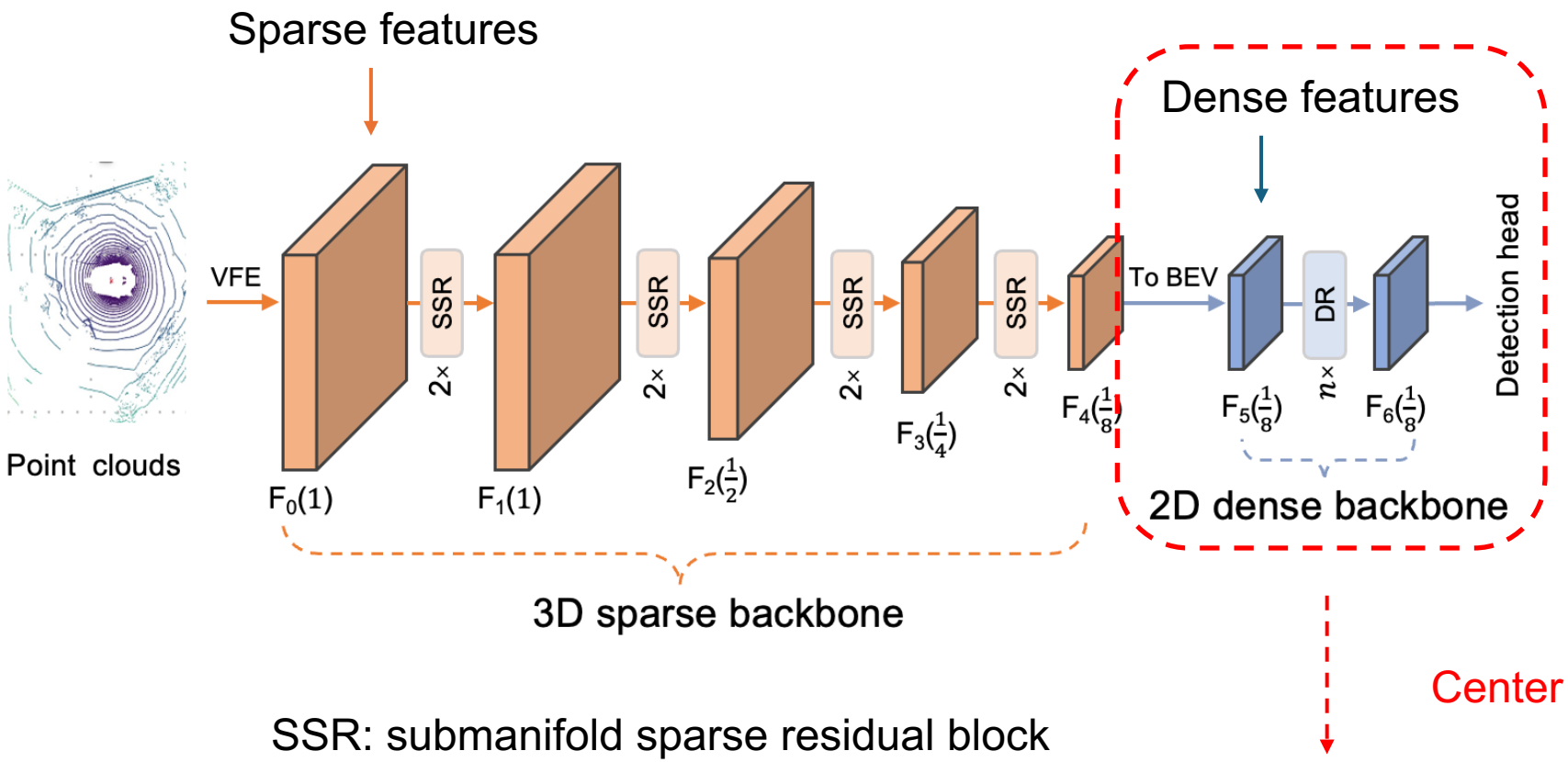
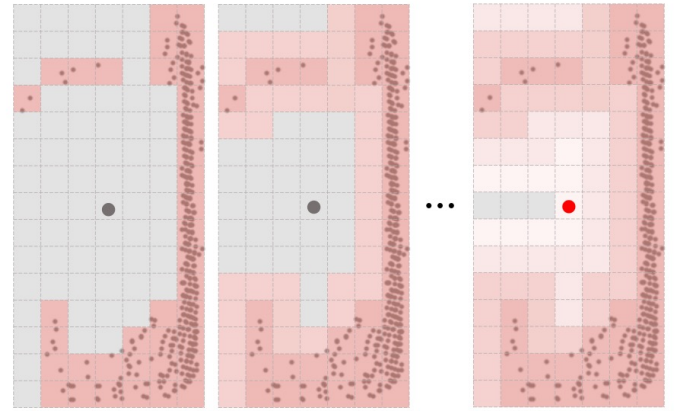
	2D/3D Backbone	2D Backbone	Head	Methods	Drawbacks
Dense Detectors	Dense	Dense	Dense	VoxelNet, PointPillars	Low efficiency, Inferior accuracy
Hybrid Detectors	Sparse	Dense	Dense	CenterPoint, TransFusion-L	Low efficiency in long-range detection
Sparse Detectors	Sparse	Sparse	Sparse	FSD v1/v2, VoxelNeXt	Complex pipeline, Inferior accuracy

