
A Semantically Disentangled Unified Model for Multi-category 3D Anomaly Detection

CVPR 2026

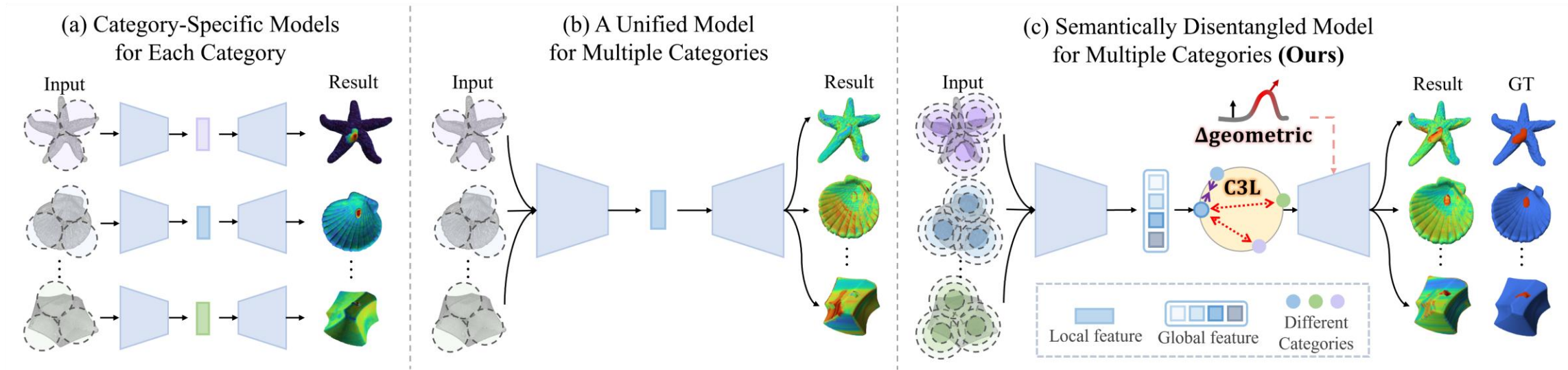
SuYeon Kim, Wongyu Lee, MyeongAh Cho[†]
Kyung Hee University

