Neural Shape Mating: Self-Supervised Object Assembly with Adversarial Shape Priors

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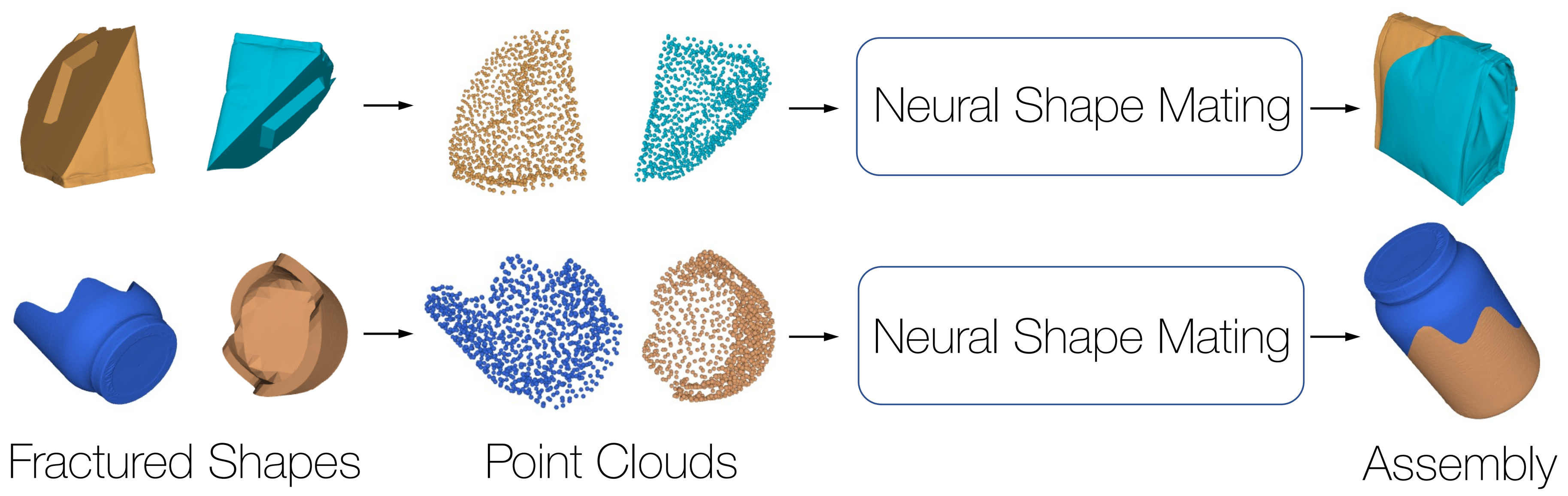
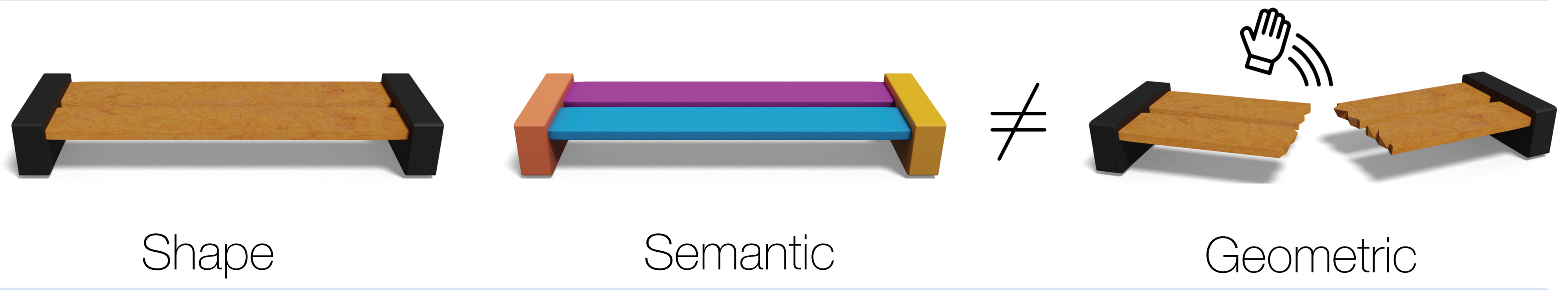
Geometric Shape Mating

- Input: Two shapes
- Goal: Develop an algorithm that learns to assemble the two shapes



