GeoFormer: Learning Point Cloud Completion with Tri-Plane Integrated Transformer

Jinpeng Yu[1,2] Binbin Huang[3] Yuxuan Zhang[4] Huaxia Li[2] Xu Tang[2] Shenghua Gao[3]

[1]ShanghaiTech University [2]Xiaohongshu Inc.

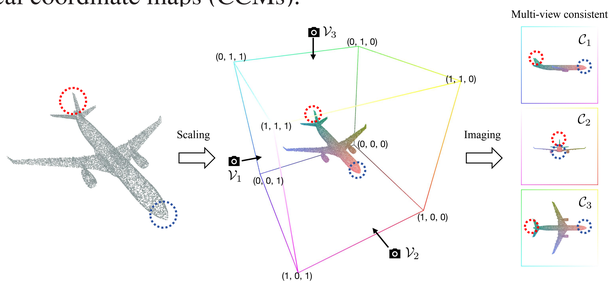
[3]The University of Hong Kong [4]Shanghai Jiao Tong University

ACM Multimedia 2024 Melbourne, Australia

Code & Data & Model: https://github.com/Jinpeng-Yu/GeoFormer

Problem and Contribution

Idea: GeoFormer simultaneously enhances the global geometric structure and local details of the point cloud by imposing the multi-view consistent canonical coordinate maps (CCMs).

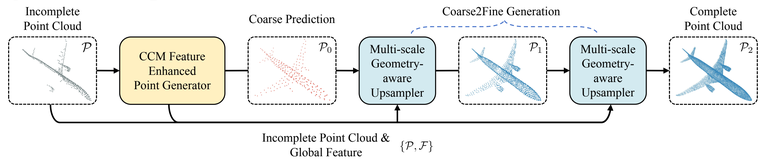


Contributions:

- We introduce multi-view consistent CCMs into point cloud completion, enhancing global features by aligning 3D and 2D features.
- An efficient multi-scale geometry-aware upsampler that accurately reconstructs missing parts by incorporating partial geometric features.
- Our method achieves state-of-the-art results.

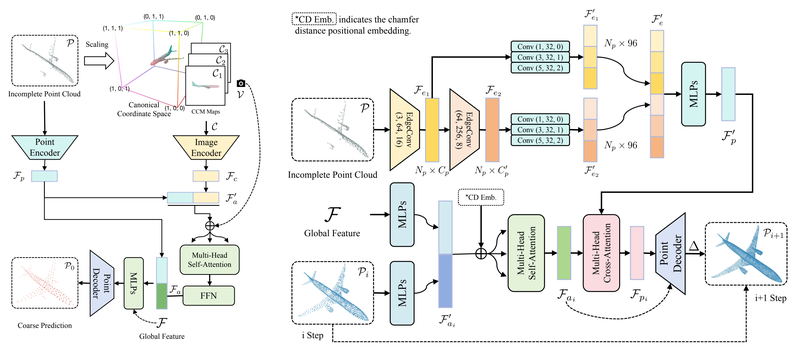
Method

Overview: GeoFormer mainly consists of one point generator module and two identical upsampler modules. The generator module aims to produce sparse yet structurally complete point clouds, and the upsampler module aims to generate complete and dense results from coarse to fine.



CCM Feature Enhanced Point Generator:

We first extract CCMs according to the views $\mathcal{V}$, and then align the 3D and 2D features through attention mechanism to obtain the global feature $\mathcal{F}$. Finally, we use the decoder to predict the coarse point cloud $\mathcal{P}_0$.



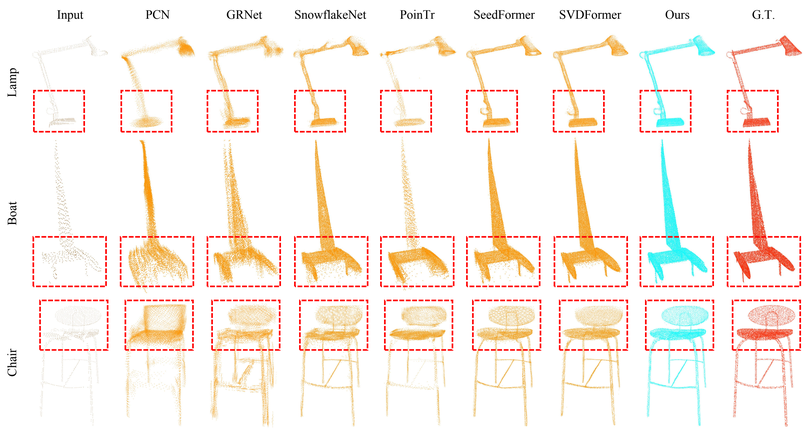
Multi-scale Geometry-aware Upsampler:

We first obtain the multi-scale local point features $\mathcal{F}'_p$, and then fuse it with the global feature $\mathcal{F}$ and previous $\mathcal{P}_i$ to predict the fine point cloud $\mathcal{P}_{i+1}$.