[†] Corresponding Author

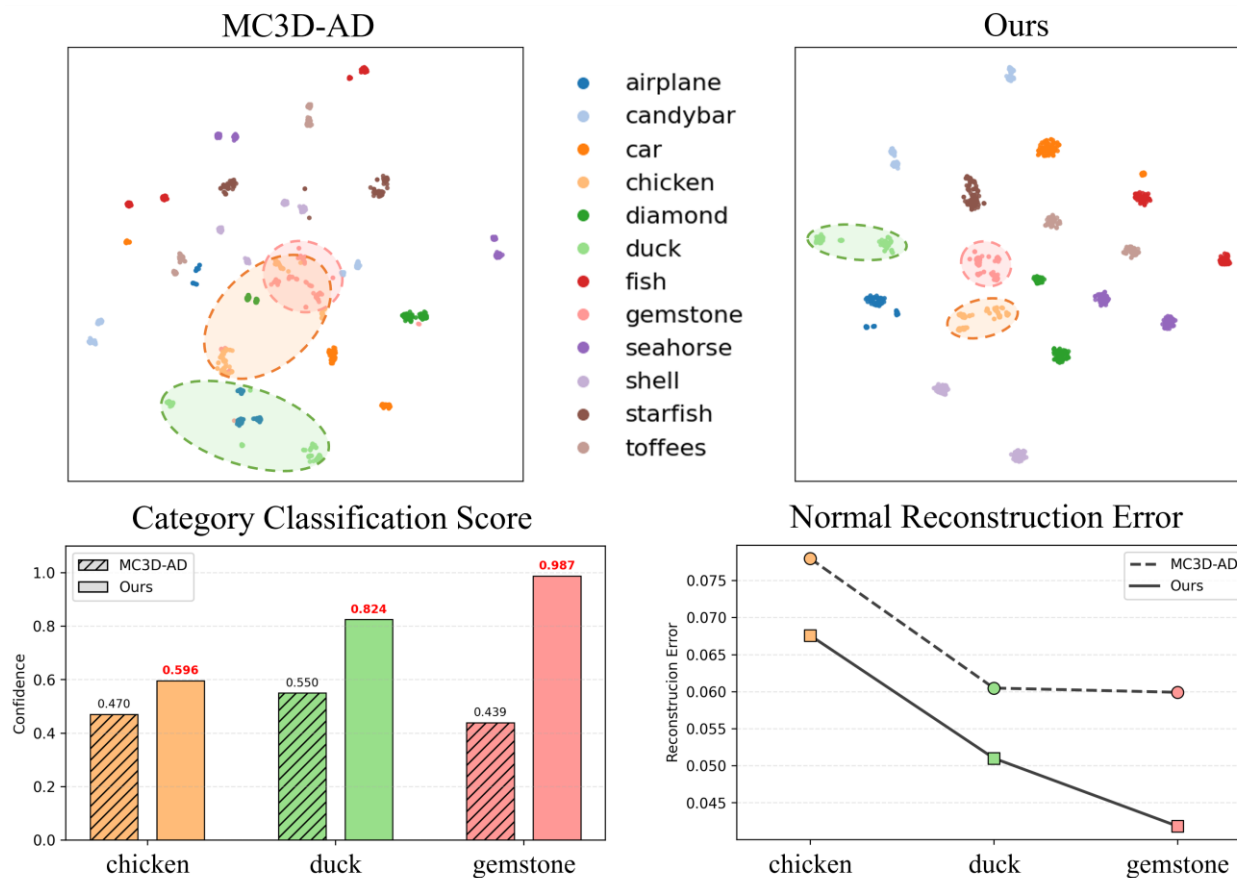


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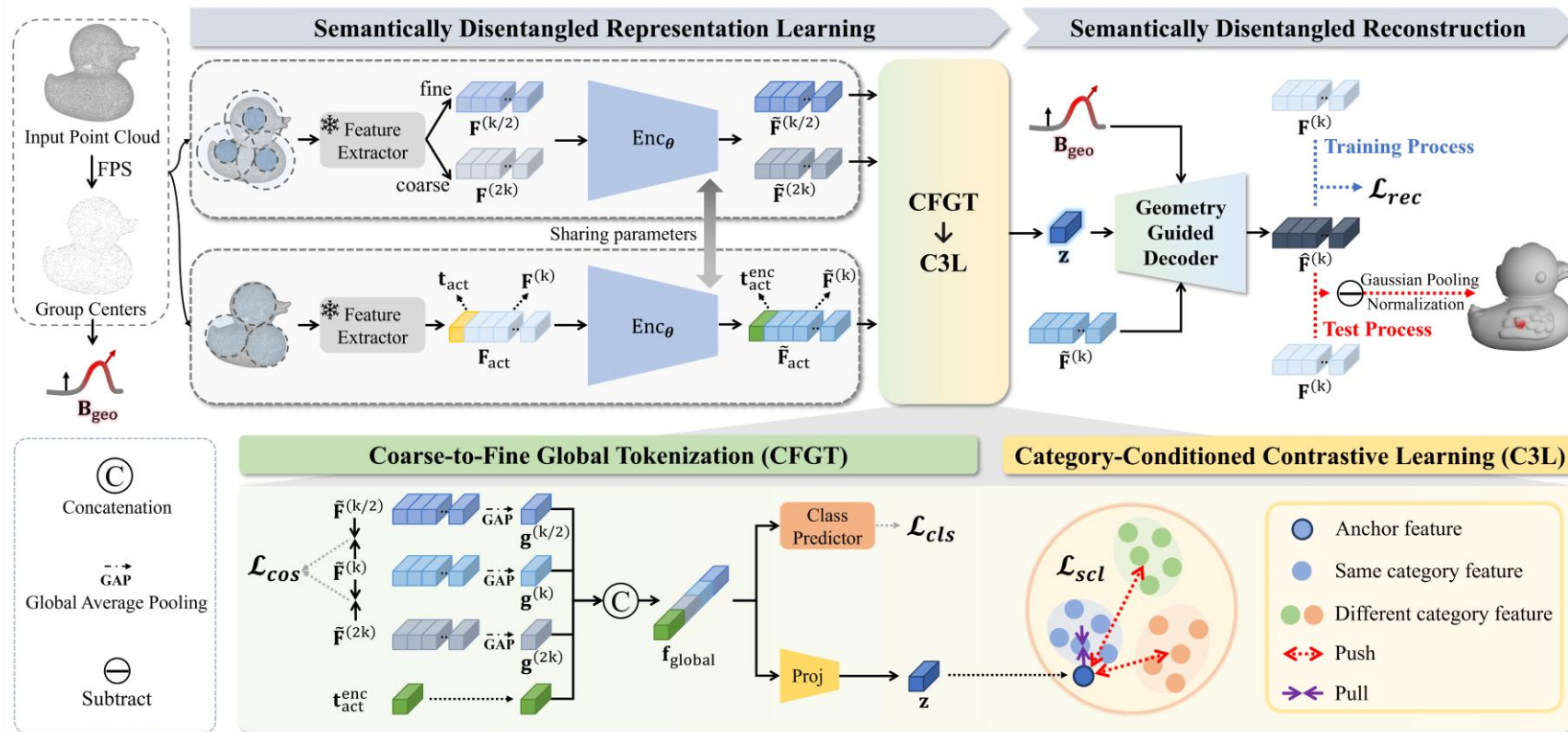




