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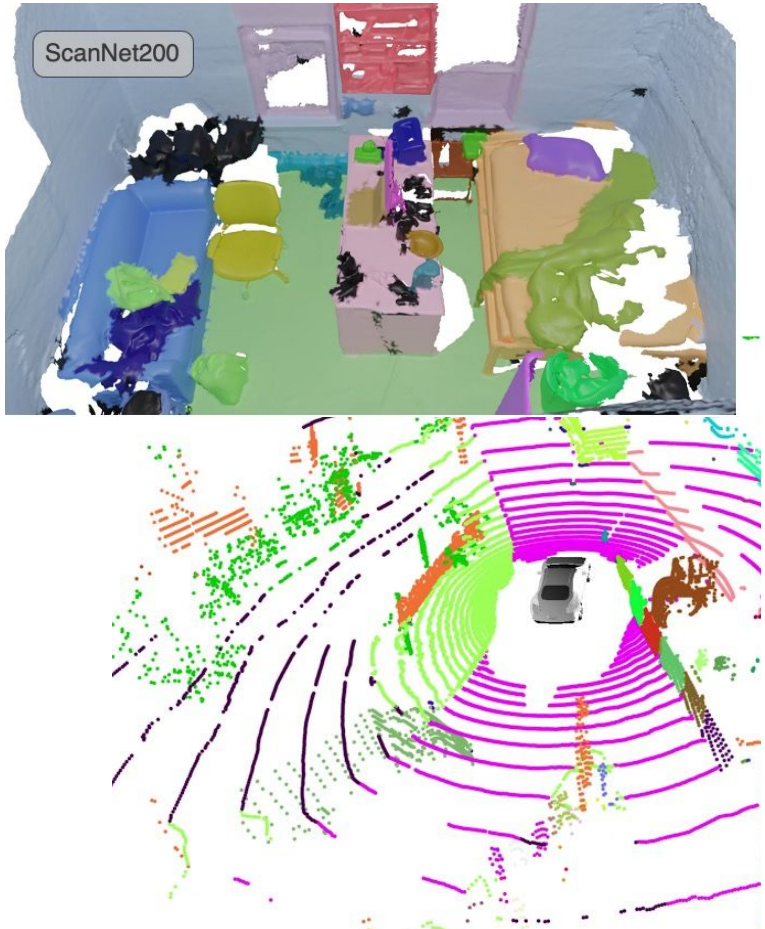
Nuages de Points et Modélisation 3D

7 - Machine learning IV



Overview

I. Tasks
II. Self-supervised learning
   A. Geometric reconstruction
   B. Contrastive learning
   C. Distillation
III. Domain adaptation
IV. OpenWorld

Classification and semantic segmentation

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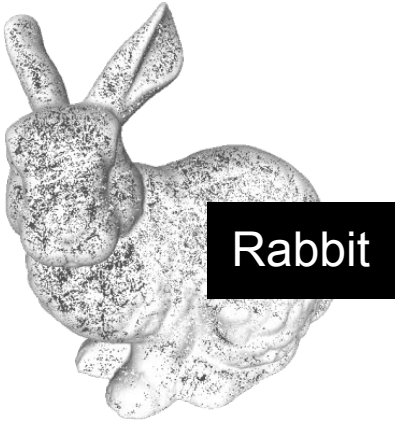
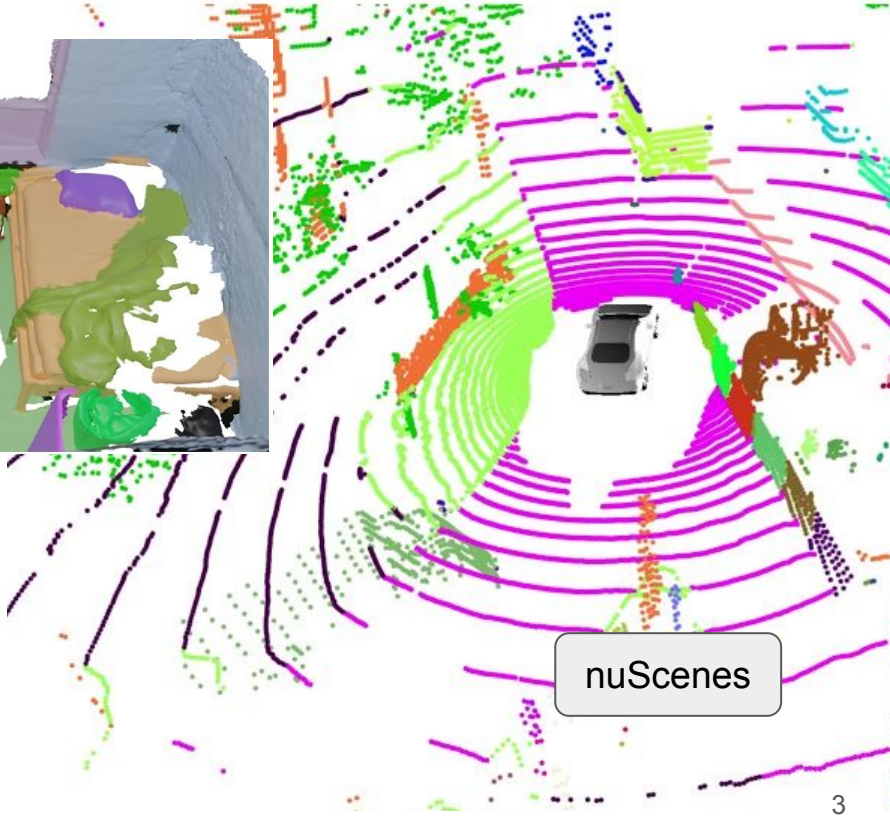
I - Tasks





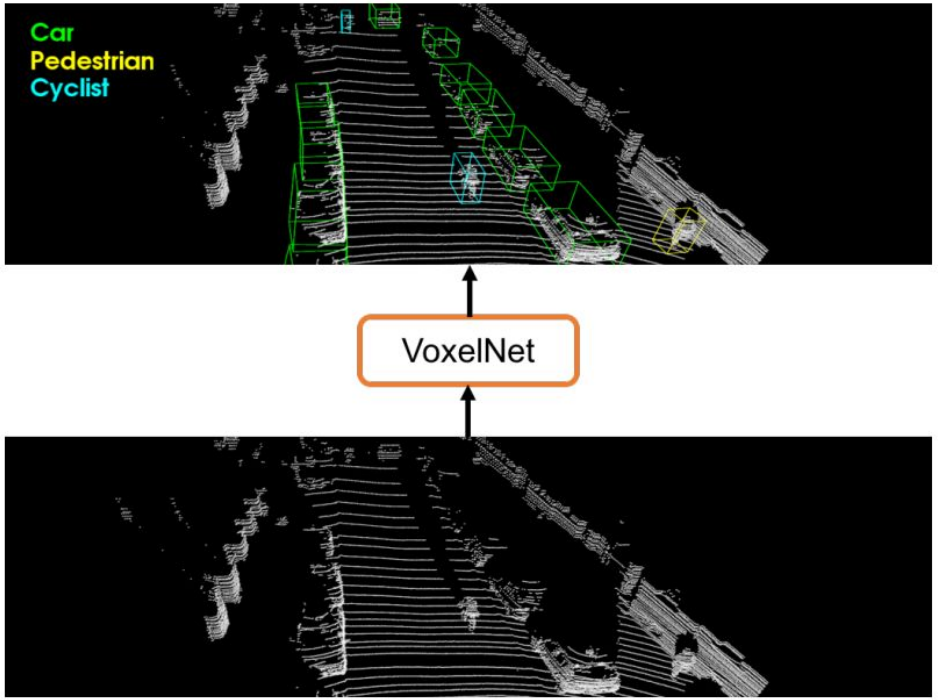
Classification → one label per point cloud

Segmentation → one label per point

Detection

I - Tasks

Put oriented boxes around objects of interest

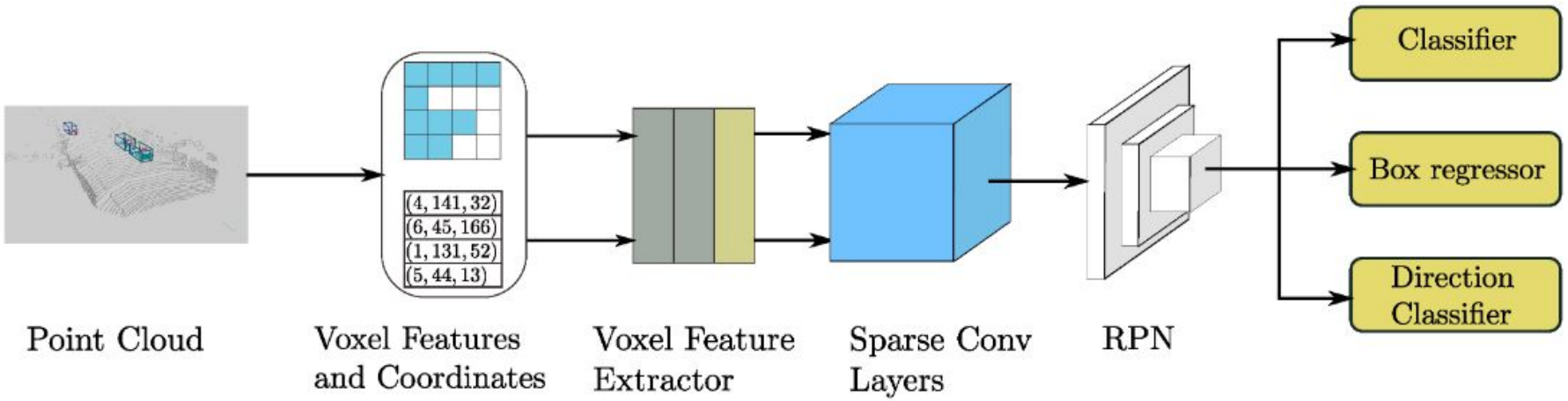


Yan, Yan, Yuxing Mao, and Bo Li. "Second: Sparsely embedded convolutional detection." Sensors 18.10 (2018): 3337.

Detection

I - Tasks

Second



Yan, Yan, Yuxing Mao, and Bo Li. "Second: Sparsely embedded convolutional detection." Sensors 18.10 (2018): 3337.

Scene completion

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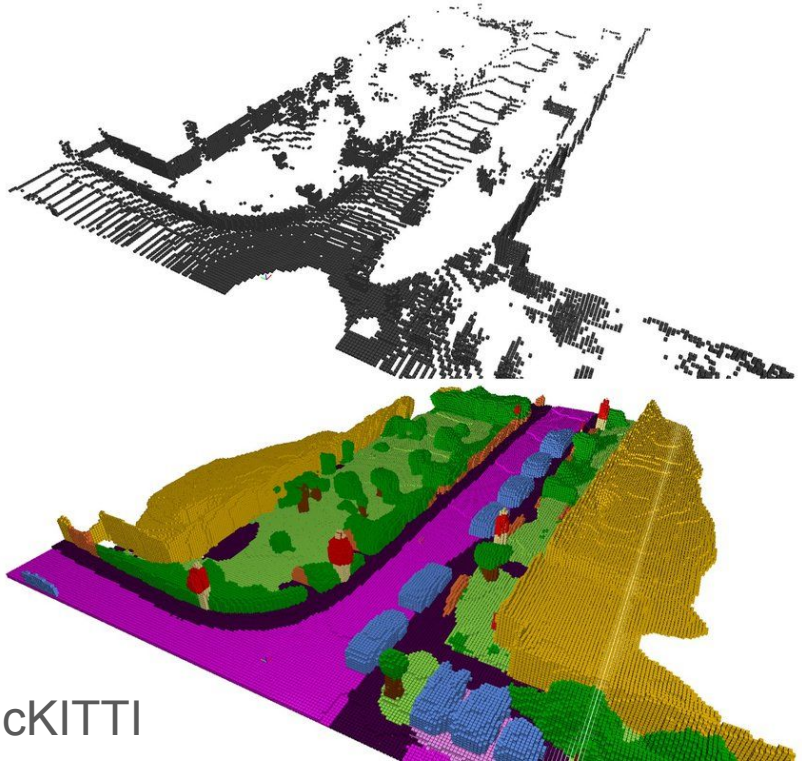
Input: lidar scan

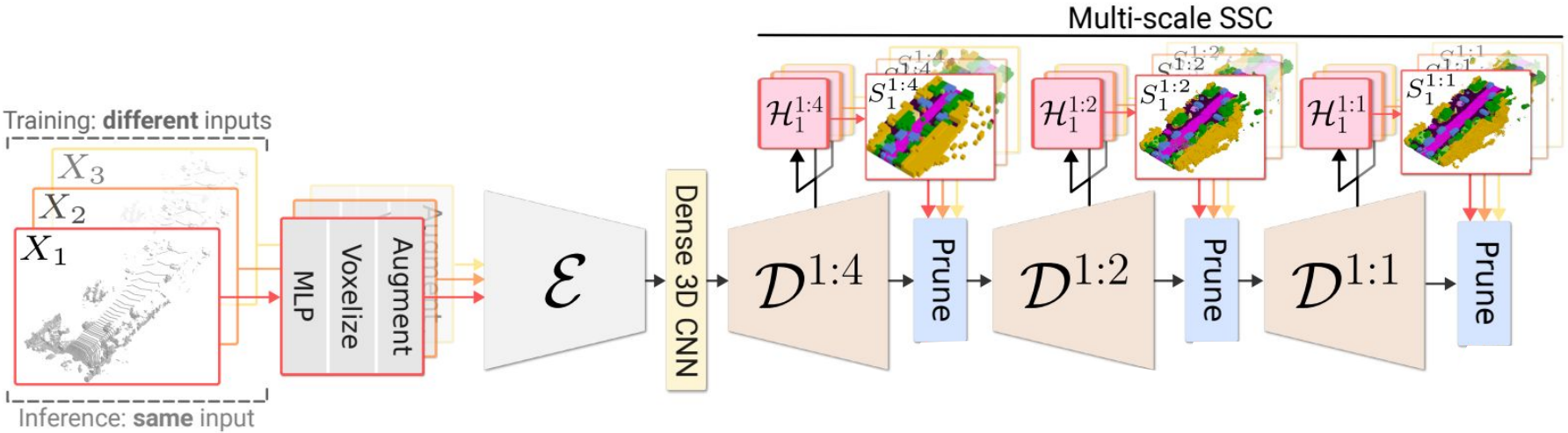
Output: completed voxel scene with semantics



SemanticKITTI

Scene completion

I - Tasks



Cao et al "Pasco: Urban 3d panoptic scene completion with uncertainty awareness." CVPR 2024.

Generation (e.g. diffusion models)

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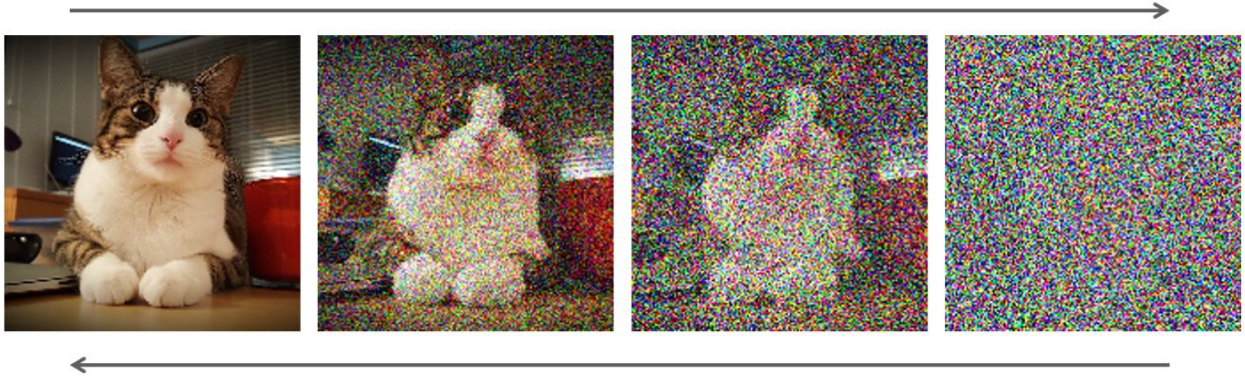
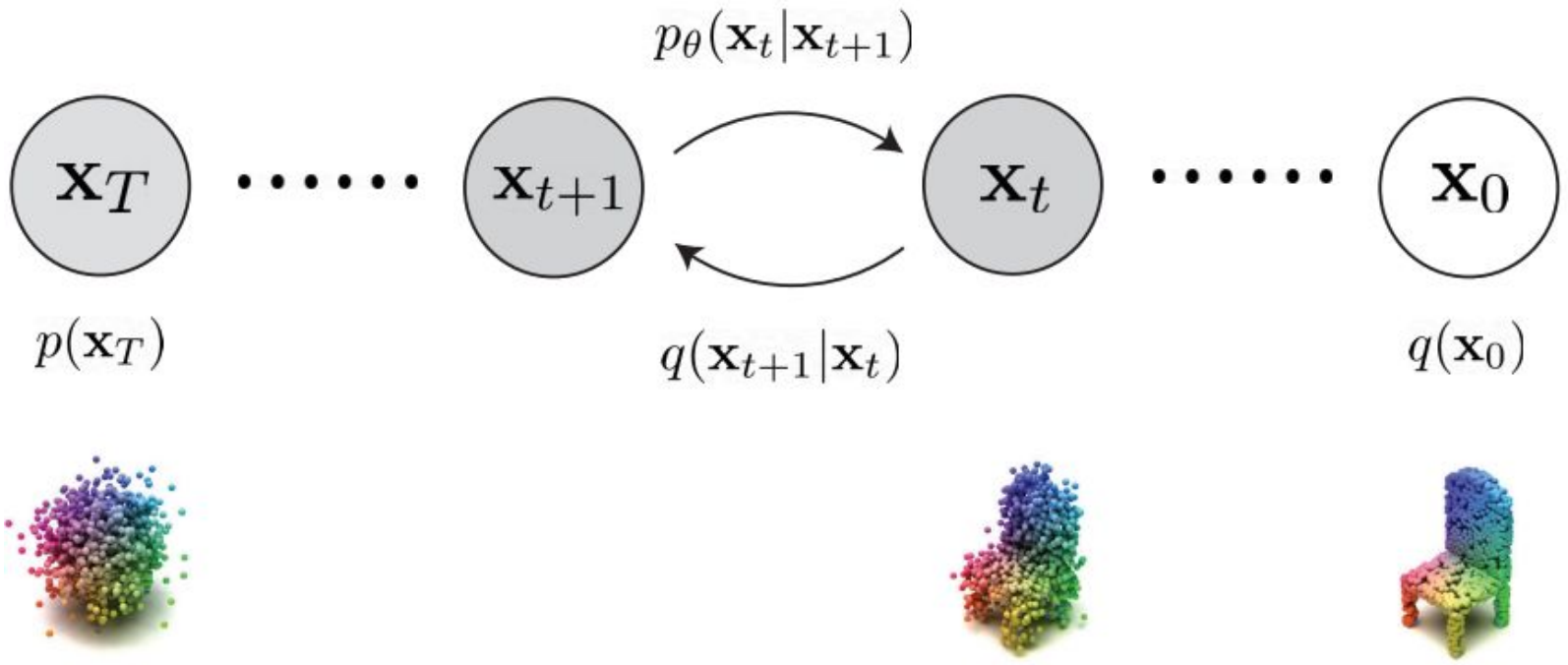
I - Tasks



https://developer.nvidia.com/blog/improving-diffusion-models-as-an-alternative-to-gans-part-2/

Generation (e.g. diffusion models)



Zhou et al. "3d shape generation and completion through point-voxel diffusion." ICCV. 2021.