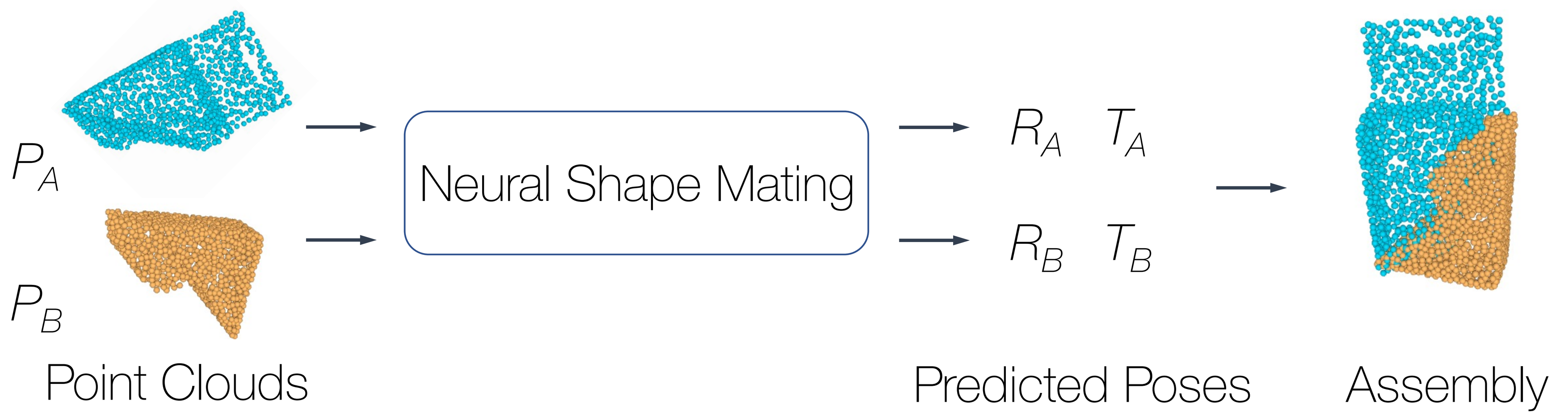
Semantic vs. Geometric



Challenges in Geometric Shape Mating

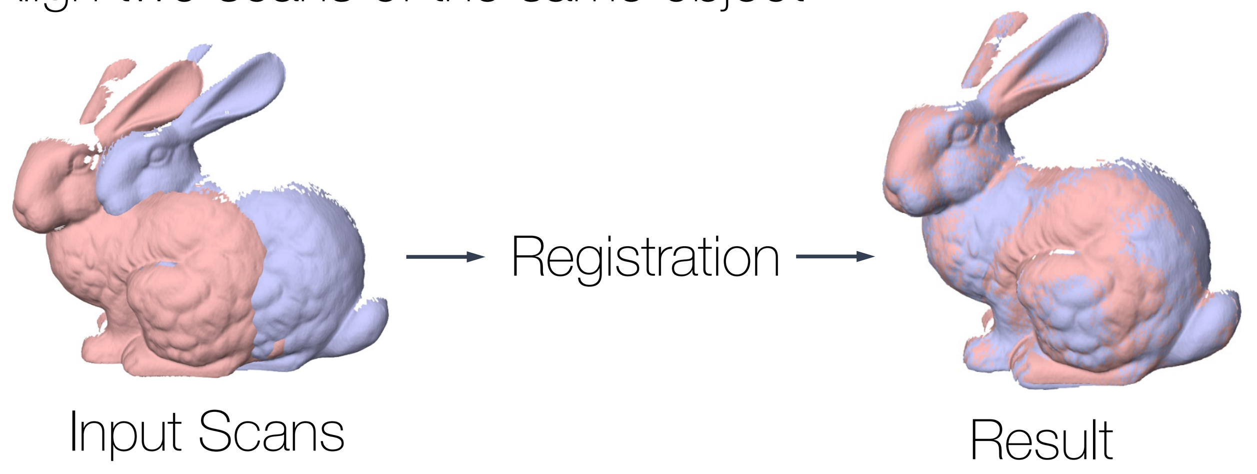
- Shape fragments do not have well-defined semantic meanings
- No target shapes available
- Shape assembly relies purely on geometric reasoning
- No large-scale datasets available