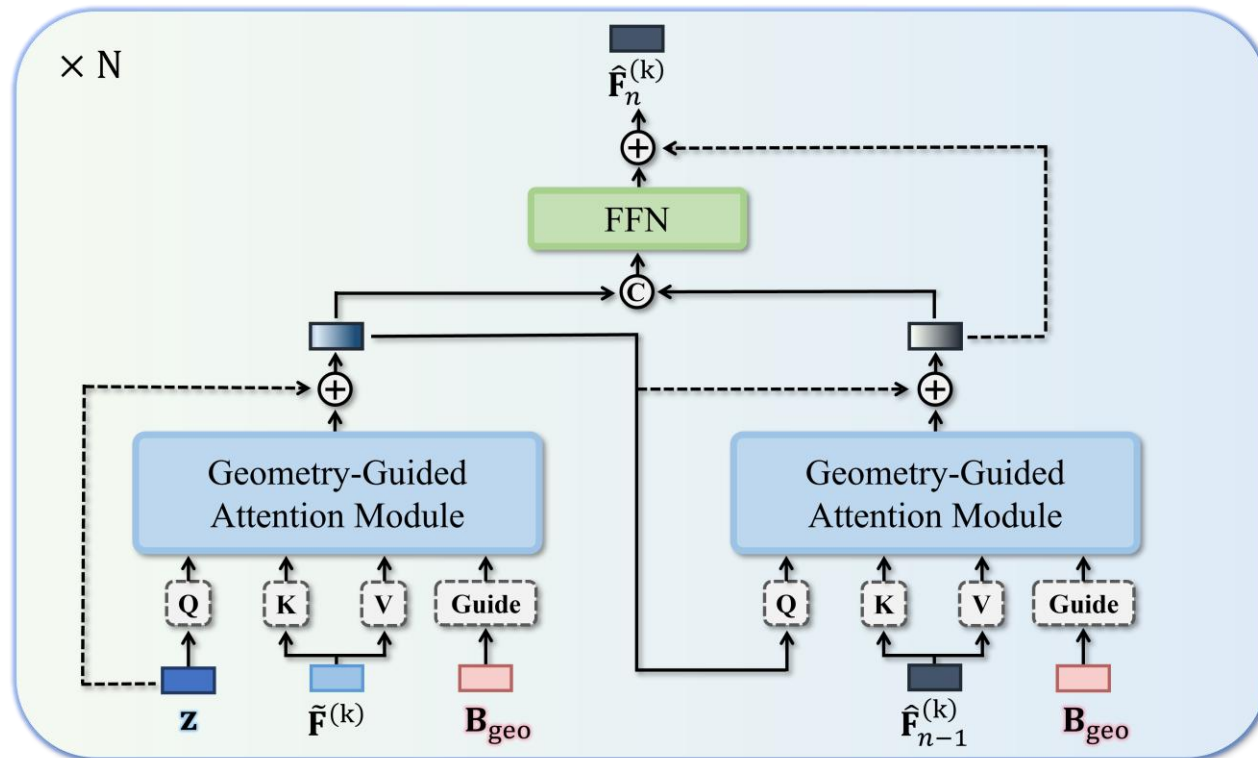
- 3D anomaly detection aims to detect defective objects and localize abnormal regions in point clouds, typically using only normal samples for training.
- Category-specific models train a separate model for each object class, which limits scalability in real industrial scenarios.
- Unified models are more practical, but they must handle multiple categories within a single latent space. This often causes category features to interfere with one another, leading to unreliable reconstruction.
- **SeDiR** addresses this by learning category-aware semantics before reconstruction.



