High Resolution UDF Meshing via Iterative Networks

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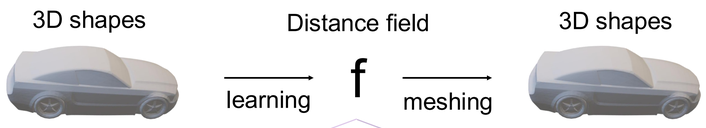
1. Meshing Unsigned Distance Fields

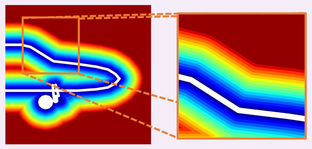


Signed Distance Fields
- Easy to learn
- Easy to mesh
- Can model watertight shapes

Unsigned Distance Fields
- Harder to learn
- Harder to **mesh**
- Can model all shapes

Meshing Unsigned Distance Fields (our focus)

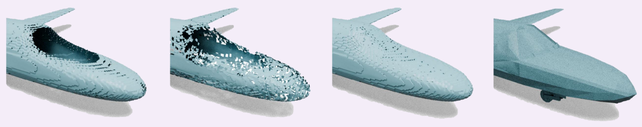
GT UDF



Perfect distance field
→ accurate reconstruction

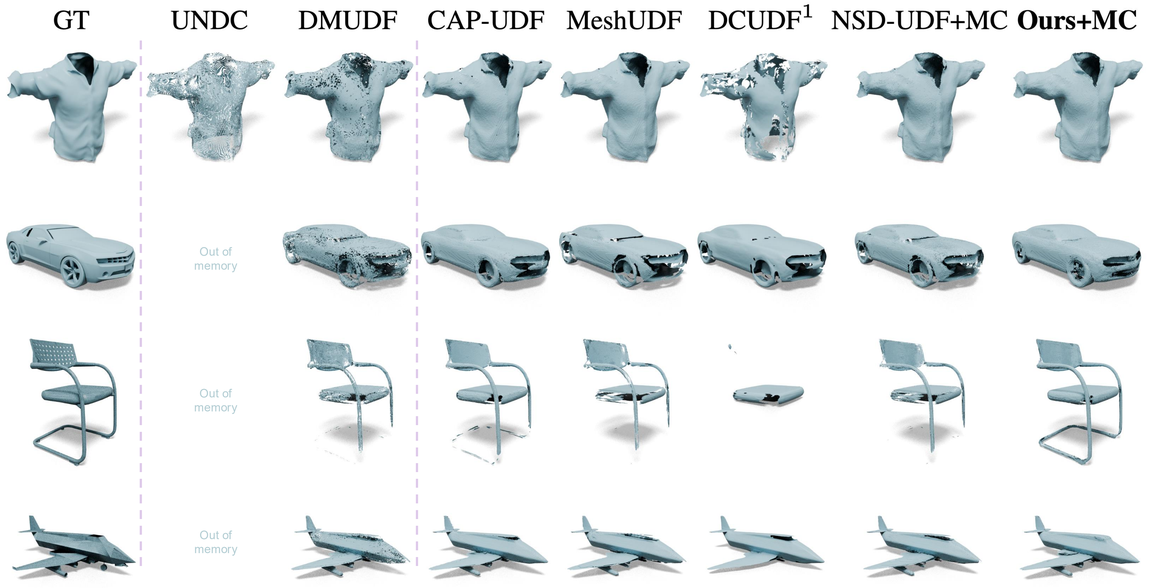
Neural UDF

Problem: neural distance fields are far from perfect
→ inaccurate reconstruction and missing surfaces

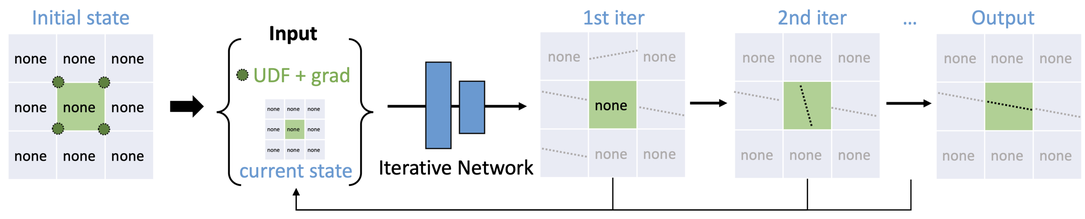


2. Increasing resolution worsens the problem

Counterintuitively, this problem manifests more at higher resolutions, or with noisier fields

