Point2Cyl: Reverse Engineering 3D Objects from Point Clouds to Extrusion Cylinders

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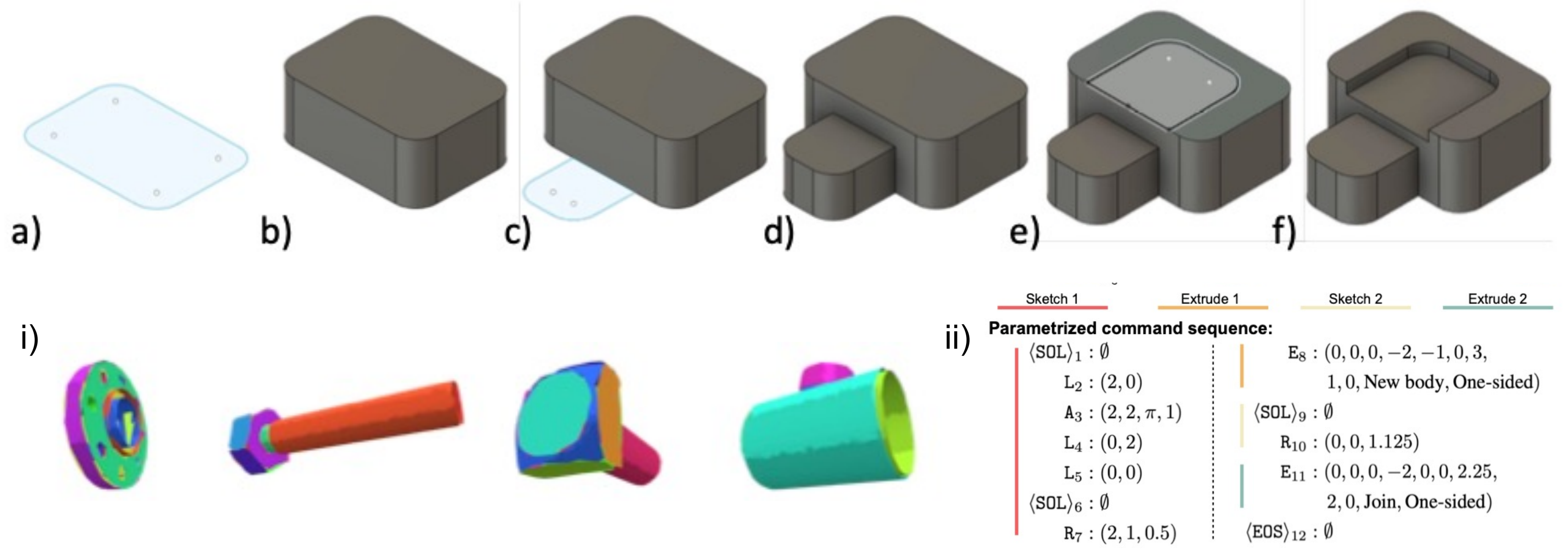
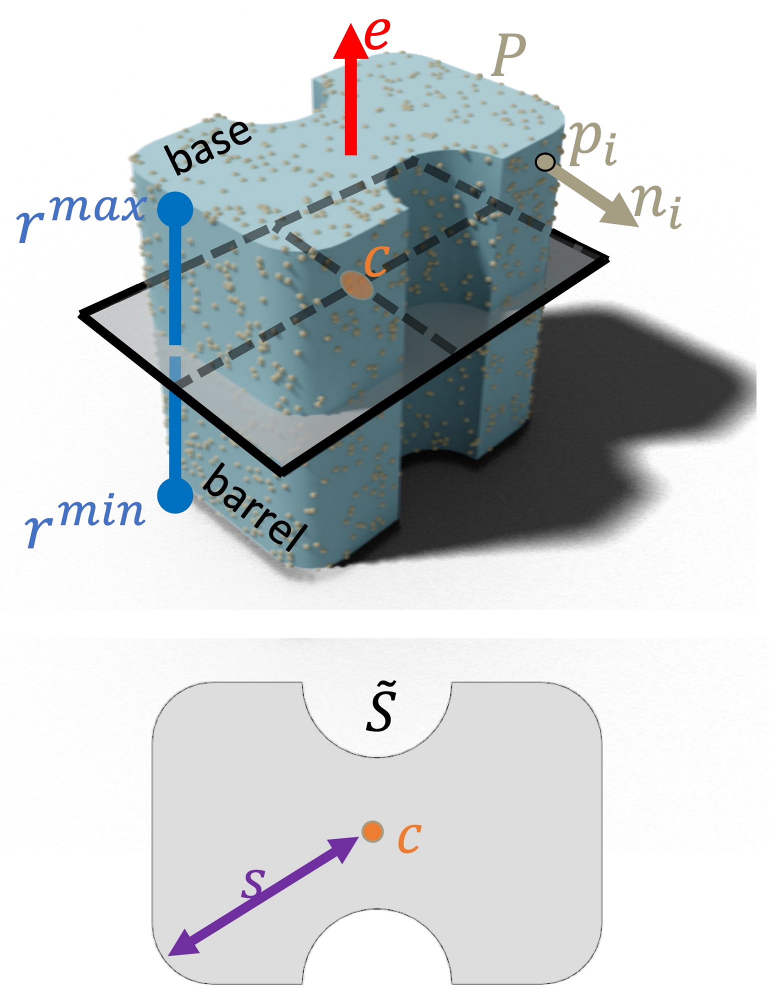
PROBLEM OVERVIEW



