Tag: WED-AM-052

Marching-Primitives: Shape Abstraction from Signed Distance Function

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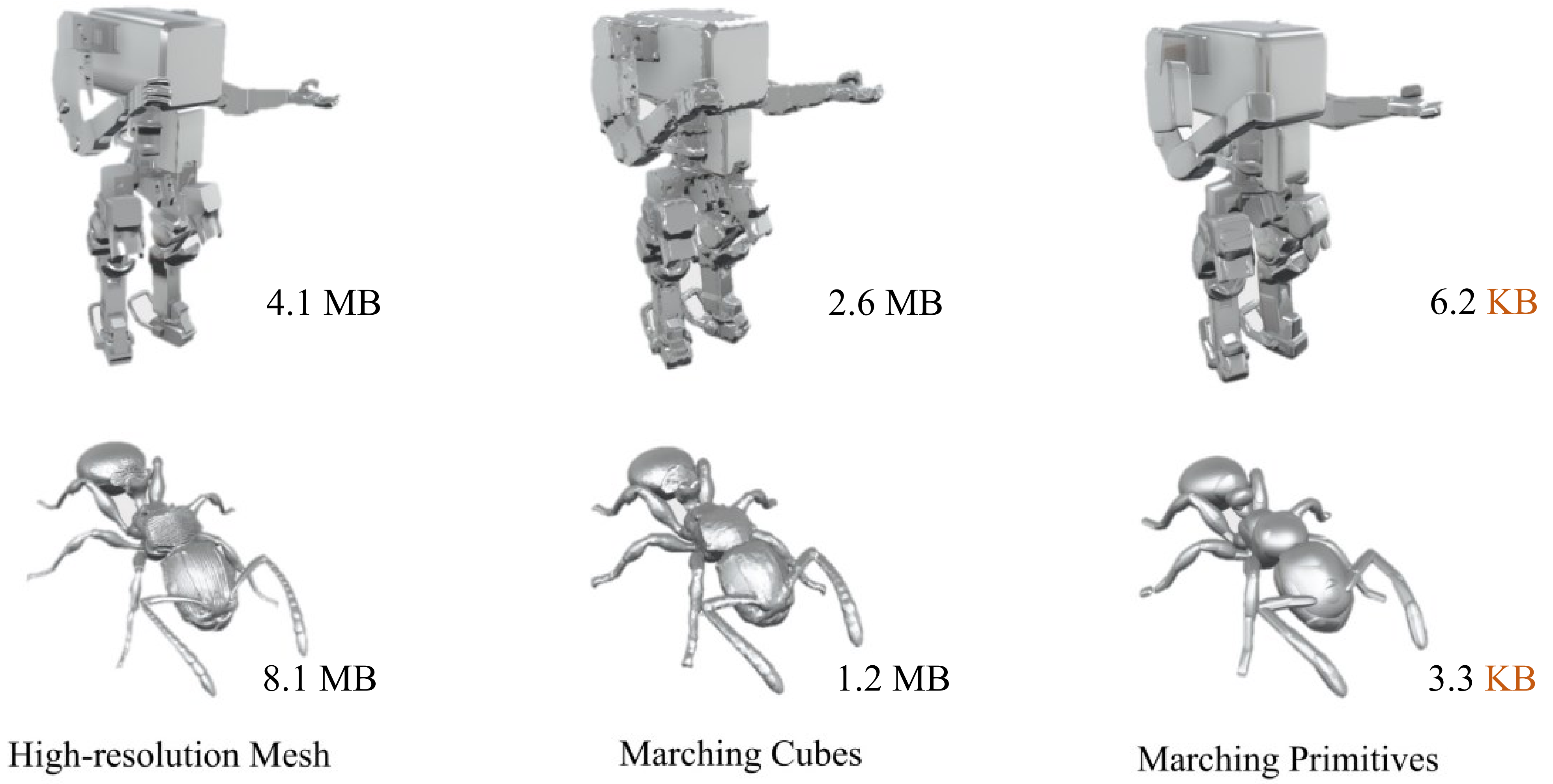
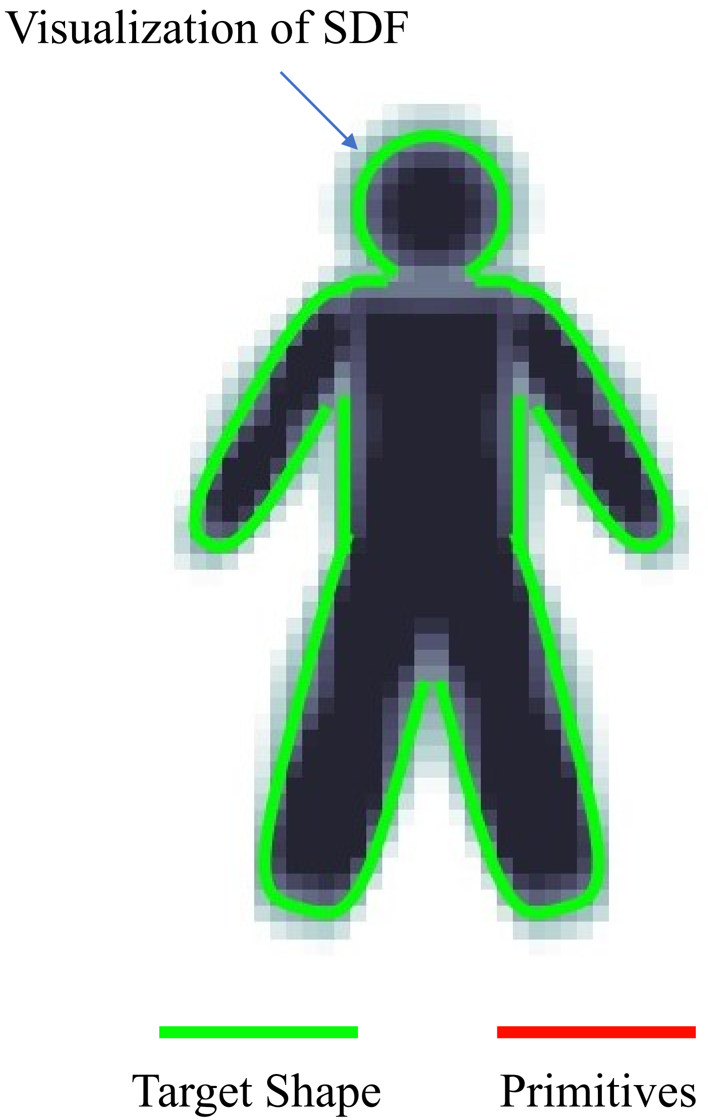
Overview