Generation (e.g. diffusion models)

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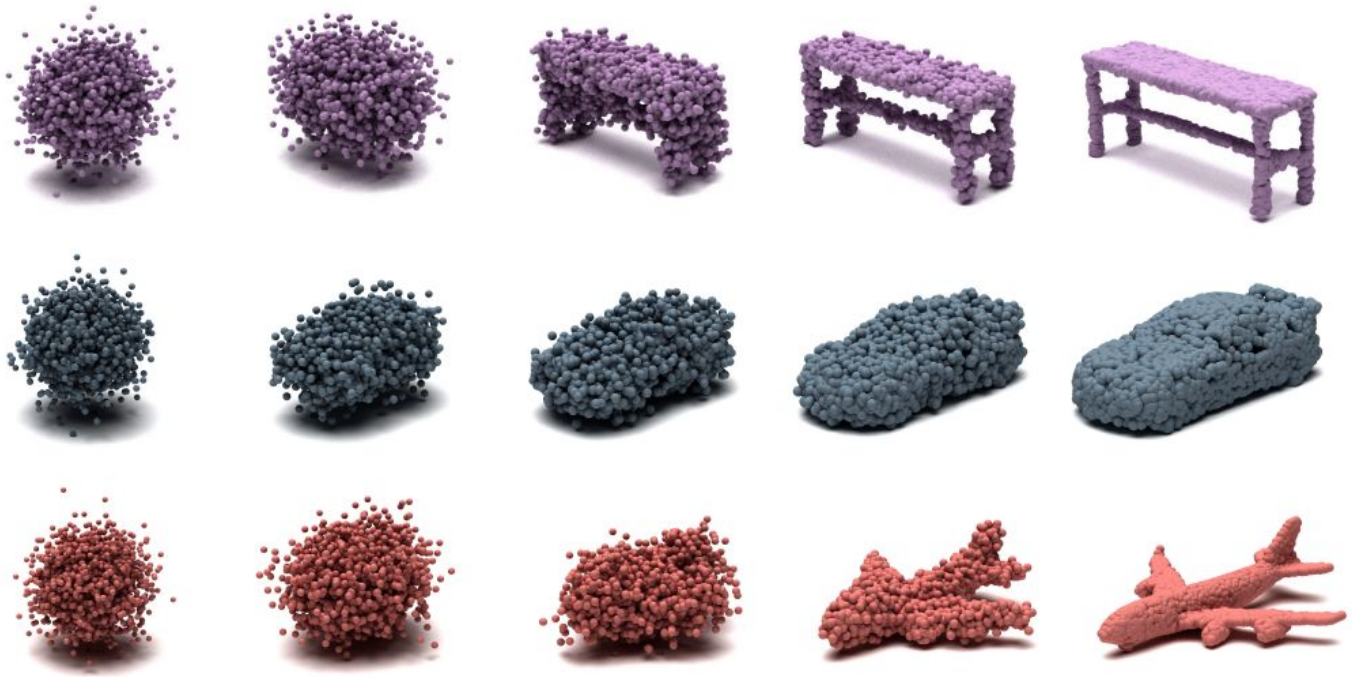
I - Tasks



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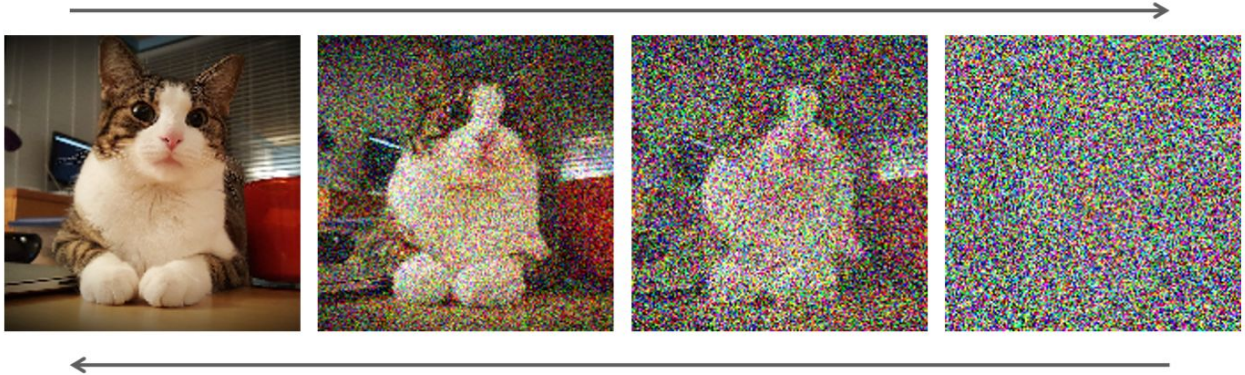
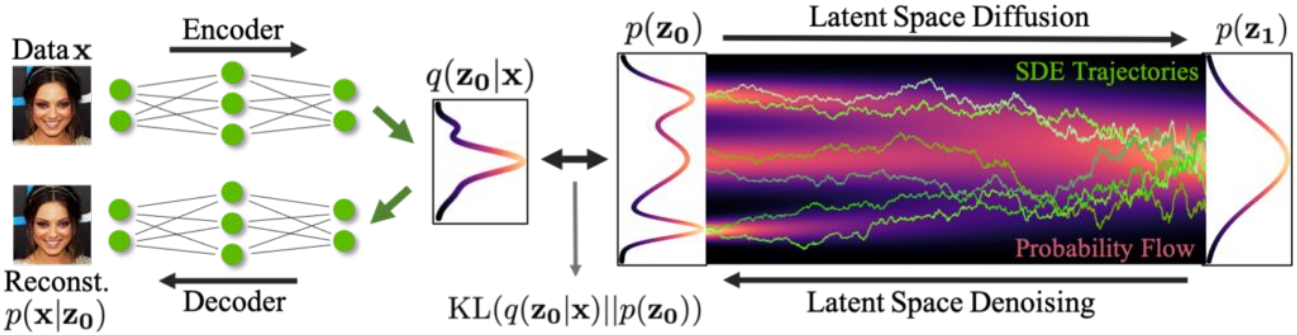
Generation (e.g. diffusion models)

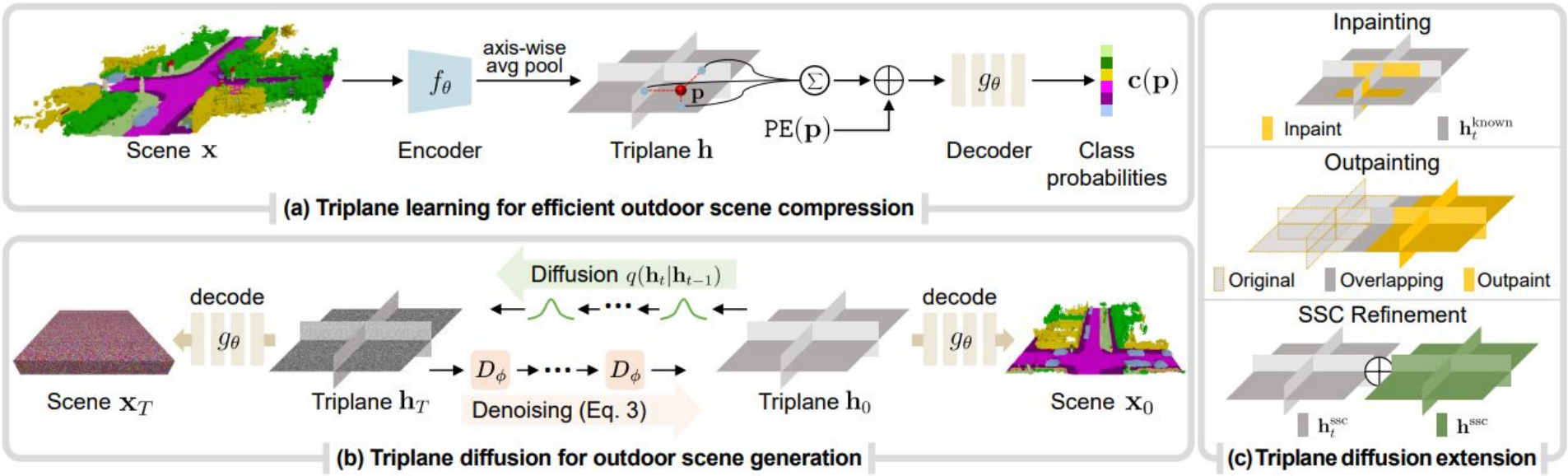




https://developer.nvidia.com/blog/improving-diffusion-models-as-an-alternative-to-gans-part-2/

Generation (e.g. diffusion models)

I - Tasks



Lee, Jumin, et al. "Semcity: Semantic scene generation with triplane diffusion." CVPR. 2024.

Generation (e.g. diffusion models)

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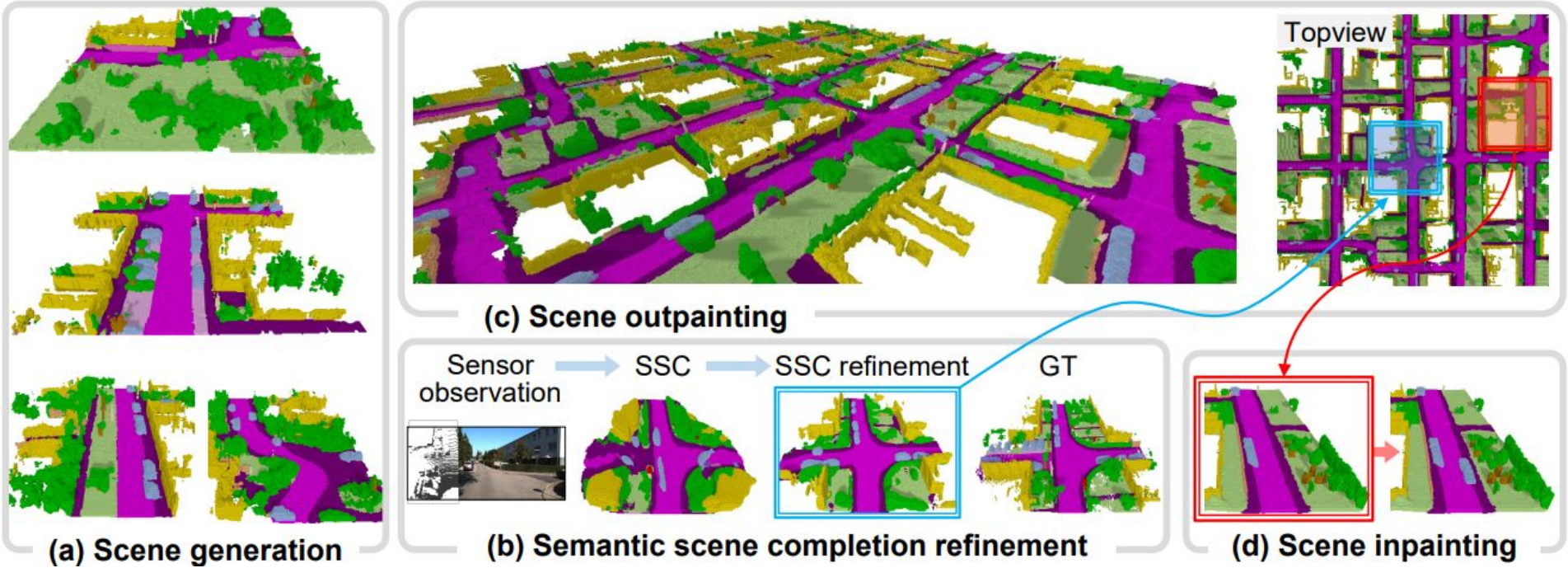
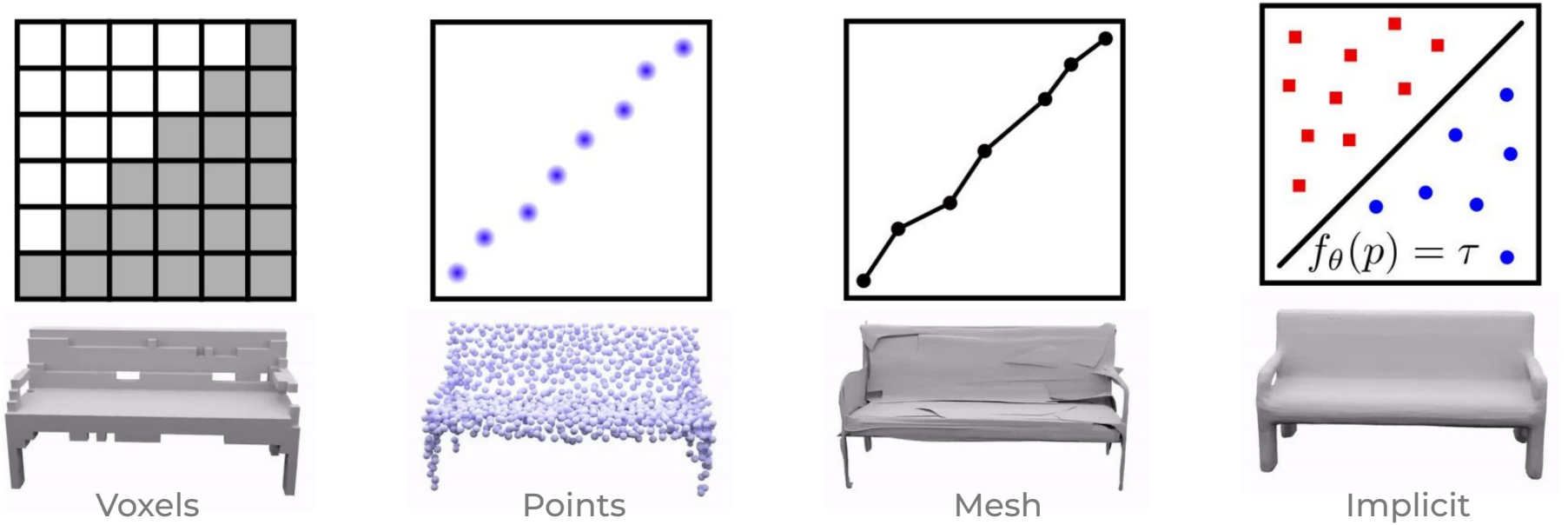
I - Tasks



Lee, Jumin, et al. "Semcity: Semantic scene generation with triplane diffusion." CVPR. 2024.

Surface reconstruction

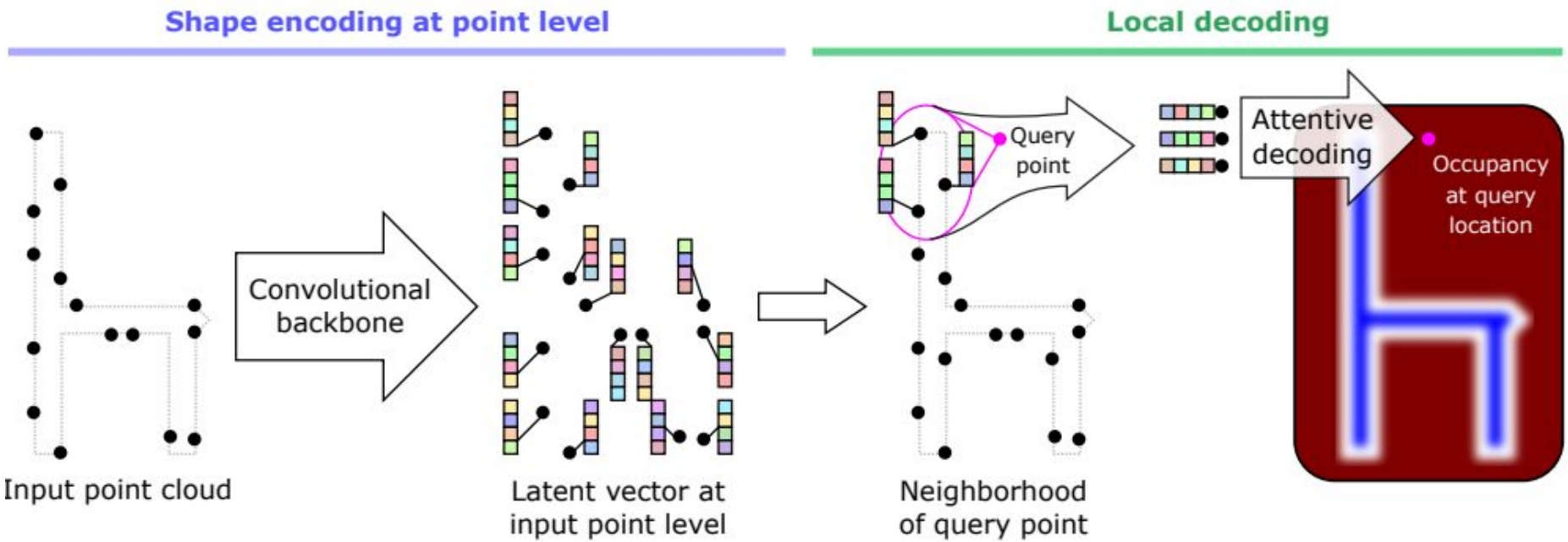
I - Tasks



Occupancy Networks: Learning 3D Reconstruction in Function Space
Mescheder, Lars and Oechsle, Michael and Niemeyer, Michael and Nowozin, Sebastian and Geiger, Andreas
Proceedings IEEE Conf. on Computer Vision and Pattern Recognition (CVPR), 2019