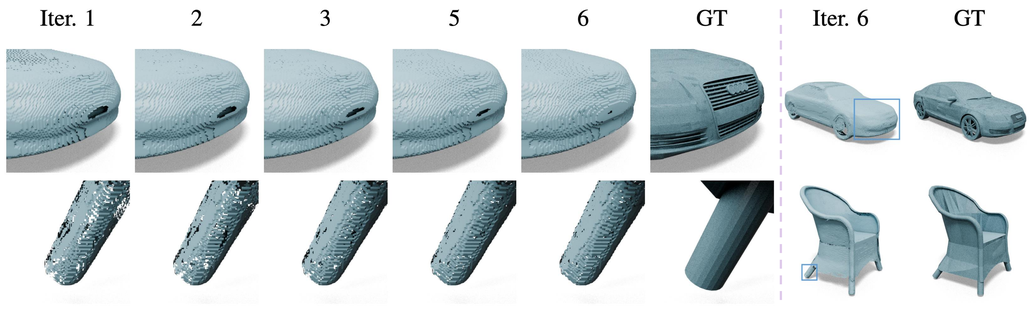


3. Proposed Method



- We formulate high-resolution meshing as an iterative process: each iteration takes the previous output state as input and refines it
- The mesh is improved over multiple iterations, where each step integrates newly detected surfaces, distance values, and gradients from neighboring cells

$$\mathbf{y}_{\mathcal{S},c}^{(i)} = f_\theta\left(U_{\mathcal{S}}(c), \nabla U_{\mathcal{S}}(c), \sigma(\mathbf{y}_{\mathcal{S},N_c}^{(i-1)})\right),$$
$$\mathbf{y}_{\mathcal{S},N_c}^{(i-1)} = \Big\Vert_{c' \in N_c} \mathbf{y}_{\mathcal{S},c'}^{(i-1)},$$
$$\mathbf{y}_{\mathcal{S},c}^{(0)} = [0, 0, ..., 0],$$



4. Results

a) MC-based methods

Res.	Method	MGN[2] CD ↓	MGN[2] F1 ↑	MGN[2] IC ↑	ShapeNet cars CD ↓	ShapeNet cars F1 ↑	ShapeNet cars IC ↑	ShapeNet chairs CD ↓	ShapeNet chairs F1 ↑	ShapeNet chairs IC ↑	ShapeNet planes CD ↓	ShapeNet planes F1 ↑	ShapeNet planes IC ↑
128	CAP-UDF	16.2	69.4	79.4	53.9	53.3	83.2	378	50.9	70.3	14.0	69.5	80.6
	MeshUDF	2.45	82.9	94.1	11.3	57.7	88.6	7.43	67.6	88.0	6.82	74.6	81.0
	DCUDF	13500	2.50	2.76	6580	7.74	14.7	17000	15.9	13.9	1880	27.6	24.5
	DCUDF-T	90.8	2.86	87.3	50.3	58.0	87.3	214	64.1	82.9	144	68.8	77.2
	DCUDF-T-nocut	-	-	-	11.4	**61.7**	**89.4**	-	-	-	-	-	-
	NSD-UDF + MC	**1.34**	**83.9**	**94.7**	6.79	59.6	88.5	6.11	**67.8**	88.1	3.82	**79.0**	**84.8**
	Ours + MC	2.04	81.9	94.1	**5.64**	59.2	88.9	**3.68**	66.7	**88.4**	**3.00**	78.5	**84.8**
256	CAP-UDF	1.66	86.8	91.8	34.0	61.2	87.6	114	70.5	82.0	5.50	83.7	85.4
	MeshUDF	0.958	89.7	95.0	13.6	62.3	88.6	27.8	**72.9**	87.3	3.47	85.8	85.2
	DCUDF	14400	4.76	3.71	346	52.6	78.2	3530	49.9	54.3	27.9	84.7	82.0
	DCUDF-T	4.63	86.8	**95.4**	347	52.6	78.2	3560	50.0	54.3	47.3	80.4	78.7
	DCUDF-T-nocut	-	-	-	52.0	58.9	82.3	-	-	-	-	-	-
	NSD-UDF + MC	**0.808**	**90.0**	95.2	10.2	62.0	87.9	10.9	72.3	86.2	2.91	87.3	86.0
	Ours + MC	0.878	88.9	94.9	**5.23**	**65.0**	**89.2**	**5.14**	**72.9**	**88.8**	**1.84**	**88.7**	**87.0**
512	CAP-UDF	0.872	90.6	94.6	31.8	61.7	87.5	63.9	71.7	82.0	5.94	87.5	86.2
	MeshUDF	0.798	90.6	**94.8**	82.7	57.0	81.7	378	61.5	65.7	12.6	88.1	84.6
	DCUDF	4.37	88.3	91.1	223	56.5	84.2	2950	55.0	70.1	48.7	85.5	82.2
	DCUDF-T	4.38	88.2	91.1	223	56.5	84.2	2000	55.0	70.1	63.0	85.4	81.3
	DCUDF-T-nocut	-	-	-	43.1	60.4	85.6	-	-	-	-	-	-
	NSD-UDF + MC	0.784	**90.8**	**94.8**	56.9	58.8	83.8	295	64.7	75.7	10.0	89.4	85.1
	Ours + MC	**0.722**	90.6	**94.8**	**8.84**	**65.6**	**88.9**	**8.76**	**74.5**	**87.2**	**2.37**	**90.9**	**87.1**