- Unified 3D-AD suffers from **Inter-Category Entanglement (ICE)**, where features from different categories overlap in the latent space.
- When ICE occurs, the model may reconstruct a normal object using an **incorrect category prior**, resulting in high reconstruction error and false positives.
- SeDiR forms more clearly separated category manifolds, improving semantic confidence and reducing normal reconstruction error.



- SeDiR consists of three key components.
- **Coarse-to-Fine Global Tokenization** builds a category-aware global token from multi-resolution geometric features.
- **Category-Conditioned Contrastive Learning** separates category semantics by pulling same-category features together and pushing different-category features apart.
- **Geometry-Guided Decoder** reconstructs features using both semantic priors and geometric evidence.



- The Geometry-Guided Decoder performs reconstruction conditioned on both semantic and geometric information.
- The global token provides the semantic prior, while local feature tokens provide detailed geometric cues.
- A geometry-derived bias is added to the attention mechanism, allowing surface normal and curvature variations to guide reconstruction.
- This helps produce category-consistent and geometry-aware reconstruction.

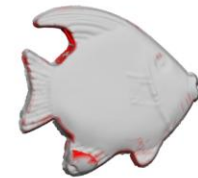
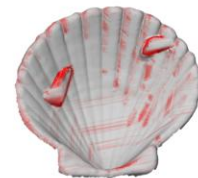
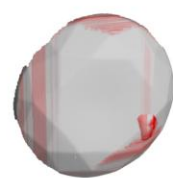
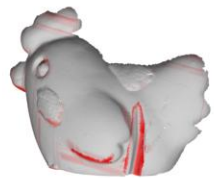
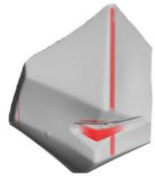
Experiment Results Real3D-AD