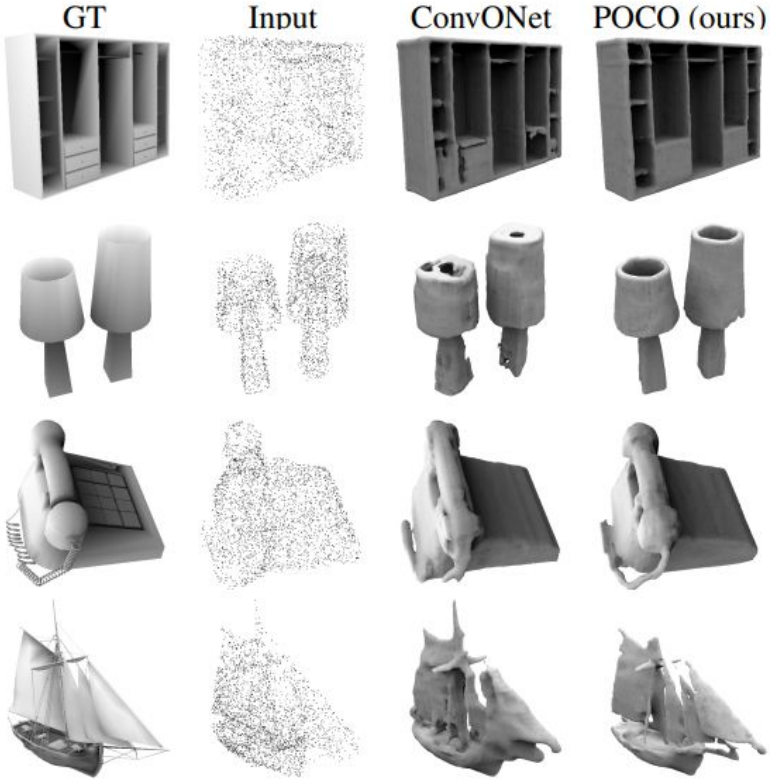
Surface reconstruction

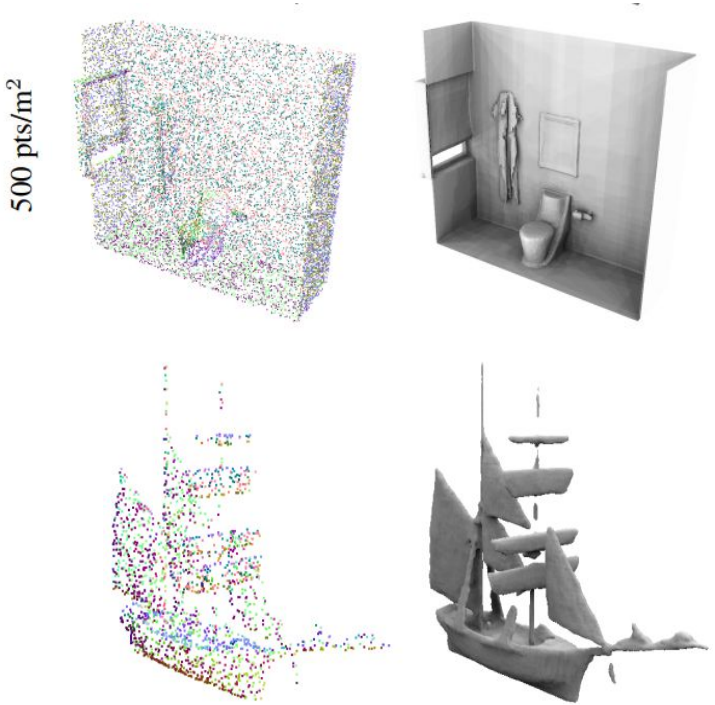
I - Tasks

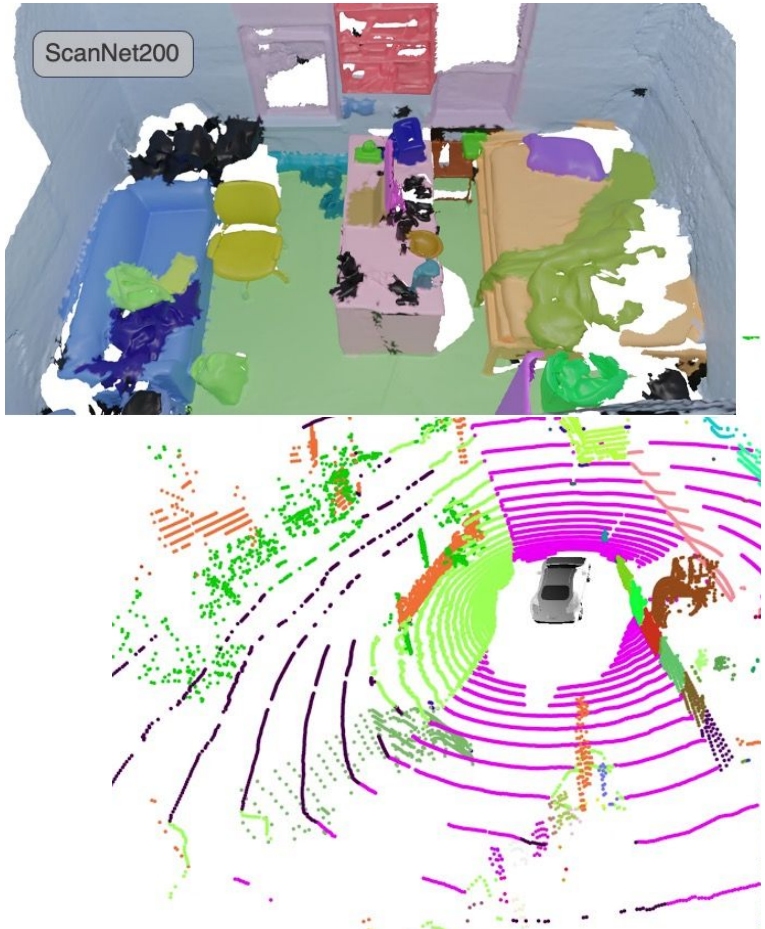


Surface reconstruction

I - Tasks







Overview

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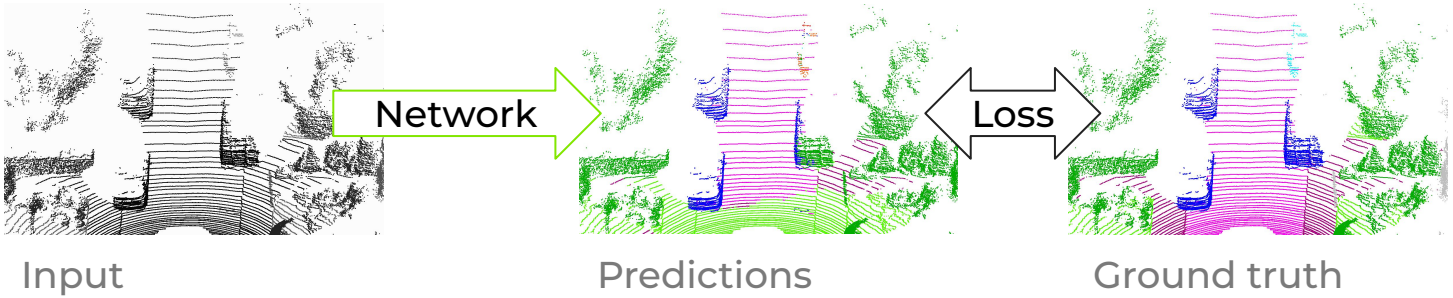
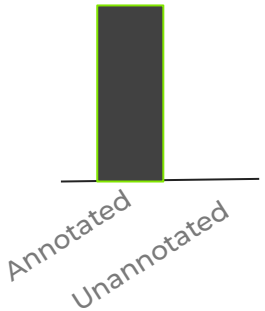
Supervised learning

Self-supervised learning



Train with annotated data

- Annotations are costly
- Limitation of the database size



Frugal learning

Self-supervised learning

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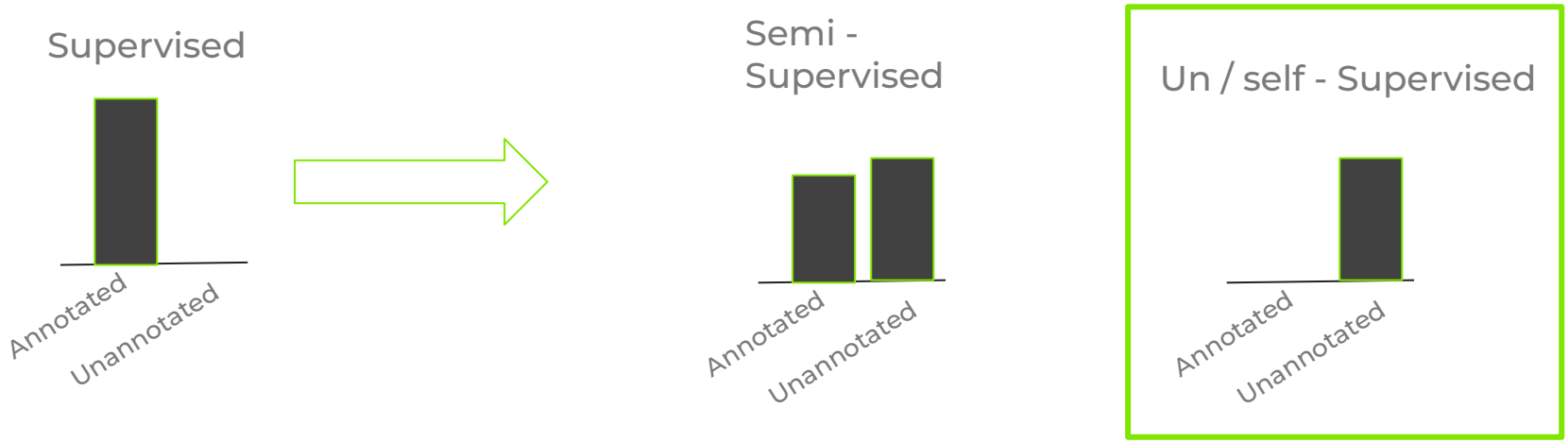
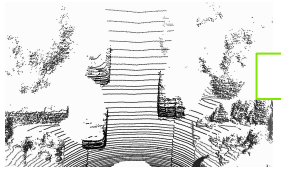
Objective: learning with less annotations



Self-supervision

What? learn useful representations without annotations

Why? better performance when finetuning / data-efficiency

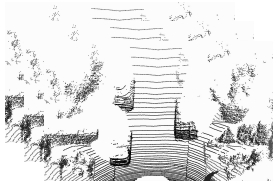


Input

Network

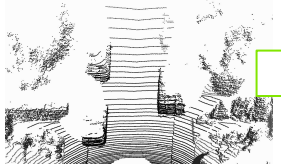
Representations

Loss



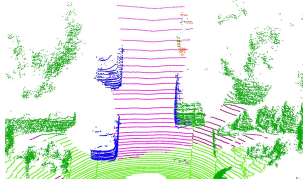
Non-annotated data

Step 2: finetuning / linear probing(supervised)

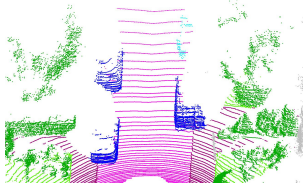


Input

Network



Loss



Self-supervision

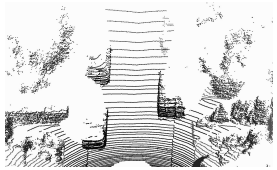
Step 1

Pretraining

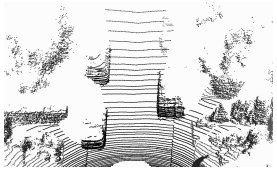
Self-supervision

Step 1

Pretraining

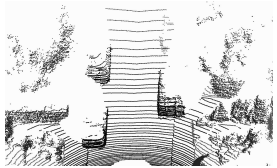


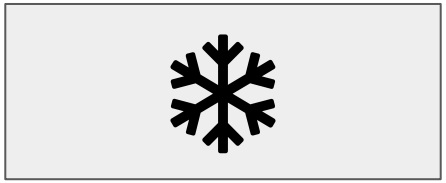
Self-sup. head



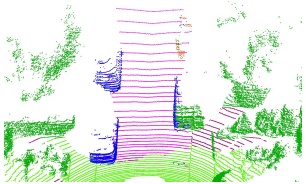
Step 2

Probing





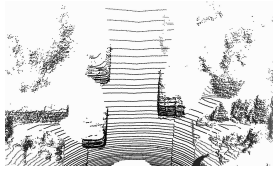
Taks head



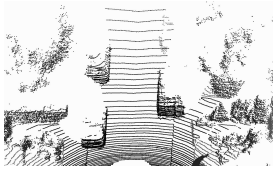
Self-supervision

Step 1

Pretraining

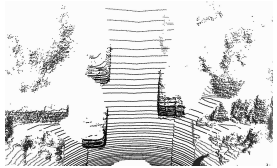


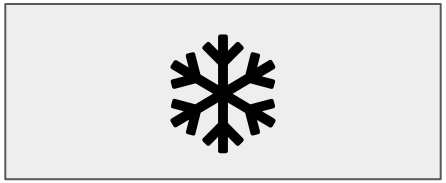
Self-sup. head



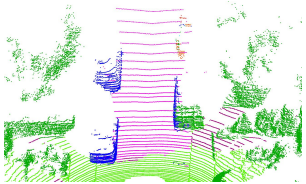
Step 2

Probing

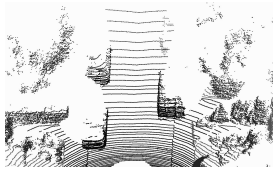




Taks head



Finetuning



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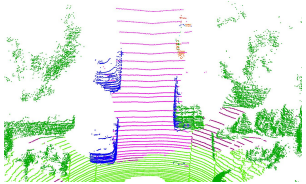

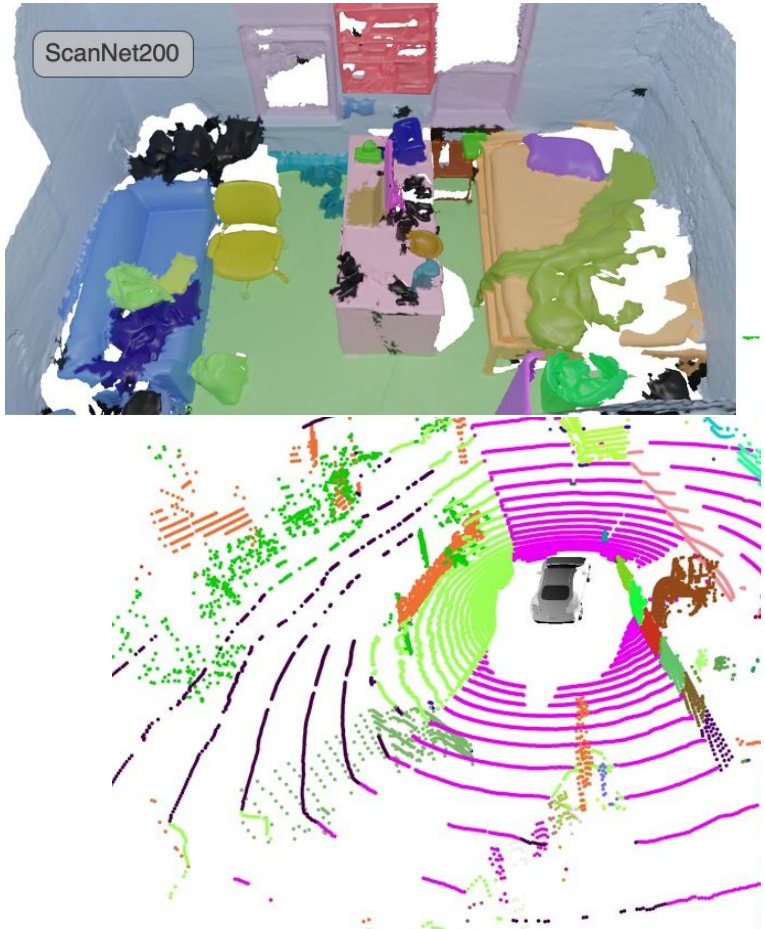

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ALSO: Automotive Lidar Self-Supervision by Occupancy Estimation

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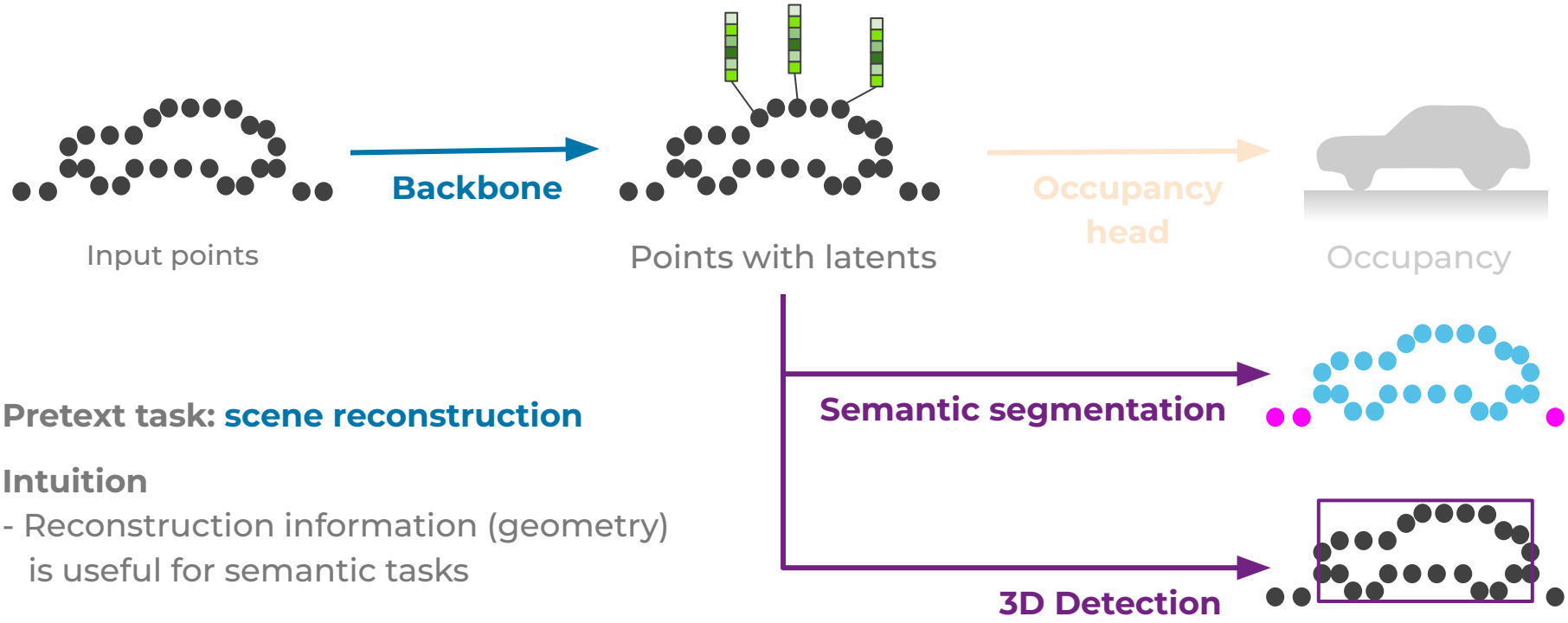
ALSO



Pretext task: scene reconstruction

Intuition

- Reconstruction information (geometry) is useful for semantic tasks

Context reconstruction vs local reconstruction

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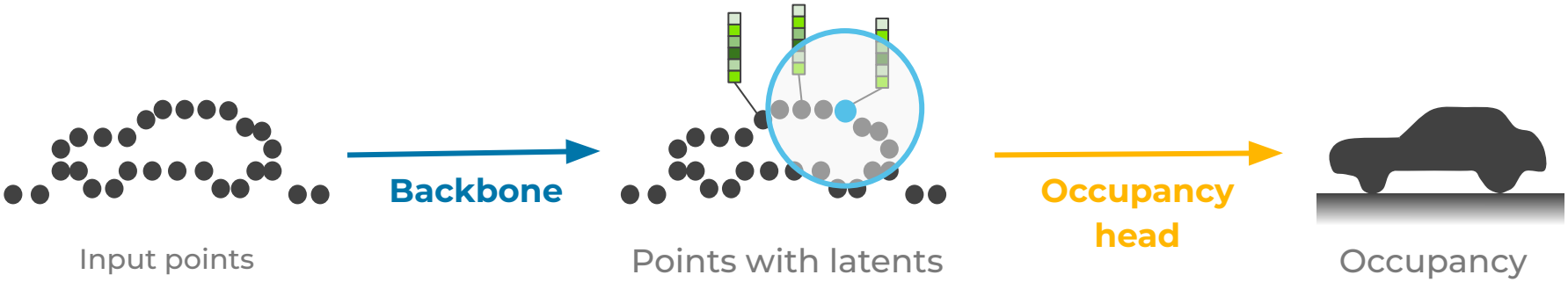
ALSO



Context reconstruction vs local reconstruction

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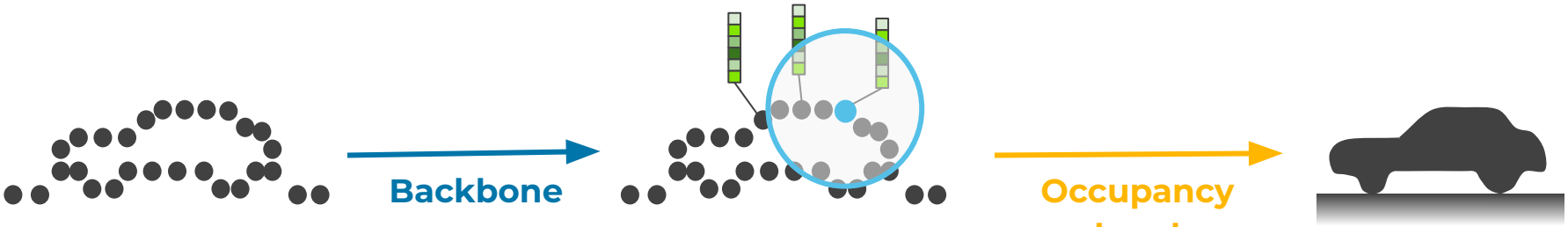
ALSO



Local reconstruction [POCO head]

- everywhere, from features of neighboring points

⇒ (too) detailed geometry

Context reconstruction [ALSO head]

- of a 1 meter ball, from each single feature point

⇒ rough geometry, more suited for object recognition

POCO: Point Convolution for Surface Reconstruction, A. Boulch, R. Marlet, CVPR 2022

