Enhancing Sampling Protocol for Point Cloud Classification Against Corruptions

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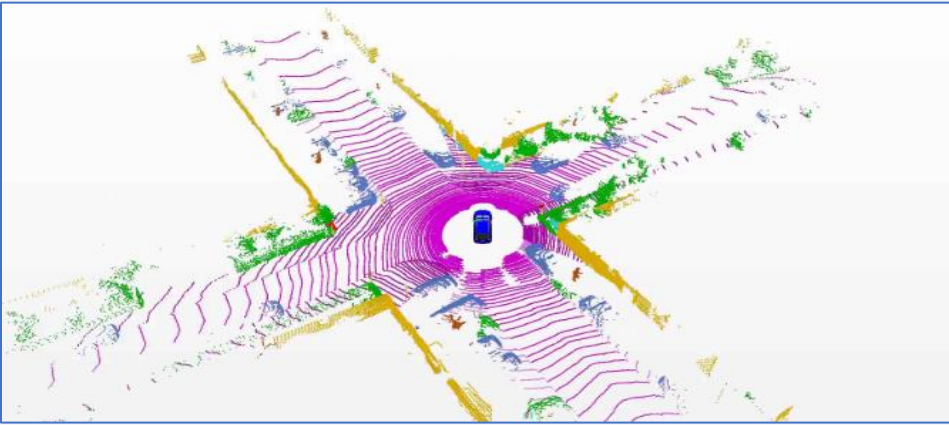## Introduction

Key Challenges of 3D Point Cloud Learning

Autonomous Driving   Medical Treatment   ......
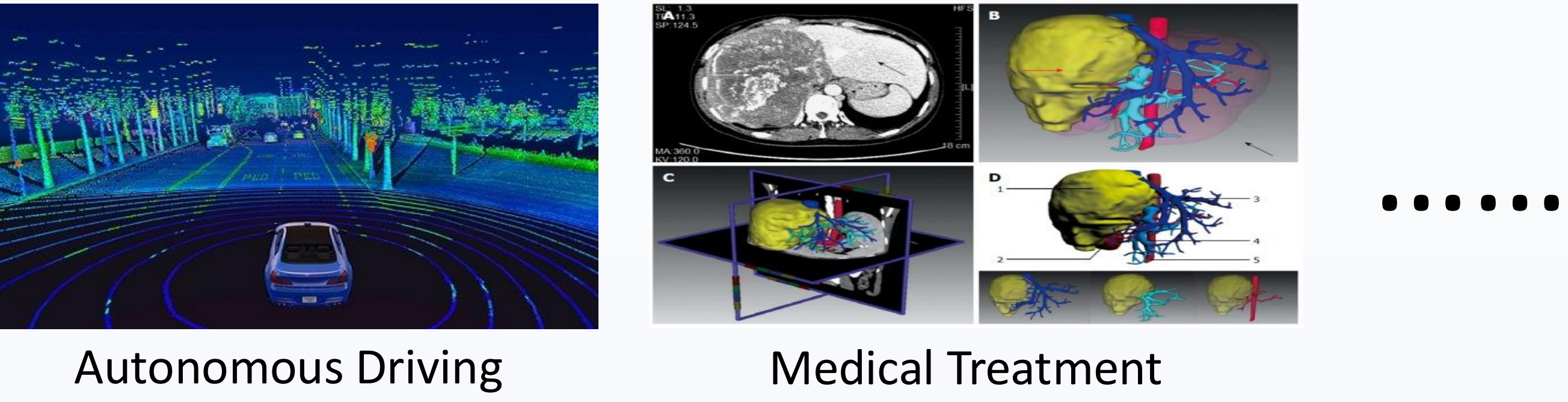
Challenges in Real-World Applications