O-AUROC(↑)													
Method	Airplane	Car	Candybar	Chicken	Diamond	Duck	Fish	Gemstone	Seahorse	Shell	Starfish	Toffees	Mean
<i>Category-Specific Method</i>													
BTF(Raw)	73.0	64.7	53.9	78.9	70.7	69.1	60.2	<u>68.6</u>	59.6	39.6	53.0	70.3	63.5
BTF(FPFH)	52.0	56.0	63.0	43.2	54.5	78.4	54.9	64.8	<u>77.9</u>	75.4	57.5	46.2	60.3
M3DM	43.4	54.1	55.2	68.3	60.2	43.3	54.0	64.4	49.5	69.4	55.1	45.0	59.4
PatchCore(FPFH)	88.2	59.0	54.1	<u>83.7</u>	57.4	54.6	67.5	37.0	50.5	58.9	44.1	56.5	59.3
PatchCore(PointMAE)	72.6	49.8	66.3	82.7	78.3	48.9	63.0	37.4	53.9	50.1	51.9	58.5	59.4
CPMF	70.1	55.1	55.2	50.4	52.3	58.2	55.8	58.9	72.9	65.3	70.0	39.0	58.6
IMRNet	76.2	71.1	75.5	78.0	90.5	51.7	88.0	67.4	60.4	66.5	67.4	77.4	72.5
Reg3D-AD	71.6	69.7	68.5	85.2	90.0	58.4	91.5	41.7	76.2	58.3	50.6	82.7	70.4
Group3AD	74.4	<u>72.8</u>	<u>84.7</u>	78.6	<u>93.2</u>	67.9	97.6	53.9	84.1	58.5	56.2	<u>79.6</u>	75.1
R3D-AD	77.2	69.6	71.3	71.4	68.5	90.9	69.2	66.5	72.0	84.0	<u>70.1</u>	70.3	73.4
ISMP	<u>85.8</u>	73.1	85.2	71.4	94.8	71.2	<u>94.5</u>	46.8	72.9	62.3	66.0	84.2	76.7
PO3AD	80.4	65.4	78.5	68.6	80.1	<u>82.0</u>	85.9	69.3	75.6	<u>80.0</u>	75.8	77.1	<u>76.5</u>
<i>Unified Method</i>													
MC3D-AD	85.0	<u>74.9</u>	83.0	<u>71.5</u>	95.5	<u>83.1</u>	<u>86.5</u>	<u>56.0</u>	71.6	80.3	<u>76.6</u>	<u>73.8</u>	<u>78.2</u>
SeDiR (Ours)	86.0	78.3	<u>81.9</u>	72.9	<u>94.8</u>	86.2	93.8	62.7	<u>67.4</u>	<u>77.9</u>	85.4	84.5	81.0

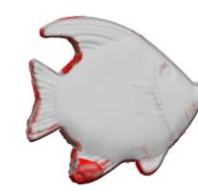
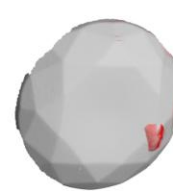
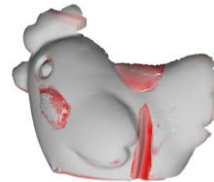
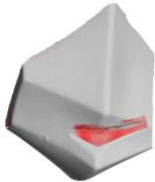
Experiment Results Anomaly-ShapeNet