Context reconstruction vs local reconstruction

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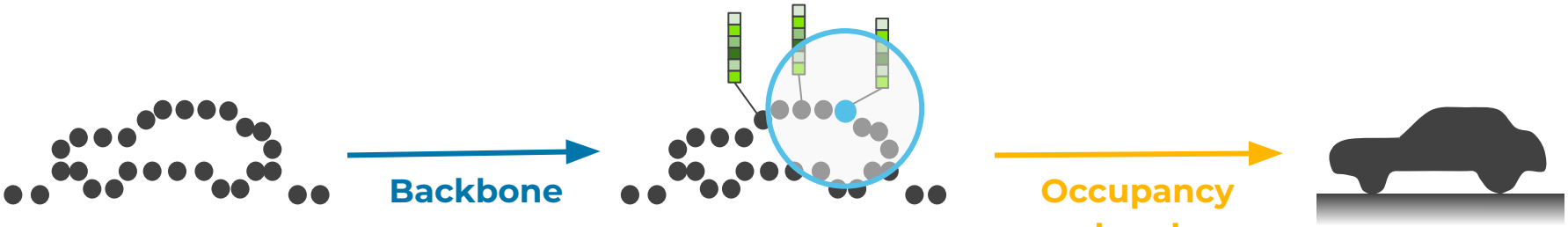
ALSO



Local reconstruction [POCO head]
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- of a 1 meter ball, from each single feature point
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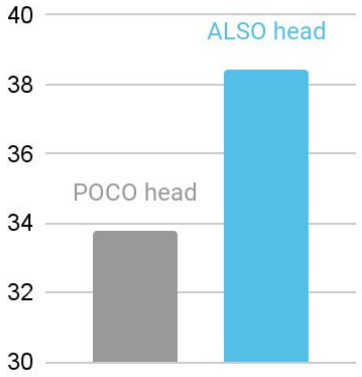

POCO: Point Convolution for Surface Reconstruction, A. Boulch, R. Marlet, CVPR 2022

Supervision

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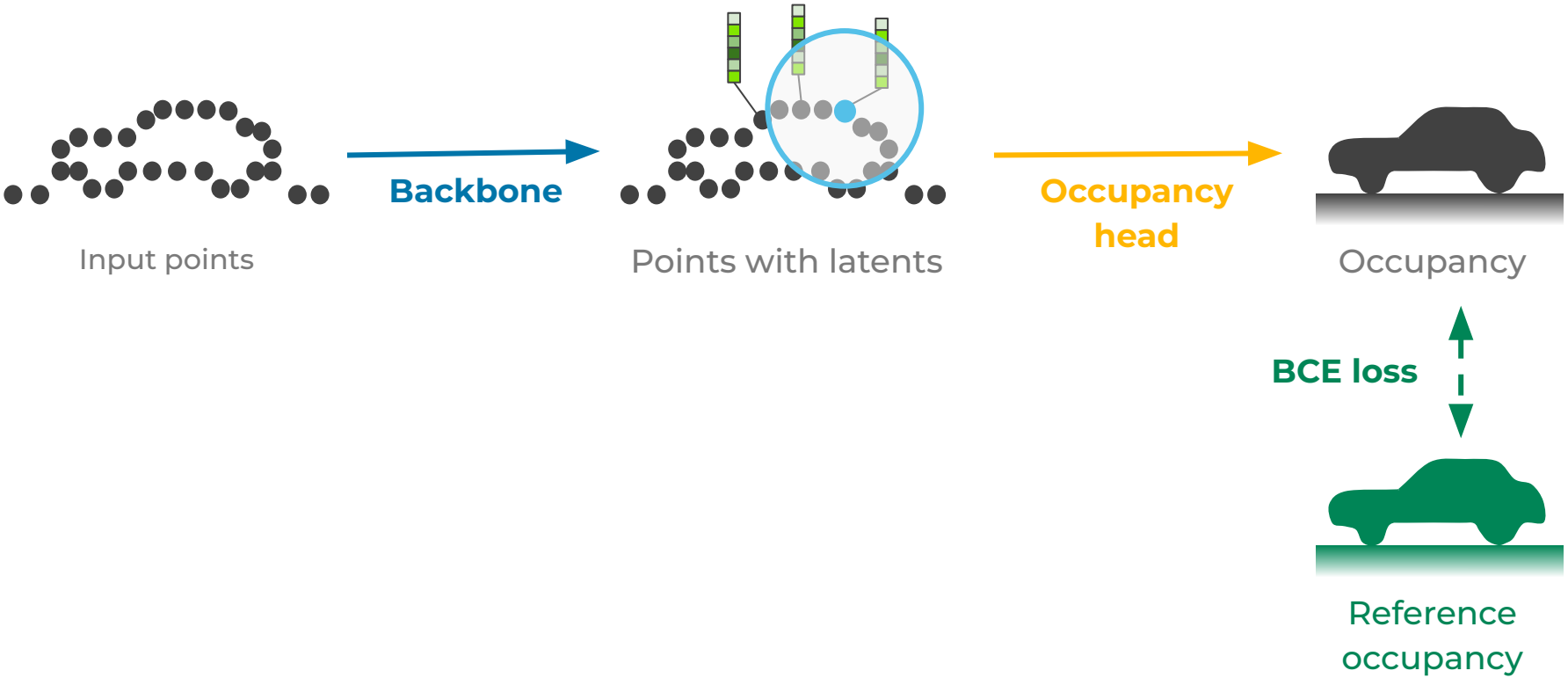
ALSO



Supervision

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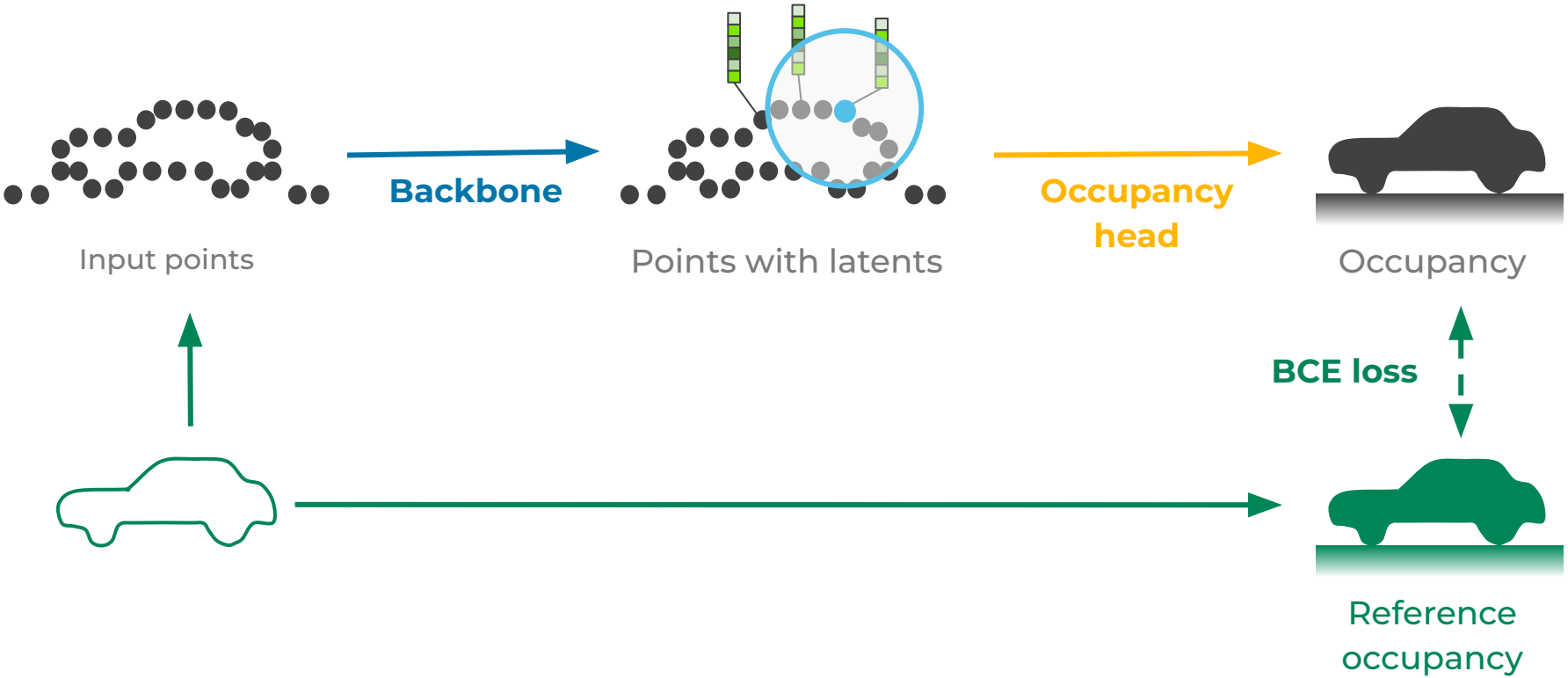
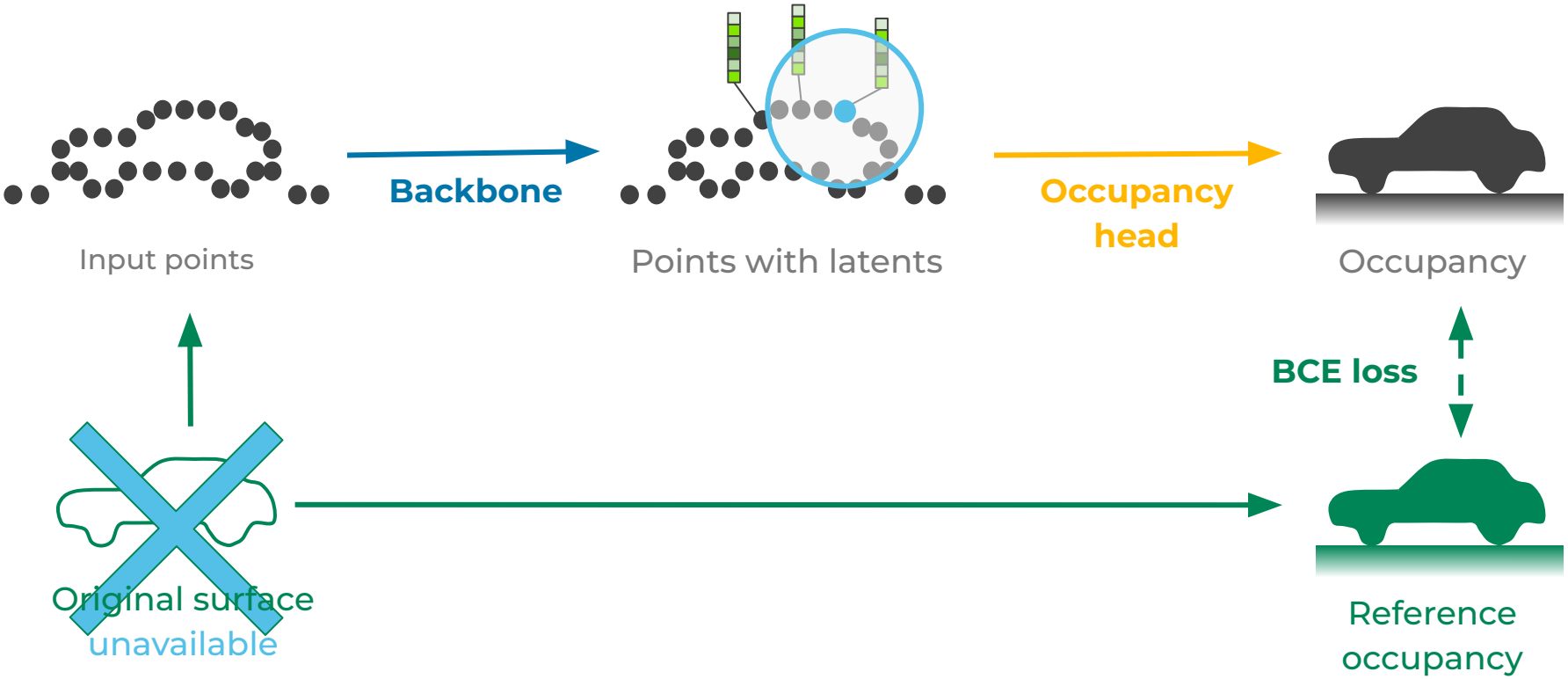
ALSO



Supervision

valeo.ai

ALSO



Self-supervised occupancy - Query point generation

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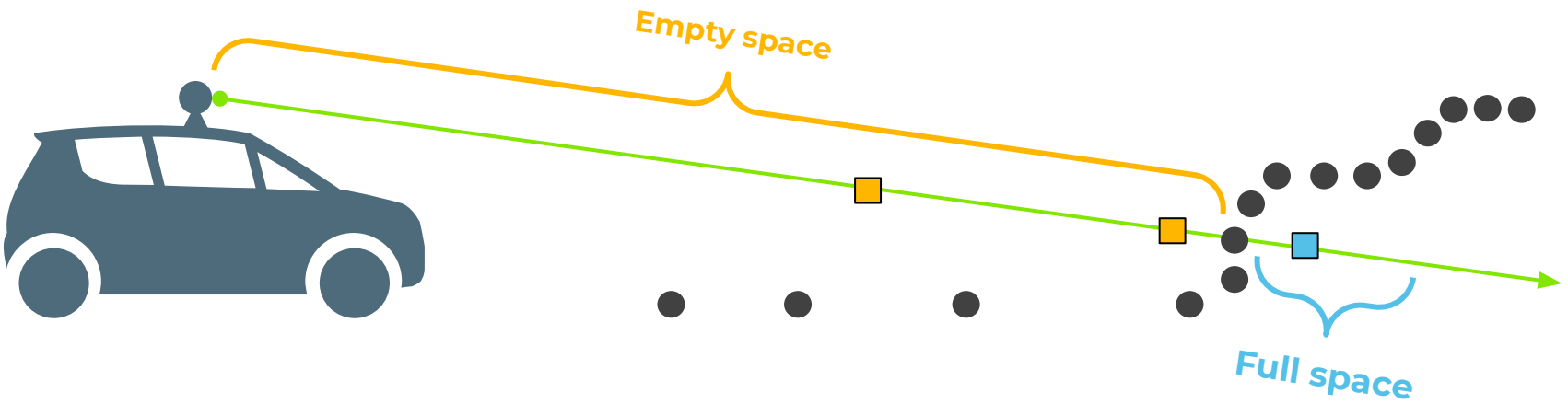
ALSO



Along lidar lines of sight

- **Empty queries:** from sensor to observed point
- **Full queries:** just behind the point (max distance δ = 0.1 m)

Self-supervision

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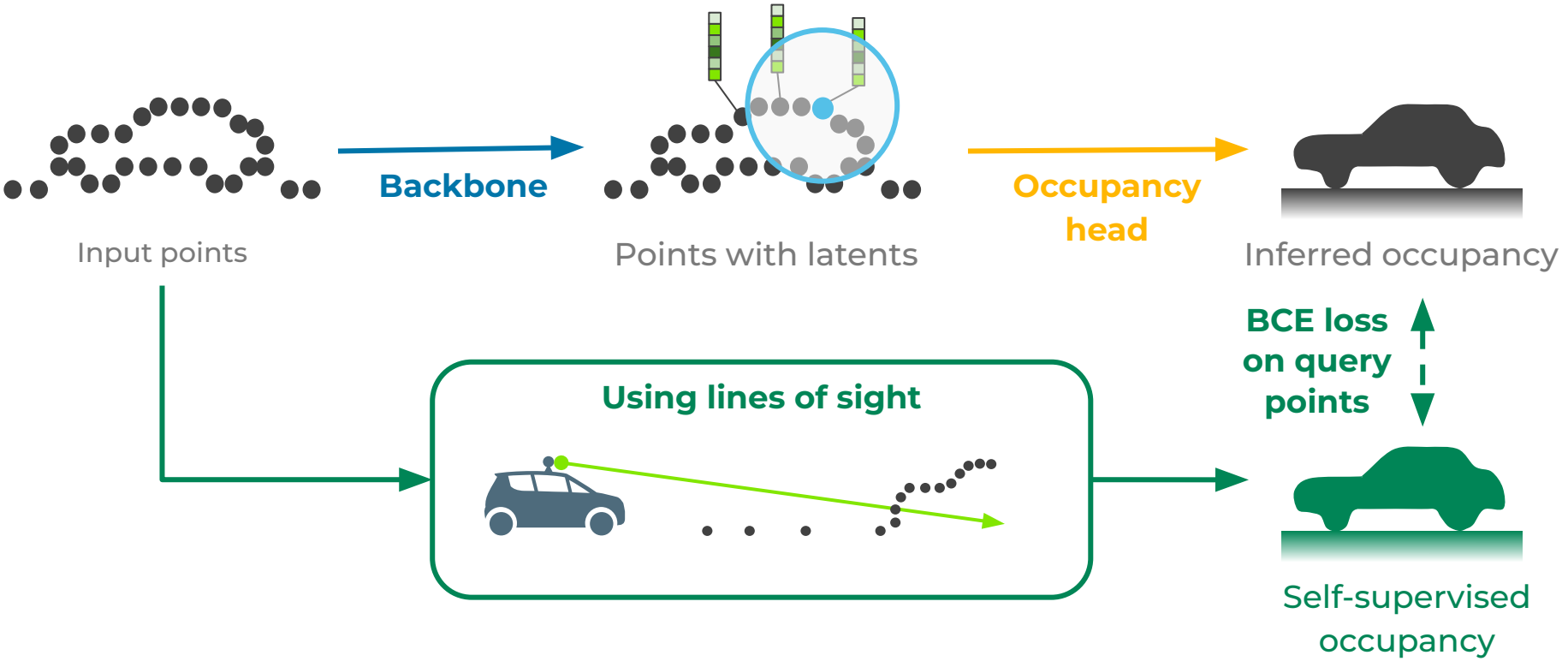
ALSO



Downstream tasks

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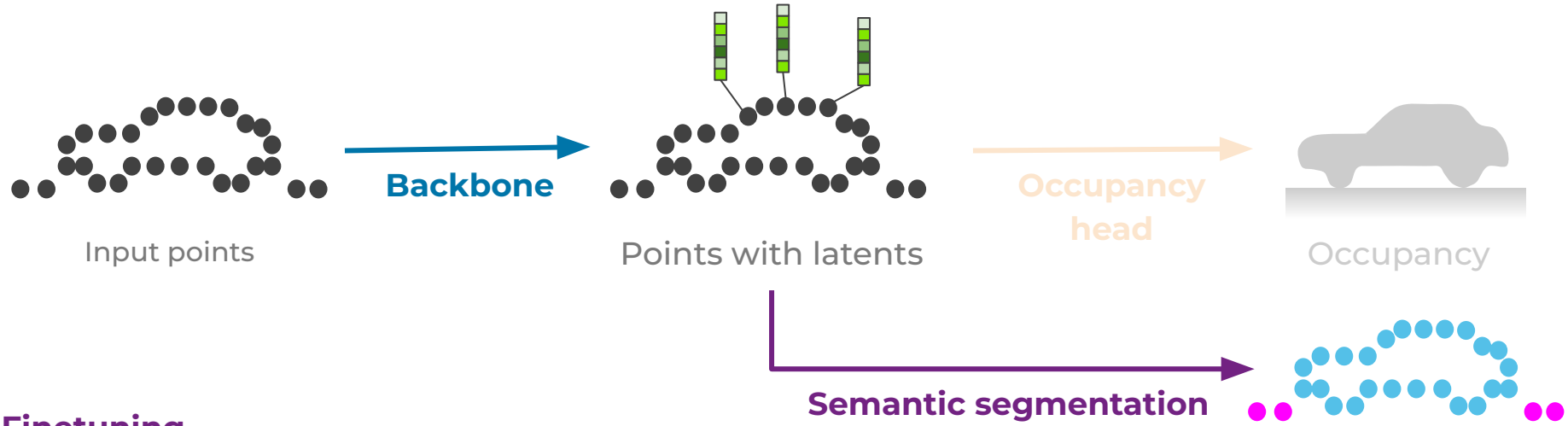
ALSO



