PO3AD: Predicting Point Offsets toward Better 3D Point Cloud Anomaly Detection

Supplementary Material

6. Visualizations of Our Pseudo Anomalies

Figure 8 presents visualizations of normal, real anomaly, and our pseudo anomaly samples. It is observed that the pseudo anomalies generated using the Norm-AS method closely resemble real anomalies, thereby supporting the efficacy of our approach in creating credible pseudo anomaly instances.

7. Additional Experimental Results

Object-level AUC-PR results on Anomaly-ShapeNet. Table 5 presents the results of our comparative analysis of object-level AUC-PR on the Anomaly-ShapeNet dataset. The results indicate that our method achieves the best mean rank and significantly outperforms the second-best method by an average of 26.0% AUC-PR. Such experimental results evidence the superiority of our method.

Results of using PTv3 [46] as backbone. Ten categories are selected to conduct experiments using PTv3 as the backbone, results are presented in Table 6. Applying PTv3 as the backbone for feature extraction, our method still outperforms R3D-AD, validating the effectiveness of our offset prediction strategy.

Table 7 presents the point-level AUC-PR results of our method on the Anomaly-ShapeNet dataset.

Table 8 exhibits the point-level AUC-ROC results of our method and competing methods on the Real3D-AD dataset.

Table 9 reports the ablation study on full categories of the Anomaly-ShapeNet dataset.

8. Visualizations of Noisy Data

Figure 9 depicts the visualizations of a clean point cloud and its noisy variants with various standard deviations. It is observed that as the noise standard deviation grows, the point cloud surface becomes progressively less smooth.

9. Visualizations of Model Attention Maps

Visualizations of model attention maps are presented in Figure 10. Evidently, our method successfully focuses on pseudo-abnormal regions, allowing the effective extraction of normal representations for anomaly detection.

References

[46] Xiaoyang Wu, Li Jiang, Peng-Shuai Wang, Zhijian Liu, Xihui Liu, Yu Qiao, Wanli Ouyang, Tong He, and Hengshuang Zhao. Point Transformer V3: Simpler Faster Stronger. In *IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pages 4840–4851, 2024.

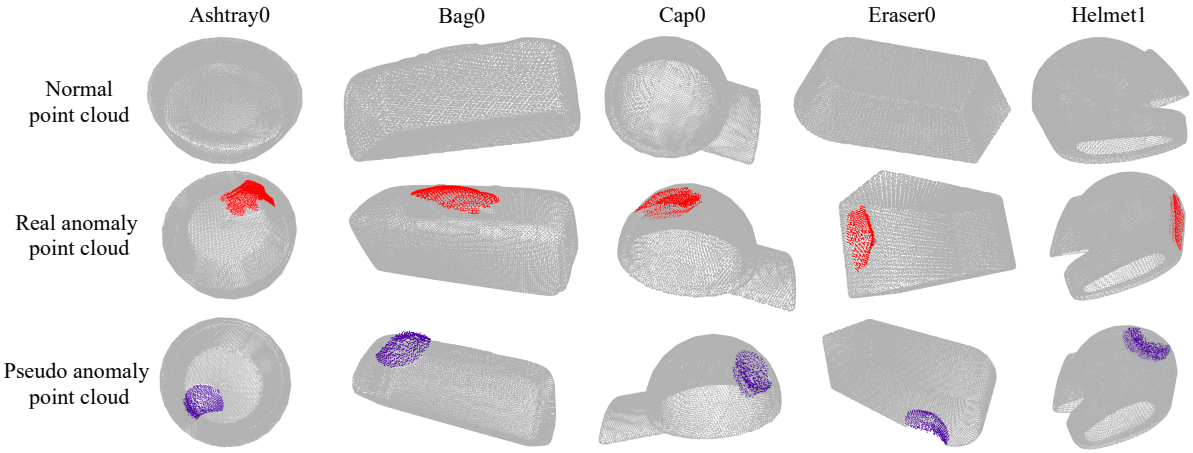

Figure 8. Visualizations of normal, real anomaly, and our pseudo anomaly samples.