Protocol under benign data assumption   Real-world Data with Noises

3D Model → Failed!
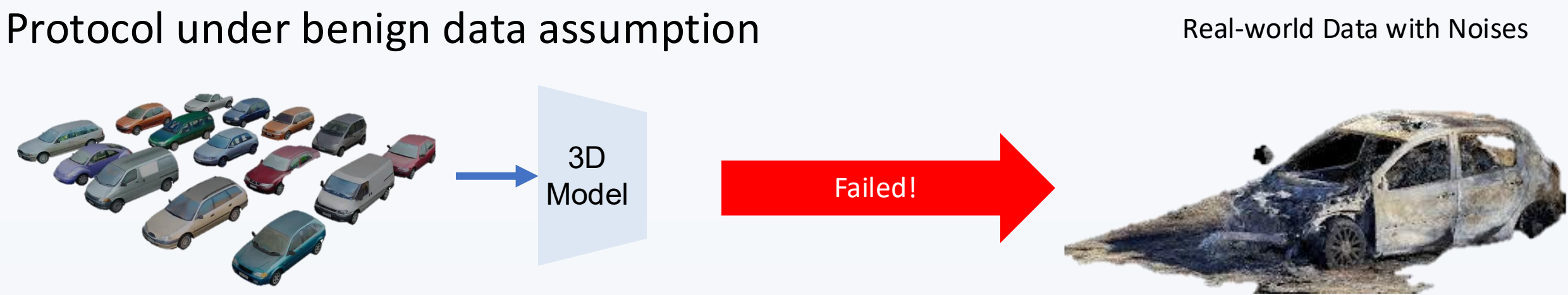
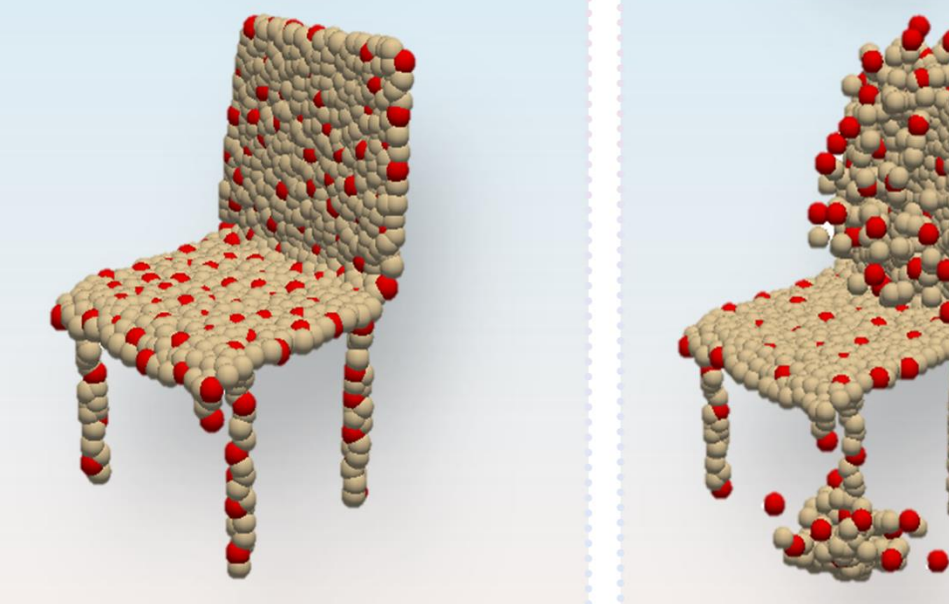### Limitations of Existing Point Cloud Sampling Protocol