Finetuning

- remove occupancy head
- add a single linear layer
- finetune the whole network

Semantic segmentation - 1% annotated data

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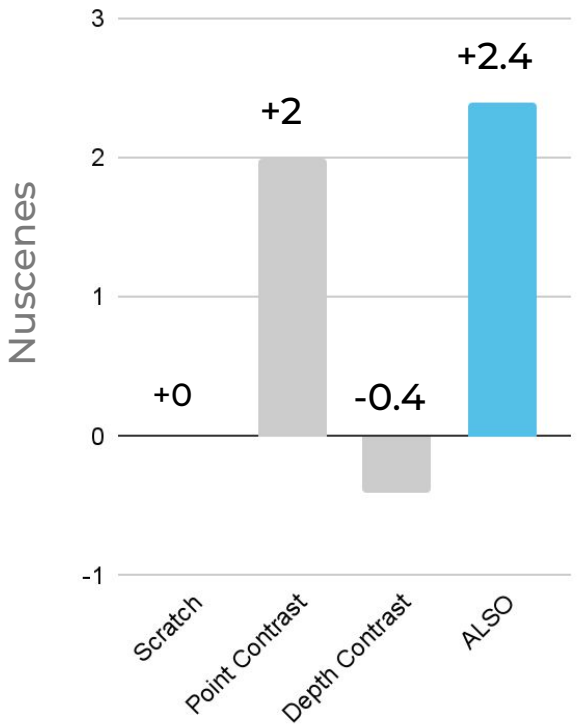
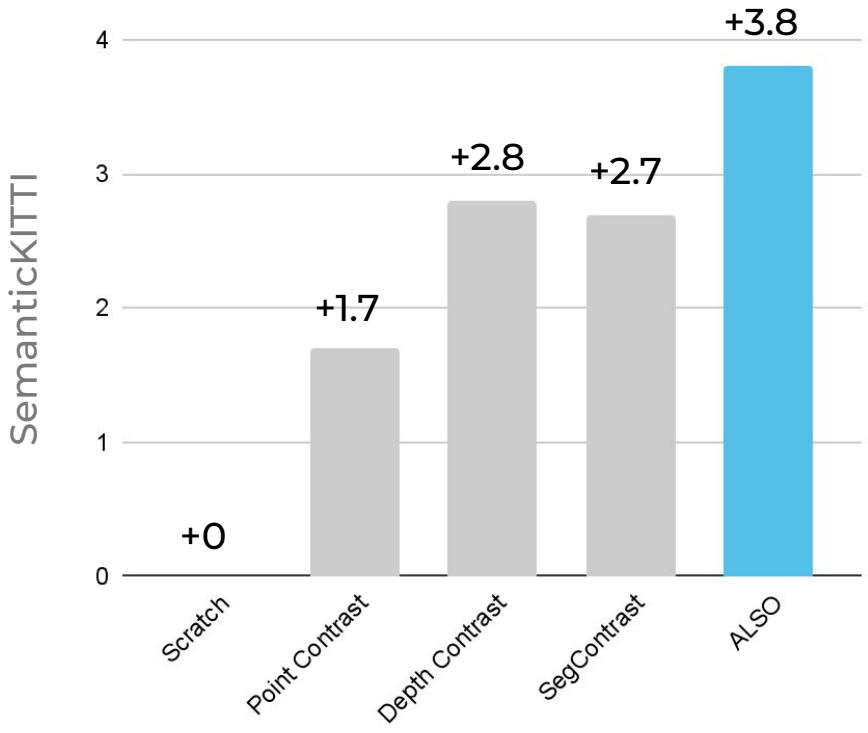
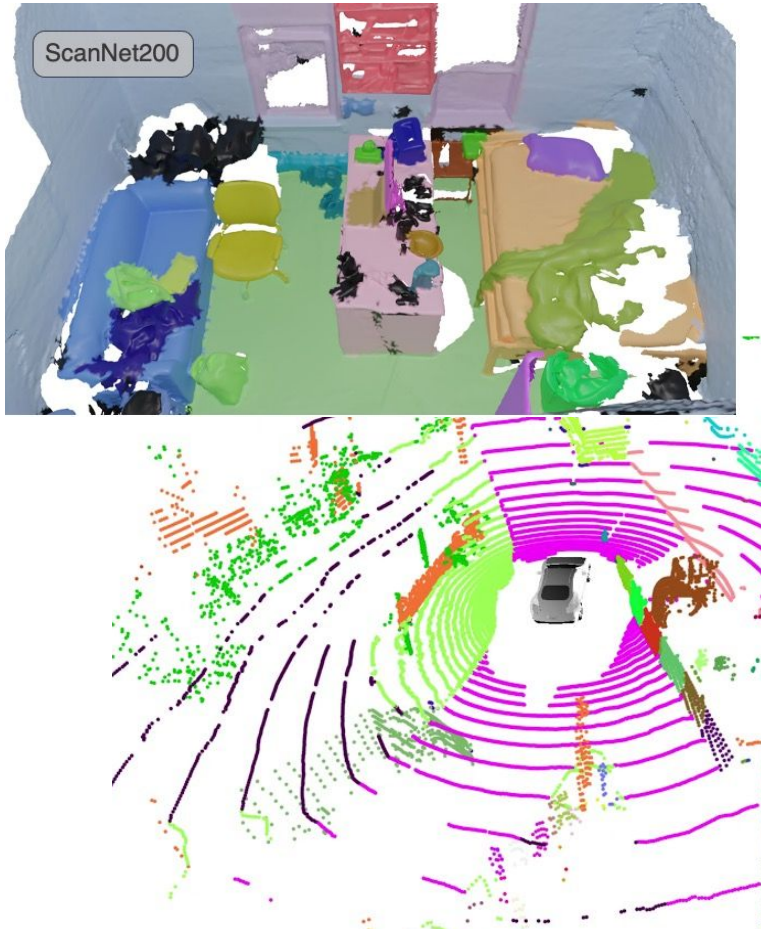
ALSO







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Contrastive learning

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Contrastive methods

Car

Network

Z_1

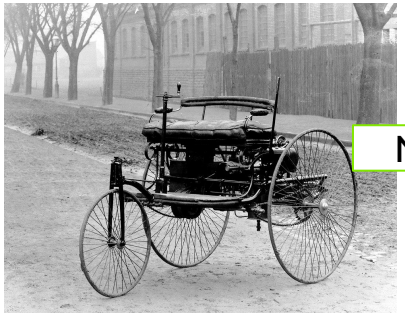
Dissimilar

Z_3

Network

Bus

Similar



Network

Z_2

Car

Contrastive learning

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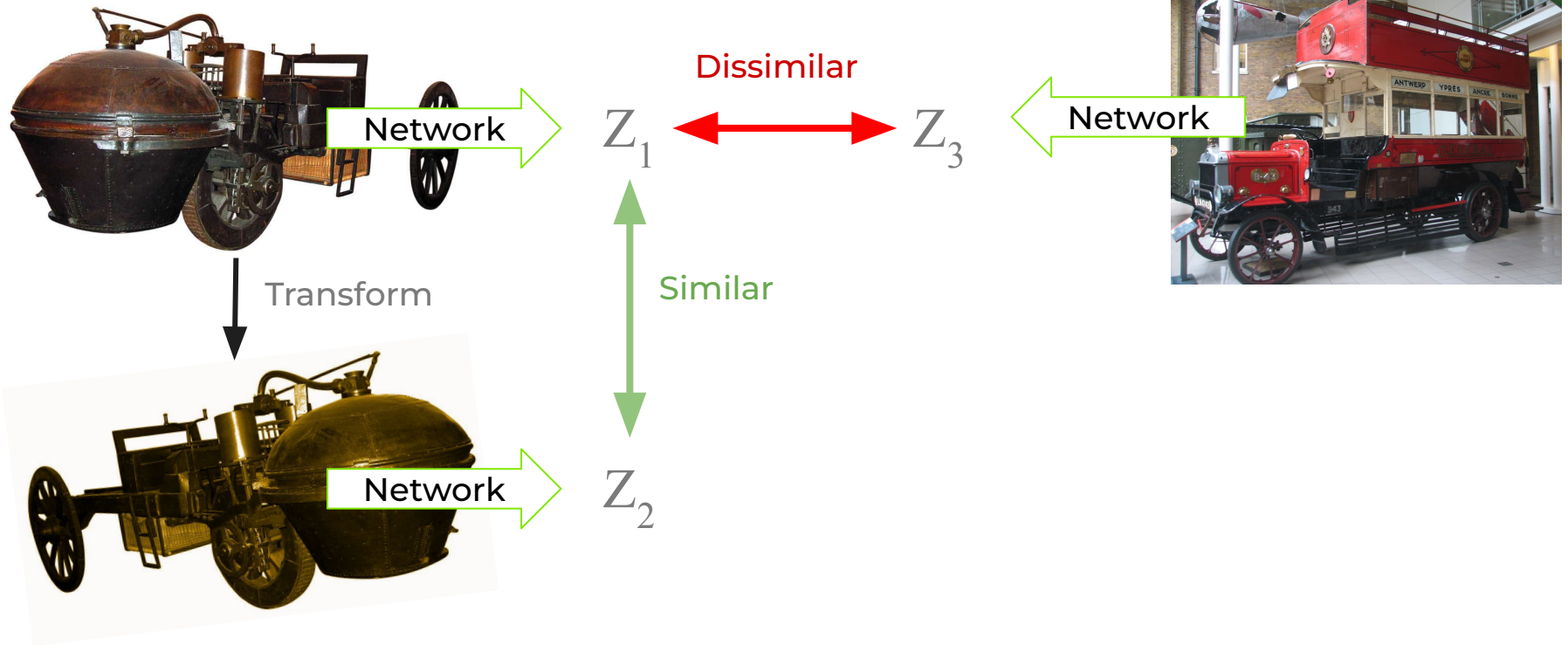
Contrastive methods



Contrastive learning

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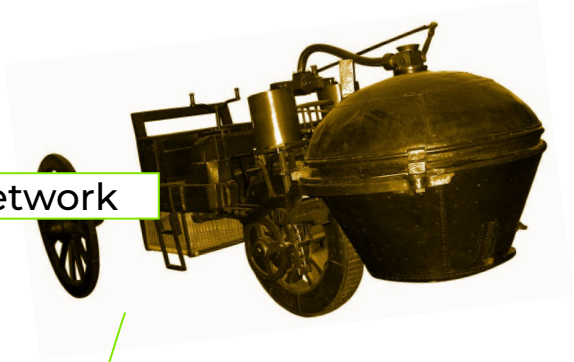
Contrastive methods

Network

q

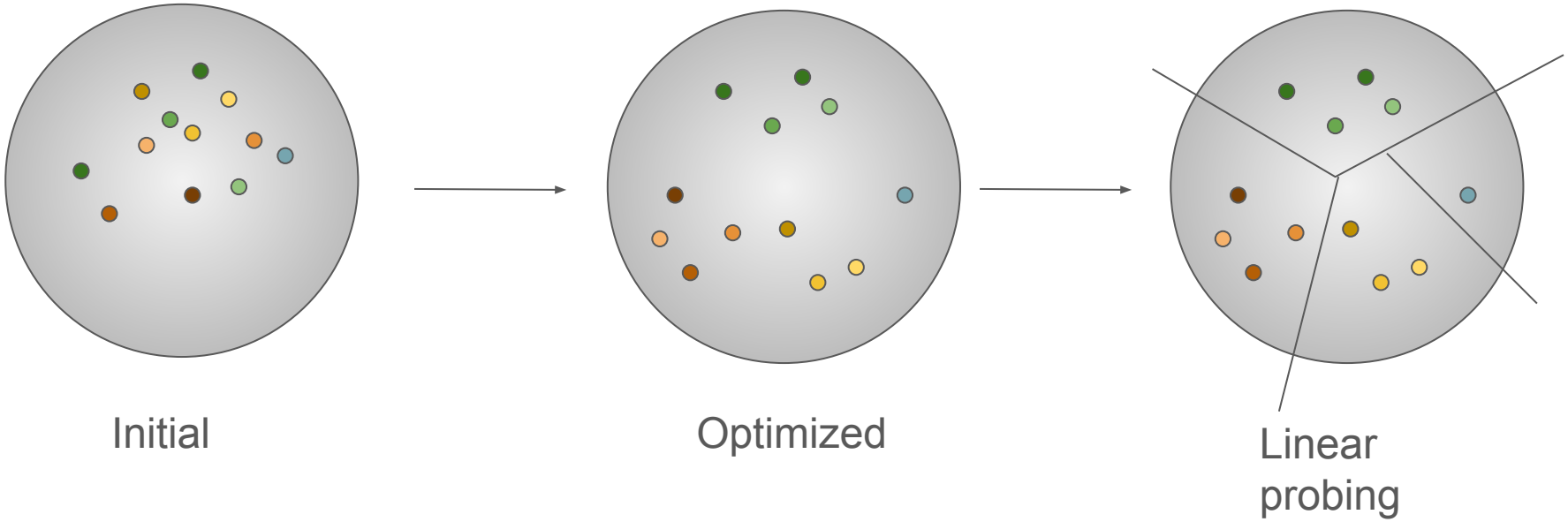
k_+

Network



$$\mathcal{L}_q = -\log \frac{\exp(q \cdot k_+ / \tau)}{\sum_{i=0}^{K} \exp(q \cdot k_i / \tau)}$$

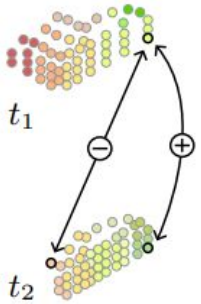
Contrastive learning



Contrastive self-supervised learning for point clouds

valeo.ai

Contrastive methods



PointContrast

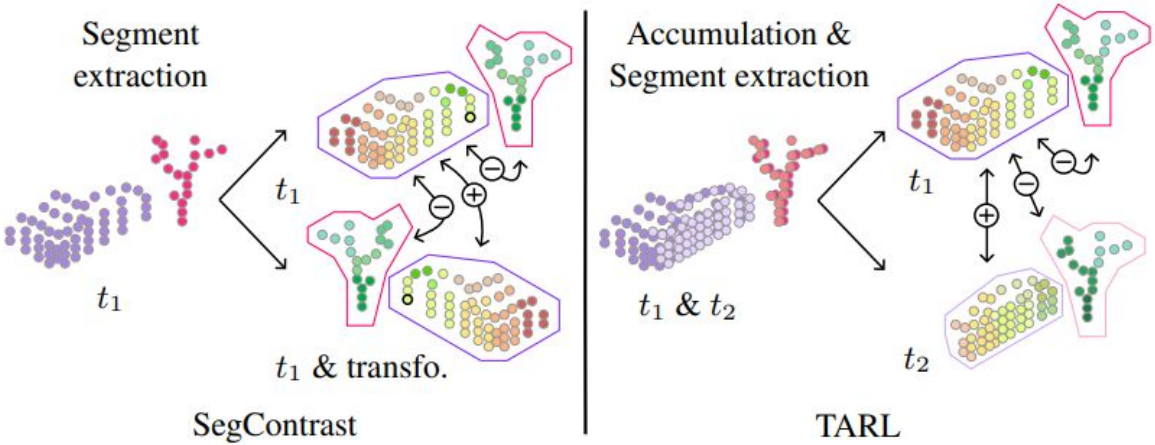
PointContrast

+++ Easy to implement
- - - Contrast in the same object

Contrastive self-supervised learning for point clouds

valeo.ai

Contrastive methods



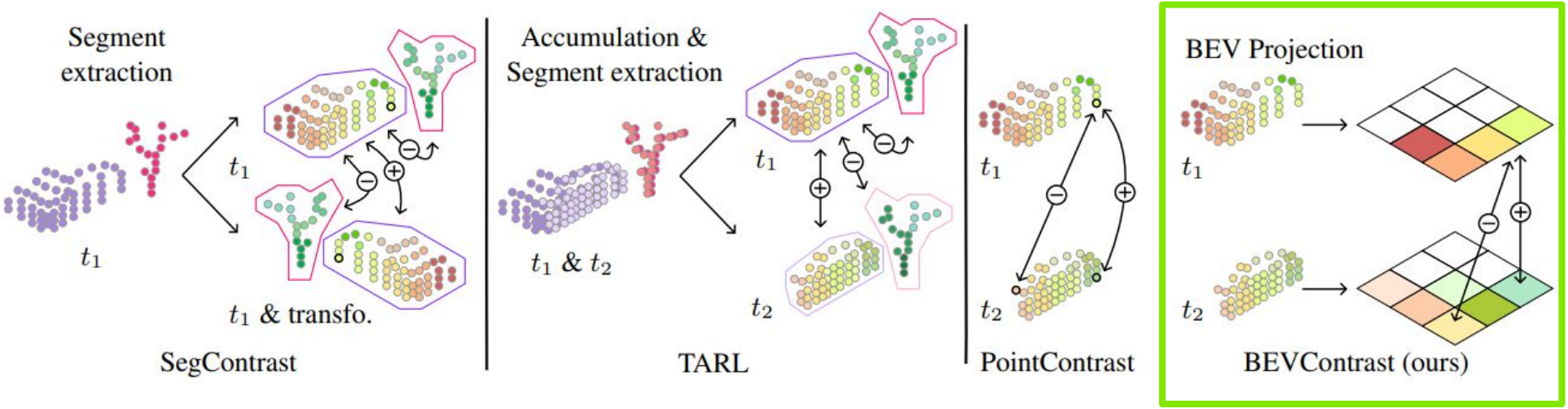
SegContrast / TARL

+++ Efficient thanks to object segmentation (temporal for TARL)
- - - Difficult to set up → rely on HDBScan (hyperparameters)

Contrastive self-supervised learning for point clouds

valeo.ai

Contrastive methods



BEVContrast

+++ Simple → easy projection in BEV
+++ Object separation approximation with BEV cells

BEVContrast

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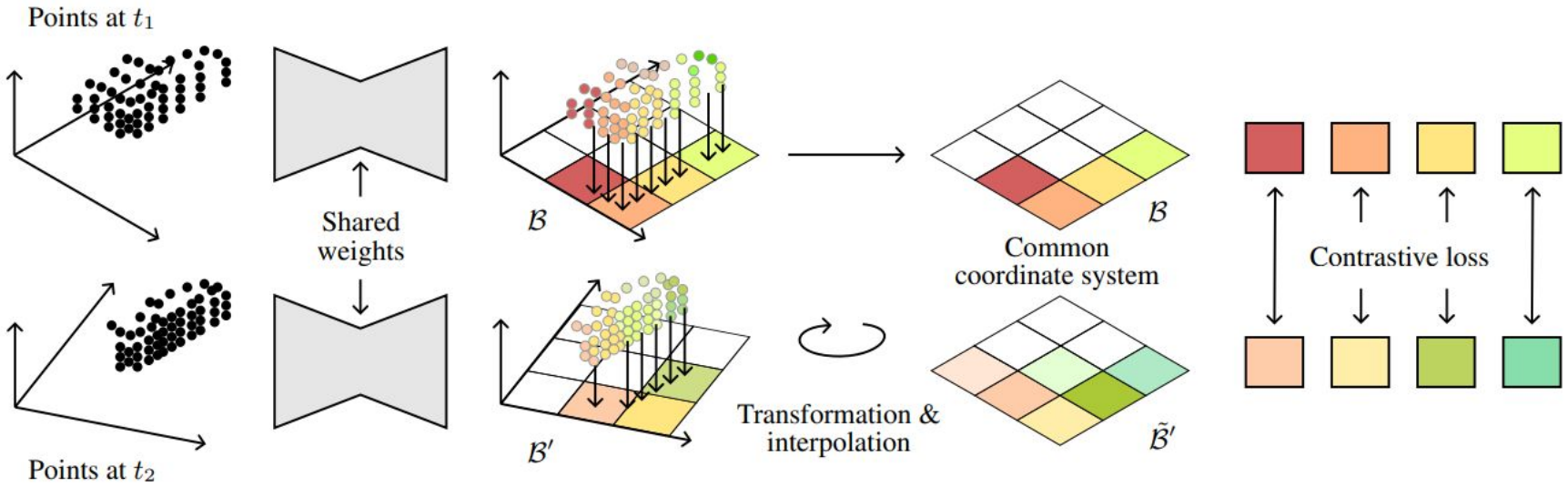
Contrastive methods