Problem Formulation: Part Pose Prediction

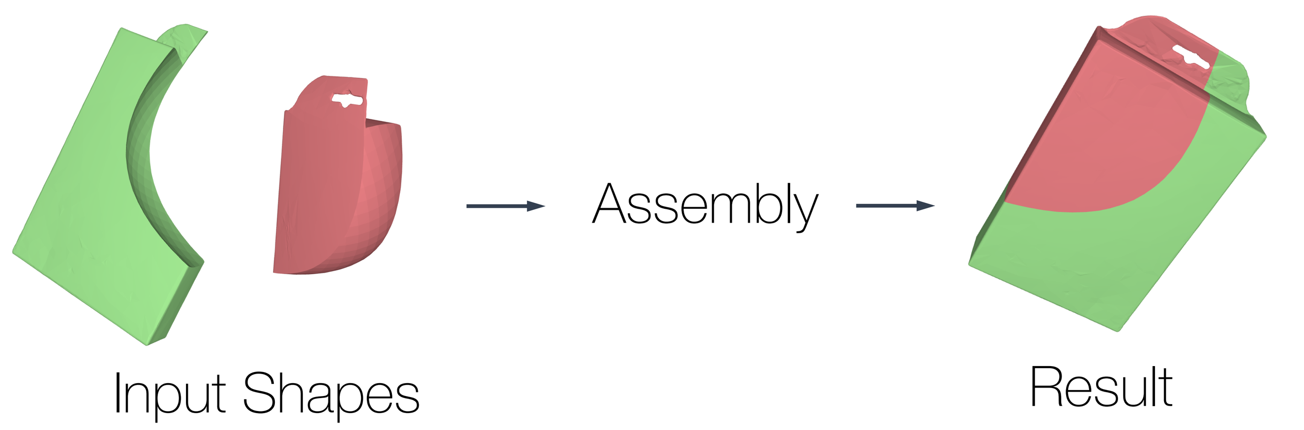


Registration vs. Assembly

Point Cloud Registration
- Align two scans of the same object

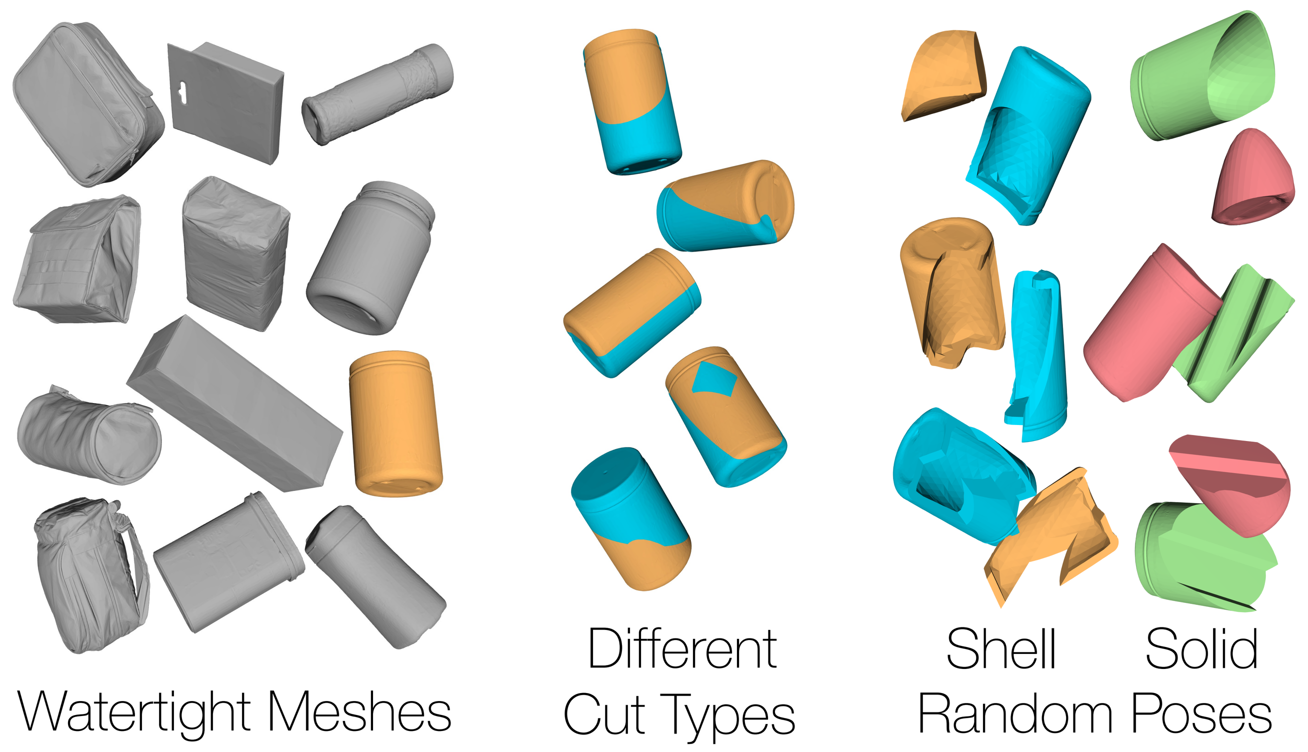


Shape Assembly
- Align the interfaces of the two shapes to form an object

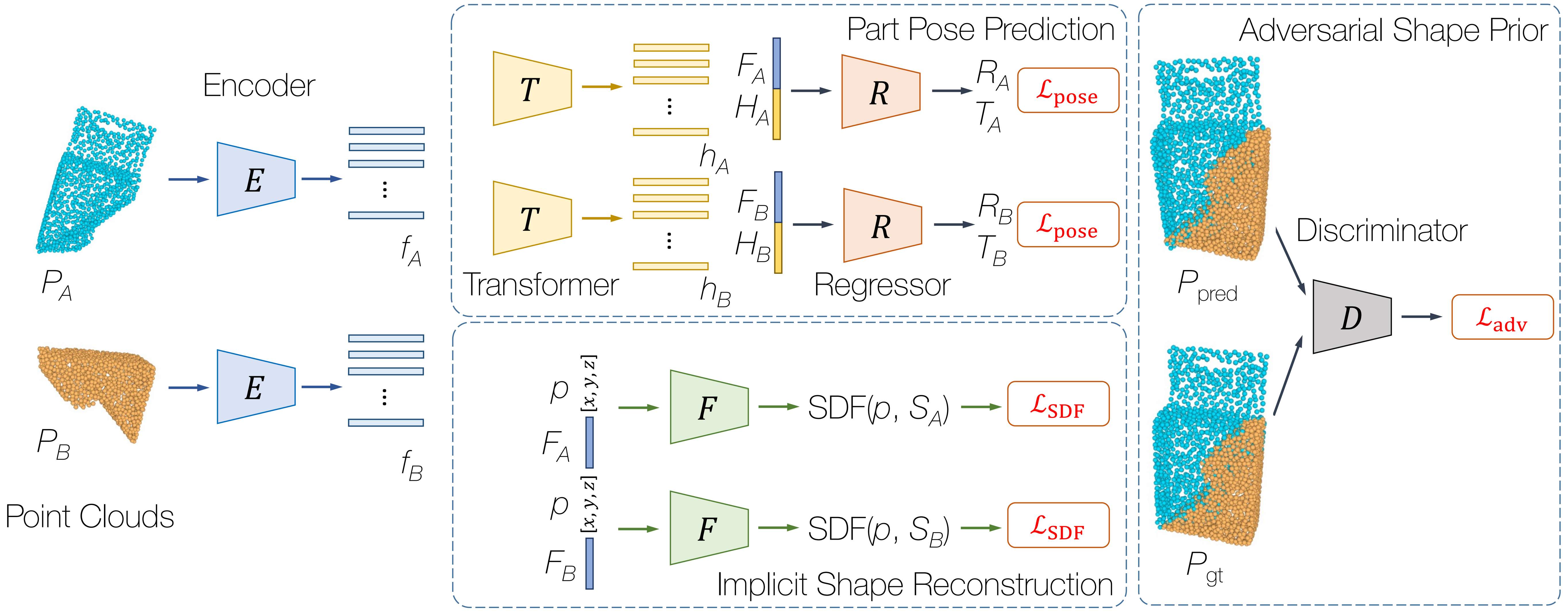


Geometric Shape Mating Dataset

- Self-supervised data collection
- Objects from 11 categories
- 5 different types of cuts
- Each object, generate shell and solid test cases
- Random initial poses for object parts



Method: Neural Shape Mating



Experimental Results

Evaluation metric: root mean squared error (RMSE)