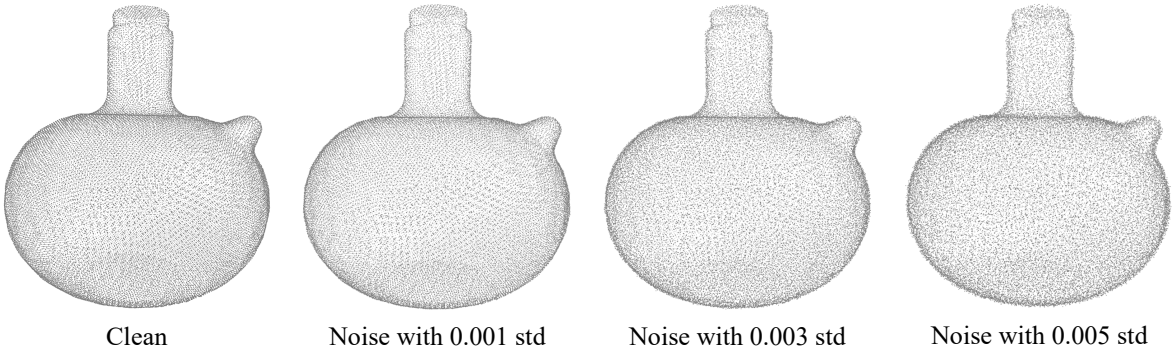

Figure 9. Visualizations of clean, and noisy point clouds with various standard deviations (std).

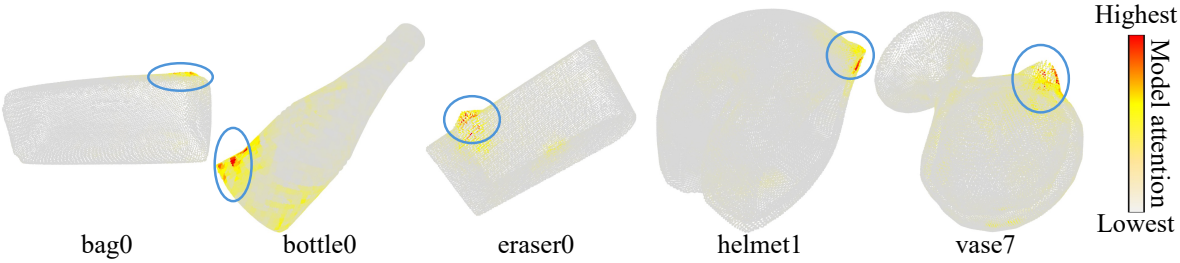

Figure 10. Visualization of model attention maps, pseudo-abnormal regions are marked with blue circles.

Method	ashtray0	bag0	bottle0	bottle1	bottle3	bowl0	bowl1	bowl2	bowl3	bowl4	bowl5	bucket0	bucket1	cap0
BTF (Raw) (CVPR 23')	57.8	45.8	46.6	57.3	54.3	58.8	46.4	57.6	65.4	60.1	61.5	65.2	62.0	65.9
BTF (FPFH)	65.1	55.1	64.4	62.5	60.2	57.6	64.8	51.5	49.9	63.2	69.9	48.3	64.8	61.8
M3DM (CVPR 23')	63.2	64.2	76.3	67.4	45.1	52.5	51.5	63.0	63.5	57.1	60.1	60.9	50.7	56.4
PatchCore (FPFH) (CVPR 22')	44.5	60.8	61.5	67.7	57.9	54.8	54.5	61.1	62.0	57.5	54.1	60.4	56.5	58.5
PatchCore (PointMAE)	67.9	60.1	54.5	64.5	65.1	56.2	61.1	45.6	55.6	60.1	58.5	54.1	64.2	56.1
CPMF (PR 24')	45.3	65.5	58.8	59.2	50.5	77.5	62.1	60.1	41.8	68.3	68.5	66.2	50.1	60.1
Reg3D-AD (NeurIPS 23')	58.8	60.8	63.2	69.5	47.4	49.4	51.5	49.5	44.1	62.4	55.5	63.2	71.4	69.3
IMRNet (CVPR 24')	61.2	66.5	55.8	70.2	64.8	48.1	50.4	68.1	61.4	63.0	65.2	57.8	73.2	71.1
Ours	**99.9**	**80.9**	**92.7**	**95.9**	**96.2**	**94.6**	**90.5**	**88.8**	**92.7**	**98.5**	**90.4**	**92.3**	**88.2**	**84.1**