Experiments & Results

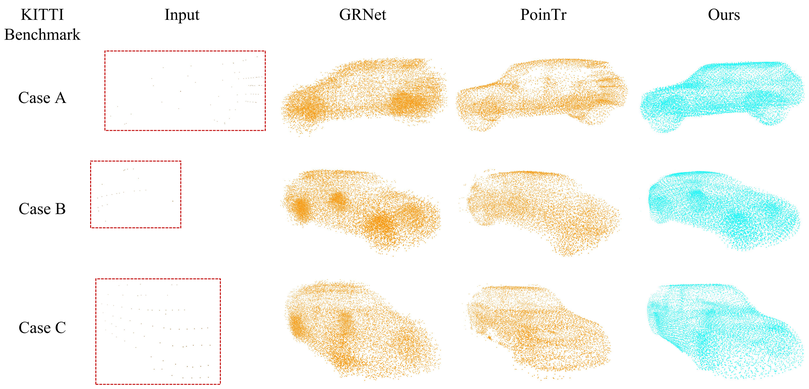
Comparison on PCN Benchmark:

Methods	Plane	Cabinet	Car	Chair	Lamp	Couch	Table	Boat	CD-Avg↓	DCD-Avg↓	F1↑
FoldingNet [46]	9.49	15.80	12.61	15.55	16.41	15.97	13.65	14.99	14.31	-	-
TopNet [28]	7.61	13.31	10.90	13.82	14.44	14.78	11.22	11.12	12.15	-	-
PCN [50]	5.50	22.70	10.63	8.70	11.00	11.34	11.68	8.59	9.64	-	0.695
GRNet [44]	6.45	10.37	9.45	9.41	7.96	10.51	8.44	8.04	8.83	0.622	0.708
CRN [35]	4.79	9.97	8.31	9.49	8.94	10.69	7.81	8.05	8.51	-	0.652
NSFA [52]	4.76	10.18	8.63	8.53	7.03	10.53	7.35	7.48	8.06	-	0.734
PoinTr [48]	4.75	10.47	8.68	9.39	7.75	10.93	7.78	7.29	8.38	0.611	0.745
SnowflakeNet [42]	4.29	9.16	8.08	7.89	6.07	9.23	6.55	6.40	7.21	0.585	0.801
PMP-Net++ [38]	4.39	9.96	8.53	8.09	6.06	9.82	7.17	6.52	7.56	0.611	0.781
FBNet [45]	3.99	9.05	7.90	7.38	5.82	8.85	6.35	6.18	6.94	-	-
SeedFormer [55]	3.85	9.05	8.06	7.06	5.21	8.85	6.05	5.85	6.74	0.583	0.818
AdaPoinTr [49]	3.68	8.82	7.47	6.85	5.47	8.35	5.80	5.76	6.53	-	0.845
AnchorFormer [4]	3.70	8.94	7.57	7.05	5.21	8.40	6.03	5.81	6.59	-	-
HyperCD [16]	3.72	8.71	7.79	6.83	5.11	8.61	5.82	5.76	6.54	-	-
SVDFormer [57]	3.62	8.79	**7.46**	6.91	5.33	8.49	5.90	5.83	6.54	0.536	0.841
FSC [41]	4.07	9.12	8.1	7.21	5.88	9.30	6.26	6.25	7.02	-	-
Ours	**3.60**	**8.69**	**7.46**	**6.71**	**5.15**	**8.28**	**5.84**	**5.63**	**6.42**	**0.526**	**0.854**



Comparison on KITTI Benchmark:

	PCN [50]	FoldingNet [46]	TopNet [28]	GRNet [44]	SeedFormer [55]	**Ours**
Fidelity↓	2.235	7.467	5.354	0.816	0.151	**0.089**
MMD↓	1.366	0.537	0.636	0.568	0.516	**0.510**



Comparison on ShapeNet-55/34 Benchmark:

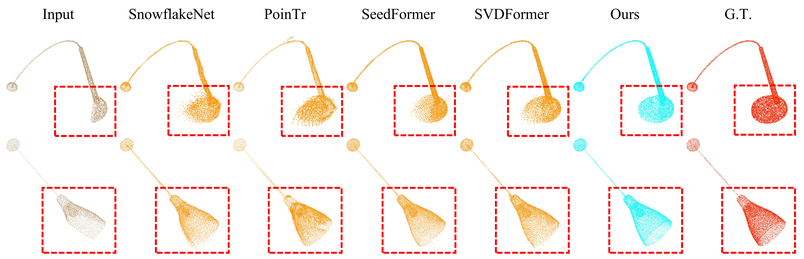
Quantitative results on ShapeNet-55 benchmark

Methods	Table	Chair	Plane	Car	Sofa	CD-S	CD-M	CD-H	CD-Avg↓	DCD-Avg↓	F1↑
FoldingNet [46]	2.53	2.81	1.43	1.98	2.48	2.67	2.66	4.05	3.12	0.082	
PCN [50]	2.13	2.29	1.02	1.85	2.06	1.94	1.96	4.08	2.66	0.618	0.133
TopNet [28]	2.21	2.53	1.14	2.18	2.36	2.26	2.16	4.3	2.91	0.126	
GRNet [44]	1.63	1.88	1.02	1.64	1.72	1.35	1.71	2.85	1.97	0.592	0.238
PoinTr [48]	0.81	0.95	0.44	0.91	0.79	0.58	0.88	1.79	1.09	0.575	0.464
SeedFormer [55]	0.72	0.81	0.40	0.89	0.71	0.50	0.77	1.49	0.92	0.558	0.472
SVDFormer [57]	-	-	-	-	-	0.48	0.70	1.30	0.83	0.541	0.451
HyperCD [16]	0.66	0.74	0.35	0.83	0.64	0.47	0.72	1.40	0.86	-	0.482
Ours	**0.58**	**0.65**	**0.34**	**0.69**	**0.57**	**0.41**	**0.64**	**1.25**	**0.77**	**0.540**	**0.514**

Quantitative results on ShapeNet-34/21 benchmark

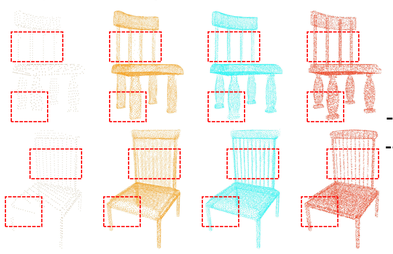
Methods	34 seen categories						21 unseen categories					
	CD-S	CD-M	CD-H	CD-Avg↓	DCD-Avg↓	F1↑	CD-S	CD-M	CD-H	CD-Avg↓	DCD-Avg↓	F1↑
FoldingNet [46]	1.86	1.81	3.38	2.35	-	0.139	2.76	2.74	5.36	3.62	-	0.095
PCN [50]	1.87	1.81	2.97	2.22	0.624	0.150	3.17	3.08	5.29	3.85	0.644	0.101
TopNet [50]	1.77	1.61	3.54	2.31	-	0.171	2.62	2.43	5.44	3.50	-	0.121
GRNet [44]	1.26	1.39	2.57	1.74	0.600	0.251	1.85	2.25	4.87	2.99	0.625	0.216
PoinTr [48]	0.76	1.05	1.88	1.23	0.575	0.421	1.04	1.67	3.44	2.05	0.604	0.384
SeedFormer [55]	0.48	0.70	1.30	0.83	0.561	0.452	0.61	1.07	2.35	1.34	0.586	0.402
HyperCD [16]	0.46	0.67	1.24	0.79	-	0.459	0.58	1.03	2.24	1.31	-	0.428
SVDFormer [57]	0.46	0.65	1.13	0.75	0.538	0.457	0.61	1.05	2.19	1.28	0.554	0.427
Ours	**0.39**	**0.57**	**1.05**	**0.67**	**0.537**	**0.515**	**0.55**	**0.99**	**2.15**	**1.23**	**0.551**	**0.483**

Qualitative comparison on ShapeNet-55 benchmark



Effectiveness of Improved Design Components:

Variants	arc-CD	**Our Designs**	CD-Avg↓	DCD-Avg↓	F1↑
A			6.54	0.536	0.841
B	✓		6.50	0.535	0.846
Ours	✓	✓	**6.42**	**0.526**	**0.854**



Variants	Enhance		Geometry	CD-Avg↓	DCD-Avg↓	F1↑
	CCM	Alignment	Inception			
C	✓			6.46	0.532	0.850
D	✓	✓		6.43	0.530	0.849
E			✓	6.45	0.533	0.847
Ours	✓	✓	✓	**6.42**	**0.526**	**0.854**