Review CenterPoint w/ SECOND (Hybrid Detector)



SSR: submanifold sparse residual block

From FSD (Fan et al., 2021)



Feature Diffusion
(2D dense backbone)

Center Feature Missing (CFM) problem

Low efficiency

Non-empty voxels, fewer than 10%

CenterPoint, Yin et al., 2021; SECOND, Yan et al., 2018.

Review FSD and VoxelNeXt (Sparse Detector)

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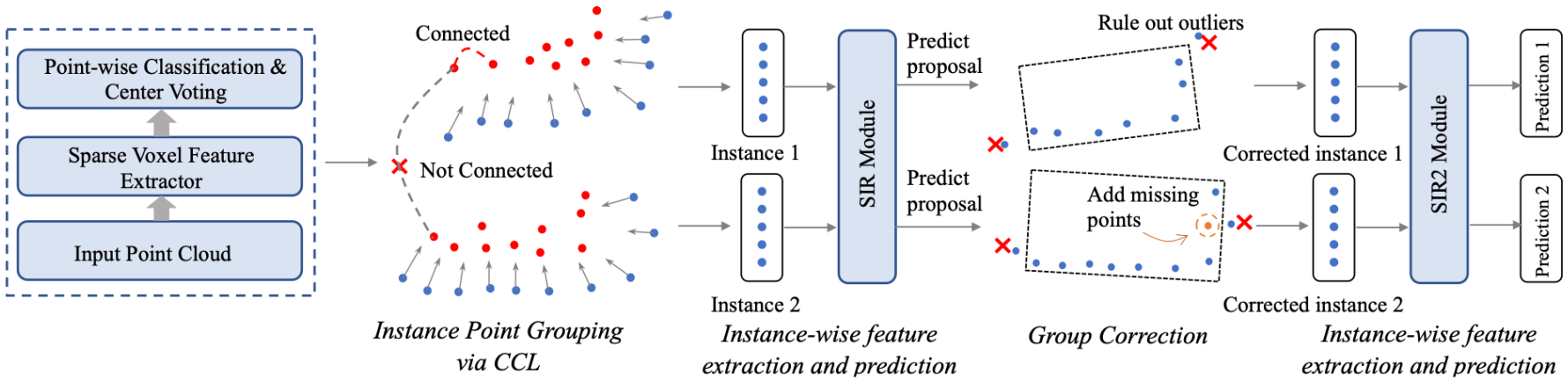
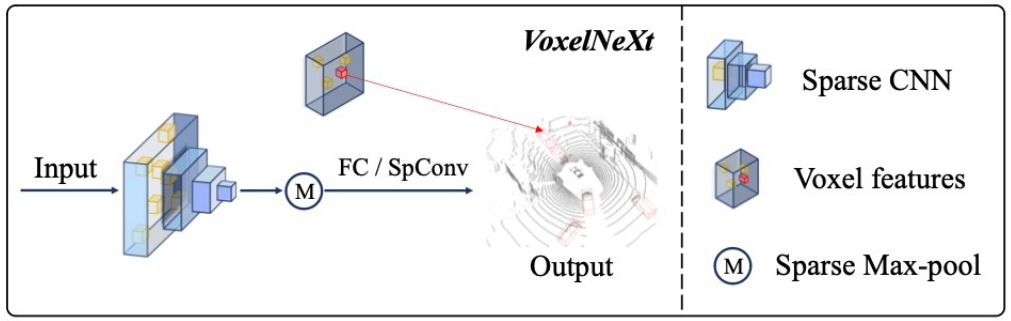