O-AUROC(↑)																					
Method	ashtray0	bag0	bottle0	bottle1	bottle3	bow10	bow11	bow12	bow13	bow14	bow15	bucket0	bucket1	cap0	cap3	cap4	cap5	cup0	cup1	eraser0	
<i>Category-Specific Method</i>																					
BTF(Raw)	57.8	41.0	59.7	51.0	56.8	56.4	26.4	52.5	38.5	66.4	41.7	61.7	32.1	66.8	52.7	46.8	37.3	40.3	52.1	52.5	
BTF(FPFH)	42.0	54.6	34.4	54.6	32.2	50.9	66.8	51.0	49.0	60.9	69.9	40.1	63.3	61.8	52.2	52.0	58.6	58.6	61.0	71.9	
M3DM	57.7	53.7	57.4	63.7	54.1	63.4	66.3	68.4	61.7	46.4	40.9	30.9	50.1	55.7	42.3	77.7	63.9	53.9	55.6	62.7	
PatchCore(FPFH)	58.7	57.1	60.4	66.7	57.2	50.4	63.9	61.5	53.7	49.4	55.8	46.9	55.1	58.0	45.3	75.7	79.0	60.0	58.6	65.7	
PatchCore(PointMAE)	59.1	60.1	51.3	60.1	65.0	52.3	62.9	45.8	57.9	50.1	59.3	59.3	56.1	58.9	47.6	72.7	53.8	61.0	55.6	67.7	
CPMF	35.3	64.3	52.0	48.2	40.5	78.3	63.9	62.5	65.8	68.3	68.5	48.2	60.1	60.1	55.1	55.3	69.7	49.7	49.9	68.9	
Reg3D-AD	59.7	70.6	48.6	69.5	52.5	67.1	52.5	49.0	34.8	66.3	59.3	61.0	75.2	69.3	72.5	64.3	46.7	51.0	53.8	34.3	
IMRNet	67.1	66.0	55.2	70.0	64.0	68.1	70.2	68.5	59.9	67.6	<u>71.0</u>	58.0	<u>77.1</u>	73.7	<u>77.5</u>	65.2	65.2	64.3	<u>75.7</u>	54.8	
R3D-AD	<u>83.3</u>	<u>72.0</u>	<u>73.3</u>	<u>73.7</u>	<u>78.1</u>	<u>81.9</u>	<u>77.8</u>	<u>74.1</u>	<u>76.7</u>	<u>74.4</u>	65.6	<u>68.3</u>	75.6	<u>82.2</u>	73.0	<u>68.1</u>	<u>67.0</u>	<u>77.6</u>	<u>75.7</u>	<u>89.0</u>	
PO3AD	100.0	83.3	90.0	93.3	92.6	92.2	82.9	83.3	88.1	98.1	84.9	85.3	78.7	87.7	85.9	79.2	<u>67.0</u>	87.1	83.3	99.5	
<i>Unified Method</i>																					
MC3D-AD	<u>96.2</u>	<u>80.5</u>	<u>79.5</u>	<u>70.9</u>	<u>75.6</u>	<u>93.0</u>	97.8	71.9	<u>88.5</u>	<u>91.1</u>	75.4	89.8	78.4	<u>79.3</u>	<u>70.1</u>	<u>83.5</u>	<u>76.1</u>	<u>74.3</u>	<u>95.2</u>	77.6	
SeDiR (Ours)	97.6	88.6	92.9	91.6	98.4	95.9	<u>95.6</u>	92.6	96.7	98.5	97.9	91.1	93.3	98.5	98.9	99.6	87.4	99.5	100.0	<u>66.7</u>	
Method	headset0	headset1	helmet0	helmet1	helmet2	helmet3	jar	phone	shelf0	tap0	tap1	vase0	vase1	vase2	vase3	vase4	vase5	vase7	vase8	vase9	Mean
<i>Category-Specific Method</i>																					
BTF(Raw)	37.8	51.5	55.3	34.9	60.2	52.6	42.0	56.3	16.4	52.5	57.3	53.1	54.9	41.0	71.7	42.5	58.5	44.8	42.4	56.4	49.3
BTF(FPFH)	52.0	49.0	57.1	71.9	54.2	44.4	58.6	67.1	60.9	56.0	54.6	34.2	21.9	54.6	69.9	51.0	40.9	51.8	66.8	26.8	52.8
M3DM	57.7	61.7	52.6	42.7	62.3	37.4	56.4	35.7	56.4	75.4	73.9	57.4	42.7	73.7	43.9	47.6	43.9	65.7	66.3	66.3	55.2
PatchCore(FPFH)	58.3	63.7	54.6	48.4	42.5	40.4	49.4	38.8	49.4	<u>75.3</u>	<u>76.6</u>	60.4	42.3	72.1	44.9	50.6	44.9	69.3	66.2	66.0	56.8
PatchCore(PointMAE)	59.1	62.7	55.6	55.2	44.7	42.4	48.3	48.8	52.3	45.8	53.8	51.3	55.2	74.1	46.0	51.6	46.0	65.0	66.3	62.9	56.2
CPMF	64.3	45.8	55.5	58.9	46.2	52.0	61.0	50.9	68.5	35.9	69.7	58.2	34.5	58.2	58.2	51.4	58.2	39.7	52.9	60.9	55.9
Reg3D-AD	53.7	61.0	60.0	38.1	61.4	36.7	59.2	41.4	<u>68.8</u>	67.6	64.1	48.6	70.2	60.5	65.0	50.0	65.0	46.2	62.0	59.4	57.2
IMRNet	72.0	67.6	59.7	60.0	<u>64.1</u>	57.3	78.0	75.5	<u>60.3</u>	67.6	69.6	55.2	75.7	61.4	70.0	52.4	70.0	63.5	63.0	59.4	66.1
R3D-AD	<u>73.8</u>	<u>79.5</u>	<u>75.7</u>	<u>72.0</u>	63.3	<u>70.7</u>	<u>83.8</u>	<u>76.2</u>	69.6	73.6	90.0	<u>73.3</u>	72.9	<u>75.2</u>	<u>74.2</u>	<u>63.0</u>	<u>74.2</u>	<u>77.1</u>	<u>72.1</u>	<u>71.8</u>	<u>74.9</u>
PO3AD	80.8	92.3	76.2	96.1	86.9	75.4	86.6	77.6	57.3	74.5	68.1	85.8	<u>74.2</u>	95.2	82.1	67.5	85.2	96.6	73.9	83.0	83.9
<i>Unified Method</i>																					
MC3D-AD	86.2	<u>88.6</u>	<u>67.2</u>	100.0	<u>60.9</u>	<u>97.9</u>	<u>97.1</u>	91.9	84.1	94.5	97.0	<u>79.5</u>	<u>85.7</u>	<u>92.9</u>	<u>76.1</u>	<u>87.6</u>	<u>76.1</u>	<u>93.8</u>	<u>67.0</u>	<u>73.6</u>	<u>84.2</u>
SeDiR (Ours)	<u>84.9</u>	89.0	96.5	100.0	87.0	100.0	100.0	<u>90.5</u>	88.7	<u>92.7</u>	<u>89.3</u>	88.8	97.1	97.6	78.8	92.4	94.8	100.0	87.3	94.2	93.3