BEVContrast

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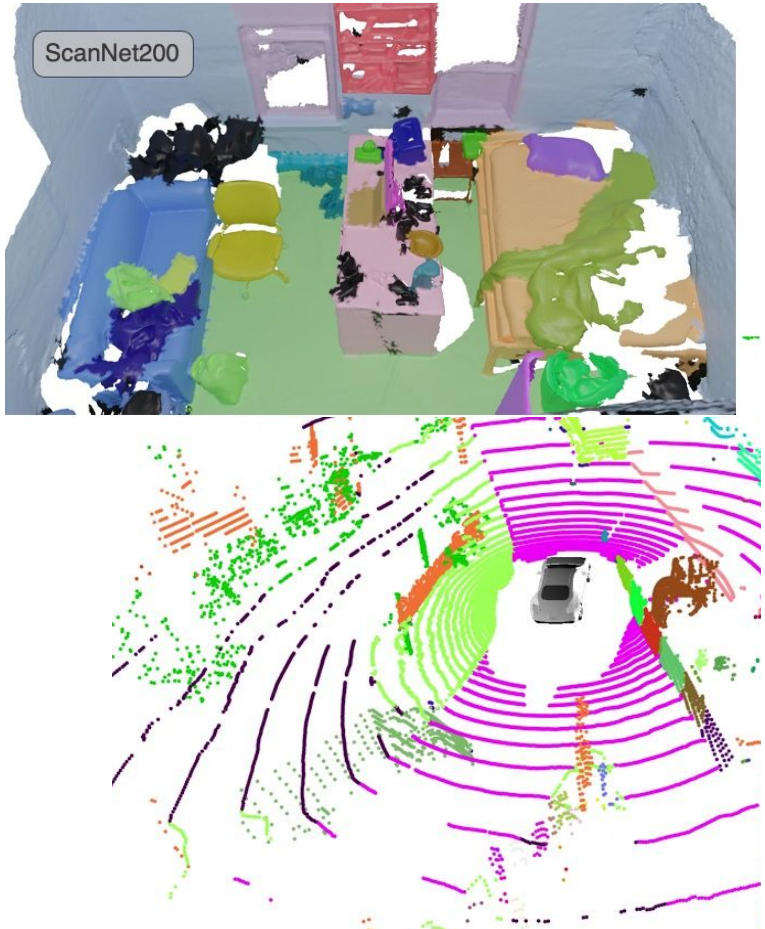
Contrastive methods

Dataset	Method	0.1%		1%		10%		50%		100%	
nuScenes	No pre-training	21.6	±0.5	35.0	±0.3	57.3	±0.4	69.0	±0.2	71.2	±0.2
	PointContrast† [40]	27.1	±0.5	37.0	±0.5	58.9	±0.2	69.4	±0.3	71.1	±0.2
	DepthContrast†[46]	21.7	±0.3	34.6	±0.5	57.4	±0.5	69.2	±0.3	71.2	±0.2
	ALSO [3]	26.2	±0.5	37.4	±0.3	59.0	±0.4	69.8	±0.2	71.8	±0.2
	BEVContrast (ours)	26.6	±0.5	37.9	±0.4	59.0	±0.6	70.5	±0.2	72.2	±0.1
SemanticKITTI	No pre-training	30.0	±0.2	46.2	±0.6	57.6	±0.9	61.8	±0.4	62.7	±0.3
	PointContrast‡ [40]	32.4	±0.5	47.9	±0.5	59.7	±0.5	62.7	±0.3	63.4	±0.4
	SegContrast [29]	32.3	±0.3	48.9	±0.3	58.7	±0.5	62.1	±0.4	62.3	±0.4
	DepthContrast† [46]	32.5	±0.4	49.0	±0.4	60.3	±0.5	62.9	±0.5	63.9	±0.4
	STSSL [39]	32.0	±0.4	49.4	±1.1	60.0	±0.6	62.9	±0.7	63.3	±0.3
	ALSO [3]	35.0	±0.1	50.0	±0.4	60.5	±0.1	63.4	±0.5	63.6	±0.5
	TARL [30]	37.9	±0.4	52.5	±0.5	61.2	±0.3	63.4	±0.2	63.7	±0.3
	BEVContrast (ours)	39.7	±0.9	53.8	±1.0	61.4	±0.4	63.4	±0.6	64.1	±0.4



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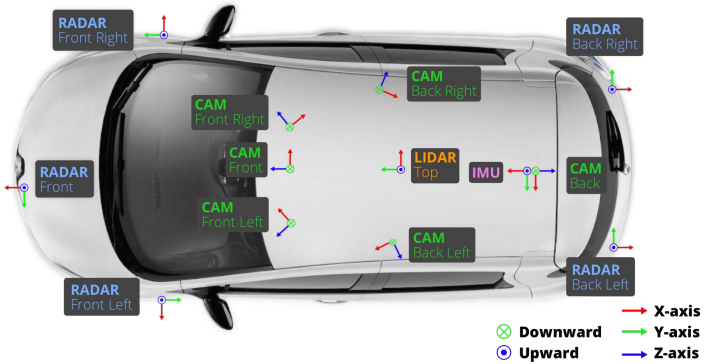
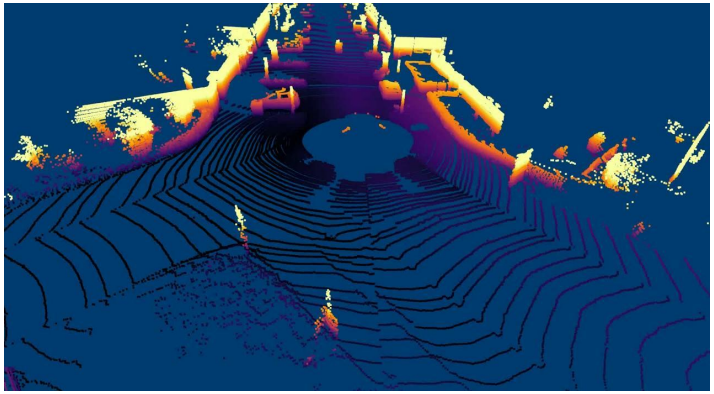
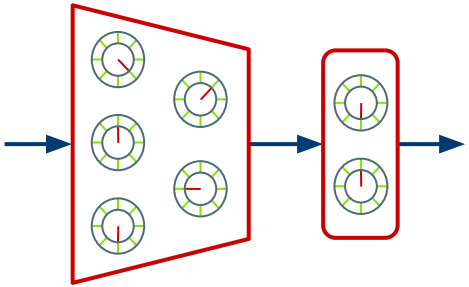
Sensor setup



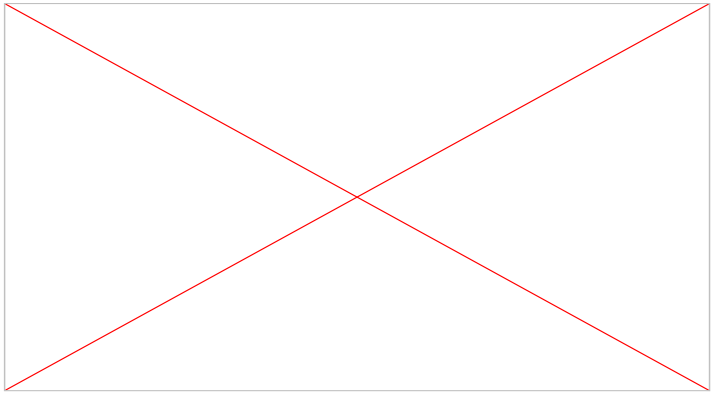
Example from nuScenes

Task of interest: point cloud semantic segmentation





Example from SemanticKITTI



Credit Gilles Puy

SEAL - Segment any point cloud

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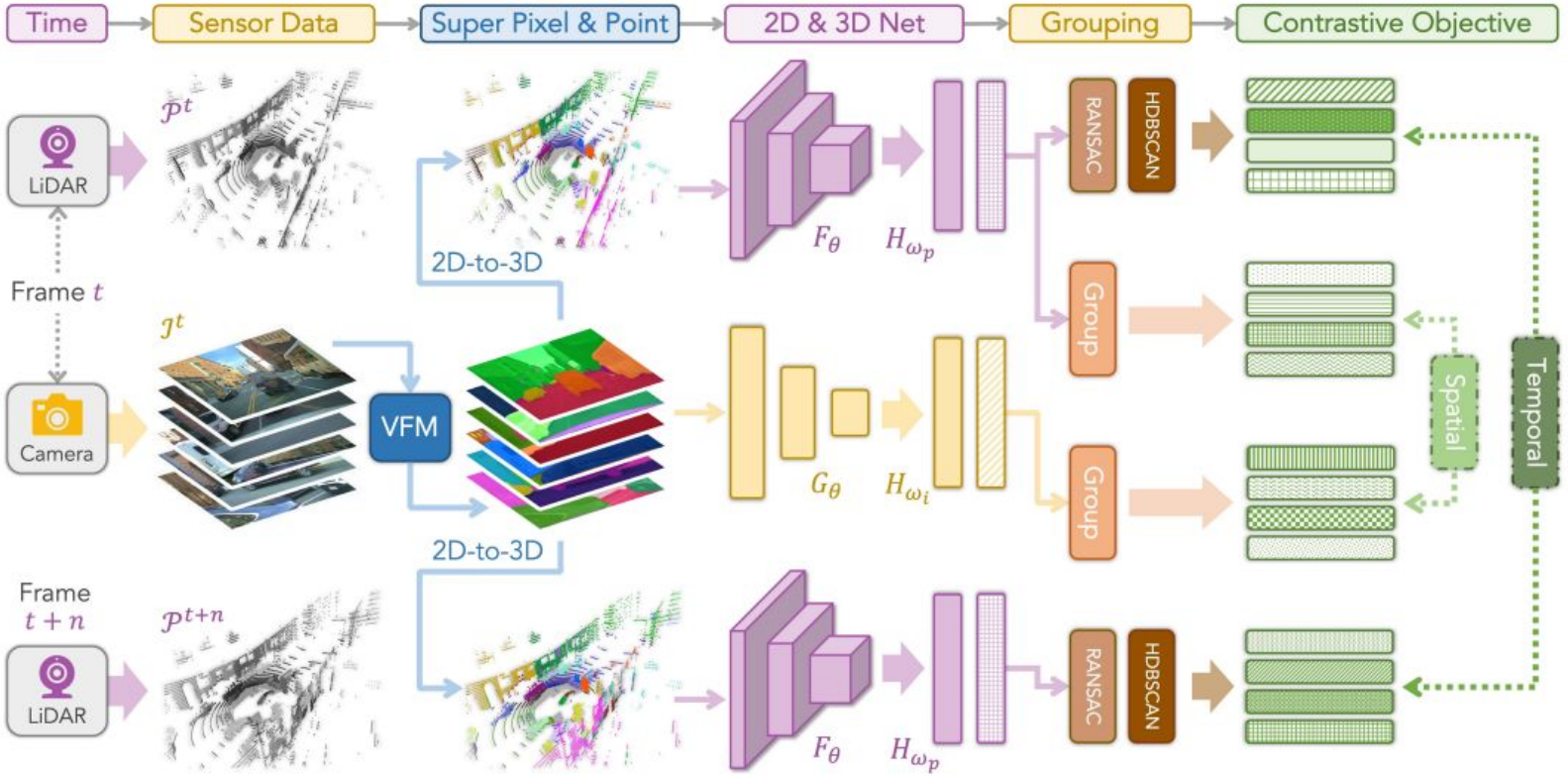
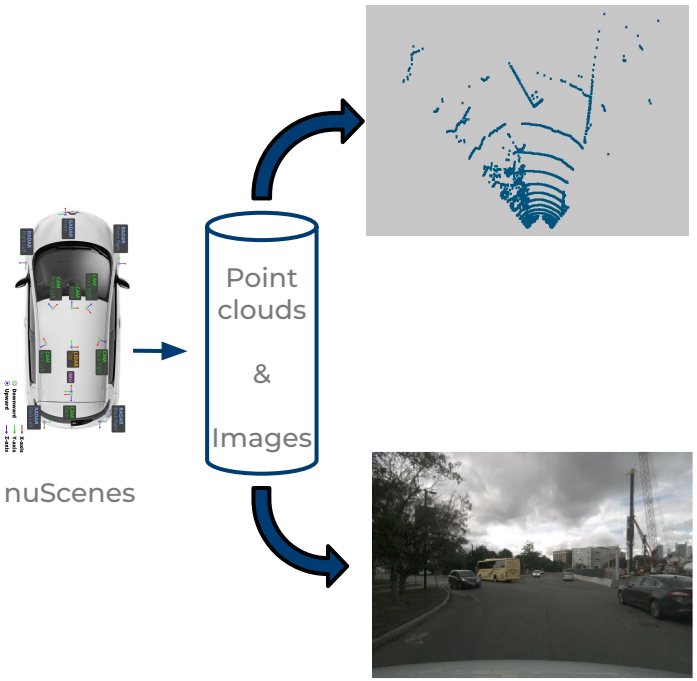


Segment Any Point Cloud Sequences by Distilling Vision Foundation Models, Liu et al.

ScaLR

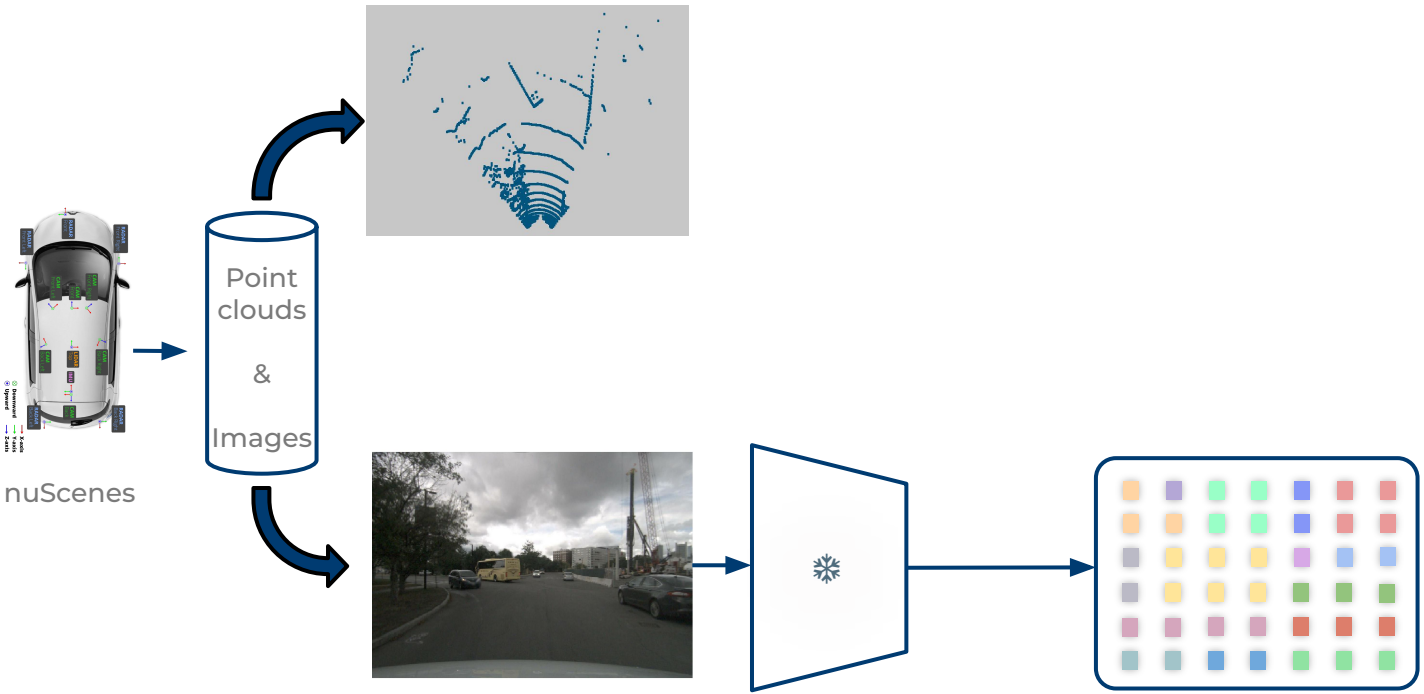
valeo.ai



Credit Gilles Puy

ScaLR

valeo.ai



Credit Gilles Puy

ScaLR

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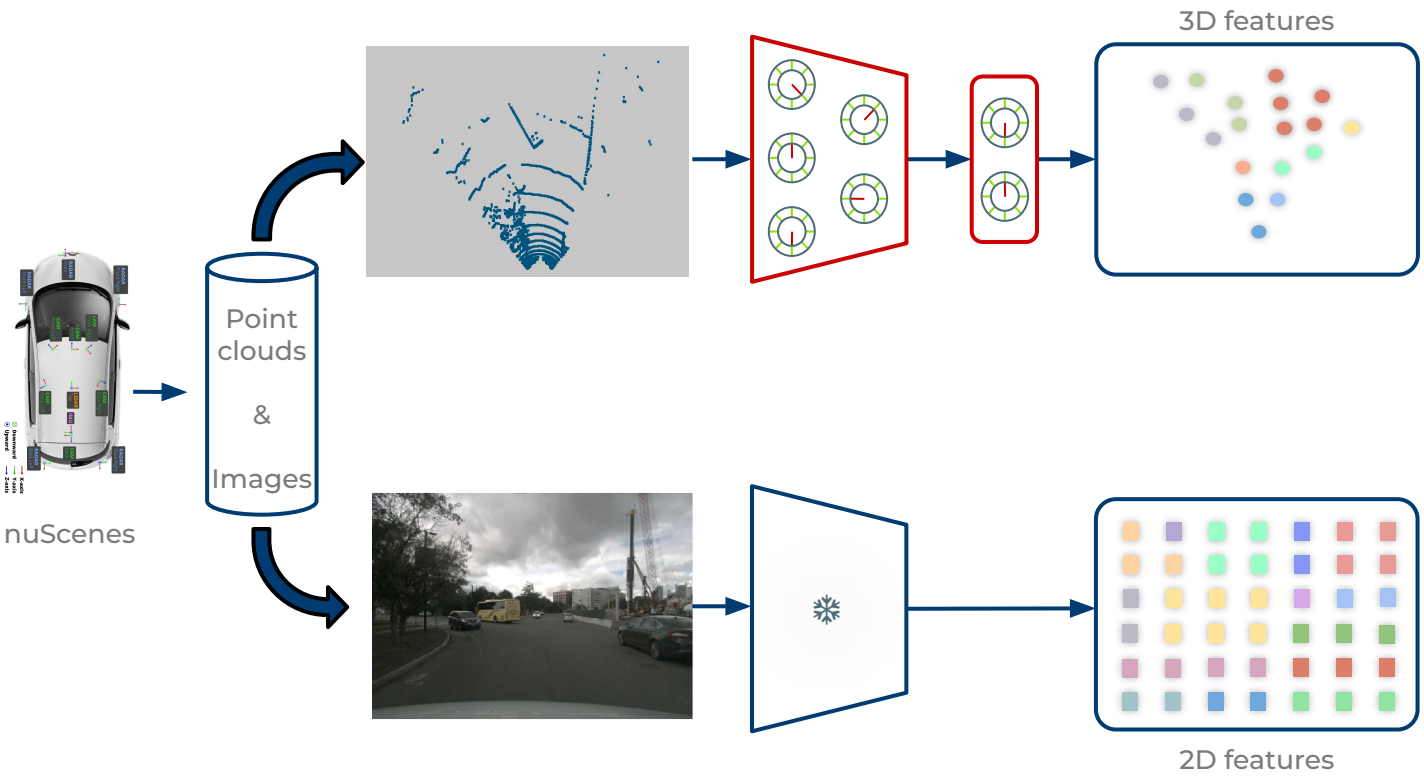