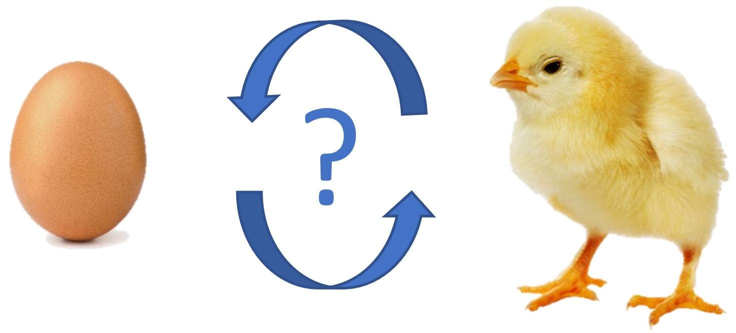
Unlike previous works which extract polygonal meshes from an SDF, we present the first method, named Marching-Primitives, to obtain a primitive-based abstraction directly from an SDF

Insights



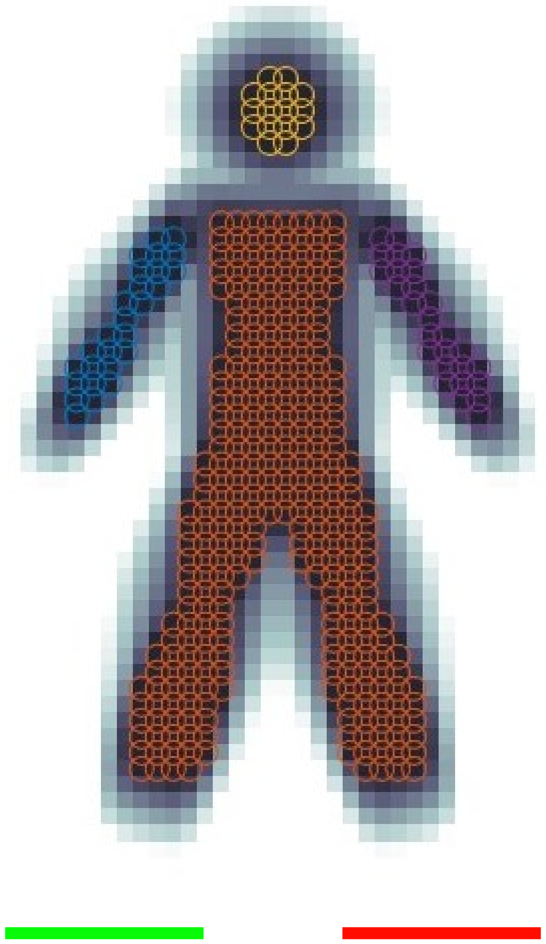
Combination of Geometric Primitives

- Voxels where geometric primitives can be extracted?



- What geometry best fit the underlying voxels?

Marching-Primitives



Connectivity-Marching

Thresholds $T^c \doteq \{t_1^c, t_2^c, ...\}, \quad t_1^c = \min_{\mathbf{x}_i \in \mathbf{V}} d(\mathbf{x}_i), \quad t_{m+1}^c = \alpha t_m^c$

Isosurfaces $S_m = \{\mathcal{S}_k, k = 1, 2, ..., |S_m|\}$

Volumes of Interest $\bar{S}_m = \{\mathcal{S}_k \in S_m, |\mathcal{S}_k| \geq N_c\} \subseteq S_m$