❏ **Heterogenous distribution**
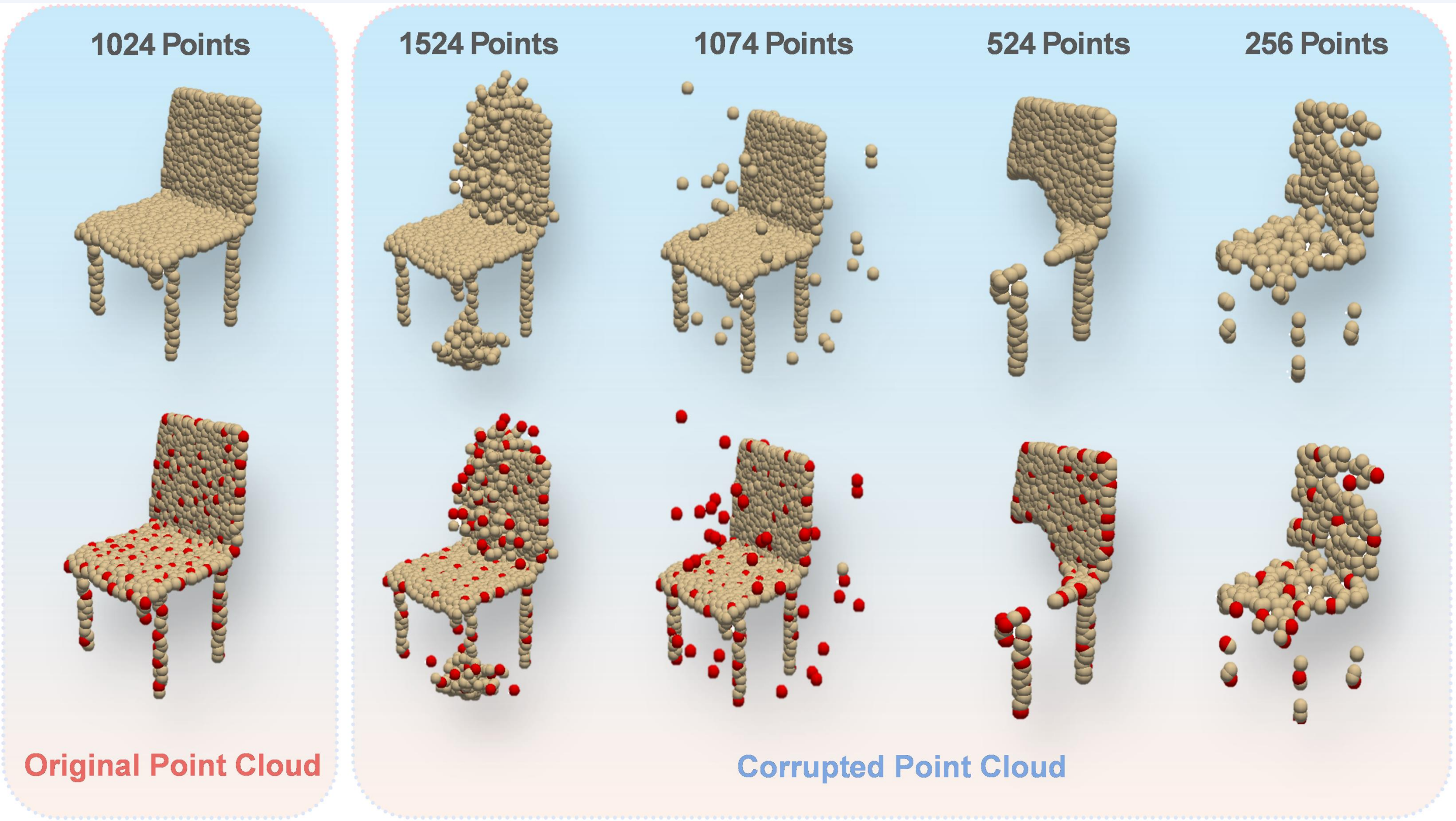

Point Cloud Sampling

- Fixed sample size
  ✗ Varied size and density in real-world
- Vulnerable to outliers
  ✗ Euclidean distance in similarity measure
- Extra learning-based sampling
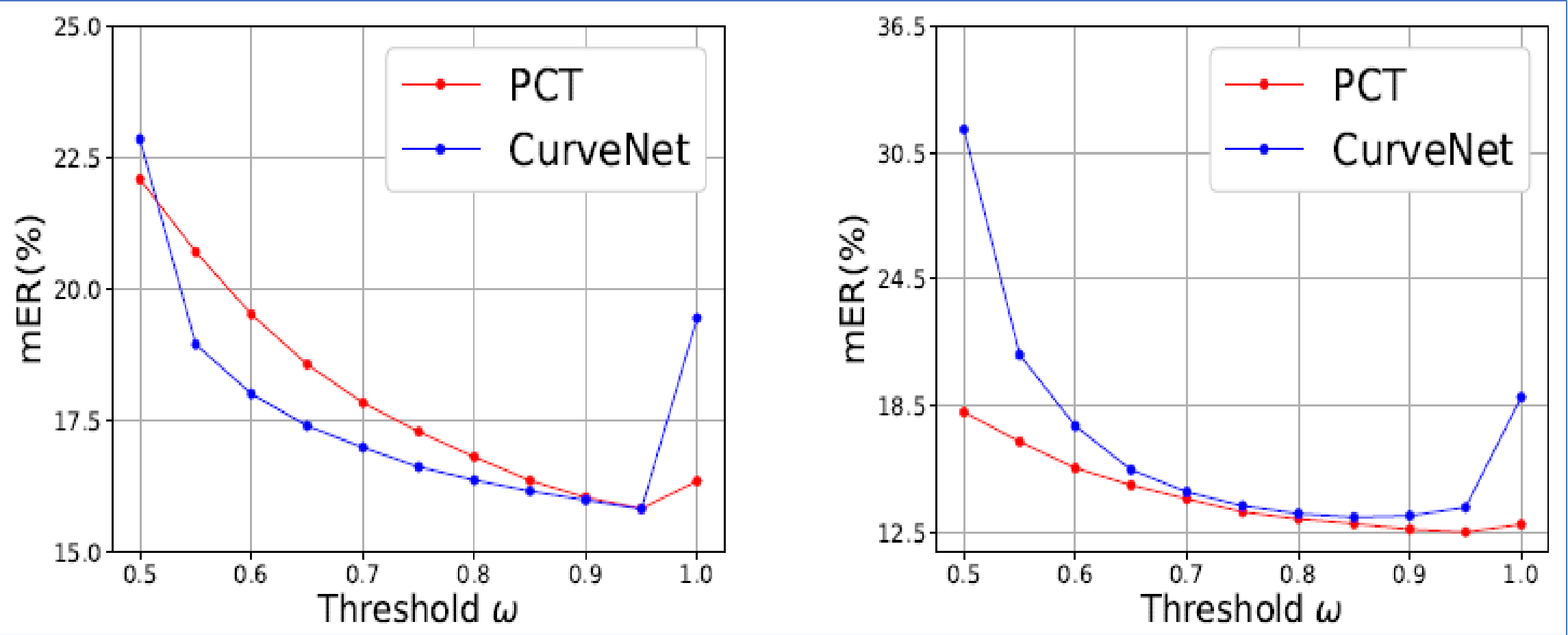 ✗ Overfitting to the clean data

❏ **Sampling on Corrupted Data**

| 1024 Points | 1524 Points | 1074 Points | 524 Points | 256 Points |

Original Point Cloud   Corrupted Point Cloud

Contributions

- Propose an alternative protocol to enhance the robustness of point cloud learning.
- Develop three learning-free techniques as the key of protocol: point reweighting, local-global balanced sampling, and local-geometry-preserved interpolation.
- Extensive experiments are conducted on synthesis and real corrupted 3D point cloud datasets.