Credit Gilles Puy

ScaLR

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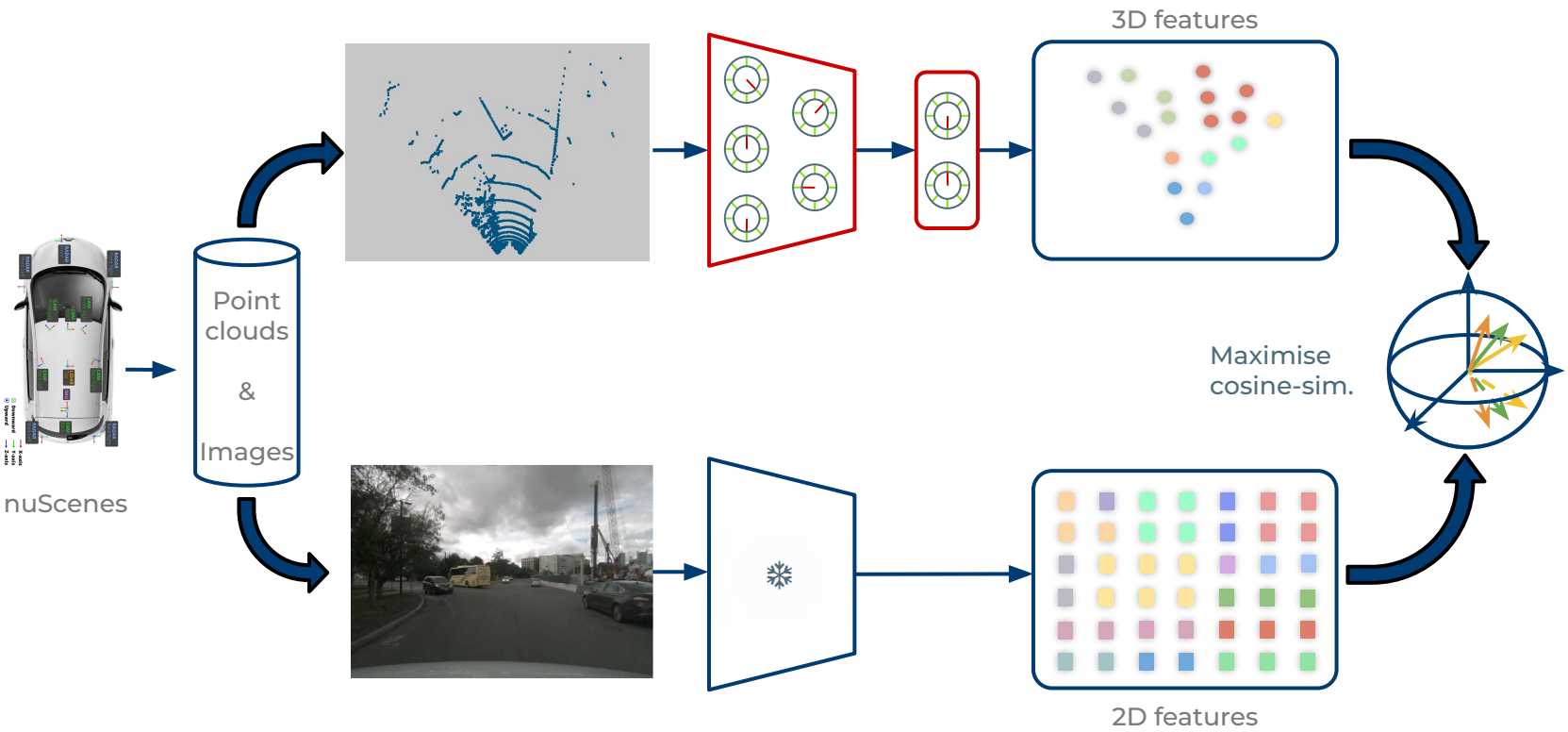

Credit Gilles Puy

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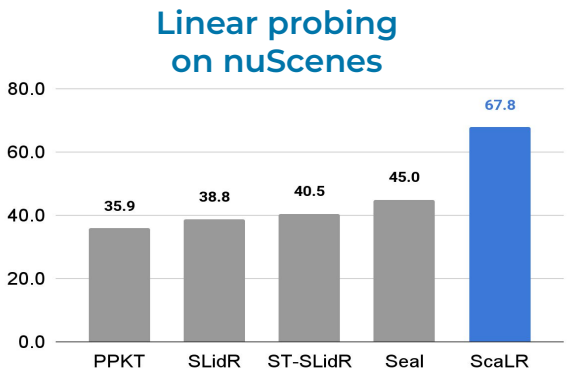
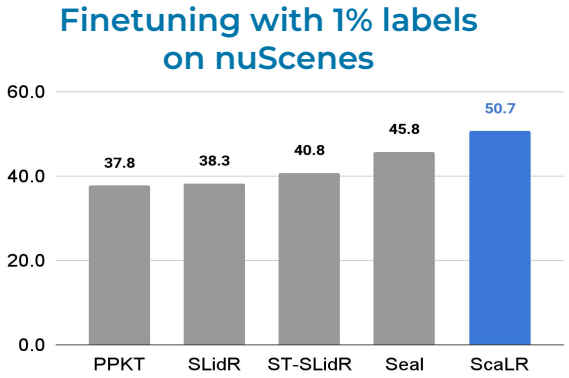
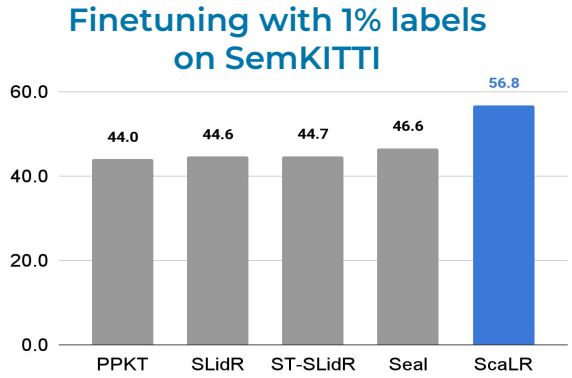
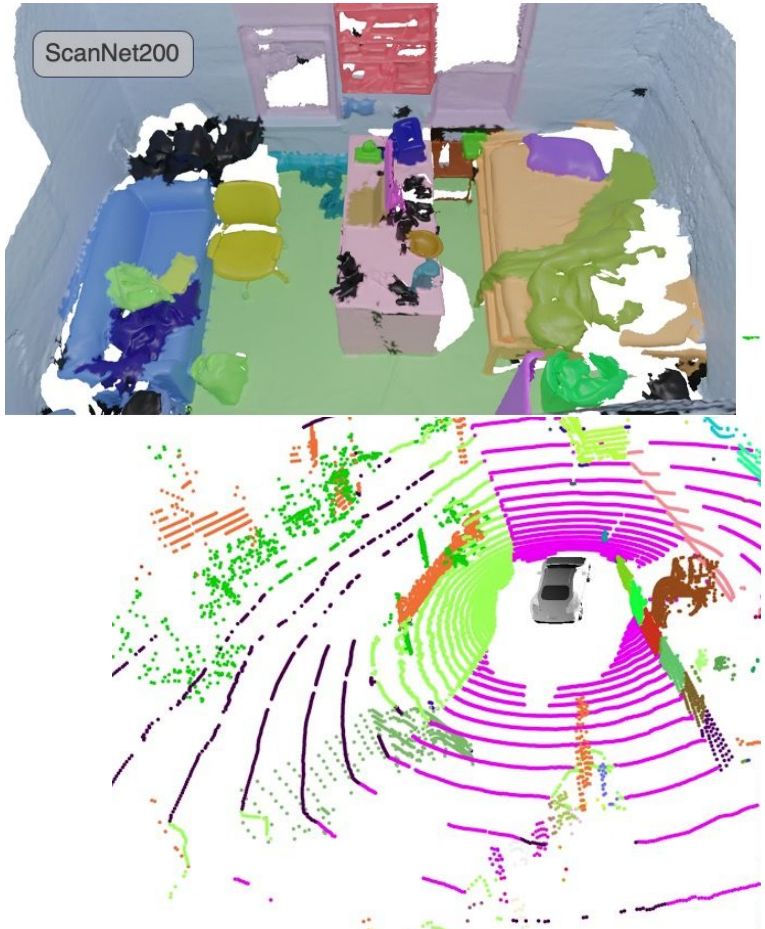






Credit Gilles Puy



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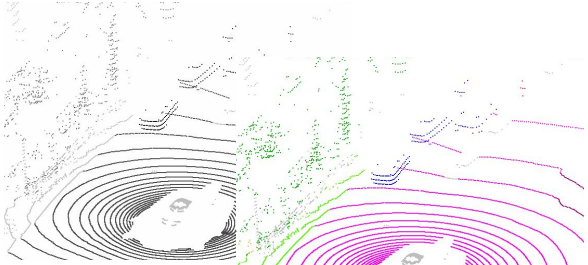
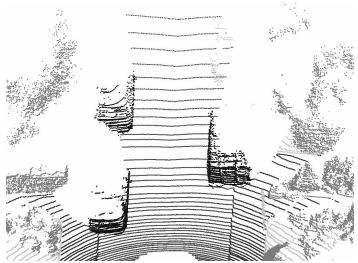
Unsupervised domain adaptation



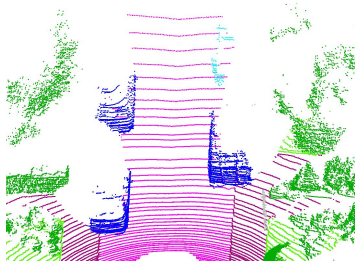
Source
(with annotations)



Target
(no annotations)

Network

Objective:
predict on target



Domain gap

Different sensors

Different locations

Different objects

⇒ source model performs poorly

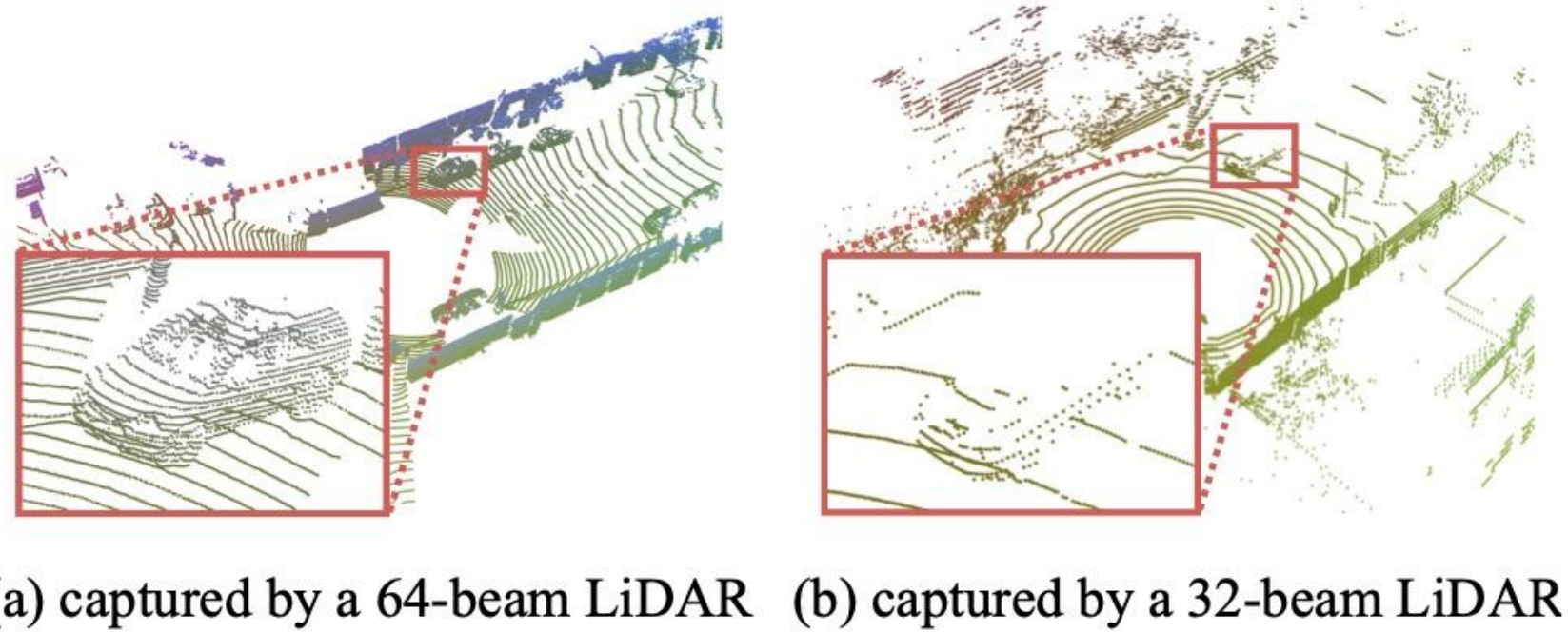
Adaptation

Use target data to enhance performances

⇒ prevent collapse

Example - sensor gap

Domain adaptation

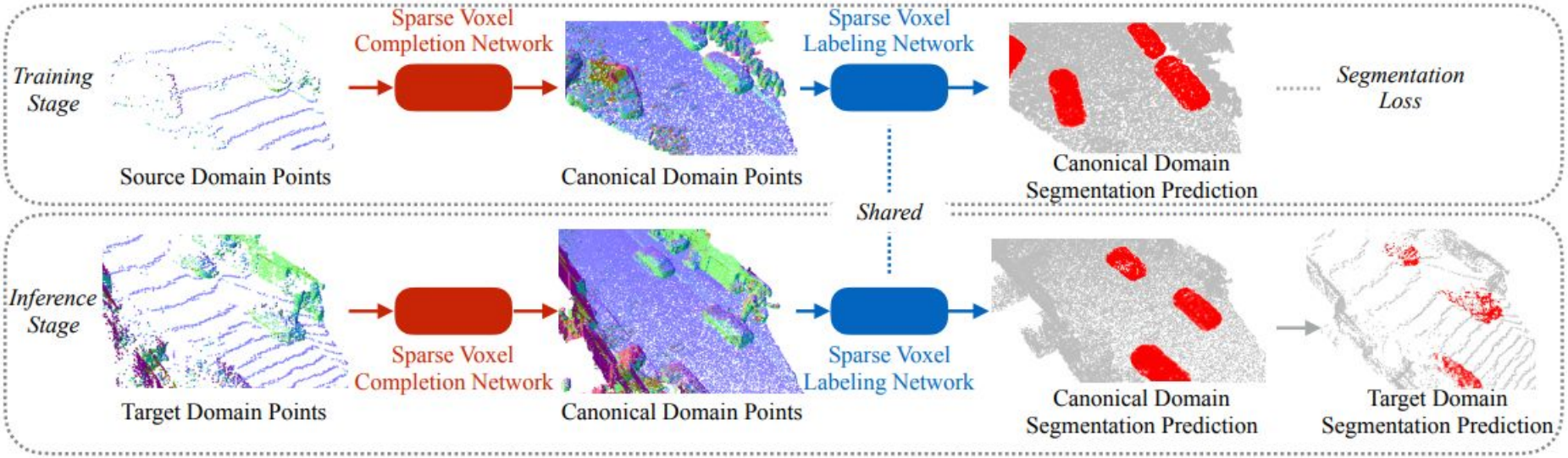


(a) captured by a 64-beam LiDAR (b) captured by a 32-beam LiDAR

(Yi et al. CVPR 2021)

Complete and label

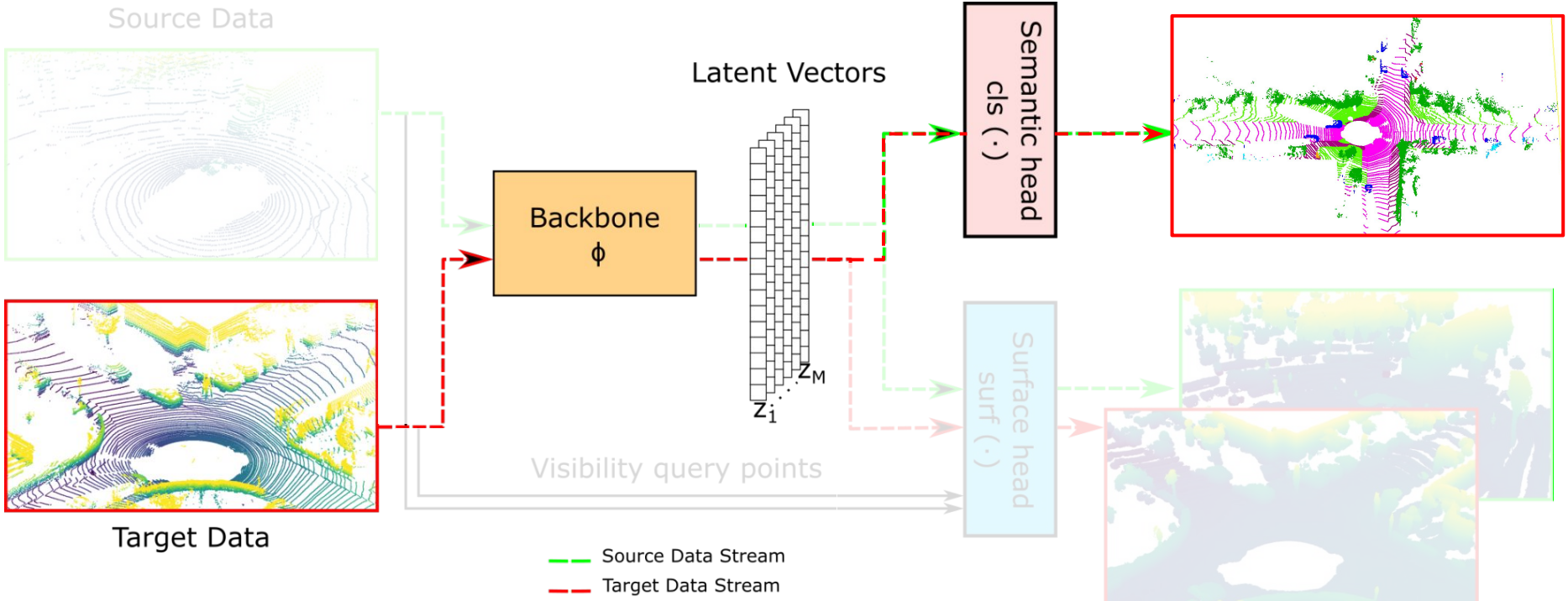
Domain adaptation



(Yi et al. CVPR 2021)