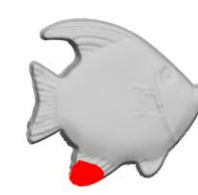
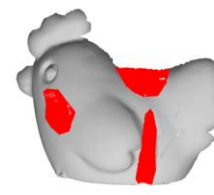
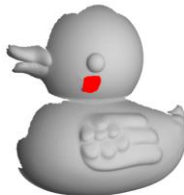
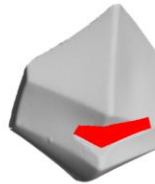
MC3D-AD



Ours



GT



- Qualitative results show that SeDiR produces more accurate anomaly localization.
- MC3D-AD often misses true defects or activates normal regions as anomalies.
- In contrast, SeDiR better aligns with the ground truth by reconstructing under clearer semantic identity and geometric guidance.

- The effectiveness of core components.

CFG	T	GD	O-AUROC (\uparrow)	P-AUROC (\uparrow)
			75.1	78.1
✓			76.4	78.4
✓	✓		79.2	79.0
✓	✓	✓	81.0	80.6

- Comparison of different guidance strategies in GGD.

Method	O-AUROC (\uparrow)	P-AUROC (\uparrow)
Masking	79.8	79.6
Gating	79.7	78.9
Bias (Ours)	81.0	80.6

- The contribution of each loss in C3L.

\mathcal{L}_{scl}	\mathcal{L}_{cls}	\mathcal{L}_{cos}	O-AUROC (\uparrow)	P-AUROC (\uparrow)
✓			79.1	78.8
✓	✓		80.0	79.3
✓	✓	✓	81.0	80.6

- Comparison of different global token strategies.

Method	O-AUROC (\uparrow)	P-AUROC (\uparrow)
ACT	78.5	78.5
Max	76.4	75.5
Mean	78.2	78.7
CFG (Ours)	81.0	80.6

Thank you!



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