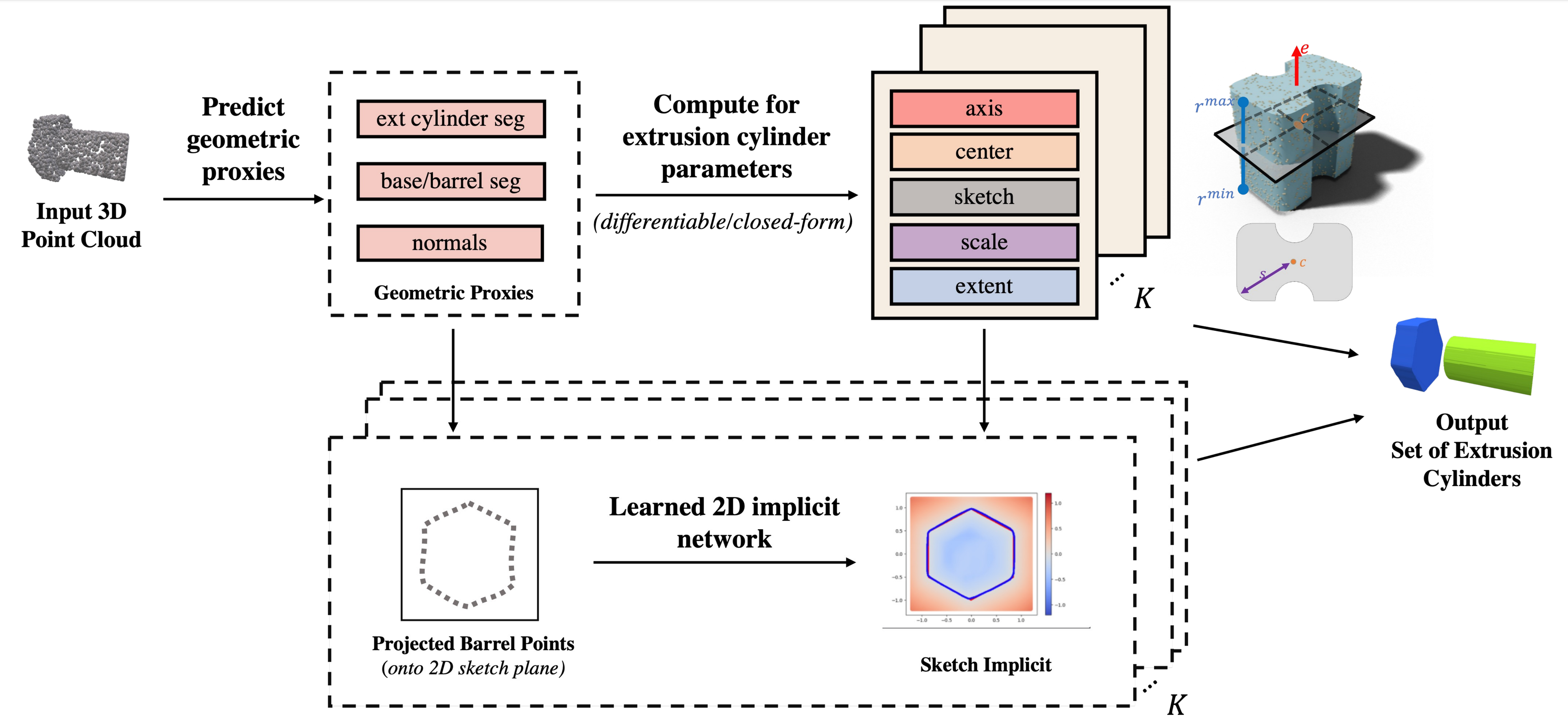
- Reverse engineering from a raw geometry to a CAD model is an essential task to enable manipulation of the 3D data.
- Given an input point cloud, our task is to infer its CAD program.
- Recent approaches either assume i) *fixed and finite number* of primitives [2], or ii) *directly predict a program without utilizing geometry* [3].
- We introduce a novel **geometry-aware approach** that casts the problem as an **extrusion cylinder decomposition** problem.