SALUDA

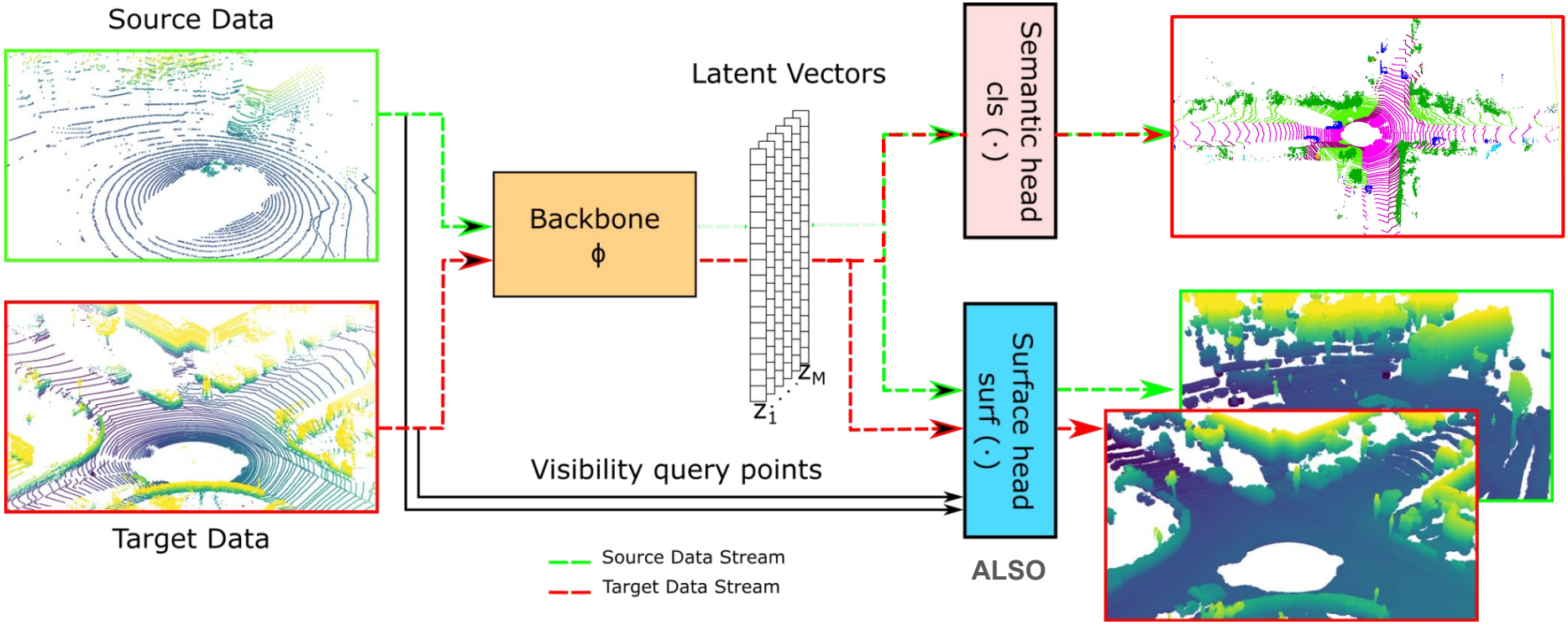
Domain adaptation



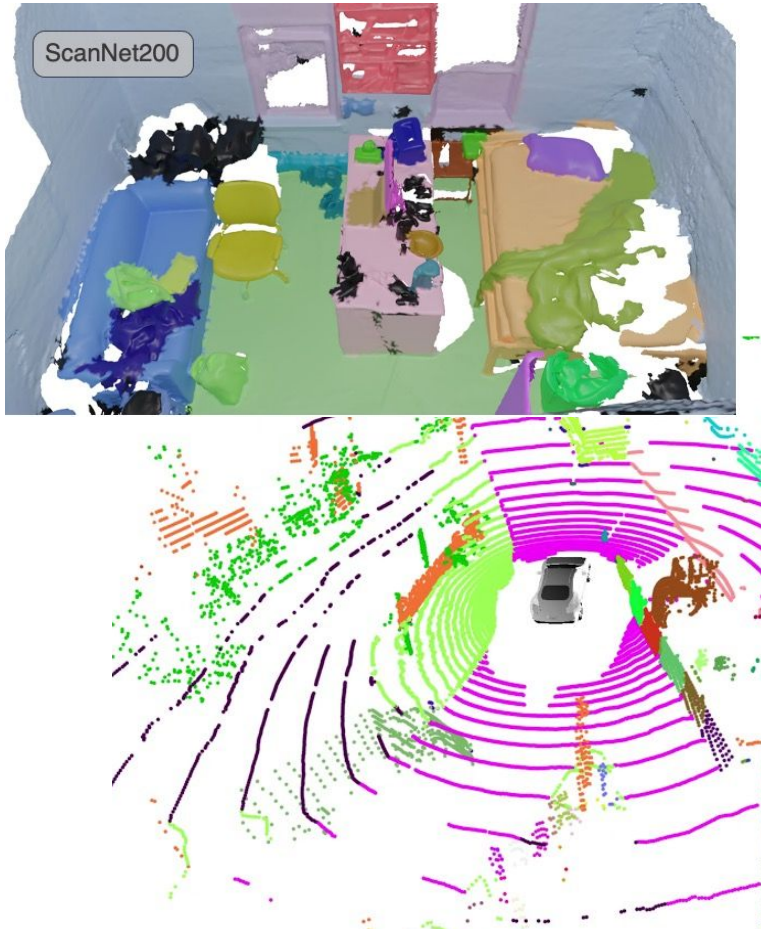
Michele et al.

SALUDA

Domain adaptation



Michele et al.



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Open vocabulary

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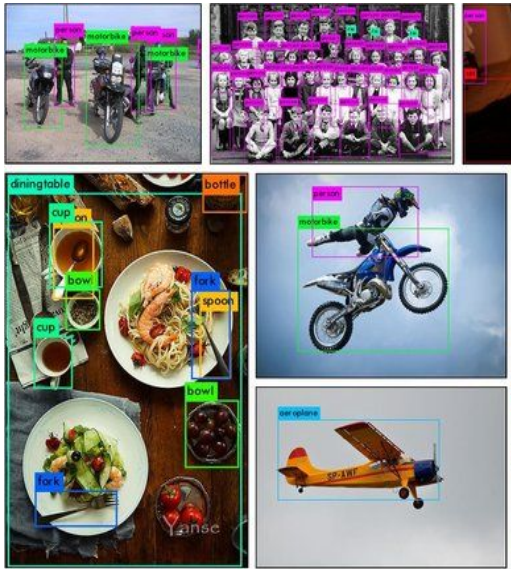
Classic benchmarks

- **Closed vocabulary** setup
- With definition of a **finite set** of classes
- Training of model in **fully-supervised** fashion
    - Requires a lot of annotation

Cityscapes dataset, **30 classes**

[road, sidewalk, parking, rail track, person, rider, car, truck, bus, on rails, motorcycle, bicycle, caravan, trailer, building, wall, fence, guard rail, bridge, tunnel, pole, traffic sign, traffic light, vegetation, terrain, sky]



Pascal VOC dataset, **20 classes**

[person, bird, cat, cow, dog, horse, sheep, aeroplane, bicycle, boat, bus, car, motorbike, train, bottle, chair, dining table, potted plant, sofa, tv/monitor]

Open vocabulary

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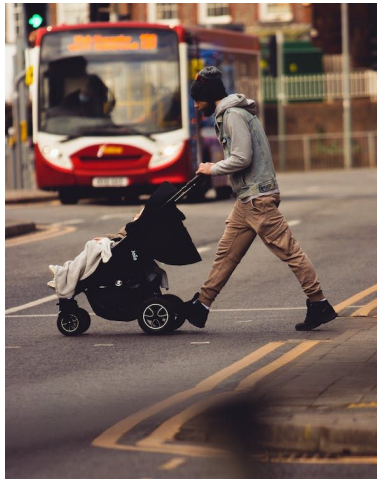
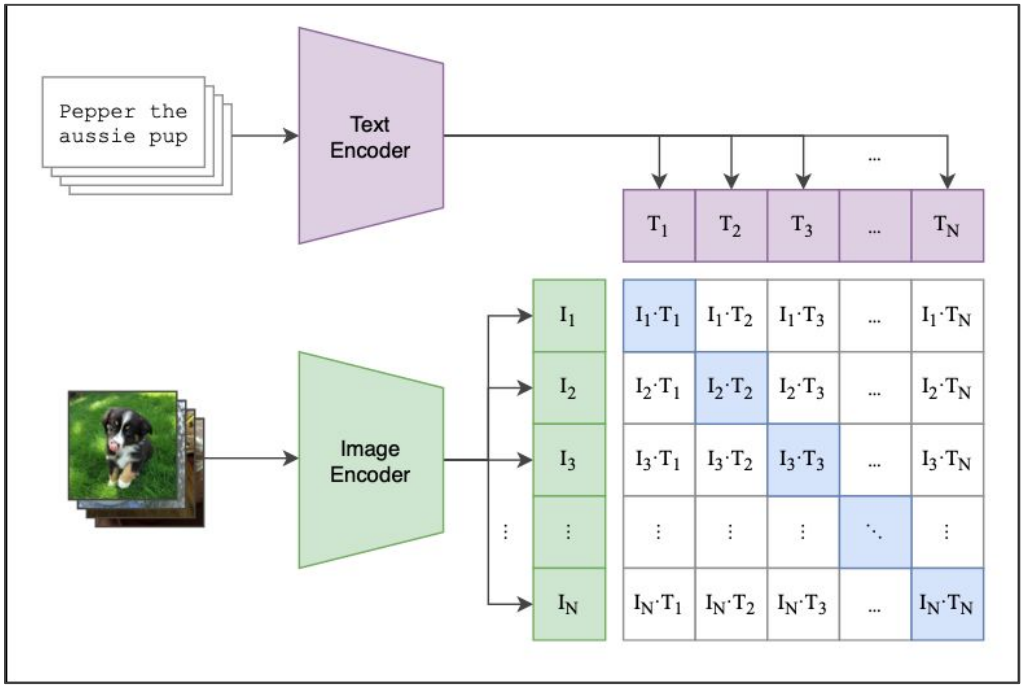
The world is complex

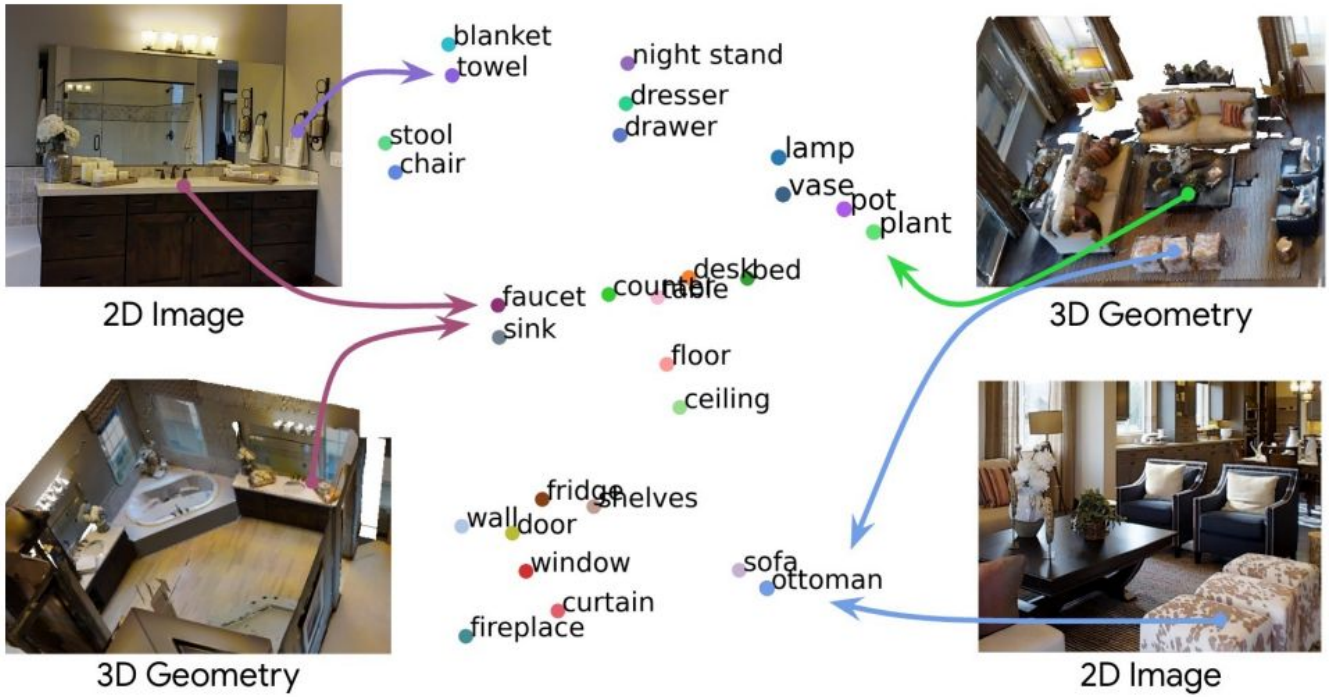


CLIP



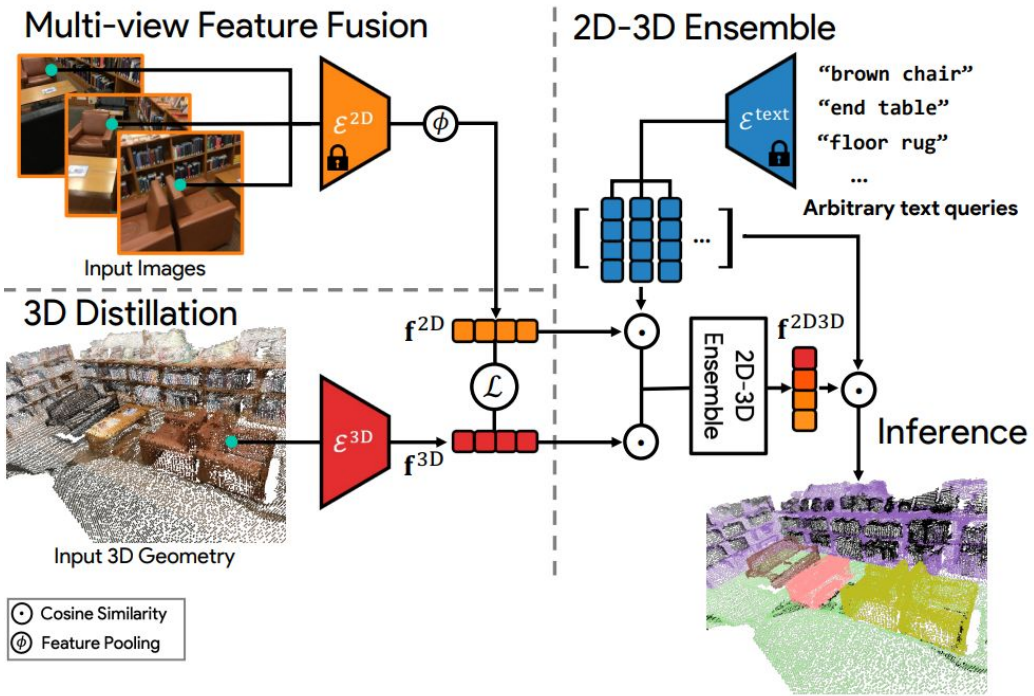
- Contrastive learning
  - Contrast positive/negative pairs
- Trained using 400 millions (**image / text**) pairs extracted from internet
  - Meta-data
  - Legends

OpenScene



Peng, Songyou, et al. "Openscene: 3d scene understanding with open vocabularies." CVPR. 2023.

OpenScene



Peng, Songyou, et al. "Openscene: 3d scene understanding with open vocabularies." CVPR. 2023.

OpenScene

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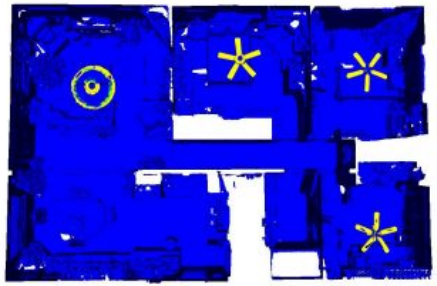
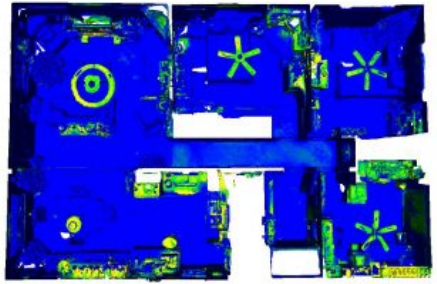
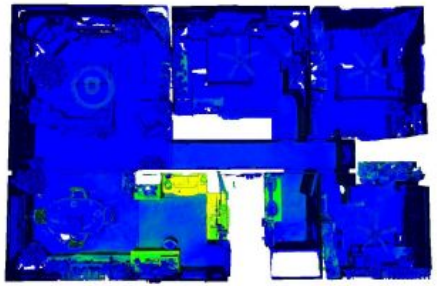
Input 3D Point Cloud



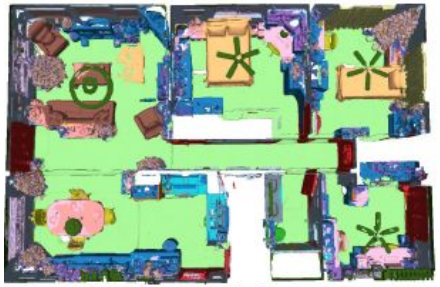
“fan” - Object



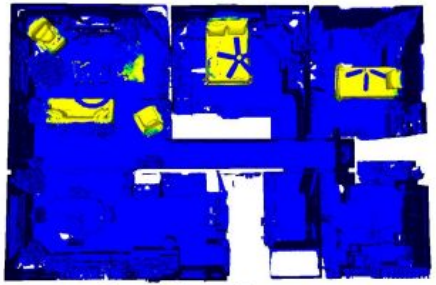
“metal” - Material



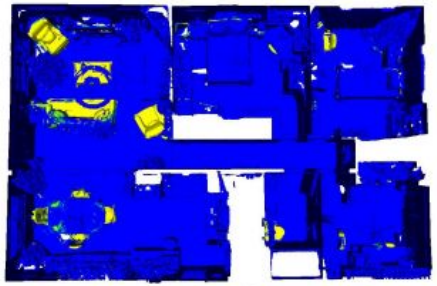
“kitchen” – Room Type



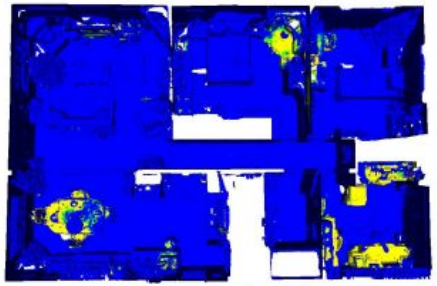
Zero-shot Semantic Segmentation



“soft” - Property



“sit” - Affordance



“work” - Activity

Peng, Songyou, et al. "." CVPR. 2023.

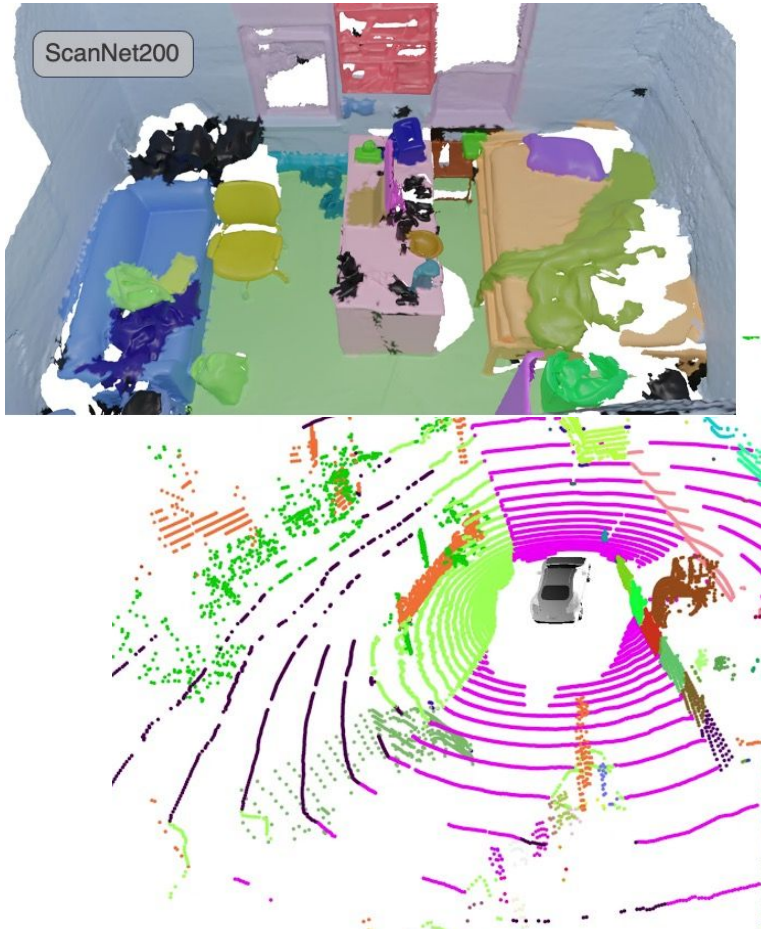
OpenScene

valeo.ai

Link to video

https://pengsongyou.github.io/openscene

Peng, Songyou, et al. "Openscene: 3d scene understanding with open vocabularies." CVPR. 2023.



Overview

Conclusion

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A very short overview of some tasks

- There are many other
- Only few methods were presented, not state-of-the-art anymore

Practical session

Open Vocabulary on point cloud with MaskCLIP

Peng, Songyou, et al. "Openscene: 3d scene understanding with open vocabularies." CVPR. 2023.