Method

- Learning-free and architecture-agnostic, requiring no extra learning or modification to the network
- Enhance the corrupted data in both training & testing stages
- Re-structure point cloud sampling as two sub-processes: Key points sampling and Full points resampling

Results

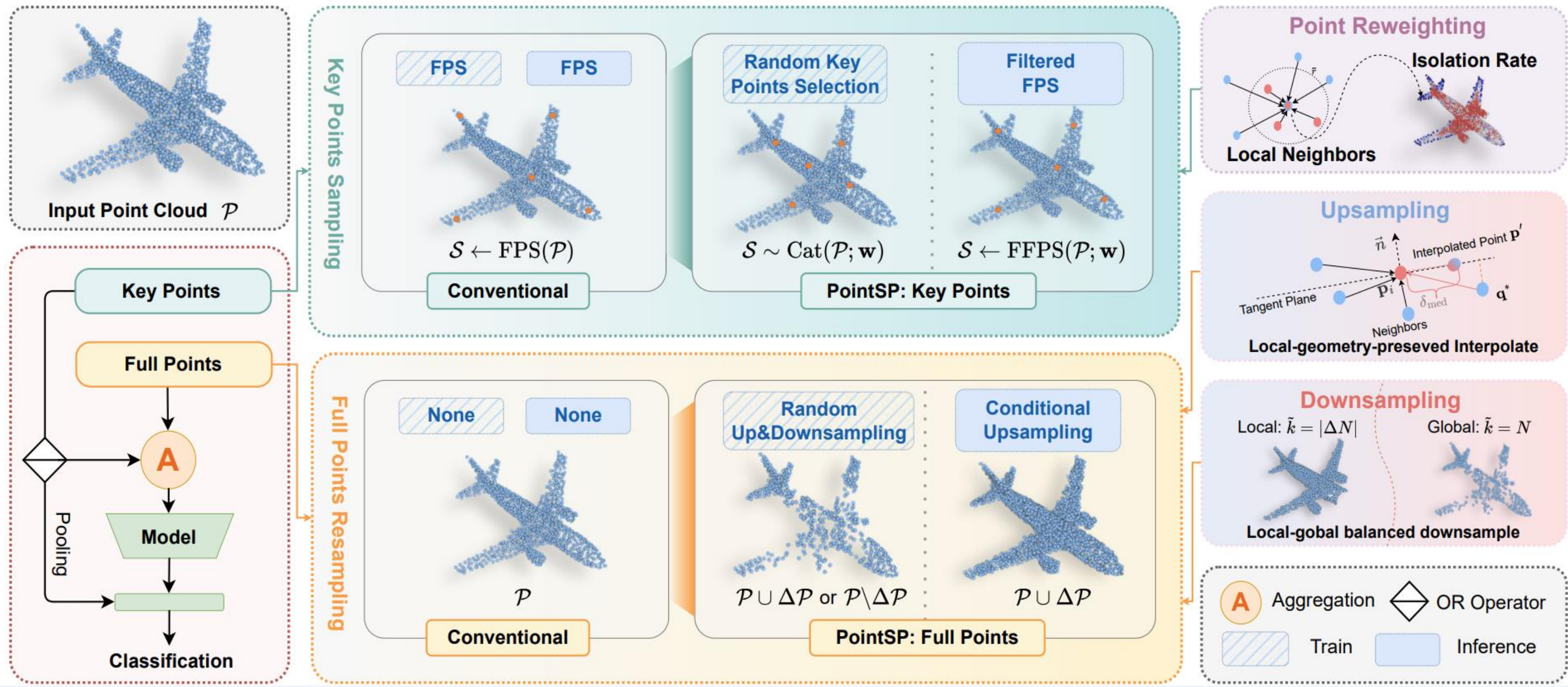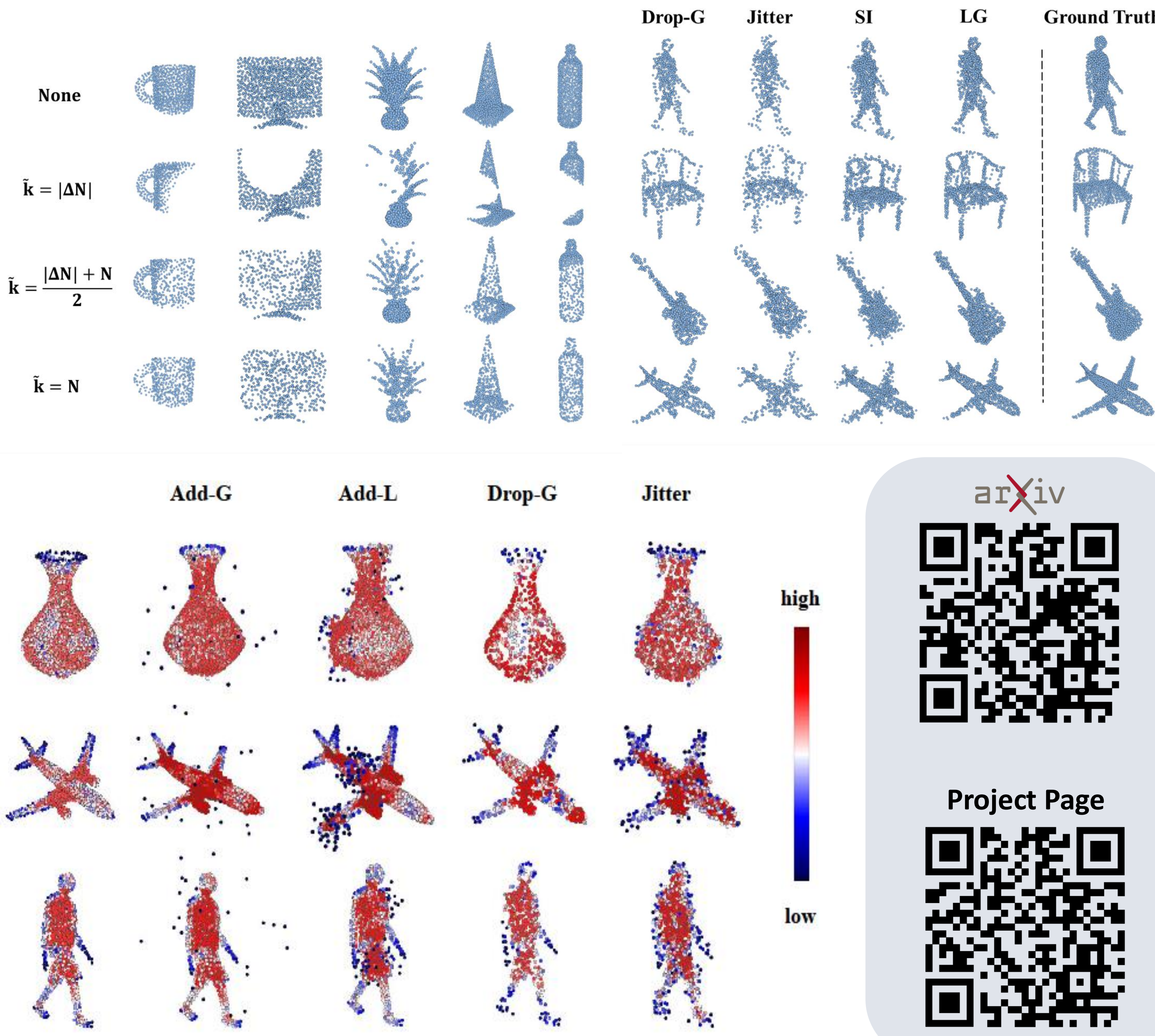| Method	PointCloud-C								OmniObject-C							
	mER	Scale	Jitter	Drop-G	Drop-L	Add-G	Add-L	Rotate	mER	Scale	Jitter	Drop-G	Drop-L	Add-G	Add-L	Rotate
PointNet++	27.7	9.4	50.3	26.2	39.6	15.9	20.2	32.5	73.9	64.9	80.7	77.9	78.5	71.6	71.1	72.4
+ CutMix-R	17.5	8.8	34.5	**9.0**	20.9	_7.7_	_8.1_	33.7	64.9	62.9	72.2	62.8	67.2	59.3	58.1	71.8
+ CutMix-K	19.1	9.2	45.0	12.8	16.0	8.1	9.5	33.4	64.8	60.9	76.1	65.6	64.6	57.7	60.1	68.8
+ Mixup	17.7	**8.5**	_25.2_	16.4	27.2	9.5	11.7	_25.4_	62.8	_59.3_	_67.1_	64.1	69.2	57.8	_57.2_	_65.3_
+ Rsmix	21.3	9.9	54.3	12.0	_14.3_	7.9	8.9	41.9	66.7	63.8	78.1	66.2	68.1	59.4	60.6	70.6