()

FSDv1: instance clustering

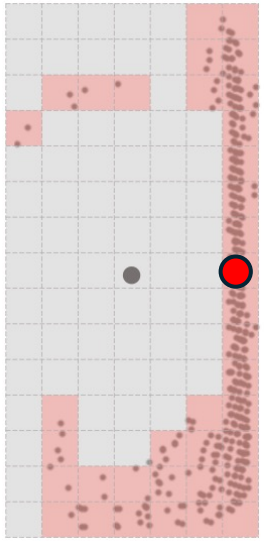
Different from CenterPoint, and complex pipline



VoxelNeXt: nearest voxels

Derived from CenterPoint, but inferior accuracy

From FSD



The desired way to solve the CFM problem should:

- Introduce minimal changes to existing detectors like CenterPoint
- Maintain performance

FSD, Fan et al., 2021; VoxelNeXt, Chen et al., 2021.

Preliminary Experiments on Waymo Open dataset

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Method	Type	mAPH	Vehicle	Pedestrian	Cyclist
HEDNet	Hybrid	73.2	72.1	72.0	75.6
Nearest	Sparse	71.5	68.9	70.9	74.7

The previous best hybrid detector (Ours, NeurIPS'23)

Backbone of HEDNet + Head of VoxelNeXt

drop dramatically on large objects

HEDNet (Hybrid detector)

Make predictions based on center voxels

VoxelNeXt Style (Sparse detector)

Make predictions based on nearest voxels

Desired solution:

- Extract center voxel features
- Scale-aware
- Maintain feature sparsity as much as possible

HEDNet: A Hierarchical Encoder-Decoder Network for 3D Object Detection in Point Clouds. Zhang et al., NeurIPS 2023.

Adaptive Feature Diffusion (AFD)

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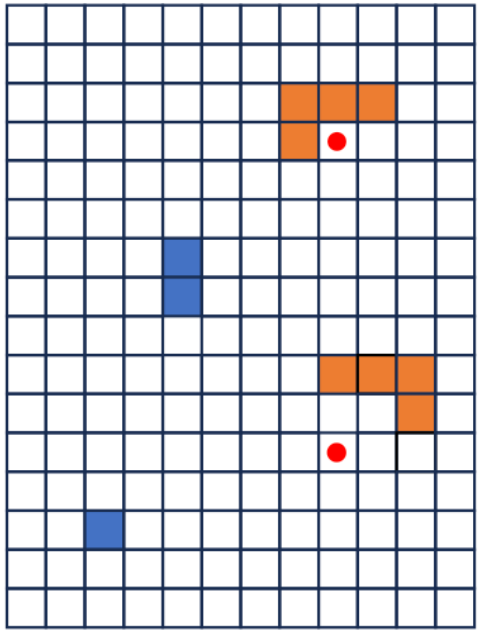
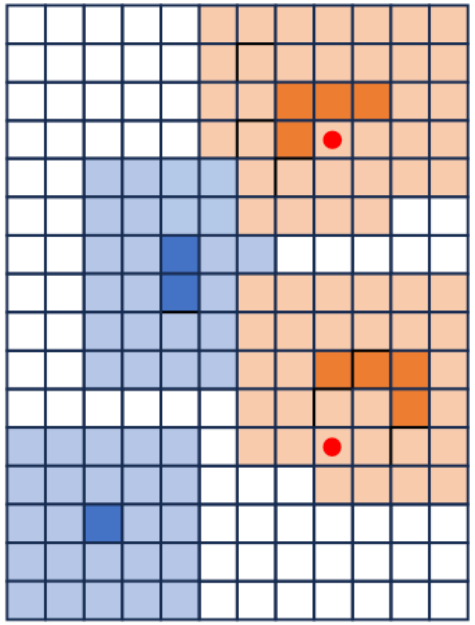
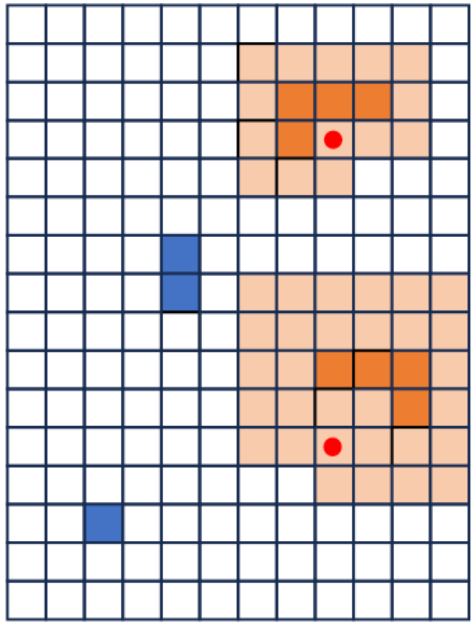
Blue: background; Orange: objects