EXTRUSION CYLINDER

- We predict **geometric proxies**, which are used to **estimate extrusion parameters** in **differentiable** and **closed-form formulations**.
- Geometric Proxies:
  - **Extrusion cylinder segmentation**
  - **Per-point normals**
  - **Base-barrel segmentation**
- Derived extrusion cylinder parameters:
  - **Extrusion axis**
  - **Extrusion center**
  - **Normalized sketch**
  - **Sketch scale**
  - **Extrusion extent**

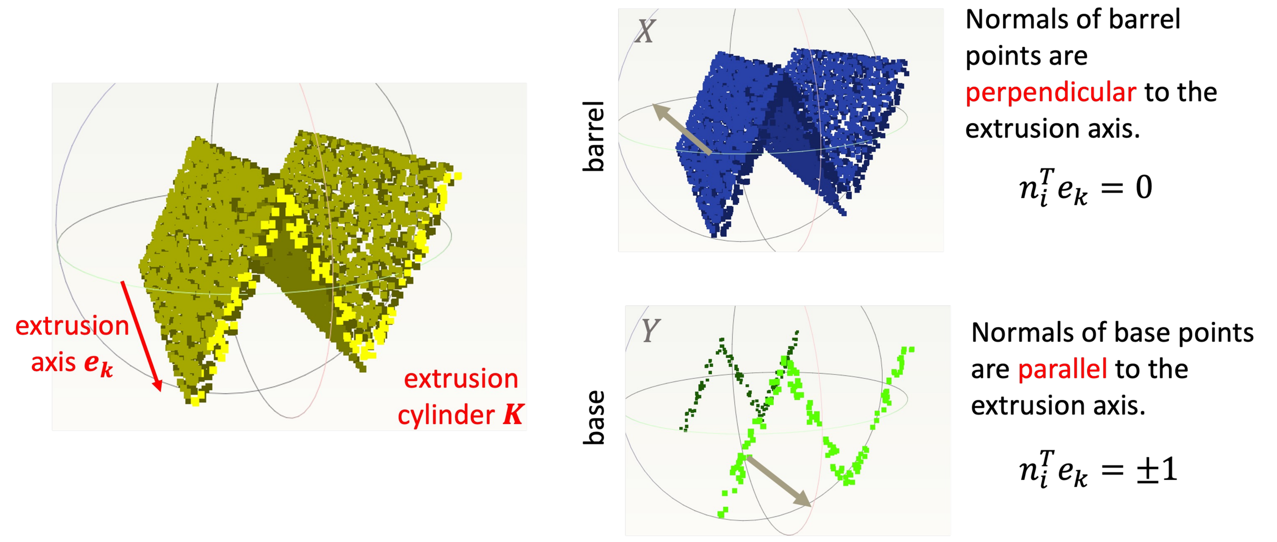


OUR POINT2CYL



We represent sketches as **implicits** [3]

Extrusion Axis Model Estimation



$$Xe_k = 0$$
$$\min(e_k^T X^T X e_k)$$

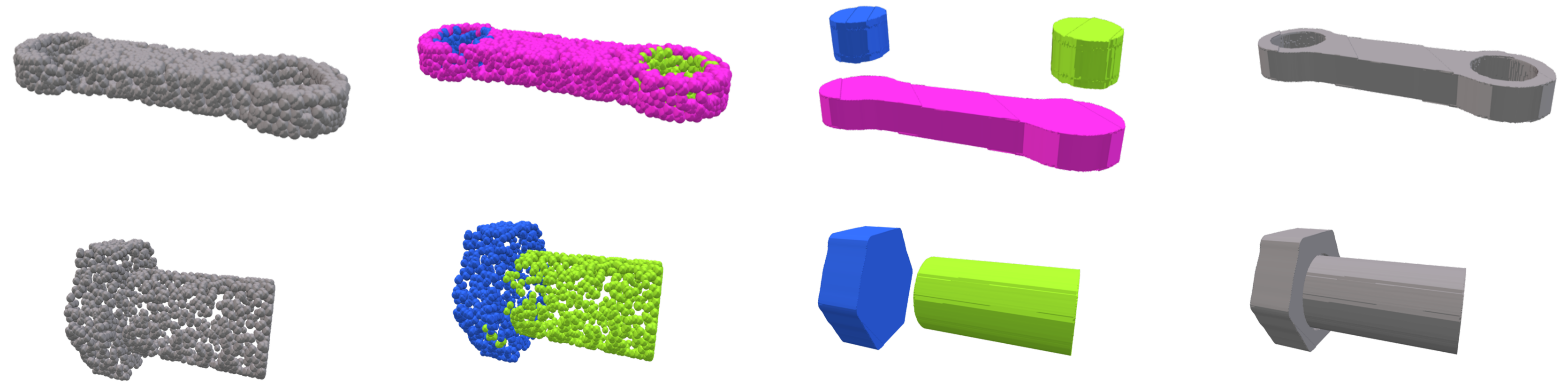
$$Ye_k = \pm 1$$
$$\max(e_k^T Y^T Y e_k)$$