+ **PointSP**	_17.3_	9.2	33.3	10.9	16.0	8.0	10.3	33.1	**62.4**	59.9	72.0	_58.6_	**64.1**	_56.8_	57.8	67.7
CurveNet	24.4	8.9	22.9	17.3	22.3	52.1	28.7	18.9	67.9	59.4	67.7	63.0	68.7	80.4	70.4	65.9
+ CutMix-R	13.8	9.1	18.2	11.1	15.5	8.1	_11.0_	22.4	63.2	61.0	68.2	59.8	65.4	58.6	61.7	68.0
+ CutMix-K	15.8	8.7	30.6	12.9	10.3	8.5	15.5	23.9	60.3	_57.3_	69.1	59.7	**56.0**	_53.2_	63.4	_63.4_
+ Mixup	19.3	_8.6_	17.9	21.6	19.8	25.7	20.1	21.4	62.5	57.7	62.7	60.9	65.7	64.1	61.7	64.6
+ Rsmix	16.9	9.1	35.0	11.0	_10.2_	9.2	13.1	30.9	62.2	59.2	73.5	57.4	59.5	56.5	61.9	67.8
+ PGD	22.7	16.8	_11.2_	12.9	26.0	48.9	25.3	_18.3_	67.4	68.9	62.8	59.2	69.1	75.5	67.2	69.3
+ **PointSP**	**13.7**	10.3	19.0	_10.3_	11.0	_7.6_	15.5	22.0	_57.9_	58.1	**61.4**	**55.0**	**56.0**	54.1	**56.6**	64.0
PCT	25.8	_9.0_	27.1	15.0	24.1	40.3	42.9	22.2	69.8	59.3	71.3	60.4	68.7	83.0	80.6	65.5
+ CutMix-R	12.7	10.1	14.5	9.3	14.3	8.3	10.9	20.7	_60.8_	59.5	62.9	58.8	60.8	57.7	61.2	64.7