- R: rotation, T: translation - The lower, the better

Results of Pairwise 3D Geometric Shape Mating

Method	RMSE (R)	RMSE (T)	RMSE (R)	RMSE (T)
	degree	$\times 10^{-3}$	degree	$\times 10^{-3}$
	Solid Shape Mating		Shell Shape Mating	
ICP (point-to-point) [1]	95.44	460.18	93.41	780.26
ICP (point-to-plane) [1]	82.15	286.61	81.83	681.09
Sparse ICP (point-to-point) [2]	68.93	184.09	71.41	629.08
Sparse ICP (point-to-plane) [2]	57.16	198.23	59.31	572.63
DCP [3]	58.31	235.08	62.14	580.11
GNN Assembly [4]	32.98	138.67	40.77	337.18
Neural Shape Mating	9.73	124.40	17.03	328.03

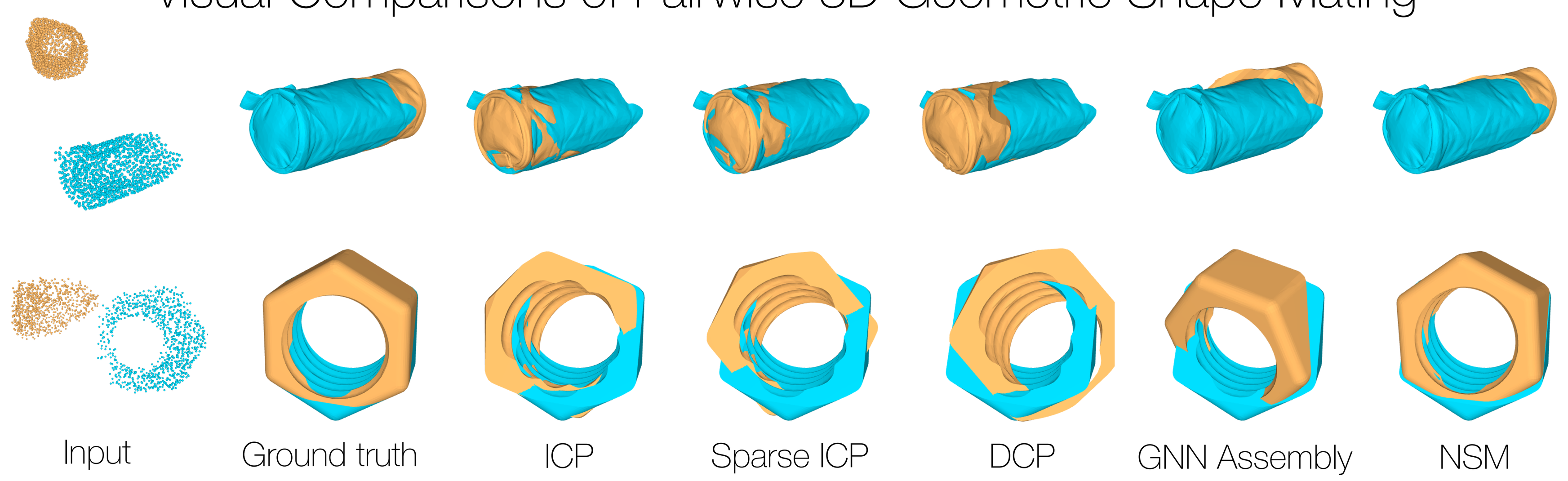
Results of Unseen Categories

Method	RMSE (R)	RMSE (T)
	degree	$\times 10^{-3}$
	Solid Shape Mating	
DCP [3]	81.04	329.65
GNN Assembly [4]	49.13	235.16
Neural Shape Mating	16.32	234.98

Results of Unseen Cut Types

Method	RMSE (R)	RMSE (T)
	degree	$\times 10^{-3}$
	Solid Shape Mating	
DCP [3]	76.85	298.16
GNN Assembly [4]	46.30	241.51
Neural Shape Mating	15.86	230.96

Visual Comparisons of Pairwise 3D Geometric Shape Mating



References

[1] Besl et al. Method for Registration of 3D Shapes. *TPAMI*, 1992.
[2] Bouaziz et al. Sparse Iterative Closest Point. *Computer Graphics Forum*, 2013.
[3] Wang et al. Deep Closest Point: Learning Representations for Point Cloud Registration. In *ICCV*, 2019.
[4] Li et al. Learning 3D Part Assembly from a Single Image. In *ECCV*, 2020.