$$\max_{e_k} \left(e_k^T (X^T X - Y^T Y) e_k \right)$$

e_k is eigenvector corresponding to the smallest eigenvalue of $(X^T X - Y^T Y)$

Reverse Engineering

Input Point Cloud | Decomposition | Extrusion Cylinders | Reconstruction



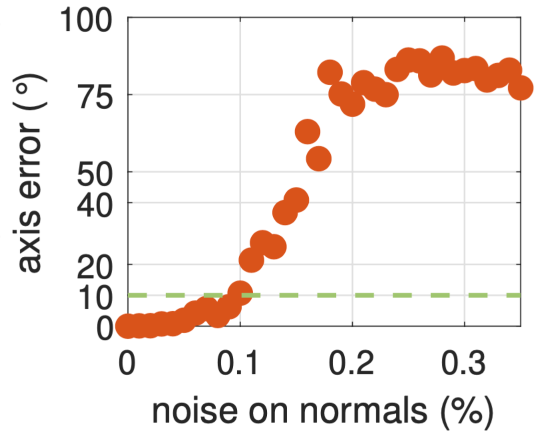
RESULTS

Quantitative Results

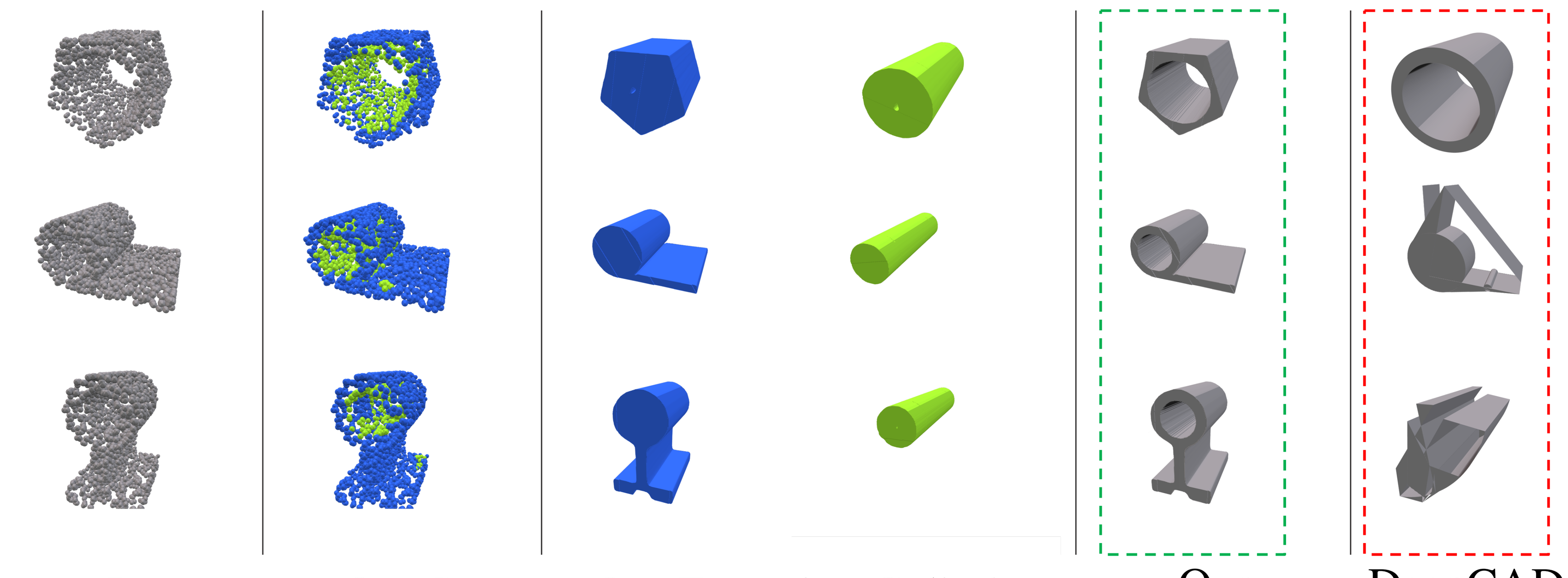
Table 1. Quantitative results on Fusion Gallery and DeepCAD datasets.

		Seg.↑	Norm.(°) ↓	B.B.↑	E.A.(°) ↓	E.C.↓	Fit Cyl ↓	Fit Glob↓
Fusion Gallery	H.V. + $\mathbf{N_J}$	0.409	12.264	0.595	58.868	0.1248	0.1492	0.0683
	D.P.	-	-	-	30.147	0.1426	1.4132	0.4257
	w/o $\mathcal{L}_{\text{sketch}} + \mathbf{N_J}$	0.699	12.264	**0.913**	14.169	0.0729	0.0828	0.0330
	w/o $\mathcal{L}_{\text{sketch}}$	0.699	8.747	**0.913**	9.795	0.0727	0.0826	0.0352
	Ours (**Point2Cyl**)	**0.736**	**8.547**	0.911	**8.137**	**0.0525**	**0.0704**	**0.0305**
DeepCAD	H.V. + $\mathbf{N_J}$	0.540	13.573	0.577	59.785	0.0435	0.1664	0.0459
	D.P.	-	-	-	48.818	0.0716	0.4947	0.4840
	w/o $\mathcal{L}_{\text{sketch}} + \mathbf{N_J}$	0.829	13.573	0.916	10.109	0.0275	0.0856	0.0312
	w/o $\mathcal{L}_{\text{sketch}}$	0.829	8.850	0.916	8.085	0.0273	0.0783	0.0324
	Ours (**Point2Cyl**)	**0.833**	**8.563**	**0.919**	**7.923**	**0.0267**	**0.0758**	**0.0308**