Input feature map



Uniform feature diffusion

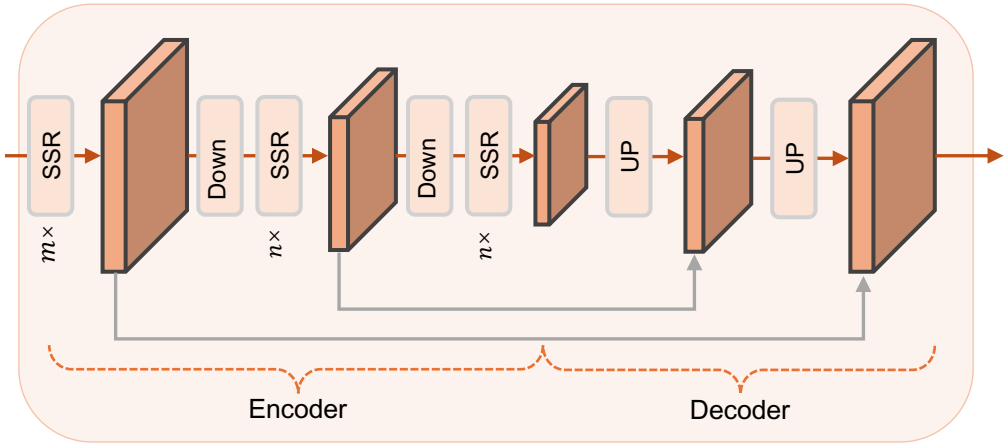


Adaptive feature diffusion

Adaptive feature diffusion: how to perform voxel classification? category group.

Larger objects, larger diffusion ranges.

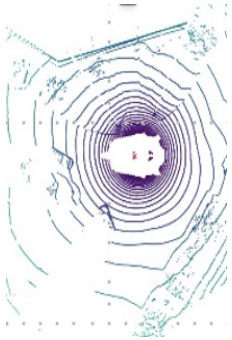
SAFDNet



3D/2D-SED

3D sparse feature map

2D sparse feature map



Point clouds

VFE → 2×SSR → 2×SSR → 4×SSR → 3D-SED → To BEV → AFD → 2D-SED → Sparse detection head

Voxel classification

$L\times W\times H$ | $L\times W\times H$ | $\frac{L}{2}\times\frac{W}{2}\times\frac{H}{2}$ | $\frac{L}{4}\times\frac{W}{4}\times\frac{H}{4}$ | $\frac{L}{8}\times\frac{W}{8}\times\frac{H}{4}$ | $\frac{L}{8}\times\frac{W}{8}$ | $\frac{L}{8}\times\frac{W}{8}$ | $\frac{L}{8}\times\frac{W}{8}$

3D sparse backbone

2D sparse backbone

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HEDNet: A Hierarchical Encoder-Decoder Network for 3D Object Detection in Point Clouds. Zhang et al., NeurIPS 2023.

Experimental Results

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Method	Waymo Open			Argoverse2			
	mAPH	FPS	Speedup	mAP	FPS	Speedup	Mem.
HEDNet [7]	73.4	17.2	1.0×	37.1	7.3	1.0×	28.7G
VoxelNeXt [13]†	70.1	15.7	0.9×	30.7	19.6	2.7×	6.2G
FSDv2 [12]†	73.5	10.3	0.6×	37.6	11.5	1.6×	8.6G
SAFDNet†(Ours)	73.9	20.2	1.2×	39.7	15.1	2.1×	7.3G

Hybrid detector

Sparse detector

On Waymo Open (Short-range detection)

- 2x faster than sparse detector FSDv2
- comparable to hybrid detector HEDNet

On Argoverse2 (Long-range detection)

- 2.1% better than sparse detector FSDv2
- 2.1x faster than hybrid detector HEDNet

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Q & A

Code

Paper

Poster #22, Arch 4A-E, 5 p.m.