+ CutMix-K	14.1	9.5	22.3	11.3	10.2	8.5	15.6	21.2	61.4	_57.3_	65.8	62.8	_58.8_	_56.3_	65.1	_63.5_
+ Mixup	18.1	9.4	15.6	15.8	18.2	23.5	22.8	21.1	62.7	57.6	62.0	58.9	63.6	65.7	67.5	_63.5_
+ Rsmix	15.2	9.3	25.7	10.2	**10.0**	8.7	13.0	29.8	63.3	59.2	70.5	60.6	59.8	58.6	65.9	68.5
+ PGD	20.0	14.6	**10.5**	16.9	24.8	29.5	22.7	21.2	65.6	65.7	_61.5_	66.7	71.8	62.6	64.3	66.7
+WOLFMix	12.7	9.4	27.0	_9.4_	10.2	8.8	13.9	**10.5**	60.5	59.3	61.9	59.1	60.7	58.2	60.1	64.5
+ **PointSP**	**12.5**	9.9	16.2	11.0	14.4	_7.5_	_7.5_	21.1	_60.8_	60.5	65.1	_58.1_	60.9	57.7	_57.5_	66.0

✓ PointSP can provide a significant improvement across various datasets and corruptions.

✓ PointSP can effectively enhance not only classification but also part segmentation.

Visualizations

Drop-G   Jitter   SI   LG   Ground Truth

None

$\bar{k} = |\Delta N|$

$\bar{k} = \frac{|\Delta N| + N}{2}$

$\bar{k} = N$

Add-G   Add-L   Drop-G   Jitter

high / low

Project Page