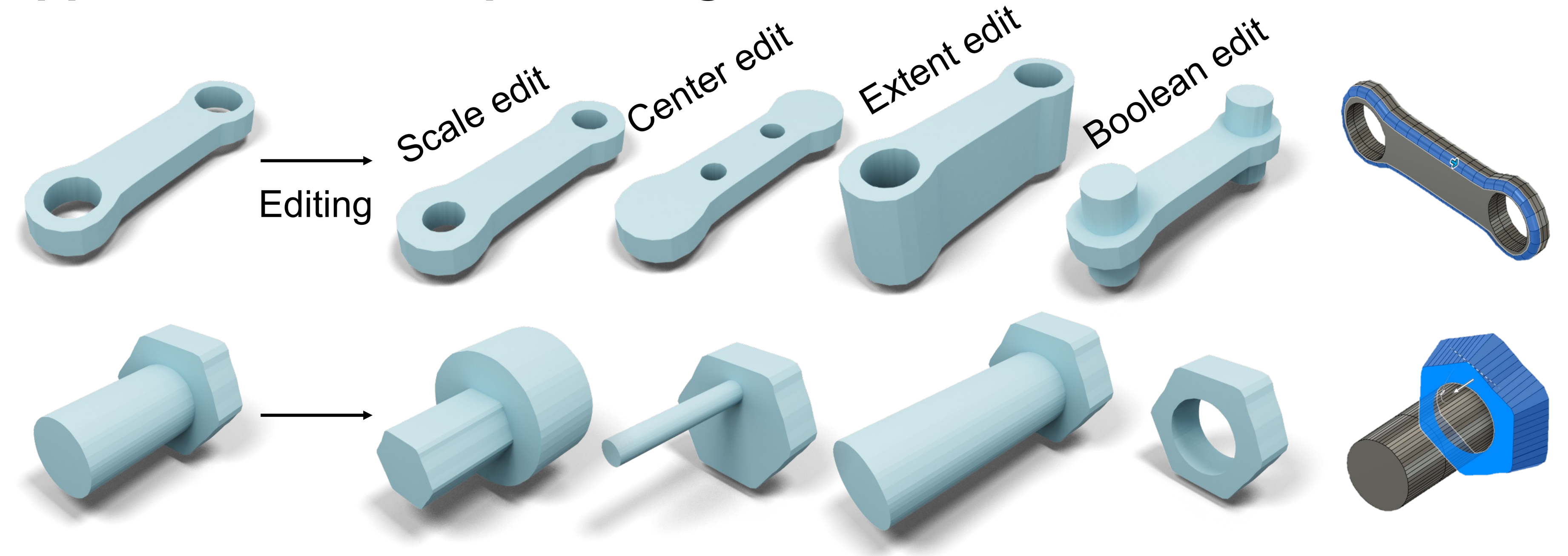
Noise Robustness



Qualitative Results



Applications for Shape Editing



References: [1] Supervised Fitting of Geometric Primitives to 3D Point Clouds. Li, et. al., CVPR 2019.
[2] DeepCAD: A Deep Generative Network for Computer-Aided Design Models. Wu, et. al., ICCV 2021.
[3] IGR: Implicit Geometric Regularization for Learning Shapes. Gropp, et. al., ICML 2020.