b) DC-based methods

Res.	Method	MGN[2] CD ↓	MGN[2] F1 ↑	MGN[2] IC ↑	ShapeNet cars CD ↓	ShapeNet cars F1 ↑	ShapeNet cars IC ↑	ShapeNet chairs CD ↓	ShapeNet chairs F1 ↑	ShapeNet chairs IC ↑	ShapeNet planes CD ↓	ShapeNet planes F1 ↑	ShapeNet planes IC ↑
128	UNDC	1.09	87.1	94.1	13.5	61.7	86.4	29.9	69.4	81.9	2.50	82.0	86.1
	DualMesh-UDF	216	68.1	68.4	952	34.4	45.5	7930	12.1	9.08	112	74.3	76.1
	DualMesh-UDF-T	0.806	89.9	95.4	5.56	63.5	89.5	5.34	**75.1**	89.1	1.96	84.3	87.5
	NSD-UDF + DualMesh-UDF	**0.760**	90.4	**95.0**	6.34	65.7	89.1	5.50	72.8	89.2	2.08	87.1	86.6
	Ours + DualMesh-UDF	0.787	**90.5**	94.9	**4.80**	**66.2**	**89.7**	**3.39**	72.8	**89.8**	**1.56**	**87.7**	**88.2**
256	UNDC	0.931	89.1	91.5	82.4	52.3	71.4	293	54.2	57.8	11.6	83.6	80.7
	DualMesh-UDF	176	66.3	66.4	846	34.0	45.1	8280	12.4	9.26	105	77.9	76.0
	DualMesh-UDF-T	0.722	**91.2**	**95.1**	10.6	64.3	87.0	22.8	**72.2**	84.1	2.43	88.2	87.0
	NSD-UDF + DualMesh-UDF	0.671	91.0	94.6	10.5	64.9	87.2	14.6	70.7	84.4	2.78	88.9	85.6
	Ours + DualMesh-UDF	**0.662**	**91.2**	94.7	**5.48**	**65.7**	**88.8**	**4.97**	71.9	**86.4**	**1.87**	**90.0**	**87.5**
512	UNDC	2.39	84.8	82.8	-	-	-	-	-	-	-	-	-
	DualMesh-UDF	167	63.7	63.9	870	32.5	43.0	8190	11.8	9.07	111	77.6	74.2
	DualMesh-UDF-T	0.827	**90.2**	**93.2**	37.8	58.2	79.3	72.7	63.7	72.5	4.77	89.0	84.0
	NSD-UDF + DualMesh-UDF	0.787	89.7	92.5	60.5	57.5	79.9	296	62.5	68.0	9.95	87.6	83.3
	Ours + DualMesh-UDF	**0.726**	89.7	92.8	**9.65**	**63.0**	**85.6**	**10.1**	**70.4**	**81.9**	**2.51**	**90.1**	**85.8**

c) Filtering strategies and speed

Res.	Filtering	CD ↓	IC ↑	Inference time ↓
256	Without filtering	5.26	89.2	7m
	Low confidence	5.24	89.2	1.5m
	UDF < 0.1 and low confidence	5.24	89.2	30s
512	Without filtering	8.91	88.9	1h
	Low confidence	8.87	88.9	7m
	UDF < 0.1 and low confidence	8.88	88.9	2.5m

Time	CAP	MeshUDF	DCUDF	NSD	UNDC	DMUDF	Ours
Query	90s	30s	/	30s	22s	19s	30s
Total	3.5m	35s	25m	35s	30s	20s	1m

[1]Run without the cutting step on cars, as recommended, producing a more complete but double-layered surface
[2]Resolution is halved for MGN garments due to their simpler shapes

References

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[UNDC] Neural Dual Contouring, Chen Z., SIGGRAPH 2022
[DMUDF] Surface Extraction from Neural Unsigned Distance Fields, Zhang et al., CVPR 2023
[ABC] ABC: A Big CAD Model Dataset for Geometric Deep Learning, Koch et al., CVPR 2019
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[ShapeNet] ShapeNet: An Information-Rich 3D Model Repository, Chang et al., 2015
[NSD-UDF] Neural Surface Detection for Unsigned Distance Fields, Stella et al., ECCV 2024