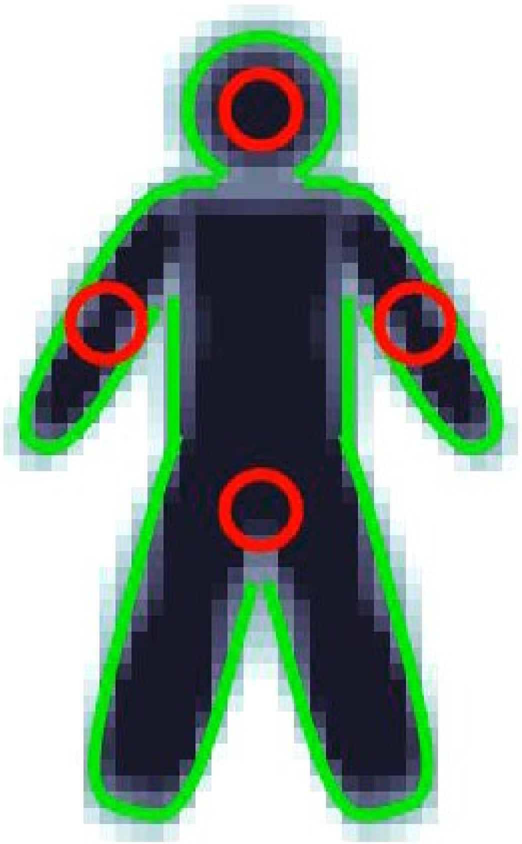
Probabilistic Primitive-Marching

Generative Model $$\boxed{p(d_i|\boldsymbol{\theta}_k, z_{ik}) = \left(\frac{\mathbb{1}_{d_i \in [-t, 0)}}{t}\right)^{1-z_{ik}} \mathcal{N}(d_i | d_{\boldsymbol{\theta}_k}(\mathbf{x}_i), \sigma^2)^{z_{ik}}}$$

Bayesian Correspondence $$p(z_{ik}|\boldsymbol{\theta}_k, d_i) = \frac{p(d_i|\boldsymbol{\theta}_k, z_{ik}) p(z_{ik})}{\sum_{z_{ik} \in \{0,1\}} p(d_i|\boldsymbol{\theta}_k, z_{ik}) p(z_{ik})}$$

Primitive Update $$\boldsymbol{\theta}_k = \arg\min_{\boldsymbol{\theta}_k} \sum_{\mathbf{x}_i \in \mathbf{V}_a} P_{ik} \| d_{\boldsymbol{\theta}_k}(\mathbf{x_i}) - d_i \|_2^2$$

Marching-Primitives



Target Shape　　Primitives

Connectivity-Marching

Thresholds　$T^c \doteq \{t^c_1, t^c_2, ...\}, \quad t^c_1 = \min_{\mathbf{x}_i \in \mathbf{V}} d(\mathbf{x}_i), \quad t^c_{m+1} = \alpha t^c_m$

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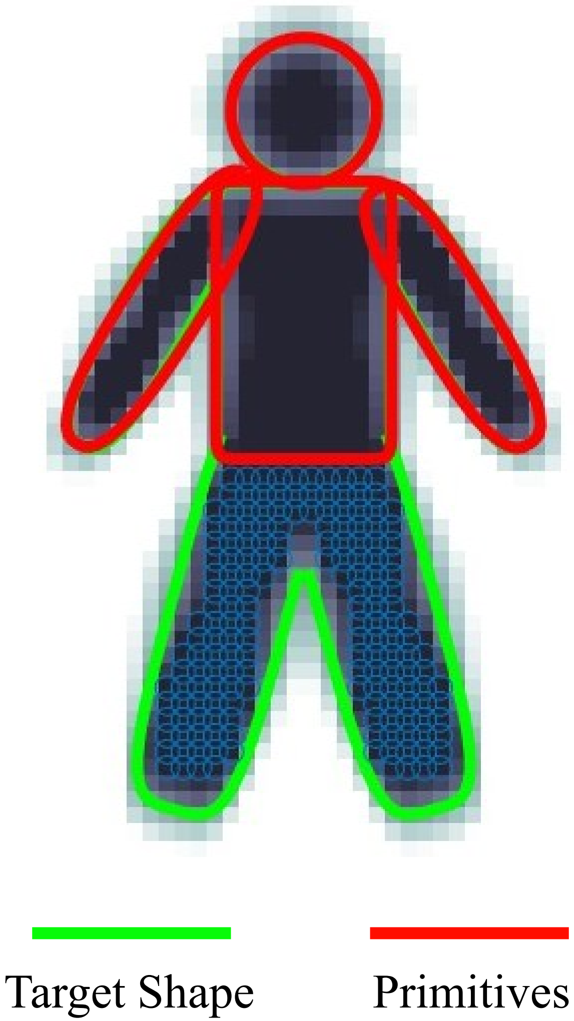