Method	cap3	cap4	cap5	cup0	cup1	eraser0	headset0	headset1	helmet0	helmet1	helmet2	helmet3	jar0	micro.
BTF (Raw) (CVPR 23')	61.2	51.5	65.3	60.1	70.1	42.5	37.9	51.5	55.9	38.8	61.5	52.6	42.8	61.3
BTF (FPFH)	57.9	54.5	59.3	58.5	65.1	71.9	53.1	52.3	56.8	72.1	58.8	56.4	47.9	66.2
M3DM (CVPR 23')	65.2	47.7	64.2	57.0	75.2	62.5	63.2	62.3	52.8	62.7	63.6	45.8	55.5	46.4
PatchCore (FPFH) (CVPR 22')	45.7	65.5	72.5	60.4	58.6	58.4	70.1	60.1	52.5	63.0	47.5	49.4	49.9	33.2
PatchCore (PointMAE)	58.3	72.1	54.2	64.2	71.0	80.1	51.5	42.3	63.3	57.1	49.6	61.1	46.3	65.2
CPMF (PR 24')	54.1	64.5	69.7	64.7	60.9	54.4	60.2	61.9	33.3	50.1	47.7	64.5	61.8	65.5
Reg3D-AD (NeurIPS 23')	71.1	62.3	77.0	53.1	63.8	42.4	53.8	61.7	60.0	38.1	**61.8**	46.8	60.1	61.4
IMRNet (CVPR 24')	70.2	65.8	50.2	45.5	62.7	59.9	70.1	65.6	69.7	61.5	60.2	57.5	76.0	55.2
Ours	**90.6**	**87.6**	**80.1**	**87.9**	**87.0**	**99.5**	**76.5**	**91.4**	**86.4**	**96.1**	**93.4**	**84.9**	**91.5**	**80.3**

Method	shelf0	tap0	tap1	vase0	vase1	vase2	vase3	vase4	vase5	vase7	vase8	vase9	Average	Mean rank
BTF (Raw) (CVPR 23')	62.4	53.5	59.4	56.2	44.1	41.3	71.7	42.8	61.5	54.7	41.6	48.2	54.9	6.5
BTF (FPFH)	61.1	61.0	57.5	64.1	65.5	56.9	65.2	58.7	47.2	59.2	62.4	63.8	59.8	5.3
M3DM (CVPR 23')	66.5	72.2	63.8	**78.8**	65.2	61.5	55.1	52.6	63.3	64.8	46.3	65.1	60.3	5.1
PatchCore (FPFH) (CVPR 22')	50.4	71.2	68.4	64.5	62.3	80.1	48.1	77.7	51.5	62.1	51.5	66.0	58.8	5.6
PatchCore (PointMAE)	54.3	71.2	54.2	54.8	57.2	71.1	45.5	58.6	58.5	65.2	65.5	63.4	59.5	5.6
CPMF (PR 24')	**68.1**	63.9	69.7	63.2	64.5	63.2	58.8	65.5	51.8	43.2	67.3	61.8	59.7	5.1
Reg3D-AD (NeurIPS 23')	67.5	67.6	59.9	61.5	46.8	64.1	65.1	50.5	58.8	45.5	62.9	57.4	58.4	5.6
IMRNet (CVPR 24')	62.5	40.1	**79.6**	57.3	72.5	65.5	70.8	52.8	65.4	60.1	63.9	46.2	62.1	4.6
Ours	68.0	**85.6**	70.9	75.3	**78.9**	**96.3**	**90.2**	**82.4**	**87.9**	**97.1**	**83.3**	**90.4**	**88.1**	**1.0**

Table 5. Comparison of object-level AUC-PR results on the Anomaly-ShapeNet dataset.

Method	bag0	bottle0	bowl0	bucket0	cap0	cup0	headset0	jar0	microphone0	vase0
R3D-AD	72.0	73.3	81.9	68.3	82.2	77.6	73.8	83.8	76.2	78.8
Ours (PTv3)	73.3	83.3	85.5	82.5	84.0	**91.4**	76.0	**96.1**	77.1	**87.0**
Ours (MinkUNet34C)	**83.3**	**90.0**	**92.2**	**85.3**	**87.7**	87.1	**80.8**	86.6	**77.6**	85.8

Table 6. Object-level AUC-ROC results *vs.* backbone.

Method	ashtray0	bag0	bottle0	bottle1	bottle3	bowl0	bowl1	bowl2	bowl3	bowl4	bowl5	bucket0	bucket1	cap0
Ours	62.5	55.5	65.3	41.6	25.0	57.5	51.3	69.7	46.1	74.4	59.2	5.3	61.6	79.3

Method	cap3	cap4	cap5	cup0	cup1	eraser0	headset0	headset1	helmet0	helmet1	helmet2	helmet3	jar0	micro.
Ours	61.5	53.9	53.5	58.2	45.5	65.3	37.9	48.4	40.1	29.1	47.0	10.3	57.0	30.3

Method	shelf0	tap0	tap1	vase0	vase1	vase2	vase3	vase4	vase5	vase7	vase8	vase9	Average
Ours	26.8	37.4	18.2	58.6	30.7	47.1	48.4	36.3	27.6	63.3	79.7	71.3	48.4

Table 7. Point-level AUC-PR results of our method on the Anomaly-ShapeNet dataset.

