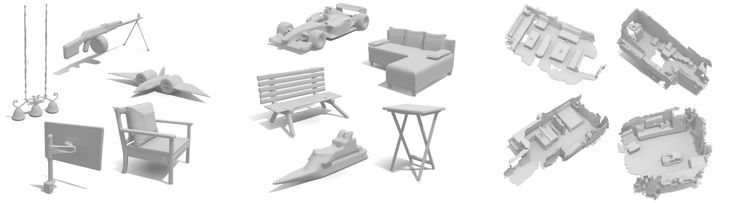
Neural Fields as Learnable Kernels for 3D Reconstruction

Francis Williams*, Zan Gojcic*, Sameh Khamis, Denis Zorin, Joan Bruna, Sanja Filder, Or Litany

NYU NVIDIA ETH zürich

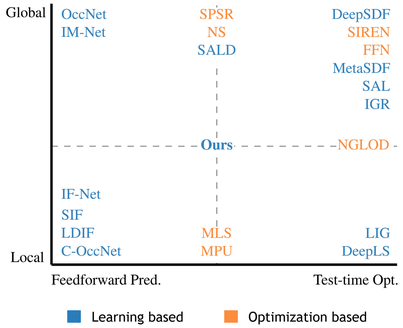
Project page

Surface Reconstruction from Sparse Point Clouds

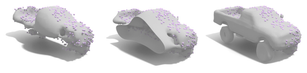


In-category (ShapeNet[1] to ShapeNet[1]) Out-of-category (chair to other) Generalization (ShapeNet[1] to ScanNet[2])

Prior Work

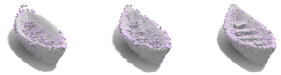


Data free methods



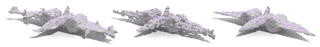
SPSR[3] NS[4] Ours

Feed-forward methods



OccNet[5] C-OccNet[6] Ours

Optimization methods



LIG[7] (0.1) LIG[7] (0.3) Ours

References

[1] Chang, Angel X., et al. "Shapenet: An information-rich 3d model repository." *arXiv preprint arXiv:1512.03012* (2015).

[2] Dai, A., Chang, A. X., Savva, M., Halber, M., Funkhouser, T., & Nießner, M. (2017). Scannet: Richly-annotated 3d reconstructions of indoor scenes. In *CVPR* (pp. 5828-5839).

[3] Kazhdan, M., & Hoppe, H. (2013). Screened poisson surface reconstruction. *ACM Transactions on Graphics (ToG)*, *32*(3), 1-13.

[4] Williams, F., Trager, M., Bruna, J., & Zorin, D. (2021). Neural splines: Fitting 3d surfaces with infinitely-wide neural networks. In *CVPR* (pp. 9949-9958).

[5] Mescheder, L., Oechsle, M., Niemeyer, M., Nowozin, S., & Geiger, A. (2019). Occupancy networks: Learning 3d reconstruction in function space. In *CVPR* (pp. 4460-4470).

[6] Peng, S., Niemeyer, M., Mescheder, L., Pollefeys, M., & Geiger, A. (2020, August). Convolutional occupancy networks. In *ECCV* (pp. 523-540). Springer, Cham.

[7] Jiang, C., Sud, A., Makadia, A., Huang, J., Nießner, M., & Funkhouser, T. (2020). Local implicit grid representations for 3d scenes. In *CVPR* (pp. 6001-6010).

[8] Peng, S., Jiang, C., Liao, Y., Niemeyer, M., Pollefeys, M., & Geiger, A. (2021). Shape as points: A differentiable poisson solver. *In NeurIPS*, *34*.

Kernel Ridge Regression

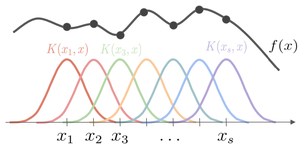
Implicit function as a sum of basis functions:

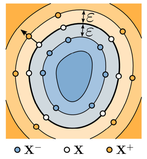
$$f(x;\theta) = \sum_{j=1}^{s} \alpha_j K_\infty(x_j, x)$$

$$(K + \lambda I)\alpha = y$$

Solution that minimizes:

$$\|f\|_K$$

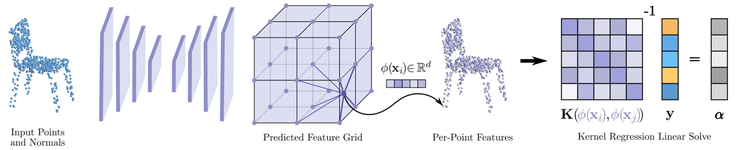




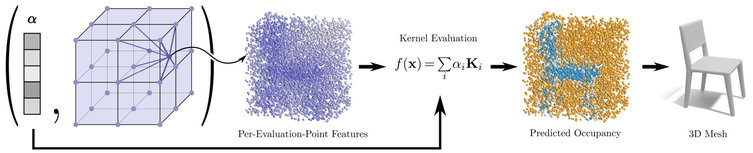
Extension to 3D

Network Architecture

Prediction:

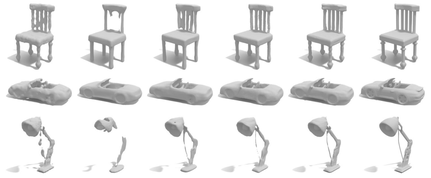


Evaluation:



In-Category Reconstruction

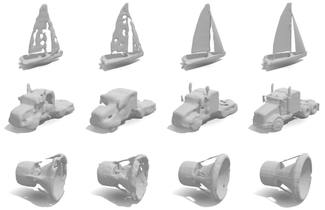
Noise	IoU ↑ $\sigma = 0.0$	$\sigma = 0.0025$	$\sigma = 0.005$
SPSR	0.772	0.759	0.735
OccNet	0.761	0.747	0.726
C-OccNet	0.828	0.848	0.857
NS	0.864	0.831	0.835
SAP	0.872	0.866	0.849
Ours	**0.947**	**0.908**	**0.866**
Ours w/o norm.	0.924	0.894	0.862



NS[4] OccNet[5] C-OccNet[6] SAP[8] Ours GT

Generalization Performance

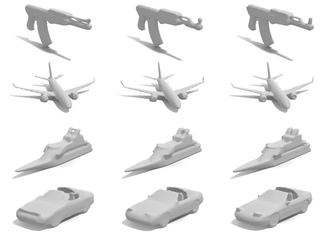
Half Categories to Other half



C-OccNet[6] SAP[8] Ours GT

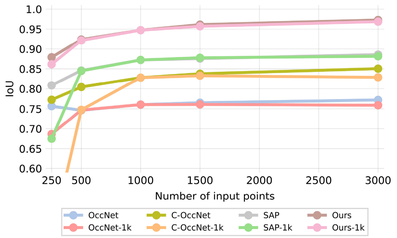
	IoU ↑	Chamfer ↓	Normal C. ↑
OccNet	0.572 (-38.6%)	0.143 (0.076)	0.824 (-10.4%)
C-OccNet	0.785 (-6.9%)	0.061 (0.013)	0.912 (-2.0%)
LIG	0.518 (N.A.)	0.112 (N.A.)	0.536 (N.A.)
NS	0.869 (0.0%)	0.049 (0.000)	0.924 (0.0%)
SAP	0.855 (-2.0%)	0.036 (0.004)	0.929 (-1.7%)
Ours	**0.939 (-1.0%)**	**0.028 (0.003)**	**0.939 (-0.9%)**
Ours w/o norm.	0.897 (-3.3%)	0.033 (0.004)	0.922 (-1.6 %)

Chair to Other Categories

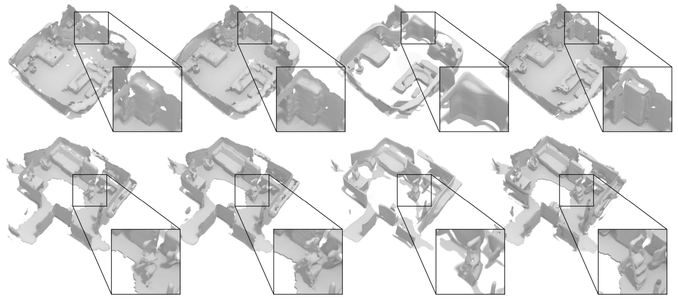


Ours (Chair) Ours GT

Across different number of points



Generalization from ShapeNet[1] to ScanNet[2]



SPSR[3] NS[4] C-OccNet[5] Ours