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Marching-Primitives

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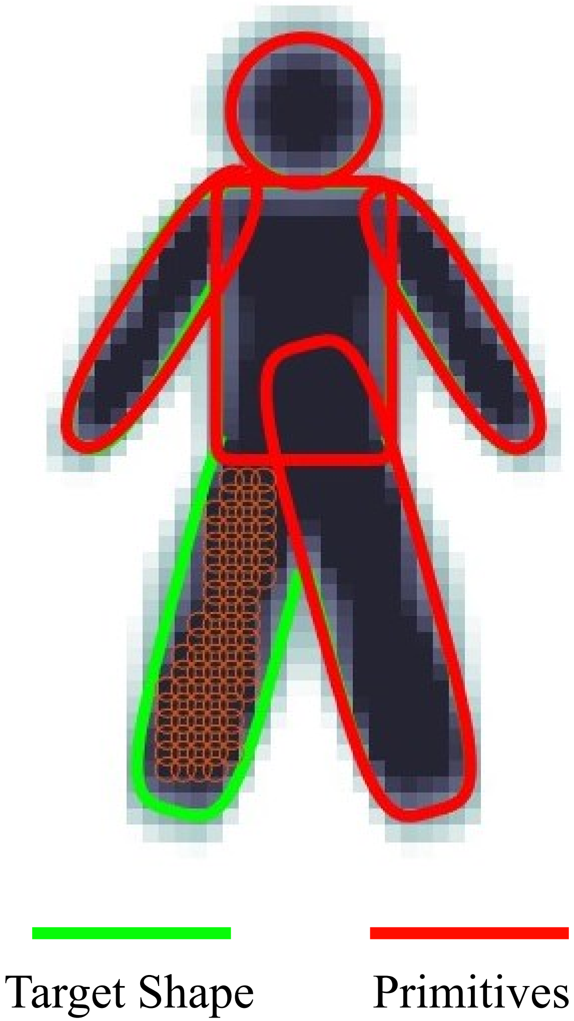

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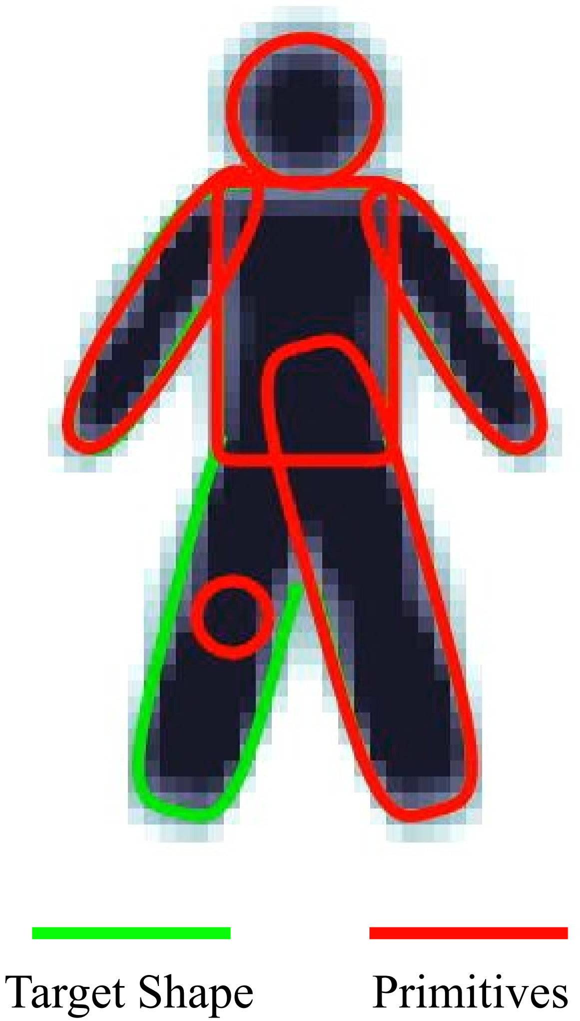
Marching-Primitives



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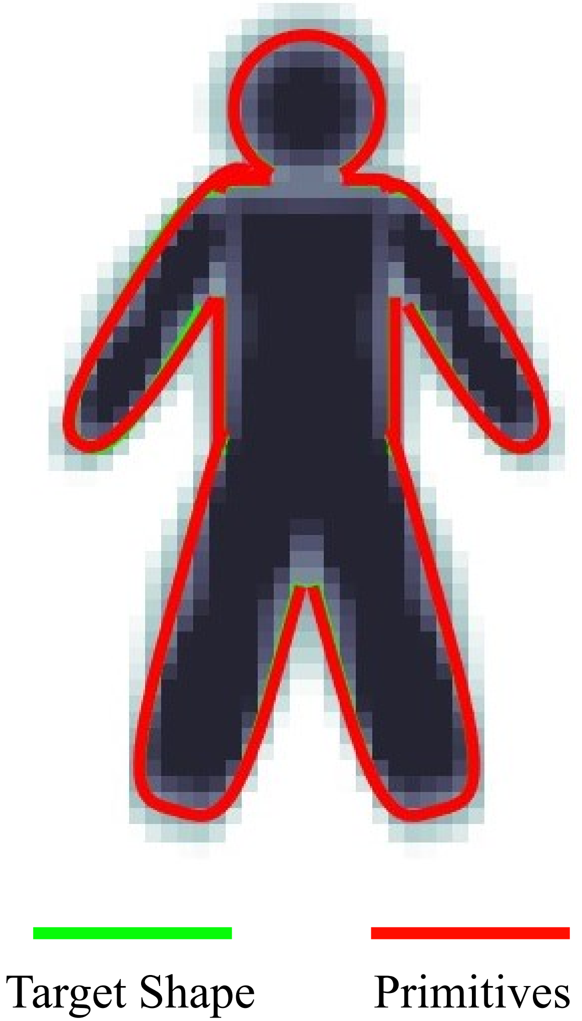
Marching-Primitives



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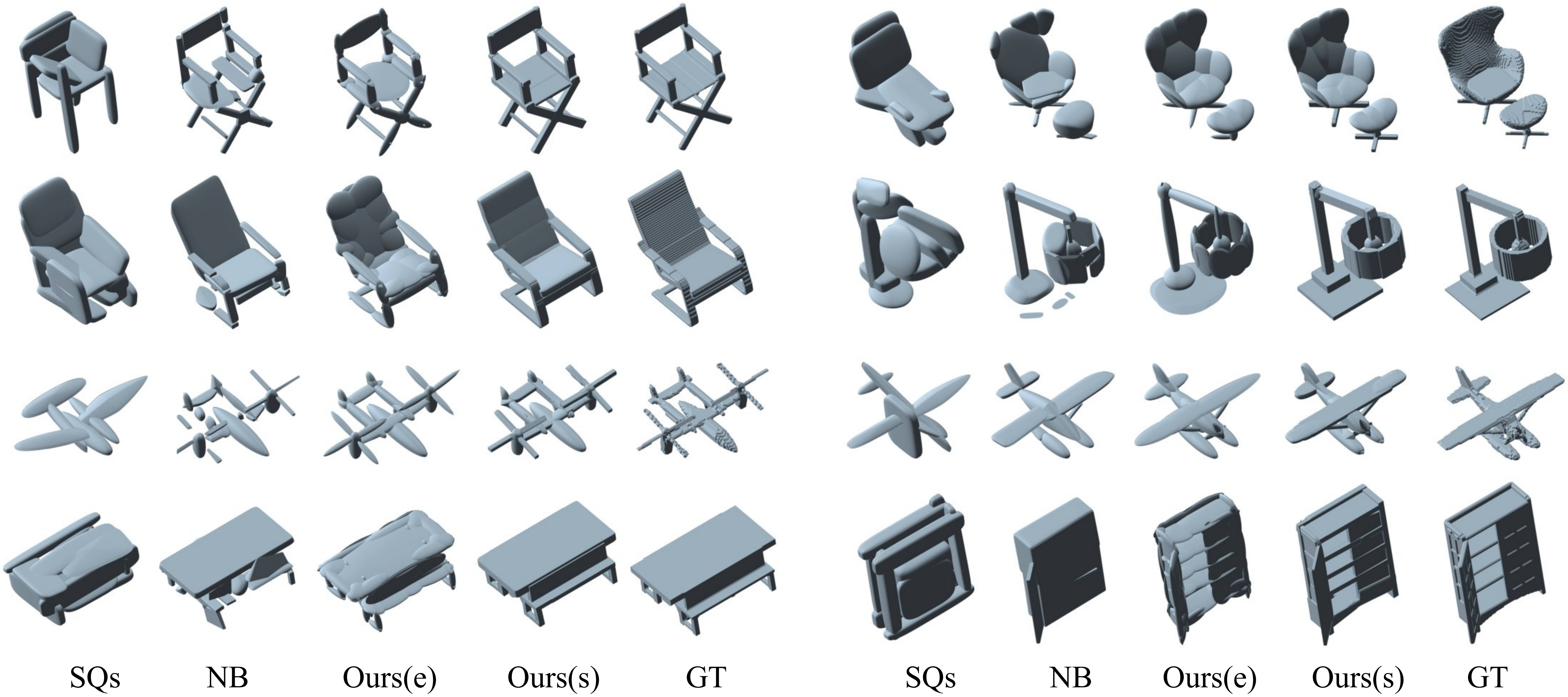
3D Visualization

Everything needed to describe the chair is here (973 bytes)

0.0397	0.0598	0.4029	0.0586	0.4465	1.4768e-06	5.9540e-05	-1.1954e-04	0.0100	-0.0099	-0.0847
0.0029	0.0474	0.4049	0.0960	0.0496	-4.4022e-09	-1.2613e-06	0.0028	0.0101	-0.0493	-0.4243
0.0451	0.9389	0.0621	0.0461	0.4283	1.5708	-0.4694	1.5708	0.0101	0.4366	0.3647
0.1380	0.4053	0.0424	0.0540	0.4421	8.2131e-04	2.6413e-04	1.0749e-04	-0.3770	-0.3078	-0.0535
0.0439	1.1220	0.0605	0.0447	0.4284	1.5708	-0.7662	1.5708	0.0101	0.5648	0.4054
0.1330	0.3491	0.0621	0.0762	0.3753	1.6425	-1.5333	3.0725	-0.3523	-0.4419	-0.4263
0.3340	0.2095	0.4446	0.0438	0.0516	-1.9746	-1.5703	0.4072	0.3987	-0.3053	-0.0523
0.0207	0.5037	0.0565	0.0407	0.4284	1.5708	-0.4782	1.5708	0.0101	0.3124	0.3273
0.3719	0.0822	0.0533	0.4021	0.0611	8.1752e-04	-0.0018	-0.2432	-0.3680	-0.4267	0.3561
0.1312	0.3489	0.0762	0.0621	0.3749	-0.0027	0.0026	-1.6082	0.3725	-0.4421	-0.4262
6.3959e-04	0.4127	0.0576	0.0884	0.4297	0.0109	-1.5818e-04	-7.4037e-04	-0.3723	-0.0591	-0.0759
0.0546	0.1936	0.0502	0.0964	0.4295	1.5708	-1.5654	1.5708	0.0101	-0.0498	0.3033
0.0944	0.2263	0.0708	0.0415	0.4285	1.5708	-0.3324	1.5708	0.0101	0.7660	0.4734
0.3714	0.0817	0.0533	0.4020	0.0611	-8.2808e-04	0.0018	-0.2432	0.3882	-0.4267	0.3561
9.1380e-04	0.4206	0.0582	0.0883	0.4297	3.1325	-7.3484e-05	7.6954e-04	0.3931	-0.0591	-0.0759
0.0512	0.2392	0.4285	0.0638	0.0494	1.5707	-0.2980	1.5670	-0.3641	0.4173	0.3847
0.1423	0.3905	0.0648	0.0548	0.3694	-1.5462	-1.2718	-0.0225	0.3891	0.3797	0.3729
0.1958	0.4215	0.0558	0.0642	0.4251	-3.1416	0.0026	1.2721	0.3898	0.4193	0.3856

Evaluation on ShapeNet



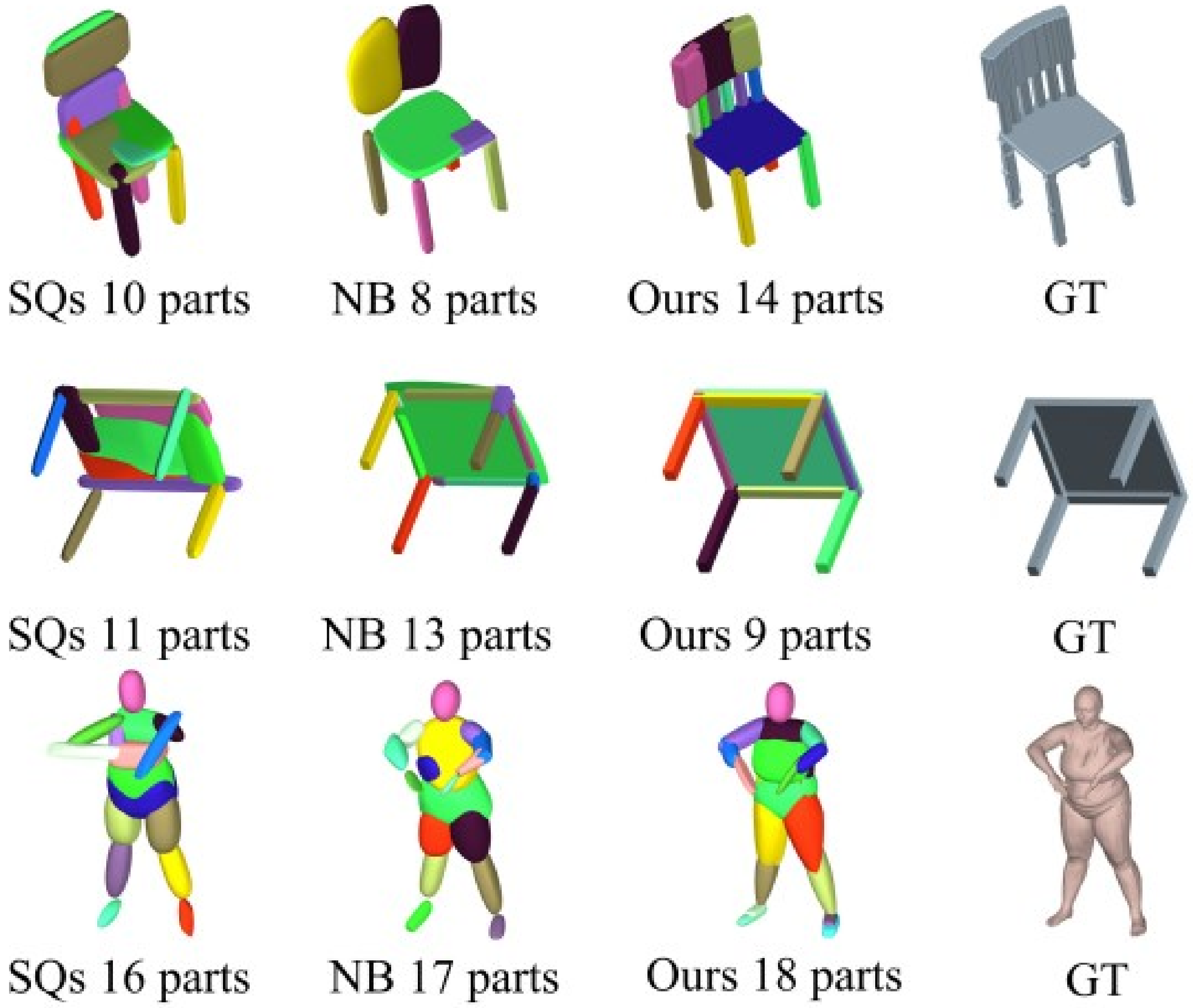
Evaluation on ShapeNet

Category	Chamfer-L_1 SQs [31]	NB [47]	MPE(Ours)	MPS(Ours)	IoU SQs [31]	NB [47]	MPE(Ours)	MPS(Ours)
airplane	0.037	0.023	0.021	**0.019**	0.441	0.671	0.731	**0.768**
bench	0.056	0.028	0.020	**0.020**	0.238	0.579	0.730	**0.819**
bottle	0.047	0.033	0.026	**0.017**	0.686	0.665	0.886	**0.924**
cabinet	0.059	0.036	0.037	**0.028**	0.394	0.666	0.840	**0.948**
can	0.066	0.036	0.036	**0.022**	0.706	0.553	0.908	**0.950**
chair	0.068	0.027	0.023	**0.020**	0.300	0.685	0.785	**0.871**
lamp	0.072	0.029	0.022	**0.021**	0.234	0.589	0.750	**0.802**
speaker	0.064	0.041	0.037	**0.033**	0.346	0.656	0.858	**0.920**
mailbox	0.095	0.026	0.026	**0.024**	0.333	0.694	0.802	**0.905**
rifle	0.038	0.020	0.019	**0.019**	0.446	0.732	0.744	**0.811**
sofa	0.054	0.037	0.029	**0.023**	0.497	0.726	0.857	**0.940**
table	0.070	0.024	0.024	**0.022**	0.247	0.745	0.818	**0.932**
phone	0.040	0.021	0.023	**0.021**	0.681	0.872	0.891	**0.947**
watercraft	0.048	0.032	0.022	**0.022**	0.465	0.618	0.793	**0.836**
mean	0.057	0.028	0.024	**0.022**	0.368	0.674	0.793	**0.870**

Table 1. Quantitative results on Shapenet. MPE and MPS are short for Marching-Primitives with ellipsoids and superquadrics, respectively

More Evaluation

	SQs	NB	MPE (Ours)	MPS (Ours)
Chamfer-L_1	0.0435	0.0303	0.0301	**0.0291**
IoU	0.7417	0.8107	0.8568	**0.8598**



More Examples

Marching Cubes

1.64MB

Marching Primitives (Ours)

1.67KB

Marching Cubes

1.11MB

Marching Primitives (Ours)

1.27KB

Marching Cubes

0.86MB

Marching Primitives (Ours)

1.12KB

Marching Cubes

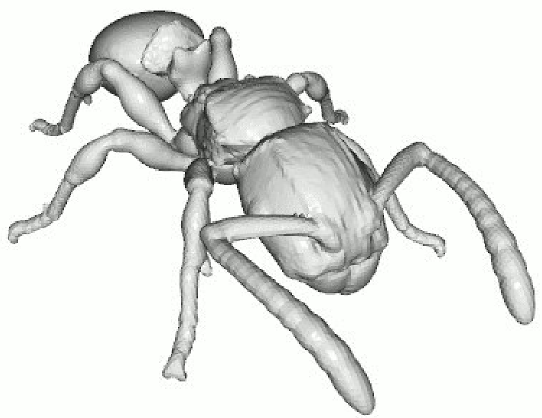
1.01MB

Marching Primitives (Ours)

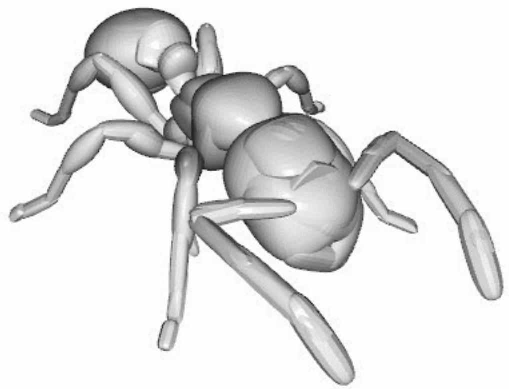
0.92KB

More Examples

Marching Cubes



Marching Primitives (Ours)



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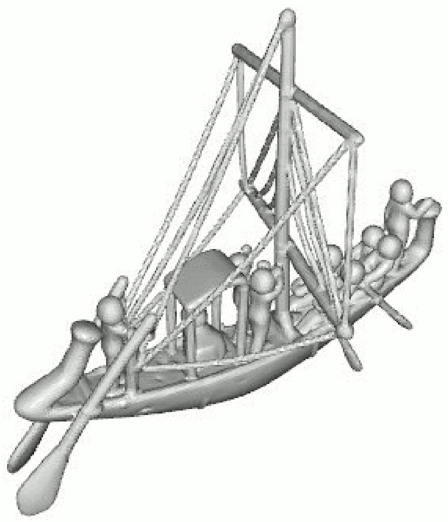

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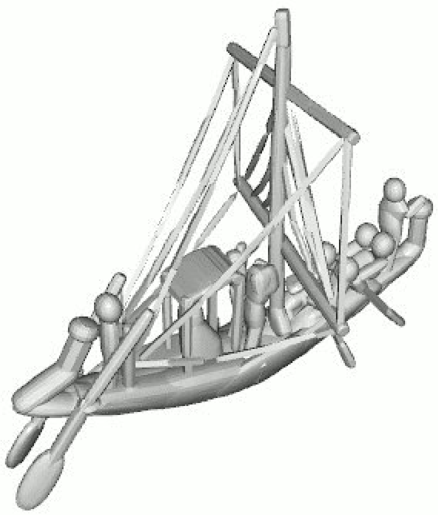
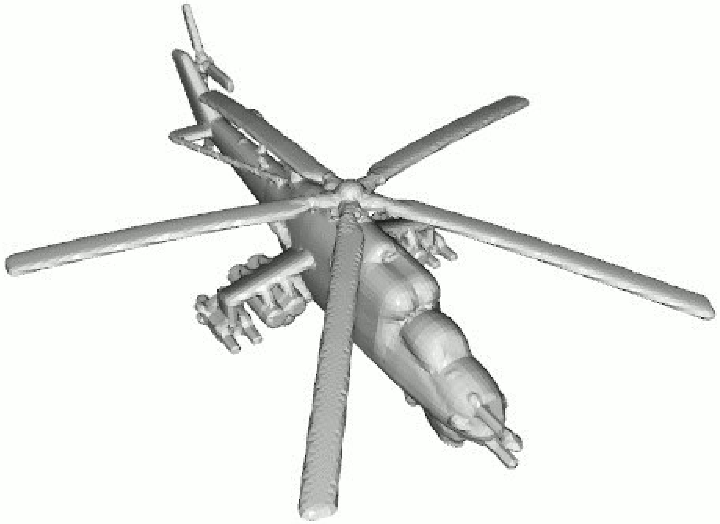


More Examples

Marching Cubes



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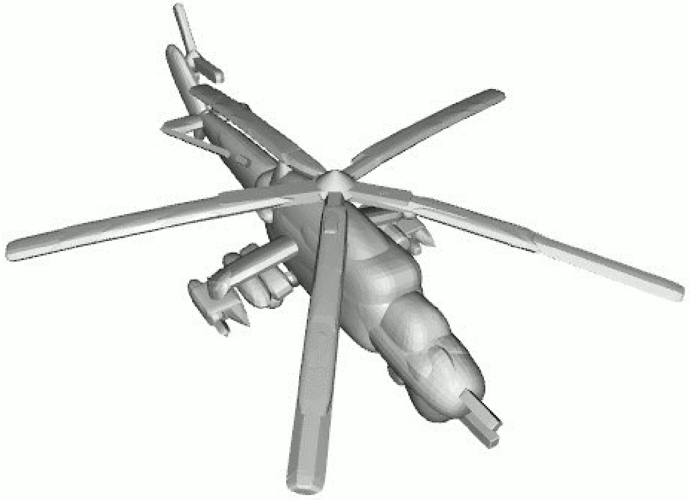

More Examples

Marching Cubes

Marching Primitives (Ours)

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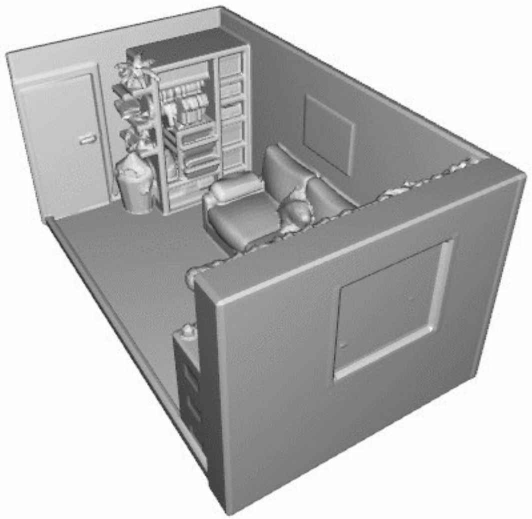

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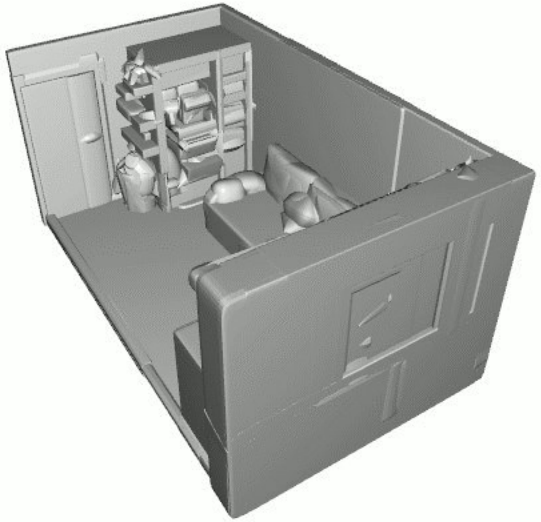

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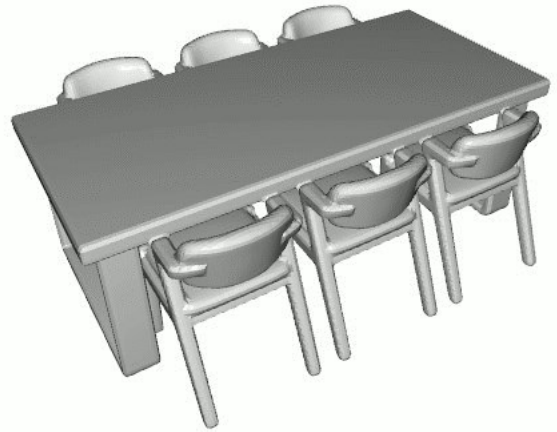

Marching Primitives (Ours)

Our code is open-sourced at
https://github.com/ChirikjianLab/Marching-Primitives
or scan the QR code