Category	BTF (Raw) (CVPR 23')	BTF (FPFH)	M3DM (CVPR 23')	PatchCore (FPFH) (CVPR 22')	PatchCore (PointMAE)	Reg3D-AD (NeurIPS 23')	Group3AD (MM 24')	R3D-AD (ECCV 24')	Ours
Airplane	73.8	56.4	53.0	47.1	57.9	63.1	63.6	-	71.5
Car	70.8	64.7	60.7	64.3	61.0	71.8	74.5	-	57.4
Candy	86.4	73.5	68.3	63.7	63.5	72.4	73.8	-	76.3
Chicken	69.3	60.8	73.5	61.8	68.3	67.6	75.9	-	56.3
Diamond	88.2	56.3	61.8	76.0	77.6	83.5	86.2	-	61.4
Duck	87.5	60.1	67.8	43.0	43.9	50.3	63.1	-	64.4
Fish	70.9	51.4	60.0	46.4	71.4	82.6	83.6	-	87.7
Gemstone	89.1	59.7	65.4	83.0	51.4	54.5	56.4	-	53.0
Seahorse	51.2	52.0	56.1	54.4	66.0	81.7	82.7	-	58.5
Shell	57.1	48.9	74.8	59.6	72.5	81.1	79.8	-	54.2
Starfish	50.1	39.2	55.5	52.2	64.1	61.7	62.5	-	65.9
Toffees	81.5	62.3	67.9	41.1	72.7	75.9	80.3	-	72.9
Average	72.9	57.1	63.7	57.7	64.1	70.5	73.5	59.2	65.0

Table 8. Comparison of point-level AUC-ROC results on the Real3D-AD dataset.

Method	ashtray0	bag0	bottle0	bottle1	bottle3	bowl0	bowl1	bowl2	bowl3	bowl4	bowl5	bucket0	bucket1	cap0
w/o $\mathcal{L}_{dir}$	55.2	41.4	50.9	57.1	62.8	66.6	44.8	50.0	44.8	41.4	55.7	59.0	41.9	38.5
w/o $\mathcal{L}_{dist}$	94.7	65.2	63.3	83.1	83.4	72.9	68.1	64.4	55.1	71.4	68.0	70.4	67.6	82.5
w/o normal vector	99.5	61.4	84.2	85.6	88.2	96.2	75.5	81.1	88.5	90.3	76.6	81.5	76.5	90.7
Ours	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

Method	cap3	cap4	cap5	cup0	cup1	eraser0	headset0	headset1	helmet0	helmet1	helmet2	helmet3	jar0	micro.
w/o $\mathcal{L}_{dir}$	49.8	51.5	58.5	52.3	49.0	50.9	49.3	48.5	50.1	48.0	33.0	48.7	48.0	47.6
w/o $\mathcal{L}_{dist}$	77.8	61.4	61.4	62.3	63.8	65.2	66.2	89.0	58.5	78.0	66.6	70.0	83.3	60.9
w/o normal vector	90.5	74.3	70.1	82.8	64.2	91.9	77.3	94.7	65.2	95.7	85.2	75.1	79.0	78.5
Ours	85.9	79.2	67.0	87.1	83.3	99.5	80.8	92.3	76.2	96.1	86.9	75.4	86.6	77.6

Method	shelf0	tap0	tap1	vase0	vase1	vase2	vase3	vase4	vase5	vase7	vase8	vase9	Average
w/o $\mathcal{L}_{dir}$	51.3	48.1	47.0	45.4	50.0	51.9	55.7	53.3	51.9	42.3	48.1	58.4	49.9
w/o $\mathcal{L}_{dist}$	42.8	56.3	57.4	68.7	63.3	68.5	54.5	69.3	68.5	87.1	70.6	69.6	68.7
w/o normal vector	70.4	73.6	57.7	85.4	63.8	77.1	80.9	64.8	53.8	92.3	77.8	84.8	79.5
Ours	57.3	74.5	68.1	85.8	74.2	95.2	82.1	67.5	85.2	96.6	73.9	83.0	83.9

Table 9. Ablation study on the Anomaly-ShapeNet dataset (object